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Goomig Farmlands development
Baseline water quality in the lower Keep River

Resource management technical report 393

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Don Bennett and Richard George

To the memory of Arjen Ryder

This report is dedicated to the memory of Arjen Ryder, Senior Technical Officer for the Department of Agriculture and Food, Western Australia. Arjen and his wife, Yvonne, were killed in the Malaysian Airlines flight MH17 tragedy over Ukraine on 17 July 2014. Arjen assisted with the field work described in this report including collecting surface water samples from the lower Keep River area. He was a trusted, hard-working colleague and friend who was also involved in significant hydrological and salinity related research and extension over many years, to the benefit of agriculture in Western Australia. He was a very fine man indeed and is sadly missed.

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Cover: The Keep River estuary at site E2

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Summary

In 2008 the Ord Irrigation Expansion Project was approved by the Western Australian Government to develop irrigated agriculture on the Weaber Plain. By mid-2014 construction of almost all of the water supply, drainage, access, monitoring and other infrastructure for the 7400ha Goomig Farmlands development had substantially been completed.

An important concern is the effect the Goomig Farmlands development may have on the water quality of the downstream lower Keep River aquatic environment, particularly as it relates to threatened species — listed as Matters of National Environmental Significance (NES) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) — that inhabit or may inhabit the area. Possible increases in salinity, nutrients, suspended sediment, heavy metals and farm chemicals delivered in run-off are therefore of primary interest.

In accordance with the EPBC Act, the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities reviewed the surface and groundwater management plans proposed by the state as part of the Goomig Farmlands development project. In 2011 Commonwealth Minister Tony Burke gave approval to proceed with the Goomig Farmlands development subject to it meeting 22 conditions relating to protection of the downstream surface water environment. One of these conditions required a baseline water quality monitoring program to be completed at four sites (pools K1, K2, K3, K4) in the Keep River, one site in the Keep River estuary and one site in Border Creek prior to irrigation commencing.

The lower Keep River system is highly dynamic and responds rapidly to prevailing rainfall and tidal influences.This report assembles and reviews physicochemical water quality, flow and tide data collected over a 40-month baseline study period (2010–2013) for the above sites that comprise the lower Keep River area. At the seven sites, wet season and dry season baseline concentrations for 12 stressors and 26 toxicants are presented for use as a basis for assessing the future environmental compliance of the Goomig Farmlands development.

Many of the aquatic stressors, in particular, have baseline levels that exceed their corresponding ANZECC and ARMCANZ (2000) default trigger value for tropical Australia (AADTVTA) at multiple sites. During the wet season, baseline concentrations of nutrients exceed the AADTVTA by factors of between 1.3 and 13 in the lower Keep River sites. Baseline levels for turbidity and total suspended solids were consistently many times higher than the AADTVTA during the wet season, 22 times higher on average across all Keep River pool sites. The baseline level for electrical conductivity greatly exceeded the AADTVTA in all Keep River pools during the dry season, being up to 167 times higher in pool K1, for example.

The baseline concentrations of several metal toxicants were also found to exceed their corresponding AADTVTA in the Keep River pools. For example, the baseline concentration of aluminium exceeded the AADTVTA by 13–28 times in wet seasons and by 1.1–2.5 times during dry seasons. The baseline concentration of zinc was between five and 20 times higher at every site in both seasons, while cadmium and copper either exceed, or were equal to, their AADTVTA in all non-estuarine locations. Likewise, the wet season baseline concentration of lead greatly exceeded its AADTVTA in Border Creek and Keep River.

The physicochemical baseline data indicate that the lower Keep River system is best classified as a ‘Category 2’ system, being a ‘slightly to moderately disturbed system’, rather than ‘Category 1’, which is defined as a ‘high conservation/ecological value system’. The lower classification is a result of the influence of natural (tidal influence, climate variability, groundwater discharge, heavy metal mineralisation, terrestrial vegetation growth dynamics and run-off dynamics) and anthropogenic (rangeland cattle grazing) factors.

Using the baseline results this report also:

- proposes interim local trigger values for the lower Keep River and relates these to water quality monitoring results from nearby, well-established areas of irrigated agricultural development
- discusses considerations for selecting, determining and applying local trigger values to meet the environmental management objectives for the Goomig Farmlands development
- documents the influence of wet seasons and tides on the pools and estuary environments for subsequent use in the Goomig Farmland developments Operational Surface Water Model (OSWM).

We conclude that it is likely that run-off from the Goomig Farmlands will contain elevated levels of soluble nutrients. However, we note that the approved Goomig Farmlands tailwater management systems plus the surface and groundwater management plans (incorporating the OSWM) were developed to account for this likelihood.

Given the data complexity and that threatened and endangered fish species are involved it is appropriate that an ‘expert panel’, such as the Independent Review Group (IRG) has a leading role in providing advice on the derivation, selection and application of local trigger values, the reference for ongoing compliance monitoring.

The derivation of baseline and interim trigger values largely followed the data analysis and interpretation procedures recommended by the ANZECC and ARMCANZ (2000) guidelines. In order that the conservative intent of the guidelines was fulfilled, some practical modifications to data analyses and interpretation procedures were undertaken after consultation with the IRG and other experts. The modified methodologies are identified and explained fully within this document and could be considered and factored into any future review or update of the ANZECC and ARMCANZ guidelines.

1 Introduction

In 2008 the Ord Irrigation Expansion Project was approved by the Western Australian Government to develop irrigated agriculture on the Weaber Plain. Construction of the M2 supply channel connecting the Ord River Irrigation Area (ORIA) and Weaber Plain, together with the final design of the irrigation layout, environmental management and related approval processes, commenced in 2009. By mid-2014 construction of almost all of the water supply, drainage, access, monitoring and other infrastructure for the 7400ha renamed Goomig Farmlands development had substantially been completed (Figure 1.1).

The approved farmland design is based on the use of an irrigation tailwater management system. The tailwater system required on the Goomig Farmlands captures irrigation run-off for re-use on farms and prevents discharge during the dry season. The tailwater system also allows the equivalent of up to 25 mm of storm run-off to be captured and stored within the boundary of each farm. The tailwater system consists of channels constructed to collect tailwater, storage areas, and pumps and pipelines that return irrigation water to supply channels to enable re-use.

In late 2009 the Department of Agriculture and Food, Western Australia (DAFWA), with partners Kellogg Brown and Root Pty Ltd (KBR) and GHD Pty Ltd (GHD), collected new information to enable development of groundwater and surface water management plans. In particular, hydrodynamic modelling (GHD 2011a and GHD 2011b) was undertaken as a foundation of the Stormwater and Groundwater Discharge Management Plan (Strategen 2012).

The requirement for the management plan had been established by the Environmental Protection Authority as part of the process of evaluating a previous proposed irrigation development project known as the Wesfarmers Marubeni Project (Kinhill 2000). During the evaluation period, KBR and others had begun to address the joint issues of salinity and water quality within the agricultural area, surrounding conservation buffers and downstream Keep River. In addition to the state government’s requirement of an environmental impact statement, the Goomig Farmlands development had to meet environmental conditions imposed by the Commonwealth Government, namely those related to the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), as well as address any concerns of the Northern Territory Government.

An important surface water related concern was the potential for the Goomig Farmlands development to adversely affect water quality of the downstream Border Creek and Keep River, particularly as it related to three threatened species, listed as Matters of National Environmental Significance (NES) under the EPBC Act. The NES species include the dwarf sawfish (*Pristis clavata*) and the freshwater sawfish (*Pristis microdon*) that have been found in the Keep River and the speartooth shark (*Glyphis glyphis*) that may inhabit the Keep River estuary (NCTWR 2005). Possible increases in salinity, nutrients and sediment loads delivered in run-off to four perennial river pools located in the lower Keep River and the Keep River estuary is therefore of primary interest, as well as farm chemicals that may be toxic to the threatened species.

In accordance with the EPBC Act, the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities (SEWPaC) reviewed the surface and groundwater management plans proposed by the Goomig Farmlands development project. In 2011 Commonwealth Ministerial approval to proceed with the Goomig Farmlands development was granted to the Department of State Development, Western Australia, subject to it meeting 22 conditions relating to protection of the downstream surface water environment (plus numerous other conditions relating to the terrestrial and groundwater environments).

One of the surface water conditions required a baseline water quality monitoring program to be completed at four sites (pools K1, K2, K3, K4) in the Keep River, one site in the Keep River estuary (E1), one site in Border Creek (BC, Figure 1.2), plus intensive monitoring of discharge rate and water quality at the outflow of the Goomig Farmlands prior to irrigation commencing. Another condition required seasonal baseline water quality parameters for the Keep River to be determined in accordance with the ANZECC and ARMCANZ (2000) Water Quality Guidelines and be agreed by an Independent Review Group (IRG). Appointment of the IRG was made (with the approval from the Commonwealth Minister for SEWPaC) in 2011. The IRG consists of four independent scientific and technical experts (each having at least five years' experience in northern Australia) in the disciplines of surface hydrology, groundwater hydrology and aquatic fauna.

The ANZECC and ARMCANZ (2000) recommended method of assessing the impact of a development on downstream water quality parameters (and aquatic species) is to first determine the pre-development (baseline) condition and then monitor to detect change. Baseline monitoring can then also enable the derivation of local (site-specific) trigger values (LTVs) for relevant water quality physical and chemical (physicochemical) stressors and toxicants, as well as provide the data against which future changes can be assessed.[1] In the absence of sufficient existing data, baseline surveys conducted over a two-year period, using sampling protocols defined by ANZECC and ARMCANZ (2000), are recommended. The 20th and/or 80th percentile value (depending on whether the parameter has a detrimental effect at high or low concentration or value, or both) of each relevant physicochemical parameter may then be used as the basis for specifying the site-specific trigger values (TV). In the absence of site-specific TVs, region-specific ANZECC and ARMCANZ (2000) default TVs are recommended. The recommended default TVs are conservative because in the absence of contrary information, target ecosystems are initially classified as being 'effectively unmodified, high conservation/ecological value systems' (ANZECC and ARMCANZ 2000) — especially if species targeted for protection are threatened or endangered.

Bennett and George (2011) assembled and reviewed the surface water physicochemical data available prior to 2010 plus reported the initial (June 2010 to July 2011) results from baseline water quality sampling and analysis from the lower Keep River area. They reported that the lower Keep River system is highly dynamic and responds rapidly to prevailing tidal and rainfall influences and also presented evidence that the dry season condition of the Keep River pools has changed in recent years. It has changed from being a seasonally flowing system to a perennial stream in response to changes in rainfall and natural groundwater conditions. On the basis of several water quality parameters, Bennett and George (2011) also concluded that the lower Keep River is more accurately classified as a 'slightly to

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[1] A trigger value is a numerical water quality objective that if exceeded, triggers a management response.

moderately disturbed system' (rather than a 'high conservation/ecological value system' or in other words pristine). They attribute this classification to a combination of inherent natural environmental conditions plus the effects of rangeland cattle grazing.

Bennett and George (2011) proposed an ongoing (until 2013) baseline sampling regime which was accepted by the IRG. The regime varied in some aspects from the ANZECC and ARMCANZ (2000) baseline sampling guidelines. These aspects include logistical considerations related to the remoteness and difficulty of access of the sites in the wet season and the knowledge gained from their study and previous studies/data. The ANZECC and ARMCANZ (2000) guidelines allow flexibility based on these considerations.

This report documents the surface water physicochemical data collected from Border Creek and the lower Keep River during a 42-month period (June 2010 to November 2013) comprising the baseline water quality sampling and analysis program and proposes a comprehensive set of baseline values. It also discusses how a set of TVs, appropriate for the intent of the relevant Commonwealth Ministerial conditions imposed on the Goomig Farmlands development, could be defined using the new baseline information.

This report also compares and contrasts lower Keep River catchment water physicochemical data with similar data collected from the D4 drain (Bennett & George 2011). The D4 drain captures water from a large area of the nearby Ivanhoe Irrigation District, within the ORIA and provides a relevant, albeit conservative local reference — given that the D4 drain area has no tailwater control system — to the quality of water that may discharge from the Weaber Plain area following development for irrigated agriculture.

The Ministerial requirements also stipulate the use of an Operational Surface Water Model (OSWM) to manage surface water discharges from the Goomig Farmlands. The OSWM is the primary operational tool to inform and manage: water quality monitoring of discharges, the water quality within the lower Keep River system, the retention and release of stormwater retained on farm and the implementation of mitigation measures and contingency actions that may be required. The framework for (Bennett & George 2012) and the software conceptual design of (Bennett 2013) the OSWM were reviewed and accepted as meeting the Ministerial requirements by the IRG in 2013. The OSWM combines continuous near-real time flow rate data with forecasts of water qualities of the various sources of run-off, to generate continuous predictions of water quality in the Keep pools and estuary. The predictions inform the Goomig Farmlands manager of appropriate management and contingency actions via the use of various pre-set alert levels and associated response recommendations. The OSWM will also routinely validate and modify its' forecasts using data collected from the routine and the OSWM-triggered water sampling and analysis programs.

In addition to the derivation of the water quality baseline levels for the lower Keep River, there are several considerations that are important to the design and functioning of the OSWM, including:

- the relative rates and temporal dynamics of run-off from the Keep River catchment, the Border Creek Catchment and those likely from the Goomig Farmlands
- the volumes of the Keep River pools

- the frequency and magnitude of tidal influence on the Keep River pools
- the priority monitoring location for the Keep River estuary
- the selection and use of relevant physicochemical water quality trigger levels.

It should be stressed that in addition to the physicochemical water quality study reported here, important parallel studies of baseline sediment physico-chemistry, aquatic biodiversity, threatened species abundance and macro-invertebrate data were also undertaken. Data for these studies were also collected in accordance with ANZECC and ARMCANZ (2000) and AUSRIVAS (2013) guidelines, by Wetland Research and Management (WRM 2014).

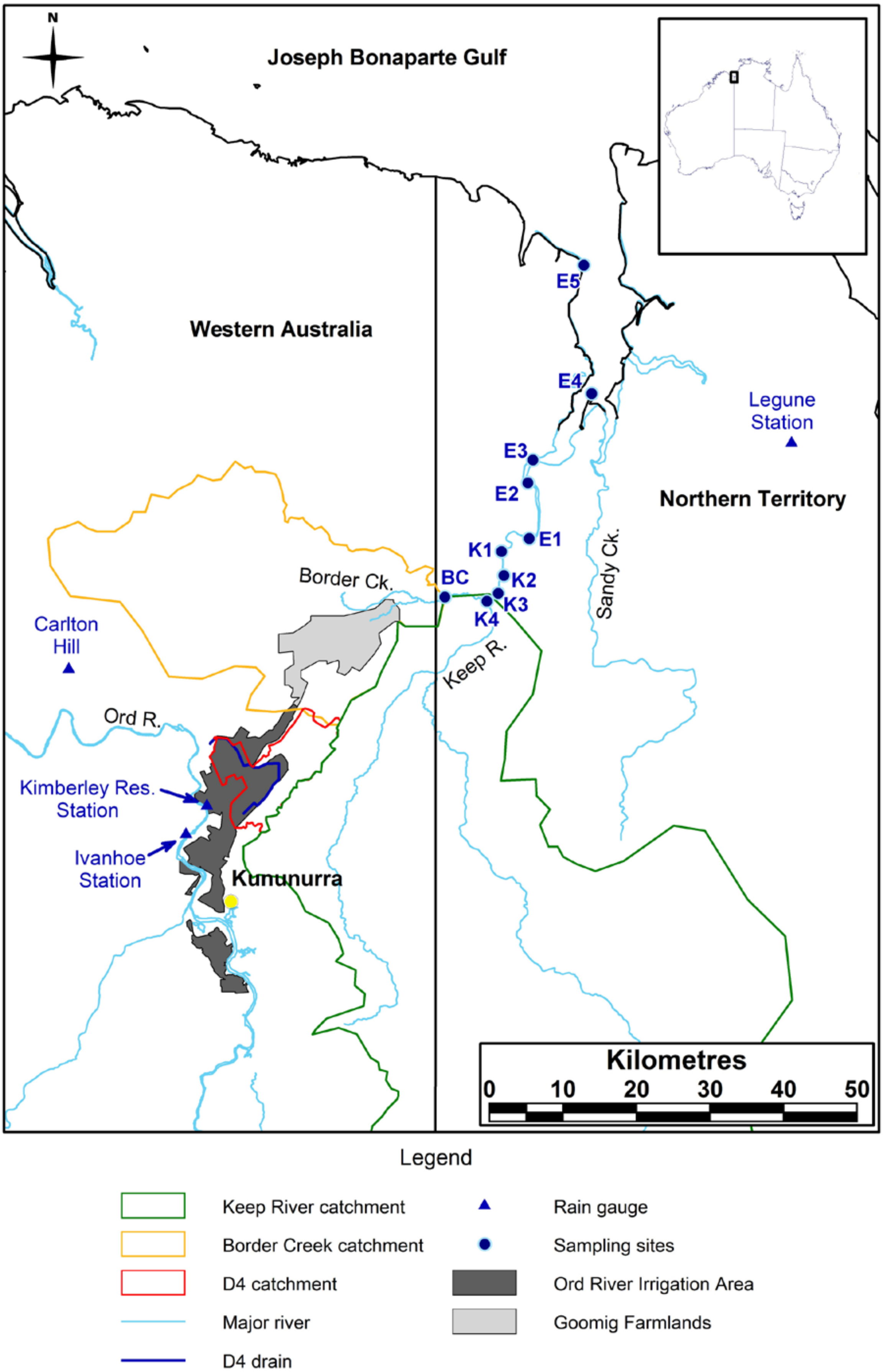

Figure 1.1 Study area locality map

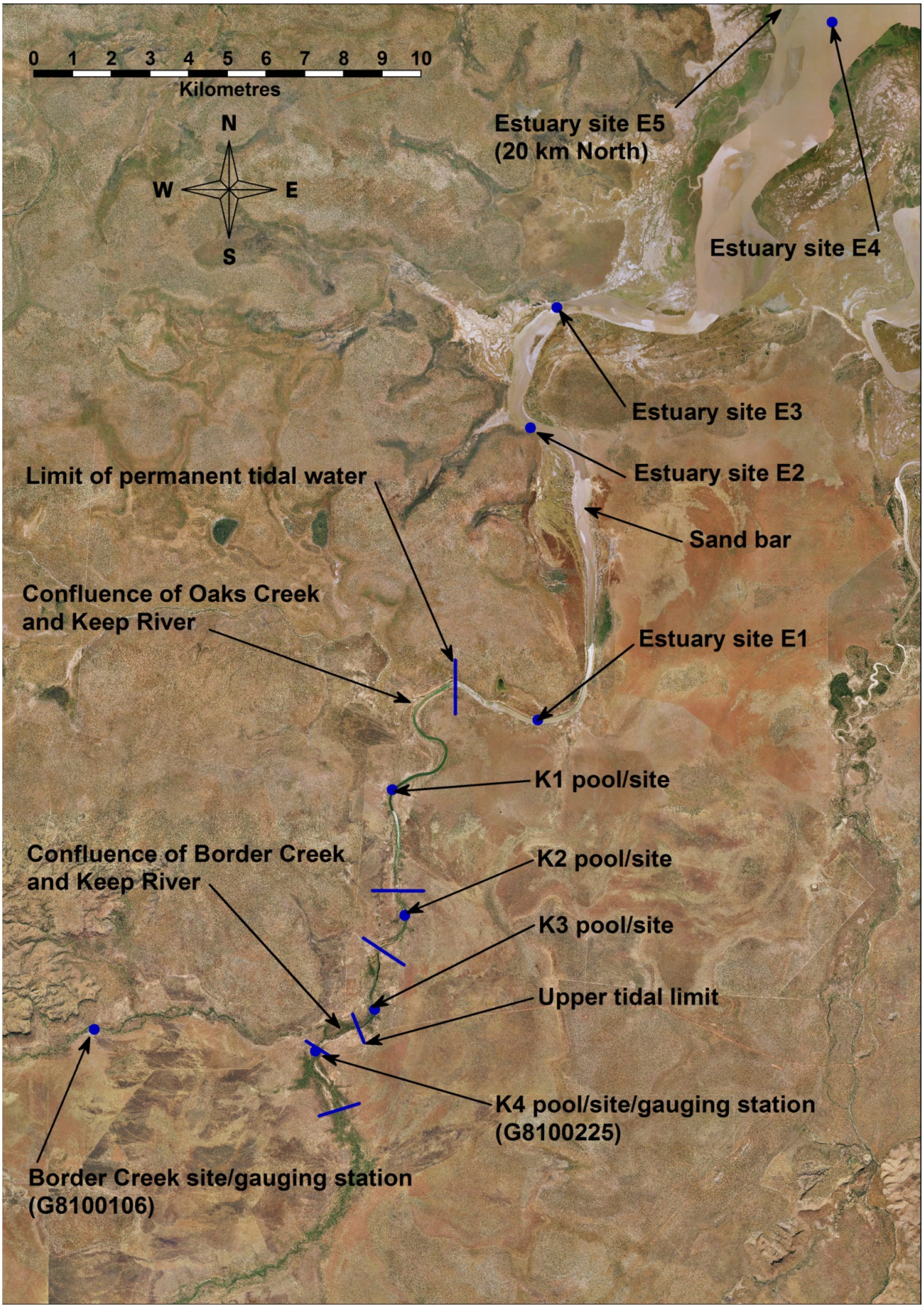

Figure 1.2 Aerial view of the lower Keep River area showing the Keep River pools, Keep River estuary, Border Creek, long-term gauging stations and the upper limit of tidal influence determined by Bennett and George (2011)

2 Methods

2.1 Sample site selection and sampling schedule

In anticipation of the Ministerial requirement for baseline water sampling to be undertaken in the lower Keep River area, detailed sampling at the Border Creek (BC) and K1–K4 sites (Figure 1.2) started in June 2010. Additionally, combined depth, electrical conductivity (EC) and temperature recording dataloggers were installed at the sample sites at this time. Sampling at the additional estuary sites E1–E3 commenced in June 2012 in response to the release of the Ministerial requirements for the Goomig Farmlands development. The Ministerial requirement for estuary sampling was that water quality baseline determination be undertaken for site E1, with aquatic fauna surveying at E1 plus two other sites, E2 and E3. The additional requirement for sites E2 and E3 was made to determine if the aquatic fauna data at site E1 was representative of the rest of the upper estuary. In view of this requirement it was decided to undertake water quality sampling at E2 and E3 also. Limited additional water quality sampling at sites E4 and E5 was undertaken to obtain data on the longitudinal extent of any terrestrial run-off influences on the lower estuarine environment during wet season flows.

In their review of the available data, Bennett and George (2011) proposed a sampling schedule for the lower Keep River area that considered the ANZECC and ARMCANZ (2000) protocols and the Ministerial requirements — together with the seasonal accessibility constraints of the area as detailed in Section 2.2. The modified schedule was reviewed and accepted by the IRG in December 2011.

The BC and K4 sites are located at the long-term flow gauging stations operated by the Northern Territory Department of Land Resource Management. The K1–K3 sites are located at about the longitudinal centre of each of pool. Site E1 is located in the narrow upper part of the Keep River estuary upstream of a large sand bar that restricts the volume of tidal water exchange during periods of neep tides. Site E2 is situated downstream of the sand bar and above a rock bar that is partially exposed at low tide. Site E4 is adjacent to the confluence with the estuarine part of the Sandy Creek system, while site E5 is located where the estuary widens to become part of the Bonaparte Gulf. The coordinates of the sample sites are listed in Table 2.1 and Figure 2.1 contains photographs of the Keep pools and the estuary sites sampling locations.

The schedule of the sampling program plus the type of sample analysis undertaken during the baseline sampling program is detailed in Table 2.2.

Table 2.1 Coordinates of the sample site locations

Sample site	Easting (GDA94, Zone 52)	Northing (GDA94 Zone 52)
BC	501231	8297621
K4	506941	8297061
K3	508923	8303810
K2	509247	8300569
K1	508469	8298138
E1	512681	8305611
E2	512492	8313162
E3	513175	8316268
E4	521200	8325310
E5	520130	8342750

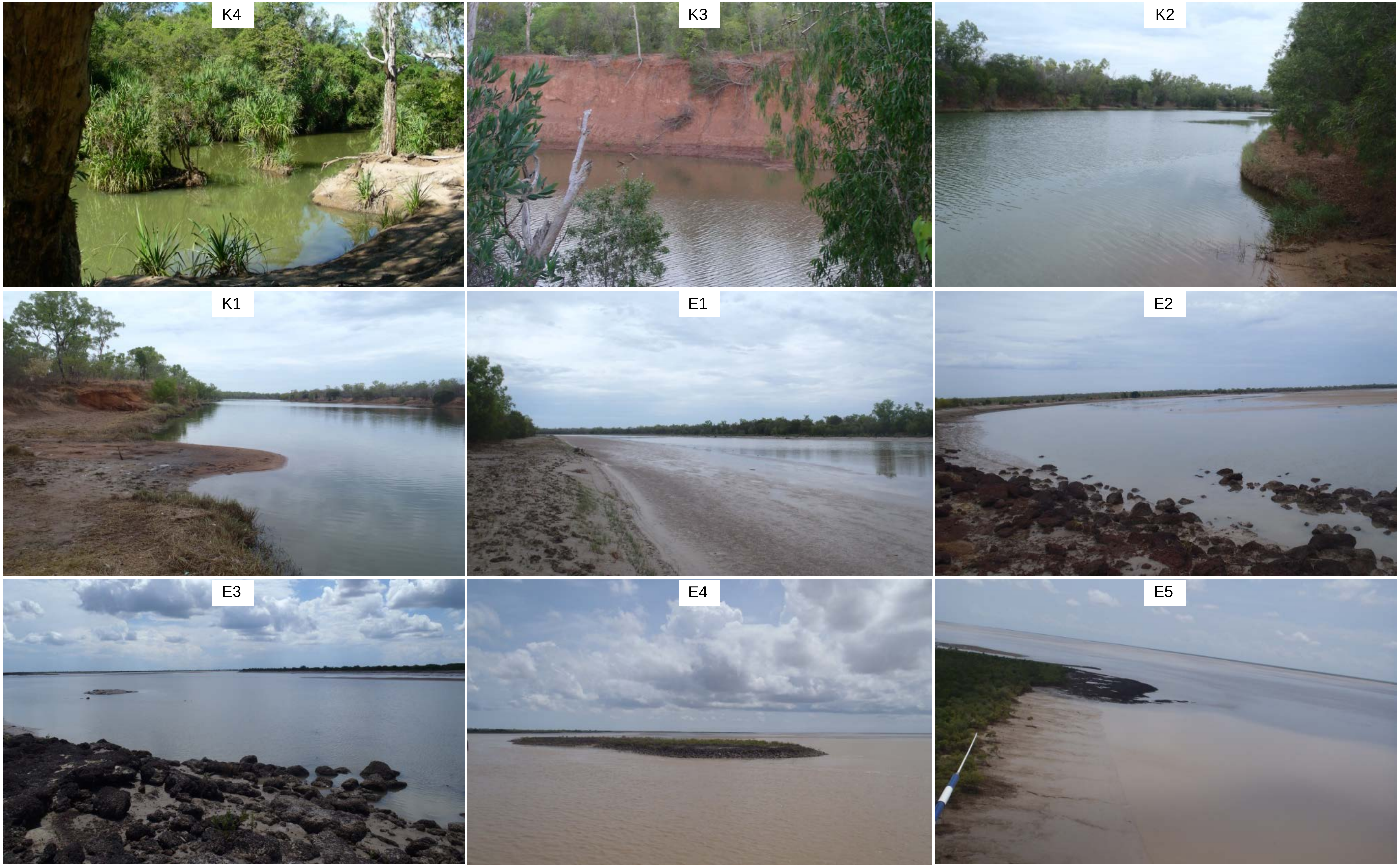

Figure 2.1 Photographs of the Keep River and Keep River estuary sampling locations

2.2 Sample collection, access and treatment considerations

The lower Keep River area is about 70km from Kununurra. Prior to construction of a sealed road to within about 20km of the river in 2013, access was via the unsealed Legune Road, which becomes impassable after rainfall. Despite the increased length of the sealed section, vehicular access to the river after rainfall is unreliable due to the remaining several kilometres of unsheeted blacksoil. The Shire of Wyndham – East Kimberley also close the unsealed sections of Legune Road during wet periods. Vehicle access to sample sites along the Keep River to the north of Legune Road is by unformed tracks that cross several creeks and gullies and areas of blacksoil. Access to the Border Creek sample site/gauging station is undertaken by traversing several kilometres of bush, through which there was often no discernible vehicle tracks to follow. This site is also inaccessible in the wet season.

2.2.1 Dry season

Access to sampling sites in the dry season (typically May to October), while sometimes difficult depending on prevailing conditions, was by four-wheel drive vehicle or quad-bike. Samples were collected at each site (BC, K1–K4, E1–E3) monthly: commencing at the end of the wet season (as soon as vehicle access became possible) and ceasing with the onset of the wet season rains. Border Creek is an ephemeral system and so very few samples were obtained during the dry seasons.

Monthly samples for general chemistry and nutrient analysis were collected in new plastic 0.5L bottles that were rinsed immediately prior to collection with sample water to minimise the risk of contamination. Samples were collected from a depth of about 0.5m, within two metres from the edge of the bank. They were kept cool in the field and during dispatch by airfreight to the laboratory for analysis. Separate samples were also periodically (Table 2.2) collected for analysis of metals by filtering water, collected in a similar way to the general chemistry samples, through 0.45µm cellulose acetate filters into new 0.25L acid-washed plastic bottles, acidified with nitric acid to pH 1–2 and then kept chilled. Samples for the marker agricultural chemical toxicant atrazine were also collected periodically (Table 2.2) into opaque glass, acid-washed bottles and kept chilled. Sampling for Chlorophyll (Chlor. a) determination was done by filtering up to 1L of water through a 0.45µm glass fibre filter paper. Often the high level of suspended inorganic material in the water meant that it was not physically possible to filter 1L of water due to repeated filter blockages. In these instances, the volume filtered was recorded to allow the calculation of Chlorophyll concentration after analysis. The filter paper containing the filtrate was sealed in a plastic bag and also kept cool during transit to the laboratory.

Field measurement of pH, EC, temperature, dissolved oxygen (DO), oxidation–reduction potential (ORP) and turbidity (Turb.) was undertaken using portable meters (WTW® brand plus Sigma® brand for turbidity).

2.2.2 Wet season

The limited access to the area by vehicle during the wet season required an alternative approach to sample collection and treatment. Autosamplers were mounted on the Border Creek (BC) and Keep River (K4) gauging stations (Figure 1.2), above the historic peak flood height. At this elevation, the autosamplers' peristaltic pumps were not able to lift the sample water at low flow levels, so the sample tube inlets were equipped with auxiliary submersible 12V marine bilge-type pumps that provided sufficient additional lift.

Sigma® (Hach Pty Ltd) brand (Model 900MAX) autosamplers equipped with 24 sample bottles, integral electronic water level, velocity and EC sensors and recorders were used. The autosamplers were used in combination with the electronic gauging equipment maintained by the Northern Territory Department of Land Resource Management, the Ceradiver® dataloggers (see below), and fixed staff gauges for added verification of water level and EC. Sampling locations (Figure 1.2) were the Department of Land Resource Management gauging stations GS8100225 (K4) and GS8100106 (BC).

The autosampler sensors and sample inlets were placed 0.2m below the baseflow level in K4 and 0.2m below the cease-to-flow level in Border Creek. The autosamplers measured water level, velocity and EC every five minutes and logged the average of each parameter every hour.

For the first half of each wet season, the autosamplers were programmed to sample at a rate of one 0.7L sample per millimetre of discharge with a timed override of one sample per week (provided there was flow). The stage to flow rate relationships used to determine the flow volume were those defined by DLRM for the gauging stations. A helicopter was used to access the sites mid wet season to retrieve the samples and reconfigure the autosamplers to continue sampling at a rate of one sample every three days (until the end of the wet season).

Mercuric chloride was added to the empty autosampler bottles at installation, at the equivalent rate of 400mg/L of sample, to minimise sample nutrient degradation by biological processes during the intervals between collection, retrieval and analysis. Mercuric chloride has been used extensively as a water sample N and P fixative in situations where samples are required to be stored for up to 100 days without refrigeration (Krawczyk 1975). Autosampler samples were transported by airfreight to the laboratory for analysis of selected general chemistry parameters.

In addition to being used to service the autosampler sites, the helicopter was used to access and manually sample sites BC, K1–K4 and E1–E5. This allowed collection of samples for analysis of the full range of physicochemical stressor and toxicant parameters. During these trips field parameters were also collected at sites where the helicopter could safely land (K1, E3 and E5). At other sites, samples were collected by suspending a sampling vessel from the helicopter while it hovered a few metres above the water. The hovering method did not allow the recording of the field parameters at these sites.

Opportunistic manual sampling was also undertaken (when track and weather conditions allowed vehicle access) during the 2011/12 and 2012/13 wet seasons, which were comparatively drier than average.

Table 2.2 Schedule of measurements, sampling and analysis suites undertaken

Date	K4	BC	K1	K2	K3	E1	E2	E3	E4	E5
Jun-10	LGF	LGF								
Jul-10	LGF	LD								
Aug-10	LGF	LD	LGF	LGF	LGF					
Sep-10	LGMF	LD	LGF	LGF	LGF					
Oct-10	LGF	LD	LGF	LGF	LGF					
Nov-10	LGF	LD	LGF	LGF	LGF					
Dec-10	LAGFT	LD	LGF	LGF	LGF					
Jan-11	LGF	LAGF								
Feb-11	LAGF	LAGF	LG	LG	LGF	GF				
Mar-11	LA	LA								
Apr-11	LA	LA								
May-11	LAGF	LAGF	LGF	LGF	LGF					
Jun-11	LGF	LGF								
Jul-11	LGMF	LGMF	LGF	LGF	LGF					
Aug-11	LGF	LD	LGF	LGF	LGF					
Sep-11	LGF	LD	LGF	LGF	LGF	GF				
Oct-11	LGF	LD	LGF	LGF	LGF	GF	GF	GF		
Nov-11	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Dec-11	LGMF	LGMF	LGMF	LGMF	LGMF					
Jan-12	LAGMF	LAGMF								
Feb-12	LA	LA								
Mar-12	LAGMF	LAGMF	LGM	LGM	LGMF	GMF	GMF	LGMF	GMF	GMF
Apr-12	LAGMF	LAGMF	LGM	LGM	LGM	GM	GM	LGM	GMF	GMF
May-12	LAGMF	LAGMF	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Jun-12	LGF	LGF	LGF	LGF	LGF	GF	GF	LGF		
Jul-12	LGMF	LD	LGF	LGF	LGF	GF	GF	LGF		
Aug-12	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Sep-12	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Oct-12	LGMFT	LD	LGF	LGF	LGF	GF	GF	LGF		
Nov-12	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Dec-12	LA	LD								
Jan-13	LA	LD								
Feb-13	LAGF	LD	LGF	LGF	LGF	GF	GF	LGF		
Mar-13	LAGF	LAGF	LGF	LGF	LGF	GF	GF	LGF		
Apr-13	LAGMFT	LAGMFT	LGM	LGM	LGMF	GMF	GMF	LGMF	GMF	GMF
May-13	LAGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Jun-13	LGF	LD	LGF	LGF	LGF	GF	GF	LGF		
Jul-13	LGF	LD	LGF	LGF	LGF	GF	GF	LGF		

Date	K4	BC	K1	K2	K3	E1	E2	E3	E4	E5
Aug-13	LGF	LD	LGF	LGF	LGF	GF	GF	LGF		
Sep-13	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Oct-13	LGMF	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		
Nov-13	LGMFT	LD	LGMF	LGMF	LGMF	GMF	GMF	LGMF		

A Autosampler suite of general chemistry and nutrients
G General chemistry and nutrients suite from manual sampling
F Field parameters from manual measurement
D Site dry or no flow
L Water height and EC from loggers
M Metals suite from manual sampling
T Toxicant agricultural chemical atrazine from manual sampling

2.3 Analytes

From Table 2.2 it can be seen that a combination of the analysis suites for general chemistry, field chemistry and autosampler analysis in addition to logger data collection, commenced in June 2010 for sites K1–K4 and BC. Subsequent to the publication of the Ministerial conditions (in September 2011) and the IRG's review of the data obtained by Bennett and George (2011), the sampling and analysis effort was increased. This resulted in the addition of the estuary sites, regular analysis for metals at all sites, analysis for atrazine, plus the installation of a depth/EC logger at E3.

The suite of analytes chosen (Tables 2.3–2.6) was comprehensive. ANZECC and ARMCANZ (2000) recommend choosing analytes for baseline monitoring based on prior knowledge of the analytes that pose a risk to the health of any target aquatic species, due to a high probability of change or sever consequence of change. The target aquatic species requiring protection in this instance are the NES species: freshwater sawfish (*Pristis microdon*) and speartooth shark (*Glyphis glyphis*). While there is some general (e.g. Bartley & Spiers 2010) and local (e.g. Bennett and George 2011, WRM 2014) data available about the expected changes to water quality under tropical irrigated agriculture, there was no specific information (Helen Larsen [IRG] 2011, pers. comm., November) about which water quality factors are of particular importance or risk to the NES species. So a precautionary approach was used to select a comprehensive list (Tables 2.3–2.6) of analytes that ANZECC and ARMCANZ (2000) categorise as stressors and toxicants to aquatic biota. The list of analytes in Table 2.3 encompasses all of the stressors and metal toxicants listed in ANZECC and ARMCANZ (2000), plus the chemical toxicant atrazine. It also encompasses those listed in Bennett and George (2011) as recommended for baseline sampling. In addition to this list, data on several other analytes were also collected, as they were part of an analysis package provided by the laboratory. Tables 2.5 and 2.6 also list these additional analytes.

Atrazine, which is an ideal indicator species for the presence of agricultural chemicals in run-off in tropical irrigated agricultural because of its apparent high mobility (Bennett & George 2011) was also tested-for on several occasions in water samples obtained from the Keep River (Table 2.2). Although the presence of atrazine was not expected — given that there is no agricultural development in the Keep River

Catchment — it was recommended by the IRG to be included as a pre-development baseline indicator for the presence of agricultural chemicals.

2.4 Chemical analysis

The list of analytes, their abbreviations, the analysis methods and the limits of reporting (LOR) within each of the analysis types shown in Table 2.2 appear in Tables 2.3–2.6. Some of the LOR levels were reduced during the study period, as laboratory analysis methods increased in precision. All laboratory sample analyses were undertaken by the ChemCentre (WA) — NATA accredited and certified to AS/NZS ISO/IEC 17025:2005.

2.5 Dataloggers

Ceradiver® (Schlumberger Pty Ltd) combined depth/EC/temperature recording dataloggers were installed at the sample sites in pools K1–K4 and BC in June 2010. An additional logger was installed in the Keep River estuary at site E3 in November 2012. The loggers were placed inside steel shrouds fixed to steel posts in relatively deep-water locations. They were positioned so that they were accessible from the bank and downstream of rock outcrops or large, anchored tree trunks that afforded protection from potential damage caused by large items of debris carried in floodwaters. They were installed so that the sensors were about 0.5m below the base water levels in pools K1–K3, 0.2m below the baseflow level in K4, 0.2m below the cease-to-flow level in Border Creek and at the low tide level at E3. The positions and elevations of the loggers (with the exception of E3) were surveyed using a differential GPS by Survey North (Pty Ltd) in November 2011. The elevation of the E3 logger was estimated by calculations that compared the water elevation recorded at K1 with the water head above the logger at E3 on the occasions when tides were high enough in the estuary to overtop into K1.

Water level, EC and temperature were logged every hour. Each time the dataloggers were visited the water depth relative to the sensor was measured and a sample obtained for EC determination. This data was subsequently compared to the datalogger data to verify the accuracy of the latter. At each download, the loggers were replaced with clean, tested and recalibrated instruments.

2.6 Defining wet and dry seasons for data separation

The flow records for K4 and BC over the study period were examined to better define the start and end of the wet and dry seasons, so that the seasonal water quality data for each site could be separated on the basis of flow rather than on arbitrary dates. At Border Creek the wet season was defined as commencing with the first flow and ceasing when the flow rate fell below $0.01m^3/s$ after the final flow event of the season. The cessation of all flow was not used for two reasons. Firstly, flows less than $0.01m^3/s$ are beyond the accuracy of the gauge and rating for the site. Secondly, trickling flows continued for several weeks after wet season rains finished, probably as a result of localised seepage from ephemeral perched groundwater systems discharging into the creek channel.

For the Keep River, the wet season was defined to have commenced when the flow rate at K4 first exceeded $0.1m^3/s$, being the consistent baseflow rate at this point. The wet season was regarded to have ended when there was 3GL of wet season-induced flow left in the system at the end of the wet season (i.e. only flows above the

0.01m^3/s baseflow rate were used to calculate the wet season-induced flow volume). The 3GL residual amount was chosen based on flow and EC data reported by Bennett and George (2011). This data showed that a discrete early wet season flow event, commencing on 1 November 2010, of 3GL volume was sufficient to completely reset the EC of pools K1–K3 to about the EC of the inflowing water (at K4).

For the downstream sample sites (K1–K3 and E1–E5), the start and end of the wet season was assumed to also coincide with the dates derived for K4. This assumption may not always be valid because the downstream sites also have their own contributing catchments (e.g. Oaks Creek, Figure 1.2) which may start to flow earlier or cease to flow later than the Keep River at K4. To confirm whether the dates chosen for K4 coincided with the other downstream pools, the datalogger-derived water elevation and EC data for the pools were compared to determine if there were any obvious inconsistencies. This process did not find any major apparent differences that would have caused samples from different sites (that were collected on the same date) to be assigned to different seasons. However, it was very difficult to routinely determine if small locally-sourced flows into downstream sites had occurred prior to the assumed start of the wet season (based on K4 data).

2.7 Data analysis

All statistical analyses of data were undertaken using Microsoft Excel®. Coefficient of Variation (COV) analyses were undertaken by dividing the statistical sample means by the statistical sample standard deviations. The analysis used to describe the statistical difference between factors at various sites or between seasons was the double-tailed Students T-test. During data preparation for statistical analysis, concentrations that were reported as being below the LOR were assigned a value equal to half of the LOR. Halving the LOR is one of the three suggested methods of dealing with LOR data during statistical analysis for determining baseline concentrations (ANZECC AND ARMCANZ 2000). Alternatively, the LOR data can be excluded from the dataset, or a value equal to the LOR assigned during data analysis. The half LOR approach was used because it was considered more conservative — as it was found that use of either of the other methods tends to artificially increase the derived baseline concentrations. The half LOR approach was proposed to, and accepted by, the IRG.

Table 2.3 The field measurement suite of analytes with their LORs, units, laboratory analysis method and whether they were filtered prior to analysis

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Dissolved oxygen	DO	1	%	galvanic electronic probe	N
Electrical conductivity	EC	0.1	mS/m	electronic probe	N
Oxidation reduction potential (as eH)	ORP	1	mV	platinum electronic probe converted to eH	N
pH	pH	0.1	none	electronic probe	N
Temperature	Temp	0.1	^oC	electronic probe	N
Turbidity	Turb.	0.1	NTU	light attenuation meter	N
Water level or flow	WL	0.001	m	logger/tape	N

Table 2.4 The autosampler measurement suite of analytes with their LORs, units, laboratory analysis method and whether they were filtered prior to analysis

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Electrical conductivity	EC	0.02	mS/m	electronic probe	N
pH	pH	0.1	none	electronic probe	N
Total dissolved solids 180	TDS 180	10	mg/L	mass of evaporated filtrate	Y
Total nitrogen	TN	0.02	mg/L	PD, CaR, CR & AFIAC	N
Total phosphorus	TP	0.01/0.005	mg/L	PD, CR & AFIAC	N
Total suspended solids	TSS	1	mg/L	filtration	Y
Turbidity	Turb.	0.5	NTU	light attenuation meter	N

PD Persulphate digestion

CaR Cadmium reduction

CR Colorimetric reaction

AFIAC Automated flow injection analysis colorimeter

Table 2.5 The general chemistry measurement suite of analytes with their LORs, units, laboratory analysis methods and whether they were filtered prior to analysis

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Acidity*	Acidity	2	mg/L	Titration	N
Alkalinity†	Alk.	1	mg/L	Titration	Y
Bicarbonate†	HCO_3	1	mg/L	Titration	Y
Carbonate†	CO_3	1	mg/L	Titration	Y
Chloride†	Cl	1	mg/L	CR & DA	Y
Chlorophyll a	Chlor. a	0.001	mg/L	Combustion	Y
Dissolved organic carbon†	DOC	1	mg/L	Colorimetry	Y
Electrical conductivity	EC	0.02	mS/m	Electronic probe	N
Fluoride†	F	0.05	mg/L	Selective electrical probe	Y
Hardness†	Hard.	1	mg/L	Calc. from Ca and Mg	Y
Hydroxide*	OH	1	mg/L	Titration	Y
Ion balance*	Ion bal.	-50	%	Calculation	Y
Sulphate*	SO_4 S	0.1	mg/L	ICPAES	Y
Total nitrogen	TN	0.02	mg/L	PD, CaR, CR & AFIAC	N
Ammonium nitrogen	NH_4 N	0.01	mg/L	CR & AFIAC	Y
Nitrate nitrogen†	NO_3 N	0.01/0.05	mg/L	CaR, CR & AFIAC	Y
Nitrite nitrogen†	NO_2 N	0.01	mg/L	CR & AFIAC	Y
Oxidised nitrogen	NO_x N	0.01/0.05	mg/L	Sum of NO_3 and NO_2 N	Y

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Soluble organic nitrogen*	SON	0.02	mg/L	Calc. TSN–(NO_x+NH_4 N)	Y
Total organic nitrogen*	TON	0.01	mg/L	Calc. TN–(NO_x+NH_4 N)	N
Total soluble nitrogen†	TSN	0.02	mg/L	PD, CaR, CR & AFIAC	Y
pH	pH	0.1		Electronic probe	N
Total phosphorus	TP	0.01/0.005	mg/L	PD, CR & AFIAC	N
Soluble reactive phosphorus	SRP	0.01/0.005	mg/L	PO_4 P by CR & AFIAC	Y
Soluble organic phosphorus*	SOP	0.02	mg/L	Calc. TSP–SRP	Y
Total organic phosphorus*	TOP	0.02	mg/L	Calc. TP–TRP	N
Total particulate phosphorus*	TPP	0.02	mg/L	Calc. TP–TSP	N
Total reactive phosphorus†	TRP	0.01	mg/L	PO_4 P by CR & AFIAC	N
Total soluble phosphorus†	TSP	0.01/0.005	mg/L	PD, CR & AFIAC	Y
Total dissolved solids 180†	TDS 180	10	mg/L	Evaporated filtrate	Y
Total dissolved solids Sum†	TDS Sum	1	mg/L	Sum of anions/cations	Y
Total suspended solids	TSS	1	mg/L	Mass of filtrate	N
Turbidity	Turb.	0.5	NTU	Light attenuation	N

* Analyte additional to ANZECC and ARMCANZ (2000) recommended baseline list

† Analyte additional to IRG and ANZECC and ARMCANZ (2000) recommended list

PD Persulphate digestion

CaR Cadmium reduction

CR Colorimetric reaction

AFIAC Automated flow injection analysis colorimeter

DA Discrete analyser

ICPAES Inductively coupled plasma atomic emission spectroscopy

CMS Coupled mass spectroscopy

Table 2.6 The metals suite of analytes and atrazine with their LORs, units, laboratory analysis methods and whether they were filtered prior to analysis

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Aluminium	Al	0.005	mg/L	ICPAES	Y
Antimony	Sb	0.0001	mg/L	CMS	Y
Arsenic	As	0.001/0.01	mg/L	CMS	Y
Barium*	Ba	0.002	mg/L	ICPAES	Y
Beryllium	Be	0.0001	mg/L	CMS	Y
Bismuth	Bi	0.0001	mg/L	CMS	Y
Boron	B	0.02	mg/L	ICPAES	Y
Cadmium	Cd	0.0001	mg/L	CMS	Y
Calcium*	Ca	0.1	mg/L	ICPAES	Y

Analyte	Symbol	LOR	Units	Analysis method	Filtered
Chromium	Cr	0.0005	mg/L	CMS	Y
Chromium	Cr	0.001	mg/L	ICPAES	Y
Cobalt	Co	0.005/0.001	mg/L	ICPAES	Y
Cobalt	Co	0.0001	mg/L	CMS	Y
Copper	Cu	0.002	mg/L	ICPAES	Y
Copper	Cu	0.0001	mg/L	CMS	Y
Gallium	Ga	0.0001	mg/L	CMS	Y
Iron	Fe	0.005	mg/L	ICPAES	Y
Lanthanum	La	0.005	mg/L	ICPAES	Y
Lead	Pb	0.0001	mg/L	CMS	Y
Lithium*	Li	0.005	mg/L	ICPAES	Y
Magnesium*	Mg	0.1	mg/L	ICPAES	Y
Manganese	Mn	0.001	mg/L	ICPAES	Y
Mercury	Hg	0.0001	mg/L	Vapour spectroscopy	Y
Mercury	Hg	0.0001	mg/L	CMS	Y
Molybdenum	Mo	0.001	mg/L	CMS	Y
Nickel	Ni	0.001	mg/L	CMS	Y
Potassium*	K	0.1	mg/L	ICPAES	Y
Selenium	Se	0.05	mg/L	CMS	Y
Silicon*	Si	0.05	mg/L	ICPAES	Y
Silver	Ag	0.0001	mg/L	CMS	Y
Sodium*	Na	0.1	mg/L	ICPAES	Y
Thallium	Tl	0.0001	mg/L	CMS	Y
Tin	Sn	0.0001	mg/L	CMS	Y
Tin	Sn	0.02	mg/L	ICPAES	Y
Titanium*	Ti	0.001	mg/L	CMS	Y
Uranium	U	0.0001	mg/L	CMS	Y
Vanadium	V	0.0001	mg/L	CMS	Y
Vanadium	V	0.005	mg/L	ICPAES	Y
Zinc	Zn	0.001	mg/L	CMS	Y
Zinc	Zn	0.005	mg/L	ICPAES	Y
Atrazine	Atra.	0.2/0.01	µg/L	Liquid chromatography	N

* Analyte additional to those recommended in ANZECC and ARMCANZ (2000)

ICPAES Inductively coupled plasma atomic emission spectroscopy

CMS Coupled mass spectroscopy

3 Results

3.1 Rainfall

Daily rainfall intensity recorded at the Keep River (at K4) and Border Creek (BC) gauging stations during the study period is shown in Figure 3.1. Significant rainfall was restricted to the wet season months of November to April. The 2010/11 wet season had the most intense and regular rainfall of the three wet seasons, followed by the 2011/12 season. Maximum rainfall intensities exceeded 100mm/day in each wet season.

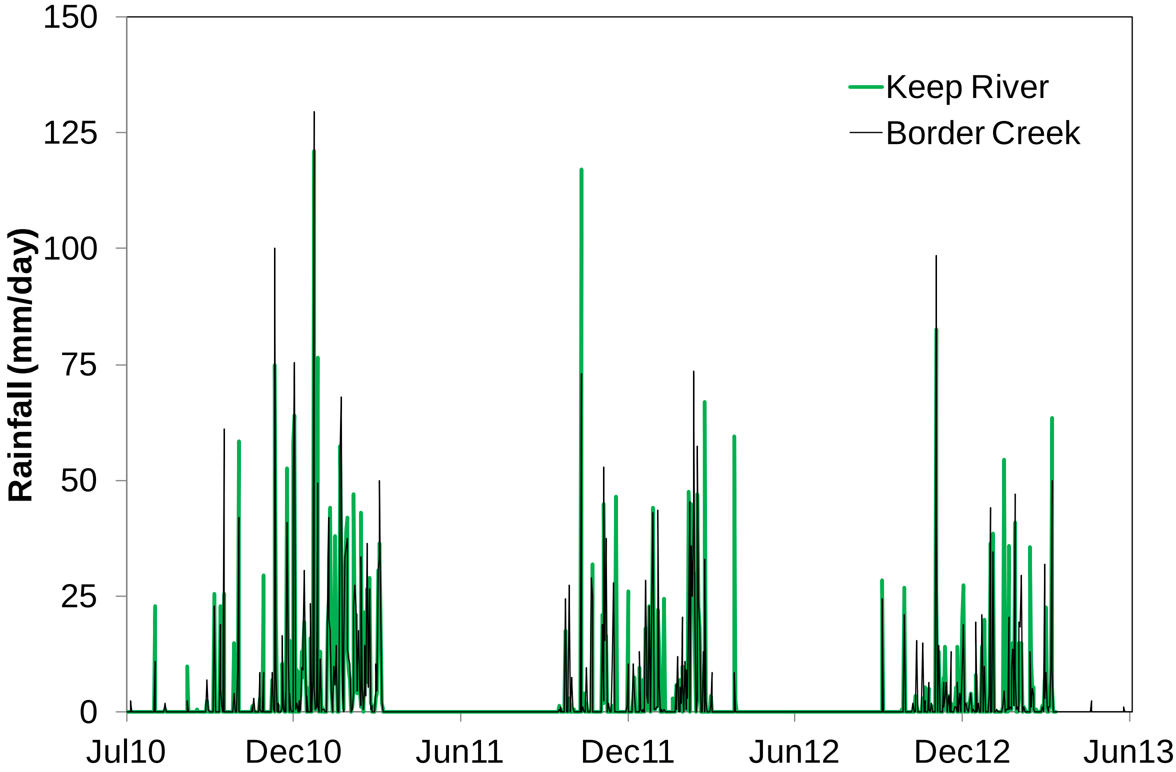

Figure 3.1 Daily rainfall intensity recorded during the 2010–13 period at the Keep River (K4) and Border Creek gauging stations (data source: Northern Territory Department of Land Resource Management)

Table 3.1 shows the annual rainfall (July to June period) recorded at the K4 and BC sites together with that recorded at the Ivanhoe rainfall station (Figure 1.1) and compares these to the respective long-term averages at each site. There is 12 years of data available for BC, 4 years available for K4 and over 100 years of data for the Ivanhoe which is included as a long-term comparison. At the K4 and BC sites: the 2010/11 season received the maximum rainfall recorded. At BC the 2011/12 season was about average, whereas the 2012/13 season was much drier than average. The 2010/11 rainfall recorded at the Ivanhoe Station site was equivalent to the 74th percentile of available data.

Table 3.1 Annual rainfall recorded during the July to June period at the Keep River (K4) and Border Creek (BC) gauging stations and at the Ivanhoe rainfall station during the 2010–13 period, with their respective long-term annual averages calculated from all available data

Period	K4 (mm)	BC (mm)	Ivanhoe (mm)
2010/11	1833	1736	926
2011/12	1063	1112	727
2012/13	837	794	817
Long-term average	1142*	1083†	795‡

* Average of available data from 2001 to 2013

† Average of available data from 2009 to 2013

‡ Average of data from 1907 to 2013

Source: Northern Territory Department of Land Resource Management and the Bureau of Meteorology

3.2 Keep River and Border Creek discharge rates

The average annual wet season flow of the Keep River (at K4) is about 638GL and has varied between 14 and 2698GL (during the periods where data is available; 1964–1986 and 1998–2013) in response to the amount of wet season rainfall. The average annual wet season flow of Border Creek (at BC) is about 62GL and has varied between 1 and 251GL (during the periods where data is available; 1971–86 and 1998–2013). The wet season flow from the Border Creek Catchment (100 700ha) is about 10%, on average (range 0.2–47%), of that from the Keep River (at K4) catchment (351 000ha).

Annual surface discharge recorded from the Keep River (at K4) and Border Creek (at BC) catchments during the 2010–13 period followed the pattern observed in the rainfall. Table 3.2 shows annual discharge (July to June period) expressed in both total flow (GL) and millimetres of discharge (flow normalised for catchment area), plus their percentiles in relation to all available data. Wet season discharge at both sites during 2010/11 was much higher than the long-term average, closer to average in 2011/12 and very much below average in 2012/13. When expressed on an areal basis (mm of discharge) and compared to the Keep River Catchment, the Border Creek Catchment produced a lower rate of run-off during the wetter 2010/11 season.

The range of rainfall and run-off characteristics during the study period, which included a high, an average and a low rainfall and run-off year, provide an ideal range of conditions against which to assess baseline flow and water quality characteristics of the lower Keep River area.

Table 3.2 Annual discharge recorded each year in the July to June period at the Keep River (K4) and Border Creek (BC) gauging stations

Period	K4 (GL)	K4 (mm)	K4 percentile	BC (GL)	BC (mm)	BC percentile
2010/11	2261	644	97	244	242	97
2011/12	311	89	45	111	110	77
2012/13	77	22	15	1	1	10
Long-term average	638	182	50	62	62	50

Source: Northern Territory Department of Land Resource Management

3.3 Temporal dynamics of water quality parameters

Figures 3.2 and 3.3 show the temporal dynamics of EC, turbidity (Turb.), dissolved oxygen (DO), total nitrogen (TN), total phosphorus (TP), aluminium (Al) and zinc (Zn) from sites BC, K1–K4 and E1. The Keep River daily mean flow rate and the ANZECC and ARMCANZ (2000) default trigger values for tropical Australia (AADTVTAs) are also shown as a visual reference to distinguish periods of active run-off and relate the observed concentrations to the AADTVTAs.

The observed values of each of the analytes regularly fell outside the relevant AADTVTA at all sites. The concentration of each of the analytes at each site also varied widely over the period of observation, with the range in values being at least an order of magnitude. EC and Turb. varied by over three orders of magnitude at many of the sites.

Though variable, EC was generally much lower during the wet seasons at all sites — as a result of their being flushed with fresh streamflow. EC was relatively low in the estuary (at E1), even during the 2012/13 wet season when run-off was very low. However, at the downstream sites E1 and K1 (or in the case of K2 and K3 in 2013) the EC values abruptly increased at the end of each wet season, presumably as a result of the first tide-induced addition of marine water. It appears that the wet season flushing effect may extend even further down the estuary, with the EC at site E4 falling to 222mS/m in March 2012.[2] This dilution effect was evident, but not as pronounced, at E5 where the EC fell from 4560mS/m to 3810mS/m in March 2012.

Following the cessation of flow each wet season, the EC in pool K4 gradually increased, to a maximum of about 100mS/m in 2013. This gradual increase is mirrored in K3, although the EC in K3 abruptly increased later in the dry seasons of 2012 and 2013 (to about 700 and 500mS/m, respectively) as a result of tidal influence. The EC in Border Creek, though variable, remained below 26mS/m.

The turbidity was highly elevated during the wet season at all sites (Figure 3.2), as a result of suspended soil, sediment, plant and other debris being washed out of the catchment and transported in the fast flowing water. Extreme turbidity values of 1500 and 2700NTU were recorded at K4 during the 2012/13 wet season (data not shown in Figure 3.2). While site E1 was also highly turbid during the wet, Figure 3.2 shows that it could be highly turbid during the dry season as well. This difference is likely to

[2] 1mS/m equals: 10µS/m, 0.01dS/m, 0.01mS/cm and about 6mg/L

be because, unlike the upstream pools, E1 is under permanent tidal influence, which continuously stirs up the muddy sediments. Only limited turbidity data was available prior to July 2011.

Dissolved oxygen (DO) levels were also highly variable at all sites over the study period, although in general they were quite low, with most recordings being below the minimum AADTVTA of 85%. On two occasions in 2013, site K1 had very high DO levels, exceeding the upper AADTVTA of 120%. DO data was not collected prior to September 2011.

In general, TN concentrations were low during the dry season but rose abruptly with the first significant wet season run-off. Concentrations then appeared to decline gradually during the latter part of each wet season, possibly, as nitrogen was progressively washed from surfaces in the catchment. TN concentrations in both Border Creek and Keep River were highest during the high discharge 2010/11 wet season, although levels also consistently exceeded AADTVTAs during each subsequent wet season. Figure 3.3 shows that the TN concentrations at the downstream sites (K3–E1) were not as extreme during wet seasons. However, this is likely to be an artefact of the low sampling intensity at these sites — compared to K4 and BC which were equipped with autosamplers during the wet seasons. At site E1, TN levels were consistently above the AADTVTA (0.3mg/L), even during the dry seasons. The concentration of TN was very high in Border Creek (BC) and Keep River (at K4) during the first part of the 2010/11 wet season in particular. During the early part of the 2010/11 wet season, TN concentrations of 21, 14 and 38mg/L were recorded in samples from Border Creek while at K4 a sample with a TN concentration of 32mg/L was recorded (data not shown).

TP concentrations recorded were, as for TN, very high during the 2010/11 wet season at sites BC and K4. As for TN, TP concentrations were relatively low during dry seasons on most occasions at most sites then rapidly increased with the onset of wet season flows. TP concentrations in the Keep River (at K4) remained consistently very high for the first part of each wet season and then fell during the latter half. Border Creek did not have a pronounced initial (wet season) period of high TP concentration, with concentrations remaining at more uniform levels for most of the wet season. In both catchments TP concentrations reached levels of around 0.4mg/L.

Data for the heavy metal toxicants Al and Zn are shown in Figure 3.3. Al and Zn were the only metal toxicants consistently found at concentrations exceeding their AADTVTAs. Aluminium concentrations were highly variable between sites and samplings, being most variable in the wet season and generally lower during the dry seasons. Zinc concentrations were extremely variable between sites and samplings in both wet and dry seasons. Limited Al and Zn data is available prior to September 2011.

3.4 Water quality data summaries

Tables 3.3–3.8 show statistical summaries of the seasonal water quality data collected from sites K1–K4, BC and E1[3], for the appropriate known environmental physicochemical stressors or toxicants listed by ANZECC and ARMCANZ (2000). Two stressor parameters, NO_x N / NO_3 N and NH_3 N, are also regarded as toxicants depending on their concentrations and the situation — and have correspondingly different default TVs (see Appendix A). Insufficient samples were collected during the dry season from the ephemeral Border Creek to warrant summarising the data.

Data from all estuary sites (E1–E3) is aggregated in Table 3.9 to indicate the overall water quality characteristics of the upper section of the estuary — rather than those obtained at each individual estuary site. With the exception of EC (see sections 3.5 and 3.6), there was no statistically significant difference in any analyte between any of the upper estuary sites (E1–E3).

As per the ANZECC and ARMCANZ (2000) recommended protocols for reporting baseline data, summary data for each analyte comprises: the number of samples collected (n), the population mean and median, the coefficient of variation (COV), plus the 80th and the 20th percentile values. Tables 3.3–3.9 also indicate, for each analyte and for each site and season, the proportion of samples that had concentrations recorded that were less than the LOR. Appendix B contains a similar array of summary results for the water quality parameters that were analysed in addition to those listed in Tables 3.3–3.9. Appendix C contains the complete water quality dataset obtained from the lower Keep River area during the field, manual and autosampler sampling programs during 2010–2013. Bennett and George (2011) report the available water quality data obtained from various studies undertaken prior to 2010 in the lower Keep River area.

[3] Sites K1–K3 and E1–E3 have limited samples during the wet season

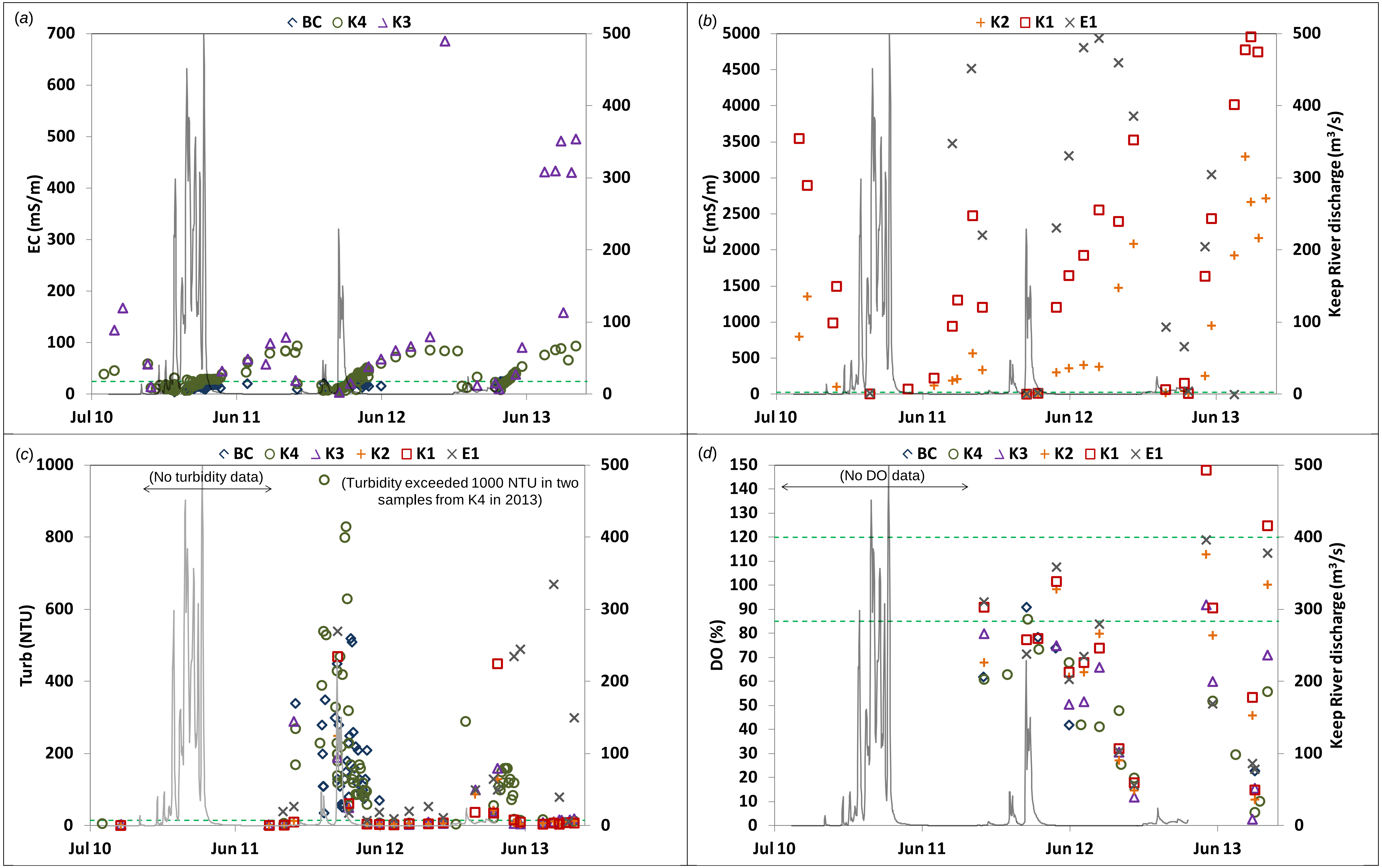

Figure 3.2 Temporal dynamics of (a) EC at sites BC, K4 and K3, (b) EC at sites K2, K1 and E1, (c) Turbidity at sites BC, K1–K4 and E1 and (d) DO at sites BC, K1–K4 and E1. Keep River daily mean flow rates are shown as a visual reference to distinguish wet and dry seasons. The green dashed lines indicate the ANZECC and ARMCANZ (2000) default trigger values (AADTVTAs) for tropical lowland rivers

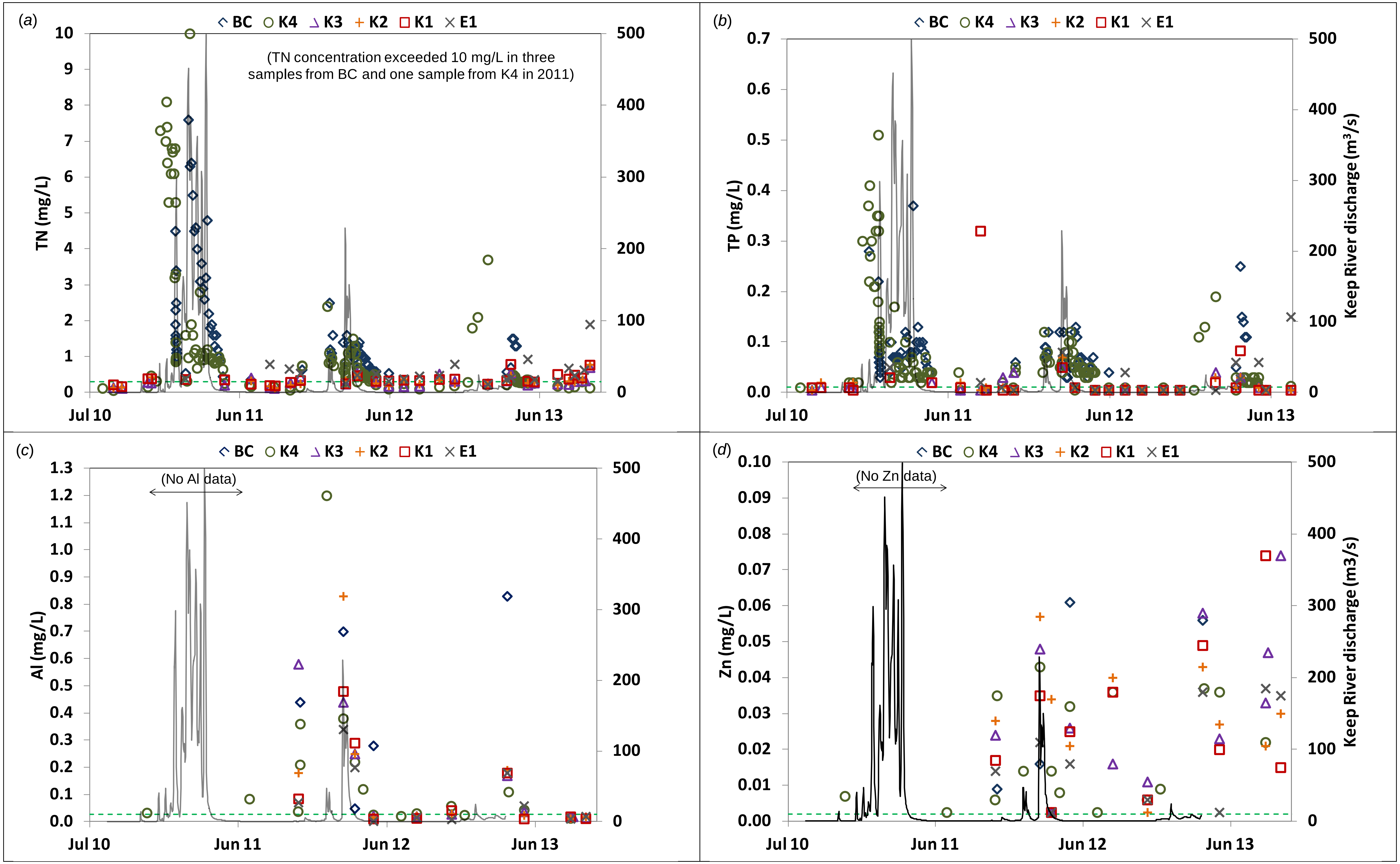

Figure 3.3 Temporal dynamics of (a) TN, (b) TP, (c) Al and (d) Zn at sites BC, K1–K4 and E1. Keep River daily mean flow rates are shown as a visual reference to distinguish wet and dry seasons. The green dashed lines indicate the ANZECC and ARMCANZ (2000) default trigger values (AADTVTAs) for tropical lowland rivers

Table 3.3 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from Border Creek (BC) during wet seasons. All units are mg/L, unless otherwise stated

Analyte	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile
Stressors							
Temp (^oC)	5	0	30.2	29.5	0.07	30.7	29.1
pH	69	0	6.6	6.5	0.11	7.1	6.0
EC (mS/m)	93	0	13.7	13.1	0.40	19.1	8.5
Turb. (NTU)	38	0	189	140	0.65	280	94
TSS	83	0	626	100	4.20	408	46
DO (%)	3	0	77	79	0.19	86	69
Chlor. a	3	67	0.0005	0.0005	0.00	0.0005	
TN	88	0	2.54	1.30	1.87	2.56	
NO_x/NO_3 N	7	86	0.01	0.01	0.33	0.01	
NH_3 N	6	0	0.02	0.01	0.72	0.03	
TP	88	0	0.082	0.070	0.64	0.100	
SRP	64	75	0.010	0.005	2.27	0.010	
Toxicants							
Al	4	0	0.505	0.570	0.68	0.752	
Sb	4	100	0.0001	0.0001	0.00	0.0001	
As	4	75	0.001	0.001	0.40	0.001	
Be	4	75	0.0001	0.0001	0.40	0.0001	
Bi	4	100	0.0001	0.0001	0.00	0.0001	
B	4	0	0.05	0.05	0.57	0.07	
Cd	4	100	0.0001	0.0001	0.00	0.0001	
Cr	4	50	0.0008	0.0008	0.41	0.0010	
Co	4	75	0.0021	0.0025	0.35	0.0025	
Cu	4	25	0.0029	0.0032	0.45	0.0035	
Ga	4	25	0.0002	0.0003	0.79	0.0004	
Fe	4	0	0.548	0.585	0.52	0.782	
La	4	100	0.0025	0.0025	0.00	0.0025	
Pb	4	0	0.0009	0.0008	0.86	0.0013	
Mn	4	0	0.022	0.008	1.47	0.034	
Hg	4	50	0.00013	0.00008	0.95	0.00018	
Mo	4	100	0.0005	0.0005	0.00	0.0005	
Ni	4	0	0.002	0.002	0.22	0.002	
Se	4	100	0.001	0.001	0.00	0.001	
Ag	4	50	0.0031	0.0027	1.16	0.0060	
Tl	4	100	0.0001	0.0001	0.00	0.0001	
Sn	4	75	0.0051	0.0052	1.10	0.0100	
U	4	50	0.0002	0.0001	1.12	0.0002	
V	4	25	0.007	0.006	0.68	0.009	
Zn	4	25	0.021	0.013	1.15	0.032	
Atra.	1	100	0.01	0.01	IND	0.01	

IND Insufficient data

Table 3.4 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from pool K4 in dry and wet seasons. All units are mg/L, unless otherwise stated

	Pool K4 dry season							Pool K4 wet season						
Analyte	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile
Stressors														
Temp (°C)	20	0	26.8	25.5	0.14	30.9	23.6	5	0	30.0	29.9	0.02	30.3	29.7
pH	68	0	7.7	7.7	0.04	7.9	7.4	91	0	6.9	6.9	0.11	7.5	6.3
EC (mS/m)	71	0	58.8	56.1	0.41	84.6	34.8	91	0	18.1	16.7	0.53	28.6	8.7
Turb. (NTU)	49	0	64	16	1.26	120	8	44	0	344	181	1.35	446	106
TSS	39	10	39	24	1.07	62	7	76	0	703	250	1.16	1400	94
DO (%)	14	0	46	45	0.64	62	23	2	0	80	80	0.11	84	76
Chlor. a	5	40	0.005	0.001	1.83	0.006		2	0	0.001	0.001	0.00	0.001	
TN	51	0	0.34	0.27	0.71	0.44		86	0	2.24	0.95	1.76	2.80	
NO_x/NO_3 N	28	54	0.01	0.01	0.80	0.01		12	33	0.02	0.01	0.99	0.04	
NH_3 N	26	54	0.02	0.01	1.46	0.03		7	43	0.02	0.01	0.94	0.03	
TP	51	22	0.022	0.020	0.72	0.040		86	2	0.102	0.060	1.02	0.130	
SRP	47	79	0.006	0.005	0.34	0.009		61	66	0.007	0.005	0.42	0.010	
Toxicants														
Al	14	0	0.070	0.032	1.38	0.068		5	0	0.406	0.220	1.13	0.544	
Sb	10	100	0.0025	0.0001	3.10	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
As	14	93	0.001	0.001	0.25	0.001		5	100	0.001	0.001	0.00	0.001	
Be	10	80	0.0001	0.0001	1.34	0.0001		3	67	0.0001	0.0001	0.43	0.0001	
Bi	10	100	0.0001	0.0001	0.00	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
B	14	0	0.08	0.08	0.20	0.09		5	0	0.04	0.03	0.29	0.05	
Cd	14	93	0.0001	0.0001	0.25	0.0001		5	80	0.0001	0.0001	1.44	0.0001	
Cr	14	86	0.0005	0.0005	0.50	0.0005		5	100	0.0005	0.0005	0.00	0.0005	
Co	14	64	0.0019	0.0025	0.50	0.0025		5	100	0.0025	0.0025	0.00	0.0025	
Cu	14	43	0.0016	0.0010	0.83	0.0021		5	20	0.0026	0.0020	0.52	0.0040	
Ga	9	78	0.0001	0.0001	1.30	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
Fe	13	8	0.080	0.072	0.64	0.130		5	0	0.498	0.410	0.55	0.746	
La	10	80	0.0025	0.0025	0.50	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Pb	14	29	0.0004	0.0001	1.41	0.0006		5	0	0.0009	0.0005	0.71	0.0015	
Mn	14	0	0.281	0.260	0.52	0.388		5	0	0.062	0.043	0.96	0.116	
Hg	13	85	0.00008	0.00005	1.23	0.00005		5	60	0.00013	0.00005	1.17	0.00016	
Mo	14	100	0.0005	0.0005	0.00	0.0005		5	100	0.001	0.0005	0.00	0.0005	
Ni	14	71	0.001	0.001	0.87	0.001		5	60	0.001	0.001	0.72	0.001	
Se	14	100	0.001	0.001	0.00	0.001		5	100	0.001	0.001	0.00	0.001	
Ag	13	92	0.0003	0.0001	2.62	0.0001		5	60	0.0020	0.0001	1.62	0.0033	
Tl	13	77	0.0001	0.0001	1.09	0.0001		5	100	0.0001	0.0001	0.00	0.0001	
Sn	9	89	0.0056	0.0100	0.94	0.0100		3	67	0.0067	0.0100	0.85	0.0100	
U	10	0	0.0003	0.0003	0.43	0.0003		3	0	0.0001	0.0001	0.00	0.0001	
V	12	75	0.004	0.003	0.86	0.003		5	60	0.005	0.003	0.89	0.007	
Zn	14	14	0.020	0.018	0.73	0.035		5	0	0.023	0.014	0.68	0.038	
Atra.	3	100	0.04	0.01	1.50	0.06		2	100	0.03	0.03	1.16	0.04	

Table 3.5 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from pool K3 in dry and wet seasons. All units are mg/L, unless otherwise stated

	Pool K3 dry season							Pool K3 wet season						
Analyte	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile
Stressors														
Temp (^{o}C)	17	0	28.0	29.3	0.10	31.4	24.4	2	0	30.7	30.7	0.03	31.1	30.3
pH	38	0	8.0	8.0	0.01	8.2	7.7	10	0	7.8	7.7	0.07	8.1	7.5
EC (mS/m)	41	0	235	111	1.11	434	60	10	0	20.3	18.0	0.75	23.1	10.3
Turb. (NTU)	33	0	34	9.5	2.32	17	6	6	0	124	130	0.57	190	51
TSS	20	15	22	10	2.01	29	2	6	0	69	44	0.96	77	26
DO (%)	13	0	56	60	1.00	78	22	0	IND	IND	IND	IND	IND	IND
Chlor. a	5	40	0.001	0.001	0.74	0.002		2	50	0.001	0.001	0.47	0.001	
TN	23	0	0.29	0.27	0.50	0.39		7	0	0.35	0.29	0.38	0.50	
NO_x/NO_3 N	20	75	0.01	0.01	0.71	0.01		6	67	0.01	0.01	0.77	0.02	
NH_3 N	23	57	0.01	0.01	1.15	0.02		6	33	0.01	0.01	0.74	0.02	
TP	23	65	0.010	0.005	0.94	0.013		7	0	0.023	0.010	0.75	0.038	
SRP	23	91	0.005	0.005	0.20	0.005		6	83	0.006	0.005	0.35	0.005	
Toxicants														
Al	9	0	0.084	0.020	2.21	0.032		3	0	0.287	0.250	0.48	0.364	
Sb	9	89	0.0056	0.0001	1.96	0.0101		3	100	0.0001	0.0001	0.00	0.0001	
As	9	89	0.001	0.001	0.30	0.001		3	100	0.001	0.001	0.00	0.001	
Be	9	78	0.0002	0.0001	1.14	0.0003		3	100	0.0001	0.0001	0.00	0.0001	
Bi	9	89	0.0001	0.0001	0.36	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
B	9	0	0.26	0.14	0.92	0.43		3	0	0.05	0.05	0.33	0.06	
Cd	9	89	0.0001	0.0001	0.36	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
Cr	9	78	0.0005	0.0005	0.37	0.0005		3	100	0.0005	0.0005	0.00	0.0005	
Co	9	67	0.0016	0.0025	0.71	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Cu	9	11	0.0021	0.0018	0.47	0.0031		3	33	0.0017	0.0020	0.37	0.0021	
Ga	9	78	0.0001	0.0001	1.33	0.0001		3	33	0.0001	0.0001	0.35	0.0001	
Fe	8	13	0.033	0.019	1.24	0.033		3	0	0.510	0.330	0.77	0.708	
La	9	78	0.0025	0.0025	0.54	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Pb	9	33	0.0004	0.0001	1.83	0.0003		3	0	0.0005	0.0005	0.29	0.0006	
Mn	9	0	0.057	0.023	1.30	0.071		3	0	0.015	0.015	0.51	0.019	
Hg	8	75	0.00006	0.00005	0.91	0.00005		3	67	0.00010	0.00005	0.87	0.00014	
Mo	9	89	0.0005	0.0005	0.36	0.0005		3	100	0.0005	0.0005	0.00	0.0005	
Ni	9	56	0.001	0.001	0.61	0.001		3	0	0.001	0.001	0.00	0.001	
Se	9	89	0.001	0.001	0.30	0.001		3	100	0.001	0.001	0.00	0.001	
Ag	9	78	0.0006	0.0001	1.75	0.0011		3	33	0.0013	0.0014	0.93	0.0021	
Tl	9	89	0.0001	0.0001	0.36	0.0001		3	100	0.0001	0.0001	0.00	0.0001	
Sn	8	88	0.0063	0.0100	0.82	0.0100		3	67	0.0067	0.0100	0.85	0.0100	
U	9	0	0.0005	0.0006	0.57	0.0007		3	67	0.0001	0.0001	0.43	0.0001	
V	8	75	0.004	0.003	0.67	0.004		3	67	0.004	0.003	0.55	0.005	
Zn	9	0	0.031	0.025	0.62	0.039		3	33	0.036	0.048	0.82	0.054	
Atra.	3	100	0.04	0.01	1.50	0.06		0	IND	IND	IND	IND	IND	

IND Insufficient data

Table 3.6 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from pool K2 in dry and wet seasons. All units are mg/L, unless otherwise stated

	Pool K2 dry season							Pool K2 wet season						
Analyte	**n**	**Proportion of samples <LOR (%)**	**Mean**	**Median**	**COV**	**80th percentile**	**20th percentile**	**n**	**Proportion of samples <LOR (%)**	**Mean**	**Median**	**COV**	**80th percentile**	**20th percentile**
Stressors														
Temp (^oC)	19	0	28.9	29.6	0.12	31.8	25.5	2	0	29.5	29.5	0.02	29.7	29.3
pH	37	0	8.2	8.2	0.04	8.4	7.9	9	0	7.5	7.4	0.05	7.6	7.2
EC (mS/m)	38	0	1144	716	0.90	2158	310	9	0	33	25	0.98	49	9.9
Turb. (NTU)	32	0	13.5	7.6	2.09	12.7	6	6	0	139	109	0.71	250	50
TSS	18	11	18	14	0.98	21	5	5	0	110	75	0.89	186	38
DO (%)	13	0	70	68	0.56	100	35	0	IND	IND	IND	IND	IND	IND
Chlor. a	5	80	0.001	0.001	0.37	0.001		2	50	0.001	0.001	0.47	0.001	
TN	21	0	0.29	0.26	0.49	0.35		6	0	0.39	0.38	0.25	0.47	
NO_x/NO_3 N	17	94	0.01	0.01	0.76	0.01		6	17	0.02	0.02	0.35	0.02	
NH_3 N	21	52	0.01	0.01	0.99	0.01		6	17	0.02	0.01	1.10	0.03	
TP	21	71	0.007	0.005	0.68	0.010		6	0	0.028	0.025	0.79	0.030	
SRP	21	95	0.005	0.005	0.21	0.005		6	67	0.007	0.005	0.39	0.010	
Toxicants														
Al	8	0	0.039	0.020	1.47	0.028		3	0	0.423	0.250	0.83	0.598	
Sb	8	100	0.0033	0.0003	2.62	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
As	8	88	0.002	0.001	1.12	0.004		3	100	0.001	0.001	0.00	0.001	
Be	8	100	0.0003	0.0003	0.87	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
Bi	8	100	0.0003	0.0003	0.87	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
B	8	0	1.22	1.04	0.88	2.20		3	0	0.05	0.04	0.45	0.06	
Cd	8	100	0.0003	0.0003	0.87	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
Cr	8	100	0.0007	0.0005	1.01	0.0005		3	100	0.0005	0.0005	0.00	0.0005	
Co	8	75	0.0015	0.0015	0.76	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Cu	8	63	0.0011	0.0010	0.58	0.0014		3	67	0.0014	0.0010	0.49	0.0017	
Ga	8	100	0.0003	0.0003	0.87	0.0005		3	33	0.0001	0.0001	0.65	0.0002	
Fe	7	0	0.031	0.015	1.45	0.034		3	0	0.650	0.620	0.67	0.908	
La	8	100	0.0025	0.0025	0.46	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Pb	8	63	0.0003	0.0004	0.69	0.0005		3	0	0.0006	0.0007	0.18	0.0007	
Mn	8	0	0.051	0.032	1.46	0.044		3	0	0.021	0.021	0.67	0.029	
Hg	7	86	0.00006	0.00005	0.95	0.00005		3	67	0.00017	0.00005	1.21	0.00026	
Mo	8	100	0.003	0.003	0.87	0.005		3	100	0.0005	0.0005	0.00	0.0005	
Ni	8	63	0.003	0.003	0.75	0.005		3	0	0.001	0.001	0.00	0.001	
Se	8	100	0.002	0.001	1.06	0.005		3	100	0.001	0.001	0.00	0.001	
Ag	8	88	0.0006	0.0005	1.38	0.0005		3	33	0.0007	0.0006	0.96	0.0010	
Tl	8	100	0.0003	0.0003	0.87	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
Sn	7	100	0.0059	0.0100	0.88	0.0100		3	100	0.0067	0.0100	0.86	0.0100	
U	8	0	0.0012	0.0014	0.62	0.0020		3	33	0.0001	0.0001	0.65	0.0002	
V	7	71	0.003	0.003	0.35	0.004		3	33	0.005	0.005	0.47	0.006	
Zn	8	13	0.024	0.024	0.45	0.029		3	0	0.045	0.043	0.26	0.051	
Atra.	3	100	0.04	0.01	1.50	0.06		0	IND	IND	IND	IND	IND	

IND Insufficient data

Table 3.7 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from pool K1 in dry and wet seasons. All units are mg/L, unless otherwise stated

	Pool K1 dry season							Pool K1 wet season						
Analyte	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile
Stressors														
Temp (^{o}C)	18	0	29.3	30.2	0.13	32.9	25.3	5	0	30.6	30.6	0.02	30.9	30.4
pH	38	0	8.3	8.3	0.03	8.4	8.2	13	0	7.9	7.8	0.04	8.2	7.6
EC (mS/m)	40	0	2706	2520	0.58	4166	1221	13	0	234	22	1.98	161	11.3
Turb. (NTU)	32	0	10.7	8.0	1.14	11.6	4	8	0	241	186	0.88	462	48
TSS	19	11	24	14	1.24	27	4	7	0	140	53	1.78	85	22
DO (%)	13	0	80	74	0.58	116	41	2	0	78	78	0.00	78	78
Chlor. a	5	100	0.0005	0.0005	0.00	0.0005		2	50	0.0009	0.0006	0.47	0.0008	
TN	22	0	0.35	0.34	0.38	0.40		8	0	0.41	0.38	0.43	0.44	
NO_x/NO_3 N	19	95	0.01	0.01	0.74	0.01		7	14	0.02	0.01	0.72	0.03	
NH_3 N	22	50	0.01	0.01	0.82	0.02		7	0	0.02	0.02	0.70	0.04	
TP	22	77	0.020	0.005	3.28	0.009		8	13	0.027	0.015	0.99	0.042	
SRP	22	91	0.005	0.005	0.27	0.005		7	86	0.006	0.005	0.33	0.005	
Toxicants														
Al	8	0	0.025	0.013	1.04	0.033		3	0	0.317	0.290	0.48	0.404	
Sb	8	100	0.0036	0.0005	2.41	0.0010		3	100	0.0001	0.0001	0.00	0.0001	
As	8	88	0.004	0.003	0.85	0.005		3	100	0.001	0.001	0.00	0.001	
Be	8	100	0.0005	0.0005	0.53	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
Bi	8	100	0.0005	0.0005	0.59	0.0008		3	100	0.0001	0.0001	0.00	0.0001	
B	8	0	3.02	2.85	0.63	4.88		3	0	0.06	0.05	0.37	0.07	
Cd	8	100	0.0005	0.0005	0.59	0.0008		3	100	0.0001	0.0001	0.00	0.0001	
Cr	8	100	0.0005	0.0005	0.00	0.0005		3	100	0.0005	0.0005	0.00	0.0005	
Co	8	88	0.0016	0.0018	0.63	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Cu	8	63	0.0015	0.0010	0.68	0.0018		3	33	0.0018	0.0020	0.42	0.0023	
Ga	8	100	0.0005	0.0005	0.59	0.0008		3	67	0.0001	0.0001	0.43	0.0001	
Fe	7	14	0.024	0.017	0.95	0.041		3	0	0.593	0.370	0.90	0.868	
La	8	100	0.0025	0.0025	0.33	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Pb	8	88	0.0006	0.0005	0.50	0.0008		3	0	0.0006	0.0007	0.29	0.0007	
Mn	8	0	0.116	0.078	0.98	0.206		3	0	0.031	0.024	0.77	0.044	
Hg	7	86	0.00015	0.00005	1.42	0.00021		3	67	0.00017	0.00005	1.21	0.00026	
Mo	8	100	0.005	0.005	0.59	0.008		3	100	0.0005	0.0005	0.00	0.0005	
Ni	8	100	0.004	0.005	0.32	0.005		3	0	0.001	0.001	0.00	0.001	
Se	8	100	0.004	0.004	0.70	0.005		3	100	0.001	0.001	0.00	0.001	
Ag	8	88	0.0009	0.0008	0.82	0.0012		3	33	0.0007	0.0007	0.94	0.0011	
Tl	8	100	0.0005	0.0005	0.59	0.0008		3	100	0.0001	0.0001	0.00	0.0001	
Sn	7	100	0.0060	0.0100	0.82	0.0100		3	67	0.0067	0.0100	0.85	0.0100	
U	8	0	0.0022	0.0023	0.49	0.0032		3	33	0.0001	0.0001	0.65	0.0002	
V	7	71	0.004	0.003	0.56	0.006		3	33	0.006	0.007	0.47	0.007	
Zn	8	0	0.027	0.021	0.78	0.032		3	33	0.029	0.035	0.83	0.043	
Atra.	3	100	0.04	0.01	1.50	0.06		1	100	0.01	0.01	IND	0.01	

IND Insufficient data

Table 3.8 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples obtained from estuary site E1 in dry and wet seasons. All units are mg/L, unless otherwise stated

	E1 dry season							E1 wet season						
Analyte	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile	n	Proportion of samples <LOR (%)	Mean	Median	COV	80th percentile	20th percentile
Stressors														
Temp (^{o}C)	16	0	31.0	32.5	0.15	34.1	27.1	3	0	29.8	30.1	0.06	30.9	28.8
pH	32	0	8.3	8.3	0.02	8.4	8.1	9	0	8.0	8.0	0.04	8.1	7.8
EC (mS/m)	31	0	4208	4600	0.39	5950	2320	9	0	364	47	1.15	764	14.5
Turb. (NTU)	30	0	315	79	2.47	438	35	7	0	231	108	1.02	458	100
TSS	16	0	1866	102	3.59	300	59	5	0	365	150	1.31	488	117
DO (%)	13	0	73	71	0.58	111	28	1	0	72	72	IND	IND	72
Chlor. a	5	60	0.0005	0.0005	0.00	0.0005		2	100	0.0005	0.0005	0.00	0.0005	
TN	17	0	0.66	0.54	0.57	0.79		6	0	0.36	0.38	0.27	0.41	
NO_x/NO_3 N	13	100	0.01	0.01	0.85	0.01		6	67	0.01	0.01	0.75	0.02	
NH_3 N	17	18	0.03	0.02	0.94	0.06		6	33	0.01	0.01	0.80	0.01	
TP	18	56	0.023	0.005	1.57	0.035		6	17	0.039	0.039	0.77	0.060	
SRP	18	78	0.007	0.005	0.58	0.008		6	50	0.008	0.008	0.37	0.010	
Toxicants														
Al	8	13	0.027	0.018	0.92	0.046		3	0	0.240	0.200	0.36	0.284	
Sb	8	100	0.0036	0.0005	2.41	0.0010		3	67	0.0001	0.0001	0.43	0.0001	
As	8	50	0.003	0.003	0.43	0.004		3	100	0.001	0.001	0.00	0.001	
Be	8	100	0.0005	0.0005	0.53	0.0005		3	100	0.0001	0.0001	0.00	0.0001	
Bi	8	100	0.0006	0.0005	0.59	0.0010		3	100	0.0001	0.0001	0.00	0.0001	
B	8	0	4.29	4.30	0.52	6.30		3	0	0.04	0.04	0.58	0.06	
Cd	8	100	0.0006	0.0005	0.59	0.0010		3	100	0.0001	0.0001	0.00	0.0001	
Cr	8	100	0.0005	0.0005	0.00	0.0005		3	67	0.0007	0.0005	0.43	0.0008	
Co	8	88	0.0016	0.0018	0.61	0.0025		3	100	0.0025	0.0025	0.00	0.0025	
Cu	8	38	0.0016	0.0016	0.37	0.0021		3	33	0.0023	0.0019	0.67	0.0032	
Ga	8	100	0.0006	0.0005	0.59	0.0010		3	0	0.0001	0.0001	0.00	0.0001	
Fe	7	14	0.025	0.014	1.00	0.043		3	0	0.487	0.300	0.79	0.678	
La	8	100	0.0025	0.0025	0.02	0.003		3	100	0.0025	0.0025	0.00	0.0025	
Pb	8	88	0.0008	0.0008	0.64	0.0010		3	0	0.0007	0.0006	0.17	0.0007	
Mn	8	0	0.017	0.015	0.88	0.027		3	0	0.023	0.019	0.75	0.033	
Hg	7	86	0.00008	0.00005	1.01	0.00009		3	67	0.00017	0.00005	1.21	0.00026	
Mo	8	88	0.007	0.008	0.58	0.010		3	100	0.0005	0.0005	0.00	0.0005	
Ni	8	100	0.005	0.005	0.53	0.005		3	0	0.001	0.001	0.00	0.001	
Se	8	100	0.004	0.003	0.87	0.005		3	100	0.001	0.001	0.00	0.001	
Ag	8	88	0.0010	0.0008	0.84	0.0017		3	33	0.0008	0.0006	1.10	0.0013	
Tl	8	75	0.0012	0.0010	1.10	0.0010		3	100	0.0001	0.0001	0.00	0.0001	
Sn	7	100	0.0060	0.0100	0.82	0.0100		3	67	0.0067	0.0100	0.85	0.0100	
U	8	0	0.0029	0.0031	0.42	0.0040		3	33	0.0001	0.0001	0.65	0.0002	
V	7	71	0.004	0.003	0.56	0.006		3	67	0.005	0.003	0.80	0.006	
Zn	8	13	0.038	0.024	1.35	0.036		3	33	0.020	0.022	0.83	0.030	
Atra.	3	100	0.04	0.01	1.50	0.06		0	IND	IND	IND	IND	IND	

IND Insufficient data

Table 3.9 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in water samples from combined estuary sites E1–E3 in dry and wet seasons. All units are mg/L, unless otherwise stated

	E1–E3 dry season							E1–E3 wet season						
Analyte	**n**	**Proportion of samples <LOR (%)**	**Mean**	**Median**	**COV**	**80th percentile**	**20th percentile**	**n**	**Proportion of samples <LOR (%)**	**Mean**	**Median**	**COV**	**80th percentile**	**20th percentile**
Stressors														
Temp (^{o}C)	48	0	29.3	29.8	0.15	33.5	24.6	10	0	29.7	29.8	0.04	30.7	28.4
pH	94	0	8.2	8.2	0.02	8.3	8.1	28	0	8.1	8.1	0.04	8.2	7.8
EC (mS/m)	91	0	4795	5070	0.26	5950	3950	24	0	1097	433	1.55	1167	24.4
Turb. (NTU)	90	0	291	113	1.69	534	44	23	0	559	530	1.10	748	99
TSS	46	0	911	160	4.33	670	72	13	0	897	410	1.44	1104	112
DO (%)	39	0	70	71	0.57	104	24	3	0	79	82	0.08	83	76
Chlor. a	15	73	0.0009	0.0005	1.05	0.0010		6	83	0.0011	0.0005	1.32	0.0005	
TN	49	0	0.52	0.45	0.61	0.77		16	0	0.46	0.42	0.53	0.49	
NO_x/NO_3 N	37	73	0.01	0.01	1.21	0.02		16	50	0.02	0.01	0.64	0.03	
NH_3 N	47	49	0.02	0.01	1.25	0.02		16	38	0.02	0.01	1.29	0.03	
TP	50	60	0.022	0.005	1.65	0.029		16	19	0.071	0.040	1.02	0.140	
SRP	50	90	0.006	0.005	0.43	0.005		16	63	0.008	0.005	0.63	0.010	
Toxicants														
Al	24	4	0.039	0.017	2.09	0.039		9	0	0.284	0.200	0.71	0.388	
Sb	24	100	0.0037	0.0005	2.23	0.0010		9	78	0.0001	0.0001	0.73	0.0001	
As	24	50	0.004	0.003	0.74	0.005		9	67	0.001	0.001	0.69	0.001	
Be	24	100	0.0006	0.0005	0.43	0.0010		9	100	0.0001	0.0001	0.86	0.0001	
Bi	24	100	0.0007	0.0005	0.42	0.0010		9	100	0.0001	0.0001	0.86	0.0001	
B	24	0	4.79	4.85	0.32	6.24		9	0	0.29	0.07	1.50	0.45	
Cd	24	100	0.0007	0.0005	0.42	0.0010		9	89	0.0001	0.0001	0.79	0.0001	
Cr	24	100	0.0007	0.0005	0.85	0.0005		9	56	0.0017	0.0005	1.81	0.0010	
Co	24	96	0.0016	0.0018	0.61	0.0025		9	100	0.0025	0.0025	0.00	0.0025	
Cu	24	67	0.0013	0.0010	0.47	0.0020		9	33	0.0020	0.0019	0.55	0.0030	
Ga	24	100	0.0007	0.0005	0.42	0.0010		9	33	0.0001	0.0001	0.64	0.0002	
Fe	21	14	0.052	0.014	2.63	0.045		9	0	0.421	0.300	0.70	0.600	
La	24	100	0.0025	0.0025	0.36	0.0025		9	100	0.0025	0.0025	0.00	0.0025	
Pb	24	96	0.0008	0.0008	0.45	0.0010		9	0	0.0007	0.0006	0.61	0.0009	
Mn	24	4	0.018	0.006	1.22	0.037		9	0	0.024	0.019	1.02	0.032	
Hg	21	81	0.00016	0.00005	1.38	0.00025		9	67	0.00017	0.00010	0.81	0.00030	
Mo	24	96	0.007	0.008	0.42	0.010		9	100	0.0005	0.0005	0.86	0.0005	
Ni	24	100	0.006	0.005	0.43	0.010		9	33	0.001	0.001	0.51	0.001	
Se	24	100	0.005	0.005	0.74	0.010		9	100	0.001	0.001	0.86	0.001	
Ag	24	88	0.0012	0.0010	0.77	0.0023		9	33	0.0014	0.0006	1.26	0.0027	
Tl	24	79	0.0013	0.0010	1.19	0.0010		9	100	0.0001	0.0001	0.86	0.0001	
Sn	21	100	0.0060	0.0100	0.79	0.0100		9	67	0.0067	0.0100	0.74	0.0100	
U	24	0	0.0033	0.0035	0.31	0.0040		9	11	0.0003	0.0002	0.88	0.0004	
V	21	67	0.004	0.003	0.47	0.006		9	44	0.006	0.006	0.66	0.010	
Zn	24	8	0.032	0.026	1.02	0.037		9	33	0.019	0.020	0.74	0.033	
Atra.	9	100	0.04	0.01	1.30	0.10		1	100	0.01	0.01	IND	0.01	

IND Insufficient data

3.5 Differences between wet and dry season water quality

Table 3.10 lists the various water quality parameters that are statistically significantly different between wet and dry seasons at each of the sample sites. The seasonal averages of several aquatic stressor parameters were significantly different in the Keep River pools and in the upper estuary (sites E1–E3 combined). pH was seasonally significantly different at all sites except K3, while K2 was the only site that did not have seasonally significantly different EC. Turbidity was not seasonally significantly different in the upper estuary, perhaps because the permanent tidal influence at this site constantly entrains sediments in the dry season while during the wet season the floodwaters are similarly turbid. TN was seasonally significantly different at K4 only, whereas TP was seasonally different at all sites except K1.

Of the toxicants, only Al (at K1), B and Fe (at K4) were seasonally significantly different in the Keep River pools (K1–K4). By contrast, the concentration of 11 of the metals (Al, Be, Bi, B, Cd, Ga, Fe, Mo, Ni, Se and U) were seasonally significantly different at the upper estuary sites. This difference may reflect the large change in the source of the water between seasons at this site — being mainly from marine sources during the dry season and from terrestrial sources during the wet season.

With the exception of EC there was no statistically significant seasonal difference in any physicochemical parameter for estuary sites E1, E2 and E3.

3.6 Comparison of water quality between the estuary sites

Table 3.11 lists the analytes that were statistically significantly different between all combinations of the five estuary sites during either the wet season (sites E1–E5) or the dry season (sites E1–E3). Sites E4 and E5 were never sampled during the dry season, being only sampled on three occasions (using a helicopter) during wet season flow events, which coincided with the collection of samples from the autosamplers at K4 and BC. Table 3.11 shows that several water quality parameters were significantly ($P < 0.001$) elevated at site E5 in comparison to site E1 during wet seasons. The elevated parameters included EC, hardness, alkalinity and several other anions and cations. Site E5 is located where the estuary opens out into the marine Bonaparte Gulf. Therefore, the elevated parameters at E5 probably indicate that by the time the floodwaters reach E5 their influence on water quality has been substantially diluted by the stronger marine water influence. The degree of marine/terrestrial water interaction at E5 will be influenced by ocean currents, tide conditions and the flood discharge rate at any given time. However, even given that there has been a maximum of 2693GL of wet season flow recorded, it is unlikely that the terrestrially derived influence, by Keep River floodwaters, on water quality would extend much further into the Gulf.

During dry seasons there was a statistically weaker level of difference ($P < 0.01$) in EC between both the E3 and E1 sites, and the E2 and E1 sites — with E1 having the lower EC. The lower EC at E1 probably reflects a weaker marine tidal influence. This is because E1 is the furthest upstream site and also has a restricted connection to the rest of the estuary because of the sand bar (Figure 1.2), resulting in a lower rate of exchange between incoming tidal marine waters and Keep River waters at the end of each wet season. No other analytes were significantly different between any of the E1–E3 estuary sites; in either wet or dry seasons.

Table 3.10 Double-tailed Students T-test P values for comparison of seasonal differences in water quality parameters at the sample sites

Site	K4	K3	K2	K1	Combined E1–E3
Stressors					
Temp	NSD	NSD	NSD	NSD	NSD
pH	<0.001	NSD	<0.001	<0.001	<0.01
EC	<0.001	<0.01	NSD	<0.001	<0.001
Turb.	<0.001	<0.01	<0.001	<0.001	NSD
TSS	<0.001	NSD	<0.001	NSD	NSD
DO	NSD	NSD	NSD	NSD	NSD
Chlor. a	NSD	NSD	NSD	NSD	NSD
TN	<0.001	NSD	NSD	NSD	NSD
NO_x/NO_3 N	NSD	NSD	<0.001	NSD	NSD
NH_3 N	NSD	NSD	NSD	NSD	NSD
TP	<0.001	<0.01	<0.001	NSD	<0.001
SRP	NSD	NSD	NSD	NSD	NSD
Toxicants					
Al	NSD	NSD	NSD	<0.001	<0.001
Sb	NSD	NSD	NSD	NSD	NSD
As	NSD	NSD	NSD	NSD	NSD
Be	NSD	NSD	NSD	NSD	<0.001
Bi	NSD	NSD	NSD	NSD	<0.001
B	<0.001	NSD	NSD	NSD	<0.001
Cd	NSD	NSD	NSD	NSD	<0.001
Cr	NSD	NSD	NSD	NSD	NSD
Co	NSD	NSD	NSD	NSD	NSD
Cu	NSD	NSD	NSD	NSD	NSD
Ga	NSD	NSD	NSD	NSD	<0.001
Fe	<0.001	NSD	NSD	NSD	<0.001
La	NSD	NSD	NSD	NSD	NSD
Pb	NSD	NSD	NSD	NSD	NSD
Mn	NSD	NSD	NSD	NSD	NSD
Hg	NSD	NSD	NSD	NSD	NSD
Mo	NSD	NSD	NSD	NSD	<0.001
Ni	NSD	NSD	NSD	NSD	<0.001
Se	NSD	NSD	NSD	NSD	<0.001
Ag	NSD	NSD	NSD	NSD	NSD
Tl	NSD	NSD	NSD	NSD	NSD
Sn	NSD	NSD	NSD	NSD	NSD
U	NSD	NSD	NSD	NSD	<0.001
V	NSD	NSD	NSD	NSD	NSD
Zn	NSD	NSD	NSD	NSD	NSD
Atra.	NSD	NSD	NSD	NSD	NSD

NSD Not statistically different (P >0.01)

Table 3.11 Water quality analytes that were statistically significantly different between the estuary sites in either wet or dry season periods determined by Double-tailed Students T-test

Analyte	Season	Site	Significance
EC	Dry	E2>E1	P<0.01
EC	Dry	E3>E1	P<0.01
EC	Wet	E5>E1	P<0.001
Sb	Wet	E5>E1	P<0.001
B	Wet	E5>E1	P<0.001
U	Wet	E5>E1	P<0.001
Alk.	Wet	E5>E1	P<0.001
DOC	Wet	E5>E1	P<0.001
Hard.	Wet	E5>E1	P<0.001
HCO_3	Wet	E5>E1	P<0.01
SO_4 S	Wet	E5>E1	P<0.001
TDS	Wet	E5>E1	P<0.001
Ca	Wet	E5>E1	P<0.001
Cl	Wet	E5>E1	P<0.001
K	Wet	E5>E1	P<0.001
Li	Wet	E5>E1	P<0.001
Mg	Wet	E5>E1	P<0.001
Na	Wet	E5>E1	P<0.001

3.7 Water level elevation, EC and temperature data from loggers

Bennett and George (2011) indicate that conditions and water quality in pools K1–K3 and the estuary can be affected by tides and catchment water flow rates. These sites can therefore exist as in either marine or freshwater states or somewhere in between. Figure 3.4 shows the tide height recorded at Wyndham (Department of Transport, Fremantle, data accessed July 2013) together with the water level elevations (mAHD) from datalogger recordings made in BC, the K1–K4 pools and site E3, between June 2010 and May 2013.

The water level response to wet season run-off is clearly visible at all Keep River pool sites (Figure 3.4). The 2010/2011 wet season, the wettest over the period of observation, resulted in the largest flows and therefore largest changes in elevation of the pools. By contrast, the water level at the permanently tidal E3 site appears almost unaffected by wet season flows. The reducing wet season effect on water levels progressing from K4 downstream through to E3 is probably because the river gets progressively wider, until by E3 it is so wide that even the largest flow causes only a negligible rise in water level.

During the dry seasons when there was minimal catchment run-off (generally before December and after April), the base water levels of pools K1–K3 are similar, confirming that they are a series of pools separated by slightly elevated rock bars. Water level responses in the K1–K3 pools during periods when there is no run-off indicate that the rock bars are occasionally overtopped on high tides. The overflow level of pool K4 (about 5.4mAHD) is about two metres above the base water levels of K1–K3 and is not influenced by tidal variation. Likewise, the BC site, with its cease-to-flow elevation of about 13.5m, is located well above the tidal influence.

Figure 3.5 shows the pool water level responses to tides in more detail during June and July 2012. From Figure 3.5, the water levels in pools K1–K3 all appear to respond whenever the tide height at Wyndham exceeds 8m (e.g. 5th, 6th and 7th of June), whereas only pool K1 is affected by tide heights between 7.9 and 8.0m (e.g. 5th, 6th and 7th of July). Tide heights below about 7.9m caused no water level response in any of the pools.

While the estuary sites E1–E3 are located within the permanent tidal zone — as previously defined by Bennett and George (2011) and Ticknell et al. (2007) and shown in Figure 1.2 — datalogger data from site E3 shows that some neap tides do not affect its water level. Datalogger records obtained over the period November 2011–June 2013 show there were 38 high tides (or about 1 180 tide cycles) that did not cause a resultant level response at E3. An example of a neap tide that did not cause a water level response at E3 occurred on July 14 (Figure 3.5). The average height (recorded at Wyndham) of the 38 tides that failed to cause a resultant water level response at E3 was 5.53m (range 4.99–5.91m). However, just because a high tide fell within the 4.99–5.91m range it did not mean that there was no response at E3. Many high tides within this range resulted in a response at E3, indicating that there were other factors, such as wind speed or direction, that also can influence the water level response at E3. There were no occasions in the November 2011–June 2013 period when consecutive high tides failed to cause the water level in E3 to respond.

As noted by Bennett and George (2011), the first significant run-off through pool K4 for the 2010 wet season commenced on 1 November (in response to 62mm of rainfall during the previous two days) and raised water levels at K1–K3 by up to 0.7m. The event produced about 3.4GL of stream flow at the K4 gauging station before the system returned to baseflow conditions. This flow event was enough to completely flush the K1–K3 pools — as evidenced by the dramatic fall in EC (Figure 3.6) in the pools over the same period. Wet season flows corresponding to K4 stage heights greater than about 6.2mAHD (i.e. about 0.8m above baseflow level) completely dominate tidal influences on water levels and EC in the lower pools (Figures 3.4 and 3.6). Electrical conductivity in the pools and at E1 varied dramatically throughout the monitoring period (Figure 3.6) in response to a combination of tidal forcing causing EC to rise, and catchment discharge in the wet seasons causing EC to fall.

The tidal influence on EC appears to be quite complex. In K1 and K2, the EC levels increase rapidly with the incoming tide and then reduce with the outgoing tide as tidal forcing pushes and pulls the body of water past the logger locations. In the period between tide cycles, the EC gradually increases as the residual higher EC water, presumably remaining at the lower end of each pool at the end of the tide cycle, gradually mixes and/or diffuses throughout each pool. By contrast, the large and rapid EC responses that are evident in K1 and K2 are almost absent in K3, although in K3 EC gradually increased to levels higher than those in K4 during the dry seasons. This different pattern of EC change in K3 is probably because the inflowing slug of tidal water does not immediately reach the logger location. However, during the subsequent non-tidal period the EC of K3 gradually increases, indicating that a residual quantity of higher EC water remains at the lower end of the pool after the tide and subsequently mixes and/or diffuses throughout the pool.

Figure 3.7 shows that the water temperature in all pools and in the estuary varied over a large seasonal range of about 15–20^{o}C. While temperature is generally consistent between all locations there are many, rapid, large intra-seasonal temperature variations of 5–10^{o}C, probably in response to flow and tide-induced mixing of temperature or density-stratified layers. Diurnal variation is in the range of 1–5^{o}C. Figure 3.7 indicates that, despite differences in location, depth and tidal influences water temperature variability is not greatly different between sites.

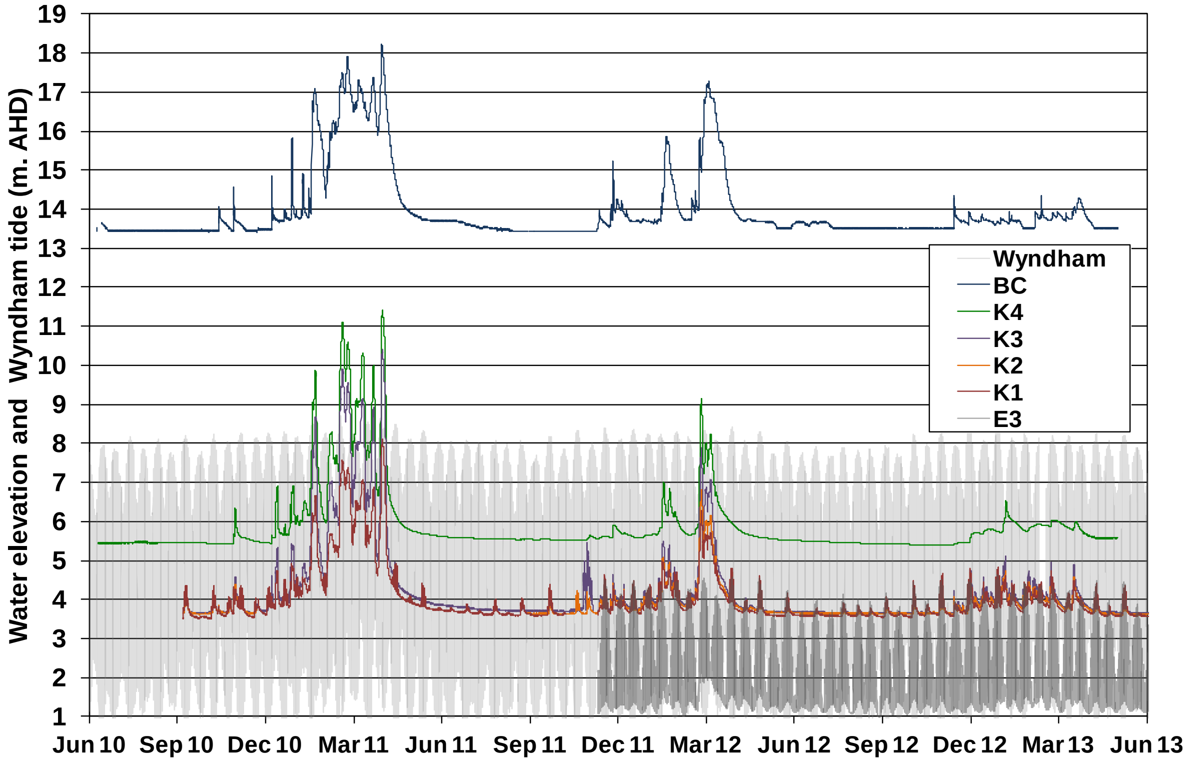

Figure 3.4 Water elevations recorded by dataloggers in the Keep River Pools, Border Creek and the Keep River estuary, together with the tide height recorded at Wyndham (light grey line). Tide data supplied by the Department of Transport, Western Australia

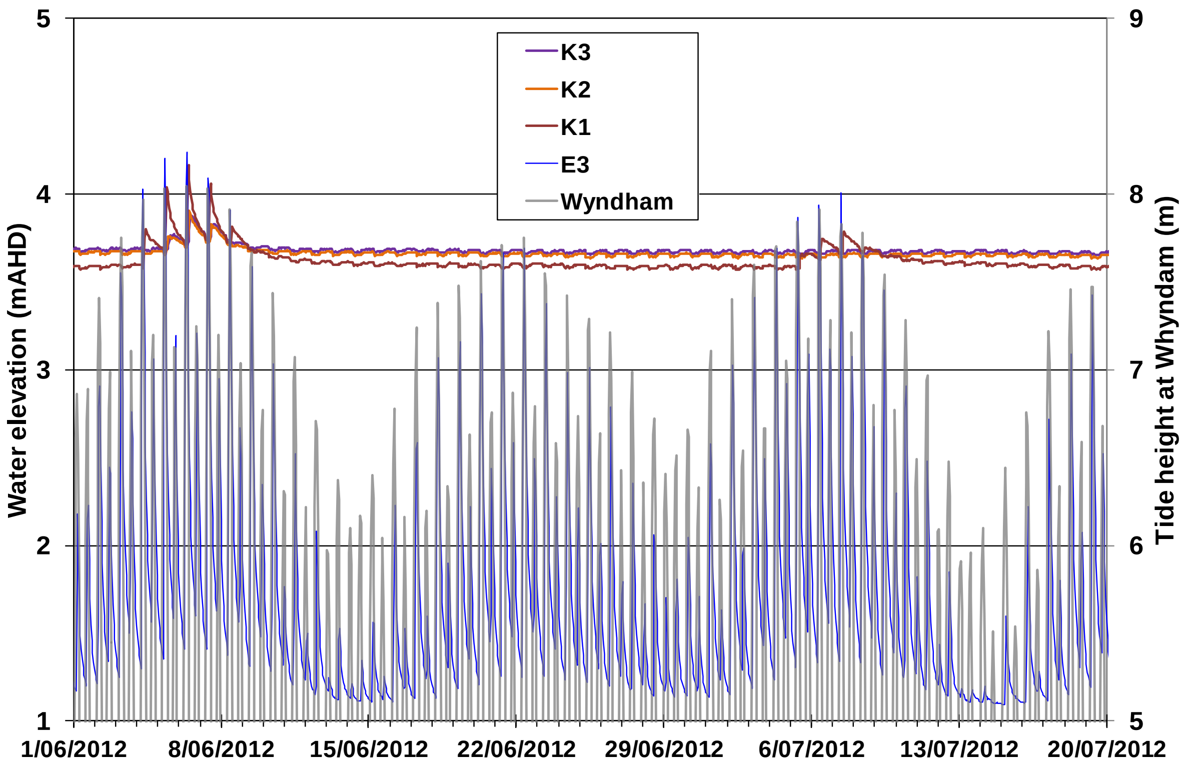

Figure 3.5 Water elevations recorded by dataloggers in K1–K3 pools and the Keep River estuary, together with the tide height recorded at Wyndham. Tide data supplied by the Department of Transport, Western Australia

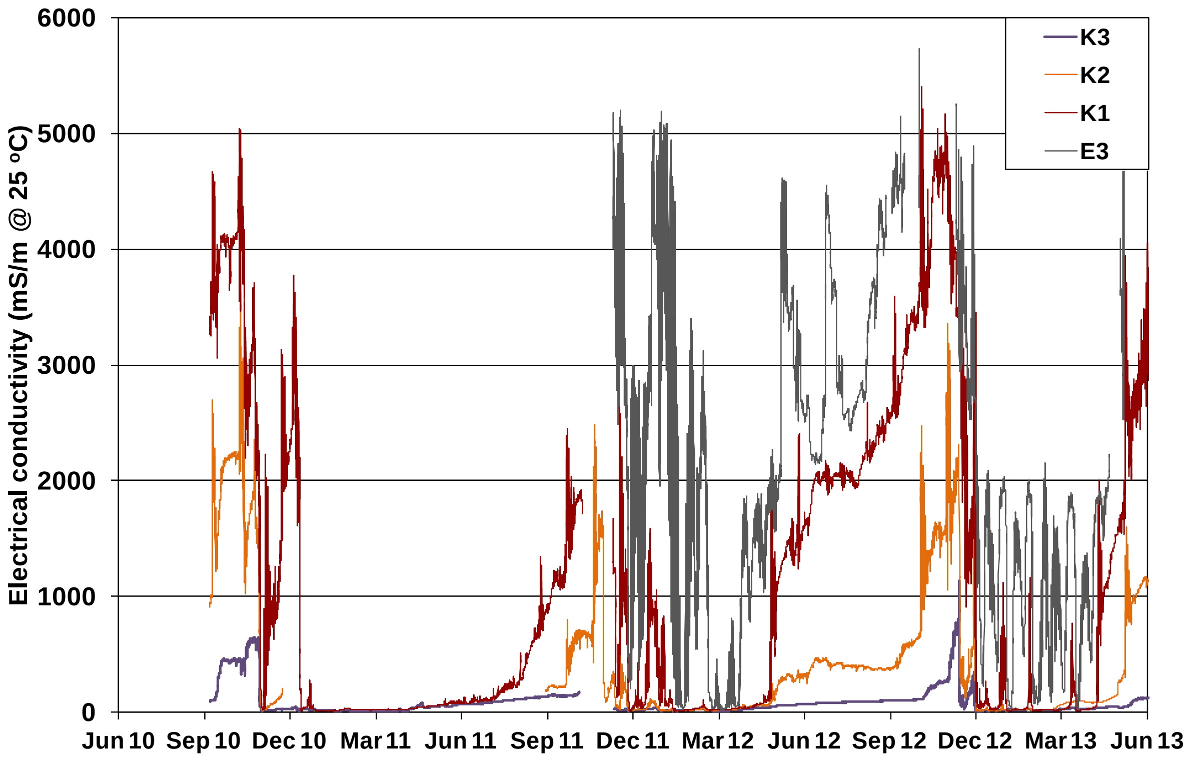

Figure 3.6 Electrical conductivity recorded by dataloggers in the Keep River pools K1–K3 and in the estuary at site E3

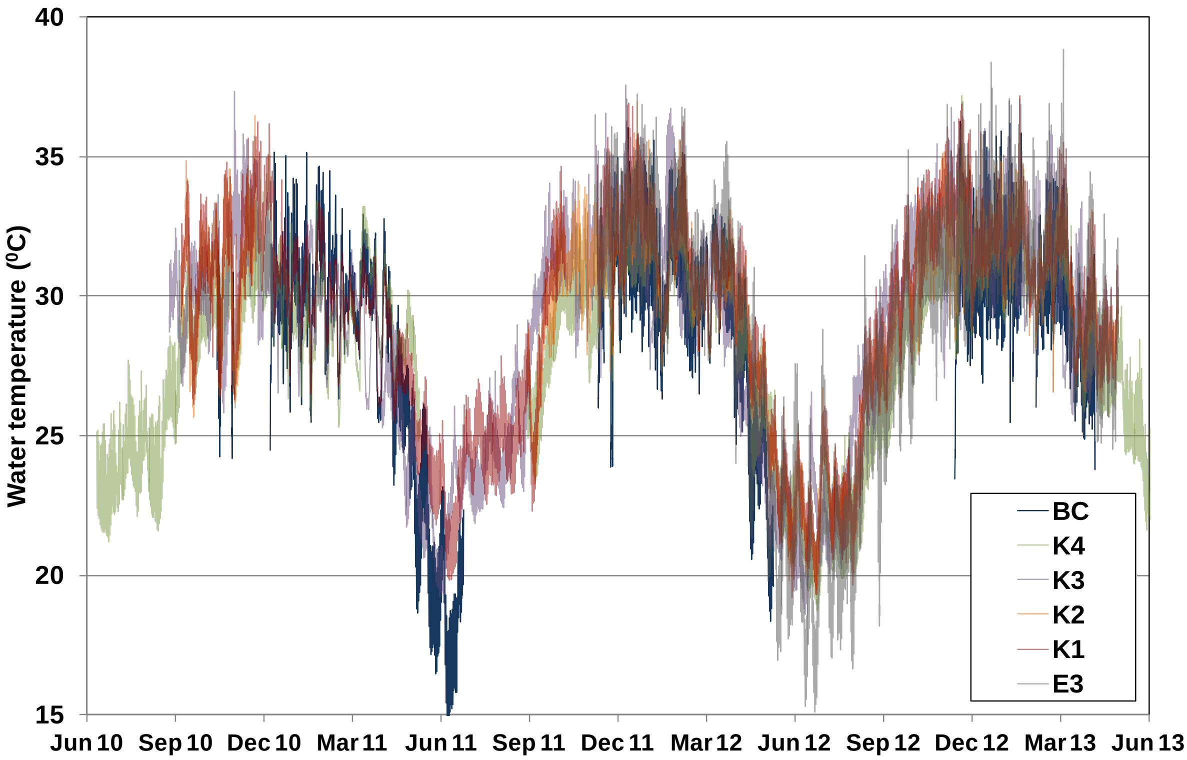

Figure 3.7 Water temperature recorded by dataloggers in Border Creek, pools K1–K4 and in the estuary at site E1

4 Discussion

Environmental conditions in place for the Goomig Farmlands development require that the baseline conditions of the lower Keep River are assessed and used to develop environmental trigger values (TVs) for important factors. The derivation of baseline condition, along with the determination of the major prevailing natural influences is an important part of the process for determining physicochemical TVs, for use as a basis for assessing the environmental compliance of the Goomig Farmlands development in the future.

Using the baseline results obtained for the lower Keep River, the following sections report and discuss:

- issues with applying ANZECC and ARMCANZ (2000) guidelines during data analysis
- interim TVs and relationship to water quality monitoring results from nearby, well-established areas of irrigated agricultural development
- the influence of wet seasons and tides on the pools and estuary environments
- considerations for selecting, determining and applying local TVs to meet the environmental management objectives for the Goomig Farmlands development.

4.1 Determination of baseline and local trigger values

ANZECC and ARMCANZ (2000) recommend that if suitable data exists, baseline levels of relevant physicochemical parameters be determined by calculating the 20th and/or 80th percentile values, depending on whether the parameter has a detrimental effect at high or low concentration or value, or both. Tables 3.3–3.9 contain the 80th percentiles (and 20th percentiles, where relevant) of the data, from the six sampling locations that represent the range of important aquatic environments in the lower Keep River area. ANZECC and ARMCANZ (2000) also recommend that the 20th and/or 80th percentile ‘baseline’ values be used as a basis to derive site referential, local trigger values (LTVs), where required. Later, in Section 4.8 we discuss additional factors that should be considered when setting LTVs for the lower Keep River.

During data analysis for the preparation of Tables 3.3–3.9, several data-related issues were encountered that relate to the derivation of the summary baseline indicators — and therefore could affect their subsequent use for defining LTVs. In the following sections, the major data uncertainties encountered and our methods for their resolution are discussed. Sections 4.1.1 and 4.1.2 discuss the major data issues encountered, while Section 4.1.3 summarises the complete set of guiding principles adopted. Table 4.1 contains the resultant set of interim local trigger values (ILTVs) that can be used as a basis for the subsequent derivation of LTVs for the lower Keep River.

In the following sections and in Table 4.1:

- the 99% species protection level (SPL) was used as the AADTVTA for toxicants, factored for water hardness (Appendix A)
- the AADTVTAs for marine toxicants were used as the comparative reference against which the estuary site data was assessed

- where a metal toxicant has individual AADTVTAs reported for individual species, the sum of the individual species' AADTVTAs was used as the comparative reference to the total concentrations of that metal.

4.1.1 Laboratory analysis limit of reporting constraints

Different laboratories often have different LOR levels for the same parameters. Additionally, during the typically extended period of baseline monitoring a laboratory's LOR levels may reduce as the laboratory refines its analytical methodology. Ideally, laboratory analysis should be undertaken using techniques that can report concentrations that are lower than the AADTVTAs, as the local baseline levels may ultimately be used for the derivation of LTVs. Also, we found that some of the analytes that have been assigned an AADTVTA, could not be routinely analysed to a LOR less than the default value; even when the default is factored for water hardness where applicable (Appendix A). For example, the analytes SRP, Co (for estuary sites only — Co does not have a AADTVTA specified for tropical lowland rivers), Cr (at all sites except K1 and E1 — which have high water hardness in the dry season) and Ag (non-estuary sites) have AADTVTAs that are less than the LORs that are routinely achievable in Australia (NMI 2013). Additionally, the laboratory used for chemical analysis was not able to analyse for Hg to a LOR that was below the AADTVTA.

Caution is therefore required to ensure that derived local baseline concentrations are not artificially raised as a result of data artefacts arising from the manipulation of the raw data, in particular LOR data.

4.1.2 Treatment of LOR data during data analysis

During data preparation for statistical analysis, concentrations that were reported as being below the LOR were assigned a value equal to half the LOR. We consider this approach to be the most conservative of the three options suggested by ANZECC and ARMCANZ (2000) for the treatment and use of LOR data.

Analytes for which a reduction in the laboratory LOR occurred during the study period, and were always reported as being below the LOR, were also problematic in terms of their summary statistics. In these situations, the resultant summary statistics have values that were very dependent on the magnitude and timing of the change in the LOR. However, where there was an LOR change (and the LOR value was below the AADTVTA) we reported summary statistics of the complete dataset. We could not see a uniformly applicable and viable alternative to using the resultant 80th percentile data as the ILTV in these situations. The analytes for which variations in LOR occurred during the study period (and where the LOR was less than the AADTVTA or there is no AADTVTA specified) include NO_x/NO_3 N at all sites, As at all sites and Co in river sites.

ANZECC and ARMCANZ (2000) recommend that if more than 25% of samples at any site have resultant concentrations (for a particular analyte) less than the LOR, then the LOR data should not be used in any subsequent statistical analysis. However, for many of the analyte/site combinations reported in this study, the removal of LOR data from the dataset greatly reduced the sample size and aberrantly raised the calculated baseline concentration. We consider that ignoring the LOR data (therefore artificially raising the resultant 80th percentile value) is not a conservative approach in terms of setting baseline levels or TVs for the lower Keep River — as it may ultimately result in artificially high LTVs. Generating artificially high

LTVs is not consistent with the intent of the ANZECC and ARMCANZ (2000) guidelines.

4.1.3 Derivation of interim trigger values for the lower Keep River

The approach used to derive a set of ILTVs (in Table 4.1) followed the ANZECC and ARMCANZ (2000) guideline's philosophy of environmental conservatism. However, in terms of the data issues discussed in the preceding sections, we found that strict adherence to the guidelines resulted in ILTVs that were inconsistent with ANZECCs conservative philosophy, or would result in ILTVs that were inappropriate for the lower Keep River. So, a set of data interpretation rules were developed so that a consistent set of ILTVs could be derived, as presented in Table 4.1. The below rules were reviewed and ratified by C. Humphrey (Supervising Scientist Division, SEWPaC 2013, pers. comm.) and subsequently by the IRG at their December 2013 meeting. The rules are as follows:

1. The dataset retained any LOR data, it being assigned a value of half the LOR for the calculation of summary statistics.
2. The AADTVTA was specified as the ILTV where the analyte's LOR exceeded the AADTVTA and the analyte was always observed to be at a concentration lower than the LOR.
3. Notwithstanding any other LOR constraints, the 80th percentile value of any stressor or metal toxicant was the ILTV, providing that the AADTVTA exceeded the LOR, even if more than 25% of observations were less than the LOR.
4. The 80th percentile value was the ILTV even where the LOR varied — provided that the AADTVTA always exceeded the LOR.
5. The upper AADTVTA was specified as the upper ILTV if the 80th percentile concentration was less that the AADTVTA.
6. The lower AADTVTA was specified as the lower-limit ILTV if the 20th percentile concentration was greater than the lower AADTVTA.
7. Metal toxicants that did not have an assigned AADTVTA had their resultant ILTVs reported.
8. Situations in which any of the above rules were applied in the specification of an ILTV were identified.

Rule number 8 is particularly important for future water quality monitoring programs. Identification of the application of the above rules is required so that any additional data, collected over a subsequent three-year period for example, could be used for a subsequent analysis of baseline conditions; provided that it can be demonstrated that any changes that occur are not a result of the Goomig Farmland development. Ideally, any subsequent physicochemical baseline analysis should also be referenced to biological data and include a comparison to biological and physicochemical data obtained over the same period from an unaffected, reference site. This approach is consistent with ANZECC and ARMCANZ principles of 'significant change' reporting.

Situations where the above rules were applied to derive an ILTV are identified in Table 4.1.

Table 4.1 Interim local trigger values (ILTVs) for aquatic environmental stressors and toxicants in the lower Keep River. Red font indicates that more than 25% of baseline data were below the LOR. All units are mg/L, unless otherwise stated

Parameter	BC wet	K4 dry	K4 wet	K3 dry	K3 wet	K2 dry	K2 wet	K1 dry	K1 wet	E1 dry	E1 wet
Stressors											
Temp (°C)	29–31	24–31	29–30	24–31	30–31	26–32	29–30	25–33	30–31	27–34	29–31
pH	6.0–8.0†	6.0†–8.0†	6.0†–8.0†	6.0†–8.2	6.0†–8.1	6.0†–8.4	6.0†–8.0†	6.0†–8.4	6.0†–8.2	7.0†–8.5†	7.0†–8.5†
EC (mS/m)	25†	85	29	434	25†	2158	50	4166	161	5950	764
Turb. (NTU)	280	120	446	17	190	15†	250	15†	462	434	458
TSS	408	62	1400	29	77	21	186	27	85	300	488
DO (%)	69–120†	23–120†	76–120†	22–120†	85†IND–120†IND	35–120†	85†IND–120†IND	28–120†	28–120†	28–120†	80†IND–120†
Chlor. a	0.005†	0.006	0.005†	0.005†	0.005†	0.005†	0.005†	0.005†	0.005†	0.002†	0.002†
TN	2.56	0.44	2.80	0.39	0.50	0.35	0.47	0.40	0.44	0.79	0.41
NO_x/NO_3 N	0.01†	0.01	0.04	0.01	0.02	0.01†	0.02	0.01	0.03	0.03†	0.03†
NH_3 N	0.03	0.03	0.03	0.02	0.02	0.01	0.03	0.02	0.04	0.06	0.02†
TP	0.10	0.04	0.13	0.013	0.038	0.01	0.03	0.01†	0.042	0.035	0.06
SRP	0.004*	0.004*	0.010	0.004*	0.005	0.004*	0.004*	0.004*	0.004*	0.005*	0.005*
Toxicants											
Al	0.752	0.068	0.544	0.032	0.364	0.028	0.598	0.033	0.404	0.046‡	0.284‡
Sb	0.0001‡	0.0001‡	0.0001‡	0.0101‡	0.0001‡	0.0005‡	0.0001‡	0.0010‡	0.0001‡	0.0010‡	0.0001‡
As	0.001†	0.001†	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.004‡	0.001‡
Be	0.0001‡	0.0001‡	0.0001‡	0.0003‡	0.0001‡	0.0005‡	0.0001‡	0.0005‡	0.0001‡	0.0005‡	0.0001‡
Bi	0.0001‡	0.0001‡	0.0001‡	0.0001‡	0.0001‡	0.0005‡	0.0001‡	0.0008‡	0.0001‡	0.0010‡	0.0001‡
B	0.09†	0.09	0.09†	0.43	0.09†	2.20	0.09†	4.88	0.09†	6.30‡	0.06‡
Cd	0.0001	0.0003†	0.0001	0.006†	0.001†	0.0022†	0.0001†	0.0044†	0.0001†	0.0695†	0.0063†
Cr	0.00001*	0.00004*	0.00002*	0.00008*	0.00001*	0.00028*	0.00002*	0.0005	0.00002*	0.5291	0.0579
Co	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.00001*	0.00001*
Cu	0.0035	0.0056†	0.0040	0.0113†	0.0021	0.0419†	0.0019†	0.0822†	0.0027†	0.0336†	0.0032
Ga	0.0004‡	0.0001‡	0.0001‡	0.0001‡	0.0001‡	0.0005‡	0.0002‡	0.0008‡	0.0001‡	0.0010‡	0.0001‡
Fe	0.782‡	0.130‡	0.746‡	0.033‡	0.708‡	0.034‡	0.908‡	0.041‡	0.868‡	0.043‡	0.678‡
La	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.0025‡	0.003‡	0.0025‡
Pb	0.0016†	0.0098†	0.0019†	0.0265†	0.0017†	0.1710	0.0021†	0.4476†	0.0034†	1.5305†	0.0497†
Mn	1.2†	1.2†	1.2†	1.2†	1.2†	1.2†	1.2†	1.2†	1.2†	0.027‡	0.033‡
Hg	0.00006*	0.00006*	0.00006*	0.00006*	0.00006*	0.00006*	0.00006*	0.00006*	0.00006*	0.0001*	0.0001*
Mo	0.0005‡	0.0005‡	0.001‡	0.001‡	0.001‡	0.005‡	0.0005‡	0.008‡	0.0005‡	0.010‡	0.0005‡
Ni	0.011†	0.037†	0.013†	0.072†	0.011†	0.250	0.013†	0.476†	0.018†	0.559†	0.056†
Se	0.005†	0.005†	0.005†	0.005†	0.005†	0.005	0.005†	0.005	0.005†	0.005‡	0.001‡
Ag	0.00002*	0.00002*	0.00002*	0.00002*	0.00002*	0.00002*	0.00002*	0.00002*	0.00002*	0.0008*	0.0008*
Tl	0.0001‡	0.0001‡	0.0001‡	0.0001‡	0.0001‡	0.0005‡	0.0001‡	0.0008‡	0.0001‡	0.0010‡	0.0001‡
Sn	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡	0.01‡
U	0.0002‡	0.0003‡	0.0001‡	0.0007‡	0.0001‡	0.0020‡	0.0002‡	0.0032‡	0.0002‡	0.0040‡	0.0002‡
V	0.009‡	0.003‡	0.007‡	0.004‡	0.005‡	0.004‡	0.006‡	0.006‡	0.007‡	0.006	0.006
Zn	0.032	0.035	0.038	0.039	0.054	0.075†	0.051	0.143†	0.043	0.560†	0.056†
Atra.	0.7†	0.7†	0.7†	0.7†	0.7†IND	0.7†	0.7†IND	0.7†	0.7†	0.7†	0.7†IND
NO_x/NO_3 N	0.017†	0.017†	0.04	0.017†	0.02	0.017†	0.02	0.017†	0.03	0.01‡	0.02‡
NH_3N	0.32†	0.32†	0.32†	0.32†	0.32†	0.32†	0.32†	0.32†	0.32†	0.50‡	0.5‡

* AADTVTA (adjusted for hardness where required) specified as the ILTV where the LOR for the analyte is greater than the AADTVTA

† AADTVTA (adjusted for hardness where required) specified as the ILTV where the 80th percentile value is less than the AADTVTA

†IND AADTVTA specified where there are insufficient baseline data

‡ No AADTVTA is assigned, so the 80th percentile value is specified as the ILTV

4.2 Comparison of interim local trigger values to the AADTVTAs

Table 4.2 shows the ratios of the ILTVs, reported in Table 4.1, to the AADTVTA values for stressors and toxicants. Many of the stressors, in particular, have ILTVs that exceed the corresponding AADTVTAs at multiple sites. During the wet season, ILTVs for nutrients exceed the AADTVTA by factors of between 1.3 and 13 in the lower Keep River sites. The ratios of exceedance for the nutrients are generally lower during the dry season, although the ratios for TN exceeded unity (and therefore, the AADTVTA) at every site. By contrast, within the estuary (site E1) the exceedance ratio for TN was higher in the dry season than in the wet. ILTVs for turbidity and TSS were consistently many times higher, than the AADTVTA during the wet season, 22 times higher on average across all Keep River pool sites. The ILTVs for EC greatly exceeded the AADTVTA in all Keep River pools during the dry season, being up to 167 times higher in pool K1, by way of example.

4.2.1 Electrical conductivity, dissolved oxygen and turbidity stressors

For EC (in particular) pools K1–K3 appear to be a special case in terms of the ANZECC and ARMCANZ guidelines. While these pools can be classified as being part of a tropical freshwater lowland river ecosystem during periods of strong flow, they also experience irregular and variable incursions of marine/estuarine water at other times (see sections 3.7 and 4.5). The application of a locally derived trigger value for EC in these pools therefore seems especially warranted. However, it is noteworthy that the dry season ILTV for EC will likely be routinely exceeded for extended intervals during dry seasons; after a series of tides that will likely raise the EC to levels above the ILTV. The upper estuary has similar alternating marine and terrestrial water influences; the salinity can be low during the wet season, but it rapidly increases once river flows reduce enough to allow tides to dominate water exchanges. However, for EC in the estuary this is of less consequence in terms of setting a trigger level (and subsequent compliance monitoring) because ANZECC and ARMCANZ (2000) does not recommend applying an upper or lower trigger value for estuarine or marine aquatic environments.

The upper ILTV for DO is below the AADTVTA upper threshold at all sites in both seasons (Table 4.1). However, the lower DO threshold ILTV in the dry season (Table 4.1) is below the AADTVTA lower threshold at every site (data not presented in Table 4.2). The lower threshold baseline levels for EC, turbidity and TSS (20th percentile values in Tables 3.3–3.9) are always above the lower AADTVTA thresholds recommended for them (data not presented in Table 4.2).

4.2.2 Nutrient stressors

The higher than anticipated nutrient concentrations, indicated by the generally high ratios for TN and TP in Table 4.2, were noted in historic (and more recent) data at all sites; summarised in Bennett and George (2011). Bennett and George also reported that high proportions of the TN and TP were in the organic and particulate forms respectively and observed the following processes occurring in the catchment and proposed that they are responsible for high nutrient loadings:

- the luxuriant herbage growth on the flood plains present in the wet season which then desiccates and degrades causing high levels of organic matter to be washed into the river tributaries during the following wet season

- the evident, often severe, erosion of drainage lines resulting in sediment and nutrient transport into river tributaries
- the tendency for cattle to congregate near waterways or on floodplains during dry seasons resulting in an associated concentration of nutrients from urine and faeces in these areas.

These observations led Bennett and George (2013) to conclude that there is a combination of natural environmental and anthropogenic factors responsible for the observed nutrient loads. Similarly, high proportions of organic forms of N and particulate forms of P were evident in the water samples collected during this study (data not shown). Similar contributory factors, to those described by Bennett and George were also observed throughout this study.

4.2.3 Metal toxicants

Several toxicants have ILTVs that are well above the relevant AADTVTA. For example, the baseline concentration of Al exceeded the AADTVTA by 13–28 times in wet season and by 1.1–2.5 times during dry seasons, across all of the Keep River pools (Table 4.2). The concentration of Al exceeded even the lowest level of aquatic species protection — the 80% SPL (Table A1) at every site during the wet season. However, during the dry season the ILTV of Al is lower, corresponding to either the 90% or 95% SPL. Zn has an ILTV that greatly exceeds (by factors of between 5 and 20) the AADTVTA at every site in both seasons. The derived ILTVs for Zn correspond to an SPL that is either less than or equal to the appropriate 80% SPL. The ILTVs of Cd and Cu also either exceed, or were equal to, the appropriate AADTVTA in all non-estuarine locations. During the dry season, B had a ILTV that was much greater (4.8 to 54 times) than the AADTVTA at sites K1–K3, while the ILTVs for Pb in BC and K4 in the wet season also exceeds the appropriate AADTVTAs.

Development in the Keep River and Border Creek catchments has been largely limited to a mixture of low intensity rangeland cattle grazing and national park, making it unlikely that the high baseline levels or ILTV s (in comparison to the AADTVTAs) of the metal toxicants are the result of anthropogenic activity. It is much more likely that they are a natural phenomenon in the catchments given that both the Keep River and Border Creek catchments contain significant outcrops containing metal mineralisation in relatively close proximity to the pools. For example, shallow open-cut mining of Pb, Ag and Zn is proposed within the Sorby Hills Project area (KBL 2014). The Sorby Hills area is situated approximately 10km west of pool K4 and lies within both the Keep River and Border Creek surface catchments. It is also located within the groundwater system connected to pool K4 (George et al. 2011). Baseline sampling of groundwater in the catchment to the west of the Keep River has shown that the average concentration of all (the ANZECC and ARMCANZ, 2000) listed heavy metals exceed their AADTVTAs (Lillicrap et al., 2014). Therefore, both the surface and groundwaters that contribute to the lower Keep River aquatic environment are likely to be influenced by the presence of the naturally occurring metal mineralisation, explaining the high baseline levels of Pb, Ag and Zn observed.

It was not possible to compare the ILTVs for several metals to an appropriate AADTVTA in Table 4.2, because, although listed as being an aquatic toxicant in ANZECC and ARMACANZ (2000), no AADTVTAs have been assigned. Some of these metals will have AADTVTAs recommended as part of a forthcoming review of the ANZECC and ARMACANZ (2000) guidelines (C Humphrey 2013, pers. comm.).

In the interim, while it may be possible to source default TVs from the international literature proposed in ecotoxicological studies undertaken on different species and in different environments, this approach was not followed for two main reasons.

First, there are no data specifically available for the threatened species, listed as Matters of National Environmental Significance (NES) under the EPBC Act that are known to or may inhabit the lower Keep River environment. We could find no suitable basis to enable data obtained for different species, from elsewhere, to be related to the NES species that are a focus of this baseline study. Second, the aquatic fauna and the NES species, in particular, that are resident in the lower Keep River aquatic environment area have adapted to the prevailing water quality conditions, even though several of the stressor and toxicants have ILTVs that exceed those (where listed) recommended by ANZECC and ARMCANZ (2000).

In the absence of suitable ecotoxicological data, we believe that a better approach to assigning toxicant TVs based on unrelated studies is to use the LTVs that are derived from local baseline data.

4.2.4 Considerations for comparison of future monitoring results

Notwithstanding the above considerations in the setting of local triggers, it is apparent that the aquatic biota present in pools K1–K3 and in the upper estuary (WRM 2014) have adapted to the highly variable water EC, DO, Turbidity, plus nutrient and metal levels that the sites experience.

For the detection of changes associated with the Goomig Farmland development, data collected from the K4 site would be an appropriate reference, as it is upstream of the Goomig Farmlands discharge, provided that it does not become influenced by additional (to current land use) anthropogenic activity.

Combining the ongoing water quality monitoring data from K4 with ongoing monitoring of its aquatic biodiversity, threatened species and macro-invertebrate abundance would provide additional rigour to the ability to detect changes and is a process also recommended by ANZECC and ARMCANZ (2000).

Table 4.2 Ratio of the upper ILTVs to the AADTVTAs for sites BC, K1–K4 and E1

Parameter	BC wet	K4 dry	K4 wet	K3 dry	K3 wet	K2 dry	K2 wet	K1 dry	K1 wet	E1 dry	E1 wet
Stressors											
Temp	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
pH	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.1	1.0	1.0	1.0
EC	1.0	3.4	1.1	17	1.0	86	2.0	167	6.4	ID	ID
Turb.	19	8.0	30	1.1	13	1.0	17	1.0	31	22	23
TSS	20	3.1	70	1.5	3.9	1.1	9.3	1.4	4.3	15	24
DO	1.0	1.0	1.0	1.0	IND	1.0	IND	1.0	1.0	1.0	1.0
Chlor. a	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TN	8.5	1.5	9.3	1.3	1.7	1.2	1.6	1.3	1.5	3.2	1.6
NO_x/NO_3 N	1.0	1.0	4.0	1.0	2.0	1.0	2.0	1.0	3.0	1.0	1.0
NH_3 N	3.0	3.0	3.0	2.0	2.0	1.0	3.0	2.0	4.0	3.0	1.0
TP	10	4.0	13	1.3	3.8	1.0	3.0	1.0	4.2	1.8	3.0
SRP	1.0	1.0	2.5	1.0	1.3	1.0	1.0	1.0	1.0	1.0	1.0
Toxicants											
Al	28	2.5	20	1.2	13	1.1	22	1.2	15	ID	ID
Sb	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
As	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	ID	ID
Be	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Bi	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
B	1.0	1.0	1.0	4.8	1.0	24	1.0	54	1.0	ID	ID
Cd	1.7	1.7	1.7	1.7	1.7	8.3	1.7	1.0	1.7	1.4	1.0
Cr	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Co	ID	ID	ID	ID	ID	ID	ID	ID	ID	1.0	1.0
Cu	3.5	2.1	4.0	3.1	2.1	1.4	1.7	1.8	2.3	9.0	11
Ga	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Fe	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
La	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Pb	1.3	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mn	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	ID	ID
Hg	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mo	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Ni	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Se	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	ID	ID
Ag	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tl	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Sn	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
U	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
V	ID	ID	ID	ID	ID	ID	ID	ID	ID	1.0	1.0
Zn	13	15	16	16	23	12	21	13	18	5.1	4.3
Atra.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	ID	ID
NO_x/NO_3 N	1.0	1.0	2.4	1.0	1.2	1.0	1.2	1.0	1.8	ID	ID
NH_3 N	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

ID AADTVTA not assigned; IND Insufficient data

4.3 Comparison of ILTVs to the D4 drain's 80th percentile data

The D4 drain (location shown in Figure 1.1) receives drainage water from irrigated agricultural development on about 5300ha of its 12 900ha catchment. It is the nearest agriculturally developed catchment to the lower Keep River area and is of comparable size to the Goomig Farmlands development. It also has a history of irrigated agricultural activity and use similar to that proposed for the Goomig Farmlands. One critical point about the ORIA Stage 1 drained by the D4, is that it does not have a requirement for on–farm tailwater management systems like that implemented on the Goomig Farmlands. Notwithstanding this important difference, water quality data obtained from the D4 drain since 1998, summarised in Appendix D (source: Ord Irrigation Cooperative),will therefore provide a conservative indication of the likely quality of any surface water discharge from the Goomig Farmland development.

Tables D2 and D3 (Appendix D) show the same set of summary statistical data for the D4 drain, as reported for the lower Keep River in Tables 3.3–3.9, Table B1 and Table B2 (Appendix B). The lists of the parameters collected in the two catchments are not the same because only those water quality parameters listed in the environmental requirements embedded in the Ord Irrigation Cooperatives' Water Licence (managed by the Department of Water), have been regularly collected for the D4 drain (Mathew Dear [Ord Irrigation Cooperative] 2014, pers. comm.). These differences arise because the Ord Irrigation Cooperative was only required to monitor environmental stressor and agricultural chemical toxicant parameters, with no requirement to monitor metal toxicants in the ORIA Stage 1.

The 80th percentile data for the D4 drain is compared to the AADTVTAs in Table 4.3 as ratios of the D4 drain data to the AADTVTAs. During both wet and dry seasons, the D4 drain 80th percentile values exceeded the AADTVTAs for most stressors. The water quality in the D4 exceeded the AADTVTA by more than an order of magnitude for sediment and some nutrient-related parameters. When classified as a toxicant (rather than a stressor), the concentration of NO_x/NO_3 N is 11 and 22 times the AADTVTA in dry and wet seasons, respectively.

Table 4.3 Ratios of the D4 drain 80th percentile values of stressors and toxicants to their AADTVTAs and to the ILTVs for K4 (red font indicates the ratios that exceed unity)

Parameter	D4 dry: AADTVTA	D4 wet: AADTVTA	D4 dry: ILTV K4 dry	D4 wet: ILTV K4 wet
Stressors				
Temp	ID	ID	1.0	1.0
pH	1.0	1.0	1.0	1.0
EC	1.7	1.9	0.5	1.6
Turb.	5.9	82	0.7	2.8
TSS	5.3	52	1.3	0.6
DO	IND	IND	IND	IND
Chlor. a	0.7	0.1	0.6	0.1
TN	6.3	6.0	4.3	0.6
NO_x/NO_3 N	19	37	19	9.3
NH_3 N	5.9	6.6	2.0	2.2
TP	12	29	3.0	2.2
SRP	15	19	15	7.6
Toxicants				
Atra.	0.9	0.4	0.9	0.4
NO_x/NO_3 N	11	22	11	9.3
NH_3 N	0.2	0.2	0.2	0.2

ID AADTVTA not determined

IND Insufficient data

Of the 47 agricultural chemicals analysed (analyses undertaken more than 100 times for most chemicals over the period 1998 to 2013) in D4 drain discharge, only six chemicals were detected at levels above the LOR. Atrazine was detected in 55 of 143 samples analysed and endosulfan in 8 of 67. For atrazine, 15 of the 55 detections were above the AADTVTA 99% SPL concentration, while endosulfan exceeded its AADTVTA (0.00003mg/L) in four of the eight detections that were above the LOR. The median concentrations of both chemicals were below the ANZECC/ARMCANZ (2000) guidelines. Endosulfan was deregistered for use as an agricultural chemical in 2010 (APVMA 2010), so cannot be used on the Goomig Farmlands development area. Chlordane, chlorpyrifos, heptachlor and simazine were each detected once in 115 samples, in each instance at levels equal to or below the AADTVTA 99% SPL concentration.

Table 4.3 also compares, using ratios, the D4 drain 80th percentile data with the ILTVs derived for site K4 (from Table 4.1). The D4 stressor parameters' 80th percentiles that exceed both the AADTVTA and the K4 ILTVs include; EC, Turb., NO_X/NO_3 N, NH_3,TP and SRP in the wet season and TSS, TN, NO_X/NO_3 N, NH_3, TP and SRP in the dry season. The ratios for NO_X/NO_3 N and SRP were extreme; during the dry season they are 19 and 15, respectively while during the wet season they were 9.3 and 7.6, respectively. The extreme ratios of these soluble nutrients, in particular, indicates that the use of soluble N and P fertilisers on the irrigated farmland in the D4 drain catchment has substantially increased their concentrations in run-off. Figure 4.1 shows that the proportions of TP and TN that are comprised of SRP and NO_3 N, respectively, are significantly higher (at the 95% confidence level) in D4 drain discharge than in the Keep River during wet seasons. While the proportion of NH_3 N is similar, the proportion of TN in organic form is significantly lower in D4 drain discharge than in K4.

It is consistent with the findings of many studies of nutrient run-off from farmland across northern and southern Australia (e.g. Bartley and Speirs, 2010) that the agricultural activity in the ORIA Stage 1 has caused an increase in the soluble nutrients in D4 discharge. It is therefore likely that run-off from the Goomig Farmlands will also contain elevated levels of soluble nutrients. However, the approved Goomig Farmlands tailwater management systems plus the surface and groundwater management plans (incorporating the OSWM) were developed to account for this likelihood.

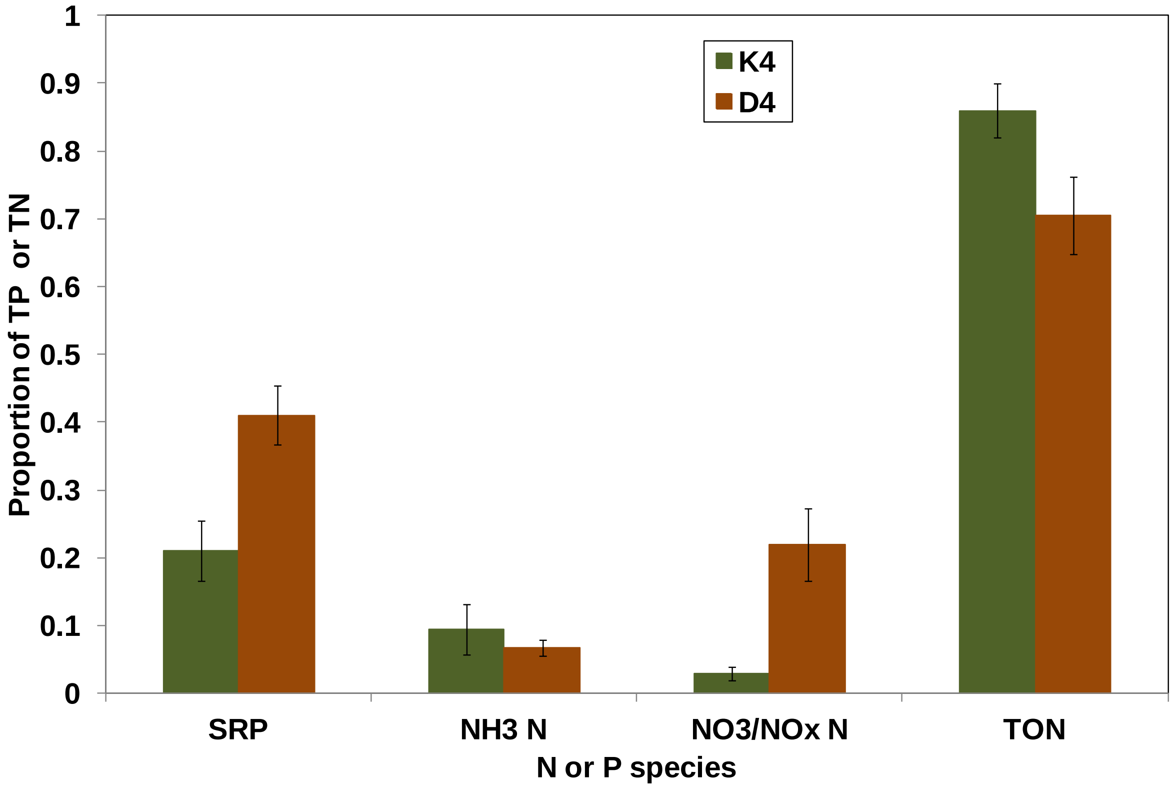

Figure 4.1 Comparison of the mean proportions of SRP, NH_3 N, NO_3 /NO_x N and TON in wet season discharge of the Keep River and the D4 drain discharge during wet seasons. Error bars shown are the 95% confidence interval of the mean

4.4 Determination of baseline in a non-stationary environment

As described in Bennett and George (2011), water is now permanently discharging from pool K4 into pool K3 (and presumably further downstream) during dry seasons. Bennett et al. (2013) conclude that this change is a consequence of groundwater levels rising in the area and attributed this to the increase in rainfall since 1993.

Figure 4.2 shows K4 pool EC data obtained in the late dry season when the water in K4 pool was known to be either at baseline (pre 2000) or baseflow (post 2000) conditions. Figure 4.2 shows two trend lines fitted for the increase in salinity; one fitted using a linear relationship to the post 1995 data and the other using an exponential relationship fitted to all data. Both methods result in highly statistically significant relationships forecasting that by 2038 (25 years) the EC in K4 will reach about 170mS/m during dry seasons.

Bennett and George (2011) proposed that towards the end of the dry seasons, K4 baseflows are comprised of a mixture of discharge from groundwater from the nearby alluvium and the deeper palaeochannel aquifer, itself of a lower salinity locally (compared to other areas) due to localised historic recharge processes near the Keep River. Modelling by KBR (2011) indicates that the relative contributions of these sources to the K4 pool will change as groundwater heads rise in the surrounding plains and pressures increase in the palaeochannel aquifer. KBR (2011) predict that baseflow into the Keep River pools will increase by 63% over the next 50 years under natural conditions. Modelling, using post 1993 rainfall conditions, forecast that K4 pool salinity would increase from its then level of 220mg/L (42mS/m) to a value near 900mg/L (150mS/m), even without agricultural development on the Goomig Farmlands.

As groundwater continues to discharge, the EC of the discharge can also be expected to increase — as higher EC groundwater from the palaeochannel aquifer, that crosses the Keep River beneath pool K4, migrates towards the river. For example, Lillicrap et al. (2014) report that the EC of groundwater in bore RN029660, which located in the paleochannel about 10km up-gradient of pool K4, is 174 mS/m.

If the EC in K4 continues to rise as expected, then the EC baseline data derived for K4 will no longer be a valid reference for the future. By the same mechanism, other physicochemical water quality properties may also change as the composition of the baseflow water in K4 continues to change to reflect those from the palaeochannel aquifer. Any resultant water quality changes in K4 would also potentially influence downstream pools. For example, Figures 3.2 and 3.5 show that the EC in K3 closely mimics that in K4, during the early part of the dry season unless, or until, there is a tide-induced disturbance.

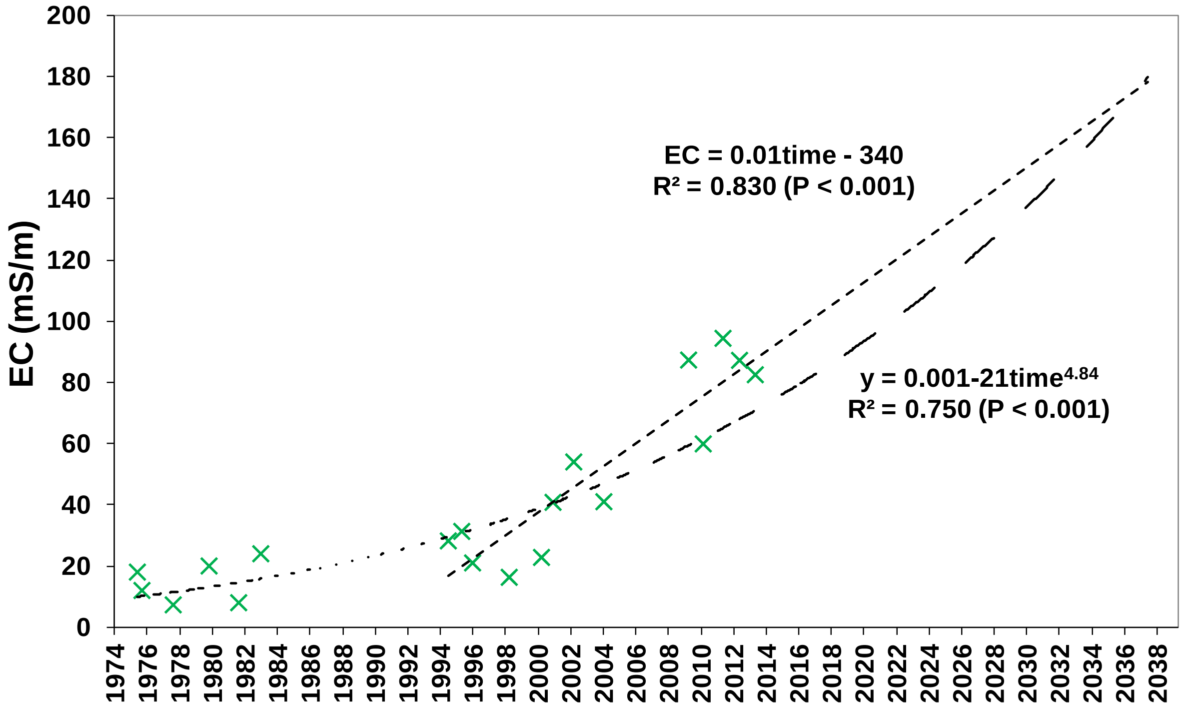

Figure 4.2 The dry season EC increase in pool K4 over time (data sources: Northern Territory Department of Land Resource Management, Department of Agriculture and Food and WRM 2014)

There appears to be limited scope in the ANZECC and ARMCANZ (2000) baseline methodology to incorporate forecasts of change into setting a LTV for water quality. This could cause future problems if, for example, compliance monitoring indicated that baseline levels and any TVs derived from the baseline data, are regularly exceeded, even when caused by natural phenomena. In terms of future compliance monitoring for the Goomig Farmlands development, we recommend that K4 continue to be monitored and used as the reference site for EC in downstream pools. The referential approach is also recommended in ANZECC and ARMCANZ (2000) as it enables reference baseline information to be updated and to be used as a comparison to the results from compliance monitoring. Of course, the approach is only valid if the reference site does not undergo change caused by additional anthropogenic activities, so the monitoring program for K4 would need to be able to demonstrate this, or propose an alternative.

4.5 Comparison of the dynamics of discharge from natural and agriculturally developed catchments

The managers of the Goomig Farmlands will use the Operational Surface Water Model (OSWM) to inform and manage: water quality monitoring of discharges, the water quality within the lower Keep River system, the retention and release of stormwater retained on farm and the implementation of mitigation measures and contingency actions that may be required.

Using hourly flow rates recorded at the Border Creek, Keep River (at K4) and the Goomig Farmlands (at its outfall) gauging stations, the OSWM will, in near-real time, compare, calculate and report their relative contributions to the run-off entering pool K3 — and thus the ratio of dilution of the Goomig Farmlands flow. Together with the estimates of the concentrations of various water quality parameters, which will be based on prior results from sampling and laboratory analysis, the OSWM will then generate forecasts of water quality for pools K1–K3. The water quality forecasts will then, also in near-real time, alert management actions — if required.

The greatest matter for concern to Keep River water quality being adversely influenced by the development is if the flow from the Goomig Farmlands is large when the Keep River flow is small **and** the concentrations of any environmentally harmful constituents in flow from the Goomig Farmlands are above certain levels.

The agriculturally developed D4 drain catchment, being of comparable size to the Goomig Farmlands development, provides an indication, though conservative given it does not have a tailwater management system, of how the timing of wet season run-off from the Goomig Farmlands, once developed, may compare to the pre-existing run-off conditions in the catchment. The following discussion compares the observed relative rates and temporal dynamics of the Border Creek and Keep River run-off to that of the D4 drain.

The analysis of long-term rainfall records shows that the wet season occurs from November to April on average, with about 90% of the annual rainfall occurring during this period (Bennett and George, 2011). However, in terms of baseline water quality assessment for aquatic environments, the catchment run-off and flow characteristics better define the different seasons. Table 4.4 shows the median dates on which wet season flow commenced and ceased in the Keep River and Border Creek, calculated from the 31 years for which there are coincident flow and rainfall data. The median data indicate that wet season, or rainfall-induced flow commences six days earlier and ceases 14 days later in the Keep River than in Border Creek. The median duration of wet season-induced flow is 23 days longer in the Keep River than Border Creek. Table 4.4 indicates that in 90% of years the wet season flow commenced on 14 November in both flow systems. However, in 90% of years Border Creek ceased flowing nearly one month earlier than the Keep River.

Table 4.5 compares the start and end dates of wet season-induced flow plus the flow duration of the Keep River and Border Creek with that recorded in the D4 drain using 15 years of data available since 1998. Some interpretation was required to derive the commencement, cessation and duration of wet season flows from the D4 catchment, as like pool K4 it is a perennial catchment; discharging water derived from groundwater interception, irrigation run-off and wet season run-off. The start of the wet season in the D4 drain was similarly defined to the Keep River (at K4) catchment — being when the baseflow rates first responded to a corresponding rainfall event (Section 2.6). To define the annual end date of wet season-induced flow, hydrographs were examined in detail to determine the date when flow declined to near baseflow rates. After this date, if the next flow response was typical of those associated with dry season tailwater responses (i.e. those associated with irrigation tailwater run-off) and also coincided with there being no significant rainfall it was classified as being the end of the wet season. While in some years there may have been subsequent minor rainfall-induced flows, these were classified as being after the end of the wet season — particularly if irrigation-induced run-off appeared to dominate the characteristics of the hydrograph.

Table 4.4 The median and 90th percentile dates of the commencement and cessation of wet season flows and the wet season flow duration in the Keep River and Border Creek as calculated from the available 31 years of coincident flow data

Catchment	Wet season flow commences		Wet season flow ceases		Wet season flow duration (days)	
	Median	90th percentile	Median	90th percentile	Median	90th percentile
Keep River	5 December	14 November	29 April	13 April	135	106
Border Creek	11 December	14 November	15 April	20 March	112	74

Source: Northern Territory Department of Land Resource Management

Table 4.5 indicates that D4 drain wet season flows commenced on a similar date to those in the Keep River and Border Creek. However, the wet season-induced flow in the D4 drain typically ceased much earlier: about 3 weeks before Border Creek and over a month before the Keep River. This difference could be due to different rainfall amounts or patterns over the three areas (e.g. Table 3.1), although we believe that most of the difference is likely to be due to a combination of land management and inherent scale-related differences. The drainage improvements installed within the agriculturally developed D4 drain catchment facilitate rapid drainage of residual water compared to the unimproved drainage conditions present in the undeveloped Keep River and Border Creek catchments. In terms of scale, the much larger Border Creek and Keep River catchments would likely discharge for a much longer residual period, as the remote areas plus the ephemeral watertables (where present) progressively drain.

The annual discharge expressed on an aerial basis (as mm of discharge) for Border Creek and Keep River (Table 3.2) was compared with that of the D4 drain (Table D1 in Appendix D) over the 2010–13 period. This indicates that during years of high run-off, scale and management factors have less relative impact than during low run-off years. For example; during 2010/11 (an above average rainfall and discharge year) the Border Creek and D4 drain catchments produced similar rates of discharge, whereas during 2012/13 (a well below average rainfall and run-off season) there was negligible discharge from Border Creek but 274mm of discharge from the D4 drain. Therefore, during 'drier' wet seasons, discharge derived from tailwater and groundwater sources in the D4 catchment contribute a higher proportion of run-off.

In terms of the Goomig Development's effect on water quality in the lower Keep River, it would therefore seem that the management of tailwater release will be particularly important during low rainfall wet seasons (and the whole dry season). Otherwise, without tailwater retention and release management, based on the D4 drain discharge, the Goomig Farmlands could contribute a disproportionate volume of run-off to the lower Keep aquatic environment.

Under average conditions (Table 4.5), the earlier cessation of wet season-induced run-off from the D4 drain catchment also indicates that the wet season-induced run-off period from the Goomig Farmlands will consistently coincide with natural run-off from the Border Creek and Keep River catchments. This is important because the run-off contributions from the various sources at the end of the wet season will largely determine the water quality of the Keep River pools during the subsequent dry season.

Table 4.5 The median and 90th percentile dates of the commencement and cessation of wet season flows and the wet season flow duration in the Keep River, Border Creek and the D4 Drain as calculated from the available 15 years of coincident flow data

	Wet season flow commences		Wet season flow ceases		Wet season flow duration (days)	
Catchment	Median	90th percentile	Median	90th percentile	Median	90th percentile
Keep River	5 December	17 November	30 April	16 April	138	118
Border Creek	7 December	13 November	17 April	23 March	132	99
D4 drain	7 December	7 November	26 March	3 March	114	75

Source: Northern Territory Department of Land Resource Management and Ord Irrigation Cooperative

Based on the D4 data, and particularly considering that the Goomig Farmlands has tailwater management systems, it seems that the likely earlier cessation of wet season-induced discharge from the Goomig Farmlands will reduce the risk that dry season water qualities in the lower Keep environment will be influenced by activities on the Goomig Farmlands. However, this can only be true if run-off caused by the early commencement of dry season irrigation does not also contribute to the end of wet season discharge from the wider catchments.

The Goomig Farmlands tailwater retention system was specifically designed to store and re-use up to 25mm of run-off. Effectively utilising this storage capacity will be important to minimising the potential risk to the lower Keep aquatic environment, particularly during low rainfall wet seasons and/or as natural catchment flows diminish at the end of each wet season.

4.6 Keep River pool volumes

In order for the OSWM to be able to forecast the effect of discharge (from various sources) on the water quality in the Keep River pools, their volumes are required to be known.

Appendix E reports the methodology and results from a bathymetric survey of the K1, K2, K3 and K4 pools undertaken in July 2014 by Surrich Hydrographics Pty. Ltd Table 4.6 shows the volume, surface area, maximum water depth, and minimum pool bed elevation of the pools collected when their water levels were at baseflow level.

From Table 4.6, the combined volume of water stored in the K1, K2, and K3 pools (at baseflow level) is 1 264 300m^3 (1.26GL). The surveyed combined volume of pools K1–K3 is slightly less than the estimate of 1 440 000 m^3 made by Bennett and George (2011). It is substantially less than the observed 3GL run-off event that reset the EC of pools K1–K3 (Section 2.6 and Bennett and George 2011). While it appears that a flow of about twice the volume of the pools was required to completely flush them, closer examination of the water flow and EC dynamics of the event (data shown in Figures 3.4 and 3.6) indicates that the first 1.6GL of flow (over 24 hours) flushed 90% of the water from K1 — based on the observed 90% reduction in EC.

Table 4.6 The volume, surface area, maximum water depth, and minimum pool bed elevation of the pools collected when their water levels were at baseflow level, in July 2014

Pool	Volume (m^3)	Surface area (m^2)	Maximum water depth (m)	Minimum pool bed elevation (mAHD)	Mean water elevation at baseflow level (mAHD)
K1	922 630	445 500	6.02	-1.53	3.44
K2	140 890	77 650	4.54	-3.33	3.65
K3	200 780	68 258	7.02	-0.88	3.72
K4	68 950	25 027	6.81	-2.58	5.28

Source: Appendix E

One of the contingencies in the Stormwater and Groundwater Discharge Management Plan (Strategen 2012) is to release irrigation water to flush the pools if required, using the OSWM as the decision tool to inform management action. The pool volumes shown in Table 4.6 will provide more accurate structural data and allow the OSWM to make more accurate predictions of the effect of irrigation water release, catchment flow events and tide influences on the water quality in pools K1–K3. The bathymetric data reported in Appendix E will also provide an accurate foundation for updating the hydrodynamic modelling (GHD 2011b) of the lower Keep system if required in the future.

4.7 Tidal influence on Keep River pools

Baseline data indicates that tidal forcing can have a large influence on water quality, in particular EC, in pools K1–K3. The short-term predictive capability of the OSWM will therefore require tidal data that allows forecasts of the timing and relative (to pool volume) volume of tide effects. In addition, one of the conditions in the Commonwealth Ministerial approval relating to any possible future discharge of groundwater from the Goomig Farmlands (into the Keep River estuary) was that tidal influence be considered prior to any potential discharge. The port of Wyndham is the closest location where routine forecasts of the magnitude and timing of tides are made (and are publically available on the Bureau of Meteorology website). Wyndham is about 100km west of the Keep River and is located within the narrow Cambridge Gulf. The distance from Wyndham to the Bonaparte Gulf is about 60km, which is similar to the distance from K1 to the Bonaparte Gulf.

Bennett and George (2011) compared the Wyndham tides with the water levels recorded in the Keep River pools during 2010–11. They reported that the dry season water levels in pools K1-3 were affected by tides greater than 8.1m, whereas water levels in pools K1 and K2 were affected by tides greater than 8.0m. They also found that, on average, each dry season there are 11 tides that are likely to force water into pool K3 and 26 tides that will likely cause water to be forced into pools K1 and K2.

Tide and pool water level data collected during 2010–13 (shown in Figure 4.3) was used to determine the relationship between the tide recorded at Wyndham and water level rises observed in pools K1–K3. Figure 4.3 shows the comparison between tides recorded at Wyndham that exceeded 7.9m (Department of Transport, Fremantle, data accessed July 2013) and the maximum increase in the water levels in the pools, for periods when the Keep River pools would otherwise be at their baseflow elevations.

Pool water levels never responded to tides than were less than 7.9m. At higher tides, the tidal forcing response was variable, probably due to non-tide related factors such as wind speed and direction over the ocean and estuary. Despite the variability, Figure 4.3 shows that there were highly statistically significant relationships between the tide at Wyndham and the water level rises in the three pools. These relationships explain more than half of the variability in water level response. The maximum tide recorded at Wyndham during the study was 8.43m.

Not all tides above 7.9m affected the pools, therefore further analysis was undertaken to determine the proportion of tides that had an effect on pool water levels. Figure 4.4 shows that all tides above 8.05m caused an associated response in K1, while all tides above 8.10m resulted in tidal forcing of water into K2. Over 80% of tides above 8.10m caused a resultant water level rise in K3. The average time lag between the peak of the tide at Wyndham and the peak in water level rise in the pools was 3.0, 3.3 and 4.3 hours for K1, K2 and K3, respectively. Tides above 7.9m at Wyndham always caused the tide to also peak at the estuary site E3 within an hour.

Utilising a combination of; the tide forecasts for Wyndham, the surface area of the water at base water level in the pools (from the bathymetric survey data reported in Appendix E), the relationships between Wyndham tide and pool responses in Figure 4.3, and the time delay data, could allow forecasts of the volume of tidal water exchange expected within each pool over a given period to be made. The tidal volume exchange forecasts could be then used to determine the likelihood of changes in water quality occurring in the pools as a result of tidal forcing. Such forecasts could be incorporated into the OSWM. The predictive modelling of water quality in the pools would assist with the surface water discharge management operations of the Goomig Farmlands.

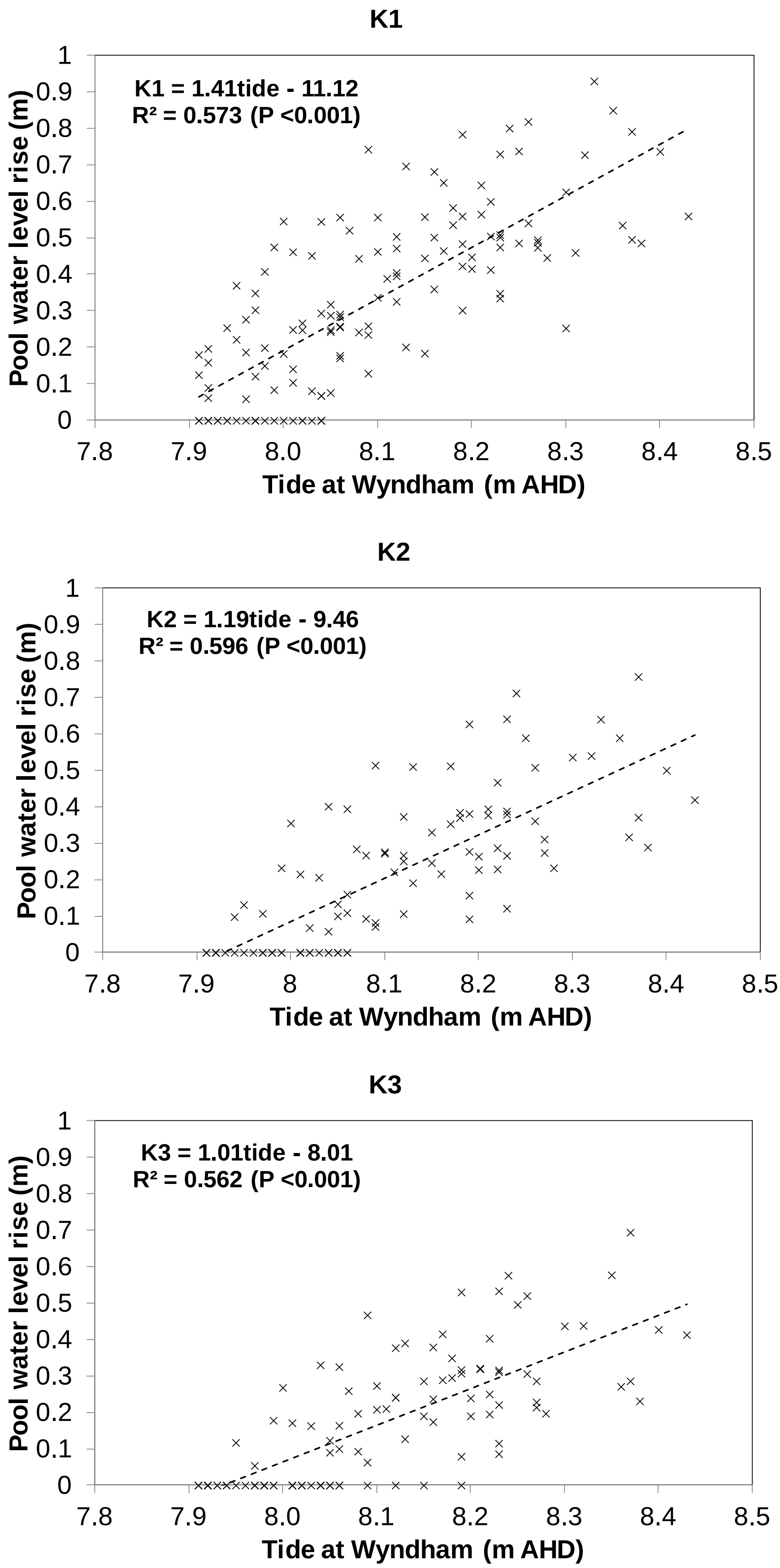

Figure 4.3 Relationship between Wyndham tides and the water level response recorded in pools K1, K2 and K3 in 2010–13

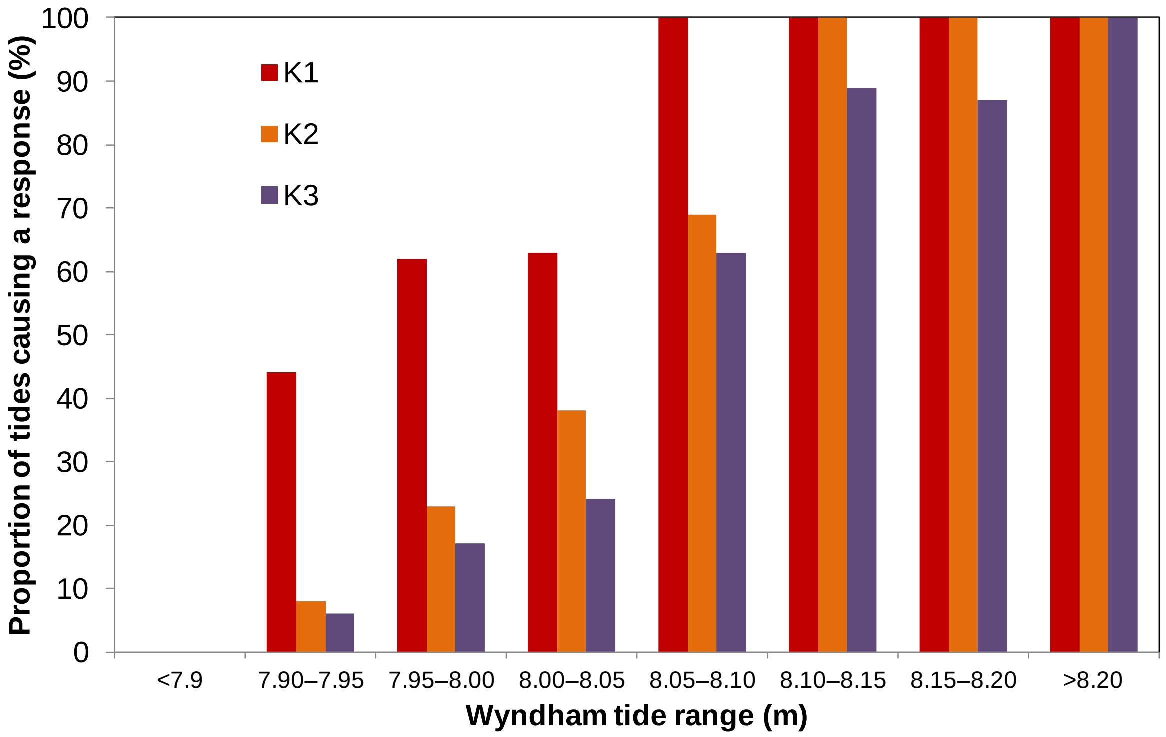

Figure 4.4 The proportion of tides causing water level responses in pools K1–K3 in 2010–13

4.8 Future monitoring location for the Keep River estuary

The only water quality parameter that was statistically different between the upper estuary sample sites (E1–E3, Figure 1.2) was EC in the dry season at sites E1 and E3. This is understandable given that E1 is uppermost in the estuary, where it is about 100m wide and closest to inputs of fresher water from upstream, while E3 is about 12km further downstream, where it is over 300m wide and more open to exchange with marine waters.

Site E1 is also located upstream of a large sand bar which is about 2km long and almost the full width of the estuary (Figure 4.5). The sand bar can limit the volume of tidal exchange during periods of smaller tidal range. Although there is no logger (or similar) data available for site E1 that would provide an assessment of the extent of the restriction, visual observations (by authors and A. Storey 2013, pers. comm.) indicate that during some neap tides, while there is a significant water elevation response at E2, there is a greatly reduced response at E1. Water flow was observed to be confined to a narrow, shallow gutter, about 10m wide and 0.5m deep, on the eastern side of the sand bar at these times.

During the aquatic fauna surveying program, the highest observed occurrences of freshwater sawfish (*Pristis microdon*) were at E1 (A. Storey 2013, pers. comm.). A couple of (related) reasons have been proposed (A. Storey 2013, pers. comm.) for the sawfish congregating at E1. One is that the area provides the sawfish with abundant food sources, held somewhat captive because of the sand bar during certain tide sequences. The other is that the sawfish, after following their prey into the area during higher tides, become periodically trapped in the area during subsequent lower tide periods.

Figure 4.5 The narrow connection at low tide on the western side of the sand bar that separates sites E1 and E2 in the Keep River estuary

On the basis of a combination of the baseline water quality monitoring results, the restrictions to water exchange, plus the sawfish prevalence, site E1 appears to be the priority site for the continuing water quality monitoring for compliance (or other) reasons in the Keep estuarine environment.

4.9 Considerations for determining and applying local water quality triggers

Table 4.1 shows the interim local trigger values (ILTVs) derived using a combination of the AADTVTA and baseline data. These ILTVs form the basis for setting LTVs that are appropriate to monitor and manage any effects of the Goomig Farmlands development on water quality in the lower Keep River.

The ANZECC and ARMCANZ (2000) guidelines indicate that LTVs can be set where baseline monitoring has shown that the aquatic ecosystem condition has been anthropogenically modified or has natural variability outside the default parameter ranges. The guidelines discuss many other considerations for the selection and determination of appropriate LTVs as a reference in ongoing water quality monitoring programs. The principle objective of the ANZECC and ARMCANZ (2000) guidelines is to protect aquatic ecosystems by maintaining or enhancing their ecological integrity; which includes biological diversity, relative abundance and ecological processes. In addition to the assessment of biological properties, assessment of aquatic physicochemical properties is important for protecting ecological integrity.

Comparing the results from monitoring physicochemical properties with the LTVs is better suited to routine and short timescale assessment of change, than is biological assessment. In this respect, it is also a methodology better suited for use in the operationally focused alert and reporting context of the OSWM for the Goomig Farmlands. The additional capabilities of the OSWM in the routine collection, storage and reporting of physicochemical data will also provide referential data for use in the ongoing biological change monitoring programs.

The following sections discuss considerations for setting physicochemical LTVs appropriate for the lower Keep River and in the context of the operation of the OSWM for the Goomig Farmland development.

4.9.1 Ecosystem condition classification and level of protection

The physicochemical baseline data indicate that the lower Keep River is best classified as a 'Category 2' system, being a 'slightly to moderately disturbed system', rather than 'Category 1', which is defined as a 'high conservation/ecological value system'. The lower classification is a result of the influence of natural (tidal influence, climate variability, groundwater discharge, heavy metal mineralisation, terrestrial vegetation growth dynamics and run-off dynamics) and anthropogenic (rangeland cattle grazing) factors. It was not possible to quantify the relative influence of each of the natural and anthropogenic factors on the condition of the lower Keep River. It does appear, however, that the anthropogenic influences mainly affect the nutrient aquatic stressors N and P.

The ANZECC and ARMCANZ (2000) guidelines define the level of protection that should be afforded to each category of ecological systems. That level of protection is defined in terms of 'a level of quality desired by stakeholders and implied by the selected management goals and water quality objectives for the water resource'. The starting-point philosophy for the protection of 'Category 2' systems is the maintenance or enhancement of the system by targeting the most appropriate condition level. The guidelines do acknowledge that local stakeholders may negotiate or select an alternative level of protection based on more than scientific advice, including socioeconomic factors. However, the ANZECC and ARMCANZ (2000) guidelines also recommend that aquatic systems that contain 'rare' species be assigned the level of protection appropriate for 'Category 1' systems. As the lower Keep River is a habitat for the threatened and endangered dwarf sawfish and freshwater sawfish, the guidelines appropriate for 'Category 1' systems would seem to take precedence over other considerations.

The ANZECC and ARMCANZ (2000) guidelines describe the preferred levels of protection for each of the stressor and toxicant water quality indicators for each ecosystem condition classification. The use of local biological effect data to derive LTVs (e.g. van Dam et al. 2013) is preferred for all ecosystem condition categories. For physicochemical parameters the guidelines recommend:

- Stressors
  - Category 1 systems should have the principle of 'no change beyond natural variability' applied using local reference data.
  - Category 2 systems should have guideline values derived from local or regional reference data applied.

- Toxicants
  - Category 1 systems should have background concentrations applied for natural toxicants (e.g. metal toxicants) and these should not be exceeded. Any detection of toxicants generated by human activities (e.g. farm chemicals) should be grounds for investigation.
  - Category 2 systems should have the AADTVTA applied.

For stressors, the relevant distinction, in terms of deriving and applying local triggers, is that for Category 2 systems regional reference data can be used, whereas for Category 1 systems local data is required.

For toxicants, particularly natural toxicants, the distinction is less logical as the guidelines indicate that for Category 1 systems, local reference data can be used to set LTVs, whereas AADTVTAs should be applied to Category 2 systems. In the lower Keep River, the use of local data would result in ILTVs that greatly exceed the AADTVTAs, so a combination of the two recommendations was used to derive the ILTVs. Where the 80th percentile of a toxicant's reference data exceeded the AADTVTA, the 80th percentile was used as the ILTV. If a toxicant had no AADTVTA assigned, the 80th percentile was used as the ILTV. As discussed in Section 4.1.3, advice on the validity of this combined approach was sought from the IRG and Chris Humphrey.

It should be noted that for biological indicators, the ANZECC and ARMCANZ (2000) guidelines more clearly define the distinctions between the ecosystem categories, than they do for physicochemical indicators. Also, for both biological and physicochemical indicators, the guidelines are clear about the requirements for ongoing assessment of changes to the ecosystem and also for the requirements for management of any changes that may be detected.

The use of a community forum to help interpret and apply relevant modifications to the ANZECC and ARMCANZ (2000) guidelines is appropriate, as the guidelines state that 'key stakeholders in a region would normally be expected to decide upon an appropriate level of protection through the determination of management goals and based on the communities long-term desires for the ecosystem'. There is likely an array of stakeholders that have a range of views on the level of protection that they think should be applied to the lower Keep River. However, given the data complexity and that threatened and endangered fish species are involved it is more appropriate that an 'expert panel', such as the IRG, has a leading role in providing advice on the derivation, selection and application of LTVs as the reference for ongoing monitoring.

4.9.2 Selection of appropriate physicochemical water quality indicators

ANZECC and ARMCANZ (2000) recommend selecting a set of appropriate physicochemical water quality parameters for ongoing monitoring. The list of analytes should be derived after consideration of the potential for their presence to be altered and assessment of the impact of any change on the aquatic environment. In this study, a wide range of parameters were selected for the baseline monitoring in consideration of the absence of specific information on the effects of any specific water quality parameter on the threatened and endangered sawfish species. This section discusses the baseline parameters chosen and what we believe is a relevant set of parameters for ongoing monitoring.

Stressors

As there is evidence from the D4 drain catchment that irrigated agriculture is likely to affect nutrient, EC and turbidity/total suspended solids levels in receiving environments, it is appropriate that ongoing monitoring for these parameters continues. It is also appropriate to continue monitoring the other stressors as they can be affected by changes in the above parameters. For example, DO levels can be affected by algal blooms, which are in turn dependent on the presence of nutrients.

Metal toxicants

The requirement for ongoing routine monitoring of toxicants in the lower Keep River is less clear. For some of the metal toxicants (for example: Al, Cu and Zn) the baseline levels and ILTVs greatly exceed the AADTVTA. However, it is unlikely that existing human activities (principally rangeland grazing) in the Keep River catchment have altered the concentrations of metal toxicants in the lower Keep River. Baseline aquatic biodiversity, threatened species abundance and macro-invertebrate baseline data have been collected (WRM 2014) in parallel with the metal toxicant baseline data to define the ecological condition of the lower Keep River prior to the operation of the Goomig Farmlands. It is therefore likely that the prevailing baseline concentrations of the metal toxicants are also reflected in the prevailing biological/ecological conditions recorded.

Irrigated farmland has been shown to cause increased concentrations of metal toxicants in run-off. However, the reports that show increased metal concentrations in run-off, attributed to agriculture, in Australia are also associated with the application of high rates of biosolids (e.g. sewerage sludge or animal wastes; McLaughlin et al. 2000, Han et al. 2000) or mining or processing wastes (e.g. coal combustion products; Seshadri et al., 2010) that also contain high levels of heavy metal contamination. Some commercial agricultural fertilisers can contain metals such as Cd, Zn and Cu, either as impurities or added to correct soil deficiencies an aid plant growth. However, several reviews of causes of degradation of aquatic ecosystems in Australia do not identify heavy metal contamination by agriculture as being a contributory factor (e.g. Anon., 2010; Simonovski et al., 2003; Haynes & Johnson, 2000; Davis & Froend, 1999; Zann, 1995; Hart & Lake, 1987).

From the available evidence and literature it seems unlikely that conventional irrigated agricultural activity on the Goomig Farmlands will lead to the increase in concentration of heavy metals in run-off or in downstream aquatic environments. Therefore, ongoing routine monitoring for heavy metal contamination is not expected to add a significant degree of protection (especially given the absence of relevant local information on the ecotoxicology of metals) for the threatened species in particular. This approach is similar to that taken locally (over the last 15 years) by the Department of Water, the licensors of the ORIA Stage 1 area (Section 4.3).

The exception to this conclusion would apply if it was likely that high levels of heavy metals were being brought onto the Goomig Farmlands. Therefore, it is appropriate that specific metals should be monitored in run-off waters if ongoing risk assessments identify that fertilisers or other soil ameliorants that are applied to the Goomig Farmlands contain heavy metals in abnormally high amounts (as either contaminants or additives).

Chemical toxicants

A similar risk assessment approach is also appropriate to the selection of farm chemical toxicants for ongoing monitoring. Local data (from the D4 drain catchment) has shown that while some farm chemicals have been detected (principally atrazine and endosulfan, Section 4.3) in run-off from irrigated farmland their 80th percentile levels are always below the AADTVTA. However, the ANZECC and ARMCANZ (2000) guidelines recommend that any detection of toxicants generated by human activities (e.g. farm chemicals) could be grounds for investigation. Rather than routinely monitoring a wide array of farm chemicals (that may or may not be used), it is more appropriate that usage of chemicals be monitored and the list of chemicals that are used on the Goomig Farmlands be considered; those known to pose an ecotoxicological risk be selected for monitoring.

Oliver and Kookana (2005) report a risk assessment of off-site impact by farm chemicals that uses a 'pesticide impact rating index' for sugar, melon, hybrid seed and mango crops locally in the ORIA. They concluded that atrazine, chlorpyrifos, chlorothalonil, cypermethrin, diuron, endosulfan, glyphosate, mancozeb, trifluralin and pendimethalin posed a risk — based on usage, site conditions, and pesticide properties — and should be included in a monitoring program. However, Oliver and Kookana's (2005) risk analysis results do not seem to be well-calibrated to the significant amount of farm chemical run-off data (collected over 15 years) in the ORIA. For example, pesticide data from the D4 drain indicates that, of Oliver and Kookana's list of risky farm chemicals, only atrazine and endosulfan have been detected at any significant frequency and/or concentration in run-off from ORIA farmland.

In the absence of suitable modelling methodology to accurately forecast risk, a list of farm chemicals to be routinely monitored in the Goomig Farmlands discharge and downstream aquatic environment should be determined by assessment of:

- the chemicals are actually being used
- of those used, which are known to be toxic to biota in the aquatic environment
- of those used and known to be toxic, which have been shown to be present in run-off waters in the ORIA.

The significant amount of farm chemical run-off data collected from the ORIA would seem to provide a good source of evidence to determine the risk of particular farm chemicals being present in run-off from irrigation areas. However, new or different chemicals may be used on the Goomig Farmlands and new or different agricultural enterprises may be pursued, so the D4 drain data may not always provide a sufficient reference.

For chemicals used that have not previously been monitored locally, a precautionary approach should be followed whereby those known to be toxic to aquatic biota be monitored until sufficient data is available to determine their risk of transport into the aquatic environment.

It is noteworthy that the Ord Irrigation Cooperative has recently followed a process similar to that outlined above to reduce the list of farm chemicals that have been routinely monitored over 15 years from 47 to just four; atrazine, oxyfluorfen, diuron and trifluralin (Mathew Dear 2014, pers. comm.).

In addition to the above risk-based monitoring approach the use of passive sampling methodology to test for the presence of farm chemicals in the discharge from the Goomig Farmlands and in the Keep River could also be considered. The passive sampling methodology traps chemical compounds from water as it flows through specially designed membranes and sorbent bases. The passive samplers can be deployed for extended periods and the membranes/sorbent bases retrieved and analysed for a wide range of chemical compounds. Shaw et al. (2010) and Smith et al. (2012) describe the passive sampling methodologies used for investigations into the presence of chemical toxicant compounds in rivers that discharge towards the Great Barrier Reef. The methodology offers a significantly lower cost alternative for testing for the presence of a wide array of chemical compounds than the conventional sampling and analysis approach (Mark Silburn 2014, pers. comm.). Using the passive sampling approach, chemicals of environmental concern that are detected could then be added to the suite of analytes for which conventional, routine concentration monitoring is undertaken. In addition to passive sampling being used for presence/absence monitoring, Quilbe et al. (2006) describe a methodology for using passive sampling to estimate the average concentrations of chemical compounds in situations where the discharge rate of the stream is also continuously monitored.

4.9.3 Application of trigger values to management objectives

Trigger values (numerical water quality objectives) are a numerical means of assessing, or interpreting, changes in water quality or assessing ‘compliance’. By virtue of their derivation by statistical means (80th or 20th percentiles), they are likely to be exceeded during the course of an ongoing monitoring program. Therefore, in the context of using LTVs as the basis for triggering management responses or compliance breach actions, a hierarchical approach in assessing LTV breaches would be appropriate. Under such a scheme, the level of exceedance of a particular LTV would dictate the level of management response.

The hierarchical approach has been used to assist management responses in situations where activities, such as mining, pose a risk to the ecological health of receiving water bodies. For example, Iles (2004) and Jones et al. (2008) describe a process where they assigned increasingly stringent management responses based on numerical derivatives of baseline and reference site data, at the Ranger Mine project in the Northern Territory. The Ranger Mine project had the benefit of being able to analyse more than 10 years of monthly monitoring data collected from receiving sites and upstream reference sites to first revise the original LTVs and then propose a set of hierarchical values that correspond to water quality objectives (and associated management responses) termed ‘focus, action and limit’ responses. A set of ‘Actions Invoked by Trigger Value Exceedances’ was specified for the operation of the Ranger Mine project.

The Ranger mines’ focus, action and limit values were assigned using percentiles of the water quality data and so inherently combine a water quality value and the proportion of time that the value could be expected to be exceeded in a given period. For the Ranger Mine project, eight physicochemical water quality indicators were monitored and reported using this approach, each having their associated measures of success defined. The focus, action and limit levels chosen corresponded to the 80th, 95th and 99.7th percentiles (or 20th, 5th and 0.3th percentiles for parameters like pH that also had a lower trigger value), respectively, of the reference site data for pH, turbidity, EC, Mg, SO_4, Mn and U. For Radium, Iles (2004) did not assign focus or action levels, instead basing the limit value on a comparison of concentrations observed in the receiving and reference site locations. The focus, action and limit parameters, plus the associated management objectives and measures of success, were reviewed and adopted by the Ranger Mine project Technical Committee and community stakeholders.

Even though the available lower Keep River water quality data is a comparatively short-term dataset, the application of focus, action and limit guidelines seems appropriate. During the initial few years of the operation of the Goomig Farmlands, interim water quality focus, action and limit levels — using a combination of the baseline data and data from the K4 site as a reference for the selected indicators — could provide a valuable basis for applying the management actions specified in the Stormwater and Groundwater Discharge Management Plan (Strategen 2012). Interim focus, action and limit levels could be derived using a similar approach to that taken by Iles (2004); using the 80th, 95th and 99.7th percentiles of the baseline data (and corresponding 20th 5th and 0.3th values where appropriate). These interim values could be reviewed at pre-determined intervals using data collected during the ongoing monitoring program.

The interim focus, action and limit levels could form the basis for both annual compliance reporting and in the more responsive context of the OSWM alert system. However, because the OSWM will make very short-term (hourly) forecasts of water quality in the highly dynamic lower Keep River, additional rules that consider the length of time of exceedance and short-term changes in flow conditions will need to be developed.

For example, rules that specify the minimum length of time over which either a focus, action and limit level is exceeded to then trigger the related management action, will need to be incorporated into the OSWM system. Similarly, rules based on flow rates that define when an OSWM alert becomes inactive will need definition and application in the OSWM.

5 Conclusion

This report describes the methodology, data and analyses used to derive the baseline physicochemical water quality conditions of the lower Keep River.

The lower Keep River system is highly dynamic and responds rapidly to prevailing rainfall and tidal influences. Even though current land use in the catchment is a mixture of low intensity cattle grazing and national park, this analysis indicates that the lower Keep River is better classified as being 'moderately disturbed' rather than 'pristine', as might have been expected given the current land use. This conclusion is made because many of the baseline physicochemical parameter levels exceed the corresponding expected levels for high conservation/ecological value systems (as recommended by ANZECC and ARMCANZ 2000). The revised classification is based on the high nutrient and suspended solid concentrations during the wet season, plus the generally high concentrations of some heavy metals in both seasons.

Accordingly, in terms of ongoing management and compliance monitoring for the Goomig Farmlands development, it is appropriate that local trigger values (LTVs) be derived for the lower Keep River. A set of interim local trigger values (ILTVs) was assigned to all of the water quality parameters collected during this baseline study.

We propose that the ILTVs listed in this report should form the basis for the subsequent derivation of a selection of operational LTVs.

Ideally ANZECC and ARMCANZ (2000) suggest that the selection and application of LTVs should be done in consultation with a local community forum who can assist by providing local perspective on the level of protection that should be afforded to the lower Keep River. However, because of the high level of scientific complexity involved in assigning trigger concentrations to multiple parameters, plus threatened and endangered species are involved (*Environmental Protection and Biodiversity Conservation Act 1999*), we recommend that a peak scientific body, such as the ministerially appointed Independent Review Group, lead this process.

While we recommend that all water quality stressor parameters continue to be monitored for future management and compliance purposes, it is unnecessary for the full list of the baseline metal toxicants to be continually monitored. Rather, an ongoing review of the risk of heavy metal contamination on the Goomig Farmlands should be undertaken, based on their presence in imported fertiliser or other farm inputs and this be used to inform the water quality monitoring program.

Similarly, ongoing risk-based reviews should be used to inform monitoring of farm chemical toxicants in the lower Keep River. While the farm chemical risk reviews should be conservative by nature, they should be based on usage, known toxicity to biota and likelihood of being present in run-off waters. To inform the latter, use should be made of the significant local monitoring data available for farm chemicals, collected over 15 years from run-off in the Ord Irrigation Area.

Sites E1, K1, K2 and K3 are recommended as suitable sites for ongoing compliance monitoring. Ongoing comparison of the water quality at these sites to site K4, as a reference site, is recommended provided that it continues to remain largely unaffected by human activity or further development.

The derivation of baseline and ILTVs largely followed the data analysis and interpretation procedures recommended by ANZECC and ARMCANZ (2000). In order that the conservative intent of the ANZECC and ARMCANZ guidelines be fulfilled, practical modifications to data analyses and interpretation procedures, mainly concerning the use of chemical analyses results that were below the limit reporting, were undertaken for some data. Instances where modification was required were identified and the methodology and reasoning explained. The requirement for these modifications could be considered and factored into any future review of the ANZECC and ARMCANZ guidelines.

Appendices

Appendix A ANZECC default trigger values for tropical Australia (AADTVTAs)

Appendix B Summary data for the additional analytes collected

Appendix C Physicochemical data collected during the study

Appendix D Summary discharge and water quality data for the D4 drain

Appendix E Keep River pools survey bathymetric report

Appendix A Default trigger values for tropical Australia

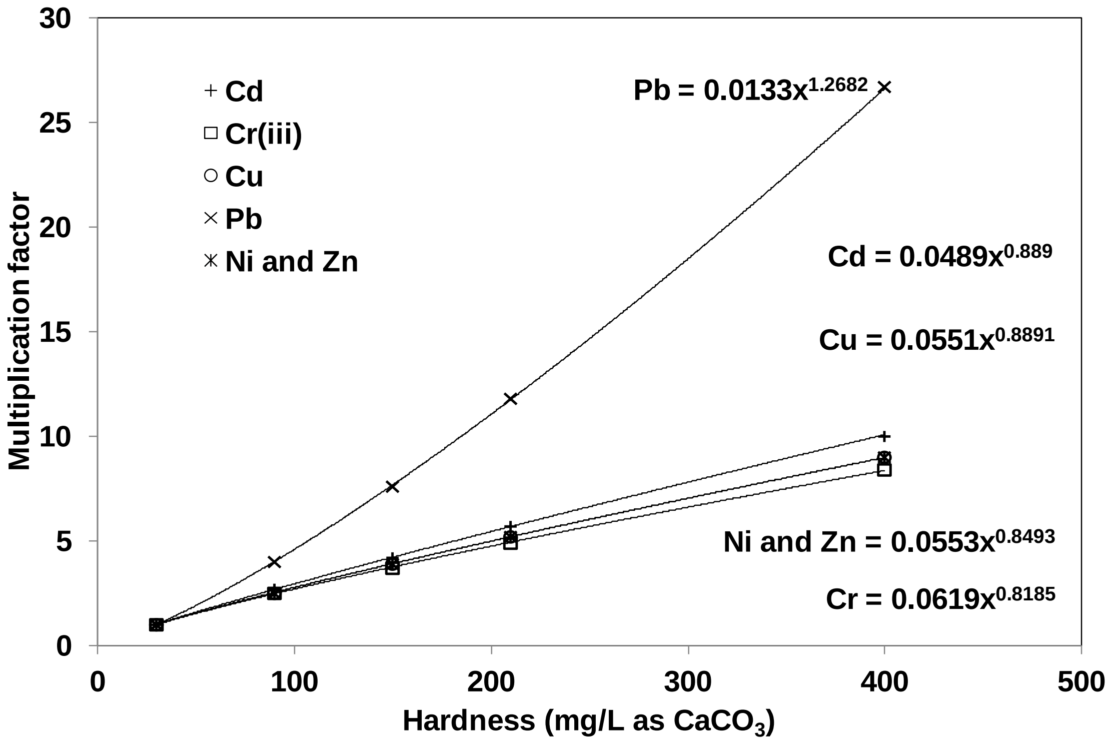

Figure A1 Relationships between the factors applied to trigger values of selected metals and water hardness (source: ANZECC & ARMCANZ 2000)

Table A1 AADTVTAs applicable for lowland rivers and estuaries for the stressors and toxicants (at alternative levels of protection) considered during the baseline monitoring period. All units are mg/L, unless otherwise stated

Parameter	Lowland River	Estuary	Freshwater				Marine water			
Species protection level	NA	NA	99%	95%	90%	80%	99%	95%	90%	80%
Stressors										
Temp (^oC)*										
pH†	6–8	7–8.5								
EC (mS/m)‡	2 to 25	NA								
Turb. (NTU)‡	2 to 15	1 to 20								
TSS (mg/L)‡	2 to 15	1 to 20								
DO (%)†	85–120	80–120								
Chlor. a	0.005	0.002								
TN	0.30	0.25								
NO_x/NO_3 N	0.01	0.03								
NH_3 N	0.01	0.02								
TP	0.010	0.020								
SRP	0.004	0.005								
Metal toxicants										
Al (pH >6.5)			0.027	0.055	0.080	0.150	ID	ID	ID	ID
Sb			ID	ID	ID	ID	ID	ID	ID	ID
As			0.001	0.024	0.094	0.360	ID	ID	ID	ID
Be			ID	ID	ID	ID	ID	ID	ID	ID
Bi			ID	ID	ID	ID	ID	ID	ID	ID
B			0.09	0.37	0.68	1.30	ID	ID	ID	ID
Cd§			0.00006	0.0002	0.0004	0.0008	0.0007	0.0055	0.014	0.036
Cr§			0.00001	0.001	0.006	0.04	0.0077	0.0274	0.0486	0.0906
Co			ID	ID	ID	ID	0.00001	0.001	0.014	0.150
Cu§			0.001	0.0014	0.0018	0.0025	0.0003	0.0013	0.003	0.008
Ga			ID	ID	ID	ID	ID	ID	ID	ID
Fe			ID	ID	ID	ID	ID	ID	ID	ID
La			ID	ID	ID	ID	ID	ID	ID	ID
Pb §			0.001	0.0034	0.0056	0.0094	0.0022	0.0044	0.0066	0.012
Mn			1.2	1.9	2.5	3.6	ID	ID	ID	ID
Hg			0.00006	0.0006	0.0019	0.0054	0.0001	0.0004	0.0007	0.0014

Parameter	Lowland River	Estuary	Freshwater				Marine water			
Mo			ID	ID	ID	ID	ID	ID	ID	ID
Ni§			0.008	0.011	0.013	0.017	0.007	0.07	0.20	0.560
Se			0.005	0.011	0.018	0.034	ID	ID	ID	ID
Ag			0.00002	0.00005	0.0001	0.0002	0.0008	0.0014	0.0018	0.0026
Tl			ID	ID	ID	ID	ID	ID	ID	ID
Sn			ID	ID	ID	ID	ID	ID	ID	ID
U			ID	ID	ID	ID	ID	ID	ID	ID
V			ID	ID	ID	ID	0.05	0.10	0.16	0.28
Zn§			0.0024	0.008	0.015	0.031	0.007	0.015	0.023	0.043
Other Toxicants										
NH_3 N			0.32	0.9	1.43	2.30	0.5	0.91	1.2	1.7
NO_x N or NO_3 N			0.017	0.7	3.4	17	ID	ID	ID	ID
Farm pesticides										
Atra.			0.7	13	45	150	ID	ID	ID	ID

NA not applicable

* 20th and 80th percentile of temperature recorded during baseline period

† range represents upper and lower limit

‡ range of maximum limit values dependant on location, catchment and flow conditions

§ values require adjustment for water hardness according to relationships in Figure A1

ID AADTVTA not determined

Source: ANZECC and ARMCANZ (2000)

Appendix B Summary data for the additional analytes collected

Table B1 Summary data for additional physicochemical parameters collected from pools K2–K4 in wet and dry seasons

	Pool K4 dry season					Pool K4 wet season					Pool K3 dry season					Pool K3 wet season					Pool K2 dry season					Pool K2 wet season				
Parameter	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile
Nutrients																														
NO_2 N	27	0.005	0.005	0.19	0.005	9	0.006	0.005	0.36	0.007	20	0.005	0.005	0.21	0.005	6	0.008	0.005	0.73	0.010	18	0.005	0.005	0.00	0.005	6	0.008	0.005	0.82	0.005
NO_3 N	15	0.014	0.005	1.11	0.020	5	0.023	0.005	1.63	0.026	12	0.009	0.005	0.78	0.017	3	0.007	0.005	0.43	0.008	11	0.009	0.005	1.22	0.005	3	0.008	0.010	0.35	0.010
SON	4	0.27	0.27	0.63	0.41	2	0.22	0.22	0.03	0.22	3	0.18	0.15	0.34	0.21	2	0.28	0.28	0.40	0.33	3	0.24	0.23	0.31	0.28	2	0.32	0.32	0.31	0.36
TON	25	0.19	0.12	0.93	0.25	7	0.18	0.18	0.32	0.22	22	0.19	0.15	0.78	0.31	6	0.23	0.19	0.65	0.27	22	0.20	0.13	0.82	0.30	6	0.28	0.25	0.31	0.28
TSN	24	0.17	0.12	0.76	0.24	7	0.21	0.21	0.14	0.23	21	0.23	0.21	0.56	0.32	6	0.24	0.23	0.26	0.23	19	0.24	0.23	0.44	0.28	6	0.29	0.29	0.22	0.30
SOP	22	0.006	0.005	0.85	0.005	25	0.005	0.005	0.34	0.005	13	0.005	0.005	0.41	0.005	6	0.005	0.005	0*	0.005	12	0.005	0.005	0*	0.005	6	0.005	0.005	0.00	0.005
TOP	25	0.014	0.010	0.98	0.021	47	0.092	0.060	1.10	0.147	15	0.007	0.005	0.72	0.006	6	0.012	0.010	0.84	0.020	14	0.005	0.005	0.25	0.005	6	0.014	0.013	0.79	0.015
TSP	29	0.008	0.005	0.80	0.010	25	0.009	0.010	0.51	0.010	20	0.006	0.005	0.696	0.005	6	0.006	0.005	0.35	0.005	18	0.005	0.005	0.33	0.005	6	0.006	0.005	0.35	0.005
TRP	30	0.007	0.005	0.36	0.010	47	0.015	0.010	1.12	0.020	21	0.007	0.005	0.68	0.005	6	0.006	0.005	0.35	0.005	19	0.005	0.005	0.22	0.005	6	0.006	0.005	0.35	0.005
TPP	15	0.008	0.005	0.73	0.010	14	0.026	0.015	1.52	0.025	14	0.007	0.005	0.81	0.007	6	0.011	0.010	0.79	0.020	13	0.005	0.005	0.41	0.005	6	0.014	0.013	0.79	0.015
General chemistry																														
Acidity	17	5.5	5.0	0.60	8.0	5	4.8	5.0	0.37	6.2	16	4.6	4.5	0.65	7.0	5	5.6	5.0	0.47	6.0	15	3.6	2.0	1.22	5.2	5	4.0	3.0	0.47	6.0
Ion bal.	16	-0.21	-0.05	-11.2	1.20	9	-0.42	-1.10	-22.9	7.26	8	-1.30	-0.55	-1.83	0.42	3	1.60	-0.60	3.34	4.38	7	-0.49	-0.40	-3.9	0.68	3	0.83	-0.30	3.67	2.46
Alk.	25	122	133	0.22	140	7	40	29	0.64	65	19	129	135	0.23	151	5	35	31	0.61	55	18	139	152	0.21	162	5	31	29	0.56	45
CO_3	31	0.5	0.5	0*	0.5	13	0.5	0.5	0*	0.5	17	0.5	0.5	0*	0.5	5	0.5	0.5	0*	0.5	16	1.41	0.5	1.62	0.5	5	0.5	0.5	0*	0.5
DOC	21	2.39	1.70	0.64	3.30	5	4.44	3.90	0.38	4.98	19	3.24	3.20	0.34	3.90	5	5.42	4.90	0.31	6.86	18	3.45	3.65	0.35	4.32	5	5.08	4.60	0.30	5.98
Hard.	23	182	200	0.25	230	7	52	52	0.52	75	17	400	260	0.77	588	5	45	49	0.42	61	16	1738	1550	0.75	3100	5	53	56	0.54	68
HCO_3	31	129	146	0.35	169	13	58	61	0.39	78	17	154	160	0.23	181	5	53	64	0.45	72	16	163	169	0.21	187	5	49	52	0.44	68
OH	19	0.5	0.5	0*	0.5	9	0.5	0.5	0*	0.5	11	0.5	0.5	0*	0.5	3	0.5	0.5	0*	0.5	10	0.5	0.5	0*	0.5	3	0.5	0.5	0*	0.5
ORP	11	349	340	0.11	380	3	360	386	0.21	405	12	334	327	0.08	361	0	IND	IND	IND	IND	12	324	326	0.09	347	0	IND	IND	IND	IND
SO_4 S	39	38	37	0.52	59	33	11	9.9	0.50	19	17	104	51	1.11	168	6	7.3	7.8	0.33	8.4	15	518	307	0.93	1002	6	15	7.4	1.17	16
TDS 180	20	353	340	0.31	472	29	119	100	0.57	180	14	1713	1480	0.91	2500	4	76	80	0.55	107	14	9343	10150	0.74	16000	3	154	130	0.63	208
TDS sum	37	283	230	0.48	450	65	97	89	0.51	150	16	1301	570	1.25	2400	5	141	96	1.03	182	14	6392	4600	0.93	12000	4	243	84	1.48	372
Other elements																														
Ba	14	0.13	0.11	0.37	0.17	5	0.10	0.12	0.34	0.13	9	0.22	0.19	0.51	0.28	3	0.11	0.14	0.49	0.14	8	0.24	0.25	0.26	0.27	3	0.11	0.13	0.50	0.15
Ca	33	28.9	29.3	0.36	38.1	13	10.9	11.0	0.40	14.5	19	50.9	44.3	0.52	69.6	5	9.5	10.2	0.41	12.5	18	140	121	0.61	225	5	10.3	10.9	0.50	13.7
K	27	3.7	3.3	0.27	4.2	13	3.1	3.0	0.26	3.4	13	15.4	8.8	1.02	23.6	5	2.7	2.8	0.18	2.9	12	80.5	70.3	0.84	150	5	3.1	3.0	0.18	3.6
Li	10	0.003	0.003	0.26	0.003	3	0.001	0.001	0.70	0.002	9	0.007	0.003	0.926	0.012	3	0.001	0.001	0.81	0.002	8	0.030	0.024	0.89	0.052	3	0.001	0.001	0.77	0.002
Mg	33	21.2	21.6	0.38	29.3	13	6.6	6.0	0.47	8.7	19	62.9	35.2	0.89	99.0	5	5.3	5.7	0.41	7.1	18	318	273	0.81	545	5	6.7	7.0	0.58	8.2
Na	39	46.7	34.8	0.65	82.3	56	8.5	6.9	0.62	14.7	17	359	113	1.34	701	7	35.04	17.10	1.52	21.84	15	2027	1050	0.97	3944	6	54.6	18.7	1.50	51.5
Si	9	14.2	16.0	0.29	17.4	3	6.8	6.4	0.30	8.0	9	10.1	9.4	0.23	13.0	3	7.3	7.3	0.31	8.6	8	7.6	7.8	0.39	9.8	3	7.4	6.6	0.32	8.6
Ti	9	0.001	0.001	0.57	0.001	3	0.004	0.001	1.26	0.006	9	0.002	0.001	1.790	0.001	3	0.005	0.001	1.36	0.008	8	0.002	0.001	0.48	0.002	3	0.01	0.001	1.56	0.017

* Analysis was less than LOR for all samples collected

IND Insufficient data

Table B2 Summary data for additional physicochemical parameters collected from pool K1 and estuary site E1 in wet and dry seasons and Border Creek in the wet season

Parameter	Pool K1 dry season					Pool K1 wet season					Site E1 wet season					E1 dry season					Border Creek wet season				
	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile
Nutrients																									
NO_2 N	19	0.005	0.005	0.00	0.005	7	0.006	0.005	0.33	0.005	16	0.005	0.005	0.24	0.005	6	0.005	0.005	0.00	0.005	7	0.006	0.005	0.38	0.009
NO_3 N	11	0.009	0.005	1.22	0.005	3	0.023	0.020	0.65	0.032	11	0.015	0.005	1.17	0.030	3	0.010	0.005	0.87	0.014	2	0.005	0.005	0.00	0.005
SON	3	0.29	0.29	0.19	0.33	2	0.29	0.29	0.42	0.34	3	0.36	0.36	0.07	0.37	2	0.28	0.28	0.45	0.33	3	0.43	0.43	0.08	0.45
TON	21	0.25	0.17	0.70	0.40	7	0.34	0.25	0.61	0.42	17	0.45	0.35	0.82	0.54	6	0.19	0.19	0.23	0.22	7	0.37	0.32	0.45	0.49
TSN	20	0.29	0.31	0.34	0.35	7	0.27	0.25	0.28	0.32	17	0.41	0.39	0.49	0.48	6	0.25	0.23	0.27	0.26	7	0.39	0.40	0.31	0.48
SOP	13	0.005	0.005	0.30	0.005	7	0.005	0.005	0*	0.005	10	0.005	0.005	0.35	0.005	6	0.003	0.005	0.77	0.005	30	0.011	0.005	2.25	0.005
TOP	15	0.016	0.005	2.55	0.005	7	0.020	0.010	1.25	0.023	11	0.007	0.005	1.08	0.005	6	0.025	0.027	0.85	0.040	54	0.046	0.040	0.71	0.070
TSP	19	0.005	0.005	0.38	0.005	7	0.006	0.005	0.38	0.009	16	0.013	0.005	2.36	0.005	6	0.007	0.005	0.39	0.010	30	0.020	0.005	2.82	0.010
TRP	20	0.005	0.005	0.21	0.005	7	0.006	0.005	0.33	0.005	17	0.009	0.005	0.82	0.018	6	0.008	0.008	0.37	0.010	54	0.030	0.020	1.65	0.030
TPP	13	0.017	0.005	2.54	0.005	7	0.020	0.010	1.20	0.024	12	0.006	0.005	1.28	0.005	6	0.026	0.027	0.78	0.040	31	0.052	0.040	0.82	0.070
General chemistry																									
Acidity	15	2.4	1.0	1.82	1.4	5	4.6	4.0	0.45	5.6	15	2.9	1.0	1.63	2.2	5	5.0	5.0	0.58	6.6	5	4.8	3.0	0.89	6.4
Ion bal.	7	1.71	1.00	1.80	3.20	3	-0.10	-0.80	-33	1.78	7	-1.96	-0.90	-1.76	-0.32	3	-2.30	-2.60	-0.35	-1.88	5	-0.02	0.40	-266	2.54
Alk.	18	150	159	0.17	171	5	35	33	0.39	46	16	160	163	0.13	175	5	44	29	0.48	67	5	29	27	0.35	31
CO_3	16	3.9	0.5	1.70	7.0	5	0.5	0.5	0*	0.5	16	2.4	0.5	1.93	3.0	5	0.5	0.5	0*	0.5	8	0.5	0.5	0*	0.5
DOC	18	3.81	3.95	0.33	4.66	5	5.42	4.60	0.36	7.44	17	3.55	3.30	0.42	4.50	5	5.30	4.40	0.35	7.18	4	9.43	9.65	0.08	9.94
Hard.	16	3713	3050	0.50	5700	5	78	59	0.79	109	16	5256	5600	0.35	7000	5	353	64	1.20	724	5	44	46	0.50	54
HCO_3	16	173	187	0.17	200	5	51	53	0.36	65	16	191	193	0.14	210	5	60	70	0.39	81	8	54	59	0.45	70
OH	10	0.5	0.5	0*	0.5	3	0.5	0.5	0*	0.5	10	0.5	0.5	0*	0.5	3	0.5	0.5	0*	0.5	5	0.5	0.5	0*	0.5
ORP	12	318	319	0.09	334	3	341	356	0.20	381	12	321	314	0.09	350	1	306	306	IND	IND	3	371	360	0.12	397
SO_4 S	16	1241	1130	0.70	2290	7	186	7.1	2.41	51	11	2005	1800	0.41	2840	6	114	13.9	1.46	267	33	2.5	1.0	2.28	1.6
TDS 180	14	20379	17500	0.49	30400	3	433	360	0.89	654	14	30071	30500	0.35	40800	4	2205	1785	1.13	4060	27	104	110	0.29	120
TDS sum	15	16180	15000	0.70	26860	6	4228	91	1.73	7100	9	25444	24000	0.42	35800	4	133	120	0.66	184	61	82	72	0.49	120
Other elements																									
Ba	8	0.230	0.225	0.18	0.236	3	0.120	0.140	0.51	0.158	8	0.164	0.155	0.24	0.192	3	0.106	0.130	0.48	0.136	4	0.080	0.055	0.86	0.112
Ca	18	257	228	0.44	374	5	12.2	12.5	0.56	15.2	16	354	378	0.32	471	5	30.6	12.3	0.98	57.6	8	12.1	13.3	0.41	16.0
K	12	210	190	0.56	339	5	4.7	3.3	0.66	5.5	10	308	312	0.46	445	5	21.4	4.6	1.15	45.2	8	4.6	5.0	0.31	5.8
Li	8	0.076	0.060	0.68	0.113	3	0.001	0.001	0.80	0.002	8	0.105	0.092	0.52	0.152	3	0.001	0.001	0.66	0.002	4	0.001	0.001	0.59	0.002
Mg	18	716	598	0.52	1118	5	11.9	6.7	0.98	17.5	16	1060	1125	0.36	1440	5	67.5	10.0	1.27	142.0	8	5.8	6.1	0.41	7.3
Na	16	4950	4885	0.73	8730	8	956	51.8	1.82	1716	11	8271	7470	0.44	11700	6	449	42.6	1.51	1010	57	5.5	2.8	1.12	7.8
Si	8	4.2	3.6	0.68	6.7	3	6.9	5.9	0.35	8.1	8	3.3	3.0	0.64	5.5	3	6.9	5.9	0.34	8.1	4	10.0	9.8	0.15	10.8
Ti	8	0.002	0.001	0.88	0.003	3	0.006	0.001	1.46	0.011	8	0.002	0.001	0.94	0.001	3	0.004	0.001	1.30	0.006	4	0.023	0.021	0.96	0.040

* Analysis was less than LOR for all samples collected

IND Insufficient data

Appendix C Physicochemical data collected during the study

Table C1 Data for water quality stressor parameters obtained from the lower Keep River sites. All units are mg/L unless otherwise stated

Site	Date/time	Temp °C	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
BC	10/06/2010 12:00		7.6	22		31			0.24	<0.01	<0.01	0.02	<0.01
BC	25/08/2010 12:00	33.0	7.9	27									
BC	25/11/2010 12:00		7.4	10		22			0.30	<0.01	<0.01	0.02	<0.01
BC	30/12/2010 23:00			20		540			21.00			0.28	
BC	21/01/2011 3:00			10		460			14.00			0.22	
BC	21/01/2011 21:00			6		270			4.50			0.12	
BC	22/01/2011 2:00			5		160			1.90			0.07	
BC	22/01/2011 6:00			5		85			2.30			0.06	
BC	22/01/2011 11:00			5		62			1.50			0.07	
BC	22/01/2011 16:00			6		44			1.60			0.06	
BC	22/01/2011 22:00			6		24			1.50			0.08	
BC	23/01/2011 4:00			6		46			1.50			0.07	
BC	23/01/2011 10:00			7		46			1.50			0.09	
BC	23/01/2011 16:00			8		36			3.40			0.08	
BC	23/01/2011 20:00			8		30			2.50			0.06	
BC	24/01/2011 0:00			8		20			1.40			0.05	
BC	24/01/2011 4:00			8		30			1.40			0.09	
BC	24/01/2011 8:00			9		34			1.20			0.06	
BC	24/01/2011 12:00			9		20			1.10			0.09	
BC	24/01/2011 17:00			9		28			1.20			0.04	
BC	24/01/2011 21:00			9		22			1.20			0.03	
BC	25/01/2011 1:00			8		24			1.00			0.06	

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
BC	25/01/2011 5:00			8		28			1.00			0.08	
BC	25/01/2011 9:00			9		16			1.00			0.04	
BC	25/01/2011 13:00			9		32			1.10			0.05	
BC	25/01/2011 17:00			9		22			0.96			0.04	
BC	25/01/2011 21:00			9		22			0.97			0.05	
BC	15/02/2011 12:00		8.3	8		82			0.54	<0.01	0.01	0.04	<0.01
BC	18/02/2011 22:44		5.4	12		190			38.00			0.10	<0.01
BC	22/02/2011 10:44		6.0	14		130			7.60			0.07	<0.01
BC	25/02/2011 22:44		5.9	11		100			6.30			0.07	<0.01
BC	1/03/2011 10:44		5.8	11		90			6.40			0.07	<0.01
BC	4/03/2011 22:44		5.9	12		88			5.50			0.07	<0.01
BC	8/03/2011 10:44		5.9	12		110			4.50			0.07	<0.01
BC	11/03/2011 22:44		5.8	11		120			4.60			0.08	<0.01
BC	15/03/2011 10:44		6.0	14		99			4.00			0.05	<0.01
BC	18/03/2011 22:44		6.0	43		140			43.00			9.80	9.00
BC	22/03/2011 10:44		6.2	16		120			3.10			0.12	<0.01
BC	25/03/2011 22:44		6.3	16		110			3.60			0.11	0.01
BC	29/03/2011 10:44		6.1	14		100			2.90			0.07	<0.01
BC	1/04/2011 22:44		7.0	14		140			2.60			0.08	<0.01
BC	5/04/2011 10:44		6.5	11		72			3.20			0.08	<0.01
BC	8/04/2011 22:44		6.4	10		86			4.80			0.37	0.18
BC	12/04/2011 10:44		6.6	14		110			2.20			0.08	<0.01
BC	15/04/2011 22:44		6.6	18		200			1.80			0.10	<0.01
BC	19/04/2011 10:44		6.7	19		770			1.90			0.13	<0.01
BC	22/04/2011 22:44		6.8	19		570			1.60			0.10	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
BC	26/04/2011 10:44		7.0	20		530			1.30			0.09	<0.01
BC	29/04/2011 22:44		7.0	19		360			1.60			0.10	<0.01
BC	3/05/2011 10:44		7.0	19		340			1.20			0.08	<0.01
BC	6/05/2011 22:44		6.9	19		2000			0.99			0.06	<0.01
BC	10/05/2011 10:44		6.7	18		85			0.87			0.05	<0.01
BC	16/05/2011 12:00		8.4	13		46			0.45	<0.01	0.01	0.04	<0.01
BC	22/07/2011 12:00		7.6	21		38		3.4	0.36	<0.01	0.01	<0.01	<0.01
BC	23/11/2011 12:00	34.0	7.1	10	340	250	62	10	0.64	<0.01		0.06	<0.01
BC	28/01/2012 13:15		5.3	22	280	23000			2.50			0.09	<0.01
BC	30/01/2012 4:06		5.6	11	200	2400			1.20			0.09	0.01
BC	31/01/2012 5:41		6.0	11	110	700			1.00			0.07	0.01
BC	1/02/2012 11:05		6.0	10	110	1100			0.95			0.08	0.01
BC	2/02/2012 18:20		6.0	10	36	900			1.10			0.07	0.01
BC	5/02/2012 9:29		6.2	14	350	2000			1.60			0.12	0.01
BC	1/03/2012 3:28		6.1	10	300	6600			1.40			0.12	0.01
BC	6/03/2012 6:35		5.9	8	450	2300			0.85			0.06	0.01
BC	7/03/2012 7:15	29.9	7.4	7	130	60	91	<0.001	0.49	<0.01	0.04	0.06	0.01
BC	10/03/2012 7:47		5.8	11	280	440			1.60			0.12	0.01
BC	13/03/2012 7:47		5.8	13	110	180			1.40			0.05	<0.01
BC	16/03/2012 7:47		6.1	15	60	54			1.30			0.03	<0.01
BC	19/03/2012 7:47		6.1	13	52	69			1.10			0.03	<0.01
BC	22/03/2012 7:47		6.0	18	60	87			1.20			0.07	<0.01
BC	25/03/2012 7:47		6.4	18	130	140			1.10			0.05	<0.01
BC	28/03/2012 7:47		6.5	18	150	140			0.94			0.05	<0.01
BC	31/03/2012 7:47		6.8	19	180	140			0.96			0.05	<0.01

Site	Date/time	Temp °C	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
BC	3/04/2012 7:47		6.7	19	230	320			1.20			0.12	<0.01
BC	4/04/2012 6:40	29.2	7.7	13	81	89	79		0.66	<0.01	0.01	0.01	<0.01
BC	6/04/2012 7:47		6.7	18	250	470			1.30			0.13	<0.01
BC	9/04/2012 7:47		6.8	23	520	540			1.40			0.11	<0.01
BC	12/04/2012 7:47		6.8	23	510	250			1.10			0.07	<0.01
BC	15/04/2012 7:47		6.7	21	260	120			1.00			0.06	<0.01
BC	18/04/2012 7:47		6.8	23	160	88			1.00			0.07	0.01
BC	21/04/2012 7:47		6.7	23	220	77			0.98			0.05	<0.01
BC	24/04/2012 7:47		6.7	24	120	65			0.95			0.05	<0.01
BC	27/04/2012 7:47		6.4	18	210	80			0.79			0.05	<0.01
BC	30/04/2012 7:47		6.3	20	130	50			0.78			0.06	<0.01
BC	3/05/2012 7:47		6.1	14	97	170			0.64			0.03	<0.01
BC	6/05/2012 7:47		6.1	19	85	63			0.69			0.05	<0.01
BC	9/05/2012 7:47		6.2	20	100	51			0.63			0.05	<0.01
BC	12/05/2012 7:47		6.3	20	76	65			0.62			0.05	<0.01
BC	15/05/2012 7:47		6.3	20	130	NSS			0.60			0.07	0.01
BC	19/05/2012 14:00	23.0	7.3	16	210	230	42	<0.001	0.59	<0.01	0.01	0.04	<0.01
BC	19/06/2012 11:50	30.0	7.3	17	71	32	83		0.54	0.01	0.02	0.04	<0.01
BC	30/03/2013 17:40	28.5	7.4	12		130			0.58	<0.01	0.01	0.05	<0.01
BC	9/04/2013 7:00	29.5	7.6	14		NSS		<0.001	0.70	0.01	0.03	0.25	<0.01
BC	12/04/2013 20:00		8.1	26		NSS			1.50			0.15	0.03
BC	16/04/2013 8:00		8.1	25		NSS			1.50			0.14	0.04
BC	19/04/2013 20:00		8.2	26		NSS			1.30			0.11	0.02
BC	23/04/2013 7:00		8.2	26		NSS			1.30			0.11	0.03
BC	16/09/2013 7:40	27.4	8.0	36	13	<1	23		0.46	0.01	0.02	0.02	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
BC	13/11/2013 12:00	32.0	8.3	33	10	<2	183	<0.001	0.47	<0.01	<0.01	0.03	<0.01
E1	15/02/2011 12:00		8.7	18		150			0.38	<0.01	0.01	0.05	0.01
E1	6/09/2011 12:00		8.3	3480		110			0.79	<0.01	0.01	0.02	<0.01
E1	23/10/2011 12:00			4520	40	72			0.66	<0.01	0.06	0.01	0.01
E1	19/11/2011 11:00	36.8	8.1	2210	54	93		<0.001	0.54	<0.01	0.07	<0.01	<0.01
E1	7/03/2012 9:55		8.1	7	540	1200		<0.001	0.26	0.01	0.03	0.08	0.01
E1	4/04/2012 7:33	31.4	7.8	24	36	26	72		0.49	<0.05	0.01	0.01	<0.01
E1	19/05/2012 15:30	25.8	8.4	2310	15	17	108	0.002	0.52	<0.01	<0.01	<0.01	<0.01
E1	19/06/2012 9:40	22.3	8.2	3310	38	72	61		0.32	<0.01	0.01	<0.01	<0.01
E1	25/07/2012 16:00	23.6	8.2	4810	20	31	71		0.38	<0.01	0.02	<0.01	<0.01
E1	1/09/2012 12:00	29.5	8.2	4940	41	160	84	0.001	0.46	<0.01	0.02	<0.01	<0.01
E1	19/10/2012 12:00	33.3	8.3	4600	54	150	31		0.48		0.01	<0.01	<0.01
E1	25/11/2012 12:00	35.1	8.4	3860	23	67	17		0.79	<0.01	0.02	<0.01	<0.01
E1	12/02/2013 14:55	30.1	8.2	935	100	140			0.23	<0.01	<0.01	<0.01	<0.01
E1	30/03/2013 9:00	28.0	8.1	664	130	310			0.37	<0.01	0.01	0.06	0.01
E1	9/04/2013 12:00		7.5	47	100	NSS		<0.001	0.41	0.02	<0.01	0.03	<0.01
E1	20/05/2013 12:00	33.3	8.3	2050	470	NSS	119	<0.001	0.93	<0.01	0.02	0.06	<0.01
E1	5/06/2013 10:30	27.9	8.3	3050	490	670	51		0.36	<0.01	0.02	<0.010	<0.01
E1	31/07/2013 14:10	27.1	8.2	5330	4300	27000			0.31		<0.01	0.15	0.02
E1	27/08/2013 12:00	33.6	8.1	5970	670	820			0.68		<0.01	<0.010	<0.01
E1	10/09/2013 11:30	34.1	8.2	5950	80	190	26		0.48	<0.05	0.01	0.01	<0.01
E1	3/10/2013 12:00	32.4	8.2	5920	12	59	24		0.63	<0.01	0.07	<0.005	<0.01
E1	17/10/2013 12:00	37.8	8.1	6650	300	300	114		1.90		0.09	0.03	<0.01
E1	13/11/2013 9:15	30.7	8.1	6020	41	51	147	<0.001	0.96	<0.01	0.06	0.05	0.01
E2	24/10/2011 12:00			5470	60	110			0.34	<0.01	<0.01	<0.01	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
E2	19/11/2011 12:00	35.0	8.3	3370	70	120		<0.001	0.34	<0.01		<0.01	<0.01
E2	7/03/2012 10:00	32.6	8.8	20	670	2400	95	<0.001	0.42	0.01	0.05	0.18	0.02
E2	4/04/2012 7:45	30.7	8.0	90	60	67	82		0.44	<0.05	<0.01	0.01	<0.01
E2	19/05/2012 15:00	24.2	8.3	3900	72	71	106	<0.001	0.36	<0.01	<0.01	0.01	<0.01
E2	19/05/2012 15:00	22.0	8.1	4810	600	780	62		0.20	0.02	0.01	<0.01	<0.01
E2	19/06/2012 10:00		8.0	5100	617								
E2	25/07/2012 16:00	23.7	8.1	5120	600	1300	65		1.10	0.02	<0.01	0.17	<0.01
E2	1/09/2012 12:00	29.4	8.1	5380	110	170	80	0.001	0.36	0.01	<0.01	<0.01	<0.01
E2	19/10/2012 12:45	33.8	8.1	5760	530	850	29		0.82		0.01	0.02	<0.01
E2	25/11/2012 12:00	34.3	8.3	4800	42	58	15		0.38	0.01	0.02	<0.01	<0.01
E2	12/02/2013 15:40	29.3	8.1	4420	400	530			0.20	<0.01	<0.01	<0.01	<0.01
E2	30/03/2013 10:30	28.4	8.0	4800	800	960			0.64	0.03	0.02	0.14	<0.01
E2	9/04/2013 12:00		8.1	639	930	NSS		<0.001	1.10	0.01	0.03	0.14	<0.01
E2	20/05/2013 10:30	31.7	8.2	4400	37	NSS	117	<0.001	0.45	<0.01	<0.01	0.02	<0.01
E2	5/06/2013 11:10	26.5	8.2	4240	37	85	86		0.25	<0.01	<0.01	<0.010	<0.01
E2	31/07/2013 15:00	23.3	8.3	5800	80	110			0.19		<0.01	<0.010	<0.01
E2	27/08/2013 12:50	26.1	8.1	6060	260	320			0.47		<0.01	<0.010	<0.01
E2	10/09/2013 12:15	31.2	8.2	6090	46	150	15		0.21	<0.05	<0.01	<0.010	<0.01
E2	4/10/2013 12:00		8.1	6100	1000	1100			0.15	<0.01	<0.01	<0.005	<0.01
E2	17/10/2013 13:00	34.9	8.2	6470	420	340	97		0.92		<0.01	0.04	<0.01
E2	13/11/2013 9:00	28.7	8.1	4240	27	33	126	<0.001	0.66	0.04	0.06	0.02	<0.01
E3	25/10/2011 12:00			5290	310	430			0.61	<0.01	<0.01	0.05	0.01
E3	19/11/2011 9:00	31.7	8.1	3990	91	160		<0.001	0.36	<0.01		<0.01	<0.01
E3	7/03/2012 10:15		8.8	37	1600	4600		0.004	0.45	0.02	0.10	0.20	0.02
E3	4/04/2012 7:57	30.9	8.1	446	80	93	83		0.38	<0.05	<0.01	0.01	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
E3	19/05/2012 14:30	23.9	8.2	4370	130	150	103	0.004	0.24	<0.01	<0.01	<0.01	<0.01
E3	19/06/2012 10:40	21.7	8.1	4820	750	1300	60		0.27	0.07	<0.01	<0.01	<0.01
E3	25/07/2012 16:00	22.1	8.1	5090	570	1100	66		0.94	0.07	<0.01	0.12	<0.01
E3	1/09/2012 12:00	28.3	8.1	5230	130	220	64	<0.001	0.22	0.05	<0.01	<0.01	<0.01
E3	19/10/2012 14:25	30.6	8.1	5560	480	850	24		0.76		0.01	0.02	<0.01
E3	25/11/2012 12:00	33.9	8.2	5240	120	160	16		0.39	<0.01	0.01	<0.01	<0.01
E3	12/02/2013 16:20	29.6	8.1	4760	240	410			0.20	0.01	<0.01	<0.01	<0.01
E3	30/03/2013 11:30	28.3	8.0	4860	530	770			0.47	0.03	0.01	0.03	<0.01
E3	9/04/2013 10:15	30.0	8.0	1360	670	NSS		<0.001	0.88	<0.01	0.01	0.18	0.01
E3	20/05/2013 8:40	22.0	8.1	5070	35	NSS	101	<0.001	0.33	<0.01	0.01	0.01	<0.01
E3	5/06/2013 11:55	25.9	8.1	5260	100	160	83		0.23	<0.01	0.02	<0.010	<0.01
E3	31/07/2013 15:40	25.9	8.3	6190	150	210			0.21		<0.01	<0.010	<0.01
E3	27/08/2013 14:00	25.3	8.4	4550	180	260			0.59		0.01	<0.010	<0.01
E3	10/09/2013 12:50	28.8	8.1	5840	44	150	13		0.29	<0.05	<0.01	<0.010	<0.01
E3	16/09/2013 10:55	31.2	8.2	5840	480	630	13		0.23	0.02	<0.01	<0.005	<0.01
E3	17/10/2013 13:30	32.7	8.1	6250	560	620	92		0.94		<0.01	0.06	<0.01
E3	13/11/2013 8:30	28.8	8.2	4260	54	69	130	<0.001	0.72	0.04	0.06	0.04	<0.01
E4	7/03/2012 10:20		8.6	222	1700	2100		0.004	0.57	0.01	0.07	0.13	0.02
E4	4/04/2012 8:05		8.1	2240	510	610			0.20	<0.05	<0.01	<0.01	<0.01
E4	9/04/2013 12:00		8.1	3870	610	NSS		0.002	0.85	0.06	0.01	0.07	0.01
E5	7/03/2012 10:35	31.4	8.2	4560	1100	1300	108	0.002	0.45	0.07	0.01	0.03	0.03
E5	4/04/2012 8:20	31.9	8.1	3810	460	490	96		0.58	0.35	<0.01	<0.01	<0.01
E5	9/04/2013 12:00	31.5	8.1	5000	900	NSS		0.001	0.83	0.08	<0.01	0.04	0.01
K1	25/08/2010 12:00	29.0	8.2	3550		110			0.22	<0.01	0.01	0.01	0.01
K1	14/09/2010 12:00			2900	2				0.17	<0.01	<0.01	0.01	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K1	16/11/2010 12:00		8.5	993		92			0.39			0.01	
K1	25/11/2010 12:00		8.4	1500		11			0.39	<0.01	0.01	<0.01	<0.01
K1	15/02/2011 12:00		8.3	9		53			0.37	0.01	0.01	0.03	<0.01
K1	20/05/2011 12:00		7.9	77		12			0.36	<0.01	<0.01	0.02	<0.01
K1	23/07/2011 12:00		8.4	228		76			0.24	<0.01	<0.01	0.01	<0.01
K1	6/09/2011 12:00		8.4	947		12			0.20	<0.01	0.02	0.32	0.01
K1	19/09/2011 12:00			1310	2				0.19	<0.01	<0.01	<0.01	<0.01
K1	26/10/2011 12:00			2480	3	14			0.29	<0.01	<0.01	<0.01	<0.01
K1	19/11/2011 13:50	35.2	8.3	1210	11	33		<0.001	0.34	<0.01	0.02	<0.01	<0.01
K1	24/11/2011 14:35	33.4	8.0	135	68		91						
K1	7/03/2012 9:55	30.7	7.5	6	470	700	78	<0.001	0.25	0.01	0.04	0.05	0.01
K1	4/04/2012 7:33	29.4	7.8	18	62	58	78		0.47	0.01	0.02	0.01	<0.01
K1	19/05/2012 12:01	24.9	8.2	1210	5	15	102	<0.001	0.32	<0.01	<0.01	<0.01	<0.01
K1	19/06/2012 9:10	22.0	8.2	1650	4	4	64		0.33	<0.01	<0.01	<0.01	<0.01
K1	25/07/2012 16:00	24.3	8.4	1930	3	2	68		0.35	<0.01	<0.01	<0.01	<0.01
K1	1/09/2012 12:00		8.5	2620	12								
K1	19/10/2012 10:55	28.0	8.3	2560	6	15	74	<0.001	0.34	<0.01	<0.01	<0.01	<0.01
K1	19/10/2012 10:55	32.4	8.3	2400	6	<2	32		0.37	<0.01	0.01	<0.01	<0.01
K1	25/11/2012 12:00	33.2	8.4	3530	9	17	18		0.38	<0.01	0.02	<0.01	<0.01
K1	12/02/2013 14:10	30.6	7.7	69	38	49			0.24	0.03	0.02	0.02	<0.01
K1	30/03/2013 16:00	30.6	7.7	157	36	15			0.34	0.04	0.05	0.01	<0.01
K1	9/04/2013 9:30	31.5	8.0	16	450	NSS		0.001	0.79	0.02	0.01	0.08	<0.01
K1	20/05/2013 12:00	31.4	8.1	1640	17	NSS	148	<0.001	0.32	0.01	0.01	<0.010	<0.01
K1	5/06/2013 9:50	26.0	8.2	2440	11	23	91		0.30	<0.01	<0.01	<0.010	<0.01
K1	31/07/2013 12:55	23.4	8.2	4020	5	9			0.51		<0.01	<0.010	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K1	27/08/2013 11:30	27.1	8.2	4780	8	21			0.38		0.02	<0.010	<0.01
K1	10/09/2013 10:30	30.0	8.2	4960	5	72	54		0.49	<0.05	0.03	<0.010	<0.01
K1	27/09/2013 12:00		8.4	4750	10	<3			0.41	<0.01	0.01	<0.005	<0.01
K1	17/10/2013 7:12	33.4	8.4	5020	8	14	125		0.77		0.04	<0.010	<0.01
K1	13/11/2013 10:00	32.5	8.3	5490	3	3	163	<0.001	0.51	<0.01	0.01	<0.005	<0.01
K2	25/08/2010 12:00	30.9	8.7	803		23			0.13	<0.01	<0.01	<0.01	<0.01
K2	14/09/2010 12:00			1360	2				0.15	<0.01	<0.01	0.02	<0.01
K2	25/11/2010 12:00		8.3	108		170			0.43	0.01	<0.01	0.02	0.01
K2	23/07/2011 12:00	25.5	8.0	126		58			0.33	<0.01	0.01	0.02	<0.01
K2	6/09/2011 12:00		7.7	194		54			0.18	<0.01	<0.01	<0.01	<0.01
K2	18/09/2011 12:00			215	3				0.13	<0.01	<0.01	0.01	0.01
K2	26/10/2011 12:00			572	2	3			0.21	<0.01	<0.01	0.01	<0.01
K2	19/11/2011 9:00	33.0	8.0	341	14	16	68	<0.001	0.25	<0.01	0.01	<0.01	<0.01
K2	7/03/2012 9:50		7.2	4	250	250		0.001	0.33	0.02	0.03	0.07	0.01
K2	4/04/2012 7:11		7.7	18	50	44			0.50	<0.05	0.01	0.01	<0.01
K2	19/05/2012 11:15	26.3	8.1	308	7	14	99	<0.001	0.26	<0.01	<0.01	<0.01	<0.01
K2	19/06/2012 9:40	23.0	8.2	365	6	4	62		0.19	<0.01	<0.01	<0.01	<0.01
K2	25/07/2012 16:00	23.5	8.2	410	6	7	64		0.37	<0.01	<0.01	0.01	<0.01
K2	1/09/2012 12:00	28.0	8.4	386	7	14	80	0.001	0.24	<0.01	<0.01	<0.01	<0.01
K2	19/10/2012 10:15	31.9	8.2	1480	5	<2	27		0.35		0.01	<0.01	<0.01
K2	25/11/2012 12:00	31.7	8.3	2090	7	16	15		0.26	<0.01	0.02	<0.01	<0.01
K2	12/02/2013 13:26		7.6	25	88	75			0.25	0.02	0.01	0.03	<0.01
K2	30/03/2013 8:30	29.1	7.5	48	44	13			0.33	0.01	0.07	0.01	<0.01
K2	9/04/2013 12:00		7.4	12	130	NSS		<0.001	0.47	0.02	0.01	0.03	<0.01
K2	20/05/2013 0:41	30.3	7.9	259	9	NSS	113	<0.001	0.27	0.01	0.02	0.01	<0.01

Site	Date/time	Temp °C	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K2	5/06/2013 9:20	25.5	7.9	956	6	12	79		0.29	<0.01	0.03	<0.01	<0.01
K2	31/07/2013 12:25	23.6	8.1	1930	8	12			0.21		<0.01	<0.010	<0.01
K2	27/08/2013 11:00	30.6	8.1	3300	13	19			0.32		0.01	<0.010	<0.01
K2	10/09/2013 9:30	29.2	8.2	2670	6	53	46		0.30	<0.05	0.01	<0.010	<0.01
K2	29/09/2013 12:00		8.2	2170	11	<3			0.36	<0.01	<0.01	<0.005	<0.01
K2	17/10/2013 8:15	33.1	8.2	2720	14	13	100		0.78		0.05	<0.010	<0.01
K2	13/11/2013 11:00	31.8	8.3	2990	6	8	143	<0.001	0.44	<0.01	0.01	<0.005	<0.01
K3	25/08/2010 12:00	30.0	8.8	125		39			0.14	<0.01	<0.01	<0.01	<0.01
K3	15/09/2010 12:00			168	4				0.12	<0.01	<0.01	0.01	<0.01
K3	16/11/2010 12:00		8.7	59		26			0.29			0.01	
K3	24/11/2010 12:00		8.9	15		25			0.27	<0.01	<0.01	0.01	<0.01
K3	20/05/2011 12:00		8.0	46		17			0.21	<0.01	<0.01	0.02	<0.01
K3	23/07/2011 12:00		7.9	69		59			0.41	<0.01	0.01	<0.01	<0.01
K3	6/09/2011 12:00		8.3	59		59			0.14	<0.01	<0.01	<0.01	<0.01
K3	17/09/2011 12:00			99	4				0.12	<0.01	<0.01	<0.01	<0.01
K3	26/10/2011 12:00			111	3	2			0.27	<0.01	<0.01	0.03	0.01
K3	19/11/2011 12:00	31.0	7.4	27	290	160	80	0.002	0.45	0.01	0.06	0.04	<0.01
K3	7/03/2012 9:40		7.2	4	190	200		<0.001	0.24	<0.01	0.03	0.05	0.01
K3	4/04/2012 7:08		7.8	22	51	42			0.54	<0.01	0.01	0.01	<0.01
K3	19/05/2012 10:30	24.4	8.0	54	6	6	75	<0.001	0.29	<0.01	<0.01	<0.01	<0.01
K3	19/06/2012 8:20	21.6	8.0	69	8	11	51		0.18	<0.01	<0.01	<0.01	<0.01
K3	25/07/2012 16:00	22.5	8.1	85	4	4	52		0.17	<0.01	<0.01	0.01	<0.01
K3	1/09/2012 12:00	27.0	8.2	94	4	8	66	<0.001	0.18	<0.01	<0.01	<0.01	<0.01
K3	19/10/2012 9:10	31.0	8.2	112	11	<2	31		0.52	<0.01	0.03	<0.01	<0.01
K3	25/11/2012 12:00	31.5	8.2	686	7	8	12		0.32	<0.01	0.02	<0.01	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K3	13/02/2013 10:40	31.4	7.6	18	100	77			0.25	0.02	0.02	0.04	<0.01
K3	30/03/2013 16:30	30.0	7.9	22	40	46			0.33	<0.01	<0.01	0.01	<0.01
K3	9/04/2013 12:00		7.5	11	160	NSS		0.001	0.55	0.02	0.01	0.03	<0.01
K3	20/05/2013 13:00	30.9	7.9	39	7	NSS	92	0.002	0.21	0.02	0.01	0.01	<0.01
K3	5/06/2013 8:45	24.9	7.8	91	6	11	60		0.27	0.02	0.04	<0.010	<0.01
K3	31/07/2013 11:40	22.6	7.9	432	10	12			0.24		<0.01	<0.010	<0.01
K3	27/08/2013 10:30	24.5	7.9	434	12	13			0.23		<0.01	<0.010	<0.01
K3	10/09/2013 8:45	28.3	8.0	492	17	26	3		0.31	0.01	0.01	<0.010	<0.01
K3	16/09/2013 8:00	29.3	8.1	159	16	<1	16		0.42	<0.01	0.01	0.02	<0.01
K3	6/10/2013 12:00		8.1	431	17	<3			0.33	<0.01	<0.01	<0.005	<0.01
K3	17/10/2013 10:00	32.6	8.1	496	20	8	71		0.70		0.04	<0.010	<0.01
K3	13/11/2013 11:30	31.8	8.1	1020	7	<2	125	<0.001	0.35	0.02	<0.01	0.02	<0.01
K4	10/06/2010 12:00		7.5	38		16			0.14	0.01	0.01	0.02	<0.01
K4	10/06/2010 12:00			40	7				0.12	0.01		0.01	<0.01
K4	30/07/2010 12:00		7.9	52									
K4	25/08/2010 12:00	24.0	8.7	47		23			0.06	<0.01	<0.01	0.01	0.01
K4	1/09/2010 13:30		7.7	60					0.16	0.01	<0.01	0.02	0.01
K4	16/11/2010 12:00	30.5	8.4	13		51			0.47			0.02	
K4	24/11/2010 12:00		8.7	12		46			0.32	<0.01	<0.01	0.02	<0.01
K4	15/12/2010 14:00		7.0	18		1800			7.30			0.30	
K4	16/12/2010 14:00		6.9	17		1700			7.00			0.37	
K4	29/12/2010 18:00		7.1	19		1500			8.10			0.22	
K4	31/12/2010 17:00		6.2	11		2200			7.40			0.41	
K4	1/01/2011 18:00		6.5	11		2400			6.40			0.27	
K4	2/01/2011 14:00		6.5	13		3400			5.30			0.30	

Site	Date/time	Temp °C	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K4	5/01/2011 20:00		6.7	13		1600			6.10			0.21	
K4	11/01/2011 11:00		6.8	12		1100			6.80			0.21	
K4	13/01/2011 17:00		6.6	9		1400			6.70			0.32	
K4	15/01/2011 12:00		6.8	11		1400			6.10			0.35	
K4	18/01/2011 13:00		6.9	12		960			3.20			0.18	
K4	20/01/2011 8:00		7.0	14		1400			6.80			0.51	
K4	21/01/2011 3:00		5.9	33		NSS			32.00			0.32	
K4	21/01/2011 15:00		6.4	14		1400			5.30			0.35	
K4	22/01/2011 8:00		6.3	11		510			3.30			0.12	
K4	22/01/2011 12:00		5.7	20		390			1.40			0.13	
K4	22/01/2011 17:00		6.3	8		240			0.86			0.10	
K4	22/01/2011 21:00		6.3	7		190			0.91			0.08	
K4	23/01/2011 2:00		6.3	7		NSS			0.91			0.09	
K4	23/01/2011 7:00		6.4	7		230			0.96			0.14	
K4	23/01/2011 11:00		6.5	8		Nss			0.97			0.11	
K4	23/01/2011 16:00		6.4	14		370			1.60			0.10	
K4	15/02/2011 7:00		8.3	8		74			0.32	0.01	<0.01	0.02	0.01
K4	18/02/2011 20:00		7.3	29		110			0.97			0.03	<0.01
K4	22/02/2011 8:00		6.9	8		180			10.00			0.17	0.01
K4	25/02/2011 20:00		6.8	26		140			1.90			0.05	<0.01
K4	1/03/2011 8:00		6.9	17		260			1.60			0.06	<0.01
K4	4/03/2011 20:00		6.7	26		140			1.10			0.05	<0.01
K4	8/03/2011 8:00		6.6	17		160			1.20			0.03	<0.01
K4	11/03/2011 20:00		7.4	23		97			0.68			0.03	<0.01
K4	15/03/2011 8:00		7.5	20		54			0.95			0.04	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K4	18/03/2011 20:00		6.9	22		76			2.80			0.10	<0.01
K4	22/03/2011 8:00		7.1	21		130			1.10			0.06	<0.01
K4	25/03/2011 20:00		7.7	30		79			0.91			0.03	<0.01
K4	29/03/2011 8:00		8.1	29		120			0.92			0.03	<0.01
K4	1/04/2011 20:00		8.0	29		230			1.10			0.07	<0.01
K4	5/04/2011 8:00		8.2	30		210			1.20			0.06	<0.01
K4	8/04/2011 20:00		7.9	30		110			0.94			0.04	<0.01
K4	12/04/2011 8:00		8.1	30		94			0.92			0.04	<0.01
K4	15/04/2011 20:00		7.9	30		100			0.96			0.03	<0.01
K4	19/04/2011 8:00		7.9	30		75			0.88			0.03	<0.01
K4	22/04/2011 20:00		8.1	30		62			0.82			0.02	<0.01
K4	26/04/2011 8:00		8.0	30		52			0.85			0.03	<0.01
K4	29/04/2011 20:00		7.9	30		54			0.85			0.03	<0.01
K4	3/05/2011 8:00		8.0	30		73			1.00			0.07	<0.01
K4	6/05/2011 20:00		8.0	29		68			0.89			0.04	<0.01
K4	10/05/2011 8:00		7.9	33		85			0.65			0.04	<0.01
K4	16/05/2011 9:00		7.7	40		27			0.26	<0.01	<0.01	0.04	<0.01
K4	20/05/2011 12:00		7.7	43		15			0.21	0.01	0.01	0.04	<0.01
K4	19/07/2011 12:00		7.5	65		45			0.17	<0.01		<0.01	
K4	23/07/2011 12:00	23.2	7.6	62		61			0.18	<0.01	0.01	<0.01	<0.01
K4	6/09/2011 12:00		7.8	80		48			0.16	<0.01	<0.01	<0.01	<0.01
K4	16/09/2011 12:00			85	8				0.07	<0.01	<0.01	0.02	0.01
K4	25/10/2011 12:00			84	2	1			0.16	0.01	<0.01	0.02	0.01
K4	25/10/2011 12:00		7.4	82		10			0.16	<0.01		0.01	
K4	19/11/2011 12:00	30.7	7.3	94	170	120		0.023	0.75	0.01	0.12	0.04	<0.01

Site	Date/time	Temp °C	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K4	23/11/2011 17:25	32.0	7.6	21	270	210	61		0.74	0.01	0.04	0.05	<0.01
K4	20/01/2012 12:27		6.1	18	230	760			2.40			0.04	0.01
K4	23/01/2012 12:00		7.5	8		770			0.83	<0.09		0.12	
K4	26/01/2012 22:55		5.5	9	390	1400			1.10			0.07	0.01
K4	28/01/2012 2:23		5.7	9	540	2200			0.84			0.06	0.01
K4	1/02/2012 8:24		6.1	12	960	2000			0.96			0.08	0.01
K4	3/02/2012 2:54		6.0	9	530	1700			0.75			0.06	0.01
K4	7/02/2012 20:15		6.3	12	330	1200			0.61			0.05	0.01
K4	2/03/2012 4:41		6.1	10	230	700			0.82			0.05	0.01
K4	5/03/2012 13:42		5.9	7	430	990			0.55			0.04	0.01
K4	6/03/2012 4:14		5.6	6	200	2800			0.72			0.06	0.01
K4	6/03/2012 13:25		5.6	5	140	3300			0.67			0.05	0.01
K4	6/03/2012 21:24		5.6	6	200	840			0.71			0.05	0.01
K4	7/03/2012 4:41		5.6	6	120	960			0.44			0.06	0.01
K4	7/03/2012 8:30	30.8	7.1	4	180	180	86	0.001	0.31	0.01	0.04	0.04	<0.01
K4	10/03/2012 9:00		6.2	14	470	530			1.10			0.08	<0.01
K4	13/03/2012 9:00		6.2	13	220	320			0.92			0.06	<0.01
K4	16/03/2012 9:00		6.2	13	420	570			1.10			0.08	<0.01
K4	19/03/2012 9:00		6.3	8	130	380			1.20			0.10	<0.01
K4	22/03/2012 9:00		6.7	18	800	1100			1.50			0.12	<0.01
K4	25/03/2012 9:00		6.7	20	830	1500			1.30			0.10	<0.01
K4	28/03/2012 9:00		6.7	23	630	720			1.10			0.08	<0.01
K4	31/03/2012 9:00		6.8	25	320	420			0.83			0.06	0.01
K4	3/04/2012 9:00		7.0	28	230	230			0.70			0.05	<0.01
K4	4/04/2012 7:00	29.8	7.7	20	58	48	74		0.30	<0.01	0.01	<0.01	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K4	6/04/2012 9:00		7.2	32	170	180			0.61			0.04	0.01
K4	9/04/2012 9:00		7.2	32	130	120			0.59			0.06	0.01
K4	12/04/2012 9:00		7.3	34	120	82			0.50			0.04	<0.01
K4	15/04/2012 9:00		6.9	10	140	98			0.42			0.05	<0.01
K4	18/04/2012 9:00		7.5	38	88	61			0.51			0.05	0.02
K4	21/04/2012 9:00		7.6	42	87	67			0.47			0.04	0.01
K4	23/04/2012 12:00		7.9	27		83			0.42	<0.01		0.04	
K4	24/04/2012 9:00		7.8	42	88	72			0.41			0.03	0.01
K4	27/04/2012 9:00		7.7	37	170	130			0.42			0.04	<0.01
K4	30/04/2012 9:00		8.0	32	160	130			0.32			0.03	<0.01
K4	3/05/2012 9:00		7.9	44	87	92			0.37			0.04	0.01
K4	6/05/2012 9:00		7.8	47	120	84			0.44			0.05	0.01
K4	9/05/2012 9:00		8.0	49	83	61			0.43			0.04	0.01
K4	12/05/2012 9:00		7.8	52	99	46			0.51			0.04	0.01
K4	15/05/2012 9:00		7.6	35	96	63			0.38			0.04	<0.01
K4	18/05/2012 9:00		7.2	49	60	62			0.43			0.04	0.01
K4	19/05/2012 10:00	24.5	7.7	46	8	10	68	0.002	0.22	0.01	<0.01	<0.01	<0.01
K4	19/06/2012 7:35	20.7	7.6	60	9	8	42		0.10	0.01	<0.01	0.01	0.01
K4	18/07/2012 12:00					22			0.25	<0.01		0.01	
K4	25/07/2012 17:45	23.7	7.7	73	8	7	41		0.15	<0.01	<0.01	<0.01	<0.01
K4	1/09/2012 12:00	25.0	7.7	82	8	8	48	0.001	0.10	<0.01	<0.01	<0.01	<0.01
K4	19/10/2012 8:30	28.8	7.7	86	8	<2	26		0.16	0.02	0.01	0.01	<0.01
K4	24/11/2012 11:45		7.8	85		19			0.19	<0.01		<0.01	
K4	25/11/2012 12:00	32.0	7.7	85	5	6	20		0.29	0.02	0.03	<0.01	<0.01
K4	26/12/2012 22:00		6.6	17	2700	NSS			1.80	0.02		0.11	<0.01

Site	Date/time	Temp ºC	pH	EC mS/m	Turb. NTU	TSS	DO %	Chlor. a	TN	NO_3 N or NOx N	NH3 N	TP	SRP
K4	6/01/2013 14:00		6.3	14	290	NSS			2.10	0.05		0.13	<0.01
K4	19/01/2013 23:00		6.9	34	1500	NSS			3.70	0.06		0.19	0.01
K4	13/02/2013 10:10	30.2	7.5	15	57	55			0.23	0.01	0.01	0.03	<0.01
K4	30/03/2013 17:00	29.9	7.3	24	22	11			0.22	0.01	0.03	<0.01	<0.01
K4	9/04/2013 8:00	29.5	7.4	9	110	NSS		0.001	0.46	0.01	<0.01	0.02	<0.01
K4	12/04/2013 21:00		6.3	18	100	NSS			0.49			0.03	<0.01
K4	16/04/2013 9:00		6.4	21	150	NSS			0.45			0.03	<0.01
K4	19/04/2013 21:00		6.8	23	120	NSS			0.30			0.02	<0.01
K4	23/04/2013 9:00		7.3	26	160	NSS			0.31			0.02	<0.01
K4	26/04/2013 21:00		7.3	27	160	NSS			0.28			0.02	<0.01
K4	30/04/2013 9:00		7.4	30	160	NSS			0.30			0.02	<0.01
K4	3/05/2013 21:00		8.0	31	120	NSS			0.27			0.03	<0.01
K4	7/05/2013 9:00		7.9	35	130	NSS			0.31			0.03	<0.01
K4	10/05/2013 21:00		8.1	40	73	NSS			0.31			0.02	<0.01
K4	14/05/2013 9:00		8.0	41	85	NSS			0.36			0.02	<0.01
K4	17/05/2013 21:00		8.0	44	120	NSS			0.36			0.03	<0.01
K4	20/05/2013 16:00		7.4	41	19	NSS	52	<0.001	0.27	0.02	0.03	0.01	<0.01
K4	5/06/2013 8:10	24.2	7.4	55	16	24	30		0.26	0.04	0.07	<0.010	<0.01
K4	31/07/2013 10:55	21.6	7.6	77	18	26			0.18		<0.01	0.01	<0.01
K4	27/08/2013 9:40	23.1	7.7	87	10	10			0.13		0.01	<0.010	<0.01
K4	10/09/2013 7:50	25.1	7.8	90	7	1	6		0.16	<0.01	<0.01	0.01	<0.01
K4	28/09/2013 12:00		7.8	94	14	<3			0.13	<0.01	<0.01	<0.005	<0.01
K4	28/09/2013 12:00		8.3	67	9	<3			0.30	<0.01	<0.01	0.01	<0.01
K4	17/10/2013 11:00	30.3	8.0	94	12	6	56		0.51		0.03	0.01	<0.01
K4	13/11/2013 0:30	31.8	7.8	97	12	<2	122	<0.001	0.37	<0.01	0.02	0.03	<0.01

Table C2 Metal toxicant data obtained from the lower Keep River sites. All units are mg/L

Site	Time	Al	Sb	As	Be	Bi	B	Cd	Cr	Co	Cu	Ga	Fe	La	Pb	Mn	Hg	Mo	Ni	Se	Ag	Tl	Sn	U	V	Zn
BC	23/11/2011 12:00	0.440	<0.0001	0.001	0.0001	<0.0001	0.06	<0.0001	0.001	0.0010	0.0032	0.0004	0.22	<0.005	0.0018	0.071	<0.0001	<0.001	0.003	<0.001	<0.0001	<0.0001	<0.0001	0.0004	0.014	0.009
BC	7/03/2012 7:15	0.700	<0.0001	<0.001	<0.0001	<0.0001	0.04	<0.0001	<0.001	<0.005	0.0040	0.0001	0.8	<0.005	0.0005	0.007	0.0003	<0.001	0.002	<0.001	0.007	<0.0001	0.0004	<0.0001	0.006	0.016
BC	4/04/2012 6:40	0.049	<0.0001	<0.001	<0.0001	<0.0001	0.02	<0.0001	<0.001	<0.005	<0.002	<0.0001	0.4	<0.005	0.0001	0.002	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.0001	<0.02	<0.0001	<0.005	<0.005
BC	19/05/2012 14:00	0.280	<0.0001	<0.001	0.0001	<0.0001	0.13	<0.0001	<0.001	0.0004	0.0040	0.0001	0.99	<0.005	0.0021	0.018	<0.0001	<0.001	0.001	<0.001	0.00012	<0.0001	<0.02	<0.0001	0.006	0.061
BC	9/04/2013 7:00	0.830	<0.0001	<0.001	<0.0001	<0.0001	0.09	<0.0001	0.001	<0.005	0.0032	0.0004	0.77	<0.005	0.0010	0.009	0.0001	<0.001	0.002	<0.001	0.0053	<0.0001	<0.02	0.0001	0.006	0.056
BC	16/09/2013 7:40	0.025	<0.05	<0.001	<0.001	<0.0001	0.07	<0.0001	<0.001	<0.005	0.0021	<0.0001	0.033	<0.005	<0.0001	0.062	<0.0001	<0.001	0.001	<0.001	<0.005	<0.0001	<0.02	0.0007	<0.005	0.11
BC	13/11/2013 12:00	0.050	<0.0001	0.001	<0.0001	<0.0001	0.20	<0.0001	<0.0005	0.0002	0.0006	<0.0001	0.18	0.0001	0.0005	0.005	<0.00005	<0.001	<0.001	<0.001	<0.0001	0.0002	<0.0001	0.0004	0.0033	0.025
E1	19/11/2011 11:00	0.071	<0.0005	<0.005	<0.0005	<0.0005	1.80	<0.0005	<0.001	0.0006	0.0012	<0.0005	0.072	<0.005	<0.0005	0.045	<0.0001	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	0.0018	0.0063	0.014
E1	7/03/2012 9:55	0.340	0.0001	<0.001	<0.0001	<0.0001	0.04	<0.0001	0.001	<0.005	0.0040	0.0001	0.3	<0.005	0.0008	0.042	0.0004	<0.001	0.001	<0.001	0.0006	<0.0001	0.0001	0.0002	0.009	0.022
E1	4/04/2012 7:33	0.200	<0.0001	<0.001	<0.0001	<0.0001	0.02	<0.0001	<0.001	<0.005	<0.002	0.0001	0.93	<0.005	0.0006	0.019	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	<0.0001	<0.005	<0.005
E1	19/05/2012 15:30	<0.005	<0.0005	<0.005	<0.0005	<0.0005	2.10	<0.0005	<0.001	<0.0005	0.0020	<0.0005	<0.005	<0.005	0.0017	0.009	<0.0005	<0.005	<0.005	<0.005	0.0021	0.0044	<0.02	0.0015	<0.005	0.016
E1	1/09/2012 12:00	0.016	<0.0010	<0.010	<0.0010	<0.0010	4.70	<0.0010	<0.001	<0.005	<0.002	<0.0010		<0.005	<0.001	0.021		0.011	<0.01	<0.01	<0.001	<0.001		0.0038	<0.005	0.16
E1	25/11/2012 12:00	0.009	<0.0010	<0.010	<0.0010	<0.0010	3.90	<0.0010	<0.001	<0.005	0.0020	<0.0010	0.014	<0.005	<0.001	0.002	<0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0026	<0.005	0.006
E1	9/04/2013 12:00	0.180	<0.0001	<0.001	<0.0001	<0.0001	0.07	<0.0001	<0.001	<0.005	0.0019	0.0001	0.23	<0.005	0.0006	0.008	<0.0001	<0.001	0.001	<0.001	0.0018	<0.0001	<0.02	0.0001	<0.005	0.036
E1	20/05/2013 12:00	0.059	<0.0005	0.002	<0.0005	<0.0005	1.90	<0.0005	<0.001	<0.005	0.0022	<0.0005	0.049	<0.005	<0.0005	0.004	0.0001	<0.005	<0.005	<0.005	<0.0005	0.001	<0.02	0.0014	<0.005	<0.005
E1	10/09/2013 11:30	0.011	<0.05	0.002	<0.001	<0.0020	6.30	<0.0020	<0.001	<0.005	0.0023	<0.0020	0.008	<0.005	<0.002	0.020	<0.0001	<0.02	<0.02	<0.02	<0.005	<0.002	<0.02	0.0043	<0.005	0.037
E1	17/10/2013 12:00	0.020	<0.0020	0.003	<0.0020	<0.0020	7.30	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.018	<0.002	<0.002	0.031	<0.00005	<0.02	<0.01	<0.001	<0.002	<0.002	<0.002	0.0041	0.0071	0.035
E1	13/11/2013 9:15	0.027	<0.0020	0.002	<0.001	<0.0020	6.30	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.014	<0.002	<0.002	0.005	<0.00005	<0.02	<0.01	<0.001	<0.002	<0.002	<0.002	0.0036	0.0048	0.032
E2	19/11/2011 12:00	0.039	<0.0010	<0.010	<0.0010	<0.0010	3.10	<0.0010	<0.001	<0.001	<0.001	<0.0010	0.044	<0.005	<0.001	0.006	<0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	0.0023	0.0059	0.03
E2	7/03/2012 10:00	0.430	<0.0001	0.001	<0.0001	<0.0001	0.06	<0.0001	0.010	<0.005	<0.002	0.0001	0.38	<0.005	0.0009	0.025	0.0003	<0.001	0.001	<0.001	0.0009	<0.0001	0.0001	0.0002	0.013	0.02
E2	4/04/2012 7:45	0.012	<0.0001	<0.001	<0.0001	<0.0001	0.07	<0.0001	<0.001	<0.005	<0.002	<0.0001	0.23	<0.005	0.0001	0.002	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	0.0001	<0.005	<0.005
E2	19/05/2012 15:00	0.016	<0.0010	<0.010	<0.0010	<0.0010	3.90	<0.0010	<0.001	<0.001	<0.002	<0.0010	0.014	<0.005	<0.001	0.004	<0.001	<0.01	<0.01	<0.01	0.0027	0.0016	<0.02	0.0028	<0.005	0.034
E2	1/09/2012 12:00	0.017	<0.0020	<0.020	<0.0020	<0.0020	5.80	<0.0020	<0.001	<0.005	<0.002	<0.0020		<0.005	<0.002	0.002		<0.02	<0.02	<0.02	<0.002	<0.002		0.0039	<0.005	0.03
E2	25/11/2012 12:00	0.011	<0.0010	<0.010	<0.0010	<0.0010	5.20	<0.0010	<0.001	<0.005	0.0013	<0.0010	0.021	<0.005	<0.001	0.003	<0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0036	0.005	0.007
E2	9/04/2013 12:00	0.700	<0.0002	<0.002	<0.0002	<0.0002	0.62	<0.0002	0.001	<0.005	0.0024	0.0003	0.94	<0.005	0.0014	0.080	<0.0002	<0.002	<0.002	<0.002	0.0049	<0.0002	<0.02	0.0005	0.008	0.033
E2	20/05/2013 10:30	0.010	<0.0010	0.002	<0.0010	<0.0010	4.50	<0.0010	<0.001	<0.005	0.0021	<0.0010	<0.005	<0.005	<0.001	0.057	0.0007	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0034	<0.005	0.021
E2	10/09/2013 12:15	0.011	<0.05	0.001	<0.001	<0.0020	6.40	<0.0020	<0.001	<0.005	<0.002	<0.0020	0.006	<0.005	<0.002	0.004	<0.0001	<0.02	<0.02	<0.02	<0.005	<0.002	<0.02	0.0056	<0.005	0.015
E2	17/10/2013 13:00	0.017	<0.0020	0.002	<0.0020	<0.0020	6.60	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.013	<0.002	<0.002	0.010	<0.00005	<0.02	<0.01	<0.001	<0.002	0.0024	<0.002	0.0046	0.0053	0.016
E2	13/11/2013 9:00	0.034	<0.0010	0.002	<0.0010	<0.0010	4.40	<0.0010	<0.005	<0.001	<0.001	<0.0010	0.024	<0.001	<0.001	0.070	<0.00005	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	0.0024	0.0054	0.058
E3	19/11/2011 9:00	0.041	<0.0010	<0.010	<0.0010	<0.0010	3.50	<0.0010	<0.001	<0.001	0.0025	<0.0010	0.045	<0.005	<0.001	0.005	0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	0.0028	0.0057	0.044
E3	7/03/2012 10:15	0.360	0.0001	0.002	<0.0001	<0.0001	0.06	0.0001	0.001	<0.005	0.0030	0.0002	0.33	<0.005	0.0010	0.019	0.0003	<0.001	0.002	<0.001	0.0006	<0.0001	0.0002	0.0002	0.012	0.016
E3	4/04/2012 7:57	0.130	<0.0001	0.001	<0.0001	<0.0001	0.34	<0.0001	<0.001	<0.005	0.0030	<0.0001	0.22	<0.005	0.0001	0.006	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.02	0.0003	0.006	<0.005
E3	19/05/2012 14:30	0.010	<0.0010	<0.010	<0.0010	<0.0010	4.50	<0.0010	<0.001	<0.0010	<0.002	<0.0010	0.008	<0.005	<0.001	0.004	<0.001	<0.01	<0.01	<0.01	0.0034	<0.001	<0.02	0.0029	<0.005	0.027
E3	1/09/2012 12:00	0.016	<0.0020	<0.020	<0.0020	<0.0020	5.00	<0.0020	<0.001	<0.005	<0.002	<0.0020		<0.005	<0.002	<0.001		<0.02	<0.02	<0.02	<0.002	<0.002		0.0034	<0.005	0.038

Site	Time	Al	Sb	As	Be	Bi	B	Cd	Cr	Co	Cu	Ga	Fe	La	Pb	Mn	Hg	Mo	Ni	Se	Ag	Tl	Sn	U	V	Zn
E3	25/11/2012 12:00	0.039	<0.0020	<0.020	<0.0020	<0.0020	5.60	<0.0020	<0.001	<0.005	<0.002	<0.0020	0.069	<0.005	<0.002	0.003	<0.0001	<0.02	<0.02	<0.02	<0.002	0.007	<0.02	0.0039	<0.005	<0.005
E3	9/04/2013 10:15	0.200	<0.0005	<0.005	<0.0005	<0.0005	1.30	<0.0005	<0.001	<0.005	0.0011	<0.0005	0.23	<0.005	0.0006	0.013	<0.0005	<0.005	<0.005	<0.005	0.004	<0.0005	<0.02	0.0008	<0.005	0.033
E3	20/05/2013 8:40	0.009	<0.0020	0.001	<0.0020	<0.0020	5.30	<0.0020	<0.001	<0.005	<0.002	<0.0020	<0.005	<0.005	<0.002	0.012	0.0006	<0.02	<0.02	<0.02	<0.002	<0.002	<0.02	0.0035	<0.005	0.018
E3	10/09/2013 12:50	0.012	<0.05	0.001	<0.001	<0.0020	6.10	<0.0020	<0.001	<0.005	<0.002	<0.0020	0.006	<0.005	<0.002	0.002	<0.0001	<0.02	<0.02	<0.02	<0.005	<0.002	<0.02	0.0038	<0.005	0.025
E3	17/10/2013 13:30	0.410	<0.0020	0.002	<0.0020	<0.0020	6.20	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.64	<0.002	<0.002	0.056	<0.00005	<0.02	<0.01	<0.001	<0.002	<0.002	<0.002	0.0042	0.0066	0.019
E3	13/11/2013 8:30	0.021	<0.0010	0.001	<0.0010	<0.0010	4.50	<0.0010	<0.005	<0.001	<0.001	<0.0010	0.015	<0.001	<0.001	0.060	<0.00005	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	0.0024	0.0046	0.085
E4	7/03/2012 10:20	0.130	0.0001	0.002	<0.0001	<0.0001	0.83	0.0003	<0.001	<0.005		<0.0001	0.12	<0.005	0.0005	0.021	0.0009	0.002	<0.001	<0.001	0.0056	<0.0001	0.0001	0.0006	0.009	0.027
E4	4/04/2012 8:05	0.160	<0.0005	<0.005	<0.0005	<0.0005	2.10	0.0005	<0.001	<0.005		<0.0005	0.18	<0.005	<0.0005	0.003	<0.0005	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.02	0.001	0.009	0.011
E4	9/04/2013 12:00	0.030	<0.0010	<0.010	<0.0010	<0.0010	4.10	0.0010	<0.001	<0.005	<0.001	<0.0010	0.025	<0.005	<0.001	0.003	<0.001	<0.01	<0.01	<0.01	0.008	<0.001	<0.02	0.0024	<0.005	0.046
E5	7/03/2012 10:35	0.058	<0.0010	<0.010	<0.0010	<0.0010	4.40	<0.0010	<0.001	<0.005		<0.0010	0.072	<0.005	<0.001	0.008	0.0025	<0.01	<0.01	<0.01	0.0045	<0.001	<0.001	0.0025	0.01	0.03
E5	4/04/2012 8:20	0.110	<0.0010	<0.010	<0.0010	<0.0010	3.80	<0.0010	<0.001	<0.005		<0.0010	0.18	<0.005	<0.001	0.003	<0.001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0018	0.01	<0.005
E5	9/04/2013 12:00	0.290	<0.0010	<0.010	<0.0010	<0.0010	5.50	0.0013	0.001	<0.005	0.0013	<0.0010	0.4	<0.005	0.0012	0.016	<0.001	<0.01	<0.01	<0.01	0.0073	<0.001	<0.02	0.0029	0.005	0.05
K1	19/11/2011 13:50	0.085	<0.0005	<0.005	<0.0005	<0.0005	1.00	<0.0005	<0.001	<0.0005	0.0014	<0.0005	0.062	<0.005	<0.0005	0.029	<0.0001	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	0.0012	0.007	0.017
K1	7/03/2012 9:55	0.480	<0.0001	<0.001	<0.0001	<0.0001	0.08	<0.0001	<0.001	<0.005	<0.002	0.0001	0.37	<0.005	0.0007	0.057	0.0004	<0.001	0.001	<0.001	0.0014	<0.0001	0.0001	0.0002	0.007	0.035
K1	4/04/2012 7:33	0.290	<0.0001	<0.001	<0.0001	<0.0001	0.04	<0.0001	<0.001	<0.005	<0.002	<0.0001	1.2	<0.005	0.0004	0.024	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	<0.0001	0.007	<0.005
K1	19/05/2012 12:01	0.011	<0.0005	<0.005	<0.0005	<0.0005	0.94	<0.0005	<0.001	0.0005	<0.002	<0.0005	0.009	<0.005	<0.0005	0.140	<0.0005	<0.005	<0.005	<0.005	0.0014	<0.0005	<0.02	0.0009	<0.005	0.025
K1	19/10/2012 10:55	0.013	<0.0010	<0.010	<0.0010	<0.0010	2.10	<0.0010	<0.001	<0.005	<0.002	<0.0010		<0.005	<0.001	0.014		<0.01	<0.01	<0.01	<0.001	<0.001		0.0021	<0.005	0.036
K1	25/11/2012 12:00	0.042	<0.0010	<0.010	<0.0010	<0.0010	3.60	<0.0010	<0.001	<0.005	<0.001	<0.0010	0.047	<0.005	<0.001	0.022	<0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0024	<0.005	0.006
K1	9/04/2013 9:30	0.180	<0.0001	<0.001	<0.0001	<0.0001	0.05	<0.0001	<0.001	<0.005	0.0025	<0.0001	0.21	<0.005	0.0007	0.011	<0.0001	<0.001	0.001	<0.001	0.0007	<0.0001	<0.02	0.0001	<0.005	0.049
K1	20/05/2013 12:00	0.011	<0.0005	<0.001	<0.0005	<0.0005	1.30	<0.0005	<0.001	<0.005	0.0021	<0.0005	<0.005	<0.005	0.0006	0.320	0.0006	<0.005	<0.005	<0.005	<0.0005	<0.0005	<0.02	0.001	<0.005	0.02
K1	10/09/2013 10:30	0.019	<0.05	<0.001	<0.001	<0.0010	4.70	<0.0010	<0.001	<0.005	0.0036	<0.0010	0.017	<0.005	<0.001	0.250	<0.0001	<0.01	<0.01	<0.01	<0.005	<0.001	<0.02	0.0036	<0.005	0.074
K1	17/10/2013 7:12	0.012	<0.0020	<0.020	<0.0020	<0.0020	5.00	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.019	<0.002	<0.002	0.058	<0.00005	<0.02	<0.01	<0.02	<0.002	<0.002	<0.002	0.0032	0.0066	0.015
K1	13/11/2013 10:00	0.010	<0.0020	0.003	<0.001	<0.0020	5.50	<0.0020	<0.001	<0.002	<0.002	<0.0020	0.008	<0.002	<0.002	0.097	<0.00005	<0.02	<0.01	<0.001	<0.002	<0.002	<0.002	0.0031	0.0055	0.021
K2	19/11/2011 9:00	0.180	<0.0001	<0.001	<0.0001	<0.0001	0.28	<0.0001	<0.0005	0.0003	0.0012	<0.0001	0.13	<0.005	0.0002	0.048	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.0001	0.0005	0.0053	0.028
K2	7/03/2012 9:50	0.830	<0.0001	<0.001	<0.0001	<0.0001	0.07	<0.0001	<0.001	<0.005	<0.002	0.0002	0.62	<0.005	0.0007	0.035	0.0004	<0.001	0.001	<0.001	0.0013	<0.0001	<0.0001	0.0002	0.007	0.057
K2	4/04/2012 7:11	0.250	<0.0001	<0.001	<0.0001	<0.0001	0.03	<0.0001	<0.001	<0.005	<0.002	0.0001	1.1	<0.005	0.0005	0.021	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	<0.0001	0.005	0.034
K2	19/05/2012 11:15	0.017	<0.0001	<0.001	<0.0001	<0.0001	0.22	<0.0001	<0.001	0.0004	<0.002	<0.0001	0.015	<0.005	<0.0001	0.230	<0.0001	<0.001	0.001	<0.001	0.00052	<0.0001	<0.02	0.0004	<0.005	0.021
K2	1/09/2012 12:00	0.022	<0.0001	<0.001	<0.0001	<0.0001	0.24	<0.0001	<0.001	<0.005	<0.002	<0.0001		<0.005	0.0001	0.004		<0.001	<0.001	<0.001	<0.0001	<0.0001		0.001	<0.005	0.04
K2	25/11/2012 12:00	0.030	<0.0010	<0.010	<0.0010	<0.0010	1.80	<0.0010	<0.001	<0.005	<0.001	<0.0010	0.038	<0.005	<0.001	0.017	<0.0001	<0.01	<0.01	<0.01	<0.001	<0.001	<0.02	0.0017	<0.005	<0.005
K2	9/04/2013 12:00	0.190	<0.0001	<0.001	<0.0001	<0.0001	0.04	<0.0001	<0.001	<0.005	0.0022	<0.0001	0.23	<0.005	0.0007	0.007	<0.0001	<0.001	0.001	<0.001	0.0006	<0.0001	<0.02	0.0001	<0.005	0.043
K2	20/05/2013 0:41	0.024	<0.0001	<0.001	<0.0001	<0.0001	0.18	<0.0001	<0.001	<0.005	0.0015	<0.0001	0.016	<0.005	0.0001	0.038	0.0002	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	0.0003	<0.005	0.027
K2	10/09/2013 9:30	0.012	<0.05	<0.001	<0.001	<0.0010	2.20	<0.0010	<0.001	<0.005	0.0023	<0.0010	0.008	<0.005	<0.001	0.033	<0.0001	<0.01	<0.01	<0.01	<0.005	<0.001	<0.02	0.002	<0.005	0.021
K2	17/10/2013 8:15	0.018	<0.0010	<0.010	<0.0010	<0.0010	2.20	<0.0010	<0.001	<0.001	<0.001	<0.0010	0.006	<0.001	<0.001	0.030	<0.00005	<0.01	<0.01	<0.01	<0.001	<0.001	<0.001	0.002	0.0038	0.03
K2	13/11/2013 11:00	0.009	<0.0010	0.002	<0.0010	<0.0010	2.60	<0.0010	<0.005	<0.001	<0.001	<0.0010	0.005	<0.001	<0.001	0.005	<0.00005	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	0.0019	0.0052	0.021
K3	19/11/2011 12:00	0.580	<0.0001	<0.001	0.0001	<0.0001	0.07	<0.0001	0.001	0.0013	0.0034	0.0005	0.13	<0.005	0.0022	0.100	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.0001	<0.0001	0.0002	0.0092	0.024

Site	Time	Al	Sb	As	Be	Bi	B	Cd	Cr	Co	Cu	Ga	Fe	La	Pb	Mn	Hg	Mo	Ni	Se	Ag	Tl	Sn	U	V	Zn
K3	7/03/2012 9:40	0.440	<0.0001	<0.001	<0.0001	<0.0001	0.06	<0.0001	<0.001	<0.005	0.0020	0.0001	0.33	<0.005	0.0005	0.015	0.0002	<0.001	0.001	<0.001	0.0014	<0.0001	0.0001	0.0001	0.006	0.048
K3	4/04/2012 7:08	0.250	<0.0001	<0.001	<0.0001	<0.0001	0.03	<0.0001	<0.001	<0.005	<0.002	<0.0001	0.96	<0.005	0.0004	0.022	<0.0001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	<0.0001	<0.005	<0.005
K3	19/05/2012 10:30	0.021	<0.0001	<0.001	<0.0001	<0.0001	0.06	<0.0001	<0.001	<0.0001	0.0030	<0.0001	0.021	<0.005	<0.0001	0.049	<0.0001	<0.001	<0.001	<0.001	0.00011	<0.0001	<0.02	0.0003	<0.005	0.026
K3	1/09/2012 12:00	0.020	<0.0001	<0.001	<0.0001	<0.0001	0.08	<0.0001	<0.001	<0.005	<0.002	<0.0001		<0.005	0.0001	0.008		<0.001	<0.001	<0.001	<0.0001	<0.0001		0.0004	<0.005	0.016
K3	25/11/2012 12:00	0.028	<0.0002	<0.002	<0.0002	<0.0002	0.53	<0.0002	<0.001	<0.005	0.0033	<0.0002	0.035	<0.005	<0.0002	0.023	<0.0001	<0.002	<0.002	<0.002	<0.0002	<0.0002	<0.02	0.0008	<0.005	0.011
K3	9/04/2013 12:00	0.170	<0.0001	<0.001	<0.0001	<0.0001	0.05	<0.0001	<0.001	<0.005	0.0022	0.0001	0.24	<0.005	0.0007	0.007	<0.0001	<0.001	0.001	<0.001	0.0025	<0.0001	<0.02	<0.0001	<0.005	0.058
K3	20/05/2013 13:00	0.037	<0.0001	<0.001	<0.0001	<0.0001	0.05	<0.0001	<0.001	<0.005	0.0013	<0.0001	0.03	<0.005	0.0001	0.023	0.0002	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.02	0.0001	<0.005	0.023
K3	10/09/2013 8:45	0.018	<0.05	<0.001	<0.001	<0.0001	0.37	<0.0001	<0.001	<0.005	0.0018	<0.0001	0.013	<0.005	0.0002	0.052	<0.0001	<0.001	<0.001	<0.001	<0.005	<0.0001	<0.02	0.0006	<0.005	0.033
K3	16/09/2013 8:00	0.019	<0.05	<0.001	<0.001	<0.0001	0.14	<0.0001	<0.001	<0.005	0.0021	<0.0001	0.014	<0.005	<0.0001	0.013	<0.0001	<0.001	0.001	<0.001	<0.005	<0.0001	<0.02	0.0006	<0.005	0.047
K3	17/10/2013 10:00	0.016	<0.0001	<0.001	<0.0001	<0.0001	0.32	<0.0001	<0.0005	0.0004	0.0010	<0.0001	<0.005	0.0001	0.0002	0.240	<0.00005	<0.001	0.002	<0.001	<0.0001	<0.0001	<0.0001	0.0006	0.0042	0.074
K3	13/11/2013 11:30	0.017	<0.0002	<0.001	<0.0002	<0.0002	0.71	<0.0002	<0.0010	<0.0002	0.0016	<0.0002	0.016	<0.0002	0.0004	0.008	<0.00005	<0.002	<0.002	<0.001	<0.0002	<0.0002	<0.0002	0.001	0.0054	0.025
K4	1/09/2010 13:30	0.033	<0.0001	<0.001	<0.0001	<0.0001	0.10	<0.0001	<0.001	<0.005	<0.002		0.11	<0.005	<0.0001	0.210	<0.0001	<0.001	<0.001	<0.001			<0.02	0.0002		0.007
K4	19/07/2011 12:00	0.084		<0.001			0.08	<0.0001	<0.001	<0.005	<0.002		0.13		0.0008	0.260	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001			<0.005	<0.005
K4	25/10/2011 12:00	0.038		<0.001			0.08	<0.0001	<0.001	<0.005	0.0020		0.072		0.0004	0.400	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.0002			<0.005	0.006
K4	19/11/2011 12:00	0.210	<0.0001	<0.001	0.0001	<0.0001	0.11	<0.0001	0.001	0.0009	0.0028	0.0002	0.13	<0.005	0.0013	0.380	<0.0001	<0.001	0.002	<0.001	<0.0001	0.0003	0.0001	0.0002	0.0053	0.035
K4	23/11/2011 17:25	0.360	<0.0001	<0.001	0.0001	<0.0001	0.06	<0.0001	0.001	0.0020	0.0056	0.0005	0.16	<0.005	0.0019	0.092	0.0004	<0.001	0.003	<0.001	<0.0001	<0.0001	<0.0001	0.0003	0.013	0.034
K4	23/01/2012 12:00	1.200		<0.001			0.03	<0.0001	<0.001	<0.005	0.0040		0.72		0.0017	0.110	<0.0001	<0.001	0.002	<0.001	<0.0001	<0.0001			0.013	0.014
K4	7/03/2012 8:30	0.380	<0.0001	<0.001	<0.0001	<0.0001	0.05	<0.0001	<0.001	<0.005	0.0040	<0.0001	0.29	<0.005	0.0005	0.009	0.0004	<0.001	0.001	<0.001	0.0023	<0.0001	0.0001	0.0001	0.005	0.043
K4	4/04/2012 7:00	0.220	<0.0001	<0.001	0.0001	<0.0001	0.03	<0.0001	<0.001	<0.005	0.0020	<0.0001	0.85	<0.005	0.0004	0.043	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.02	0.0001	<0.005	0.014
K4	23/04/2012 12:00	0.120		<0.001			0.05	<0.0001	<0.001	<0.005	<0.002		0.41		0.0004	0.140	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001			<0.005	0.008
K4	19/05/2012 10:00	0.026	<0.0001	<0.001	<0.0001	<0.0001	0.07	0.0001	<0.001	0.0006	<0.002	<0.0001	0.067	<0.005	<0.0001	0.260	<0.0001	<0.001	<0.001	<0.001	0.00031	<0.0001	<0.02	0.0002	<0.005	0.032
K4	18/07/2012 12:00	0.021		<0.001			0.06	<0.0001	<0.001	<0.005	<0.002		0.052		<0.0001	0.068	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.0004			<0.005	<0.005
K4	1/09/2012 12:00	0.031	<0.0001	0.001	<0.0001	<0.0001	0.08	<0.0001	<0.001	<0.005	<0.002	<0.0001		<0.005	0.0001	0.250		<0.001	<0.001	<0.001	<0.0001	<0.0001		0.0003	<0.005	0.036
K4	24/11/2012 11:45	0.058		<0.001			0.09	<0.0001	<0.001	<0.005	<0.002		0.14		0.0001	0.190	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001			<0.005	0.006
K4	25/11/2012 12:00	0.025	<0.0001	<0.001	<0.0001	<0.0001	0.09	<0.0001	<0.001	<0.005	0.0005	<0.0001	0.066	<0.005	0.0001	0.380	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.02	0.0002	<0.005	0.009
K4	9/04/2013 8:00	0.110	<0.0001	<0.001	<0.0001	<0.0001	0.03	0.0005	<0.001	<0.005	0.0019	<0.0001	0.22	<0.005	0.0014	0.010	0.0001	<0.001	<0.001	<0.001	0.0075	<0.0001	<0.02	0.0001	<0.005	0.037
K4	20/05/2013 16:00	0.044	<0.0001	<0.001	<0.0001	<0.0001	0.05	<0.0001	<0.001	<0.005	0.0012	<0.0001	0.079	<0.005	0.0002	0.590	0.0002	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.02	0.0001	<0.005	0.036
K4	10/09/2013 7:50	0.013	<0.05	<0.001	<0.001	<0.0001	0.09	<0.0001	<0.001	<0.005	0.0013	<0.0001	0.007	<0.005	<0.0001	0.410	<0.0001	<0.001	<0.001	<0.001	<0.005	<0.0001	<0.02	0.0003	<0.005	0.022
K4	17/10/2013 11:00	0.016	<0.0001	<0.001	<0.0001	<0.0001	0.08	<0.0001	<0.0005	0.0003	0.0006	<0.0001	<0.005	0.0001	0.0001	0.330	<0.00005	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	0.0005	0.0021	0.013
K4	13/11/2013 0:30	0.027	<0.0001	<0.001	<0.0001	<0.0001	0.08	<0.0001	<0.0005	0.0001	0.0023	<0.0001	0.024	0.0001	0.0004	0.110	<0.00005	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.0001	0.0004	0.002	0.037

Table C3 Other general chemistry and nutrient data obtained for the lower Keep River sites. All units are mg/L unless otherwise stated

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
BC	10/06/2010 12:00						29									<0.01			<0.24	0.15			<0.01	<0.02	<0.01	<0.01	<0.020		15.5			130
BC	25/11/2010 12:00						9									<0.01			<0.30	0.17			<0.01	0.00	0.01	0.02	0.01		5.4			86
BC	30/12/2010 23:00						18																	<0.28		<0.01			19.5			140
BC	21/01/2011 3:00						11																	<0.22		<0.01			4.5			57
BC	21/01/2011 21:00						3																	0.10		0.02			1.9			33
BC	22/01/2011 2:00						4																	0.05		0.02			1.9			29
BC	22/01/2011 6:00						3																	0.03		0.03			1.9			37
BC	22/01/2011 11:00						3																	0.05		0.02			1.8			30
BC	22/01/2011 16:00						2																	0.04		0.02			1.9			54
BC	22/01/2011 22:00						2																	0.05		0.03			1.9			34
BC	23/01/2011 4:00						2																	0.05		0.02			1.9			35
BC	23/01/2011 10:00						1																	0.07		0.02			2.1			39
BC	23/01/2011 16:00						<1																	0.04		0.04			2.5			35
BC	23/01/2011 20:00						1																	0.03		0.03			2.2			42
BC	24/01/2011 0:00						2																	0.03		0.02			2.3			43
BC	24/01/2011 4:00						2																	0.08		0.01			2.5			45
BC	24/01/2011 8:00						2																	0.05		0.01			2.7			48
BC	24/01/2011 12:00						2																	0.07		0.02			2.8			48
BC	24/01/2011 17:00						<1																	0.01		0.03			3.1			72
BC	24/01/2011 21:00						<1																	0.00		0.03			2.8			60
BC	25/01/2011 1:00						1																	0.03		0.03			2.7			64
BC	25/01/2011 5:00						<1																	0.05		0.03			2.6			68
BC	25/01/2011 9:00						2																	0.01		0.03			2.6			47
BC	25/01/2011 13:00						2																	0.02		0.03			2.6			62
BC	25/01/2011 17:00						2																	0.02		0.02			2.8			59
BC	25/01/2011 21:00						2																	0.02		0.03			3.1			76
BC	15/02/2011 12:00						3									<0.01			0.53	0.32			<0.02	0.03	0.02	0.01	0.02		3.1			47
BC	18/02/2011 22:44						3																<0.01	0.04	<0.01	0.06	<0.100		3.9			
BC	22/02/2011 10:44						6																<0.01	0.03	<0.01	0.04	<0.070		4.1			
BC	25/02/2011 22:44						3																<0.01	0.01	<0.01	0.06	<0.070		2.4			100
BC	1/03/2011 10:44						2																<0.01	0.00	<0.01	0.08	<0.070		2			110
BC	4/03/2011 22:44						4																<0.01	0.03	<0.01	0.04	<0.070		1.9			110
BC	8/03/2011 10:44						5																<0.01	0.04	<0.01	0.03	<0.070		2.7			110
BC	11/03/2011 22:44						4																<0.01	0.01	<0.01	0.07	<0.080		2.5			110

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
BC	15/03/2011 10:44						6																<0.01	0.02	<0.01	0.03	<0.050		2.5			120
BC	18/03/2011 22:44						34																0.00	1.00	9.00	8.80	0.80		6.6			290
BC	22/03/2011 10:44						11																<0.05	0.10	0.05	0.02	0.07		3.4			180
BC	25/03/2011 22:44						9																0.02	0.08	0.03	0.03	0.08		3.4			170
BC	29/03/2011 10:44						9																<0.01	0.06	0.01	0.01	0.06		2.6			110
BC	1/04/2011 22:44						8																<0.01	0.05	0.01	0.03	0.07		2.8			
BC	5/04/2011 10:44						4																<0.01	0.02	0.01	0.06	0.07		2.4			170
BC	8/04/2011 22:44						1																0.14	0.01	0.32	0.36	0.05		1.9			140
BC	12/04/2011 10:44						7																<0.01	0.06	<0.01	0.02	<0.08		3			110
BC	15/04/2011 22:44						11																<0.01	0.08	0.01	0.02	0.09		4.4			140
BC	19/04/2011 10:44						17																<0.01	0.12	0.01	0.01	0.12		5.4			140
BC	22/04/2011 22:44						21																<0.01	<0.10	<0.01	<0.01	<0.1		6.2			120
BC	26/04/2011 10:44						26																<0.01	<0.08	<0.01	<0.01	<0.09		7.1			94
BC	29/04/2011 22:44						22																<0.01	0.09	0.01	0.01	0.09		7.9			110
BC	3/05/2011 10:44						23																<0.01	<0.08	<0.01	<0.01	<0.08		9			100
BC	6/05/2011 22:44						21																<0.01	<0.06	<0.01	<0.01	<0.06		10.1			120
BC	10/05/2011 10:44						18																<0.01	0.04	0.01	0.01	0.04		10.6			120
BC	16/05/2011 12:00						19									<0.01			<0.45	0.17			<0.01	0.03	0.01	0.01	0.03		10.6			84
BC	22/07/2011 12:00						22									<0.01			<0.36	0.27			<0.01	<0.01	<0.01	<0.01			12.5			120
BC	23/11/2011 12:00	3	21	0.067		15.8	24	<1		79	25		5.5	0.001	9.6	<0.01		0.40	<0.64	0.40			<0.02	<0.06	0.02	<0.01	0.04	8.3	39.8	0.0026		48
BC	28/01/2012 13:15																															120
BC	30/01/2012 4:06																														60	59
BC	31/01/2012 5:41																															59
BC	1/02/2012 11:05																														35	54
BC	2/02/2012 18:20																															55
BC	5/02/2012 9:29																															76
BC	1/03/2012 3:28																															54
BC	6/03/2012 6:35																															42
BC	7/03/2012 7:15	3	27	0.043		5.3	6	<1	10	26	33		3.5	0.0012	3	0.01		0.43	<0.45	0.47		421	<0.01	<0.06	<0.01	<0.01	<0.06	10	7.5	0.036		37
BC	10/03/2012 7:47																														79	
BC	13/03/2012 7:47																														83	
BC	16/03/2012 7:47																														92	
BC	19/03/2012 7:47																														70	
BC	22/03/2012 7:47																														110	
BC	25/03/2012 7:47																														110	

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
BC	28/03/2012 7:47																														110	
BC	31/03/2012 7:47																														120	
BC	3/04/2012 7:47																														120	
BC	4/04/2012 6:40	12	27	0.03		10.8	11	<1	9.4	48	66		3.1	0.0007	5.1	<0.01		0.47	<0.65	0.48		333	<0.01	<0.01	<0.01	<0.01	<0.01	9.5	6.6	0.006	NSS	79
BC	6/04/2012 7:47																														110	
BC	9/04/2012 7:47																														150	
BC	12/04/2012 7:47																														140	
BC	15/04/2012 7:47																														120	
BC	18/04/2012 7:47																														140	
BC	21/04/2012 7:47																														160	
BC	24/04/2012 7:47																														130	
BC	27/04/2012 7:47																														110	
BC	30/04/2012 7:47																														120	
BC	3/05/2012 7:47																														64	
BC	6/05/2012 7:47																														110	
BC	9/05/2012 7:47																														120	
BC	15/05/2012 7:47																														110	
BC	19/05/2012 14:00	5	29	0.14		11.3	33	<1	7.3	100	35		7.3	<0.005	18.3	<0.01			<0.58	0.43		313		<0.04		<0.01		9.6	141	0.01	88	
BC	19/06/2012 11:50	5	30			5.9	34	<1	7.1	28	36				3.3	<0.01			0.51	0.52		298	<0.03	<0.04	0.03	<0.01	0.01				110	
BC	30/03/2013 17:40	5	22			4.9	20	<1	8.4	23	26	0.4	2.4		2.6	<0.01	<0.01		<0.57	0.37	<1		<0.01	<0.05	<0.01	<0.01	<0.05		12.5		62	
BC	9/04/2013 7:00	<2	46	0.18	<0.1	10.7	11	<1	9.9	46	57	7.1	4.4	<0.005	4.8	0.01	<0.01		0.66	0.53	<1	360	<0.01	<0.25	0.01	<0.01	0.24	12	13.8	0.047	79	80
BC	12/04/2013 20:00					17.4	33	<1			73	-1.3	6.2		7.4						<1								13.8			120
BC	16/04/2013 8:00					16	31	<1			61	1.4	5.7		7						<1								13.4			110
BC	19/04/2013 20:00					16	32	<1			92	-7.7	5.8		7.1						<1								15.4			130
BC	23/04/2013 7:00					16.3	31	<1			95	-7.7	5.9		7.3						<1								15.5			130
BC	16/09/2013 7:40	7	132	0.077	0.1	23.6	23	<1	5.3	110	160	0.2	4.1	<0.005	11.5	0.01	<0.01		0.43	0.36	<1	307			<0.010	0.02		6.2	34.7	<0.002	190	200
BC	13/11/2013 12:00	4	120	0.17		19.9	29	1	5.7	94	143	-1.1	3	0.0043	10.8	0.01	<0.01		0.46	0.34	<1	353			0.01	<0.01		8.2	30.8	0.0024	170	170
E1	15/02/2011 12:00						23									<0.01			<0.37	0.23			0.00	0.04	0.01	0.01	0.04		16.8			100
E1	6/09/2011 12:00						10900		2.8							<0.01			<0.78	0.60			<0.01	<0.02	<0.01	<0.01	<0.02		6590			18000
E1	23/10/2011 12:00		175			376	19000	18	3.1	5500	177				1110	<0.01		0.38	<0.60	0.44			0.00	0.00	0.01	0.01	0.00					28000
E1	19/11/2011 11:00	<2	126	0.14		177	8380	<1	4.5	2400	154	-6.9	164	0.063	477	<0.01		0.33	<0.47	0.40			<0.01	<0.01	<0.01	<0.01	<0.01	5.8	4000	<0.002		14000
E1	7/03/2012 9:55	4	29	0.14		6	7	<1	7.1	28	36		2.5	0.0007	3.1	<0.01		0.19	0.22	0.23			<0.01	<0.08	<0.01	<0.01	<0.08	5.2	9.2	0.01	50	41
E1	4/04/2012 7:33	9	29	0.048		12.3	36	<1	7.5	61	70		3.6	0.0011	7.3	<0.01		0.37	<0.48	0.38		306	<0.01	0.00	<0.01	0.01	<0.01	9.5	20.4	<0.002		140
E1	19/05/2012 15:30	<2	128	0.18		183	7820	3	4.3	2600	150		157	0.063	521	<0.01			<0.52	0.39		285				0.02		6	4110	<0.002	14000	
E1	19/06/2012 9:40	<2	143			266	11200	<1	3.3	3900	174				789	<0.01			<0.31	0.29		339	<0.01	<0.01	<0.01	<0.01	<0.01				21000	

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
E1	25/07/2012 16:00	<2	161			380	16100	<1	3.2	5700	196				1140	<0.01	<0.01	0.36	<0.36	0.38		363	<0.01	<0.01	<0.01	<0.01	<0.01				30000	
E1	1/09/2012 12:00	<2	167	0.11		359	16300	<1	3.3	5400	203		371	0.11	1100	<0.01	<0.01		<0.44	0.41		311	<0.01	<0.01	<0.01	<0.01	<0.01	2	10000	<0.002	31000	
E1	19/10/2012 12:00	<2	162			381	15800	<1	1.1	5700	197				1140		<0.01	#REF!	0.47	0.33	<1	358	<0.01	<0.01	<0.01	<0.01	<0.01				29000	
E1	25/11/2012 12:00	<2	170	0.17		303	13400	9	5.3	4300	189	-0.2	252	0.074	850	<0.01	<0.01		<0.69	0.43	<1	316	<0.01	<0.01	<0.01	<0.01	<0.01	0.4	7470	<0.002	22000	24000
E1	12/02/2013 14:55	<2	67			71.2	2900	<1	3.5	940	81	-1.4	53		186	<0.01	<0.01		<0.23	0.21	<1		<0.01	<0.01	<0.01	<0.01	<0.01		1570		5200	
E1	30/03/2013 9:00	6	67			54.2	1950	<1	4	670	81	-2.6	43.2		131	<0.01	<0.01		<0.36	0.19	<1		0.00	0.05	0.01	0.01	0.05		1010		3300	
E1	9/04/2013 12:00	5	28	0.13	0.2	9.1	123	<1	4.4	64	34	-2.9	4.6	<0.005	10	<0.01	0.02		<0.39	0.26	<1		<0.01	<0.027	<0.01	<0.01	<0.027	5.9	64.7	<0.002	270	250
E1	20/05/2013 12:00	<2	131	0.14	22	165	6720	<1	4.5	2200	159	-0.8	135	0.049	445	<0.01	<0.01		<0.91	0.23	<1	302	<0.01	<0.06	<0.01	<0.01	<0.06	5.1	3690	<0.002	13000	12000
E1	5/06/2013 10:30	<2	146			277	10200	3	4.1	3900	171	3.5	202		771	<0.01	<0.01		<0.34	0.28	<1	352	<0.01	<0.01	<0.005	<0.01	<0.01		6020		20000	19000
E1	31/07/2013 14:10	<2	192			422	18000	<1	1.8	6100	234				1230	<0.01	<0.01		0.31	0.29	<1				0.13	0.02					37000	
E1	27/08/2013 12:00	10	150			427	23400	<1	<1.0	7000	183				1440	<0.01	0.03		0.65	0.11	<1				<0.010	<0.01					42000	
E1	10/09/2013 11:30	<2	178	0.14	69	471	23000	<1	3.1	7200	217	-3.3	475	0.11	1460	<0.01	0.04		0.42	0.25	<1	281			<0.010	<0.05		1.4	11700	<0.002	38000	40000
E1	3/10/2013 12:00	18	195			478	20600	<1	4.6	7000	238		374		1410	<0.01			0.56	0.49	<1	289		<0.01	<0.005	<0.05			11500		42000	33000
E1	17/10/2013 12:00	3	172	0.2		528	26900	<1	6.3	7800	210	-5.1	513	0.18	1570	<0.01	0.05		1.70	1.00	<1	313			<0.010	<0.01		3.5	13300	<0.010	42000	
E1	13/11/2013 9:15	2	164	0.23		471	23100	<1	4.5	7400	200	-0.9	438	0.19	1510	0.01	<0.01		0.89	0.64	<1	342			0.01	<0.01		2.4	12600	<0.002	40000	41000
E2	24/10/2011 12:00		150			439	20300	15	1.7	6800	153				1400	<0.01		0.16	<0.34	0.16			<0.01	<0.01	<0.01	<0.01	<0.01					35000
E2	19/11/2011 12:00	<2	112	0.089		278	12800	<1	3.2	4000	137	-3.2	258	0.1	806	<0.01		0.28		0.28			<0.01	<0.01	<0.01	<0.01	<0.01	2.4	6620	<0.002		22000
E2	7/03/2012 10:00	3	39	0.16		7.3	38	3	7	38	41		4.2	0.0012	4.9	<0.01		0.21	0.36	0.27			-0.01	<0.18	0.01	<0.01	0.17	4.9	27.6	0.011	140	110
E2	4/04/2012 7:45	9	39	0.041		18.1	238	<1	7.2	120	80		6.1	0.0026	18.4	<0.01		0.33	<0.44	0.33		267	<0.01	<0.01	<0.01	<0.01	<0.01	9.2	114	<0.002		470
E2	19/05/2012 15:00	<2	166	0.15		313	13400	<1	2.8	4600	202		278	0.11	939	<0.01			<0.36	0.23		280				<0.01		4	7630	<0.002	26000	
E2	19/05/2012 15:00	<2	147			371	17100	<1	1.9	5800	179				1180	<0.01			0.17	0.20		334	<0.01	<0.01	<0.01	<0.01	<0.01				32000	
E2	19/06/2012 10:00																															
E2	25/07/2012 16:00	<2	142			375	17100	<1	1.8	5700	173				1160	<0.01	0.02	0.21	<1.08	0.23		319	<0.01	<0.16	<0.01	<0.01	<0.17				33000	
E2	1/09/2012 12:00	<2	143	0.14		418	17300	<1	1.8	6500	175		456	0.13	1320	0.01	<0.01		<0.35	0.36		295	<0.01	<0.01	<0.01	<0.01	<0.01	2.1	11000	<0.002	34000	
E2	19/10/2012 12:45	16	140			481	21500	<1	3.8	7700	170				1580		0.05		0.74	0.23	<1	370	<0.01	0.00	<0.01	0.02	<0.020				39000	
E2	25/11/2012 12:00	<2	161	0.1		383	17300	3	3.2	5600	189	0.1	353	0.1	1130	<0.01	0.01		0.35	0.23	<1	258	<0.01	<0.01	<0.01	<0.01	<0.01	2	9690	<0.002	28000	31000
E2	12/02/2013 15:40	5	122			343	14800	<1	2.1	5000	149	2.5	322		999	<0.01	<0.01		<0.2	0.15	<1		<0.01	<0.01	<0.01	<0.01	<0.01		8720		29000	
E2	30/03/2013 10:30	8	122			373	17400	<1	1	5600	149	0.0	392		1150	<0.01	0.03		0.59	0.13	<1		<0.01	0.13	<0.01	0.01	<0.14		9620		24000	
E2	9/04/2013 12:00	5	59	0.16	5.9	51.4	1990	<1	3.7	660	72	-0.8	44.4	0.019	128	<0.01	<0.01		1.06	0.19	<1		<0.01	<0.14	<0.01	<0.01	<0.14	6.2	1100	0.004	3300	3600
E2	20/05/2013 10:30	<2	169	0.16	53	355	14700	<1	3.1	5100	206	5.3	329	0.099	1030	<0.01	<0.01		<0.45	0.20	<1	314	<0.01	<0.02	<0.01	<0.01	<0.020	3	9300	0.002	30000	28000
E2	5/06/2013 11:10	<2	155			349	13900	<1	2.9	5000	189	5.6	322		1010	<0.01	<0.01		<0.25	0.21	<1	360	<0.01	<0.01	<0.005	0.01	<0.01		8770		30000	26000
E2	31/07/2013 15:00	<2	165			435	20400	<1	2.1	6800	201				1400	<0.01	<0.01		0.19	0.15	<1				<0.010	<0.01					41000	
E2	27/08/2013 12:50	<2	157			431	23000	<1	<1.0	7600	191				1580	<0.01	<0.01		0.47	0.12	<1				<0.010	0.01					43000	
E2	10/09/2013 12:15	<2	145	0.045	64	469	22400	<1	1.7	7200	177	-1.3	514	0.12	1470	<0.01	0.04		0.16	0.16	<1	284			<0.010	<0.05		0.89	12000	<0.002	40000	40000
E2	4/10/2013 12:00	16	145			482	22900	<1	1.6	7300	177		419		1480	<0.01			0.15	0.11	<1			<0.01	<0.005	<0.05			12200		44000	34000

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
E2	17/10/2013 13:00	3	156	0.06		492	24100	<1	2.9	7700	190	0.8	534	0.18	1570	<0.01	<0.01		0.91	0.32	<1	299			<0.010	<0.01		2	13600	<0.010	42000	
E2	13/11/2013 9:00	2	106	0.17		344	14800	<1	3.3	5100	129	3.8	313	0.13	1030	<0.01	0.04		0.56	0.35	<1	277			<0.005	<0.01		1.8	9030	<0.0050	27000	28000
E3	25/10/2011 12:00		133			427	19200	15	1.4	6600	131				1340	<0.01		0.12	<0.61	0.12			0.00	0.04	0.01	0.01	0.04					33000
E3	19/11/2011 9:00	<2	122	0.065		296	15500	<1	2.5	4400	149	-3.6	300	0.11	886	<0.01		0.26		0.26			<0.01	<0.01	<0.01	<0.01	<0.01	1.7	8020	<0.002		26000
E3	7/03/2012 10:15	4	43	0.14		7.8	83	3	7.9	49	45		5.1	0.0017	7.1	<0.01		0.27	0.33	0.39			-0.01	<0.19	0.01	<0.01	0.19	4.6	49.5	0.012	220	210
E3	4/04/2012 7:57	9	43	0.037		40.5	1280	<1	6.6	470	97		29.2	0.012	88.4	<0.01		0.33	<0.38	0.33		301	<0.01	<0.01	<0.01	<0.01	<0.01	8.7	716	<0.002		2100
E3	19/05/2012 14:30	<2	159	0.16		340	15200	<1	2.3	5100	194		318	0.12	1040	<0.01			<0.24	0.20		290		<0.01		0.01	<0.01	3	8450	<0.002	29000	
E3	19/06/2012 10:40	<2	133			360	17500	<1	1.7	5700	163				1170	<0.01			<0.20	0.27		329	<0.01	<0.01	<0.01	<0.01	<0.01				32000	
E3	25/07/2012 16:00	<2	133			383	17400	<1	1.6	5900	163				1200	0.01	0.06	0.19	<0.87	0.26		384	<0.01	<0.12	<0.01	<0.01	<0.12				32000	
E3	1/09/2012 12:00	<2	130	0.068		357	17500	<1	1.3	5600	159		412	0.12	1150	0.01	0.04		<0.17	0.22		345	<0.01	<0.01	<0.01	0.01	<0.01	1.7	10800	<0.002	33000	
E3	19/10/2012 14:25	18	136			440	20200	<1	1.2	7600	165				1590		0.08		0.65	0.27	<1	374	<0.01	0.00	<0.01	0.02	<0.020				36000	
E3	25/11/2012 12:00	<2	167	0.057		401	20200	<1	2.6	6200	203	-2.6	352	0.11	1250	<0.01	<0.01		<0.38	0.17	<1	257	<0.01	<0.01	<0.01	<0.01	<0.01	1.7	10600	<0.002	32000	35000
E3	12/02/2013 16:20	<2	126			363	16200	<1	2	5300	154	4.4	357		1060	<0.01	0.01		<0.19	0.18	<1		<0.01	<0.01	<0.01	<0.01	<0.01		10000		32000	
E3	30/03/2013 11:30	6	120			367	17900	<1	1.5	5600	147	-1.0	399		1140	<0.01	0.03		0.43	0.13	<1		<0.01	0.02	<0.01	0.01	<0.030		9710		28000	
E3	9/04/2013 10:15	7	70	0.16	14	104	4610	<1	3.2	1500	85	-2.3	94.9	0.035	299	<0.01	<0.01		<0.87	0.17	<1	281	<0.01	<0.18	<0.01	<0.01	<0.18	4.3	2440	0.003	6800	8200
E3	20/05/2013 8:40	<2	159	0.075	66	390	17800	<1	2.4	5800	193	4.4	392	0.11	1160	<0.01	<0.01		<0.32	0.16	<1	252	<0.01	<0.01	<0.01	<0.01	<0.01	2.1	11100	<0.002	36000	33000
E3	5/06/2013 11:55	<2	172			432	18600	<1	1.9	6900	210	4.3	438		1410	<0.01	<0.01		<0.21	0.21	<1	340	<0.01	<0.01	<0.005	<0.01	<0.01		11300		38000	35000
E3	31/07/2013 15:40	<2	168			447	21900	3	1.3	7500	199				1560	<0.01	<0.01		0.21	0.13	<1				<0.010	<0.01					43000	
E3	27/08/2013 14:00	<2	167			369	15900	9	3.6	5700	185				1150	<0.01	<0.01		0.58	0.23	<1				<0.010	<0.01					31000	
E3	10/09/2013 12:50	2	139	0.034	66	440	22000	<1	1.5	6900	169	-2.5	492	0.12	1400	0.01	0.04		0.24	0.23	<1	283			<0.010	<0.05		1.1	11500	<0.002	38000	39000
E3	16/09/2013 10:55	15	134			450	20800	<1	1.4	6800	163		397		1380	<0.01			0.13	0.17	<1	279		<0.01	<0.005	<0.01			11400		41000	32000
E3	17/10/2013 13:30	3	150	0.044		463	23000	<1	2.3	7000	183	-1.6	509	0.18	1430	<0.01	<0.01		0.93	0.24	<1	324			<0.010	<0.01		2.9	12300	<0.010	39000	
E3	13/11/2013 8:30	<2	105	0.12		342	14900	<1	3.2	5100	128	3.4	312	0.13	1020	0.01	0.04		0.62	0.44	<1	290			<0.005	<0.01		1.6	9000	<0.0050	27000	28000
E4	7/03/2012 10:20	3	50	0.18		63.2	650	3	6	1000	54		69.4	0.027	211	<0.01		0.19	0.49	0.27			0.02	0.11	0.04	0.02	0.09	3.6	1710	0.003	1200	1200
E4	4/04/2012 8:05	11	50	0.026		165	7870	<1	3.4	2500	108		200	0.067	512	<0.01		0.18	<0.2	0.18			<0.01	<0.01	<0.01	<0.01	<0.01	4.4	4300	0.004		14000
E4	9/04/2013 12:00	5	103	0.11	46	299	13200	<1	1.8	4600	125	2.4	302	0.089	939	<0.01	0.05		0.78	0.15	<1		<0.01	<0.066	<0.01	<0.01	<0.066	2.4	7710	<0.002	19000	24000
E5	7/03/2012 10:35	7	121	0.17		327	16100	<1	3.4	5100	147		385	0.12	1040	<0.01		0.20	0.37	0.28		246	<0.01	0.00	<0.01	0.03	<0.03	2.1	9220	<0.002	31000	25000
E5	4/04/2012 8:20	9	121	0.017		272	13300	<1	1.8	4200	126		338	0.11	864	<0.01		0.13	<0.23	0.21		354	<0.01	<0.01	<0.01	<0.01	<0.01	2.6	8360	<0.002		25000
E5	9/04/2013 12:00	6	117	0.12	70	383	18500	<1	1.2	5800	142	0.9	403	0.11	1190	<0.01	0.08		<0.75	0.20	<1	259	<0.01	0.03	<0.01	0.01	<0.039	2.5	10500	0.004	28000	34000
K1	25/08/2010 12:00						9570									<0.01			<0.21	0.19			0.00	<0.01	0.01	<0.01	0.00		5450			19000
K1	14/09/2010 12:00		170			256	9740						216		694				<0.17										5720			18000
K1	16/11/2010 12:00						4780																						2710			7100
K1	25/11/2010 12:00						8020									<0.01			<0.38	0.32			<0.01	<0.01	<0.01	<0.01	<0.01		4580			18000
K1	15/02/2011 12:00						4									<0.01			0.35	0.19			<0.01	<0.03	0.01	<0.01	0.02		4.6			54
K1	20/05/2011 12:00						110									<0.01			<0.36	0.08			<0.01	<0.02	0.01	0.01	0.01		82.2			400

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K1	23/07/2011 12:00						665		2.1							<0.01			<0.24	0.17			<0.01	<0.01	<0.01	<0.01	<0.01		325			1100
K1	6/09/2011 12:00						2740		2.3							<0.01			<0.18	0.14			<0.01	<0.32	<0.01	<0.01	<0.32		1590			5500
K1	19/09/2011 12:00		165			136	4000						81.8		295				<0.19										2270			7600
K1	26/10/2011 12:00		160			224	9200	24	3.6	3000	146				592	<0.01		0.24	<0.29	0.24			<0.01	<0.01	<0.01	<0.01	<0.01					13000
K1	19/11/2011 13:50	<2	118	0.17		122	4330	<1	3.6	1500	143	-2.9	83.7	0.029	280	<0.01		0.29	<0.32	0.31			<0.01	<0.01	<0.01	<0.01	<0.01	8.6	2240	0.004		7100
K1	24/11/2011 14:35																															
K1	7/03/2012 9:55	5	22	0.14		4.4	5	<1	7.6	23	27		2.7	0.0007	2.9	<0.01		0.20	0.20	0.25		398	<0.01	<0.05	<0.01	<0.01	<0.050	5.1	12.6	0.017		32
K1	4/04/2012 7:33	8	22	0.051		12.5	17	<1	7.4	59	73		3.3	0.0007	6.7	<0.01		0.37	0.44	0.39		268	<0.01	<0.01	<0.01	<0.01	<0.010	9.6	10.6	<0.002		100
K1	19/05/2012 12:01	<2	111	0.23		106	4090	<1	4.1	1300	135		75.3	0.031	252	<0.01			<0.32	0.29		323		<0.01		<0.01		7.7	2070	<0.002	7000	
K1	19/06/2012 9:10	<2	129			151	5460	<1	4.2	1900	158				381	<0.01			<0.33	0.31		361	<0.01	<0.01	<0.01	<0.01	<0.01				9700	
K1	25/07/2012 16:00	<2	141			168	6360	4	3.8	2100	164				415	<0.01	<0.01	0.35	<0.35	0.35		337	<0.01	<0.01	<0.01	<0.01	<0.01				11000	
K1	1/09/2012 12:00																															
K1	19/10/2012 10:55	3	156	0.24		208	8130	<1	4	2800	190		163	0.052	557	<0.01	<0.01		<0.34	0.33		309	<0.01	<0.01	<0.01	<0.01	<0.01	2.9	4590	<0.002	15000	
K1	19/10/2012 10:55	<2	158			232	8280	<1	4.5	3100	191				604		<0.01			0.34	<1	365	<0.01	<0.01	<0.01	<0.01	<0.01				15000	
K1	25/11/2012 12:00	<2	168	0.22		307	11500	8	4.9	4200	189	3.3	228	0.068	825	<0.01	<0.01		<0.36	0.31	<1	266	<0.01	<0.01	<0.01	<0.01	<0.01	0.93	6880	<0.002	20000	22000
K1	12/02/2013 14:10	3	44			13.4	157	<1	3.5	91	53	-0.8	4.4		14	0.01	0.02		0.19	0.23	<1		<0.01	<0.02	<0.01	<0.01	<0.02		87.2		360	
K1	30/03/2013 16:00	4	52			22.4	435	<1	4	180	63	-3.0	10.1		31.3	<0.01	0.04		0.25	0.31	<1		<0.01	<0.01	<0.01	<0.01	<0.01		224		850	
K1	9/04/2013 9:30	3	33	0.17	<0.1	8.1	21	<1	4.6	39	40	3.5	2.9	<0.005	4.5	<0.01	0.01		0.76	0.19	<1	356	<0.01	0.07	0.01	0.01	0.07	5.9	16.4	<0.002	90	82
K1	20/05/2013 12:00	3	93	0.32	16	138	5300	<1	4.7	1800	113	0.4	105	0.037	361	<0.01	0.01		0.30	0.22	<1	320	<0.01	<0.01	<0.010	<0.01	<0.01	5.2	2960	<0.002	9600	9700
K1	5/06/2013 9:50	<2	118			211	7930	<1	3.8	2900	144	7.0	158		584	<0.01	<0.01		<0.3	0.29	<1	323	<0.01	<0.01	<0.005	<0.01	<0.01		5180		15000	15000
K1	31/07/2013 12:55	<2	157			349	13100	<1	2.2	4900	191				984	<0.01	<0.01		0.51	0.37	<1				<0.010	<0.01					27000	
K1	27/08/2013 11:30	<2	172			376	16300	<1	1	5800	210				1190	<0.01	<0.01		0.36	0.30	<1				<0.010	<0.01					30000	
K1	10/09/2013 10:30	18	172	0.21	58	396	16800	<1	3.9	5700	210	1.0	351	0.088	1150	<0.01	0.04		0.41	0.38	<1	291			<0.010	<0.01		1	9500	<0.002	26000	31000
K1	27/09/2013 12:00	<2	175			372	16400	7	4.6	5300	200		292		1070	<0.01			0.40	0.34	<1			<0.01	<0.005	<0.01			8730		32000	26000
K1	17/10/2013 7:12	<2	176	0.22		424	17700	14	6.5	6000	185	0.4	361	0.13	1200	<0.01	<0.01		0.72	0.54	<1	298			<0.010	<0.01		3.4	9810	<0.010	31000	
K1	13/11/2013 10:00	<2	167	0.23		453	20100	<1	4.7	7100	204	2.8	401	0.17	1450	<0.01	<0.01		0.49	0.36	<1	318			<0.005	<0.01		3.7	11800	<0.002	37000	37000
K2	25/08/2010 12:00						2000									<0.01			<0.13	0.08			<0.01	<0.01	<0.01	0.01	<0.01		1050			3500
K2	14/09/2010 12:00		180			137	4620						86.6		317				<0.15										2480			8000
K2	25/11/2010 12:00						415									<0.01			<0.42	0.29			<0.01	0.01	0.01	0.01	0.01		219			780
K2	23/07/2011 12:00						288		2.3							<0.01			<0.32	0.22			<0.01	<0.02	<0.01	<0.01	<0.02		156			660
K2	6/09/2011 12:00						486		2.1							<0.01			<0.18	0.13			<0.01	<0.01	<0.01	<0.01	<0.01		258			980
K2	18/09/2011 12:00		160			62	521						9.4		61.3				<0.13										308			1100
K2	26/10/2011 12:00		155			82.5	1990	9	2.7	740	171				131	<0.01		0.17	<0.21	0.17			<0.01	<0.01	0.01	<0.01	0.00					2400
K2	19/11/2011 9:00	4	88	0.13		49.7	1050	<1	3.8	440	108	-3.3	17.7	0.008	75.8	<0.01		0.23	<0.24	0.24			<0.01	<0.01	<0.01	<0.01	<0.01	9.5	532	0.0022		1600
K2	7/03/2012 9:50	3	15	0.16		3.8	<1	<1	5.6	19	19		3	0.0006	2.3	<0.01		0.25	0.28	0.30			<0.01	<0.07	<0.01	<0.01	<0.07	5.5	7.5	0.028		24

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K2	4/04/2012 7:11	6	15	0.051		12.8	20	<1	7.5	61	70		3.5	0.0009	7	<0.01		0.39	<0.5	0.40			<0.01	<0.01	<0.01	<0.01	<0.01	10	12.9	<0.002		100
K2	19/05/2012 11:15	<2	107	0.21		48.3	871	<1	3.6	390	131		16.1	0.007	66	<0.01			<0.26	0.21		339		<0.01		<0.01	<0.01	10	443	<0.002	1600	
K2	19/06/2012 9:40	5	124			62.5	1040	<1	3.4	500	151				84.7	<0.01			<0.19	0.19		338	<0.01	<0.01	<0.01	<0.01	<0.01				1900	
K2	25/07/2012 16:00	<2	137			70.5	1130	<1	3.4	560	167				92.6	<0.01	<0.01	0.32	<0.37	0.32		352	<0.01	<0.01	<0.01	<0.01	<0.01				2000	
K2	1/09/2012 12:00	<2	143	0.23		70.2	989	4	3.1	540	166		17.3	0.006	87.9	<0.01	<0.01		<0.24	0.23		348	<0.01	<0.01	<0.01	<0.01	<0.01	12	559	<0.002	1900	
K2	19/10/2012 10:15	6	152			157	4860	<1	4.2	1900	185				357		<0.01		0.34	0.28	<1	374	<0.01	<0.01	<0.01	<0.01	<0.01				8300	
K2	25/11/2012 12:00	<2	168	0.26		193	6860	3	4	2400	198	-1.1	122	0.04	465	<0.01	<0.01		<0.24	0.22	<1	279	<0.01	<0.01	<0.01	<0.01	<0.01	7.1	3710	<0.002	12000	12000
K2	12/02/2013 13:26	2	43			10.9	43	<1	3.6	56	52	-0.3	2.5		7.1	0.02	<0.01		0.22	0.20	<1		<0.01	<0.03	<0.01	<0.01	<0.03		24.4		130	
K2	30/03/2013 8:30	6	55			17.2	102	<1	4.1	95	67	-1.5	3.9		12.6	<0.01	0.01		0.25	0.29	<1		<0.01	<0.01	<0.01	<0.01	<0.01		51.5		260	
K2	9/04/2013 12:00	3	29	0.13	<0.1	7	16	<1	4.6	35	35	4.3	2.7	<0.005	4.3	<0.01	0.01		0.44	0.26	<1		<0.01	<0.03	<0.01	<0.01	<0.03	6.6	12.3	<0.002	72	67
K2	20/05/2013 0:41	3	76	0.22	2.2	42.5	691	<1	4.4	340	92	2.5	13.2	0.005	56.2	<0.01	0.01		0.24	0.19	<1	303	<0.01	<0.01	<0.010	<0.01	<0.01	8.5	393	<0.002	1400	1300
K2	5/06/2013 9:20	3	98			104	3150	<1	3.8	1200	119	-0.4	54		228	<0.01	<0.01		<0.26	0.24	<1	342	<0.01	<0.01	<0.005	<0.01	<0.01		1700		5700	5700
K2	31/07/2013 12:25	6	127			198	6300	<1	2.2	2400	155				465	<0.01	<0.01		0.21	0.18	<1				<0.010	<0.01					12000	
K2	27/08/2013 11:00	<2	153			299	11000	<1	<1.0	4300	187				875	<0.01	<0.01		0.31	0.24	<1				<0.010	<0.01					20000	
K2	10/09/2013 9:30	2	152	0.26	30	245	8880	<1	3.7	3100	185	0.2	160	0.047	611	<0.01	0.04		0.24	0.29	<1	293			<0.010	<0.01		3.3	4880	<0.002	16000	16000
K2	29/09/2013 12:00	18	152			190	7150	<1	4.4	2400	185		118		456	<0.01			0.36	0.32	<1			<0.01	<0.005	<0.01			3500		14000	12000
K2	17/10/2013 8:15	<2	164	0.28		243	9080	<1	6.1	3100	200	0.8	157	0.056	598	<0.01	<0.01		0.73	0.61	<1	310			<0.010	<0.01		4.2	5110	<0.0050	16000	
K2	13/11/2013 11:00	<2	169	0.35		266	10200	<1	4.4	3500	205	-2.1	195	0.072	700	<0.01	<0.01		0.42	0.28	<1	313			<0.005	<0.01		6.3	5330	<0.0050	18000	18000
K3	25/08/2010 12:00						266									<0.01			<0.14	0.09			<0.01	<0.01	<0.01	0.02	<0.01		130			560
K3	15/09/2010 12:00		150			45	437						8.8		42.6				<0.12										228			970
K3	16/11/2010 12:00						303																						155			390
K3	24/11/2010 12:00						36									<0.01			<0.27	0.21			<0.01	0.00	0.01	0.01	0.00		22.8			96
K3	20/05/2011 12:00						33									<0.01			<0.21	0.09			<0.01	<0.02	<0.01	<0.01	<0.02		29			260
K3	23/07/2011 12:00						106		2.2							<0.01			<0.41	0.32			<0.01	<0.01	<0.01	<0.01	<0.01		66.9			370
K3	6/09/2011 12:00						99		1.3							<0.01			<0.14	0.12			<0.01	<0.01	<0.01	<0.01	<0.01		61.5			320
K3	17/09/2011 12:00		153			39.2	154						5.3		31.9				<0.12										105			540
K3	26/10/2011 12:00		153			44.3	232	<1	1.8	260	186				35.1	<0.01		0.15	<0.27	0.15			0.00	0.02	0.01	0.01	0.02					580
K3	19/11/2011 12:00	5	42	0.1		13.1	48	<1	5.6	71	51	-0.6	2.7	0.0012	9.2	<0.01		0.25	0.38	0.32			<0.02	<0.04	0.02	<0.01	0.02	7.1	23.4	0.012		180
K3	7/03/2012 9:40	5	15	0.14		3.7	3	<1	6.7	17	19		2.4	0.0005	2	0.01		0.20	<0.21	0.23			<0.01	<0.05	<0.01	<0.01	<0.04	5	5.5	0.012	26	23
K3	4/04/2012 7:08	10	15	0.047		12.3	30	<1	7.5	60	71		3.5	0.0009	7	<0.01		0.36	<0.53	0.37			<0.01	<0.01	<0.01	<0.01	<0.01	9.5	17.1	<0.002		130
K3	19/05/2012 10:30	<2	116	0.15		27.1	80	<1	3.2	150	141		3.9	<0.005	19.2	<0.01			<0.29	0.23		344		<0.01		<0.01		13	48.9	<0.002	290	
K3	19/06/2012 8:20	5	132			31.6	29	<1	2.6	180	160				23.5	<0.01			<0.18	0.17		329	<0.01	<0.01	<0.01	<0.01	<0.01				360	
K3	25/07/2012 16:00	7	139			37.3	149	<1	2.1	200	170				27.1	<0.01	<0.01	0.14	<0.17	0.14		364	<0.01	<0.01	<0.01	<0.01	<0.01				480	
K3	1/09/2012 12:00	<2	144	0.19		39.6	180	<1	2.2	220	176		5.1	<0.005	28.9	<0.01	<0.01		<0.18	0.17		365	<0.01	<0.01	<0.01	<0.01	<0.01	13	97.9	<0.002	450	
K3	19/10/2012 9:10	5	150			45.2	237	<1	3.6	260	182				35.7		<0.01			0.45	<1	377	<0.01	<0.01	<0.01	<0.01	<0.01					610

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K3	25/11/2012 12:00	<2	155	0.27		94.5	2030	<1	3.7	850	189	-0.5	33.7	0.014	150	<0.01	<0.01		<0.30	0.24	<1	350	<0.01	<0.01	<0.01	<0.01	<0.01	13	1110	<0.002	3600	3800
K3	13/02/2013 10:40	3	53			10.2	19	<1	3.4	49	64	-2.3	2.2		5.7	0.02	<0.01		0.21	0.19	<1		<0.01	<0.04	<0.01	<0.01	<0.04		15.8		99	
K3	30/03/2013 16:30	5	62			13.3	24	<1	4.6	63	75	-0.6	2.8		7.3	<0.01	<0.01		<0.33	0.23	<1		<0.01	<0.01	<0.01	<0.01	<0.01		18		120	
K3	9/04/2013 12:00	5	31	0.14	<0.1	7.9	11	<1	4.9	37	38	7.7	2.8	<0.005	4.3	<0.01	0.01		0.52	0.23	<1		<0.01	<0.03	<0.01	<0.01	<0.03	7.3	11.1	<0.002	60	64
K3	20/05/2013 13:00	4	84	0.14	0.22	20.2	60	<1	3.5	100	103	0.3	3.7	<0.005	12.9	<0.01	0.02		0.18	0.17	<1	323	<0.01	<0.01	<0.01	<0.01	<0.01	8.9	36.1	<0.002	220	200
K3	5/06/2013 8:45	3	94			29.7	243	<1	3.1	180	115	-5.0	5.8		24.8	<0.01	0.02		0.21	0.23	<1	314	<0.01	<0.01	<0.005	<0.01	<0.01		113		520	510
K3	31/07/2013 11:40	8	121			66.3	1160	<1	3.4	540	147				91.6	<0.01	<0.01		0.02	0.19	<1				<0.010	<0.01					2400	
K3	27/08/2013 10:30	10	125			71.2	1200	<1	2.8	580	152				97.6	<0.01	<0.01		0.23	0.14	<1				<0.010	<0.01					2200	
K3	10/09/2013 8:45	2	129	0.29	4	75.6	1390	<1	3.1	660	158	1.8	24.1	0.01	115	<0.01	<0.01		0.29	0.21	<1	294			<0.010	<0.01		9.3	776	<0.002	2500	2700
K3	16/09/2013 8:00	7	131	0.13	1.2	35.5	389	<1	5	230	160	-3.5	9.2	<0.005	35.2	0.01	<0.01		0.41	0.33	<1	311			<0.010	0.02		7.9	209	<0.002	760	820
K3	6/10/2013 12:00	9	135			64.2	1130	<1	3.9	530	165		19.3		90.7	<0.01			0.33	0.21	<1			<0.01	<0.005	<0.01			623		2200	2400
K3	17/10/2013 10:00	4	145	0.27		68.5	1300	<1	4.6	590	176	0.5	22.9	0.0085	101	<0.01	<0.01		0.65	0.65	<1	324			<0.010	<0.01		9.4	720	<0.0005	2500	
K3	13/11/2013 11:30	<2	159	0.46		119	3380	<1	3.9	1200	193	-3.4	56	0.02	224	<0.01	0.02		0.31	0.27	<1	317			<0.0005	<0.01		9.6	1720	<0.0010	5500	6000
K4	10/06/2010 12:00						53									<0.01			0.12	0.08			<0.01	<0.02	<0.01	<0.01	<0.02		32.4			210
K4	10/06/2010 12:00		95			17	51						2.3		12.3														34.8			220
K4	25/08/2010 12:00						53									<0.01			<0.06	0.04			0.00	0.00	0.01	0.01	0.00		38.5			270
K4	1/09/2010 13:30		120	0.091		22.5	86	<1	<1.0	120	146		2.6	<0.005	16.6				<0.15										53.3			300
K4	16/11/2010 12:00						10																						6.3			66
K4	24/11/2010 12:00						13									<0.01			<0.32	0.21			<0.01	0.00	0.01	0.02	0.01		8.7			70
K4	15/12/2010 14:00						13																	0.26		0.04			9.9			120
K4	16/12/2010 14:00						13																	0.34		0.03			6.9			110
K4	29/12/2010 18:00						9																	<0.22		<0.01			6			100
K4	31/12/2010 17:00						12																	<0.41		0.10			4.1			110
K4	1/01/2011 18:00						9																	<0.27		<0.01			3			94
K4	2/01/2011 14:00						11																	<0.30		<0.01			3.2			77
K4	5/01/2011 20:00						11																	<0.21		<0.01			3.7			110
K4	11/01/2011 11:00						8																	<0.21		<0.01			4.1			110
K4	13/01/2011 17:00						8																	<0.32		<0.01			2.9			55
K4	15/01/2011 12:00						7																	<0.35		<0.01			3.6			52
K4	18/01/2011 13:00						10																	<0.18		<0.01			4.4			93
K4	20/01/2011 8:00						11																	0.50		0.01			5.8			93
K4	21/01/2011 3:00						<1																	<0.32		<0.01			10.6			180
K4	21/01/2011 15:00						3																	0.32		0.03			5.6			76
K4	22/01/2011 8:00						3																	0.07		0.05			4.2			73
K4	22/01/2011 12:00						28																	0.11		0.02			2.6			130

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K4	22/01/2011 17:00						3																	0.07		0.03			2.4			53
K4	22/01/2011 21:00						3																	0.05		0.03			2.4			63
K4	23/01/2011 2:00						5																	0.07		0.02			2.5			40
K4	23/01/2011 7:00						3																	0.12		0.02			2.7			38
K4	23/01/2011 11:00						4																	0.09		0.02			2.9			42
K4	23/01/2011 16:00						18																	<0.10		<0.01			3.4			63
K4	15/02/2011 7:00						2									<0.01			<0.17	0.17			0.00	0.01	0.01	0.01	0.01		3.5			52
K4	18/02/2011 20:00						29																<0.01	<0.03	<0.01	<0.01	<0.03		13.3			200
K4	22/02/2011 8:00						23																<0.01	0.16	0.01	0.01	0.16		10.4			NSS
K4	25/02/2011 20:00						29																<0.01	<0.05	<0.01	<0.01	<0.05		10.9			180
K4	1/03/2011 8:00						20																<0.01	<0.06	<0.01	<0.01	<0.06		6.8			140
K4	4/03/2011 20:00						33																<0.01	0.04	0.01	0.01	<0.05		11.2			140
K4	8/03/2011 8:00						22																<0.01	<0.03	<0.01	<0.01	<0.03		6.3			140
K4	11/03/2011 20:00						14																<0.01	<0.03	<0.01	<0.01	<0.03		12.2			150
K4	15/03/2011 8:00						11																<0.02	0.02	0.02	0.02			8.5			150
K4	18/03/2011 20:00						28																<0.01	0.09	0.01	0.01			9.1			160
K4	22/03/2011 8:00						27																<0.01	0.05	0.01	0.01			9			140
K4	25/03/2011 20:00						18																<0.02	0.01	0.02	0.02			16.3			160
K4	29/03/2011 8:00						17																<0.01	0.01	0.02	0.02			16.5			170
K4	1/04/2011 20:00						18																<0.01	0.06	0.01	0.01			16.7			160
K4	5/04/2011 8:00						17																<0.01	0.05	0.01	0.01			17.4			170
K4	8/04/2011 20:00						17																<0.01	0.03	0.01	0.01			16			170
K4	12/04/2011 8:00						18																<0.01	0.03	0.01	0.01			16.5			180
K4	15/04/2011 20:00						17																<0.01	0.02	0.01	0.01			16.3			170
K4	19/04/2011 8:00						19																<0.01	0.02	0.01	0.01			15.6			160
K4	22/04/2011 20:00						16																<0.01	0.01	0.01	0.01			15.7			170
K4	26/04/2011 8:00						17																<0.01	0.02	0.01	0.01			16.3			170
K4	29/04/2011 20:00						18																<0.01	0.02	0.01	0.01			16.5			150
K4	3/05/2011 8:00						18																<0.01	0.06	0.01	0.01			16.6			170
K4	6/05/2011 20:00						20																<0.01	0.03	0.01	0.01			16.5			170
K4	10/05/2011 8:00						22																<0.01	0.03	0.01	0.01			20.5			180
K4	16/05/2011 9:00						30									<0.01			<0.26	0.05			<0.01	0.03	0.01	0.01			29.8			230
K4	20/05/2011 12:00						30									<0.01			0.19	0.06			<0.01	<0.04	<0.01	<0.01	<0.04		28.3			260
K4	19/07/2011 12:00		145	0.082		33.9	69	<1		190	177		3.3		25.4	<0.01	<0.01												53.9			350
K4	23/07/2011 12:00						81		1.6							<0.01			<0.17	0.12			<0.01	<0.01	<0.01	<0.01	<0.01		59			330

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K4	6/09/2011 12:00						95		1.3							<0.01			<0.16	0.09			<0.01	<0.01	<0.01	<0.01	<0.01		89.1			420
K4	16/09/2011 12:00		138			37.7	115						4.2		29.9				<0.07										97			450
K4	25/10/2011 12:00		138			34.7	127	<1	1.2	200	168				27.6	<0.01		0.11	<0.15	0.12			0.00	0.01	0.01	0.01	0.01					450
K4	25/10/2011 12:00		128	0.096		31.4	123	<1		170	156		3.3		23.4	<0.01	<0.01												73.8			450
K4	19/11/2011 12:00	3	50	0.079		16.4	247	<1	5.7	130	61	-5.3	5.9	0.0033	21	<0.01		0.42	0.62	0.55			<0.03	<0.04	0.03	<0.01	0.01	8.6	123	0.0017		480
K4	23/11/2011 17:25	4	52	0.092		13.6	15	<1	6.5	71	64	1.2	3.2	0.0031	9	<0.01		0.40	0.69	0.45			<0.03	<0.05	0.03	<0.01	0.02	7	13.4	0.0026		120
K4	20/01/2012 12:27																															100
K4	23/01/2012 12:00		25	0.12		6.3	4	<1		30	31		1.6		3.4	<0.01	0.09												3.3			45
K4	26/01/2012 22:55																															47
K4	28/01/2012 2:23																														42	48
K4	1/02/2012 8:24																															64
K4	3/02/2012 2:54																															47
K4	7/02/2012 20:15																														57	65
K4	2/03/2012 4:41																														53	55
K4	5/03/2012 13:42																															37
K4	6/03/2012 4:14																														29	31
K4	6/03/2012 13:25																														30	28
K4	6/03/2012 21:24																															31
K4	7/03/2012 4:41																															31
K4	7/03/2012 8:30	3	15	0.14		3.7	3	<1	7.3	17	18		2.6	0.0005	2	0.01		0.21	0.26	0.26		418	<0.01	<0.04	<0.01	<0.01	<0.04	5	5	0.009	25	23
K4	10/03/2012 9:00																														100	
K4	13/03/2012 9:00																														100	
K4	16/03/2012 9:00																														94	
K4	19/03/2012 9:00																														39	
K4	22/03/2012 9:00																														100	
K4	25/03/2012 9:00																														110	
K4	28/03/2012 9:00																														140	
K4	31/03/2012 9:00																														150	
K4	3/04/2012 9:00																														140	
K4	4/04/2012 7:00	7	15	0.066		12.5	21	<1	4.4	65	73		3.2	0.0013	8.2	<0.01		0.22	<0.29	0.23		276	<0.01	<0.01	<0.01	<0.01	<0.01	9	14.7	<0.002		110
K4	6/04/2012 9:00																														140	
K4	9/04/2012 9:00																														160	
K4	12/04/2012 9:00																														180	
K4	15/04/2012 9:00																														NSS	
K4	18/04/2012 9:00																														210	

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K4	21/04/2012 9:00																														240	
K4	23/04/2012 12:00		79	0.066		16.9	26	<1		89	96		2.5		11.4	<0.01	<0.01												20.3			150
K4	24/04/2012 9:00																														210	
K4	27/04/2012 9:00																														200	
K4	30/04/2012 9:00																														180	
K4	3/05/2012 9:00																														230	
K4	6/05/2012 9:00																														240	
K4	9/05/2012 9:00																														260	
K4	12/05/2012 9:00																														260	
K4	15/05/2012 9:00																														180	
K4	18/05/2012 9:00																														270	
K4	19/05/2012 10:00	5	115	0.13		24.9	53	<1	2.7	140	141		3.4	<0.005	18.3	<0.01			<0.21	0.20		395		<0.01		<0.01		15	40.8	<0.002	230	
K4	19/06/2012 7:35	12	125			29.2	86	<1	1.7	160	153				22.3	<0.01			<0.09	0.09		330	<0.01	<0.01	<0.01	<0.01	<0.01				310	
K4	18/07/2012 12:00		98	0.075		25.5	94	<1		140	120		2.3		18.9	<0.01	<0.01												51.2			
K4	25/07/2012 17:45	6	130			36.3	99	<1	1.4	200	158				27.1	<0.01	<0.01	0.13	<0.15	0.13		380	<0.01	<0.01	<0.01	<0.01	<0.01				380	
K4	1/09/2012 12:00	7	133	0.17		36.2	127	<1	1.4	200	162		3.7	<0.005	26.8	<0.01	<0.01		0.10	0.10		327	<0.01	<0.01	<0.01	<0.01	<0.01	18	81.5	<0.002	410	
K4	19/10/2012 8:30	6	139			40.9	149	<1	3.4	230	169				30.8		0.02			0.14	<1	424	<0.01	0.00	<0.01	0.01	<0.01				NSS	470
K4	24/11/2012 11:45		135	0.1		38	145	<1		210	164		3.9		28.5	<0.01	<0.01												83.7			470
K4	25/11/2012 12:00	<2	140	0.12		38.1	138	<1	2.2	210	170	-1.7	4.2	<0.005	28	<0.01	0.02		0.24	0.24	<1	358	<0.01	<0.01	<0.01	<0.01	<0.01	18	81.1	<0.002	470	440
K4	26/12/2012 22:00					10.7	11	<1			61	-6.5	3		5.3						<1								5.4		94	71
K4	6/01/2013 14:00					8.1	9	<1			49	-8.4	2.9		4.6						<1								5.4		80	64
K4	19/01/2013 23:00					18.5	22	<1			67	15.0	4.5		12.5						<1								21.6		280	140
K4	13/02/2013 10:10	3	52			11	13	<1	3.6	52	64	-4.8	2.2		6	0.01	<0.01		0.21	0.21	<1		<0.01	<0.03	<0.01	<0.01	<0.03		7.7		75	
K4	30/03/2013 17:00	6	68			15.9	24	<1	3	77	83	-1.1	2.9		9.1	<0.01	0.01		0.18	0.19	<1		<0.01	<0.01	<0.01	<0.01	<0.01		15.6		130	
K4	9/04/2013 8:00	5	29	0.13	<0.1	6.4	8	<1	3.9	32	35	0.9	3.3	<0.005	4	<0.01	<0.01		<0.45	0.19	<1	386	<0.01	<0.24	<0.01	<0.01	<0.024	6.4	5.7	<0.002	56	52
K4	12/04/2013 21:00					9.3	9	<1			82	-15.0	3.3		5.2						<1								8			83
K4	16/04/2013 9:00					11.1	10	<1			46	12.0	3.4		6.5						<1								9.5			73
K4	19/04/2013 21:00					11.8	19	<1			52	4.1	4.4		7.2						<1								10.8			89
K4	23/04/2013 9:00					13.9	36	<1			55	-1.7	3.1		8.7						<1								14.2			110
K4	26/04/2013 21:00					14.1	33	<1			46	3.6	2.9		9						<1								14			110
K4	30/04/2013 9:00					15.7	42	<1			46	2.1	2.9		9.8						<1								16.2			120
K4	3/05/2013 21:00					16.4	39	<1			70	-1.8	3.1		10.4						<1								17.4			140
K4	7/05/2013 9:00					18.1	47	<1			76	-1.3	5		11.7						<1								20.9			160
K4	10/05/2013 21:00					20.2	48	<1			95	-0.4	3.3		13.4						<1								26.6			180
K4	14/05/2013 9:00					20.8	48	<1			98	-0.6	3.3		13.7						<1								27.3			180

Site	Time	Acidity	Alk.	Ba	Br	Ca	Cl	CO3	DOC	Hard.	HCO3	Ion bal. (%)	K	Li	Mg	NO2 N	NO3 N	SON	TON	TSN	OH	ORP	SOP	TOP	TSP	TRP	TPP	Si	Na	Ti	TDS 180	TDS sum
K4	17/05/2013 21:00					21.8	53	<1			88	2.9	3.3		14.7						<1								30			190
K4	20/05/2013 16:00	4	93	0.19	0.18	22.9	53	<1	2.4	120	113	1.0	3	<0.005	15.9	<0.01	0.02		0.22	0.18	<1		<0.01	<0.01	<0.01	<0.01	<0.01	12	34.7	<0.002	240	210
K4	5/06/2013 8:10	8	108			29.3	79	<1	2	160	132	0.7	4.2		19.9	0.01	0.03		0.15	0.24	<1	340	<0.05	<0.01	<0.005	<0.01	<0.01		47.6		350	280
K4	31/07/2013 10:55	10	119			36.3	143	<1	1.5	200	145				26.8	<0.01	0.06		0.12	0.12	<1				<0.010	<0.01					450	
K4	27/08/2013 9:40	8	133			43.1	153	<1	1.4	230	162				30	<0.01	0.01		0.11	0.09	<1				<0.010	<0.01					460	
K4	10/09/2013 7:50	10	138	0.17	0.46	41.6	157	<1	1.6	230	168	1.1	4.2	<0.005	31.8	<0.01	<0.01		0.16	0.10	<1	326			<0.010	0.01		16	88.6	<0.002	480	470
K4	28/09/2013 12:00	<2	140			41.7	175	<1	1.6	230	170		3.7		31	<0.01			0.13	0.09	<1			<0.01	<0.005	<0.01			83.4		510	520
K4	28/09/2013 12:00	4	141			33.5	90	<1	4.4	170	172		3.9		21.6	<0.01			0.30	0.25	<1			0.01	<0.005	<0.01			58.5		330	370
K4	17/10/2013 11:00	4	144	0.15		41.5	168	<1	3.3	230	175	-3.4	4.3	0.0042	31	<0.01	<0.01		0.48	0.41	<1	307			<0.010	<0.01		16	84.2	<0.0005	500	
K4	13/11/2013 0:30	<2	150	0.22		47.1	172	<1	2.4	250	182	0.3	6.8	0.0046	33.3	<0.01	<0.01		0.35	0.24	<1	343			0.02	<0.01		17	89.6	0.0008	500	500

Appendix D Summary discharge and water quality data for the D4 drain

Table D1 Annual discharge recorded each year in the July to June period at the D4 Drain outlet from 2010–13

Period	D4 (GL)	D4 (mm)
2010/11	62	517
2011/12	48	408
2012/13	33	274

Source: Ord Irrigation Cooperative

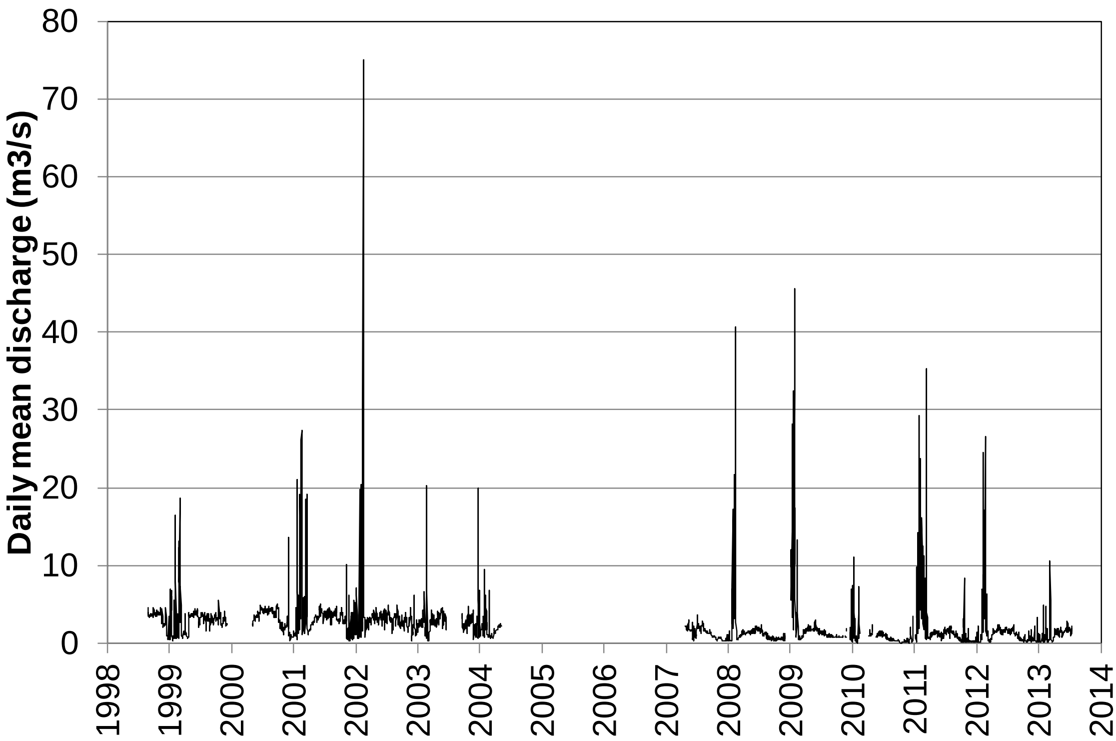

Figure D1 Daily mean discharge from the D4 drain (data source: Ord Irrigation Cooperative)

Table D2 Summary data for ANZECC and ARMCANZ (2000) listed aquatic environmental stressors and toxicants in all water samples from D4 drain during wet and dry seasons

Parameter	D4 dry season					D4 wet season				
	n	Mean	Median	COV	20th, 80th percentile	n	Mean	Median	COV	20th, 80th percentile
Stressors										
Temp	28	25.9	26.5	0.17	21, 31	7	30.0	29.5	0.09	28, 31
pH	124	8.0	8.0	0.04	7.6, 8.2	57	7.3	7.5	0.10	6.5, 8.0
EC	171	37	35	0.36	29, 44	73	38	31	1.28	11, 47
Turb.	57	104	41	3.31	10, 89	23	775	220	1.93	83, 1232
TSS	168	75	37	2.66	14, 79	126	542	357	1.11	95, 778
TN	148	1.11	0.73	0.88	1.90	117	1.31	1.10	0.60	1.80
NO_x/NO_3 N	135	0.19	0.07	2.36	0.19	34	0.19	0.11	1.13	0.37
NH_3 N	150	0.06	0.03	2.01	0.06	43	0.05	0.04	0.90	0.07
TP	166	0.092	0.070	0.81	0.120	125	0.213	0.200	0.59	0.290
SRP	159	0.042	0.030	1.15	0.058	58	0.052	0.041	0.73	0.076
Toxicants										
Atra.	107*	0.66	0.05	2.29	0.63	36*	0.50	0.05	4.30	0.28

* More than 25% of data is below LOR

Source: Ord Irrigation Cooperative and DAFWA

Table D3 Summary data for additional physicochemical parameters in all water samples collected from D4 drain in wet and dry seasons

Parameter	D4 dry season					D4 wet season				
	n	Mean	Median	COV	80th percentile	n	Mean	Median	COV	80th percentile
Nutrients										
NO_2 N	106	0.010	0.005	1.34	0.010	23	0.007	0.005	0.60	0.01
TON	135	0.66	0.43	0.86	1.03	33	0.50	0.44	0.63	0.65
TSN	49	1.3	1.1	0.69	1.94	3	0.52	0.51	0.37	0.63
SOP	58	0.005	0	1.61	0.010	18	0.009	0.010	1.28	0.01
TOP	62	0.041	0.04	0.80	0.06	36	0.14	0.15	0.44	0.19
TSP	58	0.026	0.02	0.60	0.04	18	0.065	0.055	0.62	0.09
TRP	62	0.036	0.03	0.66	0.05	36	0.060	0.050	0.67	0.08
TPP	59	0.046	0.04	0.87	0.08	18	0.16	0.17	0.28	0.20
General chemistry										
SO_4 S	63	14	8.8	0.79	25	19	21	24	0.37	25
TDS 180	62	188	190	0.24	210	36	108	110	0.43	150
Other elements										
Na	65	36	34	0.35	40	36	18	17	0.70	31

Source: Ord Irrigation Cooperative and DAFWA

Appendix E Keep River pools bathymetric survey report

SURRICH HYDROGRAPHICS Pty Ltd ABN: 11 139 627 642

KEEP RIVER POOLS

BATHYMETRIC SURVEY REPORT

SURRICH HYDROGRAPHICS JOB NO. SHP20140331

Client: LandCorp via:
Don Bennett
Department of Agriculture and Food Western Australia
PO Box 1231
Bunbury

Date: 11 February 2014

SURRICH HYDROGRAPHICS Pty Ltd ABN: 11 139 627 642

surrich HYDROGRAPHICS

REVISION HISTORY				
REV	DATE	REVISION DESCRIPTION	BY	APPROVED
A_draft	20/8/14	Issued for Client comment	JA	
B_final	29/8/14	final	JA	AR
C_final	9/9/14	Renamed 'K3' label to 'K4' in fig 5.	JA	

DISTRIBUTION LIST	
Department of Agriculture and Food WA	Don Bennett (Bunbury)
Surrich Hydrographics Pty Ltd	Project Manager

TABLE OF CONTENTS

SURRICH HYDROGRAPHICS Pty Ltd ABN: 11 139 627 642

1. ABBREVIATIONS

The following abbreviations may be used in this document

AHD	Australian Height Datum
BM	Bench Mark
CI	Confidence interval
DAFWA	Department of Agriculture and Food Western Australia
DGPS	Differential Global Positioning System
GDA94	Geocentric Datum of Australia 1994
GLONAS	Acronym for the Russian version of GNSS
GNSS	Global Navigation Satellite System
GPS	Global Positioning System - American version of GNSS
GRS80	Geodetic Reference System
HAT	Highest Astronomical Tide
HP	High Precision (Omnistar real time +/-10cm correction)
IHO	International Hydrographic Organisation
ITRF	International Terrestrial Reference Frame
kHz	Kilohertz
LAT	Lowest Astronomical Tide
MBES	Multi Beam Echo Sounder
MGA	Map Grid of Australia
MSL	Mean Sea Level
PPK	Post Processed Kinematic
IMU	Inertial Motion Unit
POSMV	Position Orientation System for Marine Vessel
PPK	Post Processed Kinematic
RTK GPS	Real Time Kinematic Global Positioning System
RMS	Root Mean Square
SBES	Single Beam Echo Sounder
SSM	Standard Survey Mark
THU	Total Horizontal Uncertainty
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UTM	Universal Transverse Mercator
VBS	Virtual Base Station (Omnistar sub-metre correction)
WA	Western Australia
WL	Water Level
WGS84	World Geodetic System of 1984

Table 1. Abbreviations

2. INTRODUCTION

Surrich was contracted by Landcorp, through the Department of Agriculture and Food Western Australia, (DAFWA), during June 2014, to perform a bathymetric survey of the Keep River pools. relevant to ongoing hydrological investigations. The pools, named K1, K2, K3 and K4[(1)],are relevant to ongoing hydrological investigations by DAFWA.

The principal aim was to determine the typical dry season volumes of the pools.

A secondary aim was to determine the elevation of the base of the pools to AHD for possible future reference (e.g. for use in groundwater models). This requires knowledge of the water levels to Australian Height Datum (WL AHD).

SURRICH HYDROGRAPHICS Pty Ltd ABN: 11 139 627 642

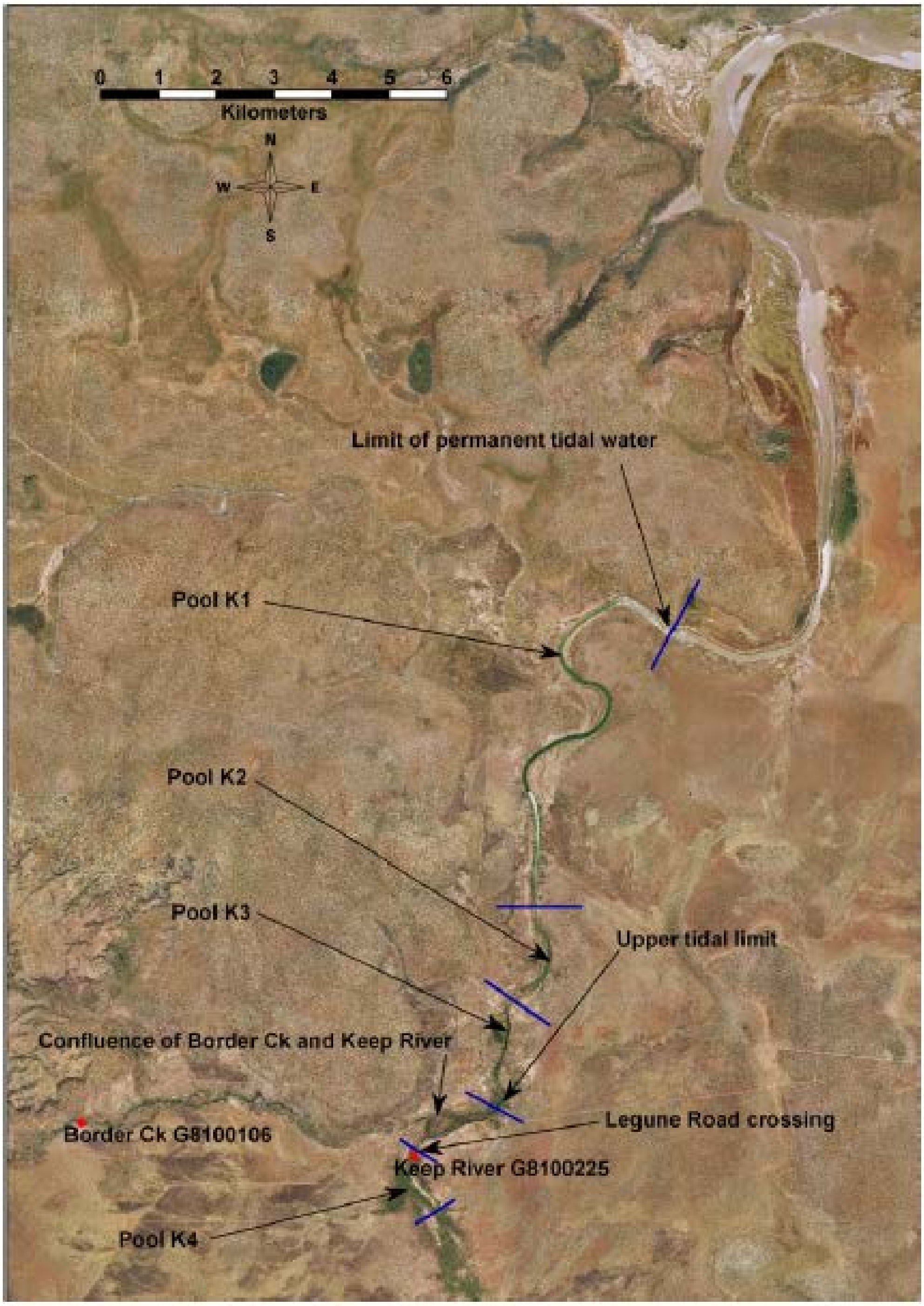

Figure 1. Location

3. EQUIPMENT

Bathymetry	Odom CVM sounder with 3° narrow beam transducer.
Positioning	Rover and Base: Novatel DLV3 dual frequency, GNSS units acquiring GPS + GLONASS. Omnistar HP/VBS corrections acquired in real time. Raw data logged for post processing (GPS + GLONASS).
Vessel	DAFWA aluminium dingy.

Table 3. Equipment.

Figure 2. *DAFWA* vessel showing over the side pole configuration with GPS antenna above and sounder transducer below the water.

4. METHODOLOGY

A narrow beam, single beam echo sounder was used to record depths. The narrow beam unit was chosen to minimize the footprint of snags (trees) in the river, assisting the process of removing these features from the record during processing.

Omnistar HP/VBS RTK corrections were used to provide reasonable horizontal accuracies in real time, and the ability to post process the GNSS positioning data was also included.

Because of the vegetation overhanging the river banks, it is not possible to obtain accurate GNSS WL AHD heights for every sounding. Therefore a WL AHD surface needs to be defined to allow calculation of the riverbed elevation to AHD.

Acquiring accurate heights was considered necessary to generate an AHD water surface model. The water surface of a stationary pool can be expected to have a constant AHD elevation across its entire surface (AHD is effectively parallel to the geoid over scales of several km). However, if there is some base-flow across the pool boundaries the AHD elevation of the water surface may fall downstream particularly in the longer pools.

Acquisition profiles were run along the river. Firstly lines were conducted close to the river banks. Then 2 to 3 central profiles were run depending on the width of the river. Navigation was done by estimation (i.e. not following planned run lines).

5. OPERATIONS

The water level in the pools is known to be affected by river flows and spring tides(1). For this reason the survey was undertaken during a period when the Keep River was flowing at its baseflow rate (< 50 L/sec measured at Legune Crossing) and also during a period of neap tides (as forecast and observed at Wyndham).

Data was acquired over the following dates.

Date	Pool
Sunday, 20 July 2014	K3
Monday, 21 July 2014	K3
Monday, 21 July 2014	K4
Tuesday, 22 July 2014	K1
Wednesday, 23 July 2014	K2

Table 4. Acquisition dates.

6. PROCESSING

6.1. DATUM

All data was acquired, or post processed to the ITRF08 coordinate system. The final data has been transformed to GDA94 using 7-parameter transformation calculated for the date 21/7/04. The AUSPOS report in Appendix 1 contains the values used.

The final positions are reported in the MGA zone52 South projection.

6.2. BATHYMETRY

Echo sounder depths were de-spiked using the “Hypack Single Beam Editor” software. The spikes methodically removed were typically where the indicated depths were shallow and narrow. These were attributed to branches and trunks of dead trees in the river.

All depth data provided has been corrected to the waterline based on calibration checks performed during surveying.

6.3. POOL SURFACE AREAS

The sounding locations were plotted over a geo-referenced dry season ortho-photo. The boundary of the river (at the waters edge) was then estimated and digitized in ‘Hypack’ software.

The surface area of the digitized boundaries was calculated from the boundary file in the Hypack software.

6.4. POOL VOLUME CALCULATIONS

Depths were gridded using 'Surfer' software using the 'minimum curvature' gridding technique at a 1m cell size. The digitized water boundary was included in the gridding process as a 'break-line' with a 0m value.

The resultant grid values outside the waters boundary were ignored in further analysis. The volume of each pool was calculated by the Surfer software.

Pool K4 had sections where the pole supporting the transducer and the GPS receiver needed to be tilted to clear fallen trees and overhead vegetation. In these locations it was not possible to acquire data. In order for the gridding process to generate a realistic river profile, data was interpolated through the areas of missing data utilizing the 'break-line' technique during gridding.

6.5. POST PROCESSING OF GNSS POSITIONING DATA

K1, K2 and K3 have adequate sub-metre horizontal accuracies. In pool K4, accuracies achieved during acquisition were not adequate and the 'post processed kinematic' (PPK) was used for final data positioning. The PPK positions provide a much more robust solution when operating in and out of the numerous overhanging trees.

The PPK height data was analysed in all pools.

'Forward' and 'reverse' PPK solutions were calculated and combined using Applanix PosGNSS software.

A temporary GNSS base station was mounted in the middle of the survey area for the duration of the survey. The AUSPOS processing report is included in Appendix 1. The data indicates that a well-constrained position for the base antenna was achieved.

6.6. HORIZONTAL POSITIONING

Sub-metre horizontal positioning accuracies were considered adequate for this survey.

Data was acquired in real-time to ITRF2008 using Omnistar HP/VBS corrections. On occasions when the HP solution was momentarily lost due to overhanging branches, the solution drops back to a more robust VBS solution, which although is less accurate, is also sub-metre.

In pools K1, K2 and K3 which were generally clear of overhanging vegetation, this correction was adequate and all horizontal positions can be considered to be sub metre.

In pool K4 there was significant vegetation on the river banks and overhead. This adversely affected most of the real-time positions. Therefore, in K4 post-processed GNSS positions were used (as they have significantly improved performance under vegetation) and this data was merged into the K4 bathymetry.

6.7. VERTICAL POSITIONING

Knowledge of the WL AHD is required to calculate the AHD elevation of the river bed.

Post processing was performed on the GNSS data recorded in all pools. The ellipsoid heights were transformed from ITRF08 to GDA94, and converted to AHD by applying the Ausgeoid09 undulation and GPS antenna offset from the waterline. Spurious and low accuracy data was removed and the results for each pool were plotted as Northing versus WL AHD. This was used to generate the WL AHD model for each pool.

7. PRE AND POST SURVEY CHECKS

The following reference marks, that were installed by DAFWA and surveyed by a local surveyor, were used to determine the WL AHD independently of the GNSS results.

Pool	Reference mark description	Reference mark AHD	Water level AHD	Position MGA Z52
K1	Star picket	3.497m	3.592m	508920.519 8303809.316
K2	Star picket	3.818m	3.798m	509250.485 8300572.263
K3	Star picket	3.754m	3.722m	508471.613 8298136.637
K4	Gauging station	9.497m	5.277m	506937.636 8297011.729

Table 5. Comparison of water surface elevation by direct measurement from the reference posts, and with the post processed GNSS data acquired during this survey

The reference marks in pools K1–K3 are located in about the longitudinal centre of each pool, whereas K4s' reference is located more towards its downstream end.

Survey accuracies were reported to be in the order of 0.03-0.05m depending on tree cover.

The WL AHD in upstream pool K3, was found to have a lower elevation than the downstream pool K2 when measured against the reference marks. This is illogical, given that there were no tide effects and there was a small gradient-induced flow of water from K4 to K1. There is no practical explanation for this apparent error — other than recent movement of the reference marks, or survey errors.

This apparent error is also discussed further in the next section.

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8. COMPARISON OF POST PROCESSED HEIGHTS AGAINST INDEPENDENTLY SURVEYED REFERENCE MARKS

The PPK derived WLs show close agreement with the reference marks in K3 and K4. However, there is a 0.15m level shift with the reference marks in pools K1 and K4 as detailed in the table and figure below.

	Units	K1	K2	K3	K4
Surveyed top of post (AHD)	M	3.50	3.82	3.75	9.50
Measured WL above top of post	M	0.10	-0.02	-0.03	-4.22
Calculated WL AHD (from reference post)	M	3.59	3.80	3.72	5.28
WL AHD (from post processed GNSS)	M	3.44	3.65	3.69	5.28
Difference (calculated WL minus processed WL)	M	0.15	0.15	0.04	0.00

Table 6. Comparison of water surface elevation by direct measurement from the reference posts, and with the post processed GNSS data acquired during this survey

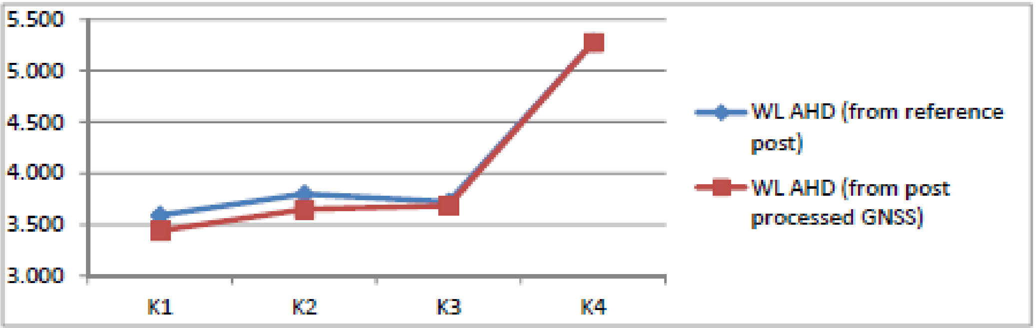

Figure 3. Graph of the comparison of water levels from the table above

Although the differences in K1 and K2 are within the calculated error budget, the independently surveyed WL shows pool K3 WL to be below the down-stream K2 WL. As this is illogical given the observed conditions the PPK WL data was used in preference to the independently surveyed reference marks.

9. WATER LEVEL AHD MODEL

To determine if there is a significant height gradient to the water surface along the length of the pools the MGA Northing was plotted against WL AHD for pools K1, K2 and K3.

K4 was not analysed as the PPK GNSS was acquired through tree canopy and the accuracy can not be relied on for this analysis.

The results (table below) show there is a negligible gradient to the WL in pools K3 and K2 in particular. K1 has a minor gradient of 0.06m along its 7 km length. After discussions about the requirements of the survey with Don Bennett (DAFWA) it was decided to ignore the small gradients for the purposes of subsequent calculations.

		Northing	WL AHD
K1	downstream end	8306590	3.41
K1	ref mark	8303809.316	3.44
K1	upstream end	8301430	3.47
K2	downstream end	8301015	3.655
K2	ref mark	8300572.263	3.655
K2	upstream end	8299850	3.656
K3	downstream end	8299570	3.67
K3	ref mark	8298136.637	3.68
K3	upstream end	8297630	3.69
K4	downstream end	8297070	5.28
K4	ref mark	8297031	5.28
K4	upstream end	8295690	5.28

Table 7. Water level variations along each pool (PPK data).

10. DATA QC

The following data QC checks were performed during the survey:

- A latency check of the sounder/GNSS/Hypack acquisition system was performed prior to mobilization.
- The depth of the sounder and height of GPS above WL was checked each day before surveying commenced and rechecked several times during the day whilst surveying.
- Sounder calibration checks were performed at the start and end of the survey.
- PPK water levels were compared to the water levels at the reference pegs to ensure the data matched within the error budget.
- Pool surface area calculations were converted to a simplified model represented by a rectangle to check that the dimensions appeared reasonable.
- Pool volume calculations were converted to a simplified model represented by a rectangular prism to check that the dimensions appeared reasonable.
- The post processed water elevations are averaged over the duration of the survey for that pool (several hours), so height errors from vessel rocking were insignificant.
- A fixed GNSS base position was used throughout the survey. The base positions was calculated at the start and end of the survey using the AUSPOS service. The calculated positions results are within 0.002m in the horizontal and vertical indicating there was no movement in base position. The base coordinates were saved in the post processing software to ensure their uniform application and prevent human error.
- 2 separate AUSPOS calculations of the base location were performed using different time spans of data to check repeatability and ensure the base antenna had not moved.
- All antenna positions were calculated to the antenna L1 phase centre to ensure errors could not be introduced by differing antenna parameters.
- An identical processing script was used to apply the corrections from ITRF08 to AHD according to the following schedule:
    - Convert post processed ITRF08 ellipsoid heights, to GDA94 ellipsoid heights.
    - Apply correction for height of antenna above the WL.
    - Apply the Ausgeoid09 undulation value to correct from GDA94 ellipsoid height to AHD.

11. RESULTS

11.1. WATER DEPTH GRIDS

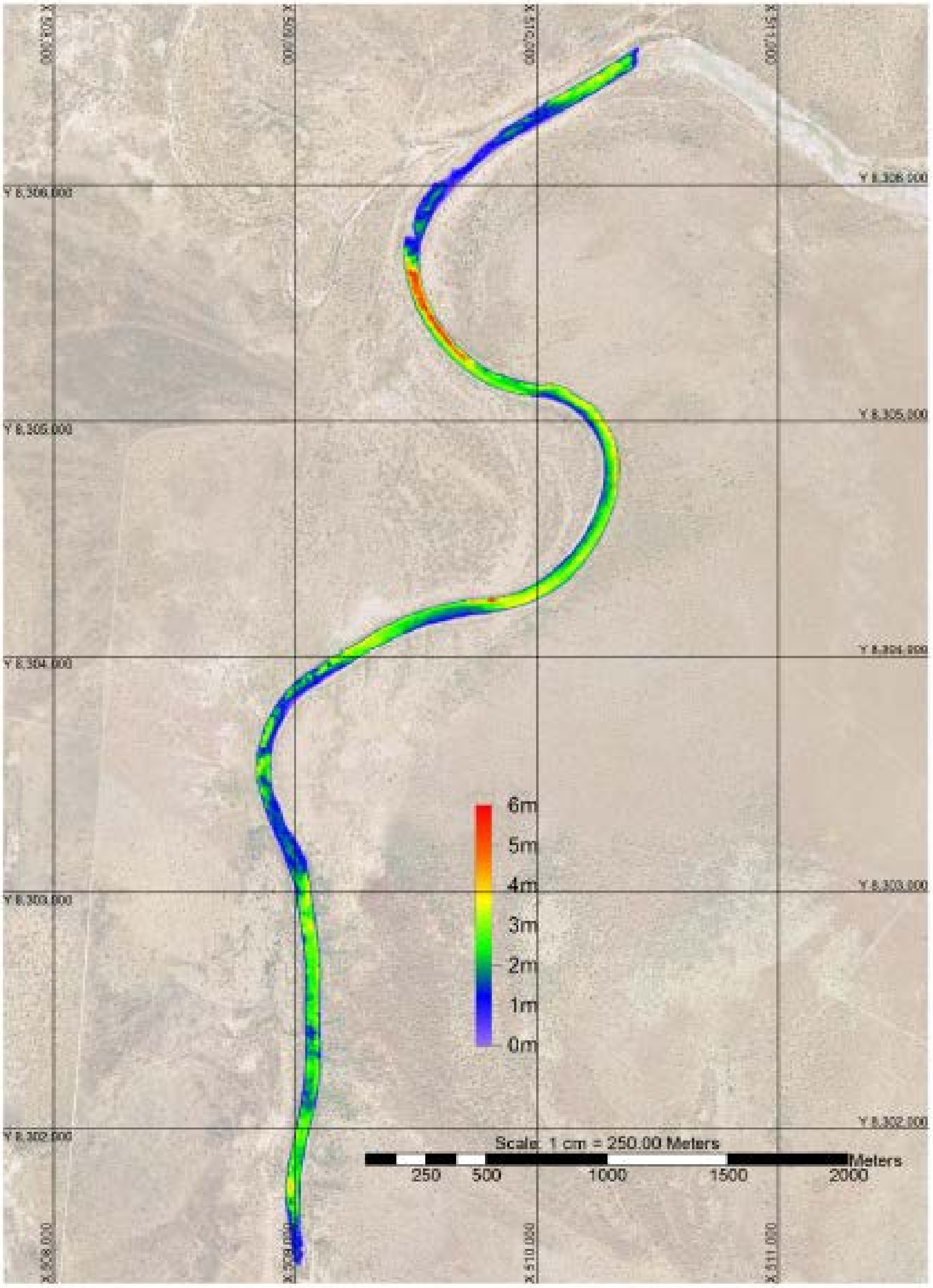

Figure 4. Pool K1 depth (under baseline conditions of tide and flow)

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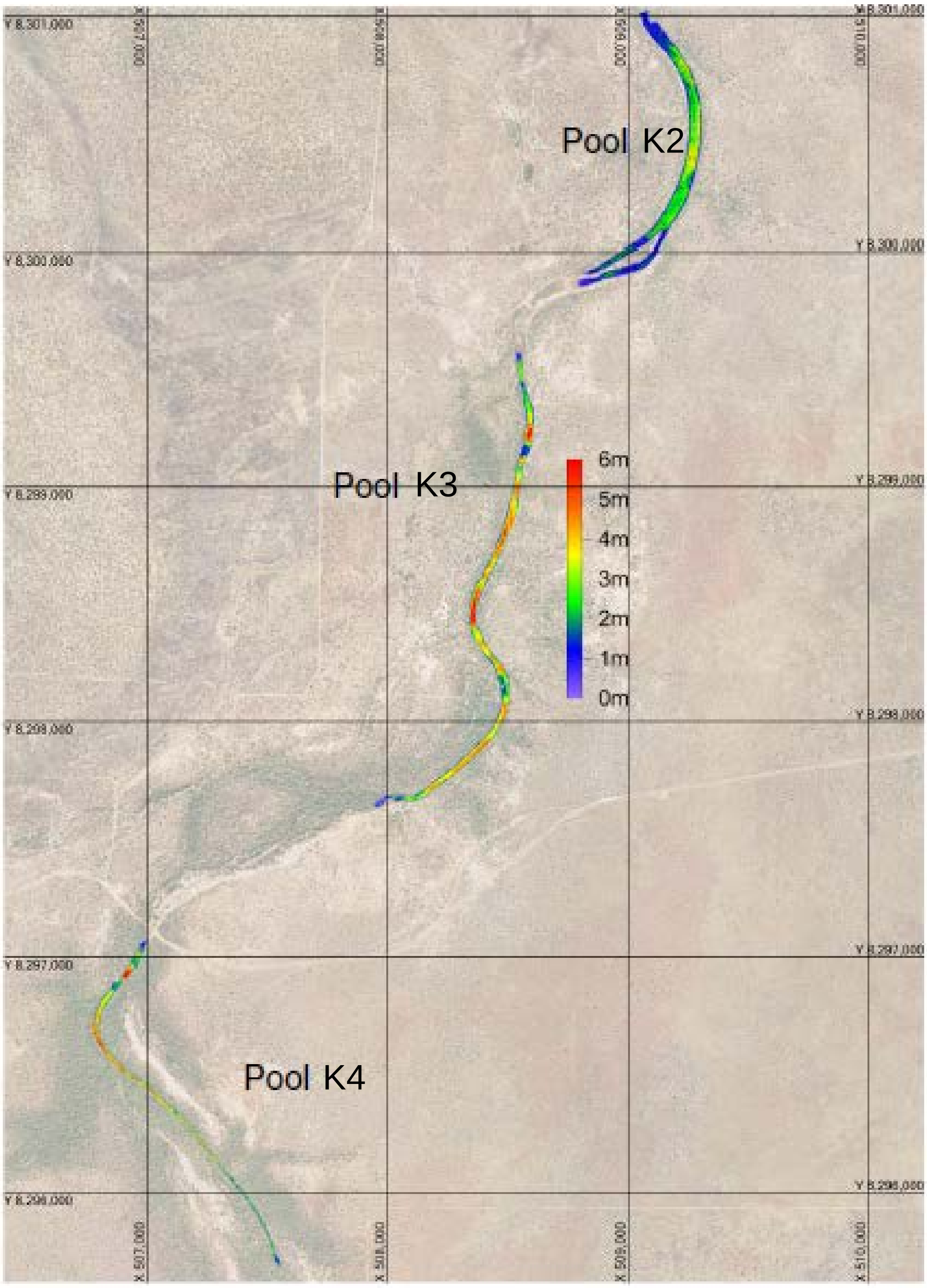

Figure 5. Pool K2 K3 and K4 depth (under baseline conditions of tide and flow).

11.2. RIVERBED ELEVATIONS GRIDS

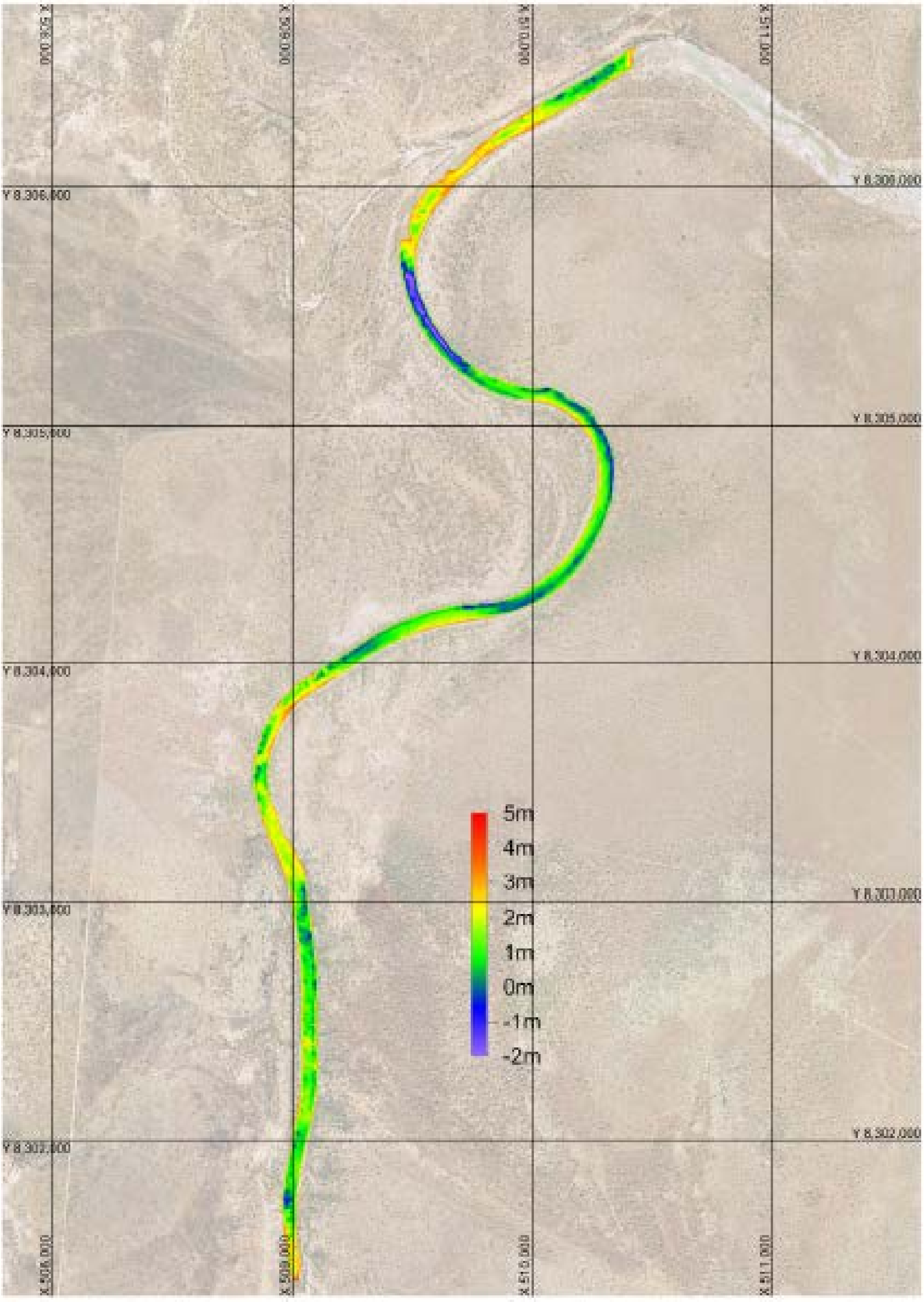

Figure 6. Pool K1 elevation of riverbed (AHD)

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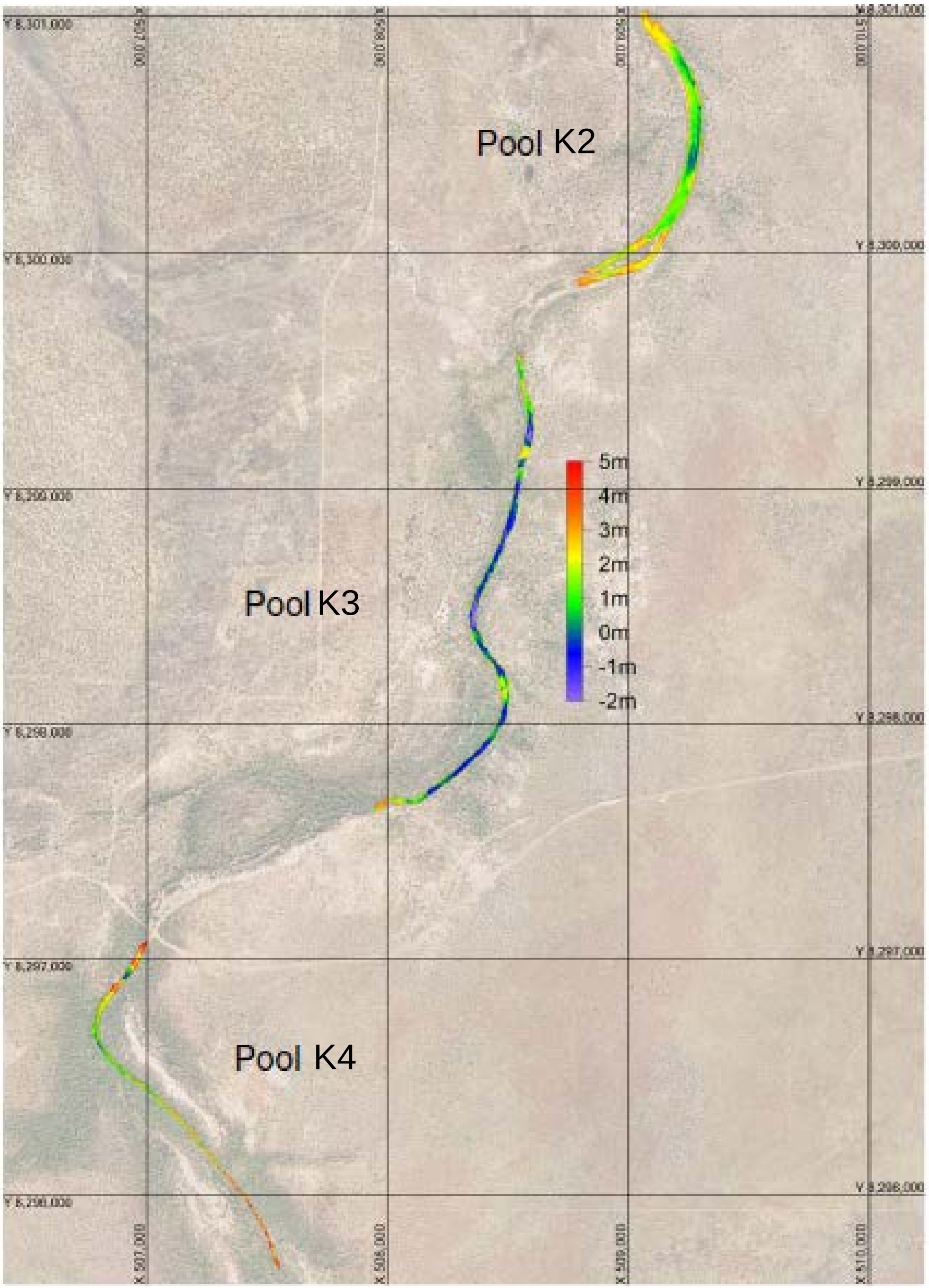

Figure 7. Pool K2 K3 and K4 elevation of riverbed (AHD)

11.3. SURFACE AREA AND VOLUME CALCULATIONS

The calculated surface area of each pool (under baseline conditions of tide and flow) is compared against a rectangular surface model as a 'QC check'.

		QC check only	
Pool	Area (m.sq)	Measured length (m)	Calculated width (m)
K1	445500	6820	65
K2	77650	1350	58
K3	68258	2300	30
K4	25027	1720	15

Table 8. Calculated water surface area.

The calculated volume of each pool (under baseline conditions of tide and flow) is compared against a rectangular prism model as a 'QC check'.

		QC check only		
Pool	Volume (cu.m)	Measured length (m)	Calculated width (m) *	Calculated depth (m)
K1	922630	6820	65	2.1
K2	140890	1350	56	1.9
K3	200780	2300	29	3.0
K4	68950	1720	15	2.7

* the 'Calculated width' is carried down from the surface area calculation.

Table 9. Calculated water volume.

11.4. ERROR ANALYSIS OF SURFACE AREA

A statistically rigorous error analysis has not been performed, however one simple calculation has been done to get a handle on the uncertainty of the surface area calculation.

The 'rectangular model' calculated in the QC check was altered by adding 4m to the width. This was to simulate over-biasing the water boundary by 2m on each side. This resulted in an increase in surface area of 6% for pools K1 and K2, and 13% and 27% for pools K3 and K4 respectively.

The narrower the pool, the greater is its susceptibility to error in the surface area calculation, which in turn is caused by errors in the digitized water boundary.

11.5. ERROR ANALYSIS OF POOL VOLUME

A statistically rigorous error analysis has not been performed however two simple checks have been done to get a handle on the uncertainty in the pool volume calculation:

1. Based on a 0.05m estimated sounder uncertainty added to an estimated 0.05m draft uncertainty, the depths in pool K3 were increased by 0.1m, the data re-gridded and the volume recalculated. This resulted in an increase in pool volume of 3% and had no effect on the surface area.
2. The water boundary of K3 was re-digitized with a bias towards strongly over-estimating the water surface of the pool. The data was re-gridded and volume calculated. This resulted in an increase in pool volume of 8%.

In addition the following factors also affect uncertainty of the volume calculation:

- The actual river boundary compared to the ortho-photo used to assist digitization of the boundary. This may change after flood events.
- The gridding technique.
- The roughness of the river bed.
- Sounder sampling density and beam size,
- The modelled cross-section profile of the pool compared to the actual profile.

If an uncertainty value is required to be used in calculations, the author considers that a standard deviation of 10% of the measured volume may be a considered reasonable value, with the disclaimer that this value is an estimate.

12. ERROR ANALYSIS OF DEPTH MEASUREMENTS

The 68% confidence interval (CI) is calculated by taking the square root of the sum of the squares of the independent errors. The 95% CI is calculated by multiplying the 68% CI by 1.96.

Error Source	value	units	Notes
Sounder error	0.02	m	
Squat and trim error	0.05	m	changes in vessel draft and orientation through water as speed and balance changes

Uncertainty 68% CI	0.05	m
Uncertainty 95% CI	0.11	m

Table 10. Depth measurement uncertainties.

12.1.

13. ERROR ANALYSIS OF WATER LEVEL ELEVATION MEASUREMENTS

Error Source	value	units	Notes
Auspos vertical error	0.02	m	
Post Processed vert error	0.05	m	Negligible as multiple readings are being averaged to determine WL
Measurement error	0.02	m	Antenna to WL when vessel stable
Non vertical pole error	0.061	m	calculated for antenna nominally 1.797m above WL and 10deg constant offset on vessel.
Squat and trim error	0.05	m	changes in vessel draft and orientation through water as speed and balance changes.

Uncertainty 68% CI	0.10	m
Uncertainty 95% CI	0.19	m

Table 11. Water Level elevation measurement uncertainties

14. DIGITAL DATA

The following digital data has been supplied (to Don Bennett, DAFWA), and is comprised of the following:

- Ascii data
    - comma separated file consisting of:
        - MGA Easting, Northing, depth, riverbed_AHD
- Geotiff
    - Depth
    - Depth with colour bar
    - Depth with colour bar 2 (larger text on colour bar)
    - Riverbed AHD
    - AGD with colour bar
    - AGD with colour bar 2 (larger text on colour bar)

    - The tiff with colour bar is also included to be of assistance when presenting.
    - Depth colour bar range = 0 to 6
    - AHD colour bar range = -2 to 5m

- Surfer grids
    - A common grid format. Compatible with most GIS

15. CONCLUSIONS

- The Keep River pool depths were mapped (under baseline conditions of tide and flow) using a SBES to record depths, and GNSS positioning.
- Pool volumes were calculated under baseline conditions of tide and flow. These volumes will vary according to changes in river flow groundwater inflow and tide effects.
- The riverbed within the navigable areas of the pools has been surveyed to AHD.
- The surveying has been performed to an adequate standard in terms of accuracies and coverage as set by the client's representative.

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Shortened forms

AADTVTA	ANZECC and ARMCANZ (2000) default trigger values for Tropical Australia
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand (former)
CaR	cadmium reduction
CMS	coupled mass spectroscopy
COV	coefficient of variance
CR	colorimetric reaction
DA	discrete analyser
DAFWA	Department of Agriculture and Food, Western Australia
DLRM	Department of Land Resource Management
DO	dissolved oxygen
EC	electrical conductivity
EPBC Act	*Environmental Protection and Biodiversity Act 1999*
ICPAES	inductively coupled plasma atomic emission spectroscopy
ILTV	interim local trigger value
IRG	Independent Review Group
LOR	limit of reporting
LTV	local trigger value
mAHD	elevation in metres with respect to the Australian height datum
NATA	National Association of Testing Authorities
NCTWR	National Centre for Tropical Wetland Research
NES	matters of national environmental significance
OIC	Ord Irrigation Cooperative
ORIA	Ord River Irrigation Area
ORP	oxidation–reduction potential
OSWM	Operational Surface Water Model
PD	persulphate digestion
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SPL	species protection level
SRP	soluble reactive phosphorus
TDS	total dissolved solids

TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
Turb.	turbidity
TV	trigger value
WRM	Wetland Research and Management

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