Shag River/Waihemo catchment: water quality and ecosystem

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Overview

Background

The Otago Regional Council (ORC) is responsible for managing Otago's groundwater and surface water resources. Although ORC carries out regular and extensive long-term water quality monitoring as part of its State of the Environment (SoE) programme, it has not previously carried out a targeted, short-term monitoring investigation in the Shag River/Waihemo catchment.

Why was this targeted investigation deemed necessary?

This investigation was undertaken to:

- Provide a baseline of water quality in the Shag River/Waihemo catchment, including at reference sites(with low-intensity land use),
- Compare water quality in the Shag River/Waihemo catchment to water quality limits set out in Plan Change 6A,
- Identify any patterns in water quality in the Shag River/Waihemo catchment and to relate these to land-use activities, where possible.

What has this study found?

- Water quality in the Shag/Waihemo catchment is generally good.
- The concentration of nitrate-nitrite nitrogen (NNN) increased at both long-term monitoring sites over the period 2001-2013 while concentrations of ammoniacal nitrogen (NH_4-N) and *Escherichia coli* declined over this period. Dissolved reactive phosphorus (DRP) increased at Goodwood Pump site, but not at Craig Road. This trend may result from the deposition of sediment in the lower river during recent high-flow events. Flow records indicate that such events have been more frequent in the past decade that in the preceding one.
- *Escherichia coli* counts were relatively low at sites sampled in 2012-2013 and indicate low densities of stock with access to waterways and adjacent areas.
- Water quality in the Shag/Waihemo catchment was compared to the receiving water limits in plan change 6A. All sites were likely to comply with limits for NH_4-N, DRP and turbidity, although Goodwood Pump approached the DRP limit. However, the limited data from the 2012-2013 study suggest that only Collins Bridge and The Grange were likely to comply with NNN limits and Craig Road, Goodwood Pump and Deepdell Creek were likely to comply with the *E. coli* limit.
- Benthic cyanobacteria and diatoms were often among the dominant periphyton taxa.
- Macroinvertebrate biomonitoring indicated that water quality was highest at Collins Bridge site and declined downstream.
- The Shag/Waihemo catchment supports a diverse fish community, including several species of conservation concern.

What should be done next?

The results of this study will be used to guide future policy decisions and to promote good practice among the community and other stakeholders to maintain and enhance water quality in the Shag/Waihemo catchment.

Technical summary

The Shag River/Waihemo is a small river arising on the slopes of Kakanui Peak and flowing in a south-easterly direction past the township of Palmerston before entering the Pacific Ocean just south of Shag Point/Matakaea. Most of the catchment consists of agriculture and forestry with some short-rotation cropping in the lower catchment.

The objectives of this report are to:

- Provide a baseline of water quality in the Shag River/Waihemo catchment, including at unimpacted (reference sites),
- Compare water quality in the Shag River/Waihemo catchment to water quality limits set out in Plan Change 6A,
- Identify any patterns in water quality in the Shag River/Waihemo catchment and to relate these to land-use activites, where possible.

Water quality in the Shag/Waihemo catchment is generally good. However, a significant increasing trend in the concentration of TN and NNN was detected for the Craig Road SoE site, and for NNN at the Goodwood Pump site. Increasing NNN at both sites suggests an increase in nitrogen leaching, with this nitrogen entering the river via groundwater inputs. In contrast, significant declining trends were evident for NH_4-N and *E. coli* indicating improved land-use practices. However, an increasing trend in DRP was observed at the Goodwood Pump site, but not at Craig Road. This trend is unlikely to have resulted from the operation of the Palmerston waste water treatment plant and may result from the deposition of sediment in the lower river during recent high-flow events. Flow records indicate that such events have been more frequent in the past decade than in the preceding one.

Escherichia coli counts were relatively low at sites sampled in 2012-2013 and indicate low densities of stock with access to waterways and adjacent areas.

Water quality at sites in the Shag/Waihemo catchment sampled in 2012-2013 and at SoE sites was compared to the receiving water limits in plan change 6A. Values calculated on the basis of data from the 2012-2013 period are limited and should be interpreted cautiously. The results of these comparisons indicate that:

- All sites were likely to comply with limits for NH_4-N, DRP and turbidity, although Goodwood Pump approached the DRP limit. Given the increasing trend in DRP observed at this site, it is likely that this site will not comply with the DRP limit in the near future.
- Collins Bridge and The Grange were the only sites sampled that are likely to comply with NNN limits, while Deepdell Creek was equal to the limit.
- Craig Road, Goodwood Pump (based on the 5-year 80^{th} percentile), Deepdell Creek and Collins Bridge complied with the *E. coli* limit.

Comparison of 80th percentiles of water quality parameters with receiving water quality limits in plan change 6A (Schedule 15, Table 3.1). Values that exceeded the limit are highlighted in red and those that are at the limit are highlighted in orange. All values calculated using samples collected when flows were at or below median flow (649 l/s), as this is when Schedule 15 limits apply. Values calculated for the 2012-2013 period are based on limited data and should be interpreted cautiously.

Site	Period	NNN 0.075 mg/l	NH_4-N 0.1 mg/l	DRP 0.01 mg/l	*E. coli* 260 cfu/100 ml	Turbidity 5 NTU
Shag R. - Collins Bridge	2012-2013	0.010	0.005	0.002	260	-
Shag R. - The Grange	2012-2013	0.033	0.005	0.004	410	-
Shag R. - Craig Road	2012-2013	0.089	0.005	0.0044	190	1.1
	2008-2013	**0.087**	**0.005**	**0.0062**	**132**	**0.6**
Shag R. - Horse Range Rd	2012-2013	0.120	0.010	0.002	280	-
Shag R. - Goodwood Pump	2012-2013	0.242	0.010	0.009	274	1.3
	2008-2013	**0.485**	**0.011**	**0.009**	**204**	**0.7**
Deepdell Creek	2012-2013	0.075	0.005	0.005	47	-
McCormick Creek	2012-2013	0.870	0.005	0.006	300	-

Water temperature records indicate that high water temperatures are likely to affect trout growth and/or survival may be affected by high water temperatures in parts of the Shag/Waihemo catchment at times.

Habitat quality was good at most sites, although fine sediments reduced habitat quality at Goodwood Pump and McCormicks Creek. Most sites had intact riparian buffers, although evidence of direct stock access was noted at Horse Range Road and Deepdell Creek. Riparian vegetation was dominated by exotic species.

The composition of the periphyton at both SoE sites varies from year to year with benthic cyanobacteria and diatoms commonly being the dominant taxa. Given this, warning signs should continue to be erected at main access points to educate the public to their presence and the risks they pose to people and animals. The frequent dominance of samples taken from The Grange by the filamentous green alga *Cladophora* over the period 2001-2008 suggests that nutrient concentrations at this site are enriched, possibly due to low nitrogen uptake by algae in upstream areas due to shading of the water resulting from the steep gorge upstream.

Macroinvertebrate sampling as part of SoE monitoring indicates that water quality has been relatively consistent since 2001. Macroinvertebrate metrics were highest at Collins Bridge site and declined downstream, largely as a result of the effects of land use practices.

The Shag/Waihemo catchment supports a diverse fish community. Sixteen fish species have been recorded from the Shag/Waihemo catchment, including 14 native species and 2 sportsfish (brown trout and brook char). Seven of the native species recorded are of conservation concern.

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1. Introduction

The Shag River/Waihemo is a small river arising on the slopes of Kakanui Peak and flowing in a south-easterly direction past the township of Palmerston before entering the Pacific Ocean just south of Shag Point/Matakaea (Figure 2.1). Its northern tributaries arise on the slopes of the Kakanui Mountains and Horse Range, while southern tributaries drain rolling hill country.

The Maori name for the Shag River is Waihemo (*Wai* = water, *hemo* = to go to ground), possibly a reference to the very low flows observed in the lower reaches of the river during summer. The Shag River has long had a reputation for very low flows in its lower reaches and for prolific growths of periphyton during such times. This is reflected in the minimum flow of 28 l/s at Goodwood Pump in the lower reaches, compared with a minimum flow of 150 l/s at Craig Road further upstream (Otago Regional Council, 2014).

The Shag River/Waihemo catchment is dominated by agricultural and forestry land uses with some short-rotation cropping in the lower catchment. Water availability has long been identified as a constraint on agricultural development in the catchment (ORC 1991). Primary allocation in the Shag/Waihemo catchment is currently over-allocated, which is likely to limit the potential for further land-use intensification without significant investment in water storage.

In addition to other land uses, Oceana Gold operates a large open-pit and underground Macraes gold mine in the Deepdell Creek catchment and its operations are controlled by a large number of resource consents. This report does not consider the water quality effects of the mine.

1.1 Purpose

The objectives of this report are:

1. To provide a baseline of water quality in the Shag River/Waihemo catchment, including at unimpacted (reference sites),

2. Compare water quality in the Shag River/Waihemo catchment to water quality limits set out in Plan Change 6A,

3. Identify any patterns in water quality in the Shag River/Waihemo catchment and to relate these to land-use activites, where possible.

2. Background Information

2.1 Catchment description

The Shag River/Waihemo rises in the Kakanui Mountains, before flowing almost 90 km in a south-easterly direction to the coast, entering the Pacific Ocean just south of Shag Point/Matakaea (Figure 2.1). It drains a total catchment area of 550 km^2. The largest single tributary of the Shag River/Waihemo is Deepdell Creek, which drains from Taieri Ridge near Macraes Flat (Figure 2.1).

Oceana Gold Ltd. operates a hard-rock goldmine at Macraes Flat, including several open pits as well as underground mining. The Macraes open pit mine has been in operation since 1990 and the Frasers underground mine was commissioned in 2008. Overall the Macraes gold mining operation has produced over 3 million ounces of gold to date. The existing mine operation discharges water and contaminants to the Deepdell Creek catchment, Tipperary Creek, a tributary of McCormicks Creek and Murphys Creek, a tributary of the Waikouaiti River North Branch.

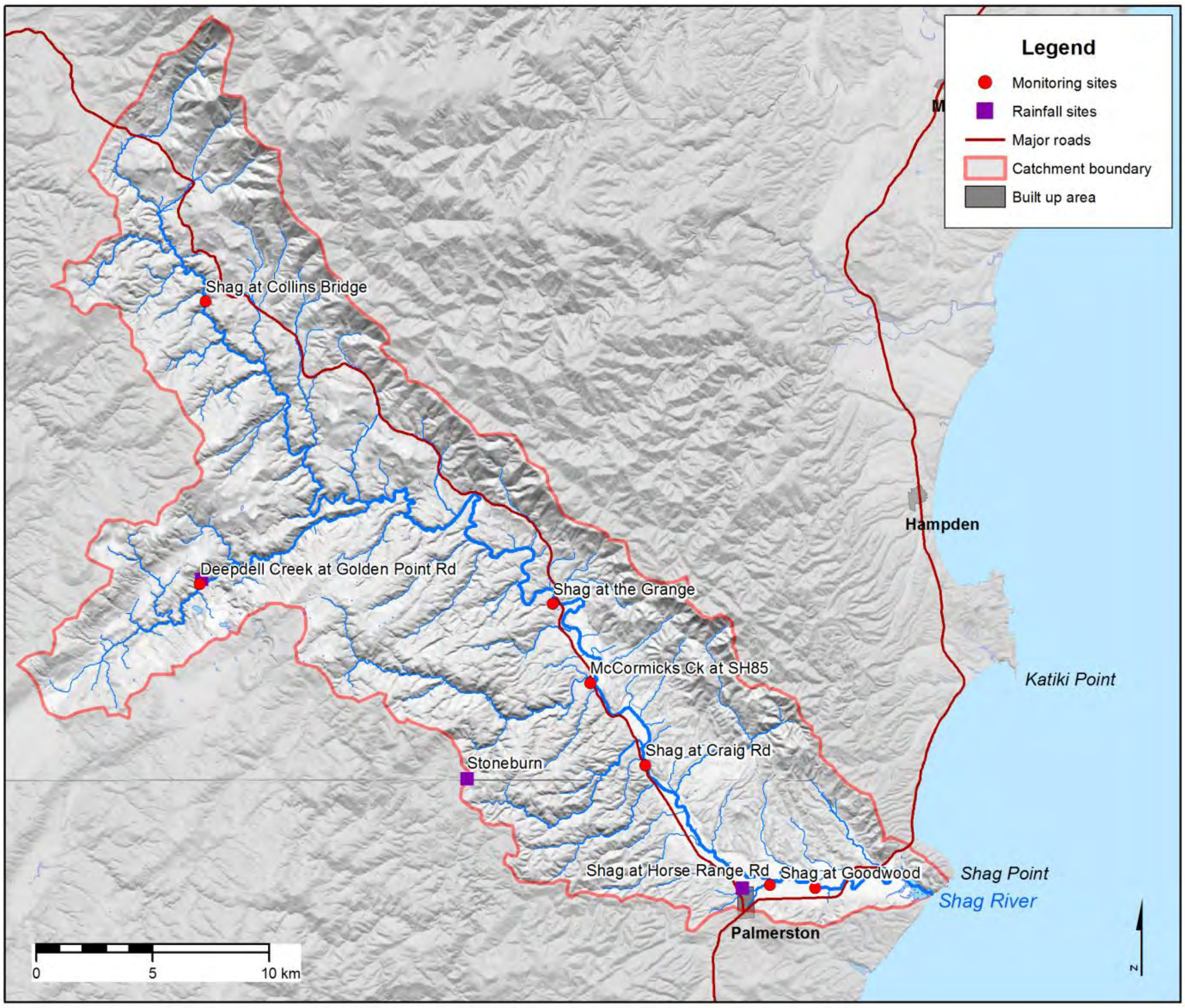

Figure 2.1 Shag/Waihemo catchment showing water quality and rainfall monitoring sites

2.1.1 Climate

The climate of most of the Shag River/Waihemo catchment is classified as ‗cool-dry' (mean annual temperature <12°C, mean effective precipitation ≤500 mm), with limited areas classified as ‗cool-wet' (mean annual temperature <12°C, mean effective precipitation 500-1500 mm) (River Environment Classification, Ministry for the Environment & NIWA, 2004). The upper reaches in the Kakanui Mountains receives the greatest amount of rainfall (>1000 mm) and the rainfall generally declines in a downstream direction, with the driest areas receiving less than 600 mm annually (Figure 2.2).

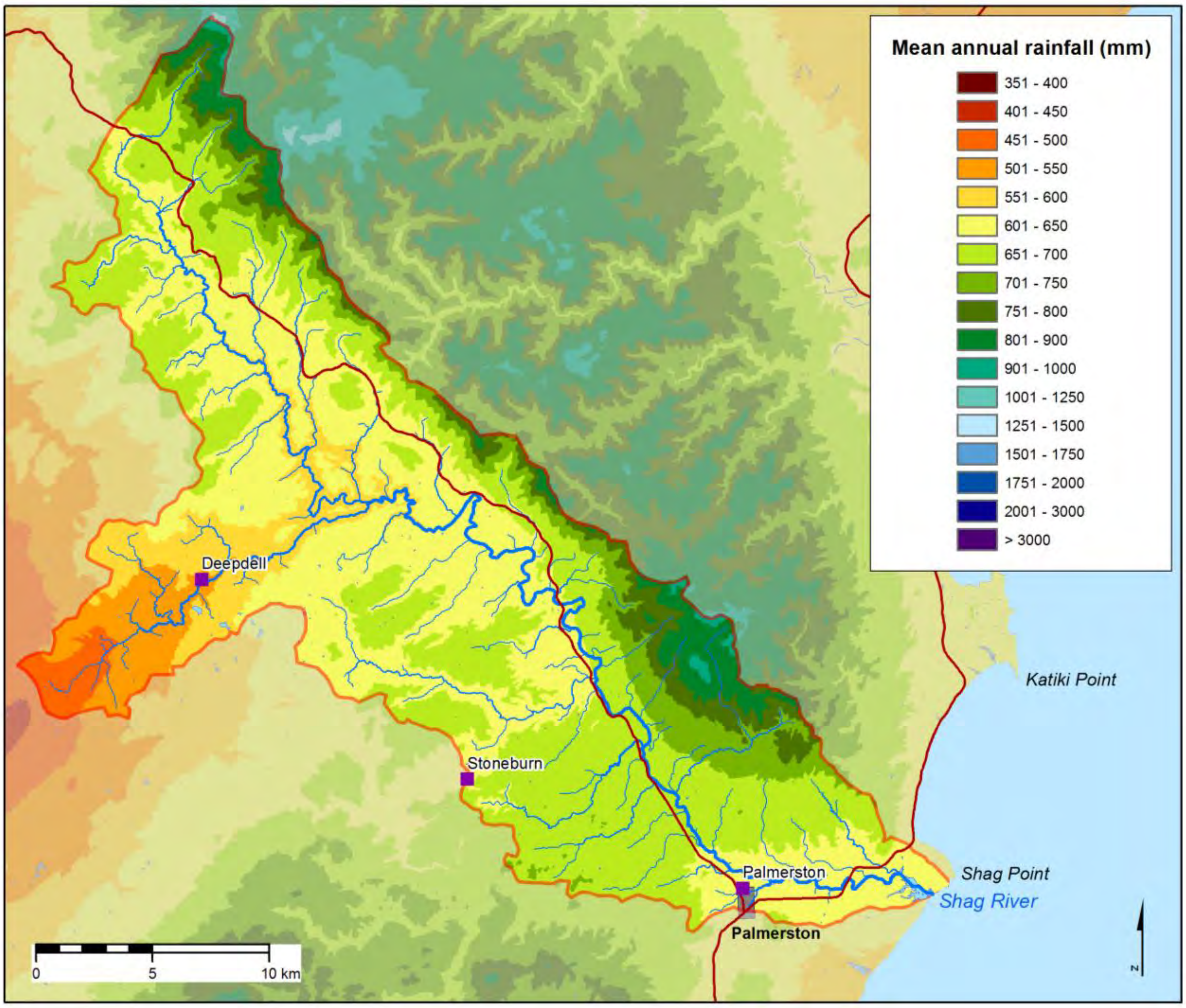

Figure 2.2 Pattern of rainfall in the Shag/Waihemo catchment. Purple squares are rainfall monitoring sites.

2.1.2 Geology

Much of the course of the Shag River/Waihemo parallels the Waihemo fault system (Forsyth, 2001). The geology of the majority of the Shag/Waihemo catchment consists of schistose to non-schistose quartzofeldspathic sandstone, with areas of igneous rock (Dunedin volcanics group) to the south of the Waihemo fault system (Forsyth, 2001). The lower catchment consists of alluvial deposits, marine and non-marine quartzose sandstone and siltstones (Forsyth, 2001).

The upper reaches of Deepdell Creek and McCormicks Creek includes the Hyde-Macraes Shear Zone, a zone of metamorphosed rock with significant mineralisation of gold that the Macraes gold mine is based on.

2.1.3 Geomorphology

The headwaters of the Shag River/Waihemo rise in the Kakanui Mountains, before flowing in a south-easterly direction to the coast, entering the Pacific Ocean just south of Shag Point/Matakaea. For much of its course it flows through confined, meandering channels, with a bed of mixed gravel, boulder and bedrock.

Previous geomorphological assessments in the Shag /Waihemo catchment have identified bed and bank degradation and limited replenishment of gravels (ORC, undated), leading to a halt to gravel extraction consents in the catchment. The most recent assessment has noted aggradation in the majority of monitored cross-sections, indicating that the river may have changed from a state of overall degradation to one of aggradation/stability (ORC, In prep).

2.1.4 Catchment land cover

The majority of the Shag/Waihemo catchment consists of agricultural grasslands (Table 2.1). The upper Shag /Waihemo catchment is dominated by tall tussock grassland and low producing grassland (Figure 2.3). Much of the lower part of the Shag/Waihemo catchment and most of the flat land in the valley floor consists of high producing grasslands, although there are areas of cropping in the lower catchment, with the largest of these downstream of Palmerston (Figure 2.3). Exotic forestry is the next most extensive landuse, representing 11% of the catchment (Table 2.1). The largest blocks of forestry are in the upper catchment adjacent to the Collins Bridge and on the hill country to the north of the Shag River/Waihemo estuary (Figure 2.3). Two categories of vegetation were common in riparian areas (areas adjacent to the river channel); gorse and broom and matagouri and grey shrub (Figure 2.3).

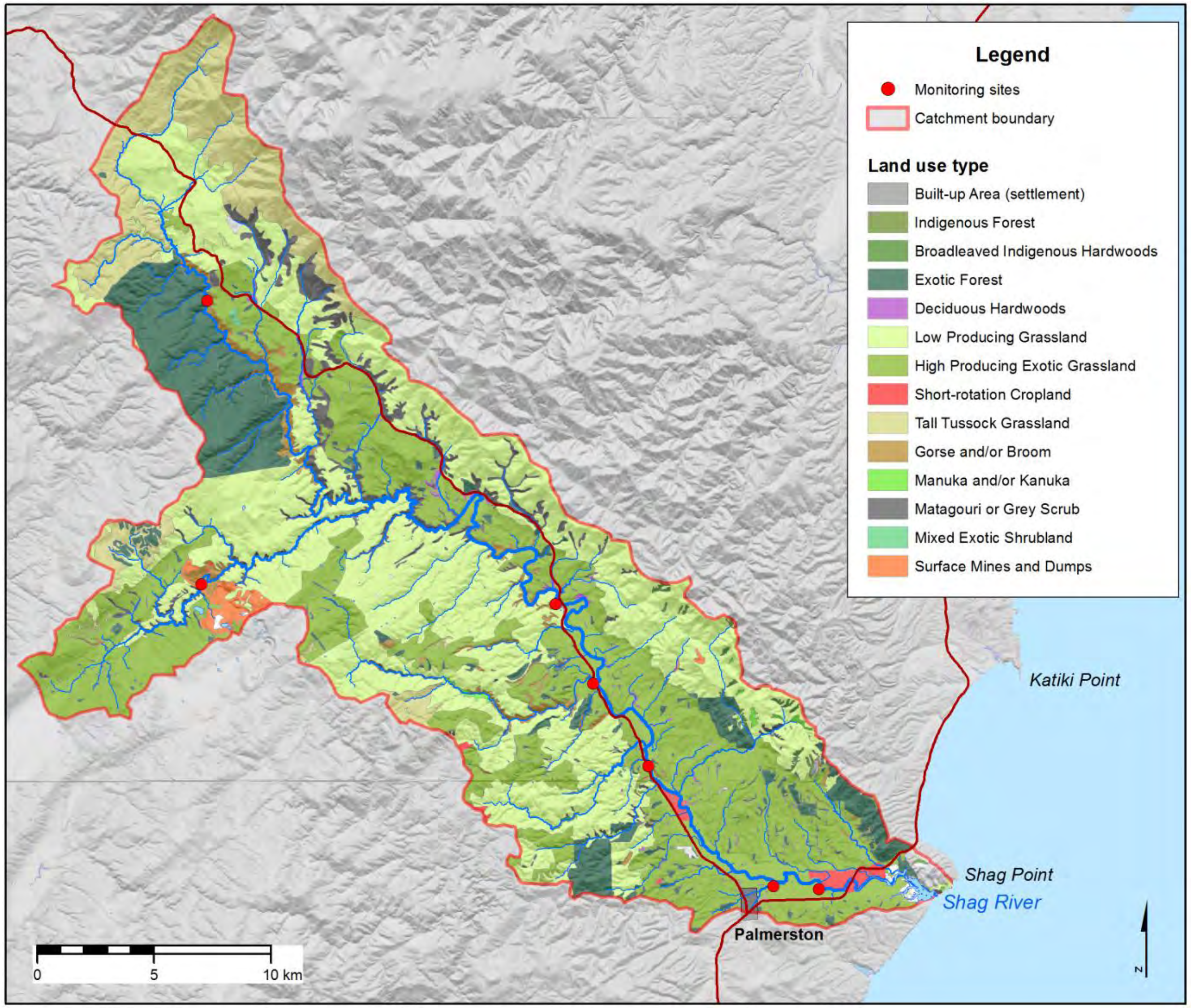
Legend
Monitoring sites
Catchment boundary
Land use type
Built-up Area (settlement)
Indigenous Forest
Broadleaved Indigenous Hardwoods
Exotic Forest
Deciduous Hardwoods
Low Producing Grassland
High Producing Exotic Grassland
Short-rotation Cropland
Tall Tussock Grassland
Gorse and/or Broom
Manuka and/or Kanuka
Matagouri or Grey Scrub
Mixed Exotic Shrubland
Surface Mines and Dumps
Katiki Point
Shag Point
Shag River
Palmerston
0
5
10 km
N

Figure 2.3 Land cover of the Shag/Waihemo catchment based on the Land Cover Database (Version 3).

Table 2.1 Percentage cover by different vegetation types in the Shag/Waihemo catchment based on the Land Cover Database (v.3)

Vegetation type	%
Low Producing Grassland	38
High Producing Exotic Grassland	32
Exotic Forest	11
Tall Tussock Grassland	9
Shrub	7
Surface Mines and Dumps	1
Short-rotation Cropland	1
Other	2

2.2 Hydrology and water use

2.2.1 Hydrology of the Shag River/Waihemo

Long-term flow statistics for the two flow recorder sites in the Shag River/Waihemo catchment are presented in Table 2.2. The Shag River/Waihemo has a highly variable flow regime, with flows ranging from floods in excess of 400,000 l/s to less than 25 l/s during low flow events. Flow statistics will change through time, as they are based on datasets that are continuing to be gathered. However, for the assessment of compliance with Plan Change 6A, reference flows have been established for each catchment and the limits apply during flows of below the reference flow. These reference flows were set at the median flow for the period 1/1/2007 to 1/1/2013. In the Shag/Waihemo catchment, the reference flow is 649 l/s at the Craig Road flow monitoring site.

Table 2.2 Flow statistics at two long-term hydrological monitoring sites in the Shag River/Waihemo catchment. These flow statistics are based on 15-minute instantaneous flows.

	Flow record			Flow statistics (l/s)			
Flow recorder site	Start date	End date	Duration (y)	Mean	Median	7-d MALF[1]	Lowest 7-d LF[2]
The Grange	11-Oct-89	16-May-14	24.6	1,701	589	166	13
Craig Road	23-Sep-93	16-May-14	20.6	2,191	714	160	18

[1] Seven-day Mean annual low flow
[2] Lowest seven-day low flow

2.2.2 Minimum flow sites and water allocation

The Shag River/Waihemo has a primary allocation limit of 280 l/s and total allocation of 262 l/s made up of 17 consented surface water takes, with the majority of these for irrigation. There are also four consented supplementary water takes, totalling 127.5 l/s, with 90 l/s in the 1st supplementary block and 37.5 l/s in the 2nd supplementary block.

There are two minimum flow sites in the catchment: Craig Road and Goodwood Pump (Figure 2.1), although only Craig Road has a permanent flow recorder.

2.3 Natural values of the Shag/Waihemo catchment

The Regional Plan: Water for Otago (2004) (RPW) lists many natural values for the Shag River/Waihemo catchment including significant spawning for inanga and trout, providing significant habitat for rare fish (Taieri flathead galaxias, koaro and lamprey) and supporting high diversity of invertebrates in its middle reaches.

Sixteen species of fish and one species of freshwater crayfish have been recorded from the Shag River/Waihemo catchment including 7 species that are classified as “declining” and one species that is classified as “not threatened” but “conservation dependent” (Hitchmough *et al.* 2007, Allibone *et al.* 2010) (Table 2.3).

Table 2.3 Fish and crayfish species present in the Shag/Waihemo catchment (NIWA Freshwater Fish Database April 2013). Conservation status is based on Allibone *et al.* (2010). * indicates species that are classified as “conservation dependent” by Allibone *et al.* (2010).

Common name	Species name	Conservation status
Shortfin eel	*Anguilla australis*	Not threatened
Longfin eel	*Anguilla dieffenbachii*	Declining
Torrentfish	*Cheimarrichthys fosteri*	Declining
Koaro	*Galaxias brevipinnis*	Declining
Taieri flathead galaxias	*Galaxias depressiceps*	Not threatened*
Inanga	*Galaxias maculatus*	Declining
Lamprey	*Geotria australis*	Declining
Upland bully	*Gobiomorphus breviceps*	Not threatened
Common bully	*Gobiomorphus cotidianus*	Not threatened
Bluegill bully	*Gobiomorphus hubbsi*	Declining
Redfin bully	*Gobiomorphus huttoni*	Declining
Koura	*Paranephrops zelandicus*	Declining
Common smelt	*Retropinna retropinna*	Not threatened
Black flounder	*Rhombosolea retiaria*	Not threatened
Brook char	*Salvelinus fontinalis*	Introduced and naturalised
Brown trout	*Salmo trutta*	Introduced and naturalised
Yellow-eyed mullet	*Aldrichetta forsteri*	Not threatened

Most of the fish recorded from the Shag River/Waihemo catchment are diadromous; spending part of their life cycle in salt and freshwater. Longfin eels are widely distributed throughout the catchment, while shortfin eels have been recorded from the main stem up to Deepdell Creek (Figure 2.4). Torrentfish and yellow-eyed mullet have been recorded from the estuary while common smelt and black flounder have been recorded from the mainstem as far upstream as the Horse Range Road (Figure 2.4). Inanga, bluegill bullies and redfin bullies have been recorded from the mainstem up to the Craig Road bridge, while lamprey and common bullies have been recorded as far upstream as The Grange (Figure 2.4 and Figure 2.5). Koaro are strong climbers and are able to negotiate steep waterfalls and even some man-made structures. They have been recorded from the mainstem and tributaries in the middle part of the catchment (Figure 2.5).

Upland bullies, one of the few non-migratory bully species, have been recorded from throughout the catchment and Taieri flathead galaxias, a non-migratory galaxid, was distributed throughout the catchment upstream of The Grange and in the upper reaches of Tipperary Creek (Figure 2.4 and Figure 2.5). Fish surveys undertaken in the Tipperary catchment by NIWA for Oceana Gold Limited in the Tipperary catchment (Glova 1996a,b, 1997; McDowall & Hewitt 2004) found that the non-migratory galaxiid population in Tipperary catchment was a hybrid between Taieri flathead (*Galaxias depressiceps*) and roundhead galaxias (*G. anomolus*). A genetic study suggests that this species is not flathead galaxias *sensu stricto* (currently listed as not threatened, but conservation dependent), but rather a naturally occurring hybrid of this species and roundhead galaxias (currently listed as nationally vulnerable; Allibone *et al.* 2010), with the possibility of some Canterbury galaxias (*G. vulgaris*) influence (McDowall & Hewitt 2004).

Brown trout are distributed throughout most of the catchment and brook char have been recorded from the upper reaches (Figure 2.6).

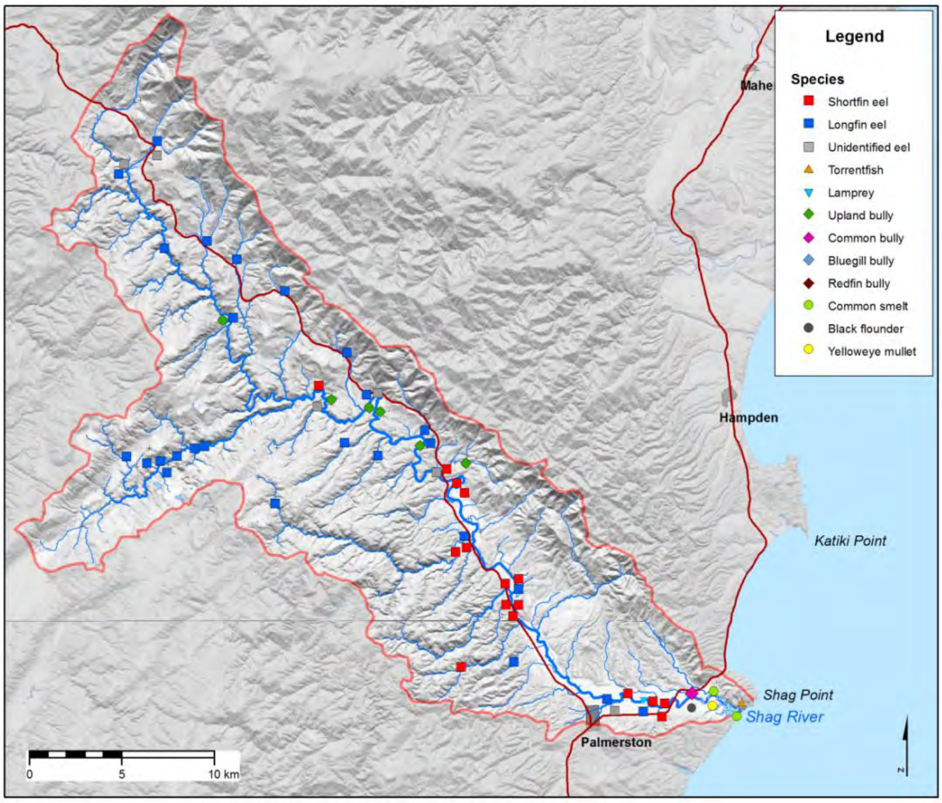

Figure 2.4 Distribution of fish species in the Shag/Waihemo catchment.

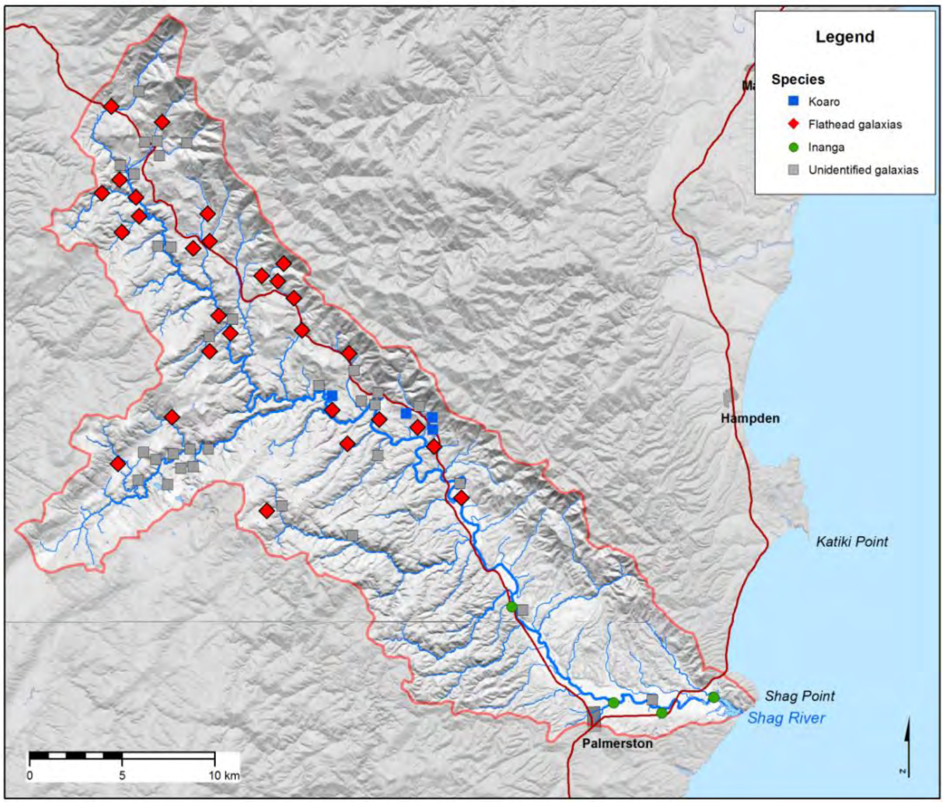

Figure 2.5 Distribution of galaxiid species in the Shag/Waihemo catchment.

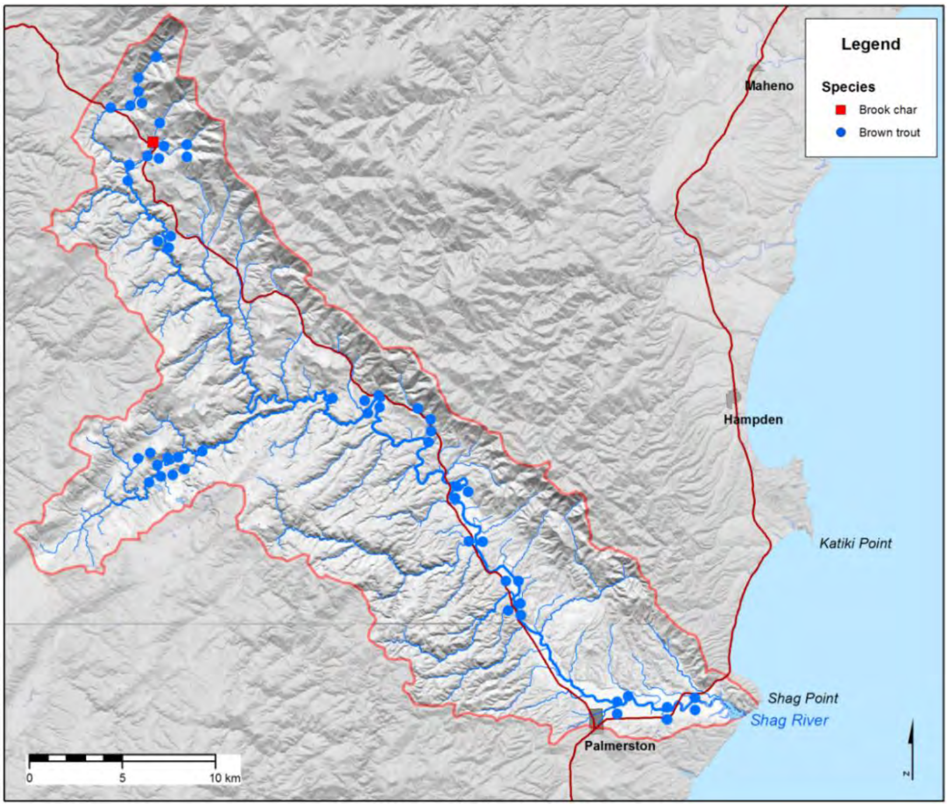

Figure 2.6 Distribution of sportsfish in the Shag/Waihemo catchment.

2.3.1 Recreational values

Recreational activities in the Shag River/Waihemo include swimming, whitebaiting, waterfowl hunting and trout fishing. The lower Shag River supports a regionally significant whitebait fishery (Otago Regional Council 1991).

The Shag River/Waihemo supports a regionally important trout fishery (Otago Fish & Game Council 2003). Angler effort in the Shag River/Waihemo has been relatively constant over the three occasions when the national angler survey has been conducted with 800 angler days estimated for the 2007/2008 season (Table 2.4).

Table 2.4 Angler effort (angler days ± 1 standard error) estimated for the Shag River/Waihemo as part of the national angler survey (Unwin 2009).

Season	Effort
1994/1995	1060 ± 290
2001/2002	890 ± 310
2007/2008	800 ± 270

2.3.2 Wildlife values

The estuary of the Shag River/Waihemo is an important habitat for wildlife with the estuary mudflats being used for feeding and roosting of various bird species and as a stop-over area for migratory species (ORC, 1991). The Shag River/Waihemo estuary is the last estuary for migratory species before the Wainono Lagoon about 100 km to the north (ORC, 1991).

3. Regional planning

3.1 Water quality guidelines – Plan Change 6A

Plan change 6A was adopted on 1 May 2014 and sets out numerical water quality limits for all catchments in the Otago region (Schedule 15). It establishes water quality thresholds for all discharges to lakes, rivers, wetlands and drains into two discharge threshold areas (Schedule 16). The Shag/Waihemo catchment is in receiving water group 2. The numerical water quality limits for this group are outlined in Table 3.1.

The receiving water limits outlined in Table 3.1 are applied as 5-year, 80th percentiles when flows are at or below a reference flow of 649 l/s, with the flows in the Shag/Waihemo catchment being set at the gauging site at Craig Road (Section 2.2.1).

Table 3.1 Receiving water numerical limits and timeframe for achieving „good" water quality in the Shag/Waihemo catchment

	Nitrate-nitrite nitrogen	Dissolved reactive phosphorus	Ammoniacal nitrogen	*Escherichia coli*	Turbidity
Numerical limit	0.075 mg/L	0.01 mg/L	0.1 mg/L	260 cfu/100 ml	5 NTU
Target date	31 March 2025	31 March 2012	31 March 2012	31 March 2012	31 March 2012

4. Sampling and analysis methods

4.1 Water quality sampling

4.1.1 Long-term monitoring

Long-term (–State of the Environment") monitoring is undertaken at two sites in the Shag/Waihemo Catchment; Craig Road (mid catchment) and Goodwood pump (lower catchment). Craig Road has been regularly monitored since May 1990 while Goodwood Pump has been regularly monitored since September 1994.

4.1.2 Catchment water quality sampling 2012-2013

Water quality samples were collected from each of the seven monitoring sites every fortnight between 26 July 2012 and 14 April 2013. These samples were analysed for total nitrogen (TN), nitrate-nitrite nitrogen (NNN), ammoniacal nitrogen (NH_4-N), total phosphorus (TP), dissolved reactive phosphorus (DRP), suspended solids (SS) and *Escherichia coli* (*E. coli*). These analyses were conducted by Hill Laboratories (Hamilton, www.hill-labs.co.nz).

The concentration of total SS was determined by filtration (nominal pore size of 1.2-1.5 μm) and gravimetric determination (following Method 2540D, APHA 21st edition, 2005). The detection limit for this analysis was 3 g/m^3.

NNN was determined by automated cadmium reduction on a flow injection analyser (Method 4500-NO3- I, APHA 21st edition, 2005), with a detection limit of 0.002 mg/l. Total NH_4-N was determined by phenol/hypochlorite colorimetry, using a discrete analyser after filtration (Method 4500-NH_3 F (modified from manual analysis), APHA 21st edition, 2005), with a detection limit of 0.010 mg/l. Total Kjedahl nitrogen (TKN) was determined after copper sulphate digestion with copper sulphate catalyst by phenol/hypochlorite colorimetry, using a discrete analyser (Method 4500-Norg (modified), 4500-NH_3 F (modified), APHA 21st edition, 2005) with a detection limit of 0.10 mg/l. TN was calculated by summing NNN + TKN, with a detection limit of 0.05 mg/l.

DRP was determined by molybdenum blue colorimetry, using a discrete analyser after filtration (Method 4500-P E (modified from manual analysis, APHA 21st edition, 2005)), with a detection limit of 0.004 mg/l. TP was determined using ascorbic acid colorimetry on a discrete analyser (Method 4500-P B & E (modified), APHA 21st edition, 2005, with modification from National Water and Soil Conservation Organisation 1982, after acid persulphate digestion). This analysis had a detection limit of 0.004mg/l.

E. coli counts were determined after membrane filtration by count on m-FC agar, which was incubated at 44.5°C for 22 hours (Method 9222, APHA 22nd edition, 2012). The detection limit was 1 cfu/100 ml.

4.2 Habitat assessment

At each sampling site, instream and riparian habitats were assessed following Protocol P2 of Harding *et al.* (2009). Instream assessments included assessment of the length of meso-habitats (rapid/run/riffle/pool/backwater/other), pool morphology (max. depth, sediment depth and crest depth), channel cross-section profile, substrate composition, macrophyte cover, periphyton cover, cover by woody debris and leaf packs, and percentage of bank cover (Field forms P2b & c). Riparian assessments also included the width and intactness of buffers, vegetation composition, bank stability and livestock access to riparian areas (Field form P2d).

4.3 Biological sampling

4.3.1 Periphyton

4.3.1.1 Field methods

Periphyton community composition was monitored at two sites as part of SoE monitoring. Algal samples were collected by selecting three stones at each site, taken from one-quarter, one-half and three-quarters of the stream width. At each collection point, a stone was randomly selected and removed to the river bank. A 5 cm x 5 cm (0.0025 m^2) area of each stone surface was scrubbed with a small brush into a tray and rinsed with river water. The scrubbings from the three stones were pooled and transferred to a sample container using river water. The sample was transported to the laboratory and preserved in formaldehyde.

4.3.1.2 Laboratory analysis

Each sample was thoroughly mixed, and three aliquots were removed to an inverted microscope settling chamber. They were then allowed to settle for 10 minutes. Samples were analysed according to the ‗relative abundance using an inverted microscope‘ method outlined in Biggs and Kilroy (2000). Samples were inspected under 200-400x magnification to identify algal species present using the keys of Biggs and Kilroy (2000), Entwisle *et al.* (1988) and Moore (2000). Algae were given an abundance score ranging from 1 (rare) to 8 (dominant), based on the protocol of Biggs and Kilroy (2000). Internal quality assurance procedures were followed.

4.3.2 Macroinvertebrates

Aquatic macroinvertebrates are organisms that live on or within the beds of rivers and streams. Examples include insect larvae (e.g. mayflies, stoneflies, caddisflies and beetles), aquatic oligochaetes (worms), snails and crustaceans (e.g. amphipods and crayfish). Macroinvertebrates are useful for assessing the biological health of a river because they are found everywhere, vary in their tolerance to temperature, dissolved oxygen, sediment and chemical pollution and are relatively long lived (taking six months to two years to complete their life-cycle). Therefore, the presence or absence of such taxa can provide significant insight into long-term changes in water quality.

Macroinvertebrate communities were sampled at seven sites in the Shag/Waihemo River in March 2013. At each site, one extensive kick-net sample was collected, following Protocol C2, ‗hard-bottomed, semi-quantitative sampling of stream macroinvertebrate communities‘ (Stark *et al.*, 2001), which requires sampling a range of habitats, including riffles, mosses, wooden debris and leaf packs. Samples were preserved in 90% ethanol in the field and returned to a laboratory for processing. Following Protocol P1, ‗semi-quantitative coded abundance‘, macroinvertebrate samples were coded into one of five abundance categories: rare (1-4), common (5-19), abundant (20-99), very abundant (100-499) or very, very abundant (500+).

In the laboratory, the samples were passed through a 500 µm sieve to remove fine material. The sieve contents were then placed onto a white tray, and the macroinvertebrates were identified under a dissecting microscope (10-40X), using the identification key of Winterbourn *et al.* (2006).

The indices commonly used to measure stream health are summarised below:

- Species richness is the total number of species (or taxa) collected at a sampling site. In general terms, high species richness may be considered ‗good'; however, mildly impacted or polluted rivers, with slight nutrient enrichment, can have higher species richness than unimpacted, pristine streams.

- Ephemeroptera plecoptera and trichoptera (EPT) richness is the sum of the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species collected. These insects are often the most sensitive to organic pollution; therefore, low numbers might indicate a polluted environment. Comparing the percentage of EPT species (%EPT_{taxa}) to the total number of species found at a site can give an indication of the importance of these species in the overall community.

- Macroinvertebrate community index (MCI) uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxa are assigned scores of between 1 and 10, depending on their tolerance. A score of 1 represents taxa that are highly tolerant of organic pollution, while 10 represents taxa that are sensitive to organic pollution. The MCI score is obtained by adding the scores of individual taxa and dividing the total by the number of taxa present at the site and multiplying this figure by 20 (a scaling factor). MCI scores can be interpreted based on the water quality classes proposed by Stark & Maxted (2007) (Table 4.1).

- Semi-quantitative macroinvertebrate community index (SQMCI) is a variation of the MCI that accounts for the abundance of pollution sensitive and tolerant species. The SQMCI is calculated from coded-abundance data. Individual taxa counts are assigned to one of the following abundance classes: rare (R, 1-4 individuals), common (C, 5-19 individuals), abundant (A, 20-100 individuals), very abundant (VA, 100-500 individuals), very, very abundant (VVA, >500 individuals). SQMCI scores can be interpreted based on the water quality classes proposed by Stark & Maxted (2007) (Table 4.1).

Table 4.1 Criteria for aquatic macroinvertebrate health, according to different macroinvertebrate indices (following Stark & Maxted 2007)

Macroinvertebrate index	Poor	Fair	Good	Excellent
MCI	<80	80-99	100-119	>120
SQMCI	<4.00	4-4.99	5-5.99	>6

4.4 Fish

4.4.1 Field surveys

Each site was electric-fished, using a pulsed DC Kainga EFM300 backpack electro-shocker. At Craig Road, fish were surveyed following the New Zealand Freshwater Fish Sampling Protocols (Joy *et al.* 2013). A 150 m reach was divided into ten 15 m-long sub-reaches, and each section was electric fished in a single pass from downstream to upstream. When each section was fished, all fish caught were measured using a fish board and recorded. When 50 individuals of an individual species had been measured, individuals in subsequent sections were counted and recorded.

Electric-fishing at other sites (Goodwood, Horse Range Road, The Grange, Collins Bridge, McCormicks Creek, Deepdell Creek) was undertaken by stop-netting off an area of about 100 m^2, and electric-fishing this area in an downstream direction in three passes, with a 15-minute rest period between each pass to allow fish to settle. The backpack operator used a sieve-dip net, while another team member used a pole seine net immediately below the electro-shocker. A third member carried buckets for fish collection. Fish from each pass were measured, counted and then released downstream of the downstream stop-net. At each site, all trout were also weighed (in grams) and then measured from the tip of the snout to the caudal fork (total length, mm).

4.4.1.1 Condition factor

The body condition of trout was assessed by relating body weight to total length of the individual using the formula (following Barnham and Baxter, 1998):

$$K = \frac{10^N W}{L^3}$$

where K is the condition factor; W is the weight of the fish in grams (g); L is the length of the fish in millimetres (mm); and N equals 5. A photographic representation is shown in Figure 4.1.

4.4.1.2 Fish density classes

Brown trout and native fish density at sites within the Shag/Waihemo catchment were classed as ‗excellent‘, ‗good‘, ‗fair‘ or ‗poor‘, based on the relative density to density quartiles, calculated using a dataset based on waterways throughout coastal Otago. This regional data set was developed using the New Zealand Freshwater Fish Database (NZFFD) to obtain fish density data for all coastal river sites in the Otago region (based on two or more electric-fishing passes over a known area (m^2)) and data collected by ORC. All sites were ranked on fish density per square metre (total fish density, brown trout density) and then broken into quartiles.

 Extremely poor K = 0.78	 Poor K = 0.95
 Fair K = 1.19	 Good K = 1.36
 Excellent K = 1.66	 Exceptional K = 2.02

Figure 4.1 Photo representation of trout with different condition factors (Barnham and Baxter, 1998)

4.5 Data analysis and presentation

4.5.1 Trend analysis

Long-term trends in water quality parameters and macroinvertebrate indices were considered using a seasonal Kendall trend test in Time Trends statistical software (Version 3.00, NIWA). Tests for water quality variables were performed with six seasons per year (fitting with the bimonthly SoE sampling) and the median value for each season was used in the analysis. All water quality data were flow-adjusted (flow was used as a covariate in the analysis), with the covariate adjustment method used being locally weighted scatterplot smoothing (Lowess) curve with a tension of 0.3 (i.e. 30% of points to fit) and ten iterations.

4.5.2 Boxplots

Where sufficient water quality data were available, they were presented as box plots, as these provide information on data distribution (Figure 4.2).

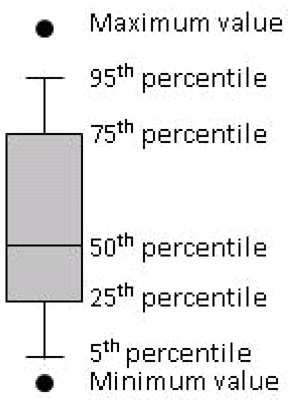

Figure 4.2 The interpretation of the various components of a box plot, as presented in this report

5. Results

5.1 SoE monitoring

5.1.1 Water quality trends

Trends for Craig Road were analysed for the period January 2000 to October 2013 while trends for Goodwood Pump were considered for the period August 2001 to October 2013. The starting dates for these analyses were the start of regular (bimonthly) sampling at each of these sites. The SoE water quality monitoring data used in these analyses are presented in Appendix 1.

Concentrations of TN and NNN at Craig Road increased over the period considerably, while the concentration of NH_4-N decreased (Table 5.1; Figure 5.1). Similar trends were apparent at Goodwood Pump, although the trend in TN was approaching significance (Table 5.1, Figure 5.2). No trend in total phosphorus was detected at either site and no trend in DRP was apparent at Craig Road, although a significant increasing trend in DRP was detected for the Goodwood Pump site (Table 5.1, Figure 5.2).

Counts of *E. coli* decreased significantly at both sites over the period considered (Table 5.1; Figure 5.1 and Figure 5.2). Turbidity increased over the period considered at Craig Road, while no trend was detected at Goodwood Pump (Table 5.1; Figure 5.1).

Plots for all parameters considered are presented in Appendix 2 and Appendix 3.

Table 5.1 Trends in water quality parameters at SoE monitoring sites in the Shag/Waihemo catchment: Craig Road (2000-2013) and Goodwood Pump (2001-2013). The *Z*-statistic indicates the direction of any trend detected. Trends with a *P*-value of 0.05 or less (highlighted red) are considered to be statistically significant.

Parameter	Craig Road		Goodwood Pump	
	Z	*P*	*Z*	*P*
TN	2.53	0.01	1.83	0.07
NNN	3.35	<0.01	2.28	0.02
NH_4-N	-2.73	0.01	-1.92	0.05
TP	-0.66	0.51	0.45	0.65
DRP	-0.09	0.93	3.97	<0.01
E. coli	-2.67	0.01	-1.97	0.05
Turbidity	2.32	0.02	0.61	0.54

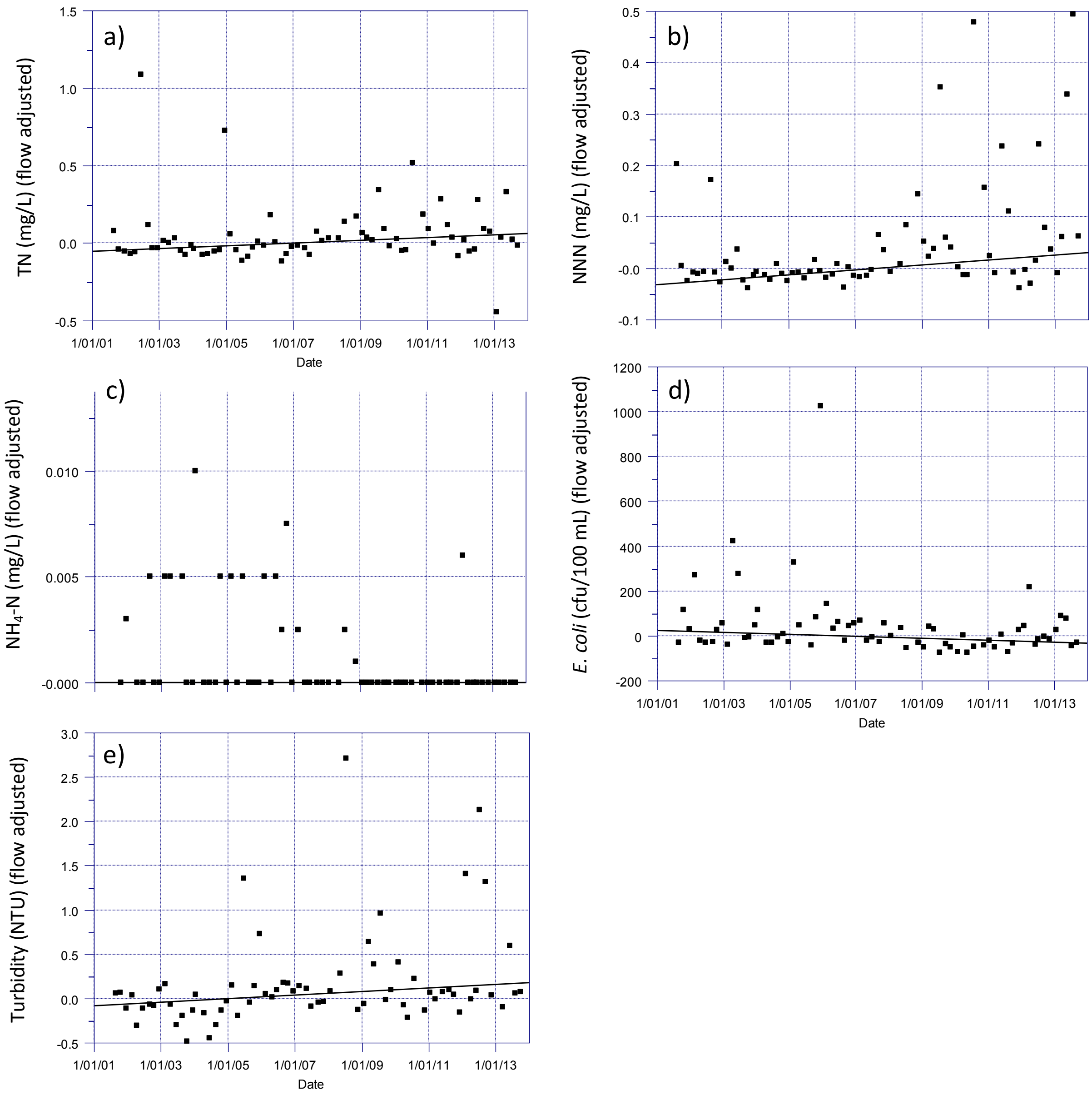

Figure 5.1 Significant trends in water quality parameters at the Craig Road SoE monitoring site on the Shag River/Waihemo. a) TN, b) NNN, c) NH_4-N, d) *E. coli*, and e) turbidity. Trend lines are the Sen slope based on the Seasonal Kendall test.

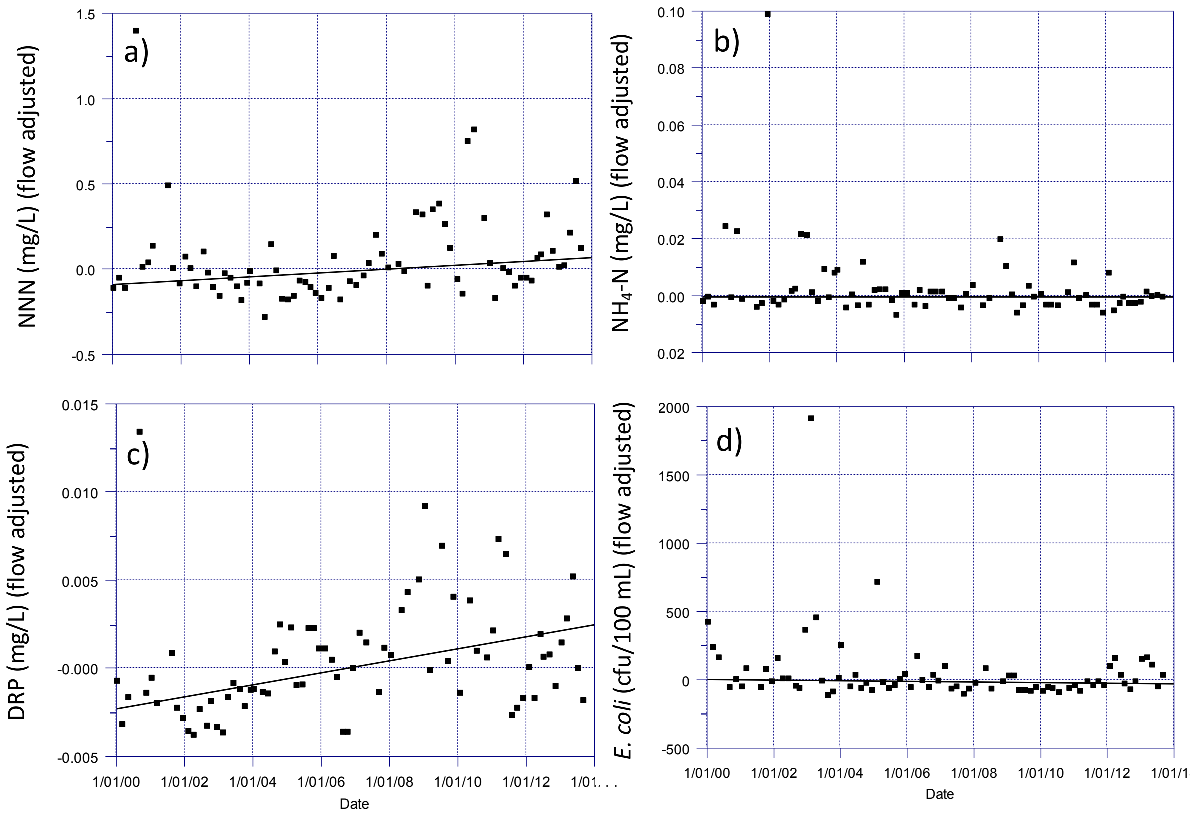

Figure 5.2 Significant trends in water quality parameters at the Goodwood Pump SoE monitoring site on the Shag River/Waihemo. a) NNN, c) NH_4-N, d) *E. coli*, and e) turbidity. Trend lines are the Sen slope based on the Seasonal Kendall test.

5.1.2 Compliance with PC6A limits

Plan Change 6A sets out water quality limits for receiving waters in the Otago Region (Schedule 15, Table 3.1). These limits apply as 5-year, 80th percentiles when flows are at or below median flow at Craig Road (649 l/s). To assess compliance with the Schedule 15 limits, SoE monitoring data collected from Craig Road (10 April 2002 – 8 April 2013) and Goodwood Pump (7 March 2000 – 17 April 2013) were used to calculate 5-year running 80th percentiles, which were then compared to the appropriate limit. Only data collected when flows were at or below median flow were used for these calculations.

At both SoE sites, NNN exceeded the Schedule 15 limit, with an increasing trend evident in recent years (Table 5.1; Figure 5.3, Figure 5.4). At the Craig Road site, NNN has only recently exceeded the limit (Figure 5.3), whereas the 80th percentile of NNN concentration at Goodwood Pump has exceeded the limit over the entire period considered (Figure 5.4). Ammoniacal nitrogen, turbidity and *E. coli* were well within the Schedule 15 limits at both sites and while DRP concentrations at Craig Road were well within the Schedule 15 limit, DRP concentrations at Goodwood pump have approached the Schedule 15 limit in recent years (Figure 5.3, Figure 5.4).

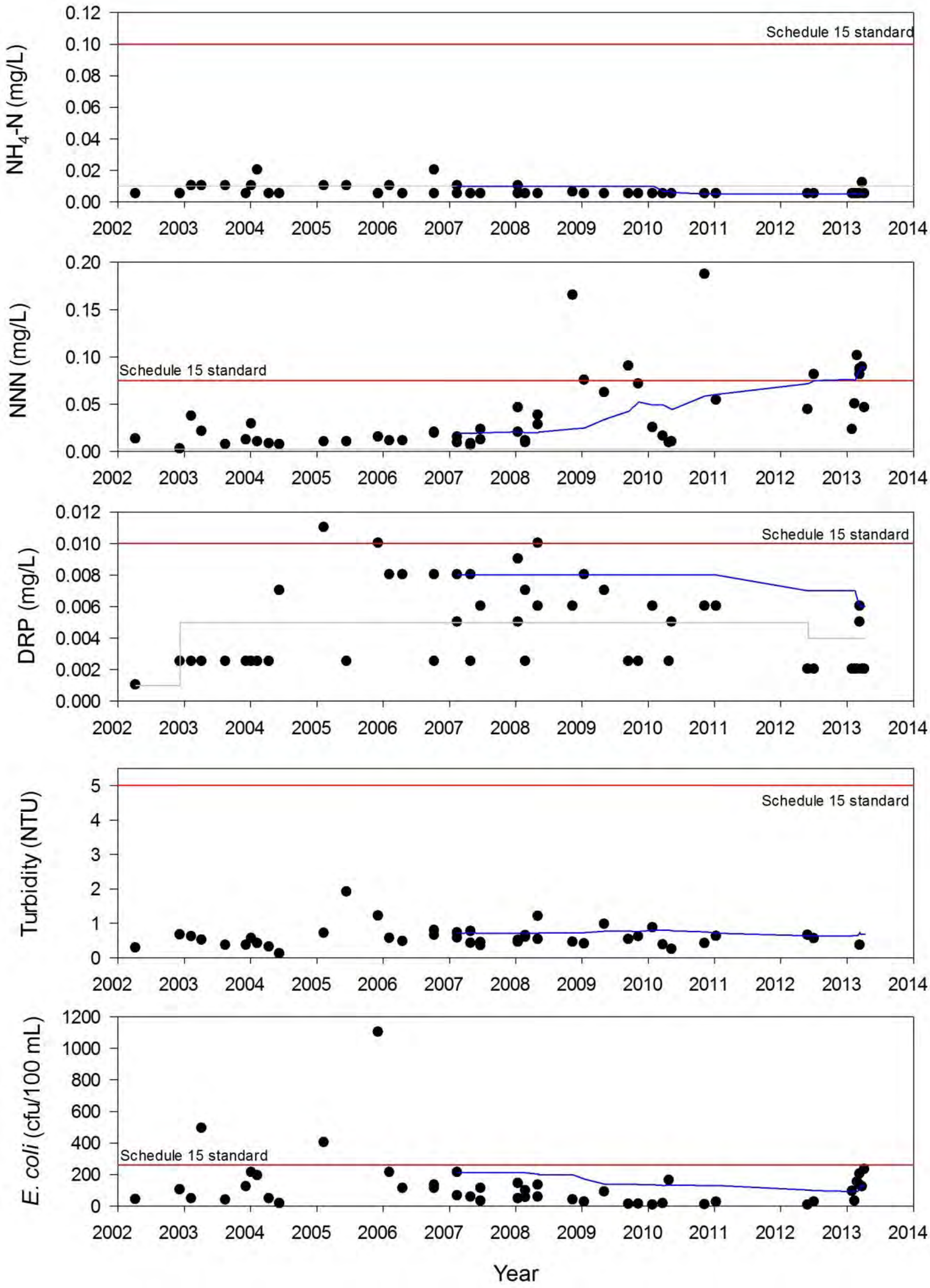

Figure 5.3 Comparison of NH_4-N, NNN, DRP, turbidity and *E. coli* readings at the Craig Road SoE site when flows are below median flow with Schedule 15 limits (red lines). Blue lines represent the 5-year moving 80th percentile and grey lines represent detection limits (where applicable).

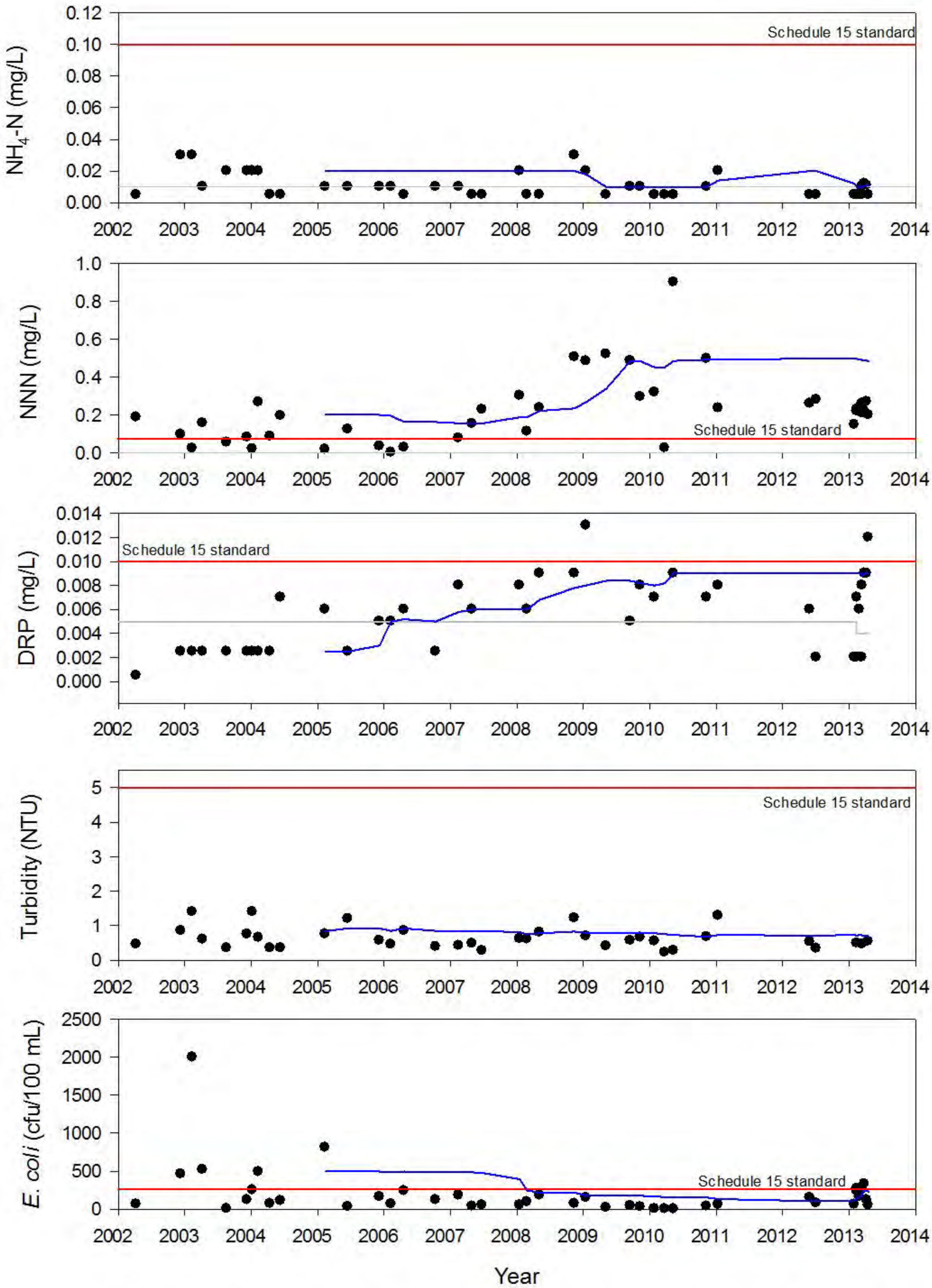

Figure 5.4 Comparison of NH_4-N, NNN, DRP, turbidity and *E. coli* readings at the Goodwood Pump SoE site when flows are below median flow with Schedule 15 limits (red lines). Blue lines represent the 5-year moving 80th percentile and grey lines represent detection limits (where applicable).

5.2 Water clarity

Several variables relating to the amount of sediment in the water and water clarity have been measured as part of water quality monitoring in the Shag/Waihemo catchment, including SS, turbidity and water clarity and all these variables are inter-related. Turbidity and SS are positively related, that is to say that more SS will increase turbidity, while water clarity is negatively related to both SS and turbidity (e.g. Figure 5.5). Most of the routine data collected by ORC, such as that collected as part of the SOE programme, are measures of turbidity rather than water clarity. As water clarity is a direct measure of underwater visibility, it may be desirable to estimate water clarity based on measures of turbidity using the relationship presented in Figure 5.5.

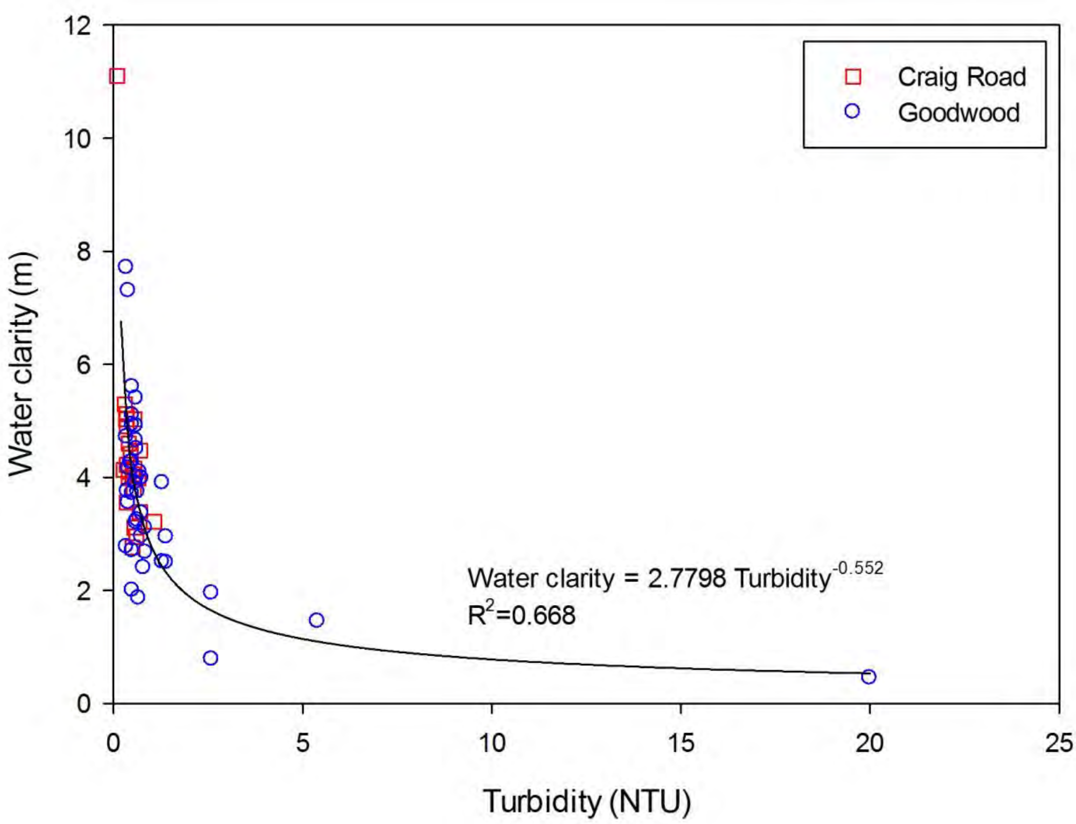

Figure 5.5 Relationship between water clarity (as measured by black disc) and turbidity measured at two sites in the Shag River/Waihemo. The fitted regression is a 2-parameter inverse power relationship.

Water clarity in the Shag River/Waihemo has ranged from 0.45 to 11.1 m, with readings from 0.45 to 7.7 m recorded at Goodwood pump (116 records) and from 2.8 to 11.1 m recorded at Craig Road (23 records)(Figure 5.5). The median value recorded at Goodwood pump during baseflow conditions (< median flow, 22 occasions) was 3.82 m and 80% of values recorded have been between 2.5 and 5.6 m (the 10th and 90th percentiles, respectively). The median value recorded at Craig Road (11 occasions) during baseflow conditions was 4.0m and 80% of values recorded have been between 3.0 and 5.3 m (the 10th and 90th percentiles, respectively).

5.3 Water temperature

Water temperature data is available for three sites in the Shag River/Waihemo. The most extensive of these records is for Craig Road, spanning 31 July 2001 to 25 June 2012. Highest water temperatures typically occur in December and January and readings as high as 25°C have been recorded at this site (Figure 5.6).

Records of water temperature were available for two sites on the Shag River/Waihemo and one site in McCormicks Creek over the period 12 October 2011 to 8 May 2012 (Table 5.2). Over this period, water temperatures at Craig Road were about 2°C higher than at Collins Bridge, but were similar to those observed in McCormicks Creek (Table 5.2).

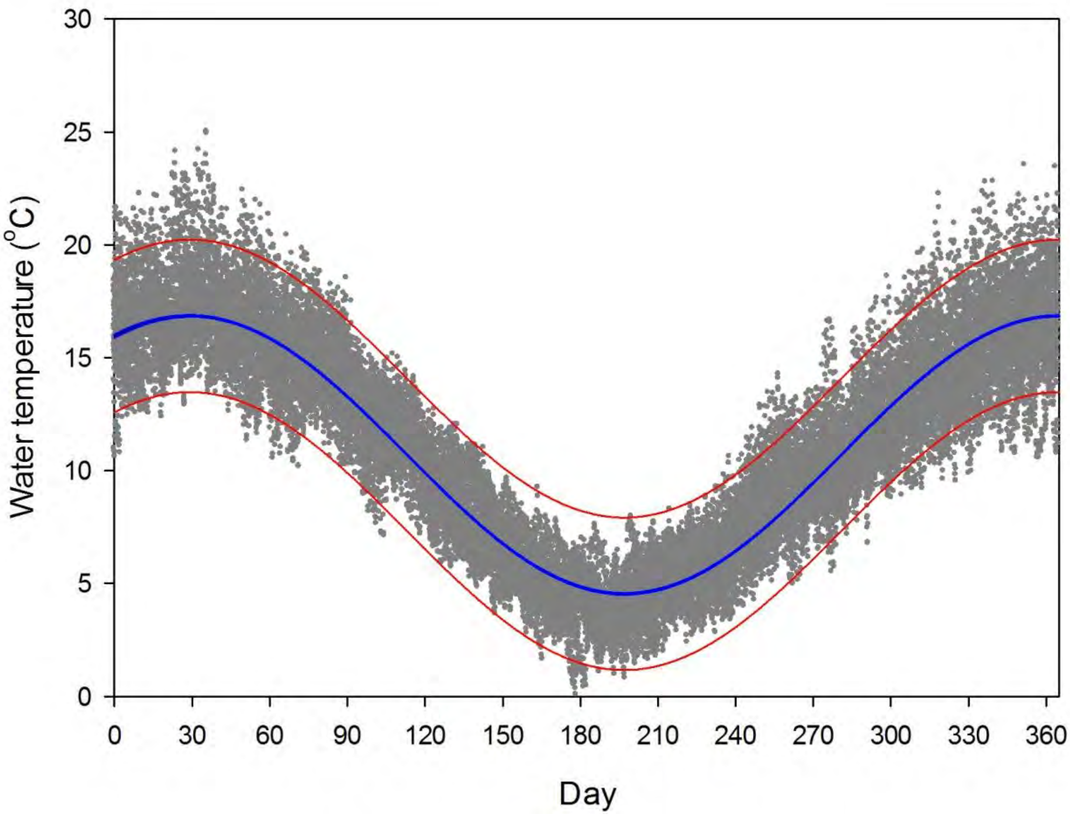

Figure 5.6 Water temperature records over the year for Craig Road between 31 July 2001 to 25 June 2012. Fitted curves are a 4-parameter Sine curve (blue line) with 95% confidence limits (red lines).

Table 5.2 Water temperature statistics for three sites in the Shag/Waihemo catchment.

Site	Period of record	Mean	Min	Max	Max 2-h running average	Maximum weekly average
Collins Bridge	12/10/11 13:00-8/5/12 10:45	12.0	4.3	19.2	19.1	16.6
McCormick	12/10/11 13:00-8/5/12 10:45	13.9	4.7	24.7	24.5	21.1
Craig Road	31/7/01 12:00-25/6/12 11:30	11.2	0.1	25.1	25.0	21.0
	12/10/11 13:00-8/5/12 10:45	14.1	6.6	22.2	22.2	20.0

5.4 Catchment water quality monitoring

Water quality data collected from each of the seven monitoring sites between 26 July 2012 and 14 April 2013 are presented in Appendix 1.

5.4.1 Nitrogen

Total nitrogen (TN) concentrations were very low at the upper site (Collins Bridge), with median concentrations being very close to the detection limit under all flows (Figure 5.7). However, TN in the Shag River increased with distance downstream, with the highest concentrations observed at Goodwood Pump (Figure 5.7). Concentrations in both tributaries were higher than observed at most sites in the mainstem (Figure 5.7). These patterns were evident when considering concentrations during low flows or all flows (Figure 5.7). NNN concentrations followed similar patterns to those observed for TN (Figure 5.7). Concentrations of NH_4-N were very low at all sites on all occasions, with the majority of readings at all sites below the detection limit (0.01 mg/L; Figure 5.7).

Plan Change 6A sets out water quality limits for receiving waters in the Otago region (Schedule 15; Table 3.1). These limits apply as 5-year, 80th percentiles, when flows are at or below median flow at Craig Road (649 l/s). While limited, data collected when flows were below median flow between 4 October 2012 and 20 September 2013 were compared to the Schedule 15 limits. The 80th percentiles of NNN concentrations at Craig Road, Horse Range Road, Goodwood Pump and McCormicks Creek exceeded the limit and the value for Deepdell Creek was at the Schedule 15 limit. Concentrations of NH_4-N at all sites were well within the limit (Figure 5.7).

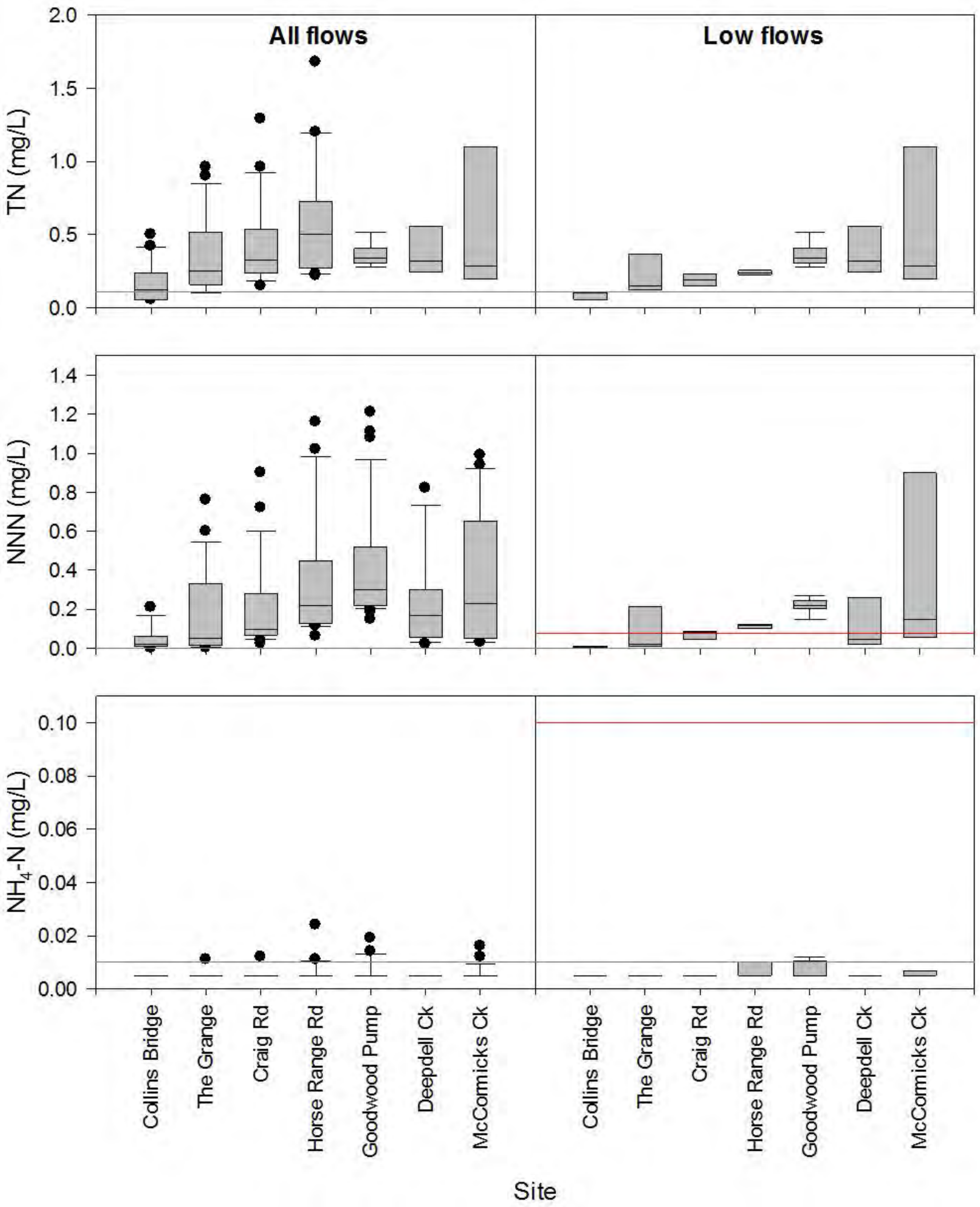

Figure 5.7 Boxplots of a) Total nitrogen, b) nitrate-nitrite nitrogen, c) ammoniacal nitrogen concentrations in the Shag River under all flows (left) and low flows (right). The red line represents the Schedule 15 limit from Plan Change 6A. Grey lines represent detection limits.

5.4.2 Phosphorus

Total phosphorus (TP) and dissolved reactive phosphorus were generally low at all sites sampled in the Shag/Waihemo catchment, with the majority of values at all sites except Goodwood Pump being below the detection limit (Figure 5.8). Consequently, the 80th percentiles of DRP readings at all sites were within the Schedule 15 limit.

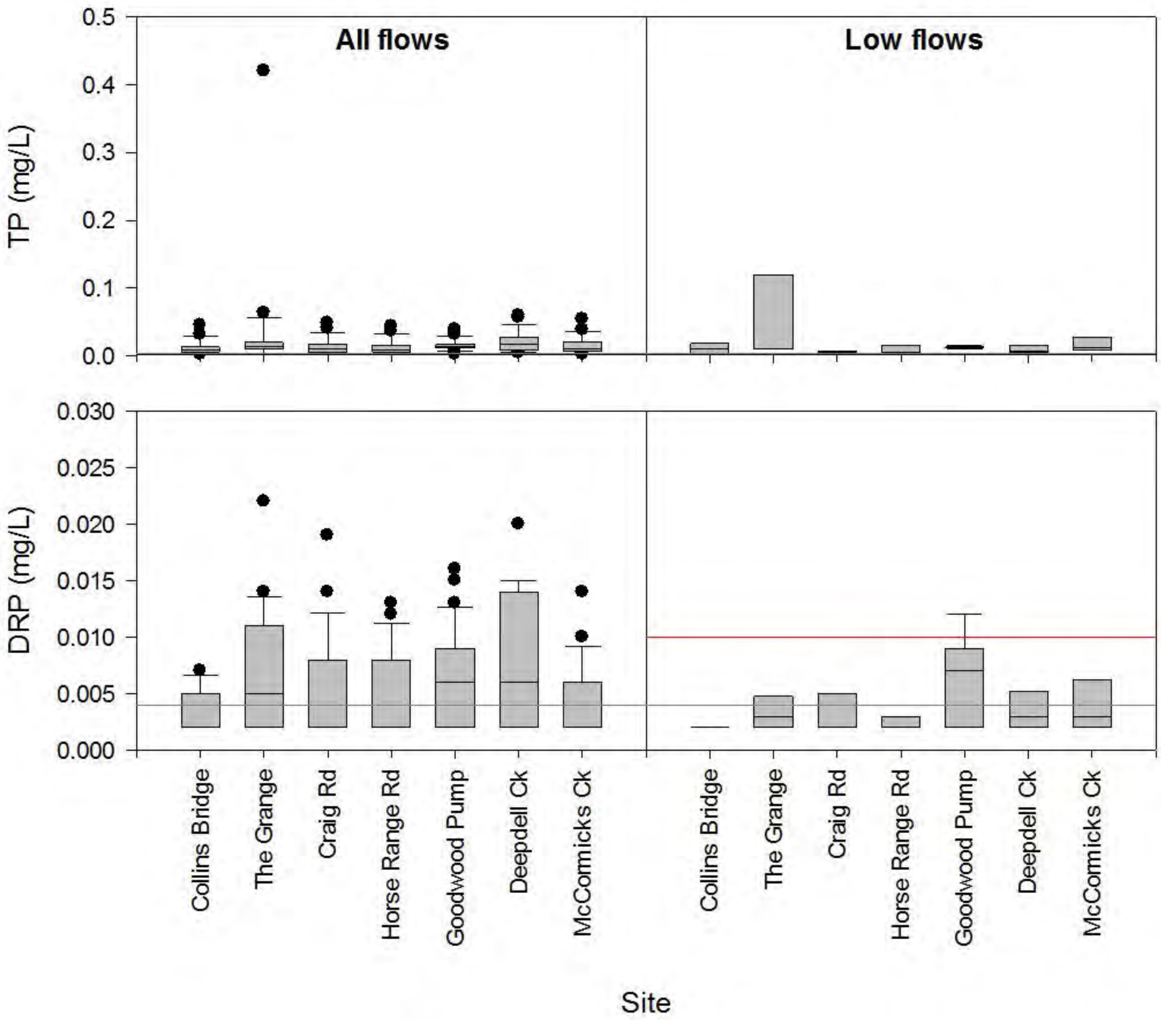

Figure 5.8 Boxplots of a) Total phosphorus, b) dissolved reactive concentrations in the Shag River under all flows (left) and low flows (right). The red line represents the Schedule 15 limit from Plan Change 6A. Grey lines represent detection limits.

5.4.3 SS, turbidity and water clarity

When flows were below the median flow, SS concentrations were at or below the detection limit (3 mg/L) at most sites. The only exception to this was a single reading of 13 mg/L at Horse Range Road on 12 March 2013, the cause of which is unknown. Turbidity was not monitored as part of the catchment sampling in 2012-2013. However, turbidity and water clarity were monitored as part of the SoE monitoring programme (see Section 5.1).

5.4.4 Escherichia coli

The highest numbers of *E. coli* were observed at The Grange and McCormicks Creek and only the 80th percentiles of counts observed at the Craig Road and Deepdell Creek sites were within the Schedule 15 limit (Figure 5.9). The 80th percentile of counts at Collins Bridge was equal to the limit (Figure 5.9).

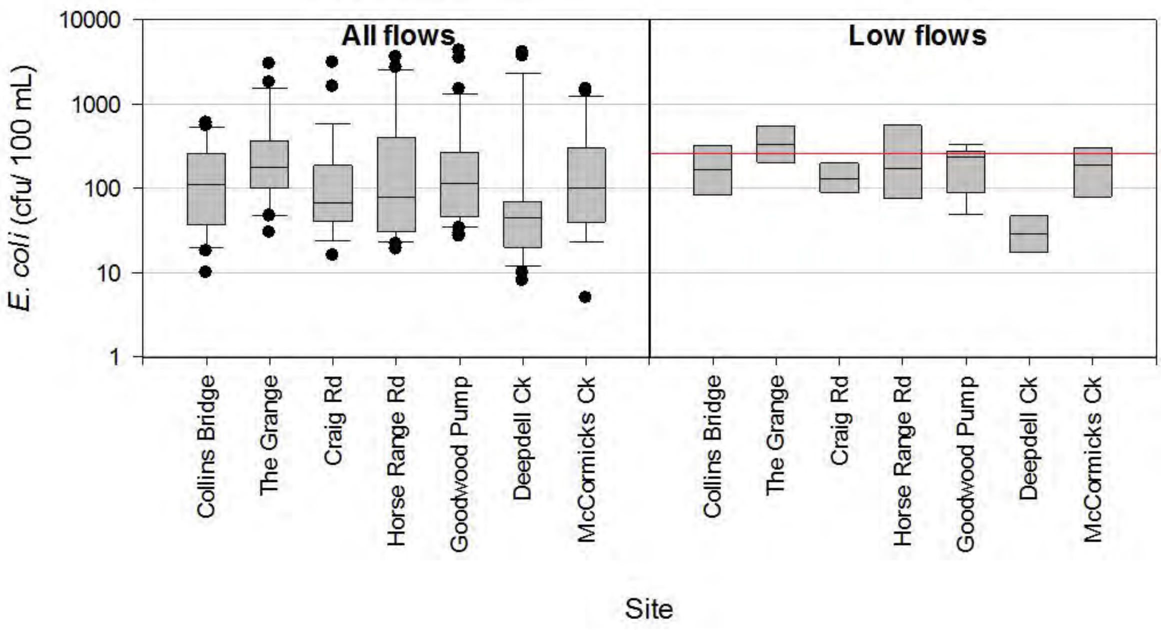

Figure 5.9 Boxplots of the concentration of *E. coli* (note that this is plotted on a logarithmic scale) in the Shag River under all flows (left) and low flows (right). The red line represents the Schedule 15 limit from Plan Change 6A.

5.5 Habitat assessments

The substrate at most sites was dominated by gravels, although cobbles formed a substantial proportion of the bed at some sites and much of the bed at The Grange consisted of bedrock (Table 5.3). Fine sediments (silts and sand, <2 mm) covered a greater proportion of the bed in pools than in other habitats (Appendix 4), but cobbles were not embedded at most sites, with the exceptions of Goodwood pump and McCormicks Creek (Table 5.3), where embeddedness in pool habitats was high due to the high proportion of fine sediments (Appendix 4). Most sites also had a low degree of sediment compaction, although there was some degree of bed compaction at Goodwood pump and Deepdell Creek (Table 5.3). Pools were present at most survey sites, with maximum water depth in excess of 2.5 m (Table 5.3).

Intact riparian buffers were present at most sites, with no buffers and direct stock access present at two of the sites: Deepdell Creek and Horse Range Road. Buffers were dominated by deciduous trees (mostly willows and poplars), exotic shrubs (including broom and blackberry) and rank grass. In the Deepdell Creek site, one bank was dominated by broom, gorse and briar rose, while the vegetation of the other bank was mostly snow tussock, *Carex* and exotic grasses.

Sites at Collins Bridge, The Grange, Craig Road, Deepdell Creek and McCormicks Creek were shaded to some degree by riparian vegetation and/or surrounding topography while sites at Horse Range Road and Goodwood were largely unshaded (Appendix 4).

Table 5.3 Instream habitat characteristics of sampling sites in the Shag River/Waihemo catchment

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="5">Shag River</th><th rowspan="2">McCormicks Creek</th><th rowspan="2">Deepdell Creek</th></tr>
<tr><th>Collins Bridge</th><th>The Grange</th><th>Craig Road</th><th>Horse Range Road</th><th>Goodwood</th></tr>
<tr><td colspan="3">Approx survey reach length (m)</td><td>80</td><td>130</td><td>150</td><td>120</td><td>80</td><td>110</td><td>60</td></tr>
<tr><td colspan="3">Wetted width (approx) (m)</td><td>4</td><td>12</td><td>12</td><td>4</td><td>5</td><td>1</td><td>2</td></tr>
<tr><td rowspan="6">Substrate composition</td><td colspan="2">%Concrete/artificial</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>%Bedrock</td><td>>4000 mm</td><td>0</td><td>73</td><td>10</td><td>0</td><td>0</td><td>7</td><td>10</td></tr>
<tr><td>%Boulder</td><td>256-4000 mm</td><td>18</td><td>0</td><td>2</td><td>0</td><td>2</td><td>3</td><td>0</td></tr>
<tr><td>%Cobble</td><td>64-255 mm</td><td>33</td><td>0</td><td>20</td><td>33</td><td>3</td><td>30</td><td>1</td></tr>
<tr><td>%Gravel</td><td>2-63 mm</td><td>30</td><td>25</td><td>55</td><td>60</td><td>61</td><td>40</td><td>78</td></tr>
<tr><td>%Silt, sand</td><td><2 mm</td><td>18</td><td>3</td><td>13</td><td>7</td><td>33</td><td>20</td><td>11</td></tr>
<tr><td colspan="3">%Embeddedness</td><td>0</td><td>0</td><td>0</td><td>0</td><td>35</td><td>10</td><td>0</td></tr>
<tr><td colspan="3">Substrate compactness</td><td>Loose</td><td>Loose</td><td>Loose</td><td>Loose</td><td>Mostly loose, little compaction</td><td>Loose</td><td>Mostly loose, little compaction</td></tr>
<tr><td colspan="3">%Woody debris & leaf packs</td><td>20</td><td>23</td><td>7</td><td>0</td><td>3</td><td>18</td><td>0</td></tr>
<tr><td colspan="3">%Obstructions to flow</td><td>26</td><td>0</td><td>2</td><td>0</td><td>7</td><td>2</td><td>2</td></tr>
<tr><td colspan="3">%Bank cover</td><td>3</td><td>0</td><td>0</td><td>10</td><td>12</td><td>40</td><td>0</td></tr>
<tr><td rowspan="4">Pools</td><td colspan="2">Max depth (m)</td><td>2</td><td>1.1->2.5</td><td>1.1->2.5</td><td>1</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="2">Fine sediment depth (m)</td><td>-</td><td>>0.01</td><td>0-<0.01</td><td>0</td><td>0</td><td>0</td><td>0-0.1</td></tr>
<tr><td colspan="2">Crest depth (m)</td><td>0.1-0.13</td><td>0.25-0.3</td><td>0.05-0.25</td><td>0</td><td>0</td><td>0</td><td>0.05-0.06</td></tr>
<tr><td colspan="2">Number of pools in reach</td><td>2</td><td>3</td><td>3</td><td>1</td><td>1</td><td>1</td><td>3</td></tr>
</table>

5.6 Aquatic plants

5.6.1 Periphyton monitoring

Periphyton community composition has been monitored at three sites in the Shag River/Waihemo catchment as part of the SOE programme. Monitoring was undertaken at The Grange between 2001 and 2008, while both the Craig Road and Goodwood sites were sampled between 2001 and 2013.

The composition of the periphyton community at the three monitoring sites is presented in Table 5.4. The periphyton community at The Grange was dominated on most occasions by the filamentous green alga *Cladophora*. In 2001 and 2008, the filamentous red alga *Audouinella* was the next most abundant taxon, while in 2004 the diatoms *Epithemia* and *Gomphoneis* were the next most abundant taxa. The exceptions to the dominance of this site by *Cladophora* were in 2002 and 2007. In 2002, the periphyton community was comprised solely of diatoms, with *Cymbella* the dominant taxon. Periphyton was very sparse in 2007, with *Cymbella* the only identified taxon, most likely due to a high flow event (peak flow = 32,000 l/s) on the 30 December 2006, about a week before the periphyton survey was undertaken.

The dominant periphyton taxon at Craig Road site has varied widely over the sampling period with diatoms being the most abundant taxa on some occasions (2001, 2007, 2008, 2010, 2012) and co-dominating on others (2011, 2013). *Gomphoneis* and the filamentous green alga *Mougeotia* were both the most common periphyton taxa present at this site in 2011, while in 2013, the community was a mix of the filamentous green alga *Microspora*, the benthic cyanobacterium *Nostoc* and the diatoms *Achnanthes* and *Synedra*. In 2009, the benthic cyanobacterium *Oscillatoria* dominated the periphyton at Craig Road.

At the Goodwood pump site, the periphyton community has been dominated by either cyanobacterium *Oscillatoria* (2001, 2006, 2011), various diatoms (2002, 2004, 2010), or co-dominated by both (2009). As for the site at The Grange, a sparse periphyton community was recorded in 2007, with *Audouinella* and the diatom *Nitzschia* the only recorded taxa.

Figure 5.10 present photographs of the most abundant periphyton taxa at SoE monitoring sites in the Shag/Waihemo catchment.

Table 5.4 Periphyton taxa collected at three sites in the Shag River/Waihemo as part of the SOE monitoring programme. Abundance codes are based on Biggs & Kilroy (2000): 1 = rare, 2 = rare-occasional, 3 = occasional, 4 = occasional-common, 5 = common, 6 = common-abundant, 7 = abundant, 8 = dominant. Only taxa that were occassional-common at at least one site or more are shown. The full table is presented in Appendix 5.

	Shag River at The Grange						Shag River at Craig Road								Shag River at Goodwood Pump									
Taxon	**2001**	**2002**	**2004**	**2004**	**2007**	**2008**	**2001**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2001**	**2002**	**2004**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Filamentous Green Algae																								
Cladophora spp.	6		8	8		6				4	6					3								
Microspora sp.											3	2	2	5	3		3		3					
Mougeotia sp.														2			7							
Oedogonium sp.				4							6	5												
Spirogyra spp.											4										5			
Filamentous Red Algae																								
Audouinella	5			5		5	2	3	2							3		3				3		
Cyanobacteria																								
Nostoc														5										
Oscillatoria							4		4	8	2		3		6				6	7			6	
Phormidium sp.																	4				5			
Diatoms																								
Achnanthes													2	5										4
Achnanthidium		4								5	2					3								
Cocconeis	2					2						4		3								2		
Cocconeis pediculus											5										4			
Cocconeis placentula		3	4								3						2				3			
Cymbella	2				1	2				3				2								1		4
Cymbella aspera		8		2																				
Cymbella cuspidata																7								
Cymbella kappii				4							5						5				6			
Cymbella cf. *kappii*		4																						
Cymbella tumida		5																						
Diatoma	3					3	6		6															
Diatoma cf. *vulgaris*											4										8			
Encyonema minutum		2									7					5	3				3			
Encyonema cf. *gracile* (40x7µm)				4																				
Encyonema prostratum											6													
Epithemia adnata			5	5																				
Epithemia sorex			7	7							2													
Fragilaria	4		6	6		4		4		4	3						3			7				
Gomphoneis sp.		7	6	7						3	2	5	4			8	8				5	3	2	
Navicula spp.		6														3								
Navicula avenacea			5																					
Navicula cf. *cryptocephala*			6														2							
Synedra							3	2	3			4	4	5	4				4			2		3
Synedra cf. *acus*																					4			
Synedra ulna		5	4	4							2					2	5				3			

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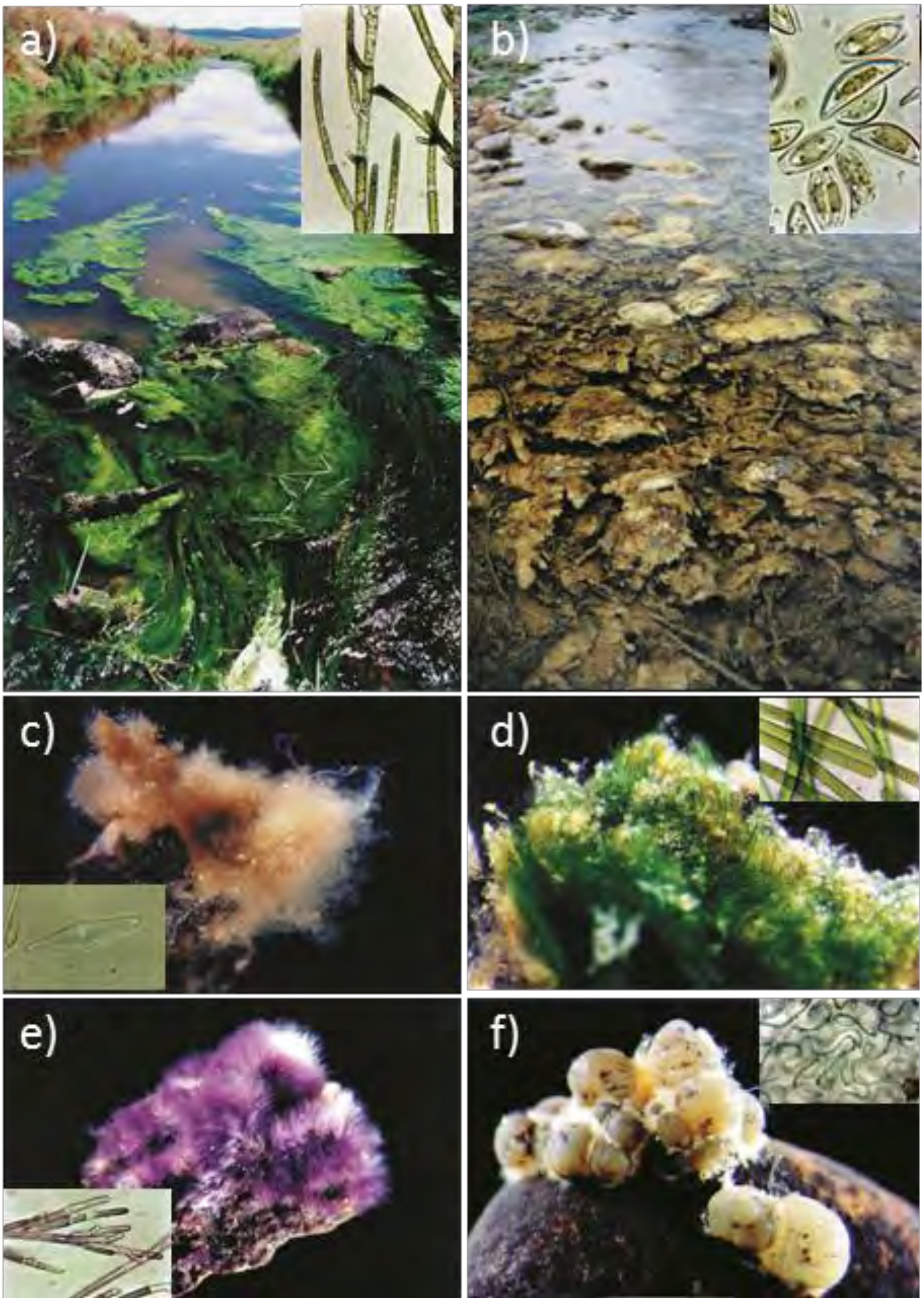

Figure 5.10 Photographs of periphyton taxa commonly abundant at SoE sites in the Shag River/Waihemo, with photomicrographs inset. a) Thick growths of the filamentous green alga *Cladophora*, b) a very extensive growth of the mat-forming diatom *Cymbella*, c) the stalked diatom *Gomphoneis*, d) the filamentous cyanobacterium *Oscillatoria*, e) the branched red alga *Audouinella*, and f) the colonial cyanobacterium Nostoc. All photographs by Stephen Moore.

5.6.2 Aquatic plant cover

The cover of aquatic macrophytes (vascular plants) and periphyton was assessed as part of habitat assessments in April 2013. Submerged macrophytes were relatively uncommon in sites in the mainstem, with some oxygen weed (*Elodea*) observed at The Grange, Craig Road and Goodwood pump sites and pondweed (*Potamogeton*) observed at Craig Road and Goodwood pump sites (Table 5.5). Emergent macrophytes were present at three sites. Watercress was present at Collins Bridge and Goodwood pump and monkey musk was present at Craig Road and Goodwood pump (Table 5.5). Oxygen weed was abundant in McCormicks Creek, while charophytes were present in Deepdell Creek (Table 5.5).

Periphyton cover at the Collins Bridge site was dominated by light brown taxa (primarily diatoms) while long filamentous green algae were the most abundant periphyton group at Horse Range Road, Goodwood pump and Deepdell Creek sites. The most abundant periphyton group at Craig Road site was dark brown-black taxa, which was likely to have been dominated by cyanobacteria, while long-filamentous green algae were also present (Table 5.5).

Table 5.5 Cover (as a percentage of the bed) of macrophytes and periphyton at sampling sites in the Shag River/Waihemo estimated during instream habitat surveys in April 2013.

	Shag River					McCormicks Creek	Deepdell Creek
	Collins Bridge	The Grange	Craig Road	Horse Range Road	Goodwood Pump		
Macrophytes							
Elodea	-	2	1	-	5	17	-
Charophytes	-	-	-	-	-	-	5
Potamogeton	-	-	1	-	2	-	-
Water cress	1	-	-	-	3	-	-
Monkey musk	-	-	3	-	1	-	-
Algae							
Light brown	13	-	-	-	-	-	-
Dark brown-black	-	-	27	-	-	-	-
Long filamentous green	-	-	3	27	77	-	12

5.7 Macroinvertebrates

5.7.1 Invertebrate monitoring

Long-term invertebrate monitoring has been undertaken annually at three sites in the Shag River/Waihemo catchment. Sampling was undertaken at The Grange between 2001 and 2008, at Craig Road from 2007 to present and at Goodwood Pump from 2001 to present.

Observed taxonomic richnesses ranged from 6 taxa (Goodwood pump, 2007) to 27 taxa (Craig Road, 2011), with similar taxon richnesses observed at the three sites ($F_{2,22}$=1.6, P= 0.23; Figure 5.11). The number of EPT taxa collected from the sites ranged from 3 to 10, with the %EPT ranging from 31 to 62%, with similar %EPT_{taxa} observed at the three sites ($F_{2,22}$=0.9, P= 0.42; Figure 5.11).

MCI and SQMCI scores were significantly higher at the Craig Road and Goodwood pump sites than at The Grange (MCI: $F_{2,22}$=7.8, P= 0.003, SQMCI: $F_{2,22}$=8.5, P= 0.002; Figure 5.11). The reason for this difference is not clear, although it may reflect the dominance of periphyton at The Grange by the green filamentous algae *Cladophora* (see Section 5.6.1).

Trends in macroinvertebrate indices were considered for the Goodwood Pump site, as sufficient data (ten years) were available for this site to allow for robust consideration of trends. No significant trends were detected for any of the metrics considered (Table 5.6)

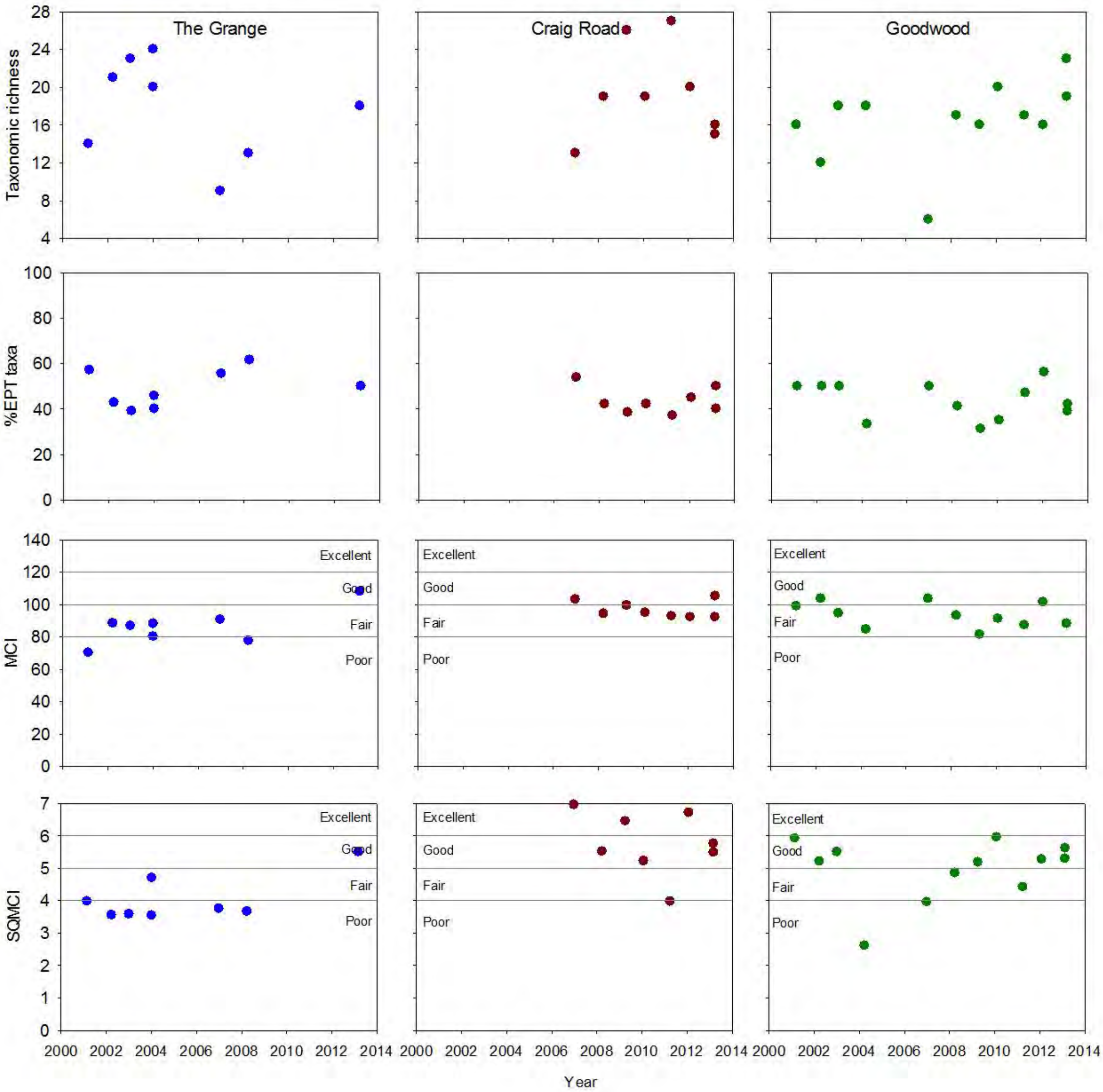

Figure 5.11 Macroinvertebrate metrics at three sites (The Grange, Craig Road, Goodwood) in the Shag River/Waihemo between 2001 and 2013. MCI and SQMCI water quality classes shown are based on Stark & Maxted (2007). Note that the two points at Craig Road and Goodwood Pump in 2013 represent samples taken as part of SoE monitoring as well as this study. The point for The Grange in 2013 represents the sample taken as part of this study.

Table 5.6 Trends in macroinvertebrate community indices at the Goodwood Pump SoE site in the Shag/Waihemo catchment between 2001 and 2013.

Metric	$F_{1, 9}$	P	R^2
Taxa	0.648	0.4416	0.0671
MCI	0.241	0.6354	0.0261
SQMCI	1.259	0.2909	0.1227
%EPT	0.0974	0.762	0.0107

The mudsnail *Potamopyrgus* (Figure 5.12) was among the most abundant macroinvertebrate taxa collected in samples at The Grange on three occasions (2001, 2003, both samples collected in 2004) while larvae of the mayfly *Deleatidium* (Figure 5.12) were among the most abundant taxa at this site in 2002, 2007 and 2008 (Appendix 6).

Larvae of the mayfly *Deleatidium* were among the most abundant taxa at Craig Road on all sampling occasions, with the exception of 2011 when *Potamopyrgus* was the most abundant taxon at this site. The net-spinning caddis fly *Aoteapsyche* (Figure 5.12) was among the most abundant taxa on several occasions (2008, 2010, 2011, 2012) (Appendix 6).

Deleatidium was also among the most abundant macroinvertebrates at Goodwood pump on most occasions, along with larvae of the cased caddis fly *Pycnocentrodes* (Figure 5.12; Appendix 6).

5.7.2 Catchment monitoring 2013

During macroinvertebrate sampling in 2013, the greatest number of macroinvertebrate taxa were collected from Collins Bridge and Goodwood pump (both 23 taxa), while the lowest numbers were collected from Craig Road (15 taxa) and McCormicks Creek (16 taxa) (Table 5.7).

Larvae of the mayfly *Deleatidium* were the most or among the most abundant invertebrate taxon abundant invertebrate taxon at all of the sites surveyed (Table 5.7). Some of the other most abundant invertebrate taxa included the mud snail *Potamopyrgus antipodarum*, the cased caddis flies *Pycnocentrodes*, *Hudsonema amabile* and *Pycnocentria* and the net-spinning caddis fly *Aoteapsyche* (Table 5.7). Ostracods (seed shrimps, Figure 5.12), chironomid midges (Orthocladiinae, Figure 5.12) and the stonefly *Zelandoperla* were all among the most abundant taxa at one of the sites surveyed (Table 5.7).

The Collins Bridge site had the highest %EPT_{taxa}, MCI and SQMCI scores, which indicated ‗excellent‘ water quality, with the stonefly *Zelandoperla* co-dominating the community along with *Deleatidium* (Table 5.7). The %EPT_{taxa}, MCI and SQMCI scores at the three downstream sites (Craig Road, Horse Range Road and Goodwood Pump) were among the lowest observed, with the MCI scores indicating ―Good" water quality at The Grange and ―Fair" water quality at Horse Range Road and Goodwood Pump (Table 5.7). In contrast, SQMCI scores suggested ―Good" water quality at the Grange, Craig Road and Goodwood Pump and ―Excellent" water quality at Horse Range Road. In the tributaries, the MCI score for Deepdell Creek indicated ―Fair" water quality, while the SQMCI score suggested that it was ―Good", while the MCI score for McCormicks Creek indicated ―Good" water quality, compared with ―Excellent" water quality indicated by the SQMCI score (Table 5.7).

Table 5.7 Macroinvertebrate taxa collected from the Shag River/Waihemo in 2013. Relative abundance scores: R = rare (1-4 individuals), C = common (4-19 individuals), A = abundant (20-99 individuals), VA = very abundant (100-499 individuals) and VVA = very, very abundant (>499 individuals). Only taxa that were abundant at one site or more are shown. The full table is presented in Appendix 6.

TAXON	MCI score	Shag River at Collins Bridge	Shag River at Grange	Shag River at Craig Road	Shag River at Horse Range Road	Shag River at Goodwood Pump	Deepdell Creek at Golden Point Road	McCormicks at State Highway 85
COLEOPTERA								
Elmidae	6	C	C	C	C	C	A	C
CRUSTACEA								
Ostracoda	3		VA	A	R	C	C	
Paracalliope fluviatilis	5				R	A	A	R
DIPTERA								
Muscidae	3			A	R	R		
Orthocladiinae	2	A		A	R	VA	R	
Tanytarsini	3			A		R		
EPHEMEROPTERA								
Coloburiscus humeralis	9	A						
Deleatidium species	8	VA	VA	VVA	VVA	VA	VVA	VVA
MEGALOPTERA								
Archichauliodes diversus	7	C	C	A	R	R	R	
MOLLUSCA								
Physa / Physella species	3		R		R	R	A	C
Potamopyrgus antipodarum	4	R	VA	A	VA	A	VVA	VA
OLIGOCHAETA	1		A	C	A	R	C	C
PLECOPTERA								
Zelandoperla species	10	VA	C					R
TRICHOPTERA								
Aoteapsyche species	4	A	C	VVA	VA	A	A	A
Hudsonema amabile	6	R	VA		A	A	VA	A
Hydrobiosis species	5	A		A	C	A	C	R
Olinga species	9	A	C			R	R	
Psilochorema species	8	C	C	A	A	C	A	C
Pycnocentria species	7	C	VA	A	A	VA		A
Pycnocentrodes species	5	A	A	A	VA	VA	VVA	A
Number of taxa		23	18	15	19	23	21	16
Number of EPT taxa		14	9	6	7	9	8	8
$\%EPT_{taxa}$		61%	50%	40%	37%	39%	38%	50%
MCI score		133	108	92	92	88	95	104
SQMCI score		7.6	5.5	5.8	6.5	5.3	5.6	7.0

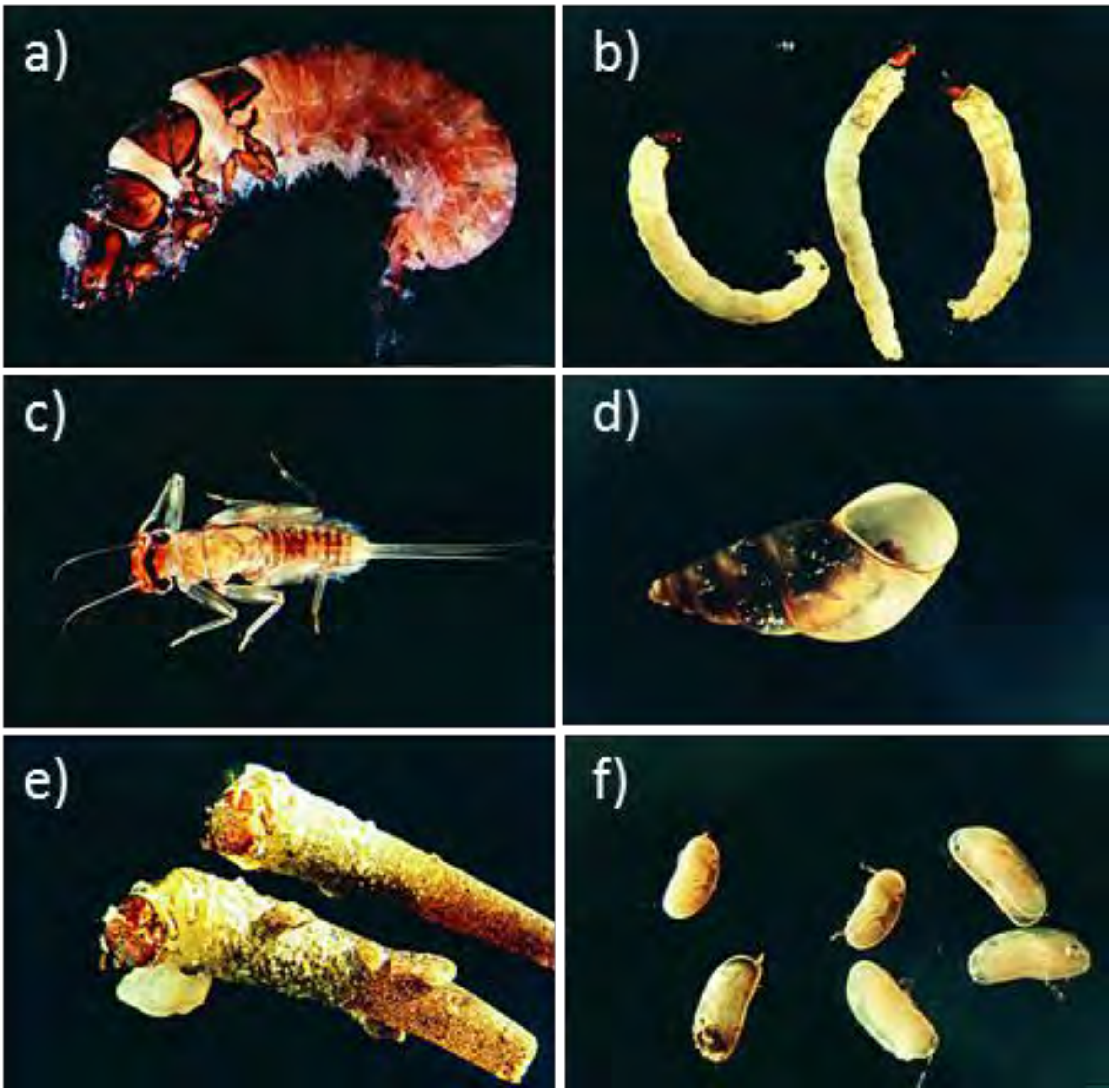

Figure 5.12 Photographs of common macroinvertebrate taxa in the Shag/Waihemo catchment. a) A larva of the net-spinning caddis fly, *Hydropsyche*, b) chironomid midge larvae, c) a nymph of the mayfly *Deleatidium*, d) the mudsnail *Potamopyrgus antipodarum*, e) larvae of the cased caddis fly *Pycnocentrodes*, and f) seed shrimp (Ostracoda). All photographs by Stephen Moore.

5.8 Fish

5.8.1 Fish monitoring

Annual SoE monitoring has been undertaken at the Craig Road SoE site since 2007 and at Goodwood Pump on two occasions (2007 and 2008). Since 2009, SoE fish monitoring has followed national sampling protocols which consists of single-pass electric fishing over a 150-m long reach, which is divided into ten 15-m sub-reaches (following Joy *et al.* 2013). In comparison, SoE monitoring sampling undertaken prior to 2009 and sampling undertaken as part of this catchment study consisted of three-pass electric fishing of an approximately 100 m^2. Data collected from Craig Road as part of the SoE monitoring programme since 2009 is not comparable with the data collected from SoE sites prior to 2009, nor with data collected from other sites in the catchment as part of this study.

Eleven species of freshwater fish have been collected from the SoE monitoring site at Craig Road since 2009. The number of fish collected within the 150 m-long monitoring reach at this site has ranged from 170 (2012) to 900 (2014) (Table 5.8). Upland bullies have been among the most abundant species on all sampling occasions (Table 5.8)

Shortfin and longfin eels, common, bluegill and upland bullies and lamprey have been collected at this monitoring site on all sampling occasions since 2009. Inanga have been collected on three occasions (Table 5.8).

Table 5.8 Abundance of fish collected at the Craig Road SoE monitoring site between 2009 and 2014.

Common name	Species	Number of fish caught in 150 m monitoring reach					
		28/04/09	16/03/10	23/02/11	29/03/12	26/03/13	3/04/14
Shortfin eel	*Anguilla australis*	21	17	60	12	6	16
Longfin eel	*Anguilla dieffenbachii*	157	67	46	7	15	12
Unident eel	*Anguilla* indet.	1	4				
Common bully	*Gobiomorphus cotidianus*	9	4	136	87	23	3
Bluegill bully	*Gobiomorphus hubbsi*	6	8	8	4	19	4
Redfin bully	*Gobiomorphus huttoni*						8
Upland bully	*Gobiomorphus breviceps*	106	279	152	48	683	849
Unident bully	*Gobiomorphus* indet.	14	3	57			
Inanga	*Galaxias maculatus*	5		1	1		
Koaro	*Galaxias brevipinnis*		1				
Indet. galaxias	*Galaxias* indet.				1		
Lamprey*	*Geotria australis*	1, 2	28, 41	1, 4	0, 5	1, 5	0, 7
Torrentfish	*Cheimarrichthys fosteri*						
Black Flounder	*Rhombosolea retiaria*						
Common smelt	*Retropinna retropinna*						
Brown trout	*Salmo trutta*	9	18	6	5	4	1
Total		328	401	466	165	750	893

* Two numbers are given for lamprey representing the number of each of the two freshwater life stages. The first is the number of ammocoetes[3], the second, the number of macrothelmia[4] collected.

[3] Ammocoetes are larval lamprey (usually up to 95 mm) found in freshwater. They are brown in colouration and live in burrows in silty/sandy substrates where they filter-feed.

5.8.2 Catchment surveys 2013

The greatest density of fish and number of fish species was collected at Goodwood Pump, the most downstream site sampled as part of this study (Table 5.9). The density and number of fish species observed at Horse Range Road were also high, with this site also being close to the estuary (Table 5.9). In contrast, the lowest numbers of fish species were observed at The Grange, Collins Bridge and Deepdell Creek. In the case of The Grange, this is likely to reflect the lack of habitat diversity and quality within the reach sampled, while the low numbers of species collected at Collins Bridge and Deepdell Creek are likely to reflect the distance of these sites from the coast (Table 5.9).

Common bullies were the most abundant fish species at Goodwood Pump and Horse Range Road (Table 5.9), while upland bullies were the most abundant species at Craig Road (Table 5.8) and McCormicks Creek (Table 5.9). Black flounder, common smelt, inanga and juvenile lamprey were abundant at Goodwood pump, but were also collected at Horse Range Road, while torrentfish were only found at Goodwood Pump (Table 5.9). Longfin eels were collected from most sites, while shortfin eels were most abundant at Goodwood Pump and Horse Range Road, although a single individual was collected from Deepdell Creek (Table 5.9). Taieri flathead galaxias were abundant at Collins Bridge and Deepdell Creek (Table 5.9). Brown trout were collected from most sites in the lower river (Table 5.9).

Table 5.9 Density (per 100 m²) and number of fish species at the six sites sampled as part of this study. The number of fish species present at Craig Road in 2013 is included for comparison (*=present).

Species	Goodwood Pump	Horse Range Road	The Grange	Collins Bridge	McCormicks Ck	Deepdell Ck	Craig Rd
Longfin eel	8.5	12.8	-	1.1	7.1	-	*
Shortfin eel	3.9	2.8	-	-	-	1.3	*
Common bully	272.1	209.2	3.2	-	2.4	-	*
Bluegill bully	7.0	-	-	-	-	-	*
Redfin bully	0.8	-	-	-	-	-	*
Upland bully	-	12.8	-	-	81.0	-	*
Inanga	34.9	1.8	-	-	-	-	*
Koaro	-	-	-	-	-	-	*
Taieri Flathead galaxias	-	-	-	79.3	-	32.5	-
Lamprey - ammocoetes	7.8	-	-	-	-	-	*
Lamprey - macrothelmia	0.8	0.9	-	-	-	-	*
Torrentfish	0.8	-	-	-	-	-	-
Black Flounder	4.7	0.9	-	-	-	-	-
Common smelt	8.5	0.9	-	-	-	-	-
Brown trout	2.3	0.9	-	-	2.4	-	*
TOTAL	**351.9**	**243.1**	**3.2**	**80.5**	**85.7**	**32.5**	-
Number of species	12	9	1	2	4	2	10
Distance from sea	6.7	9.9	31.6	71.4	25.2	62.6	18.6

[4] Macrothelmia are juvenile lamprey that have changed to a blue/silver colouration and are migrating, or are about to migrate, to the sea. They are usually between 95 mm and 105 mm long.

6. Discussion

6.1 Nutrients

Nutrient concentrations affect the growth of algae and other periphyton, and high biomasses of periphyton can affect a wide range of instream values, including aesthetics, biodiversity, recreation and water quality as well as water users (Biggs 2000). Periphyton biomass is determined by the balance between two opposing processes: biomass accrual and biomass loss (Biggs 2000). Biomass accrual is driven by the availability of nutrients, light and water temperature, while biomass loss is driven by disturbance (substrate instability, water velocity and SS) and grazing (mainly by invertebrates). In an unregulated river like the Shag/Waihemo, the processes affecting biomass loss are not able to be manipulated, meaning that nutrient management is the only practical means of managing periphyton biomass to maintain instream values. In most rivers, nitrogen and phosphorus are the main nutrients that potentially limit periphyton growth, although some periphyton taxa (e.g. cyanobacteria) are able to fix atmospheric nitrogen

A significant increasing trend in the concentration of TN and NNN was detected for the Craig Road SoE site, while increasing trends in NNN and DRP were detected for the Goodwood Pump site. In contrast, significant declining trends were evident for NH_4-N. These trends indicate a shift in land-use practices, with observed reductions in NH_4-N as well as *E. coli* suggesting improvements in livestock and farm management, including riparian fencing and stock exclusion. Increasing NNN at both sites suggests an increase in nitrogen leaching, with this nitrogen entering the river via groundwater inputs.

The increasing trend in DRP at Goodwood Pump is not consistent with improvements in livestock management that may account for improving trends in NH_4-N and *E. coli.* A similar (increasing) trend was not evident at Craig Road. Changes in the operation of the Palmerston waste water treatment plant (WWTP; Resource consent RM11.096) are unlikely to account for the observed increase in DRP. Waste from the WWTP has been flood-irrigated on to land adjacent to the river since 1974 (Oscar Smit, Waitaki District Council, *pers. comm.*), with a daily limit of 700 m^3 and an average daily limit of 420 m^3 in any given year. Census data for Palmerston indicates that the population declined between 2001 (807) and 2013 (792), suggesting that the nutrient load from the WWTP is unlikely to have increased over that time period. A possible explanation for this is the deposition of fine sediment in the lower catchment during recent flood events, with phosphorus being released from these sediments over time. Consideration of long-term flow records from The Grange flow recorder indicates that there have been more frequent high flow events in the Shag River/Waihemo since 2005 relative to the preceding decade (Figure 6.1), which may account for the deposition of fine sediment in the lower river and subsequent trend in DRP observed at Goodwood Pump.

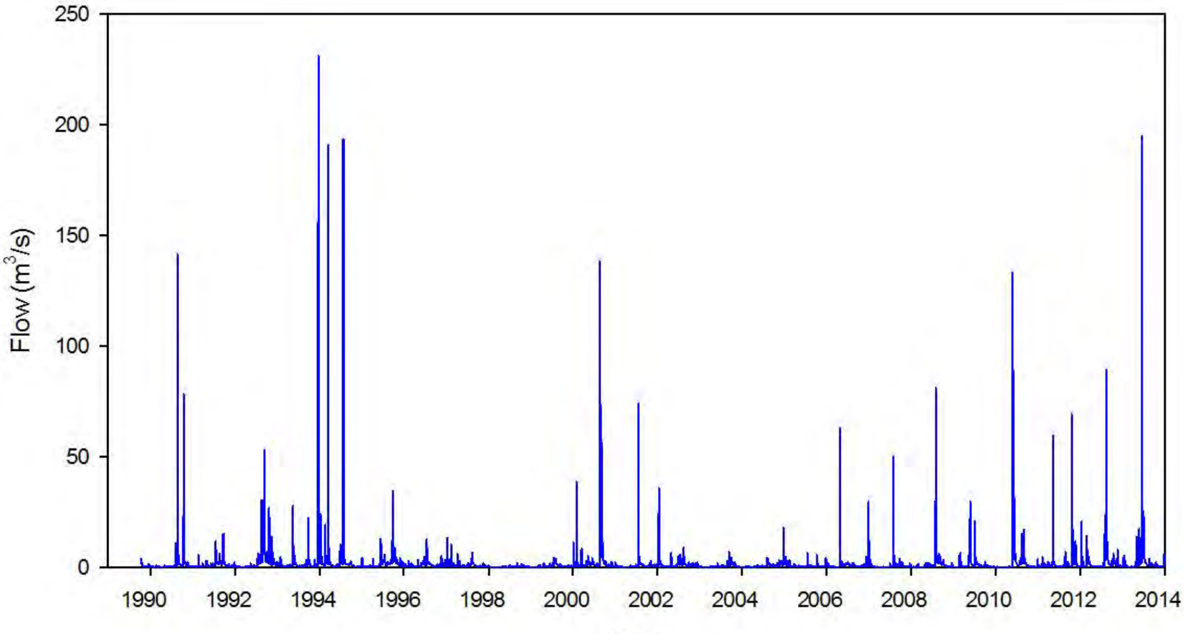

Figure 6.1 Flow (as daily means) in the Shag River/Waihemo between late 1989 and early 2014.

6.2 Water clarity

The clarity of the water in a river is one of the most noticeable water quality attributes to the casual observer and can have aesthetic, ecological and recreational effects. Davies-Colley & Close (1990) measured the visual clarity of 96 New Zealand rivers during baseflow conditions (<median flow) and found a median clarity of 3.2 m, while 5% of values were below 0.82 m and 95% of values were less than 8.42 m. In comparison, the median value recorded pump during baseflow conditions was 3.8 m at Goodwood and was 4.0 m at Craig Road. These values are very close to the 75^{th} percentile observed by Davies-Colley & Close (1990) indicating that water clarity in the Shag River is relatively high in a national context.

An increasing trend in turbidity was detected for the Craig Road SoE site. This is unexpected and cannot be easily explained. Possible causes include bank erosion or landslips in the upstream catchment. No such trend was evident at Goodwood Pump.

6.3 Water temperature

Water temperature is a fundamental factor affecting all aspects of stream systems and an essential factor to consider in the management of waterways. Water temperature (especially high water temperatures) directly affects fish populations, by affecting their survival, growth, spawning, egg development and migration, but it can also affect fish populations indirectly, through effects on physicochemical conditions and food supplies (Olsen *et al.*, 2012).

Of the fish species collected from the Shag/Waihemo River (Section 5.8), brown trout (*Salmo trutta*) and common smelt (*Retropinna retropinna*) are the most sensitive to high water temperatures. The thermal requirements of brown trout are well understood (Elliott, 1994). Significant mortality of brown trout is expected to occur in relatively short time periods at temperatures above 25°C and growth is retarded when temperatures exceed 19°C. The growth optimum for brown trout feeding on invertebrates is 14°C, but it becomes 17°C for trout fed on a fish diet (Elliott & Hurley, 1998, 1999, 2000). Todd *et al.* (2008) calculated acute and chronic thermal criteria for a range of cold-water and warm-water fish species, and, for brown trout, they recommended an acute thermal threshold of 24.6°C and a chronic thermal threshold of 19.6°C. The acute thermal threshold is calculated as the highest two-hour average water temperature measured within any 24-hour period, while the chronic thermal threshold is expressed as the maximum weekly average temperature (Todd *et al.,* 2008).

Of the native fish collected from the Shag/Waihemo River, common smelt are the most sensitive to high water temperatures, although they are likely to be more tolerant than brown trout, as they have acute and chronic thermal thresholds of 26°C (Olsen *et al.*, 2012).

Water temperatures recorded at Collins Bridge were well within the acute or chronic thermal thresholds for brown trout (based on Todd *et al.,* 2008). However, data collected at Craig Road indicated that water temperatures exceed both the chronic and acute thermal thresholds recommended for brown trout on occasion while records from McCormicks Creek show that temperatures exceeded the chronic thermal threshold for brown trout. These results suggest that trout growth and/or survival may be affected by high water temperatures in parts of the Shag/Waihemo catchment.

6.4 Faecal contamination

Water contaminated with faecal matter poses a range of possible health risks to recreational users, including serious gastrointestinal and respiratory illnesses. Counts of the bacterium *E. coli* are commonly used as an indicator of faecal contamination and a measure of the probability of the presence of other disease-causing agents, such as the protozoa *Giardia* and *Cryptosporidium*, the bacterium *Campylobacter* and various other bacteria and viruses.

SoE monitoring at both Craig Road and Goodwood Pump indicates that *E. coli* counts in the catchment have decreased over the past 13-14 years. This is most likely to reflect improvements in stock management and exclusion from waterways and stream banks. *Escherichia coli* counts were relatively low at sites sampled in 2012-2013 and were consistent with low densities of stock with access to waterways and adjacent areas.

6.5 Substrate and riparian cover

The quantity and quality of habitat are important factors that can affect many instream values, among which composition of the streambed is particularly important because it provides the attachment substrate for periphyton and the habitat for macroinvertebrates and fish.

In general, habitat quality at most sites was relatively high. The substrate at most sites was predominantly gravels, although cobbles and bedrock formed a substantial proportion of the bed at some sites. There was some evidence of cobbles becoming embedded in pools at Goodwood Pump and McCormicks Creek as a result of fine sediment. There was also some sediment compaction at Goodwood Pump and Deepdell Creek.

The bed of the Shag River/Waihemo is currently aggrading or stable, following many years of degradation resulting from excessive gravel extraction and insufficient replenishment (ORC, In prep). This is likely to change the nature of in-stream habitat in the Shag River/Waihemo.

Riparian buffers were present at most sites, although there was evidence of direct stock access at two sites: Deepdell Creek and Horse Range Road. Riparian vegetation generally consisted of exotic species, including willows and poplars, blackberry, broom and rank grass.

6.6 Compliance with plan change 6A limits

Plan change 6A outlines the water quality limits for receiving waters (Schedule 15, Table 3.1) and discharge thresholds (Schedule 16). Receiving water limits are applied as 5-year, 80th percentiles, when flows are at or below median flow (649 l/s), with the flows in the Shag/Waihemo catchment being set at the gauging site at Craig Road. For most of the sites sampled (the exceptions being the SoE sites at Craig Road and Goodwood Pump) data is only available for one year (October 2012 – September 2013). For these sites, 80th percentiles were calculated based on this limited data and should be interpreted cautiously.

Both long-term monitoring sites (Goodwood Pump and Craig Road) comply with all PC6A limits except for NNN (Table 6.1).

Sampling conducted throughout the catchment in 2012-2013 showed that all sites were likely to comply with PC6A limits for NH_4-N, DRP and turbidity, although the 80th percentile of DRP concentrations at Goodwood Pump approached the PC6A limit of 0.01 mg/l (Table 6.1). If the increasing trend observed at this site continues, it is likely that it will not comply with the DRP limit in the near future.

In contrast, Collins Bridge and The Grange were the only sites sampled that are likely to comply with NNN limits, while the 80th percentile of NNN in Deepdell Creek was equal to the limit (Table 6.1). Increasing trends at both Craig Road and Goodwood Pump indicate that NNN concentrations are unlikely to comply with PC6A limits without actions taken to address the sources. The Shag Alluvium Aquifer is identified in PC6A as a Nitrogen Sensitive Zone, with a leaching rate for permitted activities set at 20 kg N/ha/y as calculated using OVERSEER® version 6.0 effective from 1 April 2020 (Rule 12.C.1.3(a)(ii)). This rule is likely to be the most effective means of halting the observed increase in NNN when it comes into effect.

Based on the results of the 2012-2013 survey, Craig Road, Deepdell Creek and Collins Bridge were likely to comply with the *E. coli* limit of 260 cfu/100 ml and most of the other sites were close to this limit (Table 6.1). The counts observed at all sites are likely to result from low densities of stock with access to waterways and areas adjacent to waterways.

Turbidity at both SoE sites was relatively low, with 80th percentiles calculated for the 1-year and 5-year periods complying with the limit (Table 6.1).

The 80th percentiles calculated for the 1-year period at both SoE sites were generally comparable to those calculated for the 5-year period (Table 6.1). The exceptions were for NNN and *E. coli* at the Goodwood Pump site; the 80th percentile NNN concentration for the 5-year period was twice that calculated based on data from 2012-2013 alone while the 80th percentile *E. coli* concentration based on 2012-2013 exceeded the limit, while that for the 5-year period did not (Table 6.1).

Table 6.1 Comparison of 80th percentiles of water quality parameters with receiving water quality limits in plan change 6A (Schedule 15, Table 3.1). Values that exceeded the limit are highlighted in red and those that are at the limit are highlighted in orange. All values calculated using samples collected when flows were at or below median flow (649 l/s).

Site	Period	NNN 0.075 mg/l	NH_4-N 0.1 mg/l	DRP 0.01 mg/l	*E. coli* 260 cfu/100 ml	Turbidity 5 NTU
Shag R. - Collins Bridge	2012-2013	0.010	0.005	0.002	260	-
Shag R. - The Grange	2012-2013	0.033	0.005	0.004	410	-
Shag R. - Craig Road	2012-2013	0.089	0.005	0.0044	190	1.1
	2008-2013	**0.087**	**0.005**	**0.0062**	**132**	**0.6**
Shag R. - Horse Range Rd	2012-2013	0.120	0.010	0.002	280	-
Shag R. - Goodwood Pump	2012-2013	0.242	0.010	0.009	274	1.3
	2008-2013	**0.485**	**0.011**	**0.009**	**204**	**0.7**
Deepdell Creek	2012-2013	0.075	0.005	0.005	47	-
McCormick Creek	2012-2013	0.870	0.005	0.006	300	-

6.7 Biological monitoring

6.7.1 Periphyton

The periphyton community forms the slimy coating on the surface of stones and other substrates in freshwaters. This community can include green (Chlorophyta), yellow-green (Xanthophyta), golden brown (Chrysophyta) and red (Rhodophyta) algae, blue-greens (Cyanobacteria), diatoms (Bacillariophyta), bacteria and fungi. Periphyton is an integral part of stream food webs; it captures energy from the sun and converts it, via photosynthesis, to energy sources available to macroinvertebrates, which feed on it. These, in turn, are fed on by other invertebrates and fish. However, periphyton can form nuisance blooms that can detrimentally affect other instream values, such as aesthetics, biodiversity, recreation (swimming and angling), water takes (irrigation, stock/drinking water and industrial) and water quality.

The most extreme case of periphyton affecting instream values is toxin-producing benthic cyanobacteria. Some cyanobacteria, including the genera *Nostoc*, *Phormidium* and *Oscillatoria* that have been recorded from the Shag River/Waihemo, may produce toxins that pose a health risk to humans and animals. These include toxins that affect the nervous system (neurotoxins), liver (hepatotoxins) and dermatotoxins that can cause severe irritation of the skin. The presence of potentially toxic cyanobacteria can affect the suitability of a waterway for drinking, recreation (swimming), dogs, stock drinking water and food-gathering (by affecting palatability or through accumulation of toxins in organs such as the liver). Cyanobacteria-produced neurotoxins have been implicated in the deaths of numerous dogs in New Zealand (Hamill 2001, Wood *et al.* 2007). Cyanobacterial mats can be dislodged from the riverbed and wash to the bank where dogs, attracted by their distinctive musty smell, may eat them. Death occurs rapidly following the ingestion of a lethal dose.

Warning signs are erected at public access sites on the Shag River/Waihemo, including access at Old Man Road, Horse Range Road, Mill Road, Jones Road, Craig Road, Grange Hill Road (at Inch Valley and Waynes), Domain Road and Murphy Street (in Dunback).

Filamentous green algae are typically associated with nutrient enrichment and/or periods of stable flows. The frequent dominance of samples taken from The Grange by the filamentous green alga *Cladophora* over the period 2001-2008 suggests that nutrient concentrations at this site are enriched, possibly as a result of upwelling groundwater.

The dominant periphyton at both the Craig Road and Goodwood Pump sites varied from year to year with benthic cyanobacteria and diatoms commonly dominating the periphyton, although filamentous green taxa have been abundant on occasion. These results are consistent with the results of water quality monitoring and do not indicate excessive enrichment at these sites.

6.7.2 Macroinvertebrates

Macroinvertebrates are a diverse group and include insects, crustaceans, worms, molluscs and mites. They are an important part of stream food webs, linking primary producers (periphyton and terrestrial leaf litter) to higher trophic levels (fish, birds). Because of the length of the aquatic part of their life-cycles, which generally range from a few months up to two years, macroinvertebrates also provide a good indication of the medium- to long-term water quality of a waterway. For this reason, they are used in biomonitoring around the world. In New Zealand, the MCI (Stark, 1985), and its derivatives (SQMCI, QMCI: Stark, 1998), are used as a measure of organic enrichment and sedimentation in gravel-bed streams.

Macroinvertebrate monitoring has been undertaken as part of the SoE monitoring in the Shag River/Waihemo since 2001. Sampling at The Grange between 2001 and 2008 consistently indicated that water quality was poor-fair, while the sample collected from this location as part of this study indicated “good” water quality. The SoE site at Goodwood Pump has been sampled since 2001 and MCI and SQMCI scores consistently indicated “fair” to “good” water quality, with the exception of samples collected during drought conditions in 2004 when scores indicated “poor” water quality at this site. SoE monitoring conducted at Craig Road since 2007 is mixed, with MCI scores indicating “fair” to “good” water quality, while SQMCI scores indicate that water quality is “excellent” to “good”. This difference suggests that this site is numerically dominated by sensitive taxa, since the SQMCI is calculated taking account of the relative abundance of the taxa present whereas the MCI does not.

Macroinvertebrate sampling as part of the 2012-2013 survey found that the highest MCI, SQMCI and %EPT$_{taxa}$ scores were found at sites high in the catchment and declined with distance downstream, most likely reflecting changes in water quality and habitat with position in catchment. Macroinvertebrate metrics are expected to decline with distance downstream as a result of natural changes (e.g., channel gradient, water temperature, substrate composition), although not to the extent observed in the 2012-2013 survey.

6.7.3 Fish

The Shag/Waihemo catchment supports a diverse fish community. Sixteen fish species have been recorded from the Shag/Waihemo catchment, including 14 native species and 2 sports fish (brown trout and brook char). Seven of the native species recorded are classified as “declining” under the New Zealand freshwater fish threat classification (Allibone *et al.* 2010). These are longfin eel, torrentfish, koaro, inanga, lamprey, bluegill bully and redfin bully. Thirteen species have been collected from the Craig Road SoE monitoring site during annual surveys conducted between 2009 and 2014.

During catchment surveys conducted in 2013, the greatest number of species were observed at sites close to the coast (Goodwood Pump, 12 species and Horse Range Road, 9 species) while the sites with fewest species were the generally the furthest from the coast (Deepdell Creek and Collins Bridge, both with 2 species). Only one species was collected at The Grange, although this is likely to reflect poor habitat quality at this site. This pattern reflects the migratory nature of most of the fish species collected, with the upstream migration acting as a filter, whereby the ability of a species to penetrate inland is dictated by its swimming and/or climbing abilities. Migratory species with weak climbing/swimming abilities, such as black flounder, common smelt, inanga, juvenile lamprey and torrentfish, were only found at sites close to the coast. Amphidromous common bullies were found at sites close to the coast while non-migratory upland bullies (which complete their entire life-cycle in freshwater) were the most abundant bully species further inland (Craig Road and McCormicks Creek).

Migratory species with strong climbing abilities such as longfin eels and koaro were generally widespread within the catchment. Shortfin eels are generally not considered to be as adept at climbing as longfin eels but have been recorded from much of the Shag/Waihemo catchment, including in Deepdell Creek during the 2013 survey. Brown trout, which are also able to navigate rapids and low waterfalls are widespread in the catchment.

Taieri flathead galaxias are a non-migratory species of galaxias that complete their entire life-cycle in freshwater. They have been recorded from much of the upper catchment and were collected at Collins bridge and Deepdell Creek in this study.

7. Summary

1. Water quality in the Shag/Waihemo catchment is generally good.

2. A significant increasing trend in the concentration of TN and NNN was detected for the Craig Road SoE site, and for NNN at the Goodwood Pump site. Increasing NNN at both sites suggests an increase in nitrogen leaching, with this nitrogen entering the river via groundwater inputs. In contrast, significant declining trends were evident for NH4-N and E. coli indicating improved land-use practices. However, an increasing trend in DRP was observed at the Goodwood Pump site, but not at Craig Road. This trend is unlikely to have resulted from the operation of the Palmerston waste water treatment plant and may have resulted from the deposition of sediment in the lower river during recent high-flow events. Flow records indicate that such events have been more frequent in the past decade that in the preceding one.

3. *Escherichia coli* counts at some sites sampled in 2012-2013 indicate that stock access to waterways remains an issue in some parts of the catchment.

4. Water quality at sites in the Shag/Waihemo catchment sampled in 2012-2013 and at SoE sites was compared to the receiving water limits in plan change 6A:

   a. All sites were likely to comply with limits for NH_4-N, DRP and turbidity, although Goodwood Pump approached the DRP limit. Given the increasing trend in DRP observed at this site, it is likely that this site will not comply with the DRP limit in the near future.

   b. Collins Bridge and The Grange were the only sites sampled that are likely to comply with NNN limits, while Deepdell Creek was equal to the limit.

   c. Craig Road and Deepdell Creek were the only sites sampled that are likely to comply with the E. coli limit.

5. Water temperature records indicate that high water temperatures are likely to affect trout growth and/or survival may be affected by high water temperatures in parts of the Shag/Waihemo catchment at times.

6. Habitat quality was good at most sites, although fine sediments reduced habitat quality at Goodwood Pump and McCormicks Creek. Most sites had intact riparian buffers, although evidence of direct stock access was noted at Horse Range Road and Deepdell Creek. Riparian vegetation was dominated by exotic species.

7. The composition of the periphyton at both SoE sites varies from year to year with benthic cyanobacteria and diatoms commonly being the dominant taxa. Given this, warning signs should continue to be erected at main access points to educate the public to their presence and the risks they pose to people and animals. The frequent dominance of samples taken from The Grange by the filamentous green alga Cladophora over the period 2001-2008 suggests that nutrient concentrations at this site are enriched, possibly due to low nitrogen uptake by algae in upstream areas due to shading of the water resulting from the steep gorge upstream.

8. Macroinvertebrate sampling as part of SoE monitoring indicates that water quality has been relatively consistent since 2001. Macroinvertebrate metrics were highest at Collins Bridge site and declined downstream, largely as a result of the effects of land use practices.

9. The Shag/Waihemo catchment supports a diverse fish community. Sixteen fish species have been recorded from the Shag/Waihemo catchment, including 14 native species and 2 sportsfish (brown trout and brook char). Seven of the native

species recorded are classified as -declining" under the New Zealand freshwater fish threat classification (Allibone et al. 2010).

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Appendix 1. Water quality results

Site Name	Time	NH4-N	DRP	*E. coli*	NNN	SS	TKN	TN	TP
		mg/l-N	mg/l-P	cfu/100ml	mg/l-N	g/m3	mg/l-N	mg/l-N	mg/l-P
Shag at Collins Bridge	04-Oct-2012 08:30:00	<0.010	<0.004	170.00	0.01	<3	0.05	0.055	0.01
Shag at Collins Bridge	19-Oct-2012 10:00:00	<0.010	<0.004	37.00	0.03	<3	0.13	0.16	0.01
Shag at Collins Bridge	31-Oct-2012 09:30:00	<0.010	0.00	260.00	0.01	<3	0.05	0.055	0.01
Shag at Collins Bridge	12-Nov-2012 09:45:00	<0.010	0.01	600.00	0.02	<3	0.26	0.28	0.02
Shag at Collins Bridge	28-Nov-2012 09:15:00	<0.010	<0.004	120.00	0.02	<3	0.05	0.055	0.01
Shag at Collins Bridge	11-Dec-2012 08:05:00	<0.010	<0.004	52.00	0.02	<3	0.11	0.12	0.01
Shag at Collins Bridge	18-Jan-2013 08:30:00	<0.010	<0.004	550.00	0.03	3	0.13	0.16	0.02
Shag at Collins Bridge	30-Jan-2013 10:05:00	<0.010	<0.004	500.00	0.02	<3	0.10	0.12	0.01
Shag at Collins Bridge	13-Feb-2013 08:30:00	<0.010	<0.004	260.00	0.01	<3	0.05	0.055	0.01
Shag at Collins Bridge	27-Feb-2013 08:48:00	<0.010	<0.004	230.00	0.01	<3	0.05	0.055	0.01
Shag at Collins Bridge	12-Mar-2013 08:39:00	<0.010	<0.004	110.00	0.01	<3	0.05	0.055	0.03
Shag at Collins Bridge	26-Mar-2013 09:05:00	<0.010	<0.004	90.00	<0.002	<3	0.10	0.10	0.01
Shag at Collins Bridge	08-Apr-2013 09:40:00	<0.010	<0.004	70.00	<0.002	<3	0.05	0.055	<0.004
Shag at Collins Bridge	23-Apr-2013 09:25:00	<0.010	<0.004	190.00	0.00	<3	0.05	0.055	0.01
Shag at Collins Bridge	09-May-2013 10:15:00	<0.010	0.01	170.00	0.11	<3	0.13	0.24	0.01
Shag at Collins Bridge	22-May-2013 10:10:00	<0.010	0.01	390.00	0.06	12	0.44	0.50	0.05
Shag at Collins Bridge	07-Jun-2013 10:25:00	<0.010	0.01	54.00	0.21	<3	0.18	0.40	0.01
Shag at Collins Bridge	10-Jul-2013 09:50:00	<0.010	0.01	24.00	0.21	<3	0.21	0.42	0.01
Shag at Collins Bridge	25-Jul-2013 10:00:00	<0.010	0.01	22.00	0.10	<3	0.12	0.22	0.00
Shag at Collins Bridge	08-Aug-2013 10:00:00	<0.010	<0.004	18.00	0.05	<3	0.10	0.15	0.01
Shag at Collins Bridge	23-Aug-2013 10:10:00	<0.010	<0.004	39.00	0.02	<3	0.05	0.055	0.00
Shag at Collins Bridge	05-Sep-2013 09:55:00	<0.010	<0.004	26.00	0.11	<3	0.19	0.30	0.01
Shag at Collins Bridge	20-Sep-2013 11:05:00	<0.010	<0.004	10.00	0.01	<3	0.05	0.10	<0.004

Site Name	Time	NH4-N	DRP	*E. coli*	NNN	SS	TKN	TN	TP
		mg/l-N	mg/l-P	cfu/100ml	mg/l-N	g/m3	mg/l-N	mg/l-N	mg/l-P
Shag at The Grange	04-Oct-2012 10:05:00	<0.010	0.01	100.00	0.07	<3	0.19	0.26	0.01
Shag at The Grange	19-Oct-2012 10:30:00	<0.010	<0.004	30.00	0.05	<3	0.20	0.25	0.01
Shag at The Grange	31-Oct-2012 10:00:00	<0.010	0.01	230.00	0.01	<3	0.21	0.23	0.01
Shag at The Grange	12-Nov-2012 10:10:00	0.01	0.01	1800.00	0.11	18	0.41	0.51	0.04
Shag at The Grange	28-Nov-2012 09:45:00	<0.010	<0.004	90.00	0.00	<3	0.16	0.17	<0.004
Shag at The Grange	11-Dec-2012 09:25:00	<0.010	<0.004	120.00	0.01	<3	0.05	0.10	0.01
Shag at The Grange	18-Jan-2013 08:55:00	<0.010	0.01	3000.00	0.10	6	0.42	0.52	0.04
Shag at The Grange	30-Jan-2013 10:30:00	<0.010	<0.004	1000.00	0.00	3	0.19	0.19	0.01
Shag at The Grange	13-Feb-2013 10:00:00	<0.010	<0.004	190.00	0.01	<3	0.12	0.13	0.01
Shag at The Grange	27-Feb-2013 10:21:00	<0.010	<0.004	290.00	0.03	<3	0.05	0.10	0.02
Shag at The Grange	12-Mar-2013 10:12:00	<0.010	0.01	370.00	0.03	<3	0.13	0.16	0.42
Shag at The Grange	26-Mar-2013 09:00:00	<0.010	0.00	410.00	0.76	<3	0.14	0.90	0.01
Shag at The Grange	08-Apr-2013 10:10:00	<0.010	0.00	210.00	0.02	<3	0.12	0.14	0.01
Shag at The Grange	23-Apr-2013 09:55:00	<0.010	0.01	270.00	0.05	<3	0.17	0.22	0.01
Shag at The Grange	09-May-2013 11:43:00	<0.010	0.01	180.00	0.21	<3	0.20	0.40	0.02
Shag at The Grange	22-May-2013 10:40:00	<0.010	0.02	1200.00	0.34	19	0.28	0.62	0.06
Shag at The Grange	07-Jun-2013 11:00:00	<0.010	0.01	130.00	0.46	<3	0.31	0.77	0.02
Shag at The Grange	10-Jul-2013 11:17:00	<0.010	0.01	150.00	0.60	3	0.36	0.96	0.02
Shag at The Grange	25-Jul-2013 10:35:00	<0.010	0.01	48.00	0.44	<3	0.20	0.63	0.01
Shag at The Grange	08-Aug-2013 10:35:00	<0.010	0.01	47.00	0.33	<3	0.19	0.52	0.01
Shag at The Grange	23-Aug-2013 10:45:00	<0.010	0.01	62.00	0.17	<3	0.16	0.32	0.02
Shag at The Grange	05-Sep-2013 10:25:00	<0.010	<0.004	100.00	0.03	<3	0.18	0.21	<0.004
Shag at The Grange	20-Sep-2013 11:30:00	<0.010	<0.004	100.00	0.01	<3	0.05	0.10	<0.004

Site Name	Time	NH4-N	DRP	*E. coli*	NNN	SS	TKN	TN	TP
		mg/l-N	mg/l-P	cfu/100ml	mg/l-N	g/m3	mg/l-N	mg/l-N	mg/l-P
Shag at Horse Range Ro	04-Oct-2012 10:55:00	<0.010	<0.004	32.00	0.42	<3	0.18	0.59	0.01
Shag at Horse Range Ro	19-Oct-2012 11:40:00	<0.010	<0.004	30.00	0.18	<3	0.23	0.41	0.01
Shag at Horse Range Ro	31-Oct-2012 12:00:00	<0.010	<0.004	19.00	0.21	<3	0.21	0.42	0.01
Shag at Horse Range Ro	12-Nov-2012 12:00:00	<0.010	<0.004	2300.00	0.18	15	0.37	0.55	0.03
Shag at Horse Range Ro	28-Nov-2012 10:35:00	<0.010	<0.004	22.00	0.13	<3	0.20	0.33	0.01
Shag at Horse Range Ro	11-Dec-2012 10:40:00	<0.010	<0.004	2700.00	0.22	<3	0.10	0.32	0.01
Shag at Horse Range Ro	18-Jan-2013 11:00:00	<0.010	0.01	3600.00	0.15	6	0.35	0.50	0.04
Shag at Horse Range Ro	30-Jan-2013 11:25:00	<0.010	<0.004	70.00	0.06	<3	0.18	0.25	0.01
Shag at Horse Range Ro	13-Feb-2013 12:10:00	<0.010	<0.004	80.00	0.12	<3	0.12	0.24	<0.004
Shag at Horse Range Ro	27-Feb-2013 11:04:00	<0.010	<0.004	240.00	0.11	<3	0.16	0.27	0.01
Shag at Horse Range Ro	12-Mar-2013 11:05:00	0.01	<0.004	1400.00	0.12	13	0.11	0.23	0.02
Shag at Horse Range Ro	26-Mar-2013 10:10:00	<0.010	0.01	280.00	0.12	<3	0.11	0.22	0.01
Shag at Horse Range Ro	08-Apr-2013 11:05:00	0.01	<0.004	110.00	0.13	<3	0.11	0.24	<0.004
Shag at Horse Range Ro	23-Apr-2013 11:30:00	<0.010	<0.004	800.00	0.30	3	0.15	0.46	0.01
Shag at Horse Range Ro	09-May-2013 12:35:00	<0.010	0.01	170.00	0.34	<3	0.17	0.51	0.01
Shag at Horse Range Ro	22-May-2013 11:40:00	0.02	0.01	400.00	0.45	20	0.27	0.73	0.04
Shag at Horse Range Ro	07-Jun-2013 11:55:00	<0.010	0.01	100.00	0.63	<3	0.30	0.93	0.02
Shag at Horse Range Ro	10-Jul-2013 12:10:00	<0.010	0.01	40.00	1.16	3	0.52	1.68	0.02
Shag at Horse Range Ro	25-Jul-2013 11:30:00	<0.010	0.01	36.00	1.02	<3	0.18	1.20	0.01
Shag at Horse Range Ro	08-Aug-2013 12:20:00	<0.010	0.00	31.00	0.93	<3	0.26	1.19	0.01
Shag at Horse Range Ro	23-Aug-2013 11:30:00	<0.010	0.01	48.00	0.56	<3	0.21	0.78	0.01
Shag at Horse Range Ro	05-Sep-2013 11:15:00	<0.010	<0.004	25.00	0.39	<3	0.21	0.60	<0.004
Shag at Horse Range Ro	20-Sep-2013 12:40:00	<0.010	<0.004	29.00	0.34	<3	0.17	0.51	<0.004

Site Name	Time	NH4-N	DRP	*E. coli*	NNN	SS	TKN	TN	TP
		mg/l-N	mg/l-P	cfu/100ml	mg/l-N	g/m3	mg/l-N	mg/l-N	mg/l-P
Deepdell Creek at Gol	04-Oct-2012 09:30:00	<0.010	<0.004	30.00	0.08	<3	0.39	0.47	0.02
Deepdell Creek at Gol	19-Oct-2012 09:05:00	<0.010	<0.004	50.00	0.06	<3	0.40	0.47	0.03
Deepdell Creek at Gol	31-Oct-2012 08:30:00	<0.010	<0.004	48.00	0.58	<3	0.48	1.06	0.02
Deepdell Creek at Gol	12-Nov-2012 08:45:00	<0.010	0.01	3700.00	0.04	6	0.87	0.92	0.06
Deepdell Creek at Gol	28-Nov-2012 08:15:00	<0.010	0.00	100.00	0.06	<3	0.42	0.47	0.02
Deepdell Creek at Gol	11-Dec-2012 08:50:00	<0.010	<0.004	240.00	0.30	<3	0.33	0.63	0.02
Deepdell Creek at Gol	18-Jan-2013 09:30:00	<0.010	0.02	4100.00	0.07	<3	0.71	0.79	0.06
Deepdell Creek at Gol	30-Jan-2013 09:00:00	<0.010	0.01	49.00	0.05	3	0.34	0.39	0.03
Deepdell Creek at Gol	13-Feb-2013 09:20:00	<0.010	<0.004	25.00	0.08	<3	0.27	0.35	0.01
Deepdell Creek at Gol	27-Feb-2013 09:37:00	<0.010	<0.004	20.00	0.02	<3	0.20	0.22	0.00
Deepdell Creek at Gol	12-Mar-2013 09:29:00	<0.010	0.00	47.00	0.02	<3	0.27	0.29	0.01
Deepdell Creek at Gol	26-Mar-2013 08:20:00	<0.010	0.01	33.00	0.04	<3	0.21	0.25	0.01
Deepdell Creek at Gol	08-Apr-2013 09:00:00	<0.010	<0.004	10.00	0.82	<3	0.25	1.07	0.01
Deepdell Creek at Gol	23-Apr-2013 10:25:00	<0.010	<0.004	40.00	0.15	<3	0.25	0.39	0.01
Deepdell Creek at Gol	09-May-2013 11:05:00	<0.010	0.01	100.00	0.17	170	0.46	0.63	0.03
Deepdell Creek at Gol	22-May-2013 09:15:00	<0.010	0.01	45.00	0.25	<3	0.40	0.66	0.02
Deepdell Creek at Gol	07-Jun-2013 09:12:00	<0.010	0.02	62.00	0.27	<3	0.42	0.69	0.03
Deepdell Creek at Gol	10-Jul-2013 10:39:00	<0.010	0.01	30.00	0.60	<3	0.44	1.04	0.03
Deepdell Creek at Gol	25-Jul-2013 09:10:00	<0.010	0.02	17.00	0.82	<3	0.33	1.15	0.02
Deepdell Creek at Gol	08-Aug-2013 09:10:00	<0.010	0.01	15.00	0.34	<3	0.39	0.73	0.02
Deepdell Creek at Gol	23-Aug-2013 09:15:00	<0.010	0.01	20.00	0.22	<3	0.34	0.55	0.02
Deepdell Creek at Gol	05-Sep-2013 09:05:00	<0.010	0.01	70.00	0.27	<3	0.41	0.68	0.02
Deepdell Creek at Gol	20-Sep-2013 10:23:00	<0.010	0.01	8.00	0.25	<3	0.31	0.55	0.01

Site Name	Time	NH4-N	DRP	*E. coli*	NNN	SS	TKN	TN	TP
		mg/l-N	mg/l-P	cfu/100ml	mg/l-N	g/m3	mg/l-N	mg/l-N	mg/l-P
McCormicks Creek at S	04-Oct-2012 10:20:00	<0.010	<0.004	23.00	0.90	<3	0.15	1.05	0.01
McCormicks Creek at S	19-Oct-2012 10:45:00	<0.010	<0.004	140.00	0.03	<3	0.31	0.34	0.01
McCormicks Creek at S	31-Oct-2012 10:20:00	<0.010	<0.004	100.00	0.03	<3	0.25	0.28	0.01
McCormicks Creek at S	12-Nov-2012 10:25:00	<0.010	<0.004	1400.00	0.05	7	0.36	0.41	0.02
McCormicks Creek at S	28-Nov-2012 10:00:00	<0.010	<0.004	50.00	0.33	<3	0.18	0.52	<0.004
McCormicks Creek at S	11-Dec-2012 09:40:00	<0.010	<0.004	400.00	0.05	<3	0.21	0.26	0.02
McCormicks Creek at S	18-Jan-2013 10:25:00	0.02	0.01	1500.00	0.24	4	0.40	0.64	0.04
McCormicks Creek at S	30-Jan-2013 10:45:00	<0.010	<0.004	310.00	0.99	<3	0.24	1.23	0.01
McCormicks Creek at S	13-Feb-2013 10:20:00	<0.010	<0.004	90.00	0.03	<3	0.14	0.18	0.01
McCormicks Creek at S	27-Feb-2013 10:32:00	<0.010	<0.004	180.00	0.07	<3	0.14	0.20	0.02
McCormicks Creek at S	12-Mar-2013 10:34:00	<0.010	0.01	50.00	0.18	<3	0.15	0.33	0.05
McCormicks Creek at S	26-Mar-2013 09:17:00	<0.010	0.01	200.00	0.11	<3	0.13	0.24	0.01
McCormicks Creek at S	08-Apr-2013 10:25:00	0.01	0.00	300.00	0.87	<3	0.19	1.06	0.01
McCormicks Creek at S	23-Apr-2013 11:00:00	<0.010	<0.004	1000.00	0.29	<3	0.24	0.53	0.01
McCormicks Creek at S	09-May-2013 11:58:00	<0.010	0.01	40.00	0.23	<3	0.22	0.45	0.01
McCormicks Creek at S	22-May-2013 11:05:00	<0.010	0.01	280.00	0.65	5	0.76	1.41	0.03
McCormicks Creek at S	07-Jun-2013 11:25:00	<0.010	0.01	27.00	0.76	<3	0.32	1.08	0.02
McCormicks Creek at S	10-Jul-2013 11:37:00	<0.010	0.01	90.00	0.94	<3	0.37	1.31	0.02
McCormicks Creek at S	25-Jul-2013 11:05:00	<0.010	0.01	5.00	0.62	<3	0.15	0.77	0.01
McCormicks Creek at S	08-Aug-2013 10:45:00	<0.010	<0.004	23.00	0.34	<3	0.23	0.57	0.01
McCormicks Creek at S	23-Aug-2013 11:00:00	<0.010	<0.004	55.00	0.08	<3	0.22	0.30	0.01
McCormicks Creek at S	05-Sep-2013 10:40:00	<0.010	<0.004	23.00	0.07	<3	0.17	0.24	<0.004
McCormicks Creek at S	20-Sep-2013 11:45:00	<0.010	<0.004	150.00	0.05	<3	0.11	0.16	0.01

Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Craig Road	13-Nov-1989 14:45:00	0.01	<1.00		16.00	5.30	0.13	10.40		0.01		13.00	3.50		0.70	9.10	5.30	2.00			0.13	0.01	0.80	17.70	8.40
Shag at Craig Road	03-May-1990 15:30:00	<0.010			17.00	6.30	0.14			<0.005		4.50	4.00	0.01	0.80	9.40	7.30	<1			0.07	0.01	0.50	11.50	8.67
Shag at Craig Road	27-Jun-1990 09:40:00	<0.010			18.00	7.70	0.16	14.10		<0.005		23.00	4.10	0.01	0.70	10.00		2.00			0.05	0.01	0.30	6.00	7.89
Shag at Craig Road	25-Jul-1990 10:10:00	<0.010			15.00	5.60	0.13	14.40		<0.005		13.00	3.40	<0.005	0.60	8.10		<1			0.07	0.01	0.60	3.00	8.00
Shag at Craig Road	22-Aug-1990 10:20:00	<0.010			13.00	7.10	0.12	13.20		0.01		11.00	3.00	0.19	0.70	7.60	6.90	1.00			0.28	0.01	1.00	5.00	7.90
Shag at Craig Road	25-Sep-1990 10:05:00	0.01			14.00	8.10	0.13	12.90		0.01		7.80	3.30	0.16	0.90	9.00	7.50	<1			0.26	0.01	0.80	9.00	8.20
Shag at Craig Road	31-Oct-1990 10:10:00	<0.010			12.00	8.10	0.12			0.01		13.00	3.00	0.19	0.90	9.20	5.80	3.00			0.35	0.03	3.00	11.30	8.00
Shag at Craig Road	30-Nov-1990 10:30:00	<0.010			14.00	56.00	0.13			0.01		7.80	3.30	0.02	0.80	8.70	4.70	1.00			0.11	0.02	0.60	16.10	8.10
Shag at Craig Road	18-Dec-1990 13:30:00	0.02			17.00	6.80	0.16			<0.005		33.00	3.80	0.05	1.00	10.00	6.80	<1			0.08	0.02	0.60	17.50	8.60
Shag at Craig Road	01-Feb-1991 11:10:00	<0.010			17.00	7.80	0.18			<0.005		14.00	4.00	0.03	1.00	12.00	7.40	1.00			0.15	0.01	0.50	16.40	8.40
Shag at Craig Road	13-Feb-1991 12:05:00	0.01	<1		17.00	7.70	0.17	12.00		0.01		0.00	3.90	0.04	1.00	11.00	7.10	1.00			0.16	0.02	0.80	20.00	8.70
Shag at Craig Road	27-Mar-1991 11:20:00	0.01			16.00	6.00	0.15			0.01			3.70	0.04	1.10	10.00	6.10	15.00			0.20	0.04	3.40	15.80	8.00
Shag at Craig Road	01-May-1991 11:35:00	0.01			12.00	5.80	0.12			0.01		6.80	3.30	0.02	0.70	8.10	4.80	3.00			0.20	0.02	3.00	7.50	7.90
Shag at Craig Road	30-May-1991 12:00:00	0.01			14.00	5.60	0.13	11.40		0.01		2.00	3.20	0.01	0.70	8.50	5.60	<1			0.10	0.01	0.80	7.10	8.10
Shag at Craig Road	26-Jun-1991 13:00:00	<0.010			12.00	6.50	0.12			<0.005		11.00	2.80	0.01	0.60	8.10	5.20	1.00			0.16	0.01	1.20	4.30	8.00
Shag at Craig Road	31-Jul-1991 11:30:00	<0.010			11.00	6.80	0.11			0.01		11.00	2.50	0.16	0.60	7.50	5.30	<1			0.34	0.01	1.50	3.50	7.80
Shag at Craig Road	30-Aug-1991 13:15:00	0.01					0.10	13.00		<0.005		6.80		0.02				1.00				0.01	1.30	7.90	8.50
Shag at Craig Road	25-Sep-1991 11:45:00	<0.010					0.11	13.30		0.03		180.00		0.39				24.00				0.11	26.00	10.00	7.60
Shag at Craig Road	31-Oct-1991 12:10:00	<0.010			15.00	6.50	0.15			0.01		7.80	3.30	0.01	0.80	9.10	6.10	1.00			0.19	0.01	0.50		8.10
Shag at Craig Road	27-Nov-1991 12:35:00	<0.010	<1				0.14	12.00		0.01		13.00		0.02				1.00				0.02	0.50	14.70	8.30
Shag at Craig Road	17-Dec-1991 12:30:00	<0.010					0.14	10.40		<0.005		0.00		0.01				1.00				0.01	0.40	19.00	8.40
Shag at Craig Road	30-Jan-1992 14:00:00	0.01	<1		17.00	5.80	0.16	9.90		0.01		11.00	3.60	0.02	0.80	9.60	5.40	<1			0.21	0.01	0.40	19.00	8.40
Shag at Craig Road	25-Feb-1992 12:30:00	0.01					0.16			<0.005		11.00		0.01				1.00				0.02	0.40	16.00	8.20
Shag at Craig Road	31-Mar-1992 09:50:00	<0.010					0.19	10.00		0.01		4.50		0.03				2.00				0.01	0.50	12.00	7.90
Shag at Craig Road	29-Apr-1992 13:55:00				20.00	8.80	0.18	12.90		0.01			4.30	0.01	0.80	11.00	8.70	1.00			0.12	0.01		8.00	8.30
Shag at Craig Road	27-May-1992 15:30:00	<0.010					0.14	12.40		0.01		0.00		0.01				<1				0.01	0.40	4.10	8.30
Shag at Craig Road	30-Jun-1992 12:30:00	0.01					0.15	14.00		<0.005		4.50		0.01				<1				0.01	0.40	2.00	8.10
Shag at Craig Road	29-Jul-1992 11:45:00	<0.010			7.10	7.80	0.08	12.30		<0.005		21.00	1.60	0.10	0.60	5.80	3.80	4.00				0.02	3.80	6.00	7.60
Shag at Craig Road	26-Aug-1992 13:30:00	<0.010					0.11	13.40		0.01		26.00		0.24				2.00				0.02	1.90	5.20	7.70
Shag at Craig Road	23-Sep-1992 10:30:00	0.02					0.10	11.00		<0.005		17.00		0.26				2.00				0.01	1.50	4.50	7.80
Shag at Craig Road	21-Oct-1992 11:00:00	0.03			8.80	5.70	0.09	13.40		<0.005		14.00	2.10	0.03	0.80	6.50	3.00	15.00			1.60	0.03	6.40	9.00	7.70
Shag at Craig Road	25-Nov-1992 17:00:00	<0.010					0.11	10.10		0.01		13.00		0.05				2.00				0.02	1.10	14.90	8.00
Shag at Craig Road	16-Dec-1992 11:15:00	0.03					0.13	11.00		0.01		17.00		0.04				2.00				0.02	0.70	16.00	8.00
Shag at Craig Road	28-Jan-1993 12:00:00	<0.010			13.00	4.20	0.11	10.80		0.01		27.00	2.80	0.05	0.70	7.30	3.20	1.00			0.12	0.01	0.50	15.50	8.10
Shag at Craig Road	24-Feb-1993 10:00:00	<0.010					0.14	8.20		0.01		79.00		0.04				1.00				0.01	0.60	17.70	7.70
Shag at Craig Road	24-Mar-1993 12:10:00	<0.010					0.15	10.60		0.01		17.00		0.01				<1				0.01	0.26	12.50	7.50
Shag at Craig Road	28-Apr-1993 12:20:00	<0.010			12.80	4.40	0.12	12.20		0.01		540.00	2.80	<0.005	0.60	7.50	3.90	4.00			0.19		0.30	8.70	7.60
Shag at Craig Road	01-Jun-1993 12:40:00	<0.010					0.10	9.20		<0.005		240.00		0.07				2.00				0.02	1.20	7.20	7.40
Shag at Craig Road	29-Jun-1993 12:00:00	<0.010					0.13	13.00		0.01		49.00		0.04				<1				0.01	0.30	4.50	7.50
Shag at Craig Road	27-Jul-1993 10:55:00	<0.010			15.60	7.40	0.15	12.80		0.01		17.00	3.70	0.02	0.60	9.20	7.20	<1			0.14	0.01	0.30	5.40	7.80
Shag at Craig Road	31-Aug-1993 12:55:00	<0.010					0.15	11.70		0.01		33.00		<0.010				<1				0.01	0.40	6.60	8.10
Shag at Craig Road	28-Sep-1993 11:55:00	<0.010					0.09	12.60		0.01		14.00		0.12				8.00				0.03	5.60	6.30	7.80
Shag at Craig Road	27-Oct-1993 12:50:00	<0.010			13.80	5.30	0.13	9.80		0.01		49.00	3.20	0.04	0.70	8.40	4.90	1.00			0.20	0.01	0.50	16.10	8.20
Shag at Craig Road	30-Nov-1993 11:15:00	<0.010					0.12	9.30		0.01				0.02				<1				0.01	0.40	14.60	8.00
Shag at Craig Road	20-Dec-1993 13:50:00	0.01					0.08	10.20		0.01		130.00		0.03				6.00				0.03	70.00	15.00	7.90
Shag at Craig Road	26-Jan-1994 13:00:00	<0.010			12.80	5.50	0.12	10.30		0.01		47.00	3.10	0.02	1.10	9.20	4.30	3.00			0.39	0.02	2.00	16.20	8.30
Shag at Craig Road	01-Mar-1994 09:30:00	<0.010					0.12	9.40		0.01		270.00		0.20				<1				0.02	0.80	16.90	7.50
Shag at Craig Road	28-Mar-1994 11:45:00	0.02					0.12	10.30		0.02		34.00		0.30				4.00				0.02	4.20	13.70	7.50
Shag at Craig Road	26-Apr-1994 12:35:00	<0.010	1.00		16.30	7.10	0.15	12.30		<0.005		17.00	3.80	0.01	0.90	9.90	6.30	<1			0.17	<0.005	0.30	7.40	8.00
Shag at Craig Road	27-Sep-1994 12:05:00	0.01	1.00		13.00	6.30	0.13	13.80		0.01		15.00	3.30	0.02	0.90	8.40	5.50	3.00			0.26	0.14	1.40	9.60	8.30
Shag at Craig Road	30-Nov-1994 07:40:00	0.05	1.00				0.21	9.90		0.00		130.00		0.09				3.00	0.01			0.01	0.45	14.60	6.84
Shag at Craig Road	01-Mar-1995 12:00:00	0.01	1.00		24.00	8.50	0.20			0.00		140.00	5.10	<0.003	1.60	22.00	9.40	3.00	0.01		0.19	0.01	0.35	15.90	8.25
Shag at Craig Road	26-Apr-1995 14:30:00	0.01	<1				0.18	11.90		0.00		58.00		0.02				2.00	0.01			0.01	0.20	11.80	8.25
Shag at Craig Road	28-Jun-1995 11:00:00	0.01	<1					12.80		0.01		25.00		0.21				2.00	0.02			0.02	0.85	4.30	7.62
Shag at Craig Road	06-Sep-1995 11:20:00	0.01	<1				0.10	12.40		0.01		29.00		0.02				3.00	0.01			0.01	0.35	6.90	7.95
Shag at Craig Road	29-Nov-1995 09:15:00	0.02	<1				0.11	10.80		0.01		360.00		0.07				2.00	0.01		0.26	0.02	0.70	12.70	7.34

Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Craig Road	15-Jan-1996 10:15:00	0.01	<1		12.00	3.40	0.12	9.20		0.01		750.00	2.70	0.01	0.80	6.80	3.10	2.00	0.01		0.26	0.02	0.35	17.60	6.80
Shag at Craig Road	20-Mar-1996 14:55:00	0.01	<1				0.10	10.80		0.01		35.00		0.02				2.00	0.01			0.01	0.50	14.80	7.60
Shag at Craig Road	15-May-1996 11:20:00	0.01	1.00				0.14	12.60		0.01		82.00		0.03				1.00	0.01			0.01	0.15	5.40	7.37
Shag at Craig Road	31-Jul-1996 11:20:00	0.02	<1		10.00	5.30	0.09	12.90		0.01		28.00	2.40	0.21	0.70	6.90	4.50	2.00	0.02		0.39	0.01	1.90	3.70	7.25
Shag at Craig Road	25-Sep-1996 11:50:00	0.02	1.00				0.14	12.00		0.01		52.00		0.04				<1	0.01			0.01	0.30	11.90	7.95
Shag at Craig Road	11-Dec-1996 12:30:00	0.04	<1				0.18	9.30		0.00		45.00		0.03				1.00	0.01			0.02	0.40	19.10	8.30
Shag at Craig Road	04-Feb-1997 14:00:00	0.01	2.00		14.00	4.10	0.13	10.20		0.01		540.00	3.10	0.02	0.90	7.90		<1	0.02		0.26	0.02	0.50	16.80	8.00
Shag at Craig Road	21-Apr-1997 12:10:00	0.01	2.00				0.12	12.00		0.01		49.00		0.02				<1	0.01		0.16	0.01	0.40	8.00	8.00
Shag at Craig Road	11-Jun-1997 10:30:00	0.02	2.00				0.14	12.00		0.00		57.00		0.02				2.00	0.01			0.01	0.30	5.50	7.90
Shag at Craig Road	17-Dec-1998 12:00:00	<0.005	2.00		17.00	5.80	0.17	11.10		0.00	80.00	80.00	3.70	0.00	0.91	9.50	6.80	2.00	0.01		0.28	0.04	0.60	18.50	8.40
Shag at Craig Road	03-Sep-1999 15:15:00						0.12																	9.66	8.50
Shag at Craig Road	25-Feb-2000 14:16:00						0.14																	18.80	
Shag at Craig Road	16-Aug-2001 09:32:00	0.02	<1	3.22			0.14	13.20		0.01	32.00	36.00		0.25				<1	0.01		0.37	0.01	1.07	2.30	7.70
Shag at Craig Road	10-Oct-2001 08:20:00	<0.010	<1	3.78			0.22	10.30		<0.005	190.00	190.00		0.02				<1	0.02		0.16	0.02	0.54	10.30	7.60
Shag at Craig Road	13-Dec-2001 13:30:00	0.01	<1	4.10			0.11	9.80		0.00	80.00	250.00		0.01				<1	0.01		0.16	0.01	0.41	18.30	8.50
Shag at Craig Road	13-Feb-2002 08:27:00	0.02	<1	4.15			0.19	9.60		0.00	320.00	580.00		0.02				<1	<0.005		0.14	<0.005	0.55	15.00	7.40
Shag at Craig Road	10-Apr-2002 09:30:00	<0.010	<1	4.13			0.27	10.80		0.00	39.00	64.00		0.01				<1	0.01		0.12	0.02	0.27	9.10	7.80
Shag at Craig Road	11-Jun-2002 09:25:00	<0.010	<1	5.03			0.17	11.30		<0.005	36.00	78.00		0.01				<1	<0.005		1.30	<0.005	0.33	5.50	7.40
Shag at Craig Road	29-Aug-2002 09:40:00	0.01		4.47			0.14	12.40		<0.005	17.00	19.00		0.21				1.00			0.39	0.01	0.70	5.00	7.83
Shag at Craig Road	10-Oct-2002 08:40:00	<0.010		4.60			0.13	12.00		<0.005	78.00	80.00		0.01				1.00			0.16	0.01	0.40	9.00	7.80
Shag at Craig Road	10-Dec-2002 08:20:00	<0.010		3.98			0.13	9.20	91.00	<0.005	100.00	110.00		<0.005				<1			0.15	0.02	0.65	15.60	7.75
Shag at Craig Road	11-Feb-2003 10:10:00	0.01		2.95			0.22	8.10		<0.005	44.00	83.00		0.04				1.00			0.20	0.01	0.60	16.30	7.53
Shag at Craig Road	09-Apr-2003 09:30:00	0.01		2.76			0.29	10.60		<0.005	490.00	700.00		0.02				2.00			0.18	0.01	0.50	8.70	7.69
Shag at Craig Road	10-Jun-2003 09:10:00	0.02		4.22			0.26	12.00		<0.005	330.00	210.00		0.07				<1			0.26	<0.005	0.35	6.20	7.74
Shag at Craig Road	18-Aug-2003 10:35:00	0.01		3.55			0.16	13.10	103.00	<0.005	35.00	76.00		0.01				<1			0.13	<0.005	0.35	4.60	7.91
Shag at Craig Road	07-Oct-2003 08:15:00	<0.010		4.41			0.11	12.30	101.00	<0.005	47.00	46.00		0.01				1.00			0.21	<0.005	0.45	6.60	7.78
Shag at Craig Road	09-Dec-2003 09:35:00	<0.010		5.12			0.17	9.00	89.50	<0.005	120.00	200.00		0.01				<1			0.15	0.01	0.35	15.40	7.78
Shag at Craig Road	07-Jan-2004 12:30:00	0.01		5.03			0.17	10.00	111.00	<0.005	210.00	200.00		0.03				1.00			0.18	<0.005	0.55	20.50	7.81
Shag at Craig Road	10-Feb-2004 09:15:00	0.02		3.99			0.16	7.80		<0.005	190.00	210.00		0.01				<1			0.13	0.01	0.40	16.10	7.66
Shag at Craig Road	14-Apr-2004 10:20:00	<0.010		5.29			0.17	12.90	109.00	<0.005	44.00	42.00		0.01				<1			0.09	<0.005	0.30	7.06	
Shag at Craig Road	10-Jun-2004 09:45:00	<0.010		11.10			0.25	12.30		0.01	13.00	22.00		0.01				<1			0.11	0.01	0.10	5.10	7.63
Shag at Craig Road	17-Aug-2004 10:00:00	<0.010		3.11			0.25	12.70		0.01	38.00	28.00		0.05				<1			0.23	0.01	0.55	4.00	7.56
Shag at Craig Road	13-Oct-2004 12:40:00	0.01		4.90			0.11	11.30	113.00	0.01	82.00	92.00		0.01				<1			0.15	0.02	0.35	14.70	
Shag at Craig Road	14-Dec-2004 13:10:00	<0.010		4.05			0.16	10.60		0.01	22.00	52.00		0.01				2.00			0.94	0.02	0.50	15.00	7.88
Shag at Craig Road	10-Feb-2005 08:48:00	0.01		3.39			0.13	7.10	77.70	0.01	400.00	680.00		0.01				2.00			0.24	0.03	0.70	17.90	
Shag at Craig Road	12-Apr-2005 09:50:00	<0.010					0.13	11.70	110.00	0.01	120.00	150.00		0.01				<1			0.15	0.01	0.30	11.40	7.71
Shag at Craig Road	15-Jun-2005 09:58:00	0.01					0.09	13.50	95.40	<0.005				0.01				<1			0.07	0.01	1.90	0.59	
Shag at Craig Road	18-Aug-2005 09:30:00	<0.010					0.13	11.90	94.10	0.01	25.00	25.00		0.01				<3			0.12	0.01	0.40	5.19	
Shag at Craig Road	11-Oct-2005 08:05:00	<0.010					0.16	11.60		0.01	180.00	180.00		0.09				<3			0.47	0.03	2.60	6.50	6.80
Shag at Craig Road	06-Dec-2005 09:50:00	<0.010					0.12	7.40	76.00	0.01	1100.00	1100.00		0.02				3.00			0.17	0.02	1.20	16.30	
Shag at Craig Road	07-Feb-2006 08:10:00	0.01					0.11	8.30	76.80	0.01	210.00	210.00		0.01				<3			0.15	0.01	0.55	14.90	7.10
Shag at Craig Road	20-Apr-2006 10:10:00	<0.010					0.12	6.90	63.80	0.01	110.00	110.00		0.01				<3			0.36	0.02	0.46	11.80	
Shag at Craig Road	14-Jun-2006 09:40:00	0.01					0.08	8.60	65.20	0.01	110.00	110.00		0.05				<3			0.26	0.01	0.81	3.84	
Shag at Craig Road	23-Aug-2006 11:10:00	<0.010					0.12	14.10	108.00	<0.005	12.00	12.00		<0.005				<3			0.14	<0.05	0.67	4.30	7.50
Shag at Craig Road	23-Aug-2006 11:30:00	0.01								<0.005	39.00	39.00		<0.005				7.00			0.14	<0.05	1.13		7.50
Shag at Craig Road	11-Oct-2006 08:35:00	0.02					0.13	9.50	81.10	0.01	130.00	200.00		0.02				<3			0.025	0.01	0.78	8.40	7.70
Shag at Craig Road	11-Oct-2006 09:00:00	<0.010					0.16	12.10	104.00	<0.005	110.00	110.00		0.02				<3			0.20	0.02	0.64	8.70	7.70
Shag at Craig Road	06-Dec-2006 09:49:00	<0.010								<0.005	220.00	220.00		<0.005				<3			0.18	0.01	0.67		7.80
Shag at Craig Road	06-Dec-2006 10:15:00	<0.010					0.27	9.50	98.90	<0.005	26.00	31.00		<0.005				<3			0.19	0.03	0.37	13.70	7.60
Shag at Craig Road	15-Feb-2007 09:30:00	0.01					0.24	6.90	70.20	0.01	210.00	210.00		0.01				<3			0.14	0.01	0.71	15.80	7.80
Shag at Craig Road	15-Feb-2007 09:50:00	<0.010					0.23	9.10	92.50	0.01	62.00	74.00		0.02				<3			0.16	0.01	0.56	16.20	7.70
Shag at Craig Road	30-Apr-2007 09:45:00	<0.010					0.22	8.40	73.80	0.01	54.00	66.00		0.01				<3			0.17	0.02	0.75	9.20	7.50
Shag at Craig Road	30-Apr-2007 10:10:00	<0.010					0.24	9.60	85.50	<0.005	54.00	56.00		0.01				<3			0.09	0.01	0.41	10.00	7.40
Shag at Craig Road	25-Jun-2007 10:45:00	<0.010					0.21	11.20	84.00		110.00	110.00		0.02				<3			0.08		0.43	3.20	7.70
Shag at Craig Road	25-Jun-2007 11:10:00	<0.010					0.22	14.10	107.00	0.01	28.00	38.00		0.01				<3			0.09	<0.005	0.34	3.90	7.60

Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Craig Road	11-Sep-2007 10:30:00	<0.010								<0.005	17.00	18.00		0.14				<3			0.33	0.01	0.53		8.10
Shag at Craig Road	07-Nov-2007 09:45:00	<0.010								0.01	220.00	220.00		0.01				<3			0.18	0.01	0.38		7.80
Shag at Craig Road	07-Nov-2007 10:15:00	<0.010					0.18	8.90	81.00	<0.005	28.00	28.00		0.09				<3			0.27	0.01	0.44	11.50	7.70
Shag at Craig Road	16-Jan-2008 09:45:00	<0.010					0.22	4.10	42.90	0.01	44.00	56.00		0.05				<3			0.26	0.02	0.49	17.20	7.60
Shag at Craig Road	16-Jan-2008 10:15:00	0.01					0.18	4.30	43.80	0.01	140.00	200.00		0.02				<3			0.17	0.02	0.44	16.60	7.70
Shag at Craig Road	26-Feb-2008 10:00:00	<0.010					0.19	8.80	90.50	0.01	95.00	490.00		0.01				<3			0.18	0.02	0.63	16.20	7.50
Shag at Craig Road	26-Feb-2008 10:35:00	<0.010					0.21	9.00	94.80	<0.005	52.00	84.00		0.01				<3			0.22	0.01	0.58	17.30	7.70
Shag at Craig Road	05-May-2008 11:45:00	<0.010					0.18	12.40	99.60	0.01	130.00	130.00		0.04				<3			0.20	0.01	0.52	5.90	7.50
Shag at Craig Road	05-May-2008 12:15:00	<0.010					0.10	11.90	99.10	0.01	54.00	58.00		0.03				<3			0.22	0.01	1.19	7.20	7.50
Shag at Craig Road	10-Jul-2008 11:00:00	0.01					0.13	14.40	109.00	0.01	14.00	14.00		0.01				<3			0.14	0.01	0.26	3.29	
Shag at Craig Road	27-Aug-2008 11:35:00	<0.010					0.08	10.90	91.10	0.01	20.00	32.00		0.19				7.00			0.55	0.04	6.06	7.71	
Shag at Craig Road	13-Nov-2008 08:30:00	0.01					0.21	9.40	91.00	0.01	36.00	46.00		0.17				<3			0.35	0.01	0.44	14.40	7.60
Shag at Craig Road	15-Jan-2009 09:25:00	<0.010					0.23	7.90	84.00	0.01	23.00	91.00		0.08				<3			0.24	0.01	0.39	17.60	7.30
Shag at Craig Road	12-Mar-2009 10:10:00	<0.010					0.18	11.60	108.00		92.00			0.06				<3			0.26		1.26	11.40	7.80
Shag at Craig Road	06-May-2009 12:20:00	<0.010					0.23	11.70	100.00	0.01	87.00			0.06				<3			0.20	0.01	0.96	8.50	7.70
Shag at Craig Road	14-Jul-2009 12:20:00	<0.010					0.15	12.30	93.20	0.01	23.00			0.42				<3			0.73	0.02	2.92	3.68	7.80
Shag at Craig Road	16-Sep-2009 11:40:00	<0.010						11.60	103.00	<0.005	9.00			0.09				<3			0.27	0.01	0.52	10.20	7.80
Shag at Craig Road	10-Nov-2009 10:50:00	<0.010						8.30	79.90	<0.005	10.00			0.07				<3			0.15	0.01	0.60	13.80	7.70
Shag at Craig Road	27-Jan-2010 11:00:00	<0.010					0.24	9.50	100.00	0.01	4.00			0.03				<3			0.20	0.01	0.86	17.80	7.80
Shag at Craig Road	24-Mar-2010 12:40:00	<0.010					0.26	7.00	68.90		13.00			0.02				<3			0.14		0.36	14.60	7.50
Shag at Craig Road	27-Apr-2010 12:50:00									<0.005	160.00			0.01											
Shag at Craig Road	12-May-2010 12:30:00	<0.010					0.26	11.70	102.00	0.01	<1.00			0.01				<3			0.13	0.01	0.23	9.30	7.00
Shag at Craig Road	22-Jul-2010 12:30:00	<0.010					0.13	12.80	100.00	0.01	<1.00			0.52				<3			0.74	0.01	0.81	5.05	7.80
Shag at Craig Road	15-Sep-2010 10:40:00						0.16	12.50	107.00															8.60	
Shag at Craig Road	10-Nov-2010 11:30:00	<0.010					0.24	8.90	93.20	0.01	6.00			0.19				<3			0.36	0.01	0.40	17.20	7.50
Shag at Craig Road	12-Jan-2011 10:45:00	<0.010					0.23	8.60	87.40	0.01	22.00			0.05				<3			0.27	0.01	0.61	16.90	7.70
Shag at Craig Road	08-Mar-2011 10:50:00	<0.010					0.19	10.30	100.00	0.01	23.00			0.01				<3			0.19	0.01	0.49	13.90	7.80
Shag at Craig Road	26-May-2011 11:00:00	<0.010					0.18	11.60	100.00	0.01	54.00			0.28				<3			0.53	0.01	0.79	9.10	7.90
Shag at Craig Road	03-Aug-2011 13:35:00	<0.010					0.30	14.40	116.00	<0.004	1.00			0.13				<3		0.19	0.32	0.00	0.56	6.00	7.90
Shag at Craig Road	28-Sep-2011 10:15:00	<0.010					0.16	11.70	101.00	<0.004	31.00			0.01				<3		0.23	0.24	<0.004	0.49	9.00	7.80
Shag at Craig Road	29-Nov-2011 11:50:00	<0.010					0.12	11.50	111.00	<0.004	100.00			0.02				<3		0.22	0.24	0.02	1.18	13.90	8.30
Shag at Craig Road	01-Feb-2012 11:15:00	0.01					0.19	9.40	96.00	<0.004	110.00			0.01				<3		0.22	0.23	0.01	1.85	16.10	7.90
Shag at Craig Road	27-Mar-2012 10:30:00	<0.010					0.14	8.60	79.70	0.01	270.00			0.01				<3		0.18	0.18	0.01	0.69	12.10	7.80
Shag at Craig Road	30-May-2012 12:15:00	<0.010					0.05	12.30	101.00	<0.004	4.00			0.04				<3		<0.10	0.14	<0.004	0.64	6.74	7.80
Shag at Craig Road	04-Jul-2012 10:55:00	<0.010					0.24	12.40	91.50	<0.004	23.00			0.08				<3		0.12	0.20	<0.004	0.54	2.50	7.70
Shag at Craig Road	07-Aug-2012 09:10:00	<0.010					0.14	12.90	107.00	0.01	33.00			0.46				4.00		0.26	0.72	0.03	4.80	7.30	7.70
Shag at Craig Road	06-Sep-2012 09:25:00	<0.010					0.19	10.40	89.10	0.01	34.00			0.85				<3		0.22	1.08	0.01	2.20	8.68	7.80
Shag at Craig Road	04-Oct-2012 10:35:00	<0.010								<0.004	46.00			0.17				<3		0.27	0.43	0.01			
Shag at Craig Road	19-Oct-2012 11:00:00	<0.010								<0.004	51.00			0.07				<3		0.23	0.30	0.02			
Shag at Craig Road	31-Oct-2012 10:45:00	<0.010								<0.004	40.00			0.06				<3		0.26	0.32	0.01			
Shag at Craig Road	06-Nov-2012 08:40:00	<0.010					0.19	10.50	93.20	<0.004	42.00			0.08				<3		0.17	0.25	<0.004	0.69	10.20	7.70
Shag at Craig Road	12-Nov-2012 10:45:00	<0.010								<0.004	1600.00			0.07				9.00		0.40	0.47	0.03			
Shag at Craig Road	28-Nov-2012 10:12:00	<0.010								<0.004	38.00			0.04				<3		0.22	0.26	<0.004			
Shag at Craig Road	11-Dec-2012 10:00:00	<0.010								<0.004	0.5			0.10				<3		0.24	0.34	0.01			
Shag at Craig Road	14-Jan-2013 08:00:00	<0.010					0.21	8.00	85.30	<0.004	63.00			0.05				<3		0.20	0.25	0.01	0.55	18.00	7.70
Shag at Craig Road	18-Jan-2013 10:40:00	<0.010								0.01	3100.00			0.11				7.00		0.45	0.55	0.04			
Shag at Craig Road	30-Jan-2013 11:00:00	<0.010								<0.004	90.00			0.02				<3		0.17	0.19	0.01			
Shag at Craig Road	13-Feb-2013 10:40:00	<0.010								<0.004	29.00			0.05				<3		0.10	0.15	0.01			
Shag at Craig Road	27-Feb-2013 10:50:00	<0.010								<0.004	150.00			0.10				<3		0.13	0.23	0.03			
Shag at Craig Road	12-Mar-2013 10:52:00	<0.010								0.01	200.00			0.08				<3		<0.10	0.15	0.01			
Shag at Craig Road	13-Mar-2013 08:45:00	<0.010					0.24	7.40	75.10	0.01	130.00			0.09				<3		0.14	0.23	0.01	0.35	16.10	7.80
Shag at Craig Road	26-Mar-2013 09:35:00	0.01								<0.004	120.00			0.09				<3		0.27	0.36	0.01			
Shag at Craig Road	08-Apr-2013 10:45:00	<0.010								<0.004	230.00			0.05				<3		0.14	0.19	<0.004			
Shag at Craig Road	23-Apr-2013 11:15:00	<0.010								<0.004	450.00			0.08				<3		0.15	0.22	0.01			
Shag at Craig Road	09-May-2013 12:14:00	<0.010								0.01	240.00			0.21				<3		0.22	0.43	0.01			

Otago Regional Council

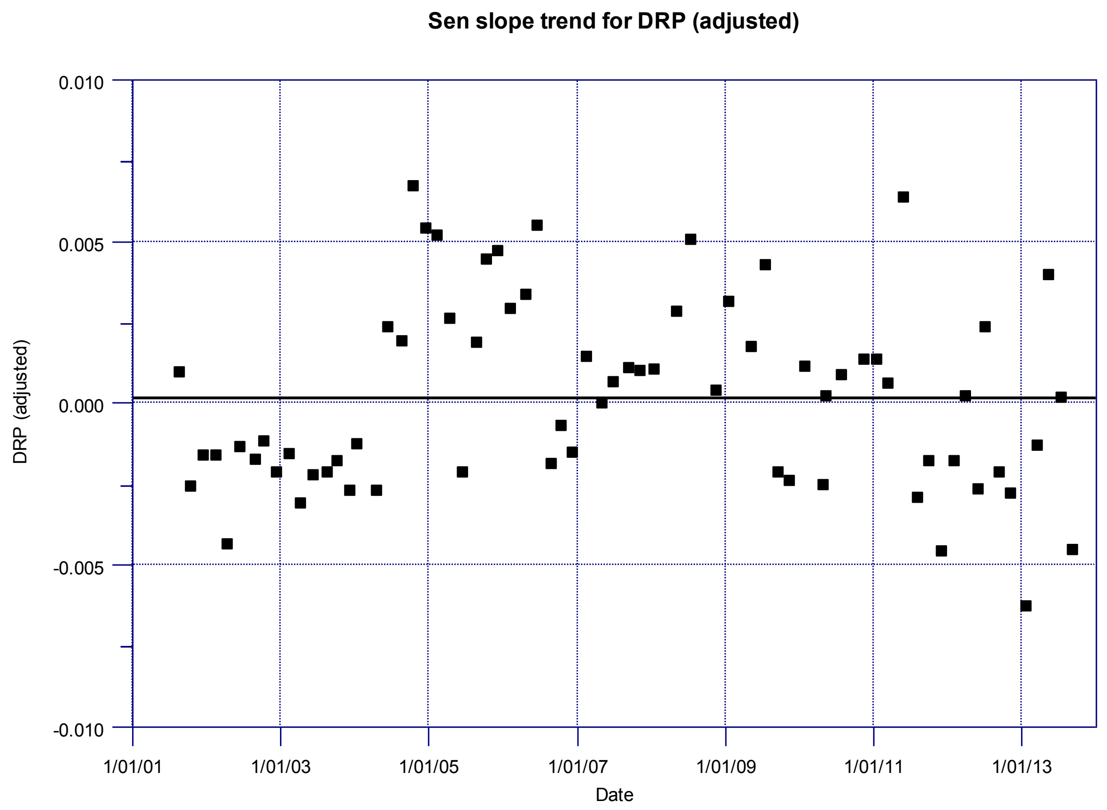
Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Craig Road	30-May-2013 09:04:00	<0.010					0.15	12.30	96.80	0.01	85.00			0.43				<3		0.18	0.61	0.01	1.58	5.10	7.70
Shag at Craig Road	07-Jun-2013 11:35:00	<0.010								0.01	60.00			0.54				<3		0.39	0.92	0.03			
Shag at Craig Road	10-Jul-2013 11:52:00	<0.010								0.01	44.00			0.90				<3		0.39	1.29	0.02			
Shag at Craig Road	25-Jul-2013 11:15:00	<0.010					0.19	11.70	93.10	0.01	47.00			0.72				<3		0.24	0.96	0.01	1.32	5.57	7.70
Shag at Craig Road	08-Aug-2013 11:05:00	<0.010								0.01	39.00			0.59				<3		0.25	0.84	0.01			
Shag at Craig Road	23-Aug-2013 11:15:00	<0.010								0.01	71.00			0.29				<3		0.20	0.49	0.01			
Shag at Craig Road	28-Aug-2013 09:00:00	<0.010					0.18	11.90	97.70	<0.004	100.00			0.25				<3		0.14	0.39	0.01	0.88	6.70	7.90
Shag at Craig Road	05-Sep-2013 10:55:00	<0.010								<0.004	25.00			0.13				<3		0.17	0.31	<0.004			
Shag at Craig Road	20-Sep-2013 12:00:00	<0.010								<0.004	16.00			0.10				<3		0.17	0.28	<0.004			
Shag at Craig Road	24-Sep-2013 09:05:00	<0.010					0.22	11.00	98.10	<0.004	59.00			0.13				<3		0.19	0.32	0.01	0.63	10.30	7.90

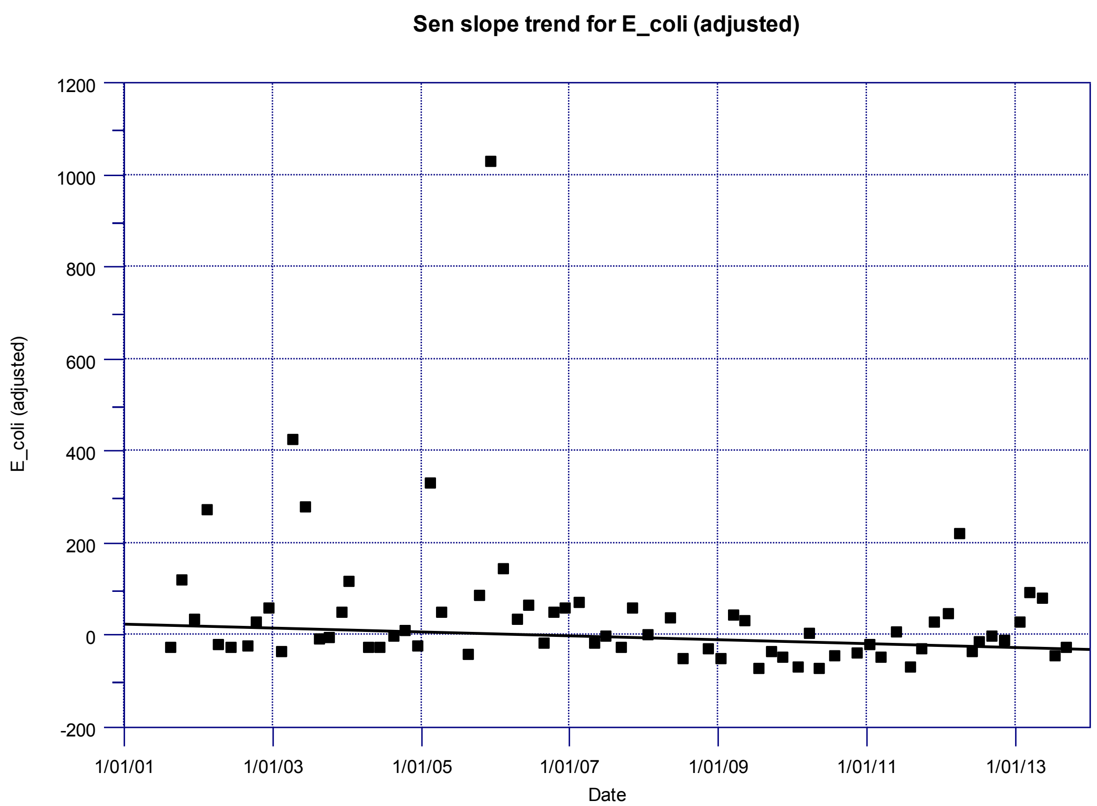
Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Goodwood	15-Mar-1989 11:45:00	0.01					0.18	11.80		<0.005				0.05				1.00			0.13	0.01		15.00	7.91
Shag at Goodwood	04-Apr-1989 11:45:00	0.02					0.17	8.20		<0.005		13.00		0.12				2.00			0.29	0.01		13.50	7.50
Shag at Goodwood	17-Apr-1989 11:35:00	0.01					0.17	10.60		<0.005		22.00		0.16				<1			0.40	0.01		13.00	7.32
Shag at Goodwood	27-Sep-1994 13:05:00	0.01	1.00		16.00	11.00	0.17			0.01		5.00	4.00	0.01	1.00	11.00	9.40	3.00			0.51	0.03	0.70	9.50	7.70
Shag at Goodwood	30-Nov-1994 10:25:00	0.03	2.00				0.22	10.40		0.00		73.00		0.38				2.00	0.01			0.02	0.45	14.00	6.63
Shag at Goodwood	01-Mar-1995 13:00:00	0.01	3.00		21.00	15.00	0.21			0.00		69.00	4.80	0.14	1.50	16.00	13.00	14.00	0.01		1.10	0.07	1.80	15.50	6.83
Shag at Goodwood	26-Apr-1995 13:20:00	0.0015	<1				0.20	10.10		0.00		53.00		0.17				1.00	0.01			0.01	0.25	13.10	7.38
Shag at Goodwood	28-Jun-1995 11:50:00	0.00	<1					12.00		0.01		43.00		0.59				3.00	0.01			0.02	1.00	5.50	7.11
Shag at Goodwood	16-Aug-1995 10:15:00						0.14					18.00		0.35									1.10	5.00	7.65
Shag at Goodwood	06-Sep-1995 10:35:00	0.02	<1				0.13	11.80		0.00		76.00		0.20				3.00	0.00			0.01	0.40	7.20	7.38
Shag at Goodwood	21-Nov-1995 10:05:00						0.21					62.00		0.24										11.20	7.26
Shag at Goodwood	29-Nov-1995 10:00:00	0.02	1.00				0.14	12.00		0.00		280.00		0.17			6.80	2.00	0.01		0.42	0.02	0.85	14.90	7.50
Shag at Goodwood	15-Jan-1996 11:10:00	0.01	1.00		16.00	7.50	0.17	9.90		0.00		170.00	3.60	0.10	1.00	10.00	6.00	2.00	0.01		0.31	0.01	0.60	16.80	7.07
Shag at Goodwood	06-Mar-1996 12:00:00						0.12							0.06										15.30	7.68
Shag at Goodwood	18-Mar-1996 14:30:00	0.01	<1				0.15	11.60		0.00		310.00		0.05				1.00	0.01			0.01	0.30	14.80	7.65
Shag at Goodwood	15-May-1996 12:05:00	0.01	1.00				0.17	11.60		0.00		62.00		0.17				2.00	0.00			0.01	0.25	8.60	7.06
Shag at Goodwood	31-Jul-1996 11:40:00	0.02	1.00		12.00	9.40	0.16	11.20		0.01		36.00	3.10	0.39	0.80	9.30	7.30	1.00	0.01		0.60	0.02	1.20	4.70	7.20
Shag at Goodwood	25-Sep-1996 12:40:00	0.01	<1				0.17	13.30		0.00		14.00		0.19				1.00	0.0015			0.01	0.40	12.90	8.23
Shag at Goodwood	04-Dec-1996 13:05:00	0.02	1.00				0.17	10.60		0.01		150.00		0.12				2.00	0.01			0.02	1.60	14.80	
Shag at Goodwood	04-Feb-1997 13:20:00	0.01	1.00		16.00	8.30	0.16	11.40		0.00		230.00	3.90	0.08	1.10	11.00		<1	0.02		0.22	0.01	0.40	16.00	7.80
Shag at Goodwood	26-Mar-1997 01:10:00						0.16					0.5		0.37				1.00					7.50	15.20	6.78
Shag at Goodwood	26-Mar-1997 11:20:00						0.16					280.00		0.06				1.00					0.60	13.10	7.55
Shag at Goodwood	21-May-1997 12:45:00	0.01	2.00				0.16	12.20		0.01		78.00		0.07				<1	0.01		0.21	0.01	0.50	10.50	7.70
Shag at Goodwood	11-Jun-1997 12:20:00	0.02	2.00				0.19	11.80		0.00		230.00		0.18				2.00	0.01			0.01	0.30	8.00	7.60
Shag at Goodwood	06-Aug-1997 12:45:00	0.03	<1	1.45	12.00	11.00	0.12	14.20		0.01		50.00	3.50	0.09	1.10	10.00	6.40	5.00	0.01		0.44	0.03	5.40	4.50	7.70
Shag at Goodwood	01-Oct-1997 13:15:00	0.03	<1	5.10	16.00	11.00	0.19	13.00		0.00		60.00	4.20	0.11	0.96	10.00	8.10	1.00	0.01		0.26	0.01	0.50	10.00	7.90
Shag at Goodwood	02-Dec-1997 11:45:00	0.01		4.25	17.00	9.60	0.18	9.90		0.01			4.20	0.10	1.10	11.00	7.40		0.01		0.27	0.02		13.50	7.70
Shag at Goodwood	04-Feb-1998 12:45:00	0.02	1.00	5.40	18.00	13.00	0.21	7.40		0.01		47.00	4.50	0.03	1.30	14.00	7.60	1.00	0.01		0.18	0.02	0.60	20.90	7.60
Shag at Goodwood	02-Apr-1998 12:30:00	0.01	<1	3.90	19.00	16.00	0.22	11.20		0.00		190.00	4.70	0.08	1.30	15.00	9.90	3.00	0.00		0.22	0.02	1.30	13.80	8.00
Shag at Goodwood	05-Jun-1998 12:50:00	0.02	<1	7.30	18.00	12.00	0.19	14.00		0.00		74.00	4.60	0.17	1.20	12.00	12.00	<1	0.01			0.01	0.40	8.70	
Shag at Goodwood	31-Aug-1998 14:40:00	0.02	1.00	5.60	19.00	11.00	0.19	14.00		0.01	11.00	11.00	4.80	0.06	1.10	12.00	16.00	<1	0.00		0.29	<0.005	0.50	9.80	8.20
Shag at Goodwood	04-Nov-1998 10:00:00	0.01	1.00	4.65	17.00	9.30		12.10		0.00	75.00	75.00	3.50	0.03	1.10	10.00	12.00	2.00	0.00		0.17	0.01	0.60	12.00	8.00
Shag at Goodwood	17-Dec-1998 13:10:00	0.0025	2.00		17.00	10.00	0.19	11.90		0.00	13.00	13.00	6.10	0.01	1.10	19.00	12.00	1.00	0.00		0.15	0.01	0.50	17.00	8.00
Shag at Goodwood	07-Jan-1999 09:30:00	0.07	2.00	3.20	16.00	11.00	0.19	7.80		0.00	180.00	180.00	4.80	0.01	1.20	15.00	12.00	<3	<0.003		0.23	0.02	0.60	17.70	7.40
Shag at Goodwood	08-Feb-1999 16:10:00							8.20																29.00	
Shag at Goodwood	27-Jul-1999 13:30:00	0.02	2.00	1.95			0.18	12.60		0.01	180.00	180.00		0.55				2.00	0.01		0.77	0.02	2.60	6.00	7.60
Shag at Goodwood	03-Sep-1999 16:00:00						0.17																	10.80	8.65
Shag at Goodwood	07-Oct-1999 13:10:00	0.01	<1	2.40				11.70		0.00	15.00	15.00		0.17				1.00	0.01		0.31	0.02	0.80	13.20	7.80
Shag at Goodwood	06-Jan-2000 11:40:00	0.01	1.00	0.78			0.08	9.00		0.00	530.00	530.00		0.06				3.00	0.02		0.38	0.03	2.60	14.50	7.60
Shag at Goodwood	25-Feb-2000 14:46:00						0.18																	19.10	
Shag at Goodwood	07-Mar-2000 10:15:00	0.01	<1	2.70			0.19	10.00		<0.001	360.00	360.00		0.10				<3	0.01		0.25	0.02	0.50	15.80	7.60
Shag at Goodwood	09-May-2000 13:10:00	0.0025	1.00				0.13	12.60		0.00	270.00	270.00		0.10				4.00	0.02		0.51	0.03	4.40	7.50	7.80
Shag at Goodwood	06-Sep-2000 12:00:00	0.03	<1	0.45				10.50		0.02	53.00	53.00		1.60				29.00	0.02		1.70	0.05	20.00	7.40	7.20
Shag at Goodwood	15-Nov-2000 12:00:00	0.01	<1	3.10			0.21	9.80		<0.005	73.00	73.00		0.20				<1	0.01		0.89	0.01	0.84	14.00	6.70
Shag at Goodwood	07-Dec-2000 11:30:00	0.01	<1	2.00			0.11	11.00		<0.005	110.00	116.00		0.17				<1	0.02		0.26	0.02	0.50	6.00	7.60
Shag at Goodwood	15-Jan-2001 13:30:00	0.03	<1	3.90			0.18	9.40		<0.005	32.00	89.00		0.22				<1	<0.005		0.44	0.01	0.59	17.80	8.10
Shag at Goodwood	06-Mar-2001 12:45:00	0.005	<1	4.50			0.21	9.60		<0.005	180.00	200.00		0.32				<1	<0.005		0.48	0.01	0.61	14.90	7.80
Shag at Goodwood	15-Aug-2001 14:30:00	0.005	<1	2.50			0.15	13.50		0.01	6.00	23.00		0.67				1.00				0.01	1.30	6.90	7.20
Shag at Goodwood	09-Oct-2001 13:12:00	0.005	<1	1.86						<0.005	180.00	240.00		0.22				1.00	<0.005		0.48	<0.005	0.67	11.50	7.50
Shag at Goodwood	13-Dec-2001 13:00:00	0.11	<1	3.24			0.15	11.30		0.00	84.00	120.00		0.08				<1	<0.005		0.27	0.01	0.64	16.50	7.50
Shag at Goodwood	12-Feb-2002 12:20:00	0.005	<1	4.00			0.22	8.60		0.00	280.00	360.00		0.29				<1	<0.005		0.47	0.02	0.63	16.80	7.20
Shag at Goodwood	09-Apr-2002 12:55:00	0.005	<1	4.26			0.26	9.70		<0.001	63.00	80.00		0.19				<1	<0.005		0.37	<0.005	0.46	13.00	7.00
Shag at Goodwood	11-Jun-2002 10:00:00	0.005	<1	3.75			0.22	9.70		<0.005	93.00	110.00		0.19				<1	<0.005		0.40	<0.005	0.37	7.50	7.30
Shag at Goodwood	29-Aug-2002 10:35:00	0.01	<1	3.36			0.22			<0.005	31.00	40.00		0.26				1.00			0.44	<0.005	0.75	5.80	7.44
Shag at Goodwood	10-Oct-2002 08:05:00	0.01	<1	3.71			0.16	10.60		<0.005	41.00	66.00		0.20				1.00			0.38	<0.005	0.50	9.50	7.34

Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Goodwood	11-Feb-2003 09:30:00	0.03		2.49			0.22	8.40		<0.005	2000.00	2100.00		0.02				<1			0.22	0.01	1.40	16.00	7.32
Shag at Goodwood	09-Apr-2003 10:10:00	0.01	<1	4.91			0.33	9.70		<0.005	520.00	620.00		0.16				1.00			0.28	0.01	0.60	11.00	7.32
Shag at Goodwood	10-Jun-2003 09:55:00	0.005	<1	3.55			0.31	11.00		<0.005	70.00	140.00		0.17				<1			0.33	<0.005	0.40	7.20	7.54
Shag at Goodwood	18-Aug-2003 11:28:00	0.02		2.77			0.18	11.90	98.00	<0.005	4.00	36.00		0.06				<1			0.21	<0.005	0.35	7.00	7.66
Shag at Goodwood	07-Oct-2003 09:15:00	0.005		4.93			0.14	12.40	102.00	<0.005	23.00	40.00		0.04				<1			0.24	<0.005	0.50	7.30	7.58
Shag at Goodwood	09-Dec-2003 08:50:00	0.02		2.95			0.18	9.40	91.10	<0.005	120.00	110.00		0.08				<1			0.27	0.01	0.75	14.10	7.38
Shag at Goodwood	07-Jan-2004 11:45:00	0.02		2.94			0.20	8.10	87.80	<0.005	250.00	230.00		0.02				3.00			0.20	<0.005	1.40	17.90	7.67
Shag at Goodwood	10-Feb-2004 08:35:00	0.02		3.74			0.18	8.20		<0.005	490.00	440.00		0.27				<1			0.55	0.02	0.65	15.50	7.37
Shag at Goodwood	14-Apr-2004 09:35:00	0.005		4.71			0.20	11.50	98.90	<0.005	70.00	88.00		0.09				<1			0.22	<0.005	0.35	8.51	
Shag at Goodwood	10-Jun-2004 09:05:00	0.005		7.71			0.30	10.20		0.01	110.00	160.00		0.20				<1			0.32	0.01	0.35	7.00	7.45
Shag at Goodwood	17-Aug-2004 09:20:00	0.005		4.09			0.19	13.80		0.01	22.00	32.00		0.32				<1			0.51	0.01	0.70	2.80	7.38
Shag at Goodwood	13-Oct-2004 13:10:00	0.02		4.16			0.14	13.10	130.00	0.01	44.00	55.00		0.13				<1			0.31	0.01	0.40	14.60	
Shag at Goodwood	14-Dec-2004 12:30:00	0.005		4.27			0.20	13.00		0.01	19.00	28.00		0.03				<1			0.20	0.01	0.50	14.40	8.09
Shag at Goodwood	10-Feb-2005 08:20:00	0.01		3.98			0.17	6.40	66.60	0.01	810.00	880.00		0.02				1.00			0.13	0.02	0.75	18.00	
Shag at Goodwood	12-Apr-2005 10:30:00	0.01					0.17	10.00		<0.005	71.00	160.00		0.04				<1			0.20	0.01	0.20	12.80	7.49
Shag at Goodwood	15-Jun-2005 09:35:00	0.01					0.11	11.70	89.90	<0.005	29.00	76.00		0.12				1.00			0.23	<0.005	1.20	3.92	
Shag at Goodwood	18-Aug-2005 10:15:00	0.01					0.16	10.50	87.00	0.01	69.00	70.00		0.09				<3			0.21	0.01	0.31	7.13	
Shag at Goodwood	11-Oct-2005 08:45:00	0.005					0.20	11.70		0.01	110.00	110.00		0.06				<3			0.39	0.02	2.20	7.80	6.80
Shag at Goodwood	06-Dec-2005 10:20:00	0.01					0.13	8.40	82.80	0.01	160.00	160.00		0.04				<3			0.18	0.02	0.57	14.80	
Shag at Goodwood	07-Feb-2006 08:50:00	0.01					0.13	8.30	83.00	0.01	67.00	68.00		<0.005				<3			0.15	0.02	0.45	15.30	6.90
Shag at Goodwood	20-Apr-2006 10:50:00	0.005					0.13	7.60	71.80	0.01	240.00	240.00		0.03				<3			0.31	0.02	0.85	13.30	
Shag at Goodwood	14-Jun-2006 10:00:00	0.01					0.10	10.60	82.90	0.01	66.00	66.00		0.22				<3			0.35	0.01	0.74	5.31	
Shag at Goodwood	23-Aug-2006 10:40:00	0.005					0.13	13.10	103.00	<0.005	29.00	30.00		<0.005				<3			0.33	<0.05	1.27	5.10	7.20
Shag at Goodwood	11-Oct-2006 09:25:00	0.01					0.17	11.50	100.00	<0.005	120.00	140.00						<3				0.01	0.39	9.20	7.60
Shag at Goodwood	06-Dec-2006 10:40:00	0.01					0.23	9.70	95.80	0.01	76.00	76.00		0.10				<3			0.26	0.01	0.71	14.90	7.60
Shag at Goodwood	15-Feb-2007 10:20:00	0.01					0.22	9.50	98.20	0.01	180.00	290.00		0.08				<3			0.22	0.01	0.42	16.90	7.50
Shag at Goodwood	30-Apr-2007 11:40:00	0.005					0.23	9.80	89.00	0.01	36.00	40.00		0.15				<3			0.26	0.02	0.48	10.90	7.20
Shag at Goodwood	25-Jun-2007 12:10:00	0.005					0.23	13.60	108.00		50.00	56.00		0.23				<3			0.32		0.27	5.60	7.60
Shag at Goodwood	11-Sep-2007 12:30:00	0.005								<0.005	18.00	21.00		0.37				<3			0.58	0.01	0.43		8.00
Shag at Goodwood	07-Nov-2007 10:45:00	0.01					0.19	9.30	86.20	0.01	54.00	54.00		0.26				<3			0.43	0.01	0.66	12.20	7.60
Shag at Goodwood	16-Jan-2008 11:00:00	0.02					0.21	4.60	46.90	0.01	50.00	70.00		0.30				<3			0.45	0.02	0.62	16.70	7.40
Shag at Goodwood	26-Feb-2008 11:15:00	0.005					0.21	9.10	93.70	0.01	94.00	110.00		0.11				<3			0.27	0.02	0.61	16.80	7.60
Shag at Goodwood	05-May-2008 11:00:00	0.005					0.21	10.10	87.90	0.01	180.00	180.00		0.24				<3			0.38	0.02	0.80	9.20	7.10
Shag at Goodwood	10-Jul-2008 11:45:00	0.01					0.15	13.30	108.00	0.01	42.00	42.00		0.13				<3			0.28	0.02	0.37	5.82	
Shag at Goodwood	27-Aug-2008 11:00:00	0.005					0.09	10.20	85.20	0.01	24.00	42.00		0.26				10.00			0.66	0.04	6.63	7.73	
Shag at Goodwood	13-Nov-2008 09:00:00	0.03					0.21	8.00	79.00	0.01	70.00	82.00		0.51				<3			0.76	0.02	1.22	14.90	7.20
Shag at Goodwood	15-Jan-2009 09:55:00	0.02					0.22	8.30	86.00	0.01	150.00	300.00		0.48				<3			0.61	0.02	0.69	16.60	7.10
Shag at Goodwood	12-Mar-2009 09:45:00	0.005					0.21	9.60	90.00	0.01	150.00			0.58				<3			0.76	0.02	1.57	11.90	7.10
Shag at Goodwood	06-May-2009 11:30:00	0.005					0.23	10.20	91.00		18.00			0.52				<3			0.69		0.41	10.10	7.30
Shag at Goodwood	14-Jul-2009 12:00:00	0.005					0.17	11.30	86.80	0.01	20.00			0.59				<3			0.90	0.02	3.17	4.22	7.80
Shag at Goodwood	16-Sep-2009 10:30:00	0.01						10.50	91.90	0.01	41.00			0.49				<3			0.70	0.01	0.57	9.80	7.50
Shag at Goodwood	10-Nov-2009 10:15:00	0.01						8.30	79.40	0.01	28.00			0.30				<3			0.38	0.02	0.66	13.20	7.40
Shag at Goodwood	27-Jan-2010 10:15:00	0.005					0.25	8.70	90.70	0.01	3.00			0.32				<3			0.51	0.01	0.55	16.80	7.40
Shag at Goodwood	24-Mar-2010 11:20:00	0.005					0.26	4.60	45.10		1.00			0.03				<3			0.16		0.22	14.40	7.50
Shag at Goodwood	12-May-2010 11:20:00	0.005					0.26	10.50	92.70	0.01	1.00			0.90				<3			1.03	0.01	0.28	9.90	7.40
Shag at Goodwood	22-Jul-2010 11:45:00	0.005					0.14	12.50	99.90	0.01	2.00			1.02				<3			1.28	0.01	0.54	5.96	7.50
Shag at Goodwood	15-Sep-2010 10:00:00						0.18	12.00	101.00															8.20	
Shag at Goodwood	10-Nov-2010 10:40:00	0.01					0.24	8.40	85.90	0.01	36.00			0.50				<3			0.69	0.02	0.67	15.60	7.30
Shag at Goodwood	12-Jan-2011 10:05:00	0.02					0.24	9.30	93.60	0.01	58.00			0.24				<3			0.47	0.02	1.29	15.60	7.30
Shag at Goodwood	08-Mar-2011 10:15:00	0.005					0.20	9.60	94.30	0.01	44.00			0.07				<3			0.25	0.01	0.62	14.20	7.50
Shag at Goodwood	26-May-2011 10:10:00	0.005					0.19	9.90	87.30	0.01	72.00			0.37				<3			0.66	0.02	0.89	10.00	7.70
Shag at Goodwood	03-Aug-2011 12:50:00	0.005					0.23	14.90	125.00	<0.004	17.00			0.15				<3		0.18	0.33	0.00	0.42	7.70	7.90
Shag at Goodwood	28-Sep-2011 09:30:00	0.005					0.17	11.00	96.50	<0.004	40.00			0.09				<3		0.26	0.34	<0.004	4.80	9.60	7.60
Shag at Goodwood	29-Nov-2011 11:25:00	0.005					0.14	11.20	106.00	<0.004	80.00			0.11				<3		0.23	0.34	0.01	0.96	12.80	7.90
Shag at Goodwood	01-Feb-2012 10:15:00	0.02					0.19	9.70	97.30	0.00	200.00			0.15				<3		0.20	0.35	0.01	0.83	15.50	7.70
Shag at Goodwood	27-Mar-2012 10:00:00	0.005					0.16	8.10	76.40	<0.004	280.00			0.08				<3		0.21	0.29	0.01	0.86	12.60	7.60

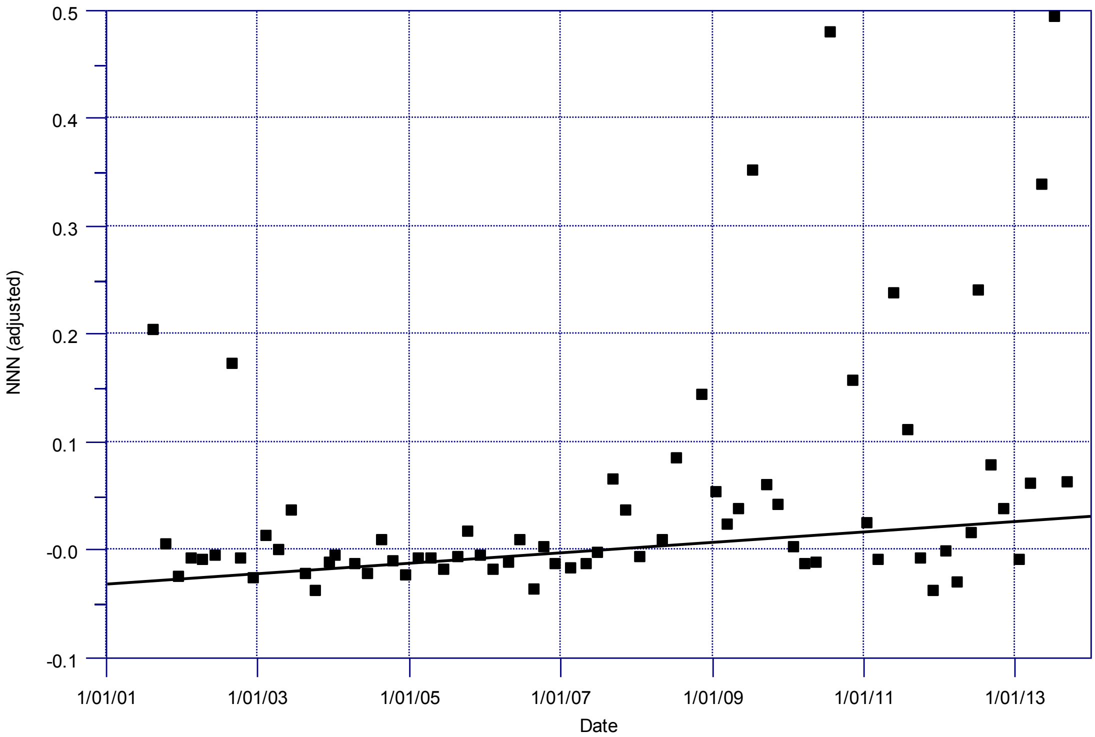
Site Name	Time	NH4-N	BOD-5	Black Disk Horizontal	Ca	Cl	Cond.	DO	DO (sat)	DRP	*E. coli*	Faecal Coliforms	Mg	NNN	K	Na	SO4	SS	TDP	TKN	TN	TP	Turbidity	Water Temp.	pH
		mg/l-N	mg/l-O	60mm dia	mg/l	mg/l	mS/cm	mg/l	%	mg/l-P	cfu/100ml	cfu/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	mg/l-P	mg/l-N	mg/l-N	mg/l-P	NTU	degrees C	
Shag at Goodwood	30-May-2012 11:15:00	0.005					0.05	11.50	96.30	0.01	150.00			0.26				<3		<0.10	0.35	0.01	0.53	7.65	7.60
Shag at Goodwood	04-Jul-2012 11:25:00	0.005					0.23	11.70	92.90	<0.004	80.00			0.28				<3		0.11	0.38	0.01	0.34	5.60	7.60
Shag at Goodwood	07-Aug-2012 09:30:00	0.005					0.15	12.30	103.00	0.01	25.00			0.58				<3		0.26	0.84	0.02	3.10	7.50	7.60
Shag at Goodwood	06-Sep-2012 09:50:00	0.005					0.20	10.20	88.10	0.01	38.00			1.27				<3		0.29	1.56	0.02	1.85	8.89	7.60
Shag at Goodwood	04-Oct-2012 11:30:00	0.005								<0.004	50.00			0.52				<3		0.20	0.72	0.01			
Shag at Goodwood	08-Oct-2012 08:30:00	0.005					0.20	9.40	83.70	0.01	39.00			0.52				<3		0.17	0.69	0.03	0.86	10.30	7.70
Shag at Goodwood	19-Oct-2012 12:00:00	0.005								<0.004	41.00			0.26				<3		0.22	0.48	0.01			
Shag at Goodwood	31-Oct-2012 12:20:00	0.005								0.01	29.00			0.33				<3		0.23	0.56	0.01			
Shag at Goodwood	06-Nov-2012 09:10:00	0.005					0.19	9.70	87.00	<0.004	69.00			0.33				<3		0.17	0.50	0.01	0.72	10.70	7.40
Shag at Goodwood	12-Nov-2012 12:20:00	0.005								0.01	4300.00			0.31				8.00		0.38	0.68	0.03			
Shag at Goodwood	28-Nov-2012 11:00:00	0.005								<0.004	34.00			0.22				<3		0.18	0.40	0.01			
Shag at Goodwood	06-Dec-2012 08:30:00	0.005					0.20	7.50	75.90	0.01	190.00			0.29				<3		0.19	0.48	0.02	1.07	16.10	7.80
Shag at Goodwood	11-Dec-2012 10:20:00	0.005								<0.004	62.00			0.29				<3		0.17	0.46	0.02			
Shag at Goodwood	14-Jan-2013 08:30:00	0.005					0.21	7.80	81.10	0.01	900.00			0.22				<3		0.22	0.44	0.01	0.68	17.40	7.60
Shag at Goodwood	18-Jan-2013 11:15:00	0.02								0.01	3500.00			0.19				7.00		0.44	0.63	0.04			
Shag at Goodwood	30-Jan-2013 12:00:00	0.005								<0.004	60.00			0.15				<3		0.15	0.30	0.01			
Shag at Goodwood	12-Feb-2013 09:00:00	0.005					0.21	7.90	79.40	<0.004	240.00			0.22				<3		0.12	0.34	0.01	0.49	15.80	7.60
Shag at Goodwood	13-Feb-2013 11:50:00	0.005								0.01	270.00			0.23				<3		0.10	0.33	0.01			
Shag at Goodwood	27-Feb-2013 11:23:00	0.005								0.01	160.00			0.22				<3		<0.10	0.28	0.02			
Shag at Goodwood	12-Mar-2013 11:16:00	0.005								<0.004	280.00			0.21				<3		0.10	0.31	0.01			
Shag at Goodwood	13-Mar-2013 09:15:00	0.01					0.22	7.30	71.60	0.01	260.00			0.26				<3		0.16	0.42	0.01	0.46	14.40	7.80
Shag at Goodwood	26-Mar-2013 10:32:00	0.01								0.01	330.00			0.22				<3		0.30	0.52	0.01			
Shag at Goodwood	08-Apr-2013 11:25:00	0.01								0.01	120.00			0.27				<3		0.12	0.39	0.01			
Shag at Goodwood	17-Apr-2013 10:05:00	0.005					0.23	7.40	70.40	0.01	50.00			0.20				<3		0.17	0.37	0.01	0.54	13.10	7.60
Shag at Goodwood	23-Apr-2013 11:50:00	0.005								<0.004	1500.00			0.34				<3		0.20	0.54	0.01			
Shag at Goodwood	09-May-2013 12:49:00	0.005								0.01	250.00			0.29				<3		0.21	0.50	0.02			
Shag at Goodwood	22-May-2013 12:10:00	0.005								0.02	310.00			0.48				14.00		0.34	0.82	0.03			
Shag at Goodwood	30-May-2013 09:35:00	0.005					0.17	11.60	93.90	0.01	140.00			0.66				<3		0.23	0.88	0.02	1.34	6.23	7.70
Shag at Goodwood	07-Jun-2013 12:20:00	0.005								0.02	110.00			0.66				3.00		0.27	0.93	0.02			
Shag at Goodwood	10-Jul-2013 12:30:00	0.01								0.01	70.00			1.21				4.00		0.45	1.66	0.02			
Shag at Goodwood	25-Jul-2013 12:10:00	0.01					0.20	11.80	95.80	0.01	38.00			1.11				<3		0.28	1.38	0.01	1.75	6.47	7.60
Shag at Goodwood	08-Aug-2013 12:59:00	0.005								0.01	60.00			1.08				<3		0.19	1.27	0.01			
Shag at Goodwood	23-Aug-2013 12:00:00	0.005								0.01	45.00			0.68				<3		0.20	0.88	0.02			
Shag at Goodwood	28-Aug-2013 09:30:00	0.005					0.21	10.70	90.00	0.01	27.00			0.70				<3		0.15	0.85	0.01	1.27	7.69	7.80
Shag at Goodwood	05-Sep-2013 12:00:00	0.005								0.01	38.00			0.44				<3		0.22	0.66	0.02			
Shag at Goodwood	20-Sep-2013 12:20:00	0.01								0.00	160.00			0.50				<3		0.16	0.65	<0.004			
Shag at Goodwood	24-Sep-2013 09:35:00	0.005					0.22	10.20	91.60	<0.004	170.00			0.54				<3		0.21	0.75	0.01	1.20	10.70	7.80
Shag at Goodwood	22-Oct-2013 08:30:00	0.005					0.22	9.40	86.80	0.01	80.00			0.37				<3		0.23	0.60	0.01	0.82	11.80	7.70

Appendix 2. Water quality trends – Craig Road

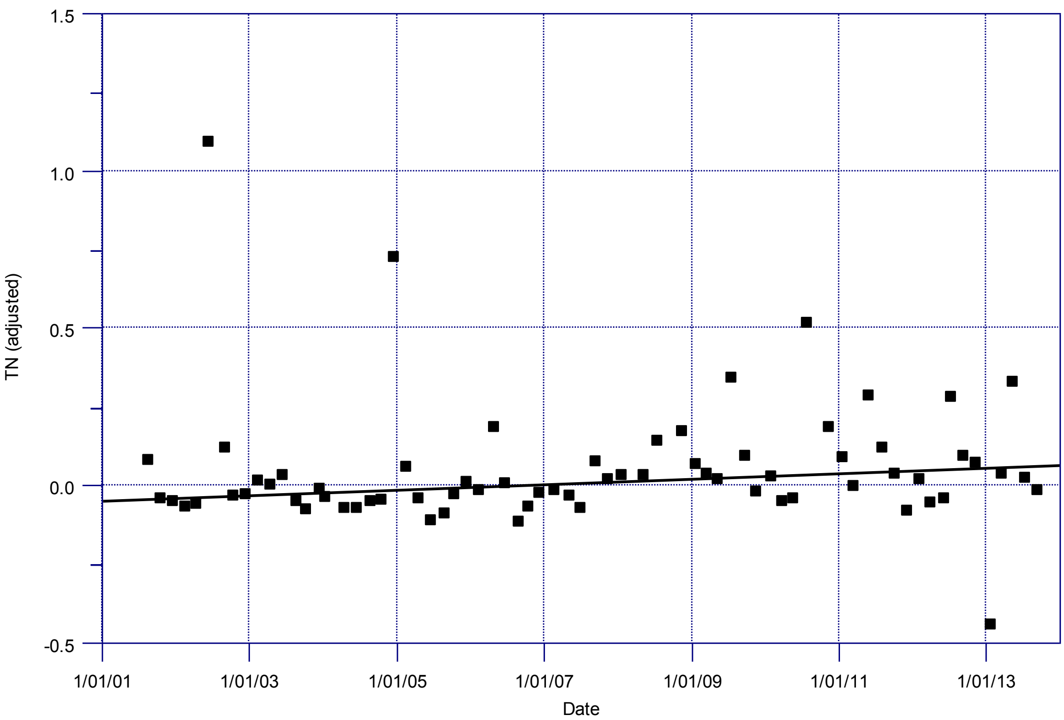


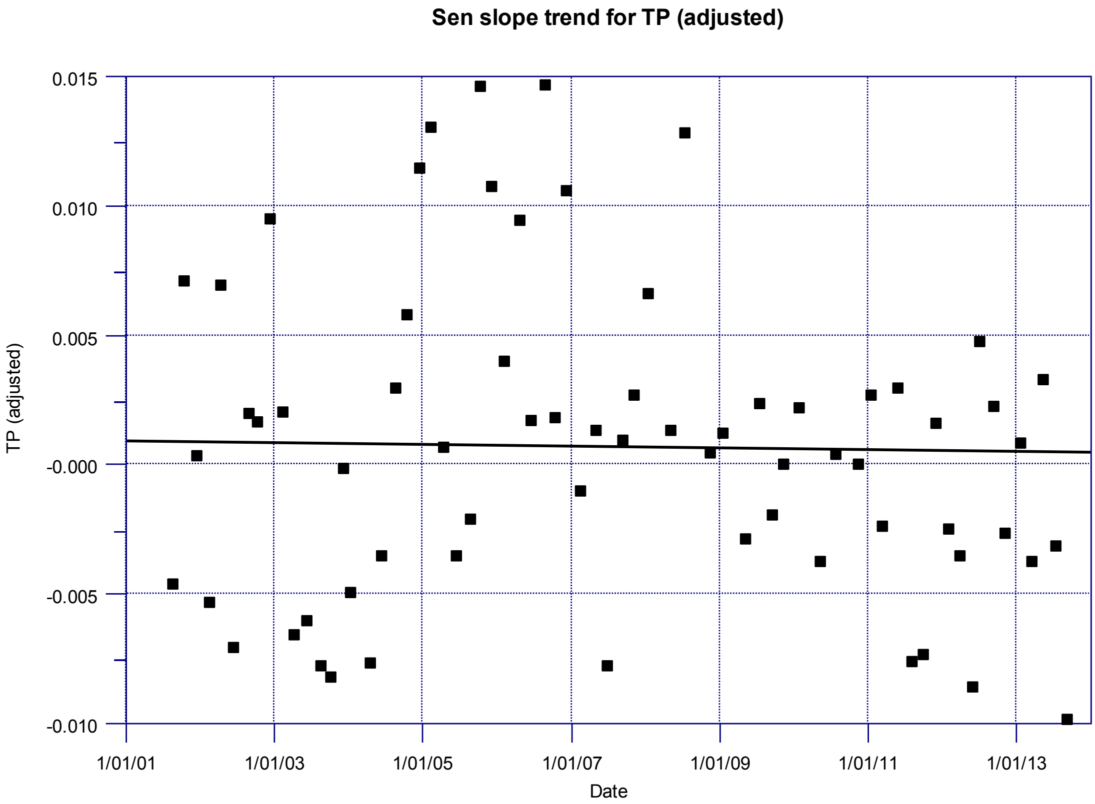


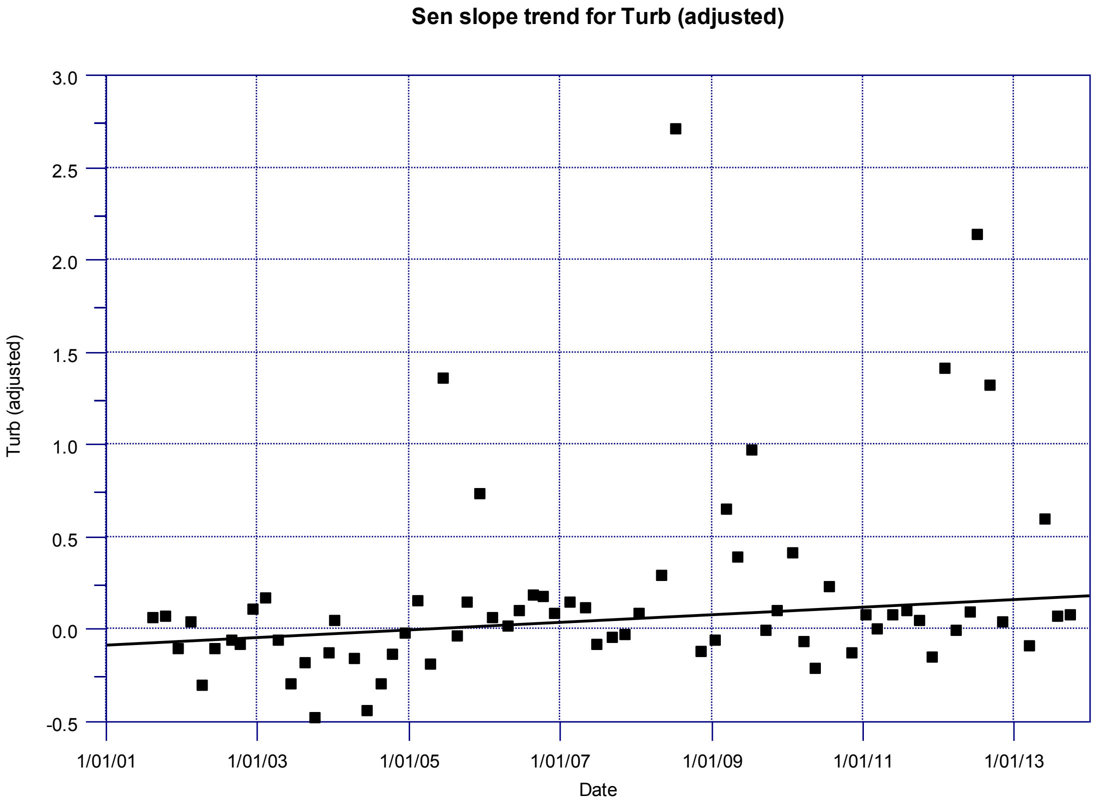
Sen slope trend for NNN (adjusted)



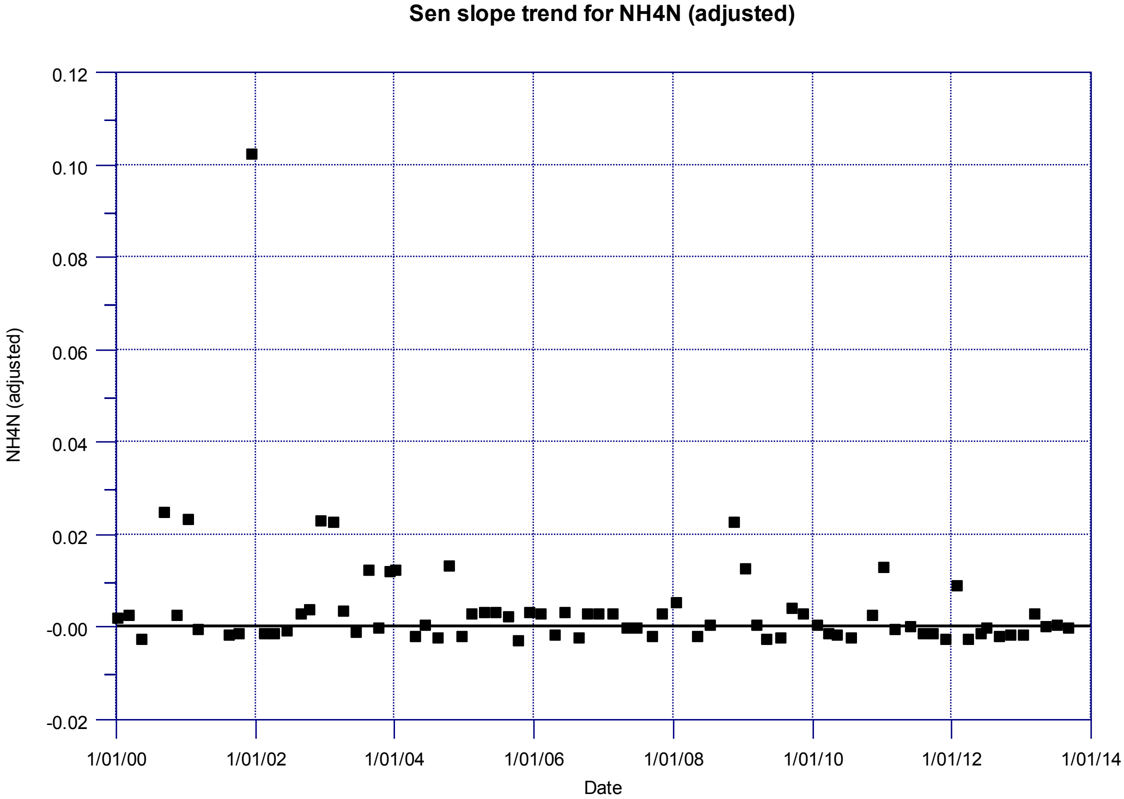
Sen slope trend for TN (adjusted)

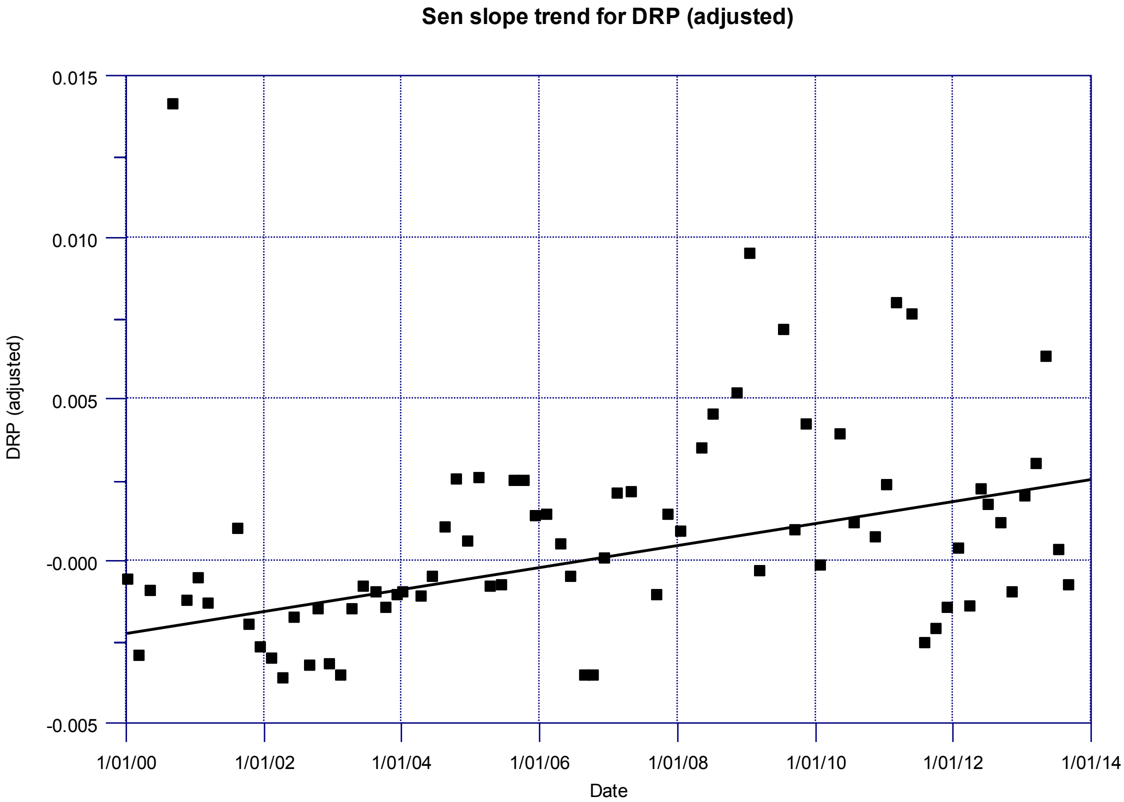


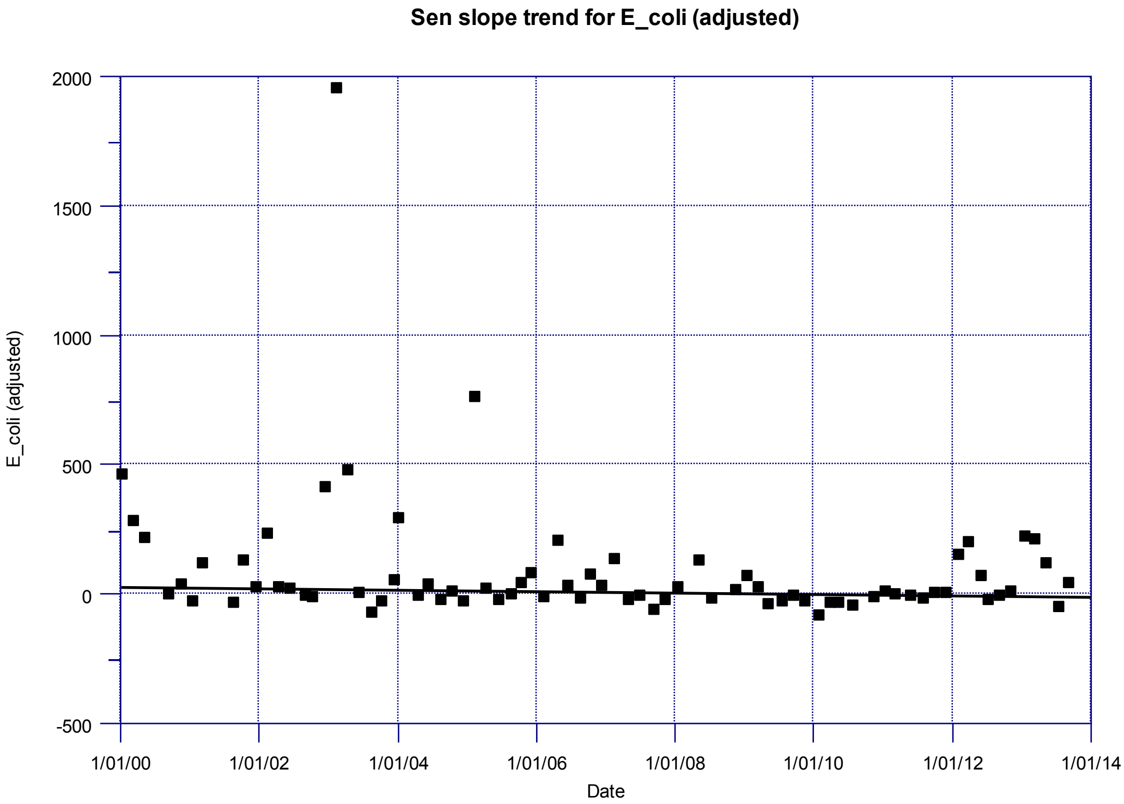

Sen slope trend for TP (adjusted)
0.015
0.010
0.005
-0.000
-0.005
-0.010
TP (adjusted)
1/01/01
1/01/03
1/01/05
1/01/07
1/01/09
1/01/11
1/01/13
Date


Sen slope trend for Turb (adjusted)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Turb (adjusted)
1/01/01
1/01/03
1/01/05
1/01/07
1/01/09
1/01/11
1/01/13
Date

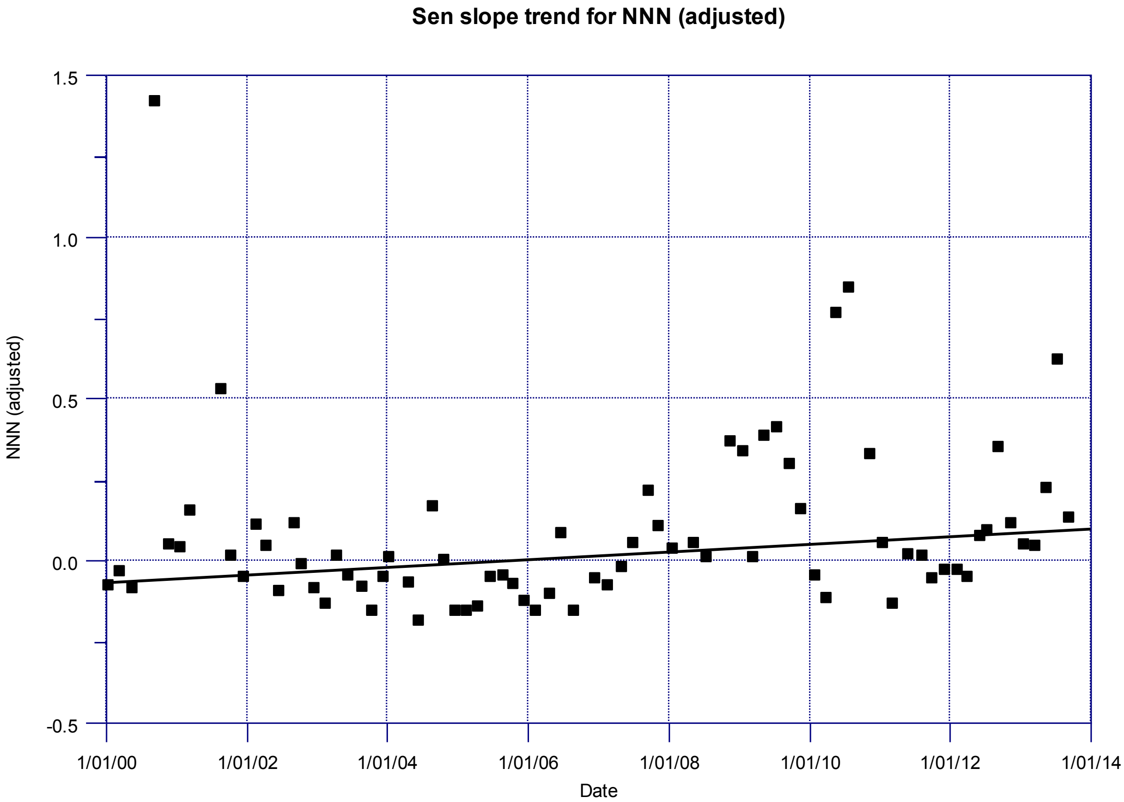
Appendix 3. Water quality trends –Goodwood Pump



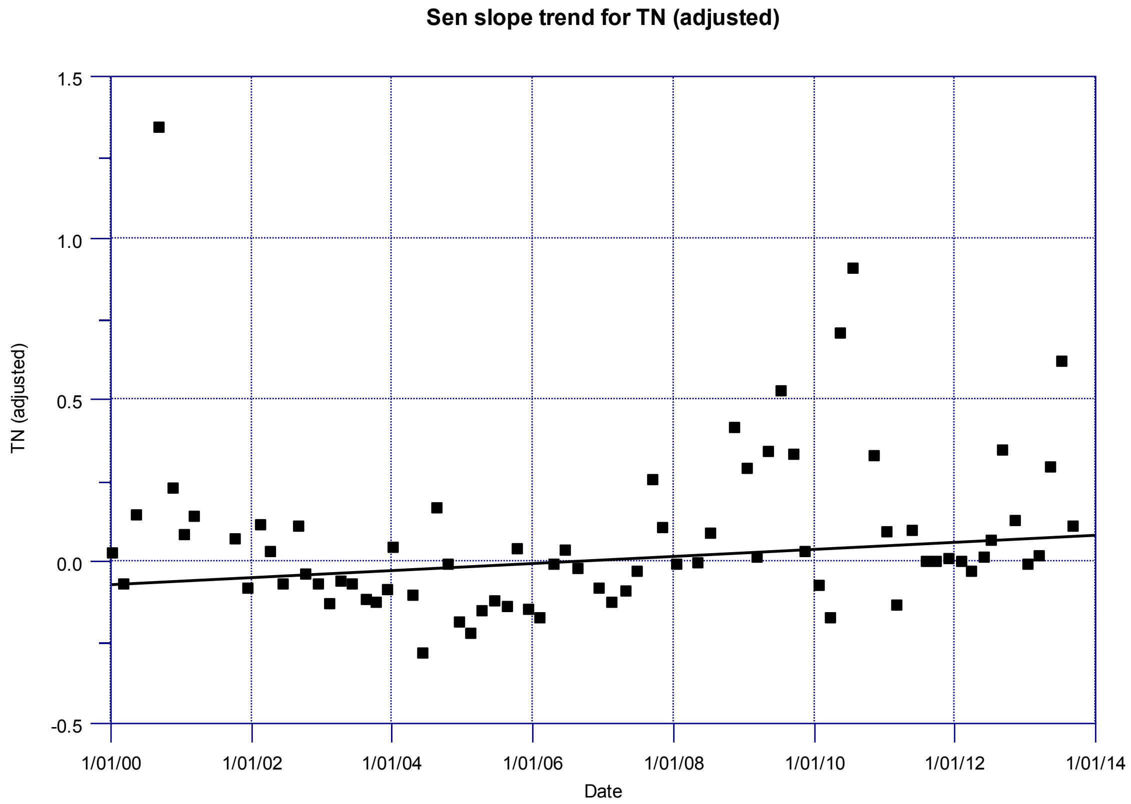


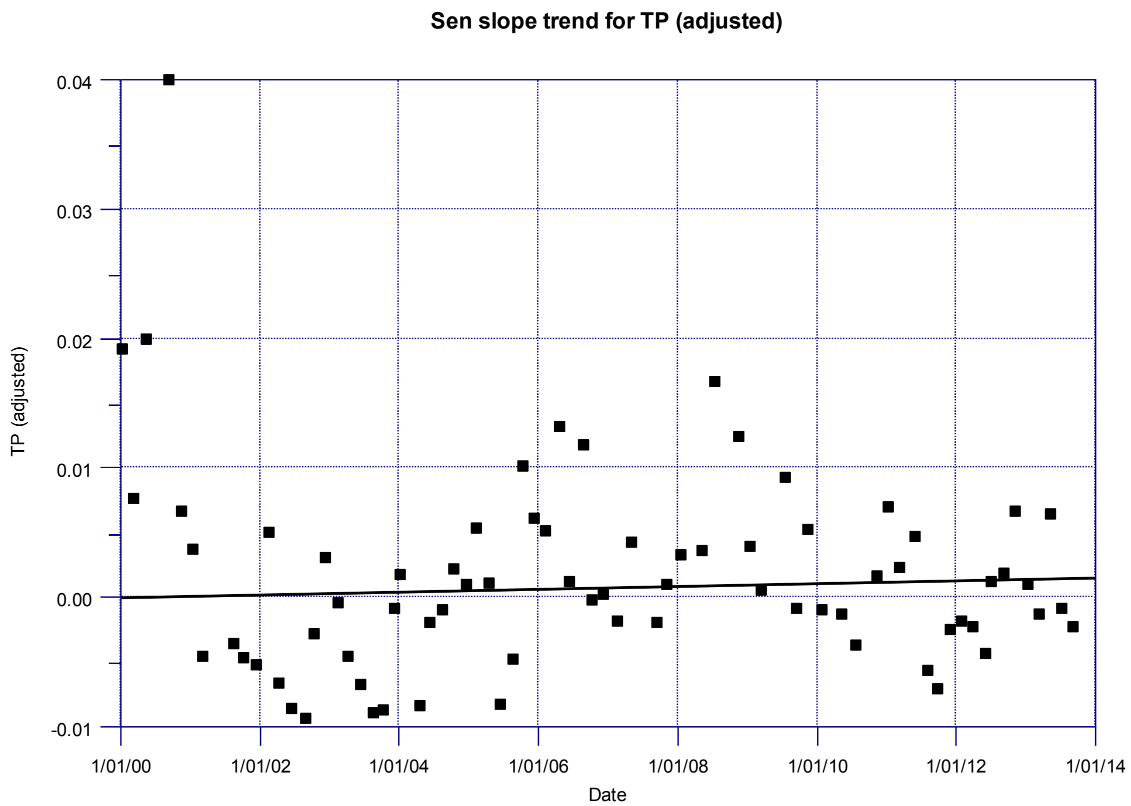


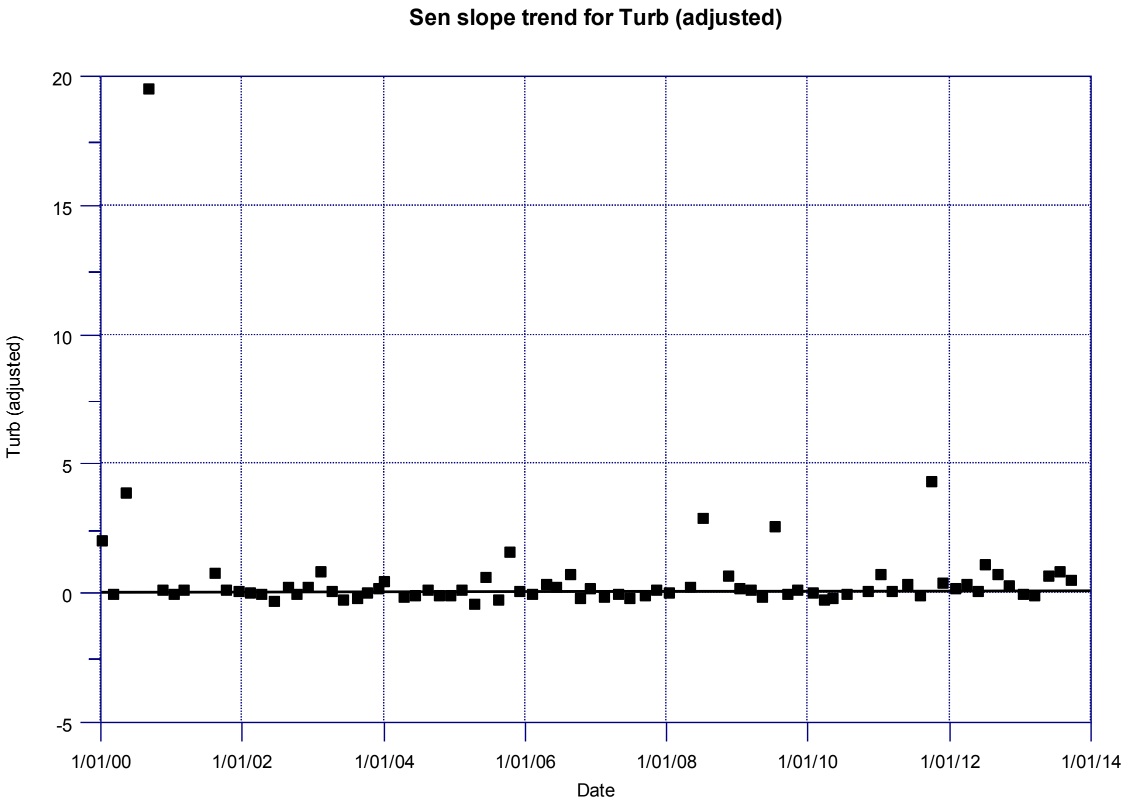
Sen slope trend for E_coli (adjusted)
2000
1500
1000
500
0
-500
E_coli (adjusted)
1/01/00
1/01/02
1/01/04
1/01/06
1/01/08
1/01/10
1/01/12
1/01/14
Date



Sen slope trend for NNN (adjusted)
1.5
1.0
0.5
0.0
-0.5
NNN (adjusted)
1/01/00
1/01/02
1/01/04
1/01/06
1/01/08
1/01/10
1/01/12
1/01/14
Date


Sen slope trend for TN (adjusted)
TN (adjusted)
1.5
1.0
0.5
0.0
-0.5
1/01/00
1/01/02
1/01/04
1/01/06
1/01/08
1/01/10
1/01/12
1/01/14
Date


Sen slope trend for TP (adjusted)
TP (adjusted)
0.04
0.03
0.02
0.01
0.00
-0.01
1/01/00
1/01/02
1/01/04
1/01/06
1/01/08
1/01/10
1/01/12
1/01/14
Date


Sen slope trend for Turb (adjusted)
20
15
10
5
0
-5
Turb (adjusted)
1/01/00
1/01/02
1/01/04
1/01/06
1/01/08
1/01/10
1/01/12
1/01/14
Date

Appendix 4. Instream habitat assessment data

Protocol 2b (hydrology and morphology) and protocol 2c (instream habitat) data

		Deepdell@Golden Pt Rd			Shag@Collins			Shag@Grange			McCormicks@SH85			Shag@Craig Rd			Shag@ Horse Range Rd			Shag @ Goodwood		
	Size	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool
Approx survey reach length (m)		60			80			130			110			150			120			80		
Wetted width (approx) (m)		2.4			3.9			11.7			1.2			11.7			4.2			5.4		
% of total habitat		31	11	58	40	38	22		34	66	20	26	54	31	39	30	42	52	6	35	41	24
%Concrete/artificial																					2	
%Bedrock	>4000 mm	5	5	20					50	95			20		20	10						
%Boulder	256-4000 mm				20	30	5						10		5						5	
%Cobble	64-255 mm	2			50	40	10				40	40	10	50	10		100				10	
%Gravel	2-63 mm	90	95	50	30	25	35		50		50	50	20	50	65	50		80	100	100	78	5
%Silt, sand	<2 mm	3		30		5	50			5	10	10	40			40		20			5	95
%Embeddedness		0	0	0	0	0	0				0	0	30	0	0	0	0	0	0	0	5	100
Substrate compactness		1.5	1.5	2.5	1	1	1				1	1	2	1	1	1	1	1	1	2	2	3
%Macrophytes	*Elodea*	15	15	20						5			50			2.5	0	0	0		1	15
	Charophytes	5	5	5																		
	Potamogeton															2.5						5
	Water cress	2																		10		
	Monkey musk													10							2	
%Moss																						
%Algae	Light brown					40																
	Dark brown-black													80								
	Short filamentous green																					
	Long filamentous green		15	20												10	30	40	10	90	90	50
%Woody debris & leaf packs		0	0	0	15	5	40		5	40	20	25	10	20	0	2				2	2	5
%Obstructions to flow			5		75	2			0	0	0	5	0	5						0	0	20
%Bank cover		0	0	0		10			0	0	30	30	60					30		10	0	25
Pool 1	Max depth (m)			0.4			2			>1.8			0.65			3			0.9			1.6
	Fine sediment depth (m)			>0.01			-			>0.01			0.27			0			0			0
	Crest depth (m)			0.05			0.1			?			0.03			0.05			0.1			0.23
Pool 2	Max depth (m)			0.35			1.05			1.08						1.1						
	Fine sediment depth (m)			0.1			0			>0.01						<0.01						
	Crest depth (m)			0.06			0.13			0.25						0.1						
Pool 3	Max depth (m)			0.4						>2.5						1.15						
	Fine sediment depth (m)			0						?						0						
	Crest depth (m)			0.05						0.3						0.25						
Riparian vegeta	TR	Broom, gorse, briar rose			Willows, broom			Willow, poplars, broom									Long grass			Grass, willow		
	TL	Tussock, Carex			Willows, broom			Willow, poplars, broom									Bare gravel, grass			Grass, willow		

Protocol 2d Riparian data

Attributes		Collins Bridge		The Grange		Craig Road		Shag@ Horse Range Rd		Shag @ Goodwood		Deepdell@Golden Pt Rd		McCormicks@SH85	
		TL	TR	TL	TR	TL	TR	TL	TR	TL	TR	TL	TR	TL	TR
Shading of water		25-50%		25-50%		10-25%		Little or no shading		Little or no shading		10-25%		50-80%	
Buffer width (m)		>30	>30	15-30	15-30	>30	15-30	<1	<1	5-15	15-30	<1	<1	>30	>30
Buffer intactness		Completely intact	Completely intact	Completely intact	Completely intact	Completely intact	Completely intact	Buffer absent	Buffer absent	1-20% gaps	1-20% gaps	Buffer absent	Buffer absent	Completely intact	Completely intact
Vegetation composition	Buffer	Willows, broom	Willows, broom	Willows, poplars, broom	Willows, poplars, broom	Willows, broom	Willows, broom, long grass, blackberry	Bare gravel, grass	Long grass	Grass, willow	Grass, willow	Tussock, *Carex*	Broom, gorse, briar rose	Mixed deciduous trees, grass and some broom	Mixed deciduous trees, grass and some broom
	Adjacent land (to 30 m)	As for buffer	As for buffer	As for buffer	As for buffer	As for buffer	As for buffer	Short, grazed grass	Short, grazed grass	Short, grazed grass	Short, grazed grass	As for buffer	1.5	As for buffer	As for buffer
Bank stability		Very high	High	High	High	Moderate	Moderate	Low	Very low	Low	Low	Moderate	Moderate	Very high	Very high
Livestock access		Some livestock access	Some livestock access	Permanent fencing	Permanent fencing	Permanent fencing	Permanent fencing	Unfenced and unmanaged with active livestock use	Some livestock access	Temporary fencing	Temporary fencing	Some livestock access	Some livestock access	Permanent fencing	Permanent fencing

Appendix 5. Algal community composition

	Shag River at The Grange						Shag River at Craig Road								Shag River at Goodwood Pump									
Taxon	2001	2002	2004	2004	2007	2008	2001	2007	2008	2009	2010	2011	2012	2013	2001	2002	2004	2007	2008	2009	2010	2011	2012	2013
Filamentous Green Algae																								
Cladophora spp.	6		8	8		6				4	6					3								
Microspora sp.											3	2	2	5	3		3		3					
Mougeotia sp.														2			7							
Oedogonium sp.				4							6	5												
Spirogyra spp.											4										5			
Stigeoclonium													3							4				2
Ulothrix spp.												2					4							
Green, non-filamentous																								
Gleocystis spp.											2													
Pediastrum spp.											1													
Scenedesmus spp.			3								3					1	2							
colonial spp.																3								
Staurastrum spp.											1													
Filamentous Red Algae																								
Audouinella	5			5		5	2	3	2							3		3				3		
Cyanobacteria																								
cf. Lyngbya																3								
Nostoc														5										
Oscillatoria							4		4	8	2		3		6				6	7			6	
Phormidium sp.																	4				5			
Diatoms																								
Achnanthes													2	5										4
Achnanthidium		4								5	2					3								
Achnanthidium minutissimum											1													
Achnanthidium minutum																	2							
Achnanthidium linearis																	3							
Aulacoseira																3								
Cocconeis	2					2						4		3								2		
Cocconeis pediculus											5										4			
Cocconeis placentula		3	4								3						2				3			
Cymbella	2				1	2				3				2								1		4
Cymbella aspera		8		2																				
Cymbella cuspidata																7								
Cymbella kappii				4							5						5				6			
Cymbella cf. kappii		4																						
Cymbella tumida		5																						
Diatoma	3					3	6		6															
Diatoma cf. *tenuis*																					2			
Diatoma cf. *vulgaris*											4										8			
cf. *Diatoma*		2														3								
Didymosphenia geminata																					1			
Encyonema minutum		2									7					5	3				3			
Encyonema cf. *gracile* (40x7µm)				4																				
Encyonema prostratum											6													

(continued on next page)

Taxon	Shag River at The Grange						Shag River at Craig Road								Shag River at Goodwood Pump									
	2001	2002	2004	2004	2007	2008	2001	2007	2008	2009	2010	2011	2012	2013	2001	2002	2004	2007	2008	2009	2010	2011	2012	2013
Diatoms (continued)																								
Epithemia	1					1																2	1	
Epithemia adnata			5	5																				
Epithemia sorex			7	7							2													
Eunotia													2											
Fragilaria	4		6	6		4		4		4	3						3			7				
Frustulia							2	2	2				1		1				1					
Gomphoneis sp.		7	6	7						3	2	5	4			8	8				5	3	2	
Gomphonema												3												
Gomphonema acuminatum			3	2							4			3							3			4
Gomphonema spp. cf. parvulum (small species)		3		3							4					3								
Gomphonema truncatum		1	4	3													3							
Gomphonema cf. *truncatum*											4										3			
Melosira varians		2								2	4		3	4						2			4	4
Navicula spp.		6														3								
Navicula avenacea			5																					
Navicula cf. *cryptocephala*			6														2							
Navicula cf. *gregaria*											3													
Naviculoid diatom										4			2	3										
Nitzschia														2				1		1				
Nitzschia cf. *gracile*			2																					
Nitzschia linearis		4																						
Nitzschia spp.(small 15x5µm)		4	4								3													
Nitzschia spp.(skinny 50x5µm)				4							3						3				3			
Rhoicosphenia	2	2		3		2					1						2						1	
Rhopalodia novae-zealandiae			2																					
Surirella										3										1			1	
Synedra							3	2	3			4	4	5	4				4			2		3
Synedra cf. *acus*																					4			
Synedra ulna		5	4	4							2					2	5				3			
Synedra ulna var. *ramesi*			3																					
Synedra spp. cf. *rumpens*							2				2													
Tabellaria		2										3			3				3	3		4		3

Code	Relative abundance
1	Rare
2	Rare-occasional
3	Occasional
4	Occasional-common
5	Common
6	Common-abundant
7	Abundant
8	Dominant

Appendix 6. Macroinvertebrate results

SOE Macroinvertebrate data (provided by Ryder Consulting).

TAXON	Taxon score	Shag River at SH85, the Grange							Shag at Craig Rd						Shag River at Goodwood Water Supply Intake									
		28-Feb-01	2002	10-Jan-03	13-Jan-04	13-Jan-04 Drought sample	04-Jan-07	04-Apr-08	4-Jan-07	4-Apr-08	15-Apr-09	7-Feb-10	11-Apr-11	9-Feb-12	28-Feb-01	2002	10-Jan-03	2004	04-Jan-07	4-Apr-08	15-Apr-09	7-Feb-10	11-Apr-11	9-Feb-12
COLEOPTERA																								
Berosus species	5																	C						
Elmidae	6	VA	A	VA	VA	VA	A	A	A	VA	A	VA	R	R	VVA	A	VVA	VA	C	V	VA	VVA	C	C
CRUSTACEA																								
Ostracoda	3	C	VA	A	VA	VA		C	C	C	VA	VA	C	C	VA		A	A		A	C	A		
Paracalliope fluviatilis	5			A					R	C	R		R					C		C	A	VVA	R	
Paraleptamphopus	5														C									
DIPTERA																								
Anthomyiidae	3	R													C									
Aphrophila species	5		R								R											R		
Austrosimulium species	3		C				A	R	C	C	C		A	R		VVA				C	R		R	
Chironominae	2			A	A	R			C		R		R				C						R	
Cricotopus spp.			C													A								
Ephydridae	4																	C				C		
Maoridiamesa species	3		C							C	C		VA	R			A							
Mischoderus species													C											
Muscidae	3		C	R	C					C	R	A	C	R			C	C		C	R	R		
Naonella			VA																					
Orthocladiinae	2		VA	C	A	A				A	A	C	A	C		A	VA	VA		VA	A	A	C	A
Stratiomyidae	5					C																		
Tabanidae	3															R								
Tanypodinae	5		C	VA	A	R					R	R												R
Tanytarsini	3		A									R		R										R
EPHEMEROPTERA																								
Coloburiscus humeralis	9								A															
Deleatidium species	8	A	VA	VA	A	VA	VA	VVA	VA	VVA	VVA	VA	VA	VVA	**VVA**	VVA	VVA	C	R	VA	VA	VVA	A	VA
HEMIPTERA																								
Sigara species	5		C	A	C	C					R	R										R		
MEGALOPTERA																								
Archichauliodes diversus	7	R		R		R					C		R	R				R				R		R
MOLLUSCA																								
Gyraulus species	3			C	C	C					R	C	A	R	R	R	A	VA			R	A	R	
Physa/Physella	3			C	A	A				C	R	A	A		C		C	A		A	R	A	C	
Potamopyrgus antipodarum	4	VVA	C	VVA	VVA	VVA	C	A	C	VA	VA	VA	VVA	VA	A	A	A	VA	C	VVA	VA	VA	VA	VA
Sphaerium novaezelandiae	3	C		A									R		R					A	R			
OLIGOCHAETA	1		A		VA	VVA	C	C		VA		R	VA	R				VVA	C	C	A	R	A	A
PLATYHELMINTHES	3			VA	VA	A				C			C											

SOE Macroinvertebrate data (continued) (provided by Ryder Consulting).

TAXON	Taxon score	Shag River at SH85, the Grange							Shag at Craig Rd						Shag River at Goodwood Water Supply Intake									
		28-Feb-01	2002	10-Jan-03	13-Jan-04	13-Jan-04 Drought sample	04-Jan-07	04-Apr-08	4-Jan-07	4-Apr-08	15-Apr-09	7-Feb-10	11-Apr-11	9-Feb-12	28-Feb-01	2002	10-Jan-03	2004	04-Jan-07	4-Apr-08	15-Apr-09	7-Feb-10	11-Apr-11	9-Feb-12
PLECOPTERA																								
Stenoperla prasina	10					R																		
Zelandobius species	5			R																				
Zelandoperla species	10					R					R		R											
TRICHOPTERA																								
Aoteapsyche species	4	C	A		A	A	A	A	A	VVA	A	VA	VVA	VA	VA	VA	VVA		R			VA	A	A
Beraeoptera roria	8			VA																				
Costachorema sp	7		R														C			VA				
Helicopsyche species	10									C														
Hudsonema alienum	6														C		A					VA		
Hudsonema amabile	6	VVA	A		VA	VA		VA		VA	A	A	C	R				A		VA	C		C	C
Hydrobiosidae early instar	5			A					R	C	C						A		R	R				
Hydrobiosis clavigera group								R																
Hydrobiosis copis																C								
Hydrobiosis umbripennis group						C	C	C	R	C	C		A	A		R	A			A			C	C
Hydrobiosis species																R								
Hydrobiosis - all species	5					C	C	C				C				C	A			A			C	C
Neurochorema confusum	6			R							R		R				C							
Olinga species	9	VA			A	C		C			A	R	R	R	R									
Oxyethira albiceps	2	R	C	A	A	A			R		C		R	R	A			VA			R	R	R	R
Paroxyethira hendersoni	2			C														C						
Polyplectropus species	8								R															R
Psilochorema species	8	C	C		C	C	C	A	A	A	A	A	C	C	C	R	VA		R	C	C	A	R	A
Pycnocentrella species	9															R								
Pycnocentria species	7	VA	A	C	C	A		A		VA	R	VA	R	R	R	A	A	C		VA		VVA	C	R
Pycnocentrodes species	5	VVA	A	A	VA	VA	R	VA		VA	A	VA	C	C	VVA		VVA	VA		VVA	VVA	VVA	VA	A
Tiphobiosis	6		C	A																				
Taxonomic richness		14	21	23	20	24	9	13	13	19	26	19	27	20	16	12	18	18	6	17	16	20	17	16
MCI		107	91	90	89	103	98	106	103	94	99	95	93	92	99	103	94	84	103	93	81	91	87	101
SQMCI		5.41	3.63	4.82	4.07	3.57	6.21	6.98	6.95	5.51	6.45	5.22	3.97	6.71	5.92	5.20	5.50	2.61	3.95	4.85	5.18	5.95	4.41	5.27
EPT taxonomic richness		8	9	9	8	11	5	8	7	8	10	8	10	9	8	6	9	6	3	7	5	7	8	9
%EPT richness		57%	43%	39%	40%	46%	56%	62%	54%	42%	38%	42%	37%	45%	50%	50%	50%	33%	50%	41%	31%	35%	47%	56%

2013 Macroinvertebrate data (provided by Ryder Consulting, May 2013).

TAXON	MCI score	Shag River at Collins	Shag River at Grange	Shag River at Craig Road	Shag River at Horse Range Road	Shag River at Goodwood Pump	Deepdell Creek at Golden Point Road	McCormicks at State Highway 85
COLEOPTERA								
Elmidae	6	C	C	C	C	C	A	C
COLLEMBOLA	6						R	
CRUSTACEA								
Ostracoda	3		VA	A	R	C	C	
Paracalliope fluviatilis	5				R	A	A	R
DIPTERA								
Aphrophila species	5	R	R				R	
Austrosimulium species	3	C				R		R
Chironomus species	1					R		
Ephydridae	4				R			
Eriopterini	9	R						
Maoridiamesa species	3	C		C		C		
Muscidae	3			A	R	R		
Orthocladiinae	2	A		A	R	VA	R	
Podonominae	8	R						
Tanyderidae	4		R					
Tanytarsini	3			A		R		
EPHEMEROPTERA								
Coloburiscus humeralis	9	A						
Deleatidium species	8	VA	VA	VVA	VVA	VA	VVA	VVA
Nesameletus species	9	C						
HEMIPTERA								
Sigara species	5		R				C	R
MEGALOPTERA								
Archichauliodes diversus	7	C	C	A	R	R	R	
MOLLUSCA								
Gyraulus species	3				C	C	R	R
Physa / Physella species	3		R		R	R	A	C
Potamopyrgus antipodarum	4	R	VA	A	VA	A	VVA	VA
Sphaeriidae	3				R		R	
OLIGOCHAETA	1		A	C	A	R	C	C
PLECOPTERA								
Stenoperla species	10	R						
Zelandoperla species	10	VA	C					R
TRICHOPTERA								
Aoteapsyche species	4	A	C	VVA	VA	A	A	A
Helicopsyche species	10	R						
Hudsonema amabile	6	R	VA		A	A	VA	A
Hydrobiosis species	5	A		A	C	A	C	R
Neurochorema species	6	R						
Olinga species	9	A	C			R	R	
Oxyethira albiceps	2		R			R	C	
Psilochorema species	8	C	C	A	A	C	A	C
Pycnocentria species	7	C	VA	A	A	VA		A
Pycnocentrodes species	5	A	A	A	VA	VA	VVA	A
Number of taxa		23	18	15	19	23	21	16
Number of EPT taxa		14	9	6	7	9	8	8
%EPTtaxa		61%	50%	40%	37%	39%	38%	50%
MCI score		133	108	92	92	88	95	104
SQMCI score		7.6	5.5	5.8	6.5	5.3	5.6	7.0