Appendix 5 Coastal and Marine Water Quality Guidelines: Cape York Technical Background document to HWMP

Water quality guidelines have traditionally been taken to mean guidelines for physico-chemical indicators such as concentrations of dissolved oxygen or nitrogen and phosphorus. In more recent times, the scope of water quality guidelines has been expanded to include a more holistic range of indicators of ecosystem health and, in particular, biological indicators. Thus “water quality” guidelines in this report include indicators of seagrass and mangrove health. These are all important components of ecosystem health.

This report sets WQOs for waters seaward of the estuary. Enclosed coastal waters (the seaward extent of estuaries) are part of the marine waters but their WQOs are documented in a separate report.

Water quality data is sourced primarily from AIMS long term monitoring data over a period spanning 1988-2006 across wet and dry seasons. For additional details of data sourcing refer to Appendix 1 herein.

WQOs for marine waters are set to be to be protective of a desired ecosystem state. Water quality improvements to levels lower than the WQOs would likely lead to further substantial ecosystem benefits. A choice of substantially lower concentrations would likely lead to further reductions in macroalgal cover and increased coral biodiversity, but may well not be achievable.

River basins covered by this document include the Jacky Jacky Creek, Olive Pascoe Rivers, Lockhart River, Stewart River, Normanby River, Jeannie River, and Endeavour basins.

The WQ guidelines for the GBRMP assigned the whole Cape York region as HEV from the mean low water mark by virtue of its not having plumes of high or very high risk of receiving poor water quality. This assignation was initially supported by the data analysis which found that all waters meet annual mean guidelines (for those parameters we have established relationships to ecosystem state, and rounding down TSS). Modelled anthropogenic load updates (2014 discussed below) identified some rivers as higher risk than previously thought, although relative to the whole GBR they remain low. As a result, and in consultation with Regional NRM staff, a modification to the waters at risk of receiving poor water quality (the plume line) has been made recognizing some slightly-disturbed waters in the region out from the Normanby, Endeavour and Annan Rivers. Wet/dry season split analysis revealed dry season exceedances of some guidelines that are derived to be protective of a desired ecosystem state. The WQOs for those parameters were set at the more conservative ecosystem supportive concentrations.

Sediment is the main anthropogenic load increase. Whilst the Normanby has extensive cattle grazing country (75% of the catchment), and rich agricultural land at Lakeland Downs (Reef Water Quality Protection Plan Secretariat 2011) less than 5% of the CY catchment has been cleared (Reef Water Quality Protection Plan Secretariat 2011).It may be that the relatively intact nature of estuaries and wetlands and deltas in the region mean that the load that does get transported out has the opportunity for more processing before it is dispersed into the marine system.

Further supporting evidence for the HEV assessment comes from ecosystem state assessments in the coral and seagrass reports that give no indications of decline in the relevant parameters. See the northern coral cover trend in the figure after the table and an extract from the Marine Monitoring Program seagrass report. Also Howley et al monitoring 2006-2013 reported in the Normanby Catchment WQMP 2014:

- Fourth largest river system in Great Barrier Reef catchment
- 3rd largest mean annual discharge to the GBR
- Highly unmodified mid & coastal catchment area
- Extensive freshwater lagoons and coastal salt flats
- Rich commercial and recreational fisheries
- High biodiversity value
- Princess Charlotte Bay: Healthy Coral Reef & Seagrass ecosystems supports large turtle & dugong populations
- However, water quality *has* been impacted by land use in some areas

The WQMP acknowledges some catchment impacts that do affect sediment and nutrient losses and that:
The impacts of land use on the discharge of suspended sediments and nutrients to the Great Barrier Reef have not been accurately quantified. Increased loads of suspended sediments or nutrients in flood plumes could potentially affect seagrass meadows and coral reef ecosystems at Princess Charlotte Bay (PCB). There is currently little evidence of a decline in the condition of these PCB ecosystems, but monitoring has been limited.

The Eastern Cape marine receiving waters generally met long-term annual mean guidelines based on condition assessments of data collected between 1988-2006. Seasonal analysis indicated wet season guidelines were generally met. For the dry season a number of parameters were slightly elevated above estimated dry season guidelines (GBRMPA 2010) so the seasonal guideline has been set as the objective for these parameters. On this basis much of the waters are classified as HEV. There is some recognition of compromised water quality out of the Normanby, Hann, Annan, Endeavour however the desired state, or the management intent, for all of these waters is that they achieve HEV condition (ie they are SD waters). This document presents the existing 20/50/80th percentile values for all physico-chemical and biological indicators that met guideline as the objective. The management aim would be “no deterioration from existing quality” for HEV waters and achieve HEV condition for any SD waters. Assessment of compliance would be based on no change to existing 20/50/80th percentile values. Progress towards HEV is reported through the Reef Water Quality Protection Plan and WQIP reporting.

WQG indicators include the following:

- ammonia N (µg/L)
- oxidised N (µg/L)
- total N (µg/L)
- total P (µg/L)
- total dissolved N (µg/L)
- total dissolved P (µg/L)
- particulate N (µg/L)
- particulate P (µg/L)
- filterable reactive phosphorus (FRP: µg/L)
- chlorophyll a (µg/L)
- silicate: (µg/L)
- Secchi depth (m)
- suspended solids (mg/L)
- turbidity (NTU)
- dissolved oxygen (% saturation)
- pH
- temperature: (˚C increase above long-term (20 year) average maximum)
- toxicants (µg/L or as specified based in ANZECC, GBRMPA).

Table 1 Water quality objectives (refer to Appendix 1 for sample site details). Enclosed coastal waters WQOs are reported separately (Appendix 9).

Water area/type Refer plans WQ1192 (s1–s5: source for WQOs, listed after table)	Management intent /Level of Protection	COASTAL AND MARINE WATERS Cape York: Water quality objectives (WQOs) [1–7] **Note:** WQOs for indicators are shown as 20th, 50th and 80th percentiles (e.g. 3–4–5), lower and upper limits (20th/80th %iles, e.g. pH: 7.2-8.2), or as a single values (mean, median or 80th percentile) (e.g. <15). HEV: high ecological value; SD: slightly disturbed; MD: moderately disturbed															
		Amm N (µg/L)	**Oxid N** (µg/L)	**Partic N** (µg/L)	**Total Diss N** (µg/L)	**Total N** (µg/L)	**FRP** (µg/L)	**Partic P** (µg/L)	**Total Diss P** (µg/L)	**Total P** (µg/L)	**Chl-a** (µg/L)	**Silicate** (µg/L)	**DO** (% sat)	**Turb** (NTU)	**Secchi** (m)	**SS** (mg/L)	**pH**
COASTAL and MARINE WATERS (Jacky-Jacky; Olive-Pascoe, Lockhart, Stewart, Normanby, Jeannie, Endeavour)																	
HEV Open coastal waters Dry season/ambient (May-Oct)	**HEV**	0–1–3 (annual)	0–0–1	≤16 (mean)	50–80–100	70–100–120	0–2–3	≤ 2.3 (mean)	3–7–13	8–10–16	0.16–0.25–0.46	60–115–190	95–105	0.6–0.9–1.8	≥10 (annual mean)	≤ 1.6 (mean)	8.1–8.3–8.4
HEV Open coastal waters Wet Season (Nov-Apr)	**HEV**	0–1–3 (annual)	0–0–1	14–20–26	55–80–105	75–105–130	0–1–2	2.2–3.0–3.9	2–5–12	5–10–20	0.30–0.46–0.78	50–90–180	95–105	0.5–0.8–1.5	≥10 (annual mean)	1.1–1.7–2.2	8.1–8.3–8.4
SD Open coastal waters Dry season/ambient (May-Oct)	**HEV**	0–1–3 (annual)	0–0–1	≤16 (mean)	50–80–100	70–100–120	0–2–3	≤ 2.3 (mean)	3–7–13	8–10–16	0.16–0.25–0.46	60–115–190	95–105	0.6–0.9–1.8	≥10 (annual mean)	≤ 1.6 (mean)	8.1–8.3–8.4
SD Open coastal waters Wet Season (Nov-Apr)	**HEV**	0–1–3 (annual)	0–0–1	14–20–26	55–80–105	75–105–130	0–1–2	2.2–3.0–3.9	2–5–12	5–10–20	0.30–0.46–0.78	50–90–180	95–105	0.5–0.8–1.5	≥10 (annual mean)	1.1–1.7–2.2	8.1–8.3–8.4

COASTAL AND MARINE WATERS Cape York: Water quality objectives (WQOs) [1–7]

Note: WQOs for indicators are shown as 20th, 50th and 80th percentiles (e.g. 3–4–5), lower and upper limits (20th/80th %iles, e.g. pH: 7.2-8.2), or as a single values (mean, median or 80th percentile) (e.g. <15).

HEV: high ecological value; SD: slightly disturbed; MD: moderately disturbed

Water area/type **Refer plans WQ1192** **(s1–s5: source for WQOs, listed after table)**	**Management intent /Level of Protection**	**Amm N** (µg/L)	**Oxid N** (µg/L)	**Partic N** (µg/L)	**Total Diss N** (µg/L)	**Total N** (µg/L)	**FRP** (µg/L)	**Partic P** (µg/L)	**Total Diss P** (µg/L)	**Total P** (µg/L)	**Chl-a** (µg/L)	**Silicate** (µg/L)	**DO** (% sat)	**Turb** (NTU)	**Secchi** (m)	**SS** (mg/L)	**pH**
HEV Midshelf waters	**HEV**	0–1–3	0–0–1	14–18–22	60–80–110	75–100–130	0–1–2	1.5–2.0–2.8	3–7–10	6–9–15	0.18–0.27–0.45	40–80–135	95–105	0.3–0.5–1.5	≥10 (annual mean)	0.9–1.5–2.3	8.1–8.3–8.4
HEV Offshore waters	**HEV**	0–0–1	0–0–1	10–16–25	50–70–90	90–100–120	0–0–1	1.1–1.9–2.8	2–4–7	5–8–10	0.17–0.26–0.39	25–45–70	95–105	0.3–0.5–1.5	≥17 (annual mean)	0.3–0.5–1.0	8.1–8.3–8.4
Coastal and marine waters (s3)	**all**	Temperature: increases of no more than 1°C above long-term (20 year) average maximum. (GBRMPA, 2010)															
Coastal waters (s3, s5)	**all**	WQGs for all toxicants in these waters (except aluminium – specified below) as per GBRMPA (2010) and ANZECC (2000) water quality guidelines, to protect marine species at the HEV (99% species protection) level of protection. Where pesticide values are specified in both the GBRMPA and ANZECC guidelines, the lower value will be adopted. Pesticides/biocides WQGs for pesticides/biocides specified in GBRMPA water quality guidelines (99% species protection) include (but not limited to): • Ametryn: <0.5 µg/L; Atrazine: <0.6 µg/L; Diuron: <0.9 µg/L; Hexazinone: <1.2 µg/L; Simazine: <0.2 µg/L; Tebuthiuron: <0.02 µg/L Other toxicants For other toxicants not listed in GBRMPA guidelines, refer to ANZECC water quality guidelines and other sources below: • Aluminium: <2.1 µg/L (applies to the measured concentration in seawater that passes through a 0.45 µm filter) [Source: Golding et al. (2015)] • Other toxicants in water: refer to ANZECC AWQG section 3.4—'water quality guidelines for toxicants' (including tables 3.4.1, 3.4.2, and Figure 3.4.1), and AWQG volume 2 (section 8). Values correspond to protection of 99% of species • Toxicants in sediments: refer to ANZECC AWQG section 3.5—'sediment quality guidelines' (including Table 3.5.1, Figure 3.5.1), and ANZECC AWQG volume 2 (section 8) Sewage: Release of sewage from vessels to be controlled in accordance with requirements of the Transport Operations (Marine Pollution) Act 1995 and Regulations. (Refer to Maritime Services Queensland website for further information.) Anti-fouling: Comply with *Anti-fouling and in-water cleaning guidelines* (June 2013) Australian Government, Canberra															

Water area/type Refer plans WQ1192 (s1–s5: source for WQOs, listed after table)	Management intent /Level of Protection	**COASTAL AND MARINE WATERS Cape York: Water quality objectives (WQOs)** [1–7]															
		Note: WQOs for indicators are shown as 20^{th}, 50^{th} and 80^{th} percentiles (e.g. 3–4–5), lower and upper limits (20^{th}/80^{th} %iles, e.g. pH: 7.2-8.2), or as a single values (mean, median or 80^{th} percentile) (e.g. <15). HEV: high ecological value; SD: slightly disturbed; MD: moderately disturbed															
		Amm N (µg/L)	**Oxid N** (µg/L)	**Partic N** (µg/L)	**Total Diss N** (µg/L)	**Total N** (µg/L)	**FRP** (µg/L)	**Partic P** (µg/L)	**Total Diss P** (µg/L)	**Total P** (µg/L)	**Chl-a** (µg/L)	**Silicate** (µg/L)	**DO** (% sat)	**Turb** (NTU)	**Secchi** (m)	**SS** (mg/L)	**pH**
Coastal waters: biological	**all**	Mangroves: No loss of mangrove area. EHP/ Queensland Herbarium conducts biennial mapping of mangrove cover and this could be used as an assessment tool. Mapping is available from EHP.															
Coastal waters: biological	**all**	**Seagrass)** Light requirements are specified as a photosynthetic active radiation (PAR) moving average, depending on seagrass species. Levels specified here are derived to support the health of all species present either as the dominant species or as one of a suite of species that are known to occur in the region, based on Chartrand *et al* (2012, 2014). It does not reflect requirements for macroalgae or other organisms. • Deep water areas (>10m) 2.5 mol m^{-2} day^{-1} over a rolling 7 day average # (Chartrand et al 2014; Rasheed et al 2014; York et al 2015) • Shallow inshore areas (<10m): 6 mol m^{-2} day^{-1} over a rolling 14 day average # (Chartrand et al, 2012) Note: # Absolute light requirements for seagrass may vary between sites. Values described here provide a conservative guide to the levels of light likely to support seagrass growth. Locally derived absolute thresholds ideally should be obtained for management of specific activities likely to impact on the light environment.															

Sources: S1: Local datasets (e.g. DSITIA, key stakeholder); S2: QWQG guidelines and /or data; S3: GBRMPA (2010) WQG; S4: GBRMPA analysis of Reef Rescue Marine Monitoring Program and/or Long Term Monitoring Program datasets; S5: ANZECC (2000) AWQG

Notes to Table 1 (where applicable):

Abbreviations: id: insufficient information; na: not applicable; -: WQO for indicator not available. Will be updated if guidelines become available

1. Nutrients: Except where specified for event conditions, nutrient objectives do not apply during high flow events in fresh and estuarine waters. During periods of low flow and particularly in smaller creeks, build up of organic matter derived from natural sources (e.g. leaf litter) can result in increased organic N levels (generally in the range of 400 to 800µg/L). This may lead to total N values exceeding the WQOs. Provided that levels of inorganic N (i.e. NH_3 + oxidised N) remain low, then the elevated levels of organic N should not be seen as a breach of the WQOs, provided this is due to natural causes. See QWQG (section 5 and Appendix D) for more information on applying guidelines under high flow conditions.

2. Suspended solids: Suspended solids (and hence turbidity and Secchi depth) levels in coastal waters are naturally highly variable depending on wind speed/wave height and in some cases on tidal cycles. The values in this table provide guidance on what the long term values of turbidity, Secchi depth or TSS should comply with. However, these values will often be naturally exceeded in the short term during windy weather or spring tides. They therefore should not be used for comparison with short term data sets. Where assessable coastal developments are proposed, proponents should carry out site specific intensive monitoring of these indicators (or equivalent light penetration indicators) and use these as a baseline for deriving local guidelines and for comparison with post development conditions.

3. Oxidised N = NO_2 + NO_3

4. Dissolved oxygen (DO): Dissolved Oxygen (DO) objectives apply to daytime conditions. Lower values will occur at night in most waters. In estuaries, reductions should only be in the region of 10–15 per cent saturation below daytime values. In freshwaters, night-time reductions are more variable. Following significant rainfall events, reduced DO values may occur due to the influx of organic material. In estuaries post-event values as low as 40 per cent saturation may occur naturally for short periods but values well below this would indicate some anthropogenic effect. In freshwaters, post-event DO reductions are again more variable. In general, DO values consistently less than 50 per cent are likely to impact on the ongoing ability of fish to persist in a water body while short term DO values less than 30 per cent saturation are toxic to some fish species. Very high DO (supersaturation) values can be toxic to some fish as they cause gas bubble disease. DO values for fresh waters should only be applied to flowing waters. Stagnant pools in intermittent streams naturally experience values of DO below 50 per cent saturation.

5. Wallum habitat: Wallum/tannin-stained waters contain naturally high levels of humic acids (and have a characteristic brown tea-tree stain). In these types of waters, natural pH values may range from 3.6 to 6. During flood events or nil flow periods, pH values should not fall below 5.5 (except in wallum/tannin waters) or exceed 9.

6. Temperature: Temperature varies both daily and seasonally, it is depth dependent and is also highly site specific. It is therefore not possible to provide simple generic WQOs for this indicator for fresh or estuarine waters. (In open coastal/marine waters a WQO based on GBRMPA WQGs is provided.) The recommended approach is that local WQOs be developed. Thus, WQOs for potentially impacted streams should be based on measurements from nearby streams that have similar morphology and which are thought not to be impacted by anthropogenic thermal influences. From an ecological effects perspective, the most important aspects of temperature are the daily maximum temperature and the daily variation in temperature. Therefore measurements of temperature should be designed to collect information on these indicators of temperature and, similarly, local WQOs should be expressed in terms of these indicators. There will be an annual cycle in the values of these indicators and therefore a full seasonal cycle of measurements is required to develop guideline values.

7. Open coastal/marine waters – GBR plume line: GBR-wide generally the plume discharge area is derived from a smoothed version of the 'high' and 'very high' risk classes of modelled outputs from the risk assessment element of the Reef Plan Scientific Consensus Statement 2013 (Waterhouse et al 2013). Any local variations applied to this derivation are detailed in Appendix 1

8. Seasonal percentiles from dry season data analysis for Cape waters were found to be higher than seasonal estimates derived to be protective of a desired ecosystem state (for some parameters). For those parameters seasonal means have been applied. While seasonal means are estimated based on biotic responses the relationship is not as strong as it is for annual mean values. They are provided here as indicative objectives to allow comparison with single season collected data sets. Wet and dry seasons can start and end at different times of the year. Seasonal dates indicated are generally applicable. Applying these values for any management action should take both of these matters into account.

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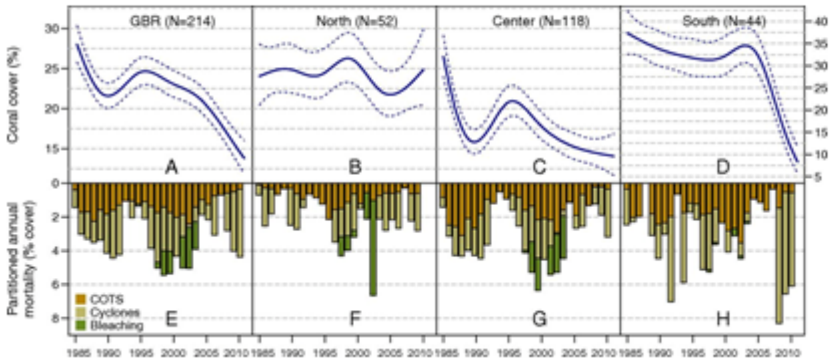
Supporting information

Coral

Temporal trends in coral cover (A–D) and annual mortality due to COTS, cyclones, and bleaching (E–H) for the whole GBR and the northern, central, and southern regions over the period 1985–2012 (N, number of reefs).



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PNAS

Seagrass

In the Marine Monitoring Program seagrass reports the current state (2012/13 report year) for the seagrass as poor, and it has been moderate-good in the past. This is a combined score however and if break down the raw score the coastal intertidal is still in the moderate range, the overall is dragged down by the reef intertidal. There is limited monitoring in the Cape – although extra sites have been added recently. There are changes proposed to the metrics that score the state. However, the reasons for this state are attributed primarily to influences other than runoff (although it is mentioned). Parameters in the nutrient ratios analysis are interpreted as indicating that the meadows are ***not suffering*** (emphasis added) from elevated N or light limitation.

This the Cape summary extract out of the MMP report:

Waters entering the GBR lagoon from Cape York catchments are perceived to be of a high quality, as the majority of the land is undeveloped, including indigenous country, national park or inactive cattle leases. Seagrass growth on reef habitats in the region appears ***primarily controlled by physical disturbance from waves/swell and associated sediment movement. Similarly, the dominant influence at coastal habitats is exposure to wind/wave disturbance, but with temperature extremes and pulsed terrigenous runoff from seasonal rains***. Seagrass abundance differed across the region in 2012/13, however extent remained stable. Seagrass abundance at reef habitats remained poor, which coupled with a greater than average proportion of colonising species may suggest weaker ecosystem resistance to perturbations. The low seed bank and poor reproductive effort at reef sites further indicates a low capacity to recover following disturbance. Although similarly composed of greater than average proportion of colonising/pioneering species, coastal seagrass meadows may have greater resistance on account of their very good abundance. The greater seed banks in coastal meadows suggests a higher capacity to recover following disturbance, although poor reproductive effort may indicate seed bank limitation in the near future. From analysis of **seagrass tissue nutrients in late 2012, there was no indication of elevated N or light limitation** across the region in any of the seagrass habitats. Epiphyte abundance decreased in 2012/13 and macroalgae remained below GBR long-term average. No extreme within canopy seawater temperatures were experienced over the monitoring period and meteorological conditions, in general, were favourable for seagrass growth apart from rougher seas which may have mobilised inshore sediments resulting in some physical disturbance of the seabed. The drier than average conditions in 2012/13 resulted in annual freshwater discharges from all Cape York rivers below the long-term median and no herbicides were found above detectable limits in the sediments of the meadows in the central and northern sections of the region (southern section not measured). On account of these favourable conditions, the regional seagrass state has improved over the last 12 months, but remains **poor** (Table 16).

Ayling et al (1996) baseline study for Cape Flattery, although there does not appear to be an established long-term monitoring program there to provide any indication of change states the objectives for management very clearly that state not be compromised going forward in to the future.

Catchment loads

Source Catchments modelling suggests the TSS, TN and TP anthropogenic loads have increased by 2-fold, 1.1-fold, and 1.5-fold respectively from predevelopment loads in the region. The estimated increase in loads is much smaller than previously reported (McKergow et al. 2005b, Kroon et al. 2010) where estimated increases were 5.4, 4.0 and 4.0-fold for TSS, TN and TP. The reasons for these differences include the use of a spatially and temporally variable BGI used to generate the C-factor in the RUSLE. McKergow et al. (2005a) used a generic low ground cover value for their current condition scenario, and then used a static and comparatively high value (95%) for the predevelopment scenario. In the Source Catchments modelling framework, an annual BGI was used for the current condition scenario, which had an average cover of 86%, and a predevelopment groundcover of 95%, leading to a smaller increase in anthropogenic baseline loads than previously reported.

- Likewise, the total fine sediment export for Cape York of 429 kt/yr is considerably lower than for previous reported estimates due to:
- Improved input datasets in the current project (for example, temporal and spatially variable cover estimates to represent grazing by using BGI scenes)
- The ability to apply the most appropriate models to each land use (as opposed to an all EMC or RUSLE approach)
- The availability of recent monitoring data with which the model can be validated against, as well as using this monitoring data to derive input parameters such as EMC/DWC values

http://www.reefplan.qld.gov.au/measuring-success/paddock-to-reef/assets/Cape-York-Catchment-Modelling-Report.PDF

APPENDIX 1 Marine Water Quality Guidelines

This appendix provides further information pertaining to marine water data sets, marine water type classification and derivation of guidelines for different water types and sub-regions. The general approach has been to use locally applicable data where available as a basis for deriving WQGs for marine water sub-regions. In the absence of local data, or where local data fail to meet relevant ecosystem protection thresholds expressed in the water quality guidelines for the Great Barrier Reef Marine Park (GBRMPA, 2010), the WQGs default back to the values in the GBR water quality guidelines.

Water types and water type sub-regions

Marine water types in the planning area include enclosed coastal, open coastal, midshelf and offshore waters.

Water types delineations are based on refined mapping of the general relative distance descriptions outlined in the GBRMPA water quality guidelines (2010).

Enclosed coastal

The enclosed coastal water type is defined in words in the QWQG as the seaward part of the estuary which is defined as the cut-off between shallow, enclosed waters near the estuary mouth and deeper, more oceanic waters further out (the full definition includes further details).

Under remote sensing work for the Reef Rescue Marine Monitoring Program the Commonwealth Scientific and Industrial Research Organisation analysed temporal patterns in the chlorophyll variability across the shelf from ten years of MODIS data.(Brando, Schroeder et al. 2011) The K-means clustering technique(Wilks 2006) was applied to group waters within which concentrations displayed similar magnitude over time and space .(Brando, Schroeder et al. 2011) Initially the analysis was run as a case study, and was later expanded to delineate the enclosed coastal water type for the entire GBR. Colour dissolved organic matter (CDOM) was selected as the cluster parameter rather than chlorophyll to remove confounding biological effect influences on the clustering.(Brando, Schroeder et al. 2014)

Open coastal

The GBRMPA water quality guidelines (2010) generally describe the open coastal water body in terms of a buffer distance from the coast (EC-6km)[1]. This average was adjusted taking into account assessment of cluster analysis from the work conducted by CSIRO. This pushes the inner-midshelf water body seaward where the change in width of the shelf is substantial within a region (eg southern Mackay and Fitzroy section) and narrows it in some northern areas where the shelf edge is close to the coast.

Generally, considering the similar hydrodynamics of the region, the clustering of the waters according to remote sensing analysis, and the spread of samples collected in the region, the open coastal portion of the waters are considered sufficiently similar to have the same objectives applied.

Ocean colour imagery characterises these waters with having similar optical properties that are proxies for turbidity, chlorophyll a and CDOM. Independent eReefs modelling of optical properties also confirm this result.

Inner-Midshelf

The GBRMPA water quality guidelines (2010) generally describe the inner-midshelf water body in terms of a buffer distance from the coast (6 – 24 km)[1]. This average has been adjusted taking into account assessment of cluster analysis from the CSIRO work. This pushes the inner-midshelf water body seaward where the change in width of the shelf is substantial within a region (eg southern Mackay and Fitzroy section) and narrows it in some northern areas where the shelf edge is close to the coast.

Generally, considering the similar hydrodynamics of the region, the clustering of the waters according to remote sensing analysis, and the spread of samples collected in the region, the inner-midshelf portion of the waters are considered sufficiently similar to have the same objectives applied.

Offshore

The GBRMPA water quality guidelines (2010) generally describe the offshore water body in terms of a buffer distance from the coast (24 – 250 km)[1]. This average has been adjusted taking into account assessment of cluster analysis from the CSIRO work. This pushes the inner-midshelf water body seaward where the change in width of the shelf is substantial within a region (eg southern Mackay and Fitzroy section) and narrows it in some northern areas where the shelf edge is close to the coast.

Generally, considering the similar hydrodynamics of the region, the clustering of the waters according to remote sensing analysis, and the spread of samples collected in the region, the offshore portion of the waters are considered sufficiently similar to have the same objectives applied.

Plume line

The modelled outputs from the risk assessment element of the Scientific Consensus Statement 2013 (Waterhouse et al 2013) have been used as the basis for creation of this shapefile. The high and very high risk classes of modelled outputs have generally been applied. Modifications are described below.

For waters of Cape York, two areas of moderate risk of receiving poor water quality were given a classification of slightly disturbed waters. Support for this determination comes from considering modelled anthropogenic loads reported in McCloskey et al 2014, sampling results from the Annan, Endeavour (Howley 2012) and Normanby Rivers (Howley et al 2014), and confirmed in discussions with local experts in the region.

Marine data sources

For open coastal, midshelf and offshore marine waters, GBRMPA reviewed AIMS data (including continuous logger data) from the Marine Monitoring Program (MMP) and Long Term Monitoring Program (LTMP). The general approach has been to use locally applicable data where available as a basis for deriving WQGs for marine water sub-regions. In the absence of local data, or where local data fail to meet relevant ecosystem protection thresholds, annual or seasonal means that support a desired ecosystem state are applied (GBRMPA, 2010).

The table below summarises data sources used in deriving marine water quality guidelines for different water type sub-regions.

Open coastal waters

AIMS LTMP data has between 145 and 228 samples taken in the open coastal waters (depending on parameter) over a period spanning 1988-2006 across wet and dry seasons. There was a wet season bias in the samples (162 wet vs 47 dry). A random number generator was activated and samples deleted from the wet season data until the seasons were represented evenly. Sufficient samples remained to support application of percentile analysis for WQOs.

Since annual mean guidelines were met for the region, and there was sufficient data, it was determined appropriate to use the data to derive seasonal guidelines. However, seasonal percentiles from dry season data analysis were found to be higher than seasonal estimates derived to be protective of a desired ecosystem state (for some parameters). For those parameters, seasonal means have been applied. While seasonal means are estimated based on biotic responses the relationship is not as strong as it is for annual mean values. They are provided here as indicative objectives to allow comparison with single season collected data sets. Wet and dry seasons can start and end at different times of the year. Seasonal dates indicated are generally applicable. Preliminary products from hydrodynamic models show relatively high current features occur, at least times, in this region. Upwelling is also known to occur. This and other features may mean that the seasonally derived means are more conservative than they need to be to protect the ecosystem. Applying these values for any management action should take all of these matters into account.

Inner-Midshelf

AIMS LTMP data has between 370 and 572 samples taken in the inner-midshelf waters (depending on parameter) over a period spanning 1988-2006 across wet and dry seasons. There was a wet season bias in the samples (322 wet vs 157 dry). A random number generator was activated and samples deleted from the wet season data until the seasons were represented evenly. Sufficient samples remained to support application of percentile analysis for WQOs.

Offshore

AIMS LTMP data has between 60 and 294 samples taken in the offshore waters (depending on parameter) over a period spanning 1988-2006 across wet and dry seasons. There was a wet season bias in the samples (213 wet vs 69 dry). A random number generator was activated and samples deleted from the wet season data until the seasons were represented evenly. There were sufficient samples to support application of percentile analysis for WQOs.

Sub-regions (refer Figure xx) and indicator	site source	no of samples	dates (years) of samples
1. open coastal waters ammonia N oxidised N total N total P total dissolved N FRP total dissolved P particulate N particulate P chlorophyll silicate: suspended solids	Multiple open coastal sites Refer Attachment A Refer Figure x	(n= 84-228 depending on parameter)	1988-2006 AIMS LTMP
Secchi	Refer GBRMPA guidelines	Secchi >2000	1988-2006 AIMS GBRMPA
turbidity	Wet Tropics regional data	>1000; continuous logger	
2: inner-midshelf waters ammonia N oxidised N total N total P total dissolved N FRP total dissolved P particulate N particulate P chlorophyll silicate suspended solids	Multiple inner-midshelf sites Refer Attachment B Refer Figure x	(n= 97-572 depending on parameter)	1988-2006 AIMS LTMP
Secchi	Refer GBRMPA guidelines	Secchi >2000	1988-2006 AIMS GBRMPA
turbidity	Wet Tropics regional data	>1000; continuous logger	
3. offshore waters ammonia N oxidised N total N total P total dissolved N FRP total dissolved P particulate N particulate P	Multiple offshore sites Refer Attachment C Refer Figure x	(n= 30-290 depending on parameter)	1988-2006 AIMS LTMP

Sub-regions (refer Figure xx) and indicator	site source	no of samples	dates (years) of samples
chlorophyll silicate suspended solids			
Secchi	Refer GBRMPA guidelines	Secchi >2000	1988-2006 AIMS GBRMPA
turbidity	Wet Tropics regional data	>1000; continuous logger	

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Attachment A

station	lat	long
CAI041	-16.1167	145.4833
CAI042	-16.1167	145.4833
CAI112	-16.1167	145.4833
CAI113	-16.1167	145.4833
CAI223	-16.1167	145.4833
CAI261	-16.1167	145.4833
CGR015	-12.3	143.1667
CGR016	-12.3	143.1667
CGR019	-12.8298	143.4167
CGR020	-12.8298	143.4167
CGR021	-12.6	143.45
CGR022	-12.6	143.45
CGR023	-12.5	143.2833
CGR024	-12.5	143.2833
CGR029	-12.8298	143.4167
CGR030	-12.8298	143.4167
CGR033	-12.3	143.1667
CGR034	-12.3	143.1667
CGR047	-12.6	143.45
CGR048	-12.5	143.2833
CGR063	-12.6	143.45
CGR065	-12.5	143.2833
CGR067	-12.8298	143.4167
CGR076	-12.3	143.1667
CGR077	-12.5	143.2833
CGR079	-12.6	143.45
CNS044	-16.1182	145.4815
CNS105	-16.1182	145.4732
CNS116	-16.1182	145.4798
CNS138	-16.1182	145.4815
CNS182	-16.1182	145.4815
CNS210	-15.9162	145.3733
CNS211	-16.1182	145.4815
CNS236	-16.1182	145.4815
CNS267	-16.1182	145.4815
CNS284	-16.1182	145.4815
CNS310	-16.1182	145.4815
CNS339	-16.1182	145.4815
CNS350	-16.1182	145.4815
CNS394	-16.1182	145.4815
CNS418	-16.1182	145.4815
CNS438	-16.1195	145.4802
CNS464	-16.1182	145.4815
CNS479	-16.1182	145.4815
CNS500	-16.1182	145.4815
CNS515	-16.1182	145.4815
CNS542	-16.1182	145.4815
CNS585	-16.1182	145.4823
CNS666	-16.1182	145.4823
CNS674	-15.8093	145.4142
CNS679	-14.9477	145.3658
CNS680	-14.8147	145.251
CNS697	-12.6143	143.4737
CNS701	-12.0152	143.2772
CNS705	-11.4728	142.9605
CNS706	-11.302	142.934
CNS707	-11.142	142.8582
CNS734	-16.1137	145.4833
CNS767	-16.1157	145.4833
CNS768	-16.1137	145.4833
CNS802	-16.1137	145.4848
CNS830	-16.1453	145.4598
CNS831	-16.1112	145.4987
CNS848	-16.1133	145.4838
CNS859	-16.1147	145.4833
CNS870	-16.1147	145.4858
CNS882	-16.1122	145.484
CNS893	-16.1112	145.4837
CNS904	-16.1133	145.4845
CNS919	-16.1137	145.4862
CNS930	-16.114	145.4833
CNS951	-16.1127	145.4835
CNS952	-16.1135	145.4847
DGL001	-15.9365	145.3985
DGL002	-16.066	145.469
DGL003	-16.2435	145.4865
DGL008	-15.9365	145.3985
DGL009	-16.066	145.469
DGL010	-16.2435	145.4865
DGL015	-15.9365	145.3985
DGL016	-16.066	145.469

DGL017	-16.2435	145.4865
DGL022	-15.9365	145.3985
DGL023	-16.066	145.469
DGL024	-16.2435	145.4865
DGL030	-15.9365	145.3985
DGL031	-16.066	145.469
DGL032	-16.2435	145.4865
DGL037	-15.9365	145.3985
DGL038	-16.066	145.469
DGL039	-16.2435	145.4865
DGL044	-15.9365	145.3985
DGL045	-16.066	145.469
DGL046	-16.2435	145.4865
DGL051	-15.9365	145.3985
DGL052	-16.066	145.469
DGL053	-16.2435	145.4865
DGL058	-15.9365	145.3985
DGL059	-16.066	145.469
DGL060	-16.2435	145.4865
DGL065	-15.9365	145.3985
DGL066	-16.066	145.469
DGL067	-16.2435	145.4865
DGL072	-15.9365	145.3985
DGL073	-16.066	145.469
DGL074	-16.2435	145.4865
DGL079	-15.9365	145.3985
DGL080	-16.066	145.469
DGL081	-16.2435	145.4865
DGL086	-15.9365	145.3985
DGL087	-16.066	145.469
DGL088	-16.2435	145.4865
FSH014	-15.703	145.3842
FSH024	-11.05	142.815
FSH025	-11.37	142.9132
FSH043	-15.7548	145.402
FSH057	-11.0727	142.8248
FSH058	-11.208	142.8873
FSH059	-11.3452	142.9412
FSH060	-11.489	142.962
FSH099	-14.8113	145.2413
FSH100	-14.9268	145.36
FSH105	-15.6825	145.3835
FSH106	-15.836	145.424
FSH129	-14.8188	145.2528
FSH133	-14.3353	144.6682
FSH141	-13.447	143.6
FSH147	-11.5768	142.97
FSH149	-11.2442	142.8848
FSH150	-11.082	142.8227
FSH157	-11.0215	142.8415
FSH158	-11.8708	143.2172
FSH192	-14.242	144.1877
FSH201	-14.8007	145.2163
FSH203	-14.9798	145.3837
FSH205	-15.266	145.3712
FSH207	-15.5442	145.3655
FSH208	-15.681	145.3617
GDR007	-11.7917	143.0833
KAT001	-15.1768	145.2482
KAT003	-14.6287	144.9468
KAT029	-16.1043	145.4678
KAT030	-16.105	145.4692
LIZ001	-14.7583	145.045
LIZ002	-14.7583	145.045
LIZ011	-15.4482	145.2833
LIZ012	-15.4482	145.2833
LIZ069	-15.4482	145.2833
LIZ072	-14.8483	145.2683
LIZ073	-14.7583	145.045
LIZ085	-15.4482	145.2833
LIZ091	-14.7583	145.045
LIZ093	-14.7583	145.045
LIZ097	-15.4482	145.2833
LIZ098	-15.4482	145.2833
LIZ127	-14.7583	145.045
LIZ128	-15.4482	145.2833
LIZ129	-15.4482	145.2833
LIZ139	-14.7583	145.045
LIZ144	-15.4482	145.2833
LIZ145	-15.4482	145.2833
LIZ146	-15.4482	145.2833
LIZ149	-14.8483	145.2683
LIZ151	-14.8483	145.2683
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NWA028	-14.8333	145.2633
NWA044	-12.6067	143.4683

NWA051	-11.565	142.9598
NWA052	-11.4033	142.9167
NWA053	-11.3283	142.8983
NWA054	-11.0983	142.8367
NWA174	-11.0698	142.8333
NWA175	-11.1967	142.8867
NWA176	-11.3465	142.9132
NWA177	-11.4992	142.9405
NWA206	-14.8132	145.2383
NWA207	-14.9132	145.3583
NWA242	-11.1365	142.8548
NWA243	-11.2982	142.9117
NWA244	-11.4683	142.9367
NWA248	-12.0017	143.2867
NWA252	-12.6025	143.463
NWA271	-14.79	145.2198
NWA279	-16.065	145.4867
PCB015	-14.263	144.1865
PCB018	-14.1858	143.7325
PCB019	-14.1008	143.725
PCB020	-14.0162	143.72
PCB022	-13.8662	143.6388
PCB079	-13.8733	143.65
PCB085	-14.26	144.1885
SHL008	-12.5932	143.4065
SHL033	-11.6265	142.8765
SHL034	-11.825	142.9367
SHL035	-11.8382	143.0782
SHL036	-11.8848	143.2083
SHL045	-12.1815	143.1265
SHL046	-12.1948	143.1265
SHL047	-12.13	143.125
SHL048	-12.0548	143.1782
SHL049	-12.1233	143.185
SHL052	-12.2573	143.13
SHL053	-12.3033	143.1333
SHL054	-12.3298	143.2
TEN007	-15	145.35
TEN018	-15.4565	145.2867
TEN051	-15.4565	145.2867
TEN062	-15	145.35
TEN085	-15.4565	145.2867
TEN096	-15	145.35
TEN119	-15.4565	145.2867
TEN130	-15	145.35
TEN143	-15	145.35
TEN154	-15.4565	145.2867
TEN181	-15	145.35
TEN192	-15.4565	145.2867
TEN215	-15	145.3417
TEN226	-15.4438	145.2615
TOR018	-15.26	145.3965
TOR038	-12.8298	143.5765
TOR040	-12.5965	143.4683
TOR044	-11.9567	143.2565
TOR045	-11.8132	143.1467
TOR047	-11.5148	142.9533
TOR048	-11.3398	142.9132
TOR049	-11.1532	142.8817
WQN001	-16.1135	145.4838
WQN040	-16.114	145.484

Attachment B

station	lat	long
CAI156	-16.11	145.61
CAI262	-16.11	145.61
CAI263	-16.03	145.63
CAI266	-16.03	145.63
CGR025	-12.55	143.57
CGR026	-12.55	143.57
CGR027	-12.41	143.44
CGR028	-12.41	143.44
CGR049	-12.41	143.44
CGR064	-12.55	143.57
CGR066	-12.41	143.44
CGR078	-12.41	143.44
CGR080	-12.55	143.57
CNS018	-16.11	145.57
FSH013	-15.98	145.49
FSH015	-15.41	145.38
FSH016	-14.68	145.08
FSH017	-14.48	144.85
FSH018	-14.27	144.63
FSH019	-14.13	144.36
FSH020	-14.10	144.07
FSH022	-13.66	143.71
FSH023	-13.36	143.65
FSH026	-11.65	143.03
FSH027	-11.88	143.23
FSH028	-12.13	143.24
FSH029	-12.40	143.35
FSH030	-12.67	143.50
FSH031	-12.95	143.60
FSH032	-13.23	143.64
FSH033	-13.54	143.69
FSH034	-13.84	143.75
FSH035	-14.08	143.90
FSH036	-14.14	144.27
FSH037	-14.20	144.57
FSH038	-14.45	144.79
FSH039	-14.64	145.05
FSH040	-14.88	145.32
FSH041	-15.15	145.42
FSH042	-15.46	145.39
FSH044	-16.07	145.53
FSH061	-11.64	143.01
FSH062	-11.72	143.12
FSH063	-11.62	143.27
FSH069	-11.97	143.44
FSH070	-12.03	143.28
FSH071	-12.16	143.25
FSH072	-12.27	143.28
FSH073	-12.39	143.38
FSH074	-12.40	143.44
FSH075	-12.48	143.41
FSH076	-12.53	143.54
FSH081	-12.96	143.60
FSH082	-13.12	143.61
FSH083	-13.27	143.64
FSH084	-13.43	143.66
FSH085	-13.58	143.69
FSH086	-13.75	143.73
FSH087	-13.86	143.80
FSH088	-14.01	143.86
FSH090	-14.10	144.15
FSH091	-14.14	144.30
FSH092	-14.13	144.45
FSH093	-14.19	144.58
FSH094	-14.31	144.67
FSH095	-14.42	144.77
FSH096	-14.51	144.90
FSH097	-14.61	145.01
FSH098	-14.72	145.13
FSH101	-15.07	145.39
FSH102	-15.22	145.40
FSH103	-15.37	145.40
FSH104	-15.53	145.39
FSH107	-15.50	145.47
FSH108	-16.14	145.51
FSH159	-11.93	143.30
FSH160	-11.88	143.42
FSH168	-12.56	143.50
FSH169	-12.63	143.54
FSH170	-12.63	143.54
FSH171	-12.74	143.53
FSH172	-12.86	143.58
FSH173	-13.00	143.56
FSH178	-13.20	143.65
FSH179	-13.33	143.65
FSH180	-13.47	143.67
FSH181	-13.62	143.66
FSH182	-13.67	143.77
FSH183	-13.67	143.77
FSH191	-14.19	144.08
FSH193	-14.22	144.32
FSH194	-14.14	144.46
FSH195	-14.19	144.58
FSH196	-14.30	144.65
FSH197	-14.41	144.74
FSH198	-14.50	144.86
FSH199	-14.58	144.97
FSH200	-14.68	145.08
FSH202	-14.87	145.30
FSH204	-15.12	145.39
FSH206	-15.41	145.37
FSH209	-15.78	145.45
FSH210	-15.83	145.58
FSH213	-16.03	145.64
KAT066	-13.88	143.72
KAT067	-13.78	143.63
KAT068	-13.78	143.63
KAT069	-13.78	143.63
KAT070	-13.81	143.69
KAT071	-13.54	143.65
KAT072	-13.48	143.68
KAT125	-13.86	143.71
KAT126	-13.65	143.71
KAT127	-13.55	143.65
KAT128	-13.77	143.64
KAT151	-13.86	143.71
KAT152	-13.50	143.67
KAT153	-13.55	143.65
KAT154	-13.65	143.71
KAT155	-13.77	143.64
KAT156	-13.86	143.71
KAT157	-13.86	143.71

KAT158	-13.86	143.71	PCB076	-13.97	143.79	TEN153	-15.46	145.37
KAT174	-13.86	143.71	PCB078	-13.92	143.79	TEN212	-14.66	145.23
KAT175	-13.65	143.71	PCB080	-13.87	143.70	TEN213	-14.70	145.16
KAT176	-13.55	143.65	PCB081	-13.87	143.83	TEN214	-14.75	145.08
KAT177	-13.65	143.71	PCB082	-13.87	143.83	TEN216	-15.00	145.41
KAT178	-13.77	143.64	PCB083	-13.87	143.83	TEN217	-15.00	145.50
PCB017	-14.22	143.84	PCB084	-13.85	143.84	TEN224	-15.46	145.46
PCB021	-13.94	143.69	SHL001	-15.62	145.40	TEN225	-15.45	145.36
PCB023	-13.78	143.62	SHL005	-12.68	143.58	TOR014	-15.50	145.50
PCB024	-13.69	143.66	SHL006	-12.72	143.49	TOR015	-15.82	145.44
PCB025	-13.69	143.66	SHL007	-12.79	143.42	TOR016	-15.63	145.40
PCB026	-13.67	143.63	SHL009	-12.51	143.45	TOR017	-15.45	145.39
PCB027	-13.87	143.83	SHL010	-12.55	143.51	TOR019	-15.07	145.40
PCB028	-13.87	143.83	SHL011	-12.49	143.60	TOR020	-14.88	145.40
PCB029	-13.87	143.80	SHL031	-11.67	143.30	TOR023	-14.59	145.12
PCB030	-13.67	143.69	SHL032	-11.65	143.11	TOR024	-14.53	144.94
PCB031	-13.77	143.63	SHL037	-11.95	143.37	TOR025	-14.44	144.79
PCB032	-13.86	143.71	SHL043	-12.19	143.49	TOR026	-14.31	144.67
PCB033	-13.94	143.74	SHL044	-12.19	143.34	TOR027	-14.16	144.55
PCB034	-14.18	143.84	SHL050	-12.19	143.19	TOR028	-14.14	144.38
PCB035	-14.21	143.79	SHL051	-12.26	143.20	TOR029	-14.11	144.21
PCB036	-14.18	143.82	SHL055	-14.56	144.95	TOR030	-14.10	144.03
PCB037	-14.21	144.14	TEN046	-16.19	145.55	TOR032	-13.88	143.77
PCB038	-14.21	144.14	TEN052	-15.46	145.37	TOR033	-13.72	143.72
PCB039	-14.23	144.12	TEN053	-15.46	145.46	TOR034	-13.54	143.69
PCB040	-14.18	144.30	TEN060	-15.00	145.52	TOR035	-13.37	143.67
PCB041	-13.67	143.69	TEN061	-15.00	145.43	TOR036	-13.19	143.63
PCB042	-13.67	143.70	TEN063	-14.74	145.09	TOR037	-13.01	143.60
PCB043	-13.68	143.69	TEN064	-14.70	145.16	TOR039	-12.76	143.44
PCB044	-13.77	143.77	TEN065	-14.65	145.23	TOR041	-12.46	143.38
PCB045	-13.78	143.78	TEN120	-15.46	145.37	TOR042	-12.30	143.28
PCB046	-13.78	143.78	TEN121	-15.46	145.46	TOR043	-12.13	143.24
PCB047	-13.86	143.72	TEN128	-15.00	145.52	TOR046	-11.67	143.05
PCB048	-13.87	143.72	TEN129	-15.00	145.43	TOR108	-15.79	145.44
PCB049	-13.87	143.72	TEN131	-14.74	145.09	WQN039	-16.20	145.53
PCB050	-13.93	143.75	TEN132	-14.70	145.16	CAI045	-16.03	145.63
PCB051	-13.94	143.76	TEN133	-14.65	145.23	CAI046	-16.03	145.63
PCB052	-13.95	143.75	TEN140	-14.65	145.23	CAI047	-16.03	145.63
PCB071	-14.22	143.81	TEN141	-14.70	145.16	CAI048	-16.03	145.63
PCB072	-14.22	143.81	TEN142	-14.74	145.09	CAI057	-16.11	145.61
PCB073	-14.17	143.80	TEN144	-15.00	145.43	CAI058	-16.11	145.61
PCB074	-13.97	143.79	TEN145	-15.00	145.52	CAI219	-16.03	145.63
PCB075	-13.97	143.79	TEN152	-15.46	145.46	CAI220	-16.03	145.63

CAI222	-16.11	145.61	CGR074	-12.00	143.30	FSH148	-11.08	142.92
CNS043	-16.11	145.62	CGR075	-12.22	143.26	GDR005	-11.96	143.50
CNS417	-16.12	145.61	CNS675	-15.63	145.38	GDR006	-11.93	143.48
CNS463	-16.10	145.61	CNS676	-15.46	145.40	KAT002	-15.13	145.32
CNS478	-16.11	145.61	CNS677	-15.28	145.40	KAT004	-13.55	143.66
CNS632	-15.76	145.54	CNS678	-15.11	145.41	KAT005	-13.50	143.72
CNS733	-16.04	145.64	CNS681	-14.70	145.11	KAT006	-13.03	143.64
KAT080	-13.88	143.72	CNS682	-14.58	144.98	KAT007	-11.87	143.28
KAT081	-13.88	143.72	CNS683	-14.47	144.84	KAT008	-11.71	143.18
KAT082	-13.78	143.63	CNS684	-14.36	144.70	KAT016	-12.16	143.37
KAT083	-13.81	143.69	CNS685	-14.21	144.59	KAT017	-12.24	143.33
KAT086	-13.86	143.71	CNS686	-14.13	144.44	LIZ140	-14.80	145.35
KAT087	-13.86	143.72	CNS687	-14.15	144.11	LIZ141	-14.78	145.33
KAT088	-13.77	143.63	CNS688	-14.08	143.95	LIZ142	-14.78	145.33
KAT089	-13.67	143.68	CNS689	-13.97	143.81	LIZ143	-14.80	145.35
KAT090	-13.67	143.70	CNS690	-13.81	143.74	NWA021	-16.16	145.55
KAT091	-13.54	143.65	CNS691	-13.66	143.71	NWA022	-15.50	145.50
KAT092	-13.50	143.67	CNS692	-13.47	143.67	NWA023	-15.83	145.45
KAT094	-13.66	143.69	CNS693	-13.30	143.65	NWA024	-15.66	145.41
KAT095	-14.13	144.23	CNS694	-13.12	143.62	NWA025	-15.49	145.39
KAT096	-14.15	144.26	CNS695	-12.95	143.60	NWA026	-15.14	145.40
KAT134	-13.86	143.71	CNS696	-12.77	143.55	NWA029	-14.71	145.13
KAT135	-13.65	143.71	CNS698	-12.46	143.39	NWA031	-14.48	144.85
KAT136	-13.55	143.65	CNS699	-12.31	143.29	NWA032	-14.38	144.70
KAT137	-13.77	143.64	CNS700	-12.16	143.24	NWA033	-14.23	144.60
LIZ013	-14.78	145.38	CNS702	-11.88	143.24	NWA034	-14.11	144.46
LIZ014	-14.78	145.38	CNS703	-11.76	143.13	NWA040	-13.26	143.71
LIZ015	-14.80	145.35	CNS704	-11.63	143.01	NWA041	-13.13	143.62
LIZ016	-14.80	145.35	FSH126	-15.97	145.48	NWA042	-12.91	143.59
LIZ017	-14.78	145.33	FSH127	-15.81	145.42	NWA043	-12.77	143.57
LIZ018	-14.78	145.33	FSH128	-14.94	145.40	NWA045	-12.45	143.39
LIZ019	-14.75	145.33	FSH130	-14.70	145.11	NWA046	-12.29	143.29
LIZ020	-14.75	145.33	FSH132	-14.47	144.83	NWA047	-12.11	143.24
LIZ021	-14.78	145.38	FSH134	-14.17	144.56	NWA048	-11.95	143.29
LIZ022	-14.78	145.38	FSH136	-14.10	144.17	NWA049	-11.81	143.16
LIZ023	-14.80	145.35	FSH138	-14.01	143.79	NWA050	-11.69	143.06
LIZ024	-14.80	145.35	FSH139	-13.86	143.70	PCB001	-13.86	143.71
LIZ025	-14.78	145.33	FSH140	-13.63	143.67	PCB002	-13.86	143.71
LIZ026	-14.78	145.33	FSH142	-13.27	143.64	PCB003	-13.62	143.76
LIZ027	-14.75	145.33	FSH143	-12.28	143.27	PCB004	-13.45	143.65
LIZ028	-14.75	145.33	FSH144	-12.11	143.24	PCB005	-13.87	143.83
TIM001	-14.44	144.78	FSH145	-11.95	143.29	PCB006	-13.87	143.83
CGR073	-11.92	143.37	FSH146	-11.71	143.04	PCB007	-13.85	143.78

PCB008	-14.14	143.85	CGR056	-11.92	143.37	LIZ086	-15.40	145.42
PCB009	-14.17	143.79	CGR057	-11.92	143.37	LIZ087	-15.40	145.42
PCB011	-14.13	143.82	CGR058	-12.00	143.30	LIZ088	-14.86	145.28
PCB013	-14.21	144.14	CGR059	-12.22	143.26	LIZ089	-14.80	145.35
PCB014	-14.21	144.14	CGR060	-12.59	143.50	LIZ090	-14.78	145.33
PCB016	-14.20	144.12	CGR061	-12.59	143.50	LIZ094	-14.78	145.33
PCB053	-15.41	145.39	CGR062	-12.59	143.50	LIZ095	-14.80	145.35
PCB054	-14.73	145.15	CNS095	-16.11	145.62	LIZ096	-15.40	145.42
PCB055	-13.75	143.66	CNS104	-16.11	145.62	LIZ099	-15.40	145.42
PCB056	-13.75	143.66	CNS499	-16.11	145.62	LIZ113	-14.86	145.28
PCB057	-13.75	143.64	CNS918	-16.12	145.62	LIZ114	-14.80	145.35
PCB058	-13.75	143.65	KAT050	-13.88	143.72	LIZ115	-14.80	145.35
PCB059	-13.77	143.64	KAT051	-13.78	143.63	LIZ116	-14.78	145.33
PCB060	-13.78	143.63	KAT052	-13.75	143.72	LIZ117	-14.78	145.33
PCB061	-13.78	143.64	KAT053	-13.68	143.69	LIZ121	-14.80	145.35
PCB062	-13.78	143.64	KAT054	-13.54	143.65	LIZ122	-14.78	145.33
PCB063	-13.87	143.83	KAT055	-13.51	143.74	LIZ147	-15.40	145.42
PCB064	-13.87	143.83	KAT056	-13.48	143.68	LIZ148	-14.86	145.28
PCB065	-13.88	143.81	KAT057	-14.17	144.23	LIZ150	-14.86	145.28
PCB066	-14.21	144.14	KAT108	-13.86	143.71	LIZ152	-14.78	145.38
PCB067	-14.21	144.14	KAT109	-13.77	143.64	LIZ153	-14.75	145.33
PCB068	-14.22	144.11	KAT110	-13.67	143.69	LIZ154	-14.75	145.33
CGR007	-11.92	143.37	KAT111	-13.55	143.66	LIZ155	-14.78	145.38
CGR008	-11.92	143.37	KAT112	-13.48	143.68	NWA178	-11.63	143.02
CGR009	-11.75	143.00	KAT113	-13.51	143.74	NWA179	-11.75	143.12
CGR010	-11.75	143.00	KAT114	-13.92	143.89	NWA180	-11.86	143.22
CGR011	-12.00	143.30	KAT115	-13.65	143.71	NWA181	-11.98	143.30
CGR012	-12.00	143.30	KAT116	-13.55	143.65	NWA182	-12.12	143.24
CGR013	-12.22	143.26	KAT117	-13.77	143.64	NWA183	-12.28	143.27
CGR014	-12.22	143.26	KAT118	-13.86	143.71	NWA184	-12.41	143.36
CGR017	-12.59	143.50	KAT143	-13.50	143.67	NWA185	-12.55	143.44
CGR018	-12.59	143.50	KAT144	-13.55	143.65	NWA186	-12.68	143.51
CGR031	-12.59	143.50	KAT145	-13.65	143.71	NWA187	-12.82	143.57
CGR032	-12.59	143.50	KAT146	-13.77	143.64	NWA188	-12.96	143.59
CGR035	-12.22	143.26	KAT147	-13.86	143.71	NWA189	-13.12	143.61
CGR036	-12.22	143.26	KAT185	-13.86	143.71	NWA190	-13.28	143.65
CGR037	-12.00	143.30	KAT186	-13.65	143.71	NWA191	-13.43	143.67
CGR038	-12.00	143.30	KAT187	-13.55	143.65	NWA192	-13.59	143.69
CGR039	-11.75	143.00	KAT188	-13.77	143.64	NWA193	-13.75	143.72
CGR040	-11.75	143.00	LIZ009	-15.40	145.42	NWA194	-13.88	143.78
CGR041	-11.92	143.37	LIZ010	-15.40	145.42	NWA195	-14.12	144.24
CGR042	-11.92	143.37	LIZ070	-15.40	145.42	NWA196	-14.10	144.03
CGR050	-12.59	143.50	LIZ071	-14.86	145.28	NWA197	-14.11	144.18

NWA198	-14.14	144.30	NWA256	-13.23	143.63	TEN004	-14.65	145.23
NWA199	-14.14	144.46	NWA257	-13.40	143.66	TEN005	-14.70	145.16
NWA200	-14.19	144.59	NWA258	-13.57	143.69	TEN006	-14.74	145.09
NWA201	-14.31	144.66	NWA259	-13.74	143.73	TEN008	-15.00	145.43
NWA202	-14.42	144.76	NWA260	-13.91	143.79	TEN009	-15.00	145.52
NWA203	-14.50	144.88	NWA261	-14.04	143.88	TEN016	-15.46	145.46
NWA205	-14.71	145.12	NWA262	-14.09	144.04	TEN017	-15.46	145.37
NWA208	-15.07	145.40	NWA263	-14.11	144.22	TEN023	-16.19	145.55
NWA209	-15.24	145.40	NWA264	-14.14	144.39	TEN086	-15.46	145.37
NWA210	-15.41	145.39	NWA265	-14.16	144.54	TEN087	-15.46	145.46
NWA211	-15.57	145.40	NWA266	-14.27	144.65	TEN094	-15.00	145.52
NWA212	-15.74	145.42	NWA267	-14.40	144.74	TEN095	-15.00	145.43
NWA213	-15.91	145.45	NWA268	-14.49	144.87	TEN097	-14.74	145.09
NWA245	-11.63	143.01	NWA269	-14.58	144.98	TEN098	-14.70	145.16
NWA246	-11.75	143.12	NWA270	-14.69	145.10	TEN099	-14.65	145.23
NWA247	-11.88	143.23	NWA272	-14.90	145.34	TEN178	-14.65	145.23
NWA249	-12.16	143.25	NWA273	-15.05	145.39	TEN179	-14.70	145.16
NWA250	-12.31	143.29	NWA274	-15.22	145.40	TEN180	-14.74	145.09
NWA251	-12.46	143.38	NWA275	-15.39	145.38	TEN182	-15.00	145.43
NWA253	-12.75	143.54	NWA276	-15.56	145.40	TEN183	-15.00	145.52
NWA254	-12.90	143.58	NWA277	-15.73	145.42	TEN190	-15.46	145.46
NWA255	-13.07	143.60	NWA278	-15.90	145.45	TEN191	-15.46	145.37

Attachment C

station	lat	long
CAI043	-16.06	145.67
CAI044	-16.06	145.67
CAI049	-16.06	145.67
CAI050	-16.06	145.67
CAI218	-16.06	145.67
CAI221	-16.06	145.67
CAI264	-16.06	145.67
CAI265	-16.06	145.67
CGR001	-12.38	143.75
CGR002	-12.38	143.75
CGR003	-12.33	143.75
CGR004	-12.33	143.75
CGR005	-11.79	143.67
CGR006	-11.79	143.67
CGR043	-12.33	143.75
CGR044	-12.33	143.75
CGR045	-12.38	143.75
CGR046	-12.38	143.75
CGR051	-12.33	143.75
CGR052	-11.79	143.67
CGR053	-11.59	144.03
CGR054	-11.60	143.92
CGR055	-11.79	143.67
CGR068	-12.38	143.75
CGR069	-12.33	143.75
CGR070	-12.33	143.75
CGR071	-11.79	143.67
CGR072	-11.79	143.67
CHA001	-13.93	144.33
CHA002	-13.93	144.33
CHA003	-13.86	144.06
CHA004	-13.86	144.06
CHA005	-14.05	144.22
CHA006	-14.05	144.22
CHA007	-14.05	144.22
CHA008	-14.05	144.22
CHA009	-13.86	144.06
CHA010	-13.86	144.06
CHA011	-13.93	144.33
CHA012	-13.93	144.33
CHA013	-13.93	144.33
CHA014	-13.86	144.06
CHA015	-14.05	144.22
CHA016	-14.05	144.22
CHA017	-14.05	144.22
CHA018	-13.93	144.33
CHA019	-13.86	144.06
CNS098	-15.50	145.82
CNS099	-15.50	145.82
CNS101	-15.50	145.82
CNS102	-15.50	145.82
CNS461	-15.86	145.66
CNS462	-15.76	145.81
CNS630	-15.37	145.71
CNS631	-15.36	145.75
CNS730	-15.50	145.60
CNS731	-15.90	145.72
CNS732	-15.82	145.81
FSH021	-13.94	143.97
FSH064	-11.61	143.45
FSH065	-11.60	143.63
FSH066	-11.69	143.84
FSH067	-11.73	143.73
FSH068	-11.95	143.61
FSH077	-12.44	143.67
FSH078	-12.44	143.72
FSH079	-12.57	143.77
FSH080	-12.63	143.81
FSH135	-14.08	144.35
FSH161	-11.84	143.56
FSH162	-11.83	143.69
FSH163	-11.90	143.77
FSH164	-12.06	143.75
FSH165	-12.21	143.72
FSH166	-12.34	143.69
FSH167	-12.38	143.62
FSH174	-13.02	143.71
FSH175	-13.03	143.83
FSH176	-13.12	143.86
FSH177	-13.14	143.80
FSH184	-13.56	143.96
FSH185	-13.56	143.96
FSH186	-13.69	144.07
FSH187	-13.80	144.06
FSH188	-13.88	144.05
FSH189	-14.03	144.50
FSH211	-15.89	145.75
FSH212	-15.94	145.75
GDR003	-12.92	143.86
GDR004	-12.93	143.84
KAT018	-13.34	143.96
KAT019	-13.41	143.83
KAT020	-13.71	144.22
KAT021	-13.85	144.14
KAT073	-14.59	145.63
KAT074	-14.70	145.46
KAT093	-13.46	143.84
LIZ003	-14.19	144.82
LIZ004	-14.19	144.82
LIZ005	-14.51	145.15
LIZ006	-14.51	145.15
LIZ007	-15.13	145.70
LIZ008	-15.13	145.70
LIZ029	-14.66	145.50
LIZ030	-14.66	145.50
LIZ031	-14.64	145.48
LIZ032	-14.64	145.48
LIZ033	-14.64	145.48
LIZ034	-14.64	145.48
LIZ035	-14.66	145.50
LIZ036	-14.66	145.50
LIZ037	-14.75	145.45
LIZ038	-14.75	145.45
LIZ039	-14.52	145.48
LIZ040	-14.52	145.48
LIZ041	-14.51	145.58
LIZ042	-14.51	145.58
LIZ043	-14.58	145.60
LIZ044	-14.58	145.60
LIZ045	-14.57	145.62
LIZ046	-14.57	145.62
LIZ047	-14.63	145.63

LIZ048	-14.63	145.63	LIZ110	-14.66	145.66	SHL002	-12.60	143.85
LIZ049	-14.63	145.63	LIZ111	-14.63	145.65	SHL003	-12.63	143.78
LIZ050	-14.63	145.63	LIZ112	-14.63	145.63	SHL004	-12.65	143.68
LIZ051	-14.57	145.62	LIZ118	-14.75	145.45	SHL012	-12.43	143.70
LIZ052	-14.57	145.62	LIZ119	-14.73	145.51	SHL013	-12.41	143.80
LIZ053	-14.58	145.60	LIZ120	-14.73	145.51	SHL014	-12.41	143.69
LIZ054	-14.58	145.60	LIZ123	-14.65	145.43	SHL015	-12.55	143.69
LIZ055	-14.51	145.58	LIZ124	-14.64	145.48	SHL016	-12.34	143.81
LIZ056	-14.51	145.58	LIZ125	-14.73	145.51	SHL017	-12.36	143.75
LIZ057	-14.19	144.82	LIZ126	-15.13	145.70	SHL018	-12.33	143.81
LIZ058	-14.19	144.82	LIZ130	-14.67	145.48	SHL019	-12.32	143.79
LIZ059	-14.75	145.45	LIZ131	-14.66	145.50	SHL020	-12.34	143.78
LIZ060	-14.75	145.45	LIZ132	-14.64	145.48	SHL021	-12.38	143.80
LIZ061	-14.75	145.52	LIZ133	-14.65	145.43	SHL022	-12.37	143.82
LIZ062	-14.75	145.52	LIZ134	-14.67	145.48	SHL023	-12.36	143.84
LIZ063	-14.73	145.51	LIZ135	-14.66	145.50	SHL027	-11.63	144.08
LIZ064	-14.73	145.51	LIZ136	-14.64	145.48	SHL028	-11.65	143.86
LIZ065	-14.73	145.51	LIZ137	-14.65	145.43	SHL029	-11.70	143.71
LIZ066	-14.73	145.51	LIZ138	-14.30	144.96	SHL030	-11.67	143.55
LIZ067	-14.75	145.52	LIZ156	-14.75	145.45	SHL038	-11.95	143.60
LIZ068	-14.75	145.52	LIZ157	-14.75	145.45	SHL039	-11.96	143.76
LIZ074	-14.52	145.48	LIZ158	-14.52	145.48	SHL040	-11.97	143.93
LIZ075	-14.58	145.60	LIZ159	-14.52	145.48	SHL041	-12.18	143.92
LIZ076	-14.63	145.65	LIZ160	-14.51	145.58	SHL042	-12.18	143.72
LIZ077	-14.66	145.66	LIZ161	-14.57	145.62	TEN001	-14.52	145.45
LIZ078	-14.63	145.63	LIZ162	-14.58	145.60	TEN002	-14.52	145.45
LIZ079	-14.64	145.48	LIZ163	-14.51	145.58	TEN003	-14.61	145.30
LIZ080	-14.67	145.48	LIZ164	-14.58	145.60	TEN010	-15.00	145.60
LIZ081	-14.67	145.48	LIZ165	-14.57	145.62	TEN011	-15.00	145.67
LIZ082	-14.66	145.50	LIZ166	-14.66	145.66	TEN012	-15.13	145.71
LIZ083	-14.66	145.50	LIZ167	-14.63	145.65	TEN013	-15.46	145.72
LIZ084	-15.13	145.70	LIZ168	-14.63	145.63	TEN014	-15.46	145.63
LIZ092	-14.19	144.82	LIZ169	-14.63	145.65	TEN015	-15.46	145.55
LIZ100	-14.75	145.45	LIZ170	-14.63	145.63	TEN054	-15.46	145.55
LIZ101	-14.75	145.45	LIZ171	-14.66	145.66	TEN055	-15.46	145.63
LIZ102	-14.65	145.43	LIZ172	-14.73	145.51	TEN056	-15.46	145.72
LIZ103	-14.65	145.43	LIZ173	-14.75	145.52	TEN057	-15.13	145.71
LIZ104	-14.64	145.48	LIZ174	-14.73	145.51	TEN058	-15.00	145.67
LIZ105	-14.64	145.48	LIZ175	-14.75	145.52	TEN059	-15.00	145.60
LIZ106	-14.53	145.55	LIZ176	-15.13	145.70	TEN066	-14.61	145.30
LIZ107	-14.51	145.58	LIZ177	-15.13	145.70	TEN067	-14.56	145.37
LIZ108	-14.57	145.62	NWA036	-13.85	144.22	TEN068	-14.52	145.45
LIZ109	-14.58	145.60	NWA037	-13.73	144.09	TEN088	-15.46	145.55

TEN089	-15.46	145.63	TEN137	-14.52	145.45	TEN189	-15.46	145.55
TEN090	-15.46	145.72	TEN138	-14.56	145.37	TEN209	-14.52	145.44
TEN092	-15.00	145.67	TEN139	-14.61	145.30	TEN210	-14.57	145.37
TEN093	-15.00	145.60	TEN146	-15.00	145.60	TEN211	-14.61	145.30
TEN100	-14.61	145.30	TEN147	-15.00	145.67	TEN218	-15.00	145.58
TEN101	-14.56	145.37	TEN149	-15.46	145.72	TEN219	-15.00	145.67
TEN102	-14.52	145.45	TEN150	-15.46	145.63	TEN221	-15.45	145.78
TEN122	-15.46	145.55	TEN151	-15.46	145.55	TEN222	-15.45	145.67
TEN123	-15.46	145.63	TEN175	-14.52	145.45	TEN223	-15.46	145.57
TEN124	-15.46	145.72	TEN176	-14.56	145.37	TOR021	-14.68	145.42
TEN126	-15.00	145.67	TEN177	-14.61	145.30	TOR022	-14.63	145.29
TEN127	-15.00	145.60	TEN184	-15.00	145.60	TOR106	-13.03	143.70
TEN134	-14.61	145.30	TEN185	-15.00	145.67	TOR107	-13.05	143.90
TEN135	-14.56	145.37	TEN187	-15.46	145.72			
TEN136	-14.52	145.45	TEN188	-15.46	145.63			