Seqwater EEMP 2017 Annual Report

Seqwater

Estuarine Ecology Monitoring Program report 2017

Revision 2

30 October 2018

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Seqwater EEMP 2017 Annual Report

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Executive Summary

This report presents the 2017 Wyaralong Dam environmental monitoring program, which was completed as part of the dam's Estuarine Ecology Management Plan (EEMP). The purpose of the EEMP program is to monitor and detect any change in condition of the Logan River estuary, as well as any downstream effects on the Moreton Bay Ramsar-listed wetland during construction and operation of the Wyaralong Dam. Construction of the dam commenced in January 2010, was completed in January 2011 and operational management of the dam was transferred to Seqwater in July 2011.

The EEMP was developed in consideration of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Directory of Important Wetlands (DIWA) and a range of other applicable Commonwealth policies. The monitoring program (outlined in the EEMP) was developed in accordance with the Queensland Coordinator-General's (CG) Report (DSD, 2008) and Schedule C, Part 4, Condition 21 (e and f) of Department of Environment (DoE) conditions, which specified the features that must be monitored, analysed and reported for a minimum period of five years under the CG conditions and ten years under the DoE conditions. In accordance with the approved monitoring program, results are presented for river flow, water quality, habitat assessment and estuarine fisheries productivity in the Logan River estuary.

Queensland experienced its warmest year on record during 2017 with some areas of the east coast receiving above average rainfall. Torrential rainfall occurred across eastern Queensland from Bowen to the southeast at the end of March, as a result of severe tropical cyclone Debbie. The Logan-Albert River systems subsequently experienced one of the largest floods in recent times. Overall mean river flow for the Logan-Albert systems was therefore higher in 2017 than in previous years, with flooding recorded at all four gauging stations (major flooding in the Logan River at Yarrahapinni, moderate flooding in the Albert River at Bromfleet station, and minor flooding in the Logan River at Forest Home and in the Coomera River at Army Camp station).

Water quality results for the Logan River remained below impact trigger values throughout 2017. Nutrient concentrations fell *below* the lower operational trigger values in the section of the Logan River above the confluence of the Albert River. No substantial change in ambient water quality was evident for either the Albert or Coomera River reference systems.

Mangrove and saltmarsh habitat change assessment between 2009 and 2017 showed increases in reporting zones C (1.9%), E (7.1%), G (0.3%) and F (20.6%), with a slight decrease in reporting zones A (0.2%), B (3.8%) and D (1.1%). Habitat change results did not indicate that construction and operation of the Wyaralong dam has impacted mangrove and saltmarsh habitat in the Logan River estuary. The 2017 reporting period assessment of mangrove and saltmarsh habitat showed increases for zones A to F (0.3% to 9.4%), and a slight decrease for zone G (2%).

The index of vegetation health (measured through mean normalised difference vegetation index or NDVI) for the 2017 reporting year ranged from 0.52 to 0.66, which was within the range defined as healthy and consistent with results from previous years. NDVI results for the duration of monitoring (2009-2017) showed that the vegetation health index has increased between 7% and 13%. Monitoring zones C and D had the highest percent change (12% in zone C and 13% in zone D).

The targeted mud crab surveys could not be completed in 2017 due to the Biosecurity Emergency Order (BEO) that was implemented in the Logan River estuary. The BEO was declared on 11 December 2016 by the Queensland Government, as a quarantine restriction in response to the white spot disease outbreak in the Logan River. Restrictions were placed on commercial and recreational users of the Logan estuary, including the use of vessels and sampling apparatus in the quarantined area. When permission to enter the quarantined area was granted, flooding prevented the surveys going ahead. Consultation on this component of the EEMP was undertaken by Seqwater with the Department of the Environment and Energy.

Results for seagrass depth range (SDR) were consistent with previous years, where SDR fluctuated over time, with a slight downward trend since monitoring began in 1996 (Long Island) and 2003 (Pannikin Island). Decreases in water clarity may contribute to shallower depth range changes in SDR, that have occurred since monitoring for the EEMP commenced. A very wet year was experienced in 2010, followed by extreme flood events in 2011, extensive flooding across parts of SEQ in 2012 and 2013, higher than average rainfall in 2014 and 2015 and significant flooding in 2017. The increased wet periods over the past eight years, together with rapid increases in urban development in the Logan River catchment that has occurred since data collection began, are likely to have influenced water clarity in the Logan River estuary and downstream inshore waters of Moreton Bay.

Commercial fisheries catch rates in 2017 remained consistent with previous trends. CPUE for pot fisheries has remained stable, and the CPUE for trawl and net fisheries remained within historical variation. Results do not show any indication that dam operation has impacted downstream commercial fisheries productivity.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess the impact of Dam operations as required by the Wyaralong Dam Estuarine Ecological Management Plan in accordance with the scope of services set out in the contract between Jacobs and Seqwater. That scope of services, as described in this report, was developed with Seqwater.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by Seqwater and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Queensland Department of Agriculture and Fisheries, Seqwater, Healthy Land & Water and the Department of Natural Resources and Mines, and/or data available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Seqwater, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Seqwater. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

List of Acronyms

AMTD	Adopted Middle Thread Distance
CEMP	Construction Environmental Management Plan
CPUE	Catch rates per unit effort
CG	Coordinator General
DAF	Department of Agriculture and Fisheries
DNRM	Department of Natural Resources and Mines
DIWA	Directory of Important Wetlands
EEMP	Estuarine Ecology Management Plan
EPBC	Environmental Protection and Biodiversity Conservation
DoE	Department of Environment
DO	Dissolved Oxygen
EEMP	Estuarine Ecology Management Plan
EHMP	Ecosystem Health Monitoring Program
FRP	Filterable Reactive Phosphorus
ML	Megalitres
NDVI	Normalised difference vegetation index
NOx	Nitrogen Oxides
OEMP	Operation Environmental Management Plan
SEP	Scientific Expert Panel
SEQ	South East Queensland
STP	Sewage Treatment Plant
TN	Total Nitrogen
TP	Total Phosphorus
WRP	Water Resources Plan

1. Introduction

This annual report documents results from the 2017 environmental monitoring program for the Logan River estuary and southern Moreton Bay Marine Park, undertaken in accordance with the Wyaralong Dam Estuarine Ecology Management Plan (EEMP; QWI, 2009). The monitoring program forms part of the approval conditions for the construction and operation of Wyaralong Dam. Construction commenced in January 2010 and was completed in January 2011, with operational management of the dam transferred to Seqwater in July 2011. The purpose of the monitoring program is to detect any change in condition of the Logan River estuary and downstream on the Moreton Bay Ramsar-listed wetland.

Wyaralong Dam is located on Teviot Brook (a tributary of the Logan River), approximately 51 km southwest of Brisbane and within the Scenic Rim Regional Council local government area (Figure 1.1). Wyaralong Dam was designed to supply 21,000 megalitres (ML) of water each year to South-East Queensland (SEQ) and is operated in conjunction with existing storages in the Logan catchment (Cedar Grove Weir and Bromelton off-stream storage). This allows system yield to be maximised, while achieving the environmental flow outcomes required under the Logan Basin Water Resource Plan (WRP; PB & MWH, 2007). Controlled water releases are made from Wyaralong Dam to Teviot Brook for subsequent diversion from Cedar Grove Weir.

The EEMP was developed in 2009 with consideration of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), the Directory of Important Wetlands (DIWA) and a range of other applicable Commonwealth policies including:

- Water Reform Framework, Council of Australian Governments Agreement 1994
- National Water Initiative
- National Action Plan for Salinity and Water Quality 2000
- National Strategy on Conservation of Australia's Biological Diversity
- National Strategy for Ecologically Sustainable Development
- National Biodiversity and Climate Change Action Plan 2004-7.

The EEMP is undertaken in accordance with the Coordinator General’s (CG’s) Report Schedule C, Part 4, Condition 21 (e and f) and Department of Environment (DoE) conditions, which specify the features that must be monitored, analysed and reported for minimum periods of five years under the CG conditions and ten years under the DoE conditions. This monitoring program is carried out in parallel with monitoring conducted within the Wyaralong Dam reservoir (as required by Condition 17(c), Part 4, Schedule C of the CG report) and the Operation Environmental Management Plan. Monitoring within the reservoir is not reported in this document. This is the eighth consecutive year of monitoring since the EEMP began (including construction and operational monitoring) and fulfils the minimum five years of operational monitoring and reporting required in the CG conditions.

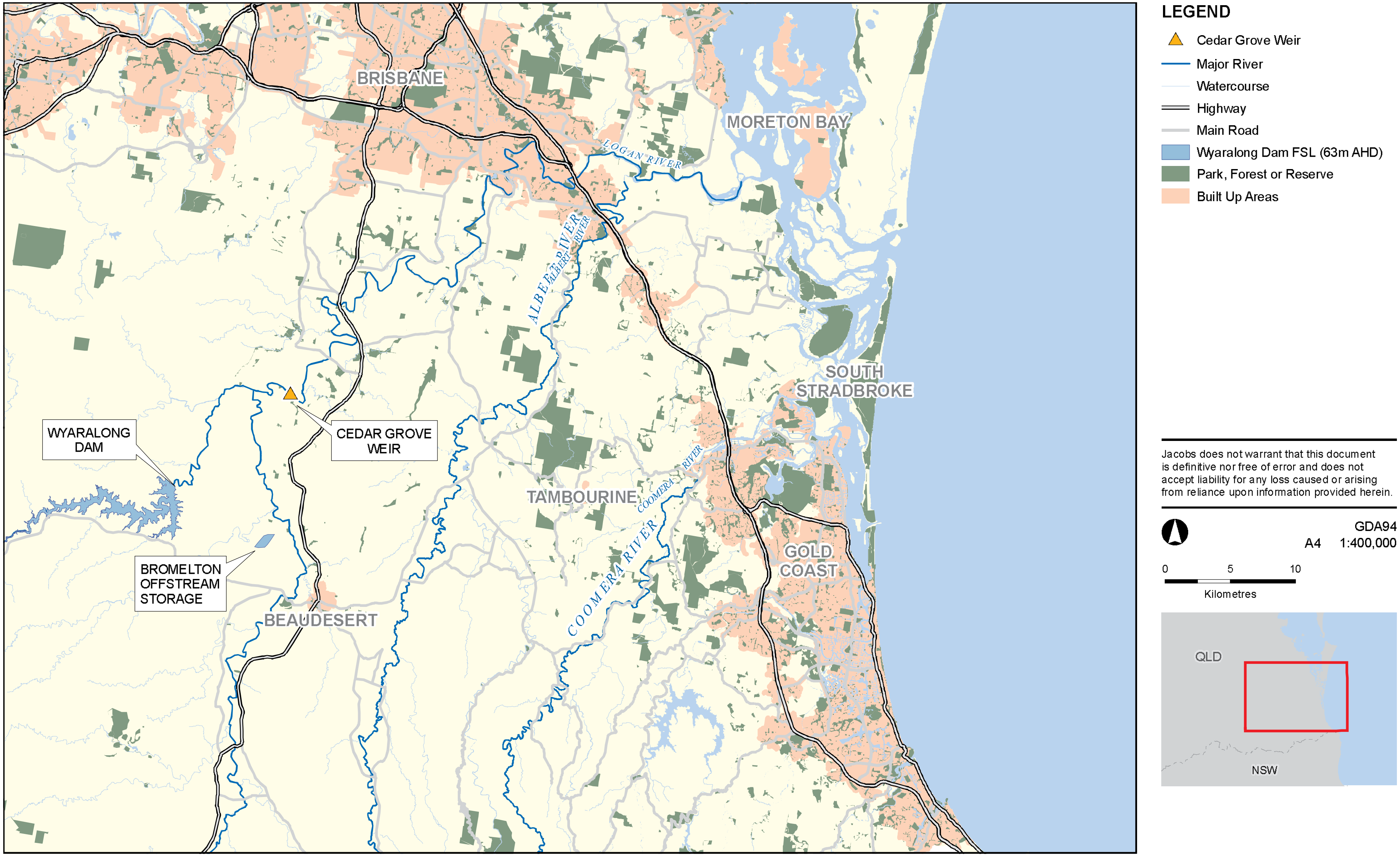

FIGURE 1-1 LOCALITY MAP

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2. The monitoring program

2.1 Purpose

The EEMP monitoring program was developed to detect change in condition of the Logan River estuary and subsequent effects on the Moreton Bay Ramsar-listed wetland during the construction and operation of Wyaralong Dam. The philosophy of the EEMP was based on a tiered set of potential downstream effects the construction and operation of Wyaralong Dam may have had on the downstream environments of the Logan River estuary and the Moreton Bay Ramsar-listed wetland.

The ability to delineate influence on the system from dam activities versus other natural and human influences presents a challenge for the monitoring program. It is important to recognise that the catchment was a highly disturbed system prior to the construction of Wyaralong Dam, with multiple urban and agricultural inputs and severely deteriorated water quality. In addition, meteorological conditions changed during the period of dam construction, marking the end of several years of prolonged drought conditions in South-East Queensland. This period included monitoring data used to determine the baseline variability of the system, further confounding the ability to delineate any influence of dam activities. Irrespective of this, where change exceeds variability, advice on potential causes is sought from the Healthy Land and Water Limited Scientific Expert Panel (SEP), which is familiar with the region and the anthropogenic pressures within the Logan River catchment (Figure A.1).

Water quality underpins the existing monitoring program and forms the basis for all short-term trigger events. The concurrent monitoring of flow, estuarine fisheries productivity and habitat is designed to assist the SEP in their deliberations on the cause of any change beyond natural variability (e.g., construction of dam, new sewage treatment plant, changed land management practices in catchment) and what mitigation measures, if any, may be required.

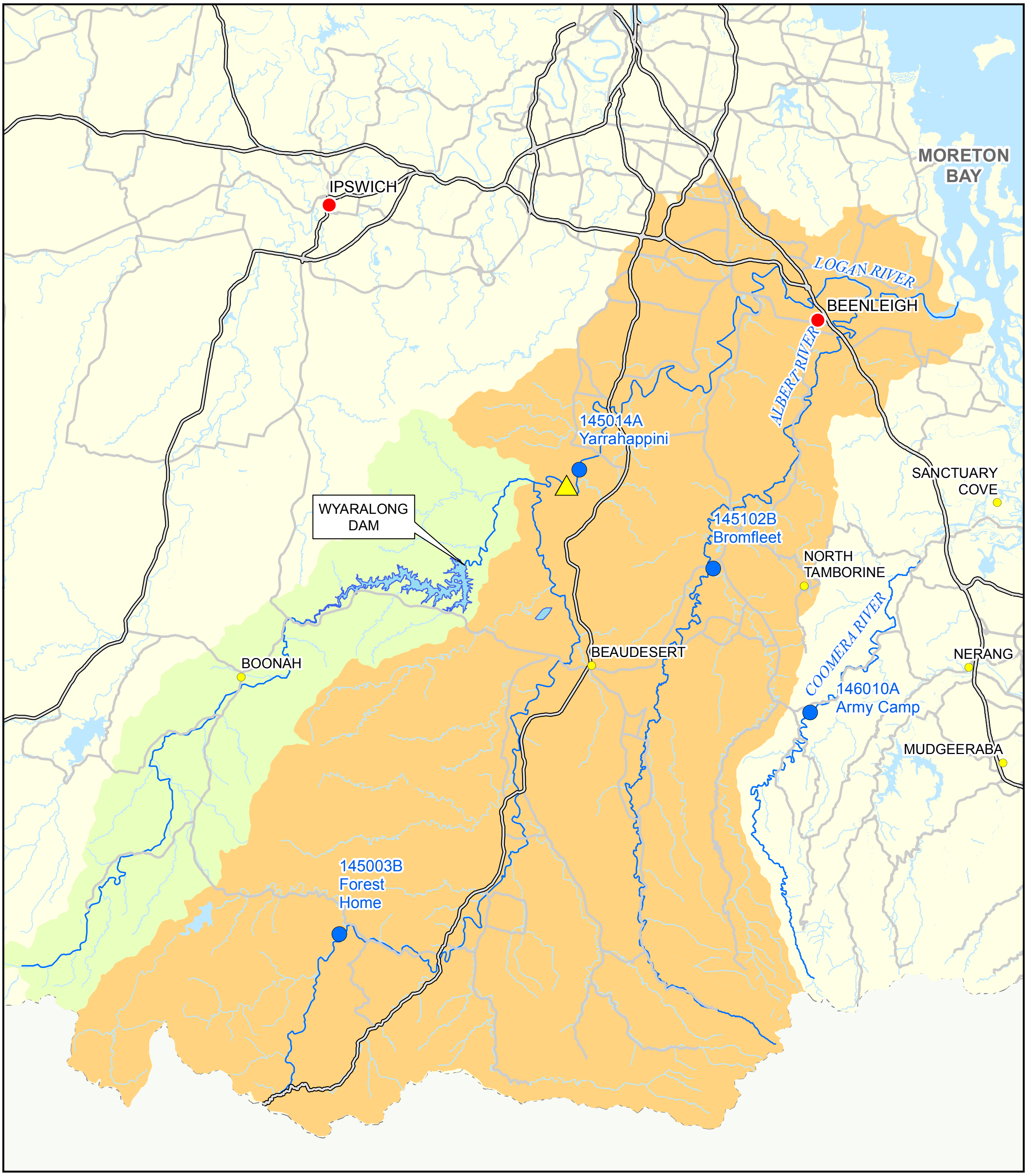
2.2 Monitoring methods

The EEMP captures and reports river flow and water quality information on a monthly basis and habitat and fisheries productivity on an annual basis (Figure 2.1). Each aspect of the monitoring program is further described below.

Figure 2.1: The Wyaralong dam environmental monitoring program

2.2.1 River flow

Data from the Department of Natural Resources and Mines (DNRM) gauging stations is used to evaluate the mean daily flows for each month at both the downstream (Yarrahappini) and upstream (Forest Home) gauging stations. Figure 2.2 illustrates the locality of these gauging stations in relation to the Wyaralong Dam.



LEGEND

- Cedar Grove Weir
- DERM Streamflow Gauge
- Major Locality
- Other Locality
- Major River
- Watercourse
- Highway
- Main Road
- Wyaralong Dam FSL

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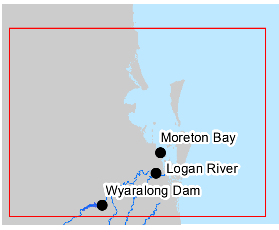

FIGURE 2-2 LOGAN BASIN CATCHMENT DRAINAGE NETWORK AND STREAM FLOW GAUGES

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2.2.2 Water quality

Water quality is assessed at 12 sites within the Logan River estuary. Sampling is conducted from the river mouth (0 km AMTD) to 33 km AMTD (Figure 2.3). These locations were selected based on the approximate extent that mangroves and saline water penetrated up the Logan River at the time the program was developed.

Water quality was assessed monthly from January 2000 until June 2014. In July 2014, changes to the Healthy Land and Water Ecosystem Health Monitoring Program (EHMP) resulted in a reduction in the number of monthly sampling events from twelve to eight per year (sampling in January, April, June and July ceased to occur). Therefore, the annual rolling median values changed to comprise eight months of data instead of twelve, and are reported as 'eight-month' rolling medians. This accounts for the recent gaps in plots of the annual rolling medians (Appendix D).

The EEMP identified the Albert River estuary (tributary of the Logan River) and the Coomera River estuary as comparable coastal river estuaries (reference sites) to the Logan River. The Albert River was chosen due to its similar catchment, pressures and water quality conditions to the Logan River estuary (EHMP, 2008). The Coomera River estuary was chosen as an additional reference system because it also discharges to southern Moreton Bay, and detailed water quality information was available through the EHMP.

Water quality data for the EEMP is sourced from the regional EHMP through an agreement between Seqwater and south-east Queensland's Healthy Land and Water. This arrangement enables comparison of data (spatially and temporally) and continuity of collection, analysis methods and QA/QC procedures. The water quality parameters listed below were included in the EEMP, with region-specific trigger values that were calculated based on historical data collected by the EHMP (presented in section 2.2.2.1):

- Physico-chemical
  - Dissolved oxygen (DO)
  - pH
  - Temperature
  - Conductivity
  - Turbidity
  - Secchi depth
- Biological
  - Chlorophyll-a (chl-a)
- Nutrients
  - Total nitrogen (TN)
  - Total phosphorus (TP)
  - Organic nitrogen
  - Ammonia (NH_3)
  - Nitrogen oxides (NOx)
  - Filterable reactive phosphorus (FRP).

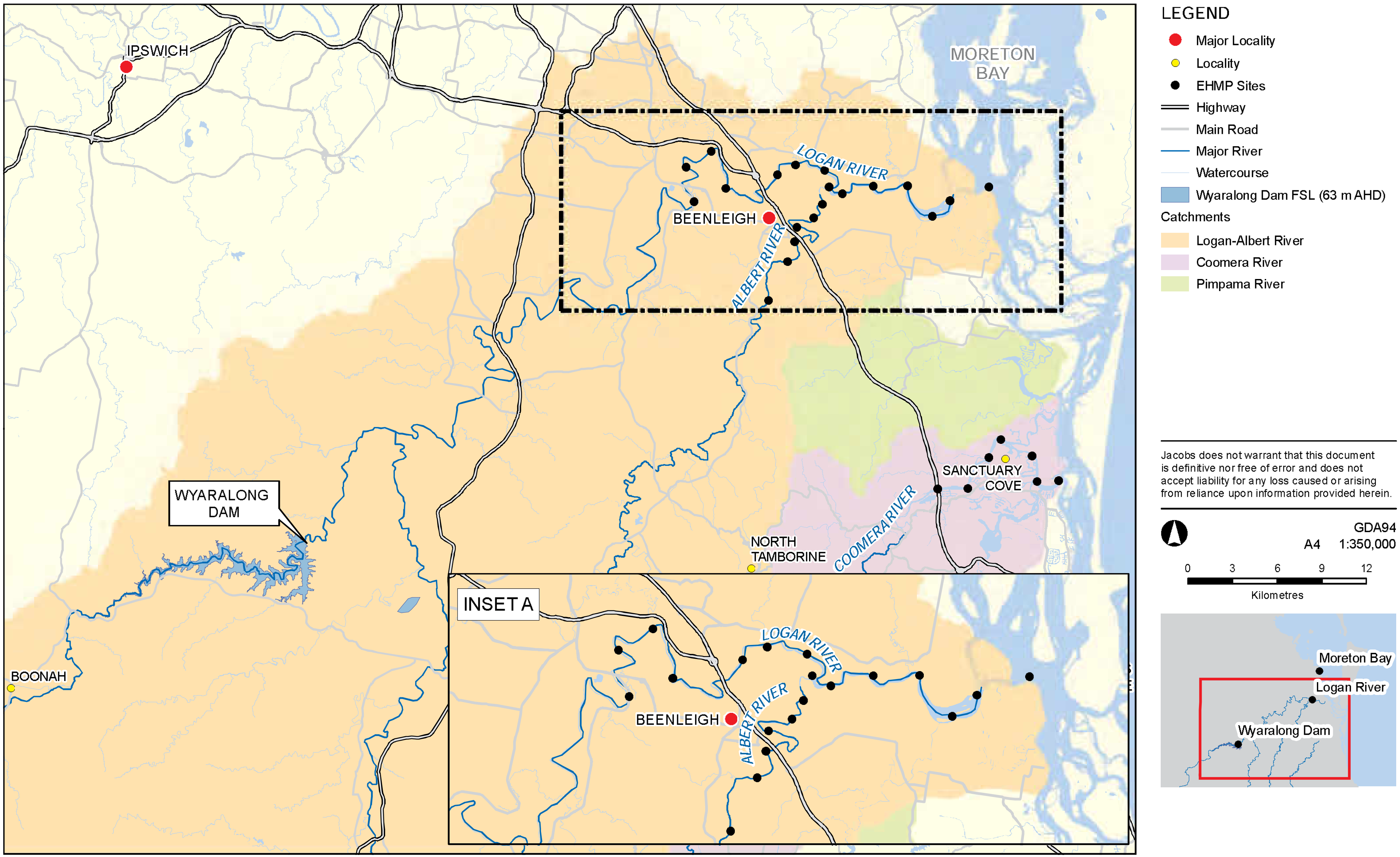

FIGURE 2-3 EHMP WATER QUALITY SAMPLING SITES

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2.2.2.1 Water quality trigger values

Ten years of water quality data (January 2000 to September 2009) sourced from the EHMP was used to establish two sets of water quality trigger values (based on the 20th and 80th percentiles) in the EEMP, for above and below the confluence of the Albert River and Logan River (Table 2.1).

In July 2012, the Wyaralong project passed the 12-month post-construction period. The applicable water quality monitoring trigger values were then transferred from the previous construction trigger values (5th and 95th percentiles) to the operational trigger values (20th and 80th percentiles). An “exceedance” of the operational trigger value occurs when the eight-month rolling median (for data collected over the previous twelve month period) value for a parameter falls above the 80th percentile (termed a “trigger event”) in any month.

Table 2.1: Water quality trigger values used for the EEMP (Logan River estuary)

Logan River estuary zone	Water Quality Parameter	Water Quality Trigger Values*	
		20th percentile 2000 – 2009	80th percentile 2000 - 2009
Logan River estuary **Above Albert River** confluence *13 - 33 km AMDT*	Chlorophyll-a (µg/L)	2.2	9.1
	Conductivity at 25 °C (mS/cm)	0.5	26.1
	Secchi depth (m)	0.2	0.6
	Nitrogen (ammonia) as N (mg/L)	0.01	0.14
	Nitrogen (organic) as N (mg/L)	0.36	0.66
	Nitrogen (oxidised) as N (mg/L)	0.28	0.81
	Nitrogen (total) as N (mg/L)	0.79	1.50
	Oxygen per cent saturation (%)	65	86
	pH	7.4	7.8
	Phosphorus (filterable reactive) as P (mg/L)	0.14	0.42
	Phosphorus (total) as P (mg/L)	0.26	0.60
	Temperature (°C)	18	27
	Turbidity (NTU)	24	157
Logan River estuary **Below Albert River** confluence *0 - 11 km AMDT*	Chlorophyll-a (µg/L)	1.9	5.9
	Conductivity at 25 °C (mS/cm)	30.5	51.3
	Secchi depth (m)	0.5	1.5
	Nitrogen (ammonia) as N (mg/L)	0.004	0.073
	Nitrogen (organic) as N (mg/L)	0.18	0.37
	Nitrogen (oxidised) as N (mg/L)	0.02	0.34
	Nitrogen (total) as N (mg/L)	0.22	0.77
	Oxygen per cent saturation (%)	79	97
	pH (Unit)	7.7	8.1
	Phosphorus (filterable reactive) as P (mg/L)	0.03	0.14
	Phosphorus (total) as P (mg/L)	0.05	0.20
	Temperature (°C)	18	26
	Turbidity (NTU)	5	23

*Trigger Values derived from 2000 – 2009 EHMP data sourced from DNRM waterways database.

2.2.3 Habitats

Changes in mangrove, saltmarsh and/or seagrass habitat were selected as indicators of environmental change, as many plant processes including photosynthesis, respiration, reproduction and growth are influenced by the environment, including water quality. Variations to the extent, distribution and condition of these habitats are often indicators of change in the surrounding environment. An assessment of intertidal (mangrove and saltmarsh) and subtidal (seagrass) habitats was included as part of the EEMP.

2.2.3.1 Mangroves and saltmarsh

For the purposes of assessment, the Logan River estuary was divided into seven discrete regions (Zones A-G):

1. Zone A – encompasses part of the Ramsar-listed communities in southern Moreton Bay adjacent to the mouth of the Logan River estuary
2. Zone B - encompasses Ramsar-listed communities at the mouth of the Logan River estuary, including Lagoon Island
3. Zone C - the lower stretch of the Logan River estuary between the Carbrook Wetland of National Significance (Zone E) and the mouth of the Logan River. Zones A-C historically contained the majority of the saltmarsh communities (Connolly et al. 2006).
4. Zone D - the Ramsar-listed Serpentine Creek Wetland
5. Zone E - the Carbrook Wetland of National Significance
6. Zone F - the stretch of the Logan River above the Albert River confluence, which typically has a narrow fringe of mangroves along the river banks
7. Zone G - the upper extent of mangroves in the Logan River (Figure 2.4).

The linear extent of intertidal habitat along the length of the Logan River Estuary monitoring zone is illustrated in Appendix C, showing presence/absence from 2009 to 2017.

Figure 2.4: Habitat assessment zones

High-resolution satellite imagery of the area (2009 to 2017) was used to estimate the extent of mangrove and saltmarsh habitat in each of the regions described above. Image analysis techniques in the ERDAS Imagine and ArcGIS software packages were used to complete this assessment, with key analytical steps involving:

a) Image selection
b) Image classification

c) Post processing
d) Reporting zone calculations.

These methods are further described in Appendix B. Trigger levels assigned to the habitat assessment was based upon the Moreton Bay Ecological Character Description (BMT WBM, 2008), which identified interim limits of acceptable change in mangrove habitats as <10% in area. If change greater than 10% was detected in any of the defined zones, the approach for assessing the cause of change was based on assessment and monitoring tools developed by Duke *et al.* (2003). This approach categorised causes of change based on main four types of disturbance, including:

e) Direct – intended and obviously human related
f) Direct – unintended and obviously human related
g) Indirect – unintended and less obviously human related
h) Not obviously human related, if at all.

If results determined that geographical changes in intertidal and/or sub-tidal habitat was greater than 10% area within any of the assessment zones (compared to the baseline 2009 imagery), further asssesment should be implemented to determine the cause of change, using the methodology developed by Duke *et al*. (2003).

2.2.3.2 Seagrass habitat

The EHMP, carried out in collaboration with SEQ Healthy Land and Water, has a standard methodology for periodic assessment of seagrass depth range (Healthy Land and Water, 2009). The seagrass depth range (SDR) is the difference (in metres) between the upper and lower depth of the seagrass *Zostera muelleri* subspecies *capricorni* at a site. This seagrass is the most common species in the south east Queensland region and the SDR monitoring technique is used as an indicator of ecosystem health.

Currently there are 18 SDR sites in the Moreton Bay region. Two of these long-term SDR sites are located adjacent to the lower Logan River estuary, at Long Island (Southern Moreton Bay site code E002010) and Pannikin Island (Southern Moreton Bay site code E002018).

Data from the Long Island and Pannikin Island sites (provided by Healthy Land and Water) was used for the seagrass habitat assessment. Seagrass depth range data is reported under the EEMP for reference and is used to support the deliberations of the SEP in the event of exceedances. No trigger values for action currently exist.

2.2.4 Fisheries productivity

Estuarine fisheries productivity for the EEMP is monitored primarily through fisheries-independent trial fishing for mud crabs. Available commercial fishers' catch and effort logbook data provided by the Department of Agriculture and Fisheries (DAF) are used as supplementary information.

2.2.4.1 Mud crab sampling - the white spot disease outbreak

The targeted mud crab surveys could not be completed in 2017, as a result of the Biosecurity Emergency Order (BEO) that was implemented in the Logan estuary. The BEO was declared on 11 December 2016 by the Queensland Government, as a quarantine restriction in response to the white spot disease outbreak in the Logan River. Restrictions were placed on commercial and recreational users of the Logan estuary, including the use of vessels and sampling apparatus in the quarantined area. Permission to enter the quarantined area to conduct the mud crab surveys was granted by the Queensland Department of Agriculture and Fisheries (DAF) and the Queensland Parks and Wildlife Service (QPWS) in March, however flooding in the Logan River prevented the surveys going ahead. Consultation on this component of the EEMP was undertaken by Seqwater with the Department of the Environment and Energy.

2.2.5 Fisheries assessment

Analysis of available commercial fishers' catch and effort logbook data collated by DAF is used for part of the EEMP annual assessment. Figure 2.5 shows the locations for data which is provided by DAF for the 30-minute grid cell (W38) and the aggregated six-minute cells (W38.8, W38.9, W38.13 and W38.14). W38 data is collected for the commercial trawl, net and pot fisheries to provide data on fisheries trends in southern Moreton Bay. Data for the aggregated six-minute cells provide a more focused view of the region in the lower Logan River estuary and areas around the Logan River mouth.

As outlined in the EEMP, commercial fisheries data are provided as supporting information only, and are not relied upon as an indicator of estuarine fisheries production or health. Due to the confidentiality agreement between DAF and commercial fishers, no data are provided if fewer than five boats report catches. There are no set trigger values for mud crabs.

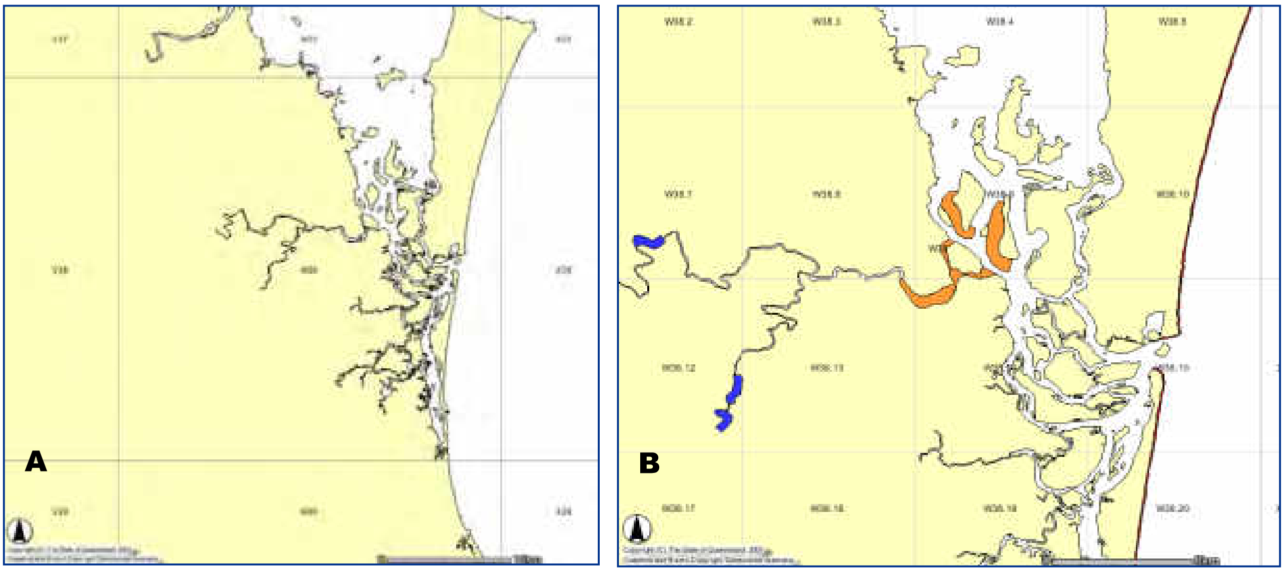


Figure 2.5: Queensland Department of Agriculture and Fisheries map of commercial fisheries grid W38 (A) and map of six-minute commercial fisheries grid, encompassing the Logan estuary and surrounding waters* (B).

*Orange highlights indicate the DAF Long Term Monitoring Program mud crab sampling locations.

3. Results

Results for the Wyaralong Dam EEMP 2017 annual monitoring program are provided below for Logan River estuary flow, water quality, habitat assessment and estuarine fisheries productivity.

3.1 Weather

Queensland experienced its warmest year on record during 2017, and some areas of the east coast received above average rainfall (BOM, 2018a; Figure 3.1). Little rainfall occurred during February, until severe tropical cyclone Debbie crossed the Whitsunday Islands on 28 March. This produced torrential rainfall across eastern Queensland from Bowen to the southeast, with the highest daily rainfall occurring at many locations during March. This resulted in one of the largest floods in recent times for the Logan-Albert Rivers, with new record flood levels set along the Logan River at Beaudesert and Maclean Bridge (BOM, 2018d). In the Albert River, a new flood record was set at the Bromfleet gauging station, and Beenleigh experienced its highest flood since 1887 (BOM, 2018d). Annual rainfall recorded at the Logan City Water Treatment Plant station (site 040854, adjacent to the Logan River) in 2017 was 1,254 mm, compared to 712 mm in 2016 (BOM, 2018c). Rainfall records from this station peaked at 405.6 mm, in the end of March (Figure 3.2).

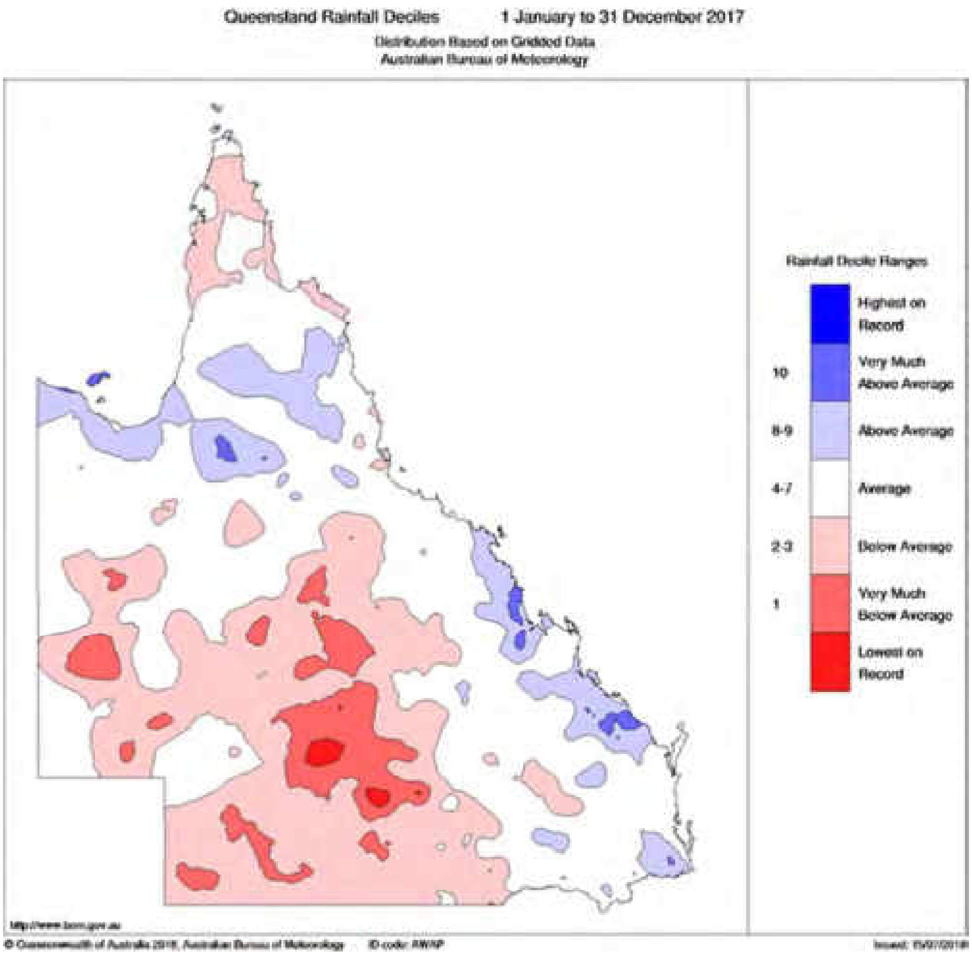


Figure 3.1: Queensland rainfall deciles in 2017 (BOM, 2018b).

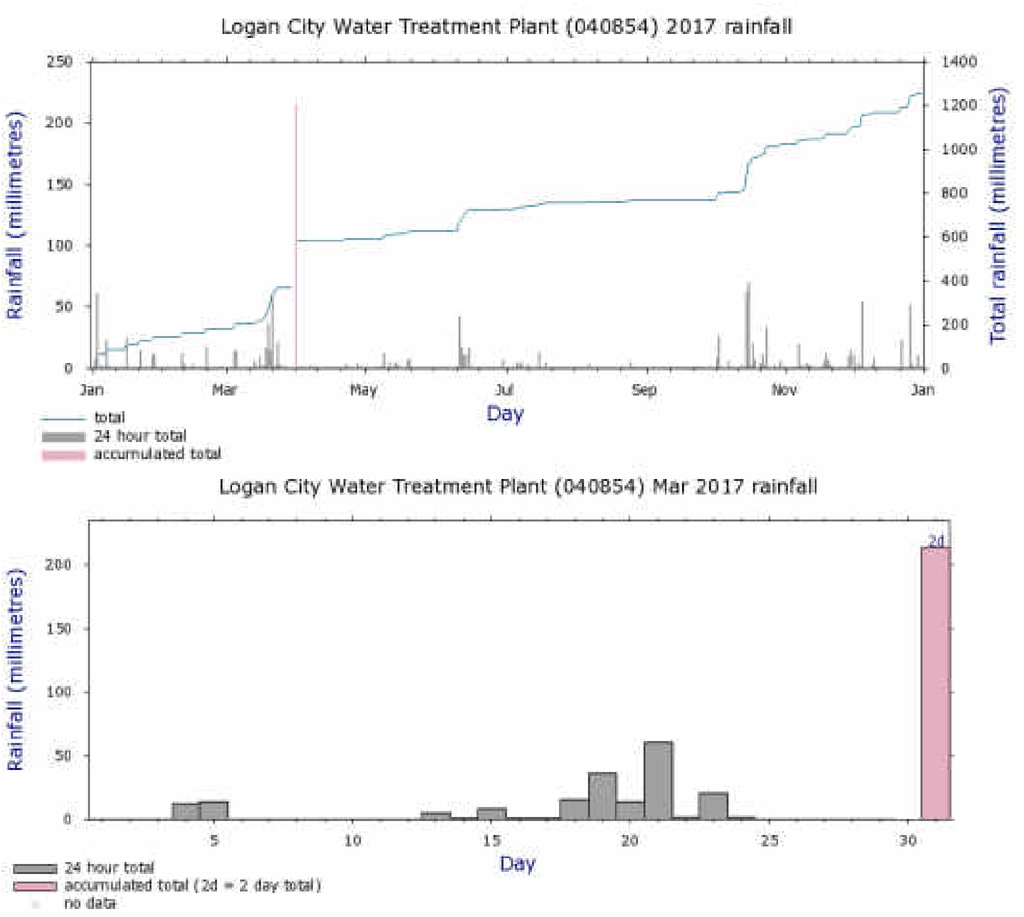


Figure 3.2: Monthly rainfall recorded at the Logan City Water Treatment Plant in 2017 (top) and in March 2017 (bottom) (Source: BOM 2018c).

3.2 River flow

Mean daily river flow data from the Yarrahappini and Forest Home gauge stations in the Logan River catchment, Army Camp gauge station in the Coomera River catchment, and Bromfleet gauge station in the Albert River catchment are presented in Figure 3.3 and Figure 3.4. The flow data from the Logan, Albert and Coomera River catchments demonstrate highly correlated flow patterns. This demonstrates the influence that periods of high and low rainfall events have on mean daily flow, and that flow response has not been noticeably altered within the Logan River subsequent to construction of the Wyaralong Dam (i.e. flow response remains highly correlated with the adjacent unimpounded drainages).

Overall mean flow was higher in 2017 than in 2016. Highest flows were associated with severe tropical cyclone Debbie at the end of March and early April, which is evident at all flow gauging stations. Flooding at all four stations was recorded as follows:

- Major flooding in the Logan River at Yarrahapinni station (3,102 cumecs mean flow on 31 March and 1,813 cumecs on 1 April).
- Minor flooding in the Logan River at Forest Home (244 cumecs on 30 March).
- Moderate flooding in the Albert River at Bromfleet station (650 cumecs on 30 March and 1,091 cumecs on 31 March).

- Minor flooding in the Coomera River at Army Camp station (265 cumecs on 30 March and 123 cumecs on 31 March).

Mean daily flow rates for each catchment as well as the indicative minor and moderate flood levels for each gauging station as defined by Bureau of Meteorology flood classifications (BOM, 2012) are illustrated in Figure 3.4.

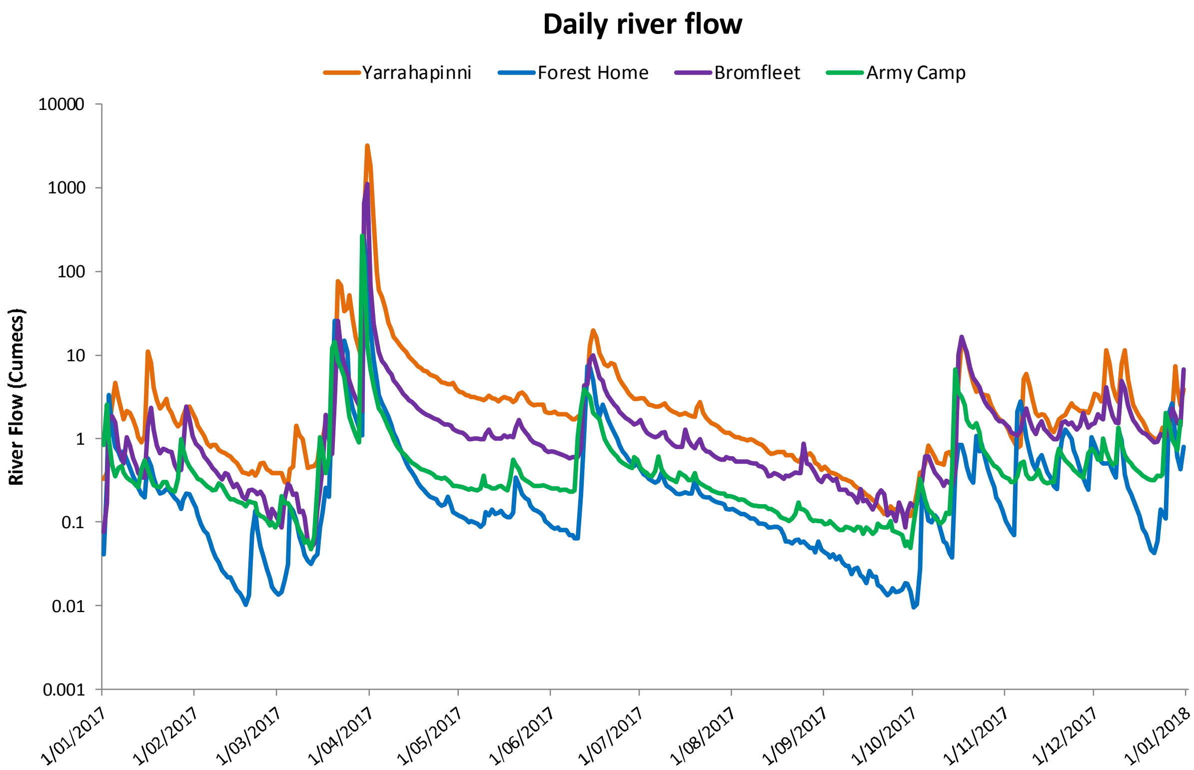


Figure 3.3: Mean daily flows from 1 January 2017 to 31 December 2017 at Yarrahappini, Forest Home, Bromfleet and Army Camp gauging stations, presented on a log scale.

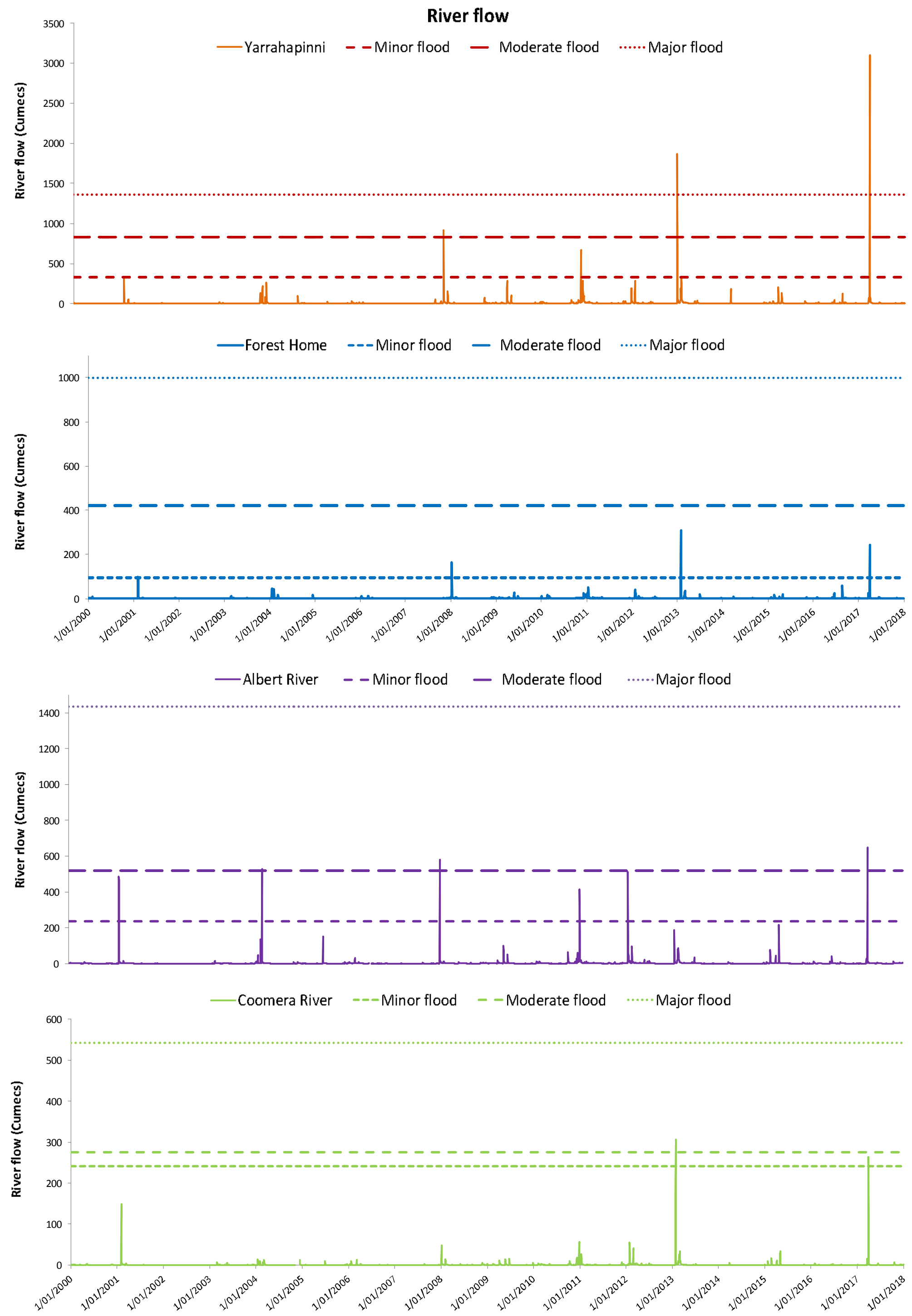
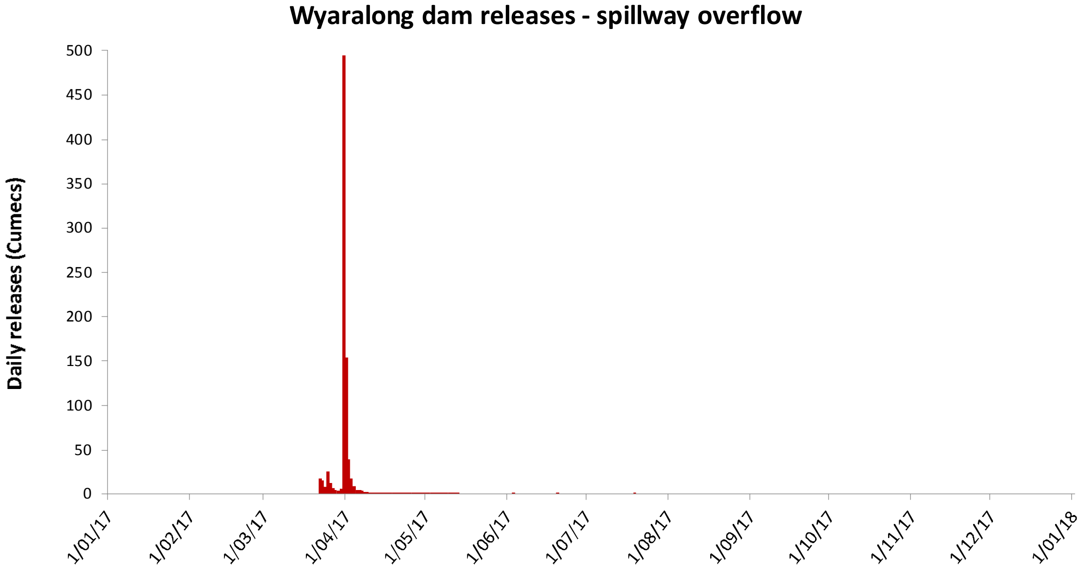


Figure 3.4: Mean daily flows from 1 January 2000 to 31 December 2017 at Yarrahappini (Lower Logan River), Forest Home (Upper Logan River), Bromfleet (Albert River) and Army Camp (Coomera River) gauging stations[1]. 1 - Flood levels developed by BOM (2012)

3.2.1 Wyaralong dam and Cedar Grove weir water releases

Water releases from Wyaralong Dam and Cedar Grove Weir in 2017 are presented in Figure 3.5 and Figure 3.6. The largest releases from the Wyaralong dam spillway occurred after the flood event in early April, with 495 and 154.5 cumecs released on 1 and 2 April, respectively. Total flows at the spillway were higher than in 2016, where a maximum release of 37 cumecs occurred in August (Jacobs, 2017). Other minor releases from Wyaralong Dam occurred throughout the year, as shown in Figure 3.5.



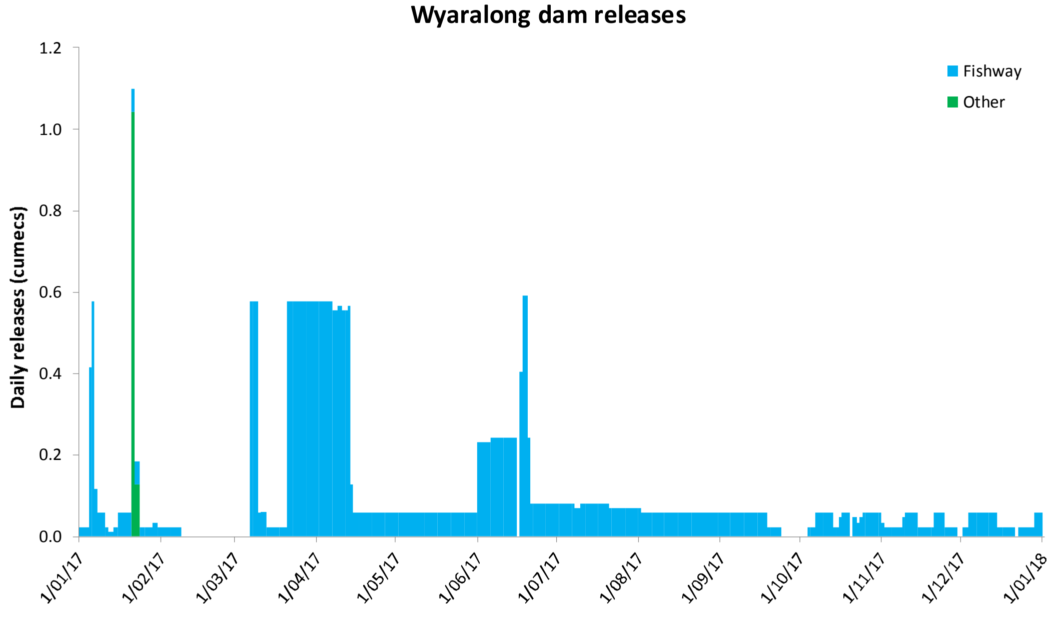
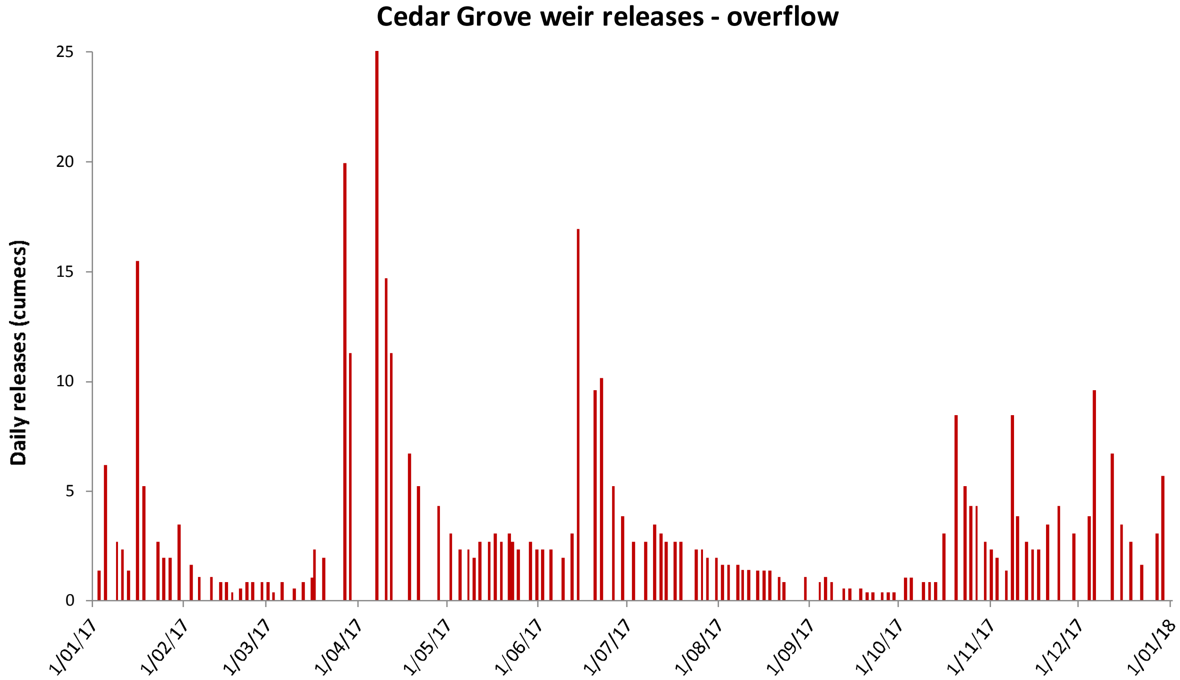


Figure 3.5: Total daily water releases from Wyaralong dam from 1 January 2017 to 31 December 2017.

Water releases from Cedar Grove Weir at the spillway in 2017 ranged from 0.4 to 25 cumecs, with the highest releases occurring in January, March, April and June (Figure 3.6). Overflow from the spillway was lower in 2017 (407 cumecs) than recorded in 2016 (806 cumecs). Fishway releases also occurred throughout the year, but at much lower volumes as illustrated in Figure 3.6.



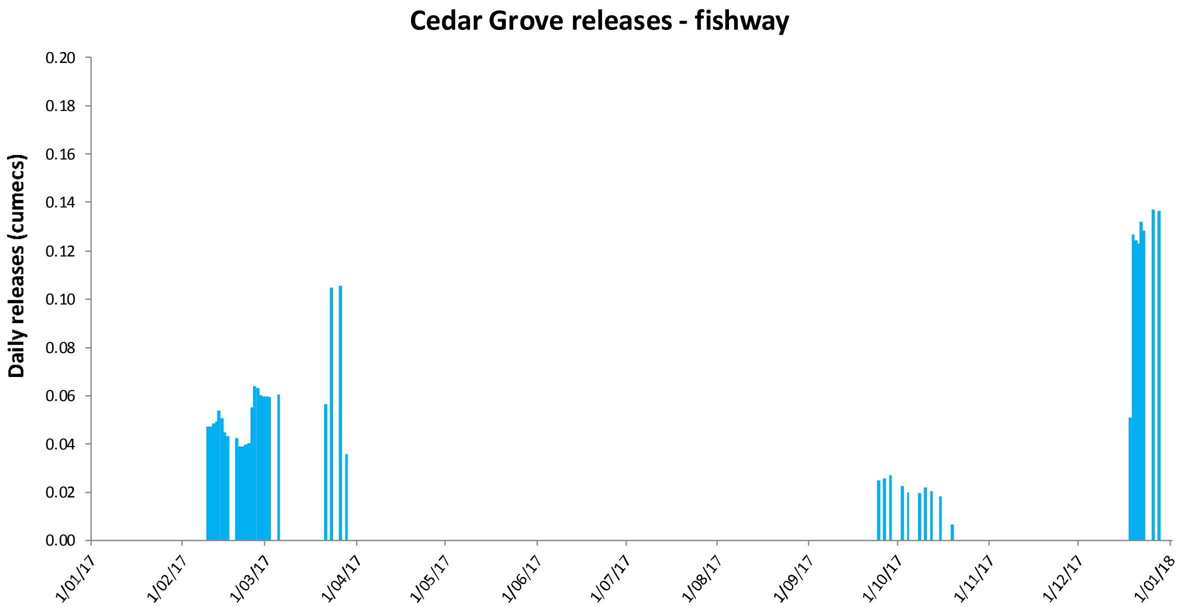


Figure 3.6: Total daily water releases from Cedar Grove weir from 1 January 2017 to 31 December 2017.

3.3 Water quality

3.3.1 Logan River

Water quality results for the Logan River remained below the 80th percentile operational trigger values throughout 2017 (see Table 3.1 and Appendix D). Nutrient concentrations fell *below* the lower operational trigger values in the Logan River above the confluence of the Albert River (concentrations of total nitrogen, oxidized nitrogen, total phosphorus and filterable phosphorus were below the 20th percentile trigger values) for most of the year. Previous assessment of these improved nutrient concentrations was completed by the SEP in 2013. They concluded that the decreases in nutrients may be attributable to a combination of:

- Diffuse pollution from the catchment being contained within the Wyaralong Dam
- Increased flow enabling nutrients from Loganholme STP to flush through the system and reach Moreton Bay, subsequently reducing the residence time for point-source pollution
- Improvement in the functioning of Loganholme STP and reduced emissions.

The SEP recommended that no action was required, on the basis that the low exceedances are in line with Healthy Land and Water's strategic goals and are of benefit the environment.

3.3.2 Reference system data

Water quality data for the Albert River and Coomera River systems are provided in Table 3.2 and Table 3.3. Results showed no significant change in ambient water quality for either system in 2017. Total phosphorus fell slightly below the locally derived trigger values of 0.18 mg/L and 0.019 mg/L in the Albert and Coomera Rivers, respectively. Chlorophyll-a also fell slightly below trigger value of 2.0 µg/L in August and September in the Coomera River. These small improvements in water quality may be related to increased flushing after the rainfall events early in the year.

Table 3.1: Logan River eight-month rolling median values and operational trigger values for water quality in 2017.

Logan River estuary	Water quality parameter	Water quality trigger values 20th percentile 2000-2009	Water quality trigger values 80th percentile 2000-2009	February	March	May	August	September	October	November	December^
Logan River estuary **Above Albert River** confluence 13 - 33 km *AMDT*	Chlorophyll-a (µg/L)	**2.2**	**9.1**	no data	4.1	5.2	6.0	4.3	4.8	5.1	4.9
	Conductivity at 25 °C (mS/cm)	**0.5**	**26.2**	2.5	4.2	2.6	2.9	4.6	6.7	4.3	4.1
	Secchi depth (m)	**0.2**	**0.6**	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.3
	Nitrogen (ammonia) as N (mg/L)	**0.01**	**0.14**	no data	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Nitrogen (organic) as N (mg/L)	**0.36**	**0.66**	no data	0.40	0.43	0.41	0.42	0.42	0.39	0.40
	Nitrogen (oxidised) as N (mg/L)	**0.28**	**0.81**	no data	0.31	0.27^	0.21^	0.18^	0.17^	0.16^	0.18^
	Nitrogen (total) as N (mg/L)	**0.79**	**1.50**	no data	0.8	0.7^	0.64^	0.61^	0.58^	0.56^	0.58^
	Oxygen per cent saturation (%)	**65**	**86**	79	79	82	82	79	79	82	82
	pH (unit)	**7.4**	**7.8**	7.7	7.7	7.7	7.8	7.7	7.7	7.7	7.7
	Phosphorus (filterable reactive) as P (mg/L)	**0.14**	**0.42**	no data	0.2	0.14	0.14	0.12^	0.12^	0.12^	0.13^
	Phosphorus (total) as P (mg/L)	**0.26**	**0.60**	no data	0.24^	0.22^	0.18^	0.18^	0.18^	0.16^	0.18^
	Temperature (°C)	**18**	**27**	25	25	25	27	27	27	25	25
	Turbidity (NTU)	**24**	**160**	66	61	44	40	32	30	29	28
Logan River estuary **Below Albert River** confluence 0 - 11 km *AMDT*	Chlorophyll-a (µg/L)	**1.9**	**5.9**	2.2	2.0	2.0	2.4	2.3	2.8	2.9	2.9
	Conductivity at 25 °C (mS/cm)	**30.6**	**51.4**	43.6	47.8	46.9	47.1	48.5	48.7	47.2	43.6
	Secchi depth (m)	**0.5**	**1.5**	0.9	0.8	0.7	0.7	0.6	0.7	0.7	0.8
	Nitrogen (ammonia) as N (mg/L)	**0.004**	**0.073**	no data	0.02	0.02	0.01	0.01	0.01	0.004	0.003^
	Nitrogen (organic) as N (mg/L)	**0.18**	**0.37**	no data	0.24	0.23	0.23	0.23	0.23	0.23	0.26
	Nitrogen (oxidised) as N (mg/L)	**0.02**	**0.34**	no data	0.07	0.07	0.07	0.03	0.03	0.06	0.09
	Nitrogen (total) as N (mg/L)	**0.22**	**0.77**	no data	0.33	0.33	0.34	0.28	0.28	0.30	0.32
	Oxygen per cent saturation (%)	**79**	**97**	89	91	91	91	91	91	92	91
	pH (unit)	**7.7**	**8.1**	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.8
	Phosphorus (filterable reactive) as P (mg/L)	**0.03**	**0.14**	no data	0.06	0.05	0.05	0.04	0.04	0.05	0.05
	Phosphorus (total) as P (mg/L)	**0.05**	**0.20**	no data	0.07	0.07	0.07	0.06	0.06	0.07	0.07
	Temperature (°C)	**18**	**26**	24	24	24	25	26	26	26	26
	Turbidity (NTU)	**5**	**23**	17	13	13	13	14	15	13	12

** No water quality data are available for January, April, June or July. Sampling in these months was removed from the Healthy Land & Water monitoring program. Rolling medians are comprised of data collected from eight months of the year presented over a 12-month period. Water quality data could not be collected for some parameters during February, due to the Queensland Fisheries Biosecurity closures, as a result of the White spot disease outbreak in the Logan River Estuary (https://www.daf.qld.gov.au/animal-industries/animal-health-and-diseases/a-z-list/white-spot-disease). ^ Data below locally derived trigger value.*

Table 3.2: Albert River 2017 monthly eight-month rolling median values and operational trigger values for water quality.

Albert River	Water quality parameter	Water quality trigger values		February	March	May	August	September	October	November	December
		20th percentile 2000-2009	80th percentile 2000-2009								
Albert River	Chlorophyll-a (µg/L)	**2.7**	**17.8**	3.6	3.7	3.7	3.8	3.7	4.4	4.6	5.1
	Conductivity at 25 °C (mS/cm)	**0.4**	**28.8**	10.5	11.7	10.1	8.9	11.4	12.4	11.1	8.9
	Secchi depth (m)	**0.2**	**0.6**	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5
	Nitrogen (ammonia) as N (mg/L)	**0.004**	**0.095**	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02
	Nitrogen (organic) as N (mg/L)	**0.32**	**0.58**	0.38	0.38	0.39	0.38	0.40	0.41	0.35	0.37
	Nitrogen (oxidised) as N (mg/L)	**0.058**	**0.524**	0.22	0.20	0.19	0.14	0.13	0.13	0.13	0.13
	Nitrogen (total) as N (mg/L)	**0.54**	**1.10**	0.74	0.66	0.62	0.59	0.57	0.58	0.53	0.54
	Oxygen per cent saturation (%)	**66**	**94**	81	81	81	81	82	82	83	80
	pH (unit)	**7.3**	**7.8**	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	Phosphorus (filterable reactive) as P (mg/L)	**0.09**	**0.26**	0.18	0.17	0.16	0.13	0.12	0.12	0.10	0.12
	Phosphorus (total) as P (mg/L)	**0.18**	**0.38**	0.26	0.24	0.23	0.21	0.17^	0.16^	0.15^	0.17^
	Temperature (°C)	**18**	**27**	25	25	25	25	25	25	24	24
	Turbidity (NTU)	**17**	**74**	37	31	32	26	20	20	17	17

** No water quality data are available for January, April, June or July. Sampling for these months was removed from the Healthy Land and Water monitoring program. Rolling medians are comprised of data collected from eight months of the year presented over a 12-month period. ^ Data below locally derived trigger value.*

Table 3.3: Coomera River 2017 eight-month rolling median values and operational trigger values for water quality.

Coomera River estuary	Water quality parameter	Water quality trigger values		February	March	May	August	September	October	November	December
		20th percentile 2000-2009	**80th percentile 2000-2009**								
Coomera River	Chlorophyll-a (µg/L)	**2.0**	**5.7**	2.2	2.1	2.1	1.9^	1.8^	2.2	2.2	2.2
	Conductivity at 25°C (mS/cm)	**39.4**	**52.8**	51.6	52.2	51.1	51.2	52.2	52.2	51.4	50.8
	Secchi depth (m)	**1.0**	**1.8**	1.4	1.4	1.3	1.3	1.4	1.4	1.4	1.4
	Nitrogen (ammonia) as N (mg/L)	**0.001**	**0.011**	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	Nitrogen (organic) as N (mg/L)	**0.16**	**0.30**	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
	Nitrogen (oxidised) as N (mg/L)	**0.001**	**0.011**	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	Nitrogen (total) as N (mg/L)	**0.17**	**0.33**	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25
	Oxygen per cent saturation (%)	**90**	**100**	96	96	96	94	94	92	92	92
	pH (unit)	**7.8**	**8.0**	7.9	7.9	7.9	8.0	7.9	7.9	7.9	7.8
	Phosphorus (filterable reactive) as P (mg/L)	**0.005**	**0.013**	0.008	0.008	0.007	0.007	0.008	0.007	0.007	0.005
	Phosphorus (total) as P (mg/L)	**0.019**	**0.038**	0.017^	0.022	0.017^	0.015^	0.014^	0.013^	0.013^	0.012^
	Temperature (°C)	**19**	**26**	24	24	24	24	23	25	25	25
	Turbidity (NTU)	**3**	**8**	5	4	4	4	4	4	4	4

** No water quality data are available for January, April, June or July. Sampling for these months has been removed from the Healthy Land and Water monitoring program. Rolling medians are comprised of data collected from eight months of the year presented over a 12-month period. ^ Data below locally derived trigger value.*

3.4 Mangroves and saltmarsh

The areas of mangrove and saltmarsh habitat for each of the seven reporting zones (A-G) and monitoring years (2009 to 2017) are presented in Table 3.4. Data shows the area (in hectares) classified as mangrove/saltmarsh habitat and the mean normalised difference vegetation index (NDVI). The NDVI results are discussed in section 3.4.1. The technical methods used to determine the areas and potential health of these habitats are provided in Appendix B.

Table 3.4: Areas of classified mangrove/saltmarsh habitat and mean NDVI for reporting zones A-G from 2009 to 2017

Reporting zone	Classified area of mangrove/saltmarsh habitats (ha)*									% Habitat change (2009 to 2017)	% Habitat change (2016 to 2017)
	2009	2010	2011	2012	2013	2014	2015	2016	2017		
A	829	829	833	831	831.5	831.4	889.0	810.9	827.0	-0.2	2.0
B	766	760	758	764	755.3	730.3	772.0	706.3	736.8	-3.8	4.3
C	112	111	113	113	111.8	109.9	115.1	113.8	114.1	1.9	0.3
D	3	3	3	3	2.72	2.69	2.85	2.75	2.97	-1.1	8.1
E	66	66	67	66	66.7	66.8	68.1	68.6	70.7	7.1	3.1
F	44	44	46	46	45.9	47.4	48.3	48.5	53.0	20.6	9.4
G	3	3	3	3	3.15	3.44	3.45	3.07	3.01	0.3	-2.0

Reporting zone	Mean NDVI									% NDVI Change (2009-2017)	% NDVI Change (2016/2017)	Mean NDVI (2009-2017)
	2009	2010	2011	2012	2013	2014	2015	2016	2017			
A	0.48	0.58	0.58	0.61	0.59	0.58	-	0.56	0.52	8.3	-6.24	0.56
B	0.50	0.59	0.61	0.61	0.61	0.57	-	0.56	0.54	7.0	-3.82	0.57
C	0.53	0.62	0.60	0.63	0.59	0.59	-	0.59	0.60	12.4	0.74	0.59
D	0.56	0.6	0.59	0.72	0.57	0.62	-	0.64	0.63	13.4	-0.44	0.62
E	0.6	0.71	0.64	0.71	0.64	0.66	-	0.64	0.66	9.4	3.06	0.66
F	0.57	0.66	0.60	0.64	0.61	0.48	-	0.59	0.60	4.9	1.68	0.59
G	0.59	0.63	0.64	0.63	0.63	0.4	-	0.60	0.65	10.0	8.88	0.60

** Unrounded data provided for area classified as mangrove/saltmarsh for 2013 to 2017. Further breakdown for 2009-2012 data unavailable.*

Habitat change over the duration of the EEMP (2009-2017)

Assessment of area classified as mangrove and saltmarsh habitat found small decreases for zones A (-0.2%), B (-3.8%) and D (-1.1%). These changes remained below the threshold trigger value of 10%. Slight increases occurred for reporting zones C (1.9%), E (7.1%) and G (0.3%), and a larger increase was calculated for zone F (20.6%). Visual inspection of the 2017 classification data showed slightly wider fringes of mangroves in areas along the length of the river's edge in this zone (53 hectares), when compared to the previous year (49 hectares). In 2016, changes to mangrove habitat in zone F was 10.2% (48 to 49 hectares in 2015 and 2016, respectively). Changes to area of mangrove habitat in zone F for the duration of monitoring equate to a total of ~9 hectares over 9 years.

The increases of intertidal habitat in Zone F fall above the 10% threshold, thereby potentially triggering further assessment under the approach identified in the EEMP. This approach was based on the process developed by Duke *et al.* (2003) and outlined in Table 6-1 of the EEMP, which rated disturbance categories and change types, drivers and indicators. Change types identified in this approach primarily related to mangrove/saltmarsh dieback or loss, rather than to increases in vegetation. Category 8 change type refers to an "estuarine shift" in mangroves, where colonization occurs above previously reported upstream limits. This is not reflected in the results for the EEMP assessment, as the observed changes in mangrove vegetation were not isolated to the upper reaches of the estuary, nor are they identified in areas where mangrove habitat was previously unrecorded. Zone G is defined in the EEMP as the area containing the upper extent of mangroves in the Logan

River estuary, and the region that would be used to detect any movement of mangroves upstream. Given that changes to mangrove habitat in zone G were negligible (0.3%), that increases in mangrove habitat in zone F were not isolated to any particular area of the assessment zone, and that NVDI results show improvements in vegetation health (see section 3.4.1), further site investigations are not considered to be warranted. Results did not suggest that construction and operation of the Wyaralong dam has resulted in impacts to mangrove and saltmarsh habitat, nor any upwards incursion of mangroves in the Logan River estuary.

Changes in the distribution of mangroves may relate to many factors, including changes to sediment regimes, nutrient fluxes, chemical pollutant inputs and hydrological regimes (Eslami-Andargoli *et al.* 2010). Research on the effects of rainfall on the spatial distribution of mangroves in the Moreton Bay region was published by Eslami-Andargoli *et al.* in 2010. The research used aerial photography and satellite imagery to compare spatial changes in mangroves over a period of relatively high rainfall (1972-1990) with a significantly drier period (1990-2004). A key finding of the research was that the rate of mangrove expansion significantly increased during periods that experienced higher rainfall. Gradual increases in mangrove habitat observed in the Logan River estuary for the duration of the EEMP program may be partially related to higher rainfall and associated changes to sedimentation that has occurred throughout the catchment since monitoring began in 2010.

Annual Reporting Period (2017)

Imagery analysis for 2017 showed an increase in mangrove/saltmarsh vegetation for zones A to F, and a slight decrease for zone G. Mangrove/saltmarsh communities for reporting zones A to F ranged from 0.3% in zone C (<1ha) to a maximum of 9.4% in Zone F. Results suggest that mangrove communities in Zone F have continued to increase in area since monitoring began. In Zone D, an 8.1% increase was recorded in the intertidal zone. As discussed in previous annual reports, zone D as a very small area of ~3 hectares, and small changes in habitat can have a relatively large impact in percentage terms. In this instance, the net increase area in Zone D equates to approximately 0.2 hectares. Mangrove vegetation in zone G decreased slightly (-2%). Zone G is one of the smallest reporting zones (approximately 3 hectares in total area) and this 2% change equates to 0.06 hectares.

3.4.1 Mean normalised difference vegetation index (NDVI)

The EEMP monitoring program aims to provide an indicator of vegetation health using the established mean normalised difference vegetation index (NDVI) technique. This technique uses a ratio of the red and near infrared light bands to detect vegetation health by detecting the amount of chlorophyll. Areas of higher chlorophyll are associated with more ‘lush’ vegetation. This allows broad-scale analysis of areas for vegetation health monitoring. NDVI yields a ratio between -1 to 1, with vegetation NDVI typically ranging from 0.1 to 0.6. Healthier or ‘greener’ vegetation generally has a value in the higher of the 0.1 to 0.6 value range, whilst vegetation under stress, or dying, generally exhibits values in the lower range of the 0.1 to 0.6 value range. Significant changes in NDVI from year to year or areas of known intertidal habitat that show an NDVI outside the normal range are flagged for further investigation.

NDVI results for the 2017 reporting year are provided in Table 3.4. The NDVI values for 2017 ranged from 0.52 to 0.66. These results fall with the range of “healthy” vegetation and are consistent with results from other years. The change in each reporting zone from 2009-2017 show an overall increase in the vegetation heath indicator. The table also presents an average of NDVI values across all the reporting years (2009-2017) showing that despite variation in NDVI from year to year, the index remains relatively constant. Changes in NDVI values are also measured in percentage terms from the previous year, to give an indication of potential changes in health in each zone from year to year. The percent NDVI change for the 2016-2017 year ranged from -6.24% in Zone A to 8.8% in Zone G. These values do not trigger any reportable changes being below the 10% threshold.

NDVI results for the duration of monitoring (2009-2017) showed that the vegetation health index has increased between 7% and 13%. Monitoring zones C and D had the highest percent change (12% in zone C and 13% in zone D).

3.4.2 Seagrass

Seagrass depth range (SDR) data for Long Island and Pannikan Island are shown in Figure 3.7. The data included SDR from survey sites at Long Island from 1996 to 2017, and at Pannikin Island from 2003 to 2017. SDR is the difference in depth (in metres) between the upper and lower depth limits of the seagrass *Zostera muelleri* subspecies *capricorni* at a site. SDR is a useful indicator of ecosystem health because of the sensitivity of seagrass habitats to changes in water clarity. The seagrass in southern Moreton Bay generally doesn’t occur much deeper than 1 m and has been shown to be highly variable, due to the poor water clarity and inputs from the Logan, Pimpama and Coomera Rivers. For these reasons, seagrass was not chosen as a key indicator of habitat disturbance for the Wyaralong EEMP. It was stipulated that data were to be included in the annual reports but without trigger values.

Results from the EHMP data show that SDR at these locations has fluctuated over time, with a slight downward trend since monitoring began in 1996 (Long Island) and 2003 (Pannikin Island). Decreases in water clarity may contribute to shallower depth range changes in SDR, that have occurred since monitoring for the EEMP commenced in 2010. It may also be correlated with increased rainfall that occurred in south east Queensland since the dam was built. A very wet year was experienced in 2010, followed by extreme flood events in 2011, extensive flooding across parts of SEQ in 2012 and 2013, higher than average rainfall in 2014 and 2015 and significant flooding in 2017. The increased wet periods over recent years, together with rapid increases in urban development in the Logan River catchment that has occurred since data collection began, is likely to have influenced water clarity in the Logan River estuary and downstream inshore waters of Moreton Bay. This results in increased turbidity in the water column, hence reducing light availability for seagrass and the depths at which it can survive.

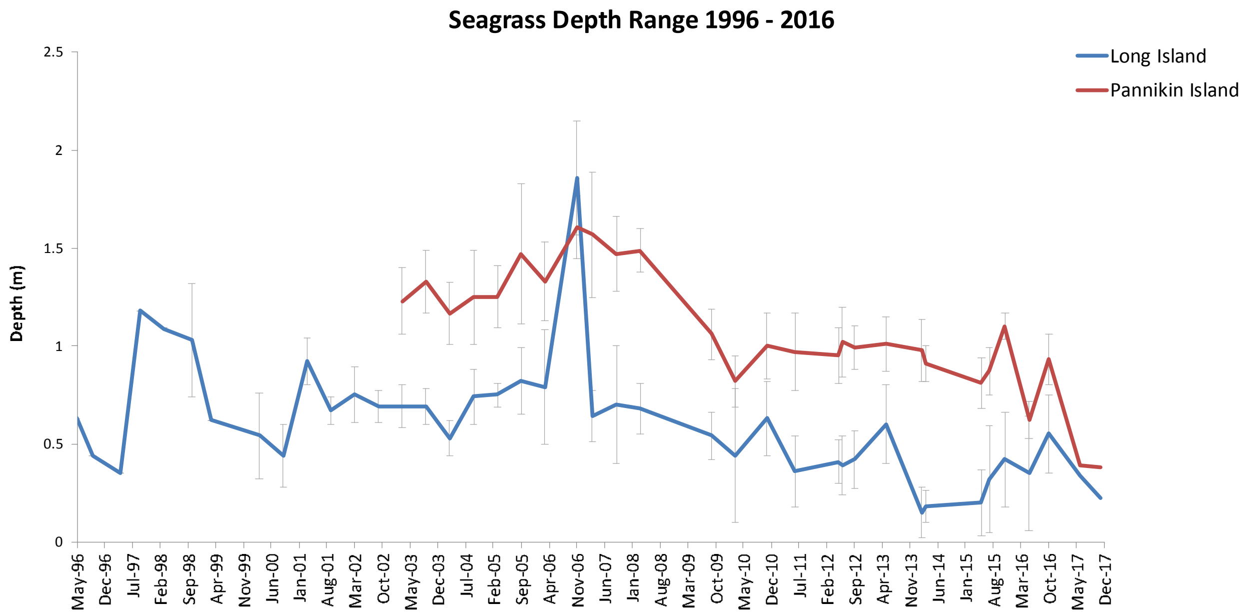


Figure 3.7: Seagrass depth range (SDR) at Long Island (1996-2017) and Pannikin Island (2003 to 2017).

3.5 Estuarine fisheries productivity

Fisheries catch rates for commercial catch grid W38 and the aggregated 6-minute cells W38.8, W38.9, W38.13 and W38.14 are provided below. Results show catch per unit effort (CPUE) using data collated by DAF from 2000 to 2017 for:

- Trawl, pot and net fisheries
- Prawns (bay, eastern, school, greasy, tiger and banana prawns
- Crab fisheries (mud, blue-swimmer)
- Fish (mullet, whiting, flathead).

Productivity in Australian tropical and subtropical estuaries can be related to freshwater flow rates and increases in rainfall events (Robins *et al.* 2005). In December 2016, the outbreak of whitespot in the Logan River resulted in the immediate closure of the Logan River and estuary waters to commercial prawn and crab fishers, and quarantine control across the whole of Moreton Bay, including the Brisbane River. This directly impacted commercial prawn and crab fisheries at a time when the season was nearing its peak in productivity, through loss of access to local wild catch harvest areas and volumes (Ridge Partners, 2017). There is no indication that fisheries productivity has been impacted by operation of the Wyaralong dam. .

Figure 3.8 presents the commercial fisheries CPUE in tonnes/boat-day for the period 1 January 2000 to 31 December 2017 for trawl, pot and net fisheries in commercial catch grid W38 (30-minute grid cell). CPUE for the trawl and net fisheries has fluctuated somewhat over the monitoring period (trawl and net fisheries CPUE of 0.12 and 0.18 in 2010, to a CPUE of 0.13 and 0.13 in 2017, respectively). Pot fisheries have been stable with CPUE fluctuating between 0.02 to 0.04 between 2010 and 2017.

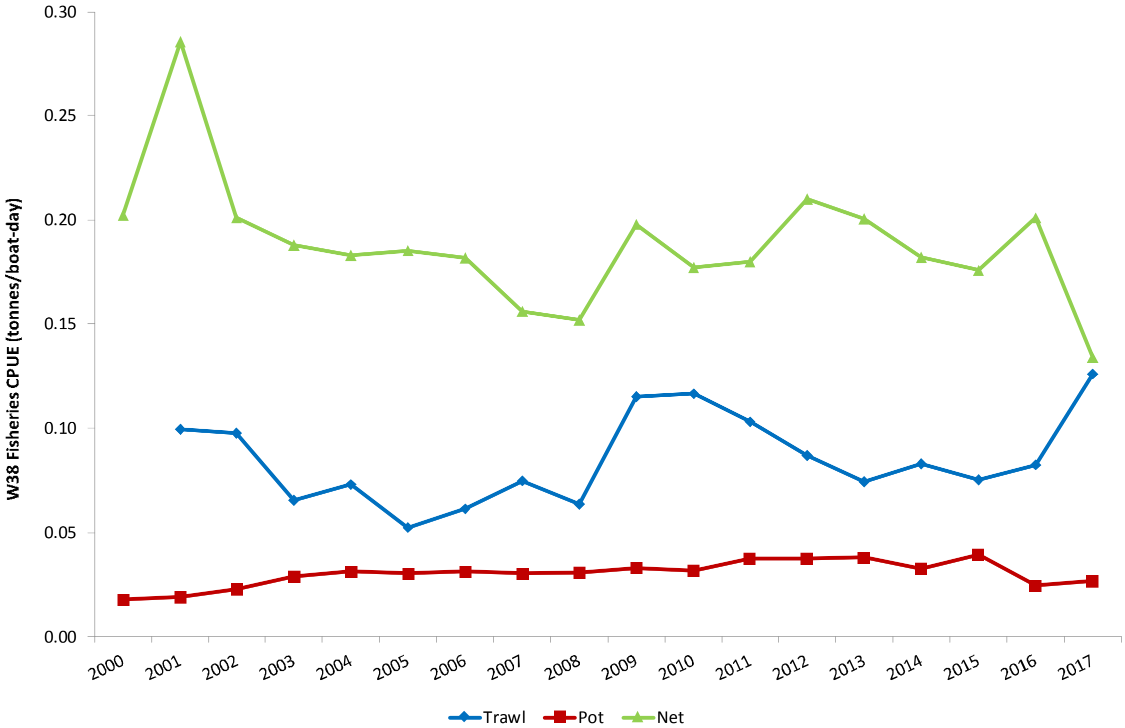


Figure 3.8: Reported CPUE (tonnes/boat-day) from 1 January 2000 to 31 December 2017 in Queensland commercial catch grid W38 for trawl, net and pot fisheries. Data from Queensland Department of Agriculture and Fisheries (DAF).

Figure 3.9 presents the CPUE for pot and net fisheries for the aggregated 6-minute cells W38.8, W38.9, W38.13 and W38.14 for the period from 1 January 2000 to 31 December 2017. CPUE for trawl fisheries is only shown for 2004 to 2010 and 2012, as there were less than five boats working in these areas during other times. Pot fisheries remained relatively stable between 2000 and 2016, with CPUE fluctuating between 0.02 to 0.04, and declining to 0.01 in 2017. Net fisheries CPUE ranged from 0.14 in 2003, to 0.15 in 2012 and 0.08 in 2017. Overall fisheries productivity appears to be similar between the large catch grid (W38) and the aggregated 6-minute cells.

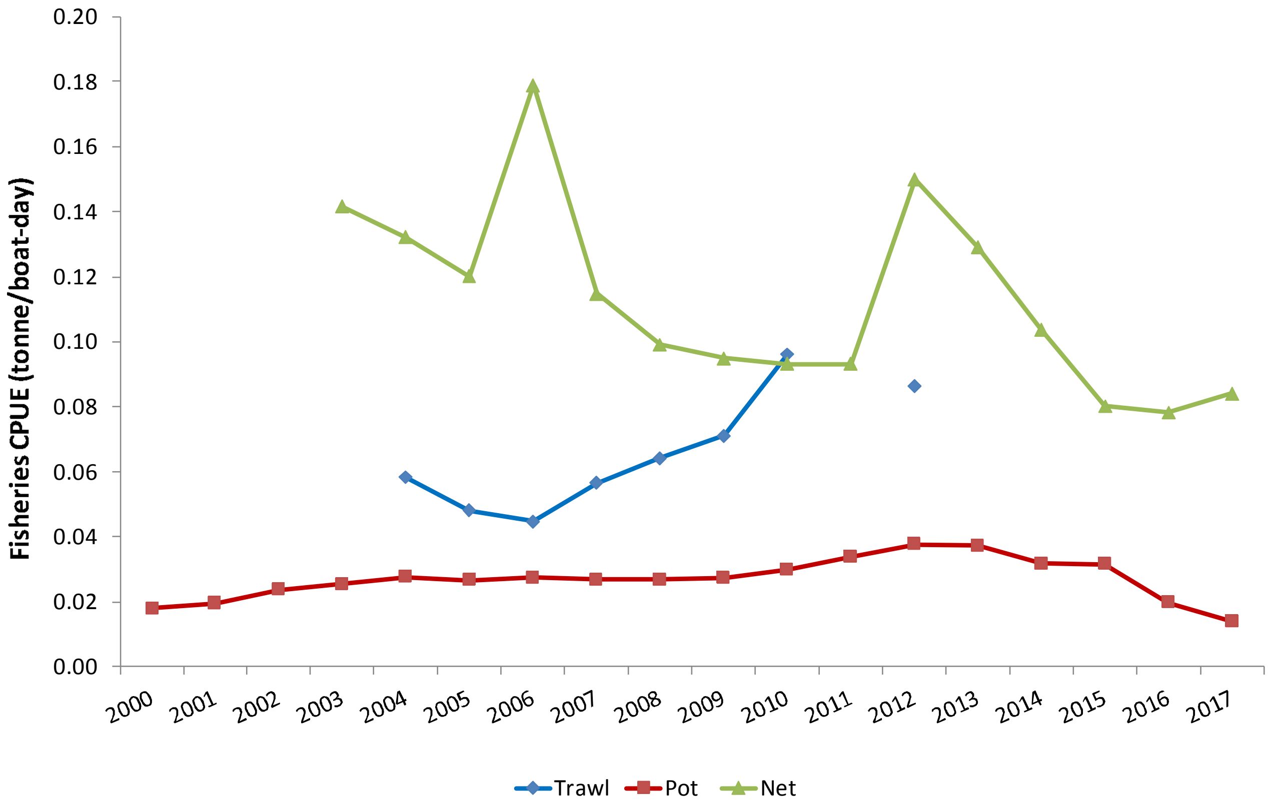


Figure 3.9: Total reported CPUE (tonnes/boat-day) from 1 January 2000 to 31 December 2017 in Queensland commercial aggregate catch cells W38.8, W38.9, W38.13 and W38.14 for trawl, pot and net fisheries. Data are not reported for years in which fewer than five boats report catches of a species. Data sourced from DAF.

Figure 3.10 presents the CPUE for bay, eastern, school, greasy, tiger and banana prawns in commercial catch grid W38 from 1 January 2000 to 31 December 2017. No data are provided in years where fewer than five boats reported catches, therefore results often only include one or two species of prawn. In 2017, no data was available for prawn fisheries in the W38 area. CPUE for all species has fluctuated considerably since 2000, demonstrating the variability of prawns in Moreton Bay. It should also be noted that trawl effort targeting different prawn species can fluctuate dramatically as a function of market conditions. Overall trends during 2017 could not be assessed due to limited data.

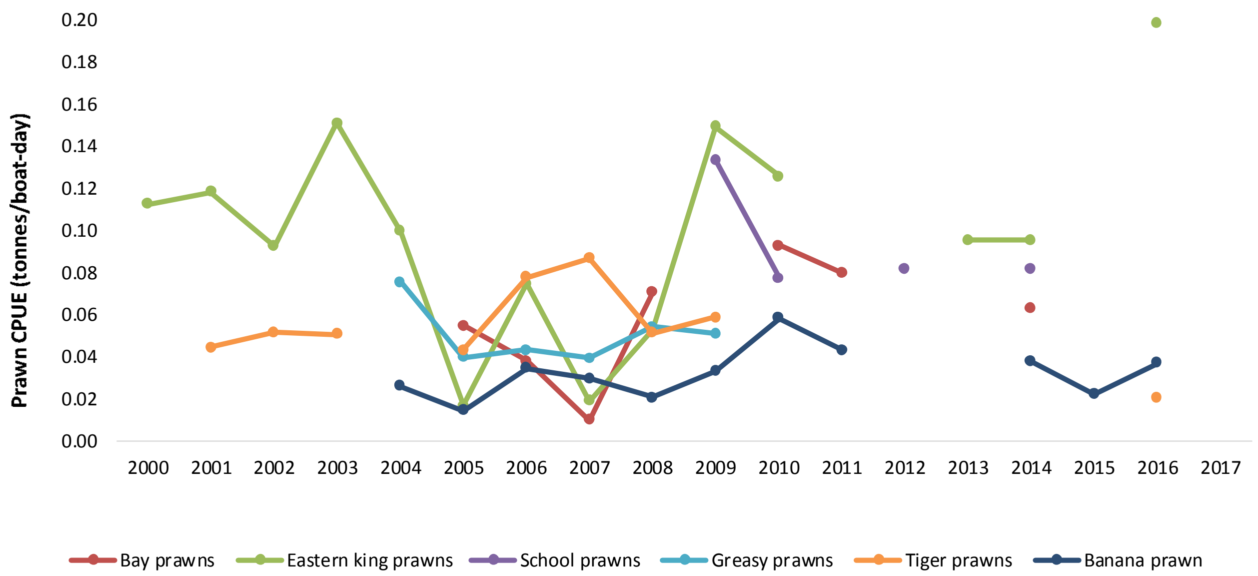
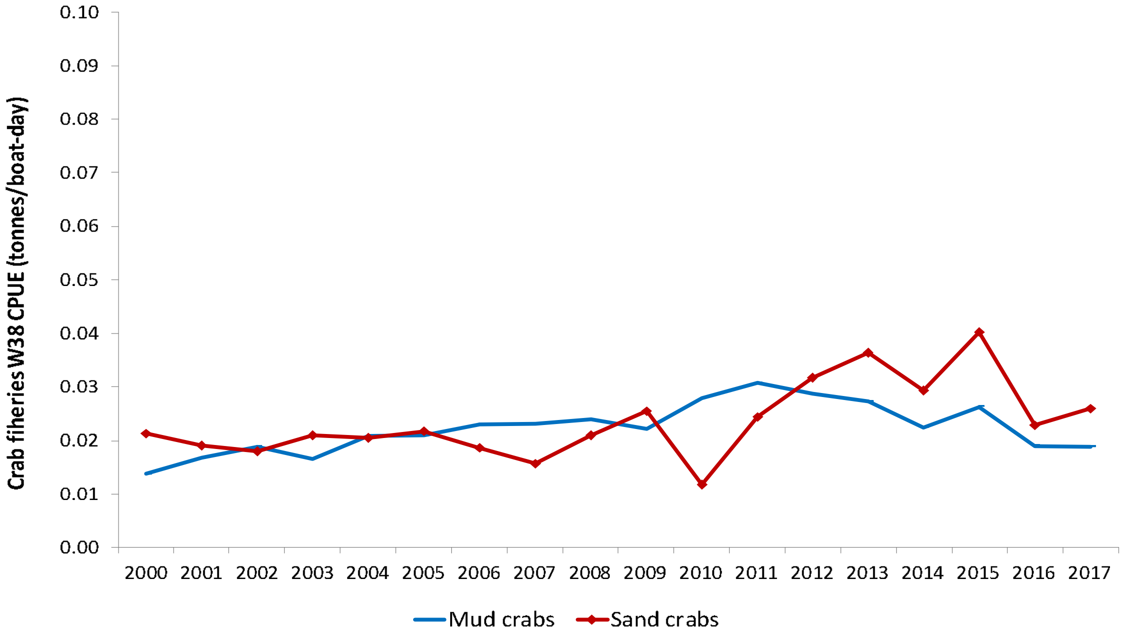


Figure 3.10: Total reported CPUE (tonnes/boat-day) from 1 January 2000 to 31 December 2017 in Queensland commercial catch grid W38. *Data are not reported for years in which fewer than five boats report catches of a species. Data sourced from DAF.*

Figure 3.11 presents the CPUE for mud crabs and sand crabs from 1 January 2000 to 31 December 2017 for commercial catch grid W38 (top) and the aggregated 6 minute cells (W38.8, W38.9, W38.13 and W38.14; bottom). Productivity in these fisheries has been relatively stable with similar catch rates for the 30-minute and 6-minute cells.



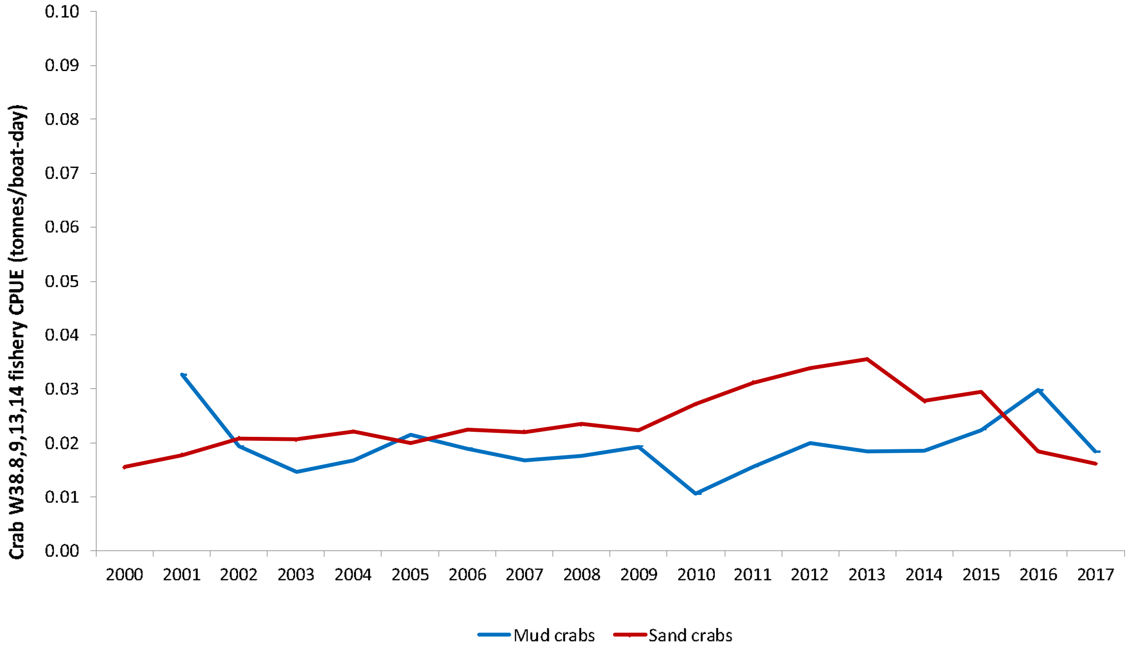
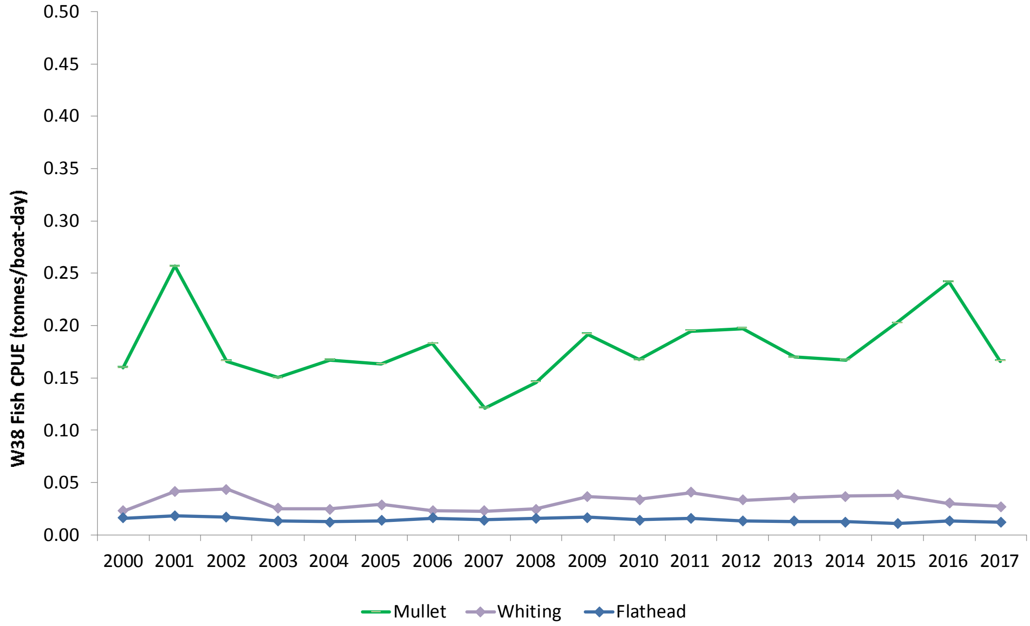


Figure 3.11 Total reported CPUE (tonnes/boat-day) from 1 January 2000 to 31 December 2017 in Queensland commercial catch grid W38 (top) and aggregate catch cells W.38.8, W38.9, W38.13 and W38.14 (bottom) of mud and sand crab species. Data sourced from DAF.

Figure 3.12 presents CPUE from 1 January 2000 to 21 December 2017 for mullet, whiting and flathead in catch grid W38 (top) and the aggregated six-minutes cells (W38.8, W38.9, W38.13 and W38.14; bottom). CPUE for mullet has fluctuated since 2000, while CPUE for whiting and flathead have generally remained stable. Historical whiting and flathead data for the aggregated six-minute cells generally display similar productivity trends to those recorded in the larger catch grid (W38). CPUE in the six-minute cells for mullet was lower than CPUE for mullet in the commercial grid.



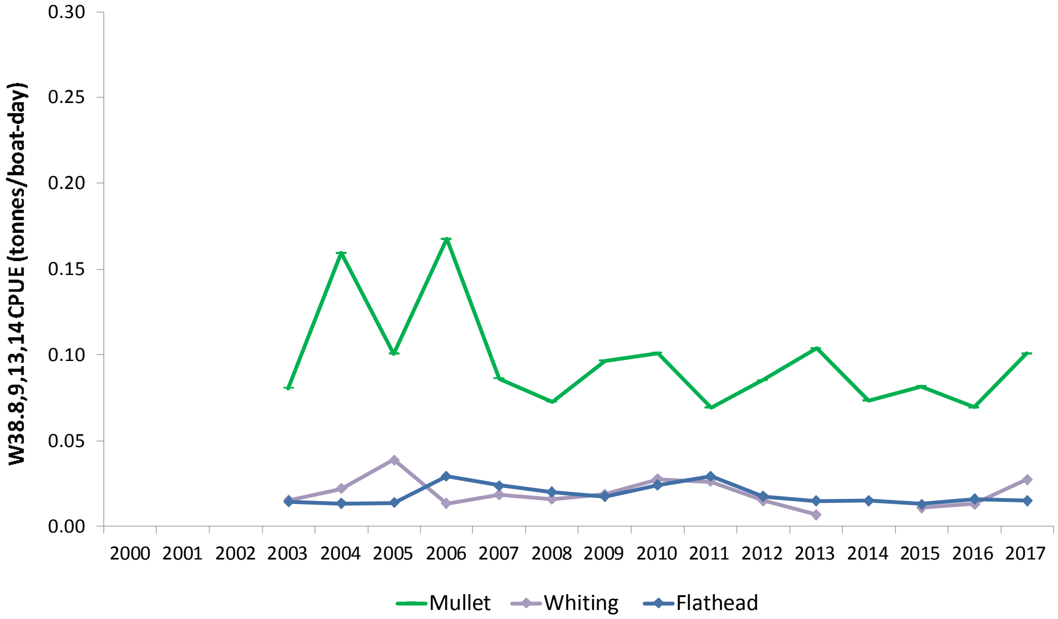


Figure 3.12: Total reported CPUE (tonnes/boat-day) from 1 January 2000 to 31 December 2017 in Queensland commercial catch grid W38 (top) and aggregate six-minute cells W.38.8, W38.9, W38.13 and W38.14 (bottom) for important fin fish species. Data sourced from DAF.

4. Summary

This report documents the 2017 annual monitoring results in accordance with the Wyaralong Dam EEMP, including data on river flow, water quality, habitat assessment and estuarine fisheries productivity. Data from 2017 showed no evidence of impact to ecological conditions in the Logan River estuary or southern Moreton Bay attributable to the operation of Wyaralong Dam. Findings were as follows:

- Queensland experienced its warmest year on record during 2017 with some areas of the east coast receiving above average rainfall. Torrential rainfall occurred across eastern Queensland from Bowen to the southeast at the end of March, as a result of severe tropical cyclone Debbie. The Logan-Albert River systems subsequently experienced one of the largest floods in recent times.
- Overall mean river flow for the Logan-Albert systems was therefore higher in 2017 than in previous years, with flooding recorded at all four gauging stations (major flooding in the Logan River at Yarrahapinni, moderate flooding in the Albert River at Bromfleet station, and minor flooding in the Logan River at Forest Home and in the Coomera River at Army Camp station).
- Water quality results for the Logan River remained below impact trigger values throughout 2017. Nutrient concentrations fell *below* the lower operational trigger values in the section of the Logan River above the confluence of the Albert River. No substantial change in ambient water quality was evident for either the Albert or Coomera River reference systems.
- Mangrove and saltmarsh habitat change assessment between 2009 and 2017 showed increases in reporting zones C (1.9%), E (7.1%), G (0.3%) and F (20.6%), with a slight decrease in reporting zones A (0.2%), B (3.8%) and D (1.1%). Habitat change results did not indicate that construction and operation of the Wyaralong dam has impacted mangrove and saltmarsh habitat in the Logan River estuary. The 2017 reporting period assessment of mangrove and saltmarsh habitat showed increases for zones A to F (0.3% to 9.4%), and a slight decrease for zone G (2%).
- NDVI results for the duration of monitoring (2009-2017) showed that the vegetation health index has improved (increased between 7% and 13%). Monitoring zones C and D had the highest percent change (12% in zone C and 13% in zone D).
- The targeted mud crab surveys could not be completed in 2017 due to the Biosecurity Emergency Order (BEO) that was implemented in the Logan River estuary from the whitespot outbreak. When permission to enter the quarantined area was granted, flooding prevented the surveys going ahead. Consultation with the Department of the Environment and Energy was conducted by Seqwater regarding this matter.
- Results for SDR were consistent with previous years, where SDR fluctuated over time, with a slight downward trend since monitoring began in 1996 (Long Island) and 2003 (Pannikin Island). This may be related to changes in water clarity and turbidity as a result of development within the catchment, as well as increased rainfall and flooding events over recent years, hence reducing light availability for seagrass and the depths at which it can survive.
- Commercial fisheries catch rates in 2017 for trawl, pot and net fisheries in commercial catch grid W38, and pot and net fisheries for the aggregated 6-minute cells W38.8, W38.9, W38.13 and W38.14 remained consistent with previous trends. Results do not show any indication that dam operation has impacted downstream commercial fisheries productivity.

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Appendix A. Management Framework

Seqwater implement the Operational Environmental Management Plans (OEMP), as described in the Environmental Impact Statement, to manage the potential for any negative impacts associated with the project on the Logan River estuary. The EEMP aims to enable early detection of any non-conformity, should it occur. The EEMP is completed in accordance with the CG report Schedule C, Part 4, Condition 21 (e and f) and DoE conditions, which specify the features that, following commissioning of the dam, must be monitored, analysed and reported for a minimum period of five years under the CG conditions and ten years under the DoE conditions.

Seqwater must implement and maintain the EEMP for at least 10 years from operation of the Project. During this time Seqwater undertake and provide the necessary non-conformity, corrective and preventative monitoring and actions and reporting as required by the conditions set out by the CG and DoE and included in the EEMP.

A.1 Incidence and exceedance reporting

Seqwater established, implemented and maintained procedures for dealing with actual and potential nonconformity, and for undertaking the necessary corrective actions in the event of a project impact. This procedure, as illustrated in the Decision Framework outlined below, included:

- Periodic evaluation of compliance through monitoring for exceedances and annual performance reviews
- Expert analysis of project influences on any identified exceedances
- Reviews of OEMP and Construction Environment Management Plan implementation and risk matrices
- Evaluation and implementation of corrective actions if required
- Reporting of incidences and actions to the CG and DoE and the documentation of all project activities.

During construction and the first 12 months of dam operation, a more sensitive water quality criteria threshold of three consecutive months lying outside the 5^{th} or 95^{th} percentile was applied to enable a quick response to any potential project impacts. After the initial 12 months of operation, the trigger became an exceedance of the rolling 12-month median (outside of the 20^{th} or 80^{th} percentiles of the threshold criteria). On a twelve-monthly basis, or in the event of an exceedance due to project operations, the monitoring methods and trigger thresholds were to be reviewed and modified, if required.

A.2 Scientific expert panel

In the event of an exceedance of threshold criteria, Seqwater will convene a scientific expert panel (SEP) to assess the potential influence of dam construction or operation on that exceedance. The SEP will be based on a group of experts currently involved in assisting the Healthy Land and Water Partnership to validate the Ecosystem Health Monitoring Program. This panel is made up of representative experts from the fields of freshwater and marine biology and ecology, fisheries and water quality. All members of the expert panel are familiar with the Logan River estuary and the pressures that exist in the region. The SEP will be annually updated on the progress of the EEMP (in the event of no exceedances) through revision of annual reports.

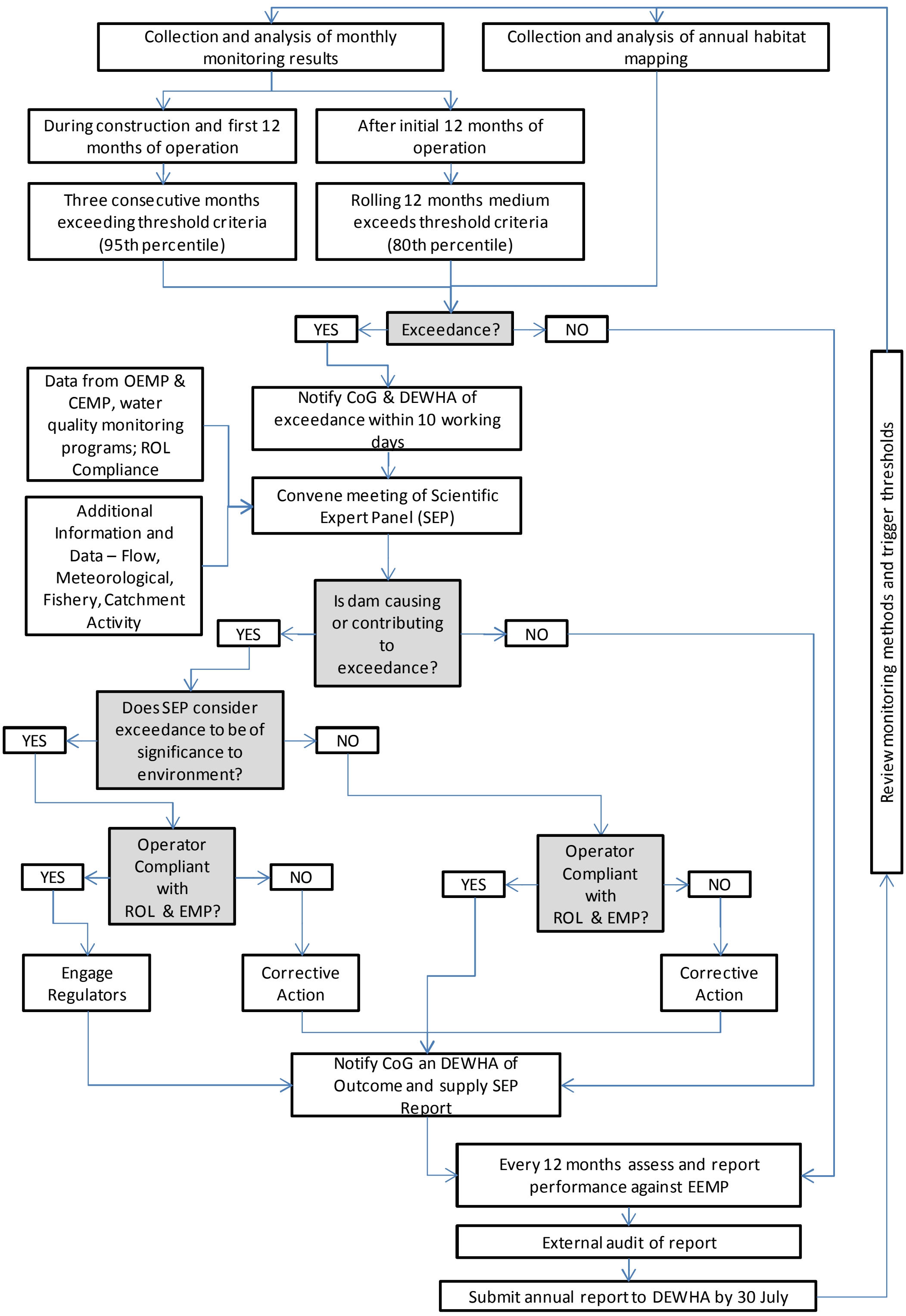


Figure A.1: Decision framework for EEMP implementation

Appendix B. Mangrove/saltmarsh assessment classification

The desktop remote sensing analysis methods used to determine the spatial extent of mangrove/saltmarsh habitat for the 2017 reporting period are described below. This is the ninth year of analysis for the EEMP monitoring program.

B.1 Image selection

High resolution satellite imagery was sourced from Digital Globe for the 2017 reporting period, to compare to the previous years' analyses and identify significant visible change in the intertidal habitat. The images were selected for the 2017 reporting period based on a number of parameters that were identified as important for conducting the analysis in previous years. The selection process considered the following:

- Season (a winter image was preferable due to typically low cloud cover)
- Minimal cloud cover
- Low tide
- Similarity in sensor bands (if same product not available as previous year's analyses)
- Same day imagery capture (where possible)
- Weather conditions around the time of the imagery capture.

Using the selection criteria listed above, two Worldview-2 imagery couplets were selected for the 2017 analysis. Each couplet was comprised of a four-band, multi-spectral image at a resolution of 2 m and a panchromatic image at a resolution of 0.5 m. Similar products have been used for the project since 2010. Table B.1 describes images selected for the 2017 analysis, as well as the images that were used for the analysis in previous years.

Using the selection criteria listed above, one Worldview-2 image and two Worldview-3 image couplets were selected for the 2017 analysis. Each couplet was comprised of a four-band, multi-spectral image at a resolution of 2 m and a panchromatic image at a resolution of 0.5 m. Similar products have been used for the project since 2010. Table B.1 describes images selected for the 2017 analysis, as well as the images that were used for the analysis in previous years. The images were delivered by Digital Globe with the study area split into three regions, captured on 17 and 29 August 2017. Figure B.1 below details the coverage of each image, the reporting zones and the acquisition date.

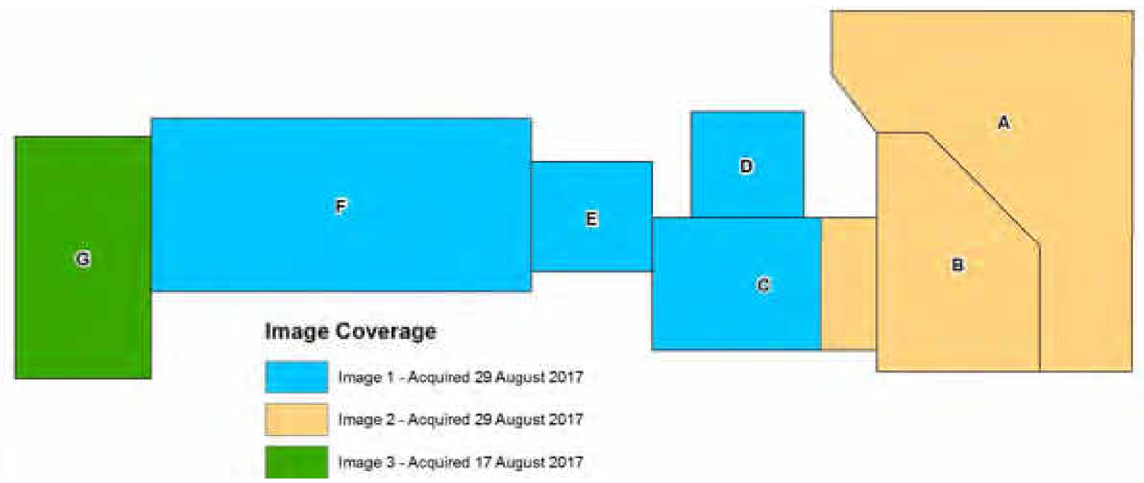


Figure B.1: Wyaralong EEMP 2017 imagery coverage (Image 1 and image 2 denote different swaths on the same day).

Table B.1: Satellite imagery product information, 2009 to 2017 capture period

Year	Product	Capture date	Sensor bands (wavelength)	Cloud cover	Resolution
2009	Quickbird: Multispectral	20 & 25 April 2009 ~ 10.30 am	**Blue**: 450 – 520nm **Green**: 520 – 600nm **Red**: 630 – 690nm **Near IR**: 760 – 900nm	0 %	Multispectral: 2.4 m
2010	Worldview-2: Multispectral and Panchromatic	4 June 2010 ~ 10.30 am	**Panchromatic**: 450 – 800nm **Coastal**: 400 – 450nm **Blue**: 450 – 510nm **Green**: 510 – 580nm **Yellow**: 585 – 625nm **Red**: 630 – 690nm **Red Edge**: 705 – 745nm **Near IR-1**: 770 – 895nm **Near IR-2**: 860 – 1040 nm	0 to 1%	Multispectral: 2 m Panchromatic: 0.5 m
2011	Worldview-2: Multispectral	17 May 2011; 16 June 2011 ~10.30 am	**Panchromatic**: 450 – 800nm **Coastal**: 400 – 450nm **Blue**: 450 – 510nm **Green**: 510 – 580nm **Yellow**: 585 – 625nm **Red**: 630 – 690nm **Red Edge**: 705 – 745nm **Near IR-1**: 770 – 895nm **Near IR-2**: 860 – 1040 nm	0%	Multispectral: 2m
2012	Worldview-2: Multispectral and Panchromatic	3 July 2012; 5 August 2012 ~ 10:30 am	**Panchromatic**: 450 – 800nm **Coastal**: 400 – 450nm **Blue**: 450 – 510nm **Green**: 510 – 580nm **Yellow**: 585 – 625nm **Red**: 630 – 690nm **Red Edge**: 705 – 745nm **Near IR-1**: 770 – 895nm **Near IR-2**: 860 – 1040 nm	0 - 1%	Multispectral: 2 m Panchromatic: 0.5 m
2013	Worldview-2: Multispectral and Panchromatic	13 July 2013 ~10:30 am	**Panchromatic**: 450 – 800nm **Coastal**: 400 – 450nm **Blue**: 450 – 510nm **Green**: 510 – 580nm **Yellow**: 585 – 625nm **Red**: 630 – 690nm **Red Edge**: 705 – 745nm **Near IR-1**: 770 – 895nm **Near IR-2**: 860 – 1040 nm	0%	Multispectral: 2 m Panchromatic: 0.5 m
2014	Worldview 2 – Multispectral and Panchromatic	11 July 2014 ~23:59; 12 July 2014 ~00:00	**Panchromatic**: 450 – 800nm **Coastal**: 400 – 450nm **Blue**: 450 – 510nm **Green**: 510 – 580nm **Yellow**: 585 – 625nm **Red**: 630 – 690nm	0%	Multispectral: 2m Panchromatic: 0.5m

Year	Product	Capture date	Sensor bands (wavelength)	Cloud cover	Resolution
			Red Edge: 705 – 745nm **Near IR-1**: 770 – 895nm **Near IR-2**: 860 – 1040 nm		
2015	Worldview 2 – Multispectral and Panchromatic	1 July 2015 ~ 17:51	**Panchromatic: 450 – 800nm** **Blue: 450 – 510nm** **Green: 510 – 580nm** **Red: 630 – 690nm** **Near IR-1: 770 – 895nm**	0%	Multispectral: 2m Panchromatic: 0.5m
2016	Worldview 2 – Multispectral and Panchromatic	1 July 2016 ~ 11:11am	**Panchromatic:** 450 – 800nm **Blue**: 450 – 510nm **Green:** 510 – 580nm **Red:** 630 – 690nm **Near IR-1:** 770 – 895nm	0%	Multispectral: 2m Panchromatic: 0.5m
2017	Worldview 2 & 3 – Multispectral and Panchromatic	17 August 2017 ~ 23:52; 29 August 2017 ~ 00:11	**Panchromatic:** 450 – 800nm **Blue**: 450 – 510nm **Green:** 510 – 580nm **Red:** 630 – 690nm **Near IR-1:** 770 – 895nm	0%	Multispectral: 2m Panchromatic: 0.5m

B.2 Image classification

To determine the visible areas of intertidal habitat in the 2017 reporting period, a supervised classification method was chosen and applied to all images. This methodology involved selecting training areas based on known areas of intertidal habitat within each image. A training area is a small sample of a homogenous area that is selected by the image analyst prior to classification (Figure B.2). The training areas have remained the same since 2009 to ensure consistency from year to year.

This method relies on some knowledge of the location to identify the known areas of intertidal habitat; in this case, the training areas were selected through study of the satellite image and other independent sources of information, such as the DNRM Regional Ecosystem Mapping and previous years' analysis. For each image, approximately 8 to 12 training sites were selected that represented known areas of intertidal habitat, and the supervised classification was processed using ERDAS Imagine. The classification used all of the multi-spectral bands within the images.

Figure B.2 : Example training areas

B.3 Post processing

A series of processes were applied to clean the interim classification datasets to ensure that any erroneous areas of classification were not included in the final classification layer, and subsequently in the calculation of habitat areas.

B.3.1 Normalised Differential Vegetation Index (NDVI) analysis - masking

Initially, the areas of water, shadow and bare earth were masked out of the interim classification layers. This was achieved through creating a masking layer by the application of NDVI to the original images. This analysis uses a ratio of the red and near infrared light bands to detect vegetation health by detecting the amount of chlorophyll. An NDVI analysis yields a ratio between -1 to 1, with different land cover types corresponding to a typical value range, which enables the resulting datasets to be classed according to land cover type. For the purposes of this analysis, the areas that yielded a ratio of -1 to 0.1 encompassed the areas of water, shadow and bare earth. Areas that yield a moderate value (0.2 to 0.3) represented shrub and grassland, and higher values (0.4 to 1) representing vegetation, that appears denser and greener the closer to 1 the value is.

B.3.2 Elimination of singular pixels

Following the use of the NDVI mask, the interim classification layers were cleaned by eliminating all areas that were less than 2 pixels in size.

B.3.3 Visual validation

The interim classification analysis results were then visually validated against the satellite imagery and further areas of erroneous classification eliminated. This step was done by first eliminating areas that had been classified as mangroves that were not within 100 m of a watercourse or wetland, and then manually reassigning the incorrect pixels. The panchromatic image was used as a visual aid in this step of the analysis, as it has a higher resolution and the texture and extent of vegetation is more clearly visible.

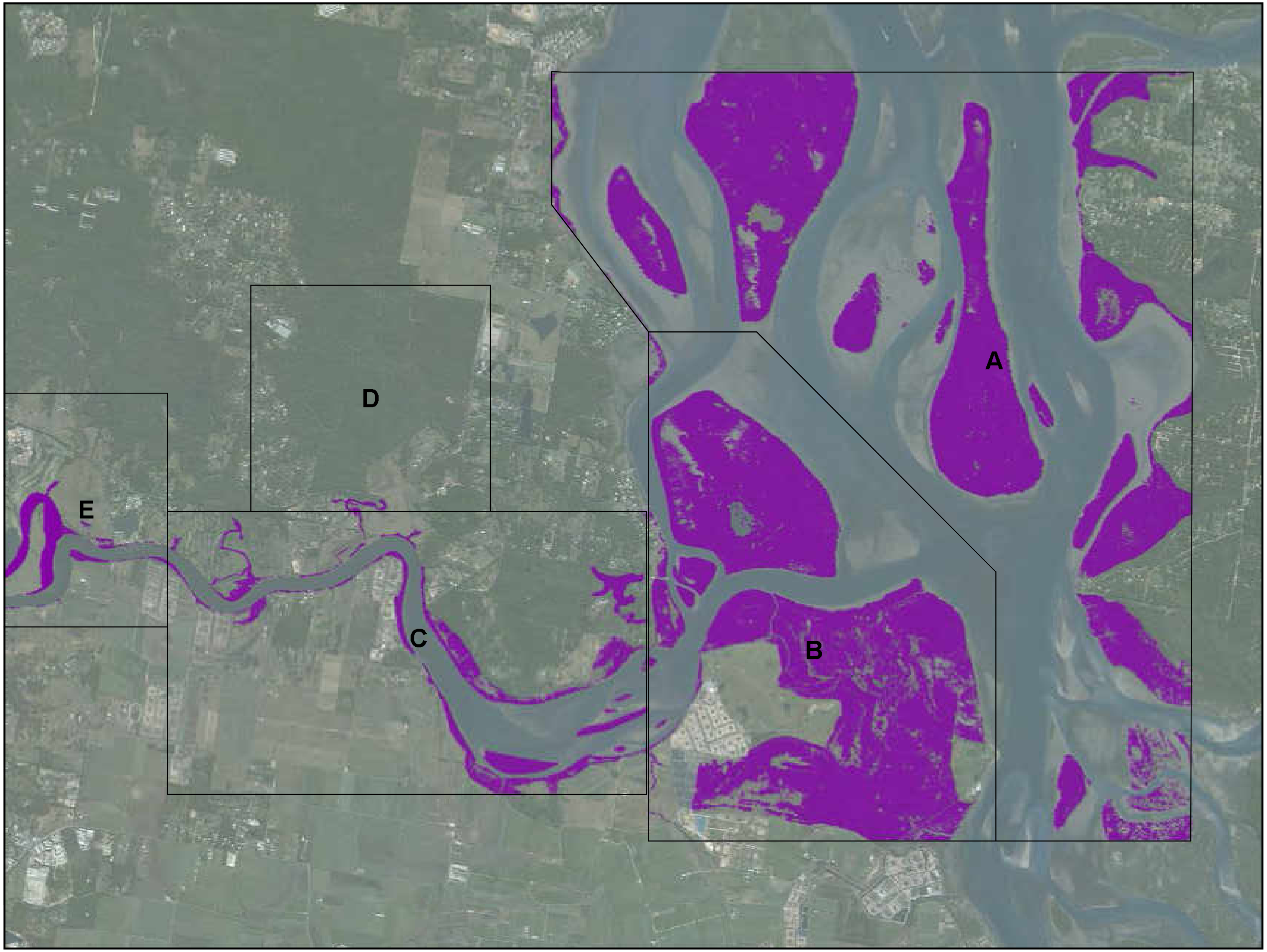
B.3.4 Reporting zone calculations

For each of the seven reporting zones (A-G), the area of intertidal habitat was then calculated and reported in hectares. Using the NDVI layer that had been calculated for each of the images, a mean NDVI value was calculated to give an indicator of overall health of the reporting zone.

Appendix C. Linear extents of intertidal habitat

The following figures show the linear extent of mangrove/saltmarsh habitat along the Logan River Estuary annually, for each assessment zone, from commencement of the Wyaralong EEMP monitoring program in 2009 through to 2017.

2009 LINEAR LENGTH (Zone A to E)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

IMAGERY SOURCES
SPOTMaps - 2008

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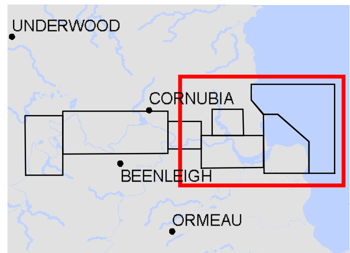

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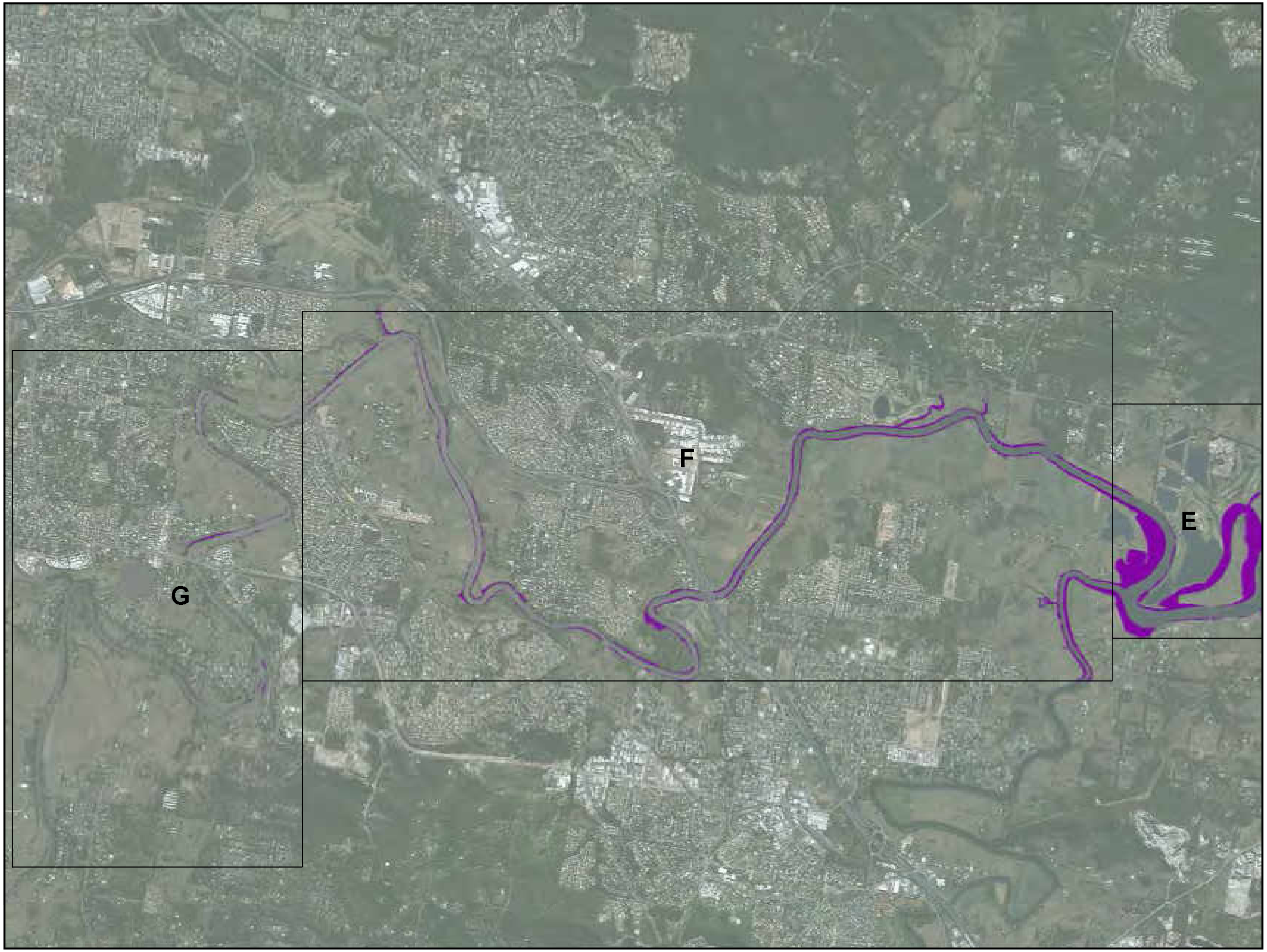
WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

2009 LINEAR LENGTH (Zones E to G)



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A Reporting Zone

Mangrove and Intertidal Habitat

IMAGERY SOURCES
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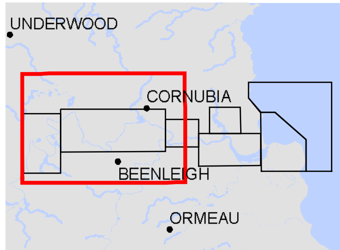

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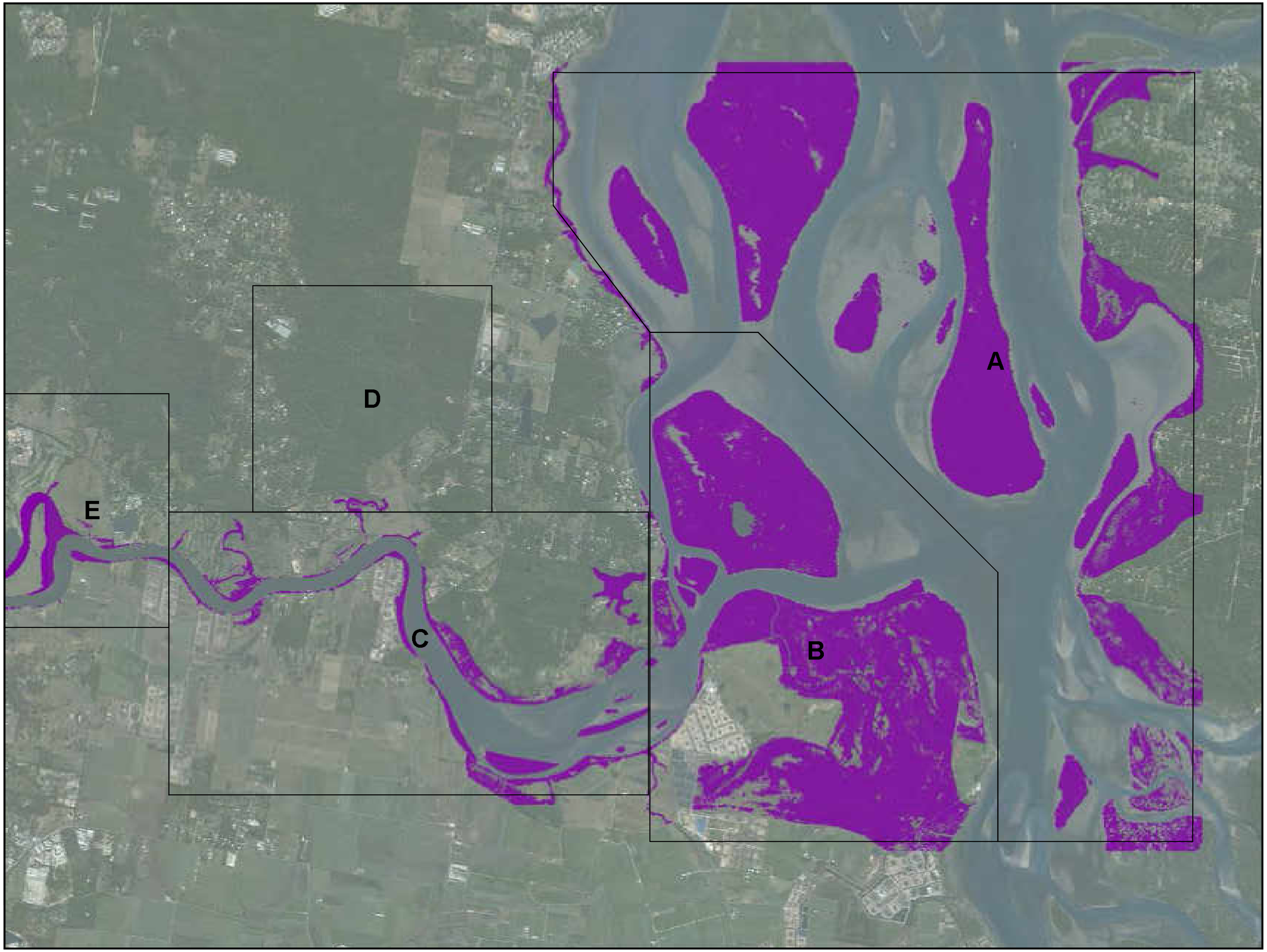
2010 LINEAR LENGTH (Zone A to E)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

IMAGERY SOURCES
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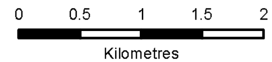

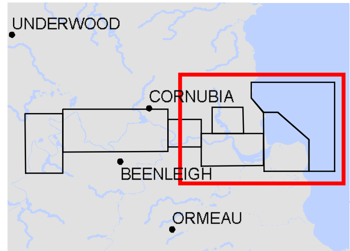

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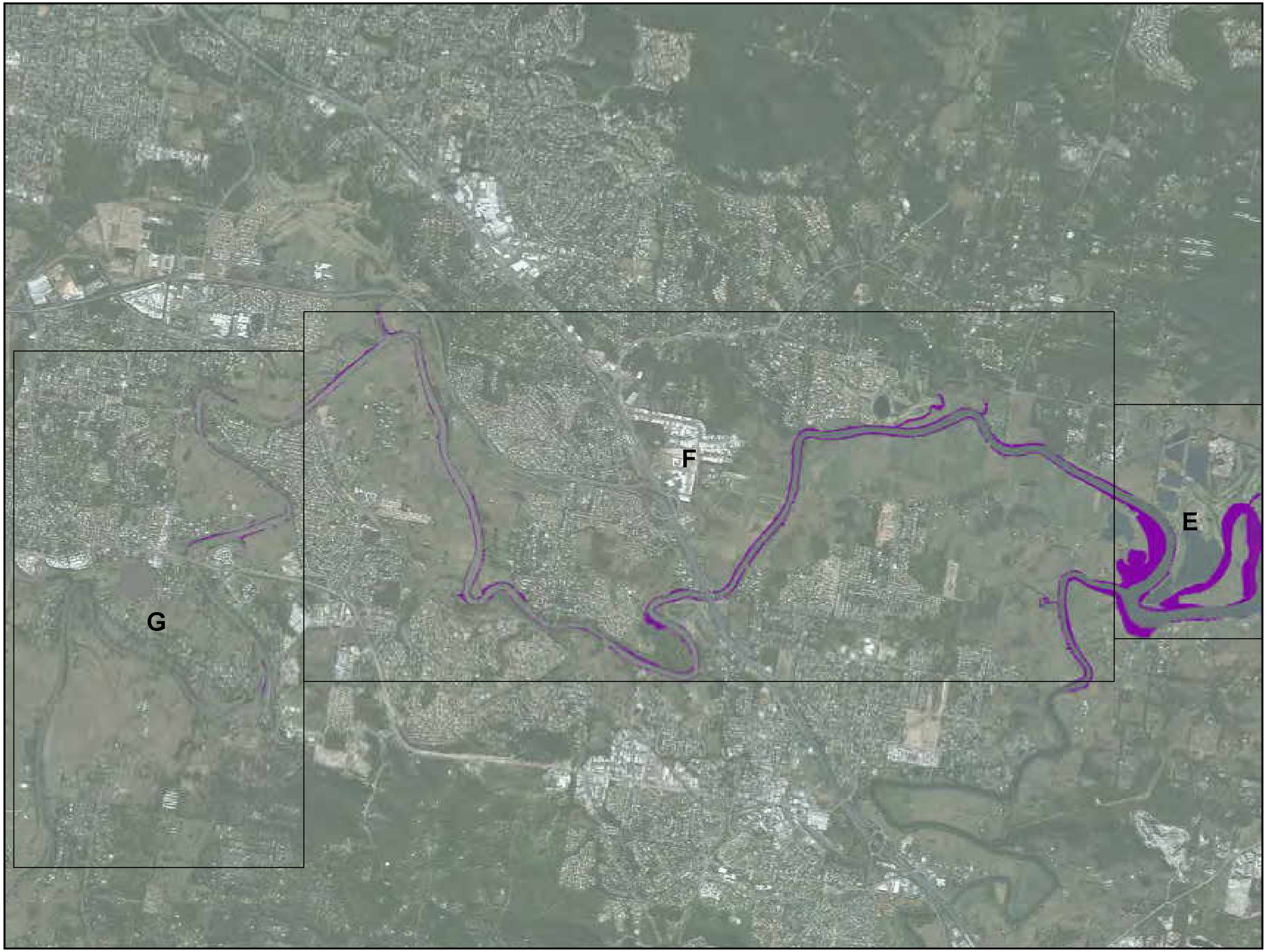
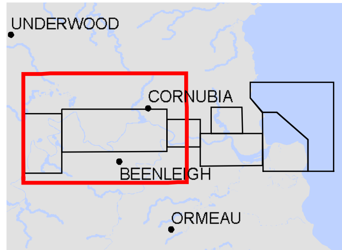
2010 LINEAR LENGTH (Zones E to G)





LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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A4 1:62,000

0 0.5 1 1.5 2
Kilometres

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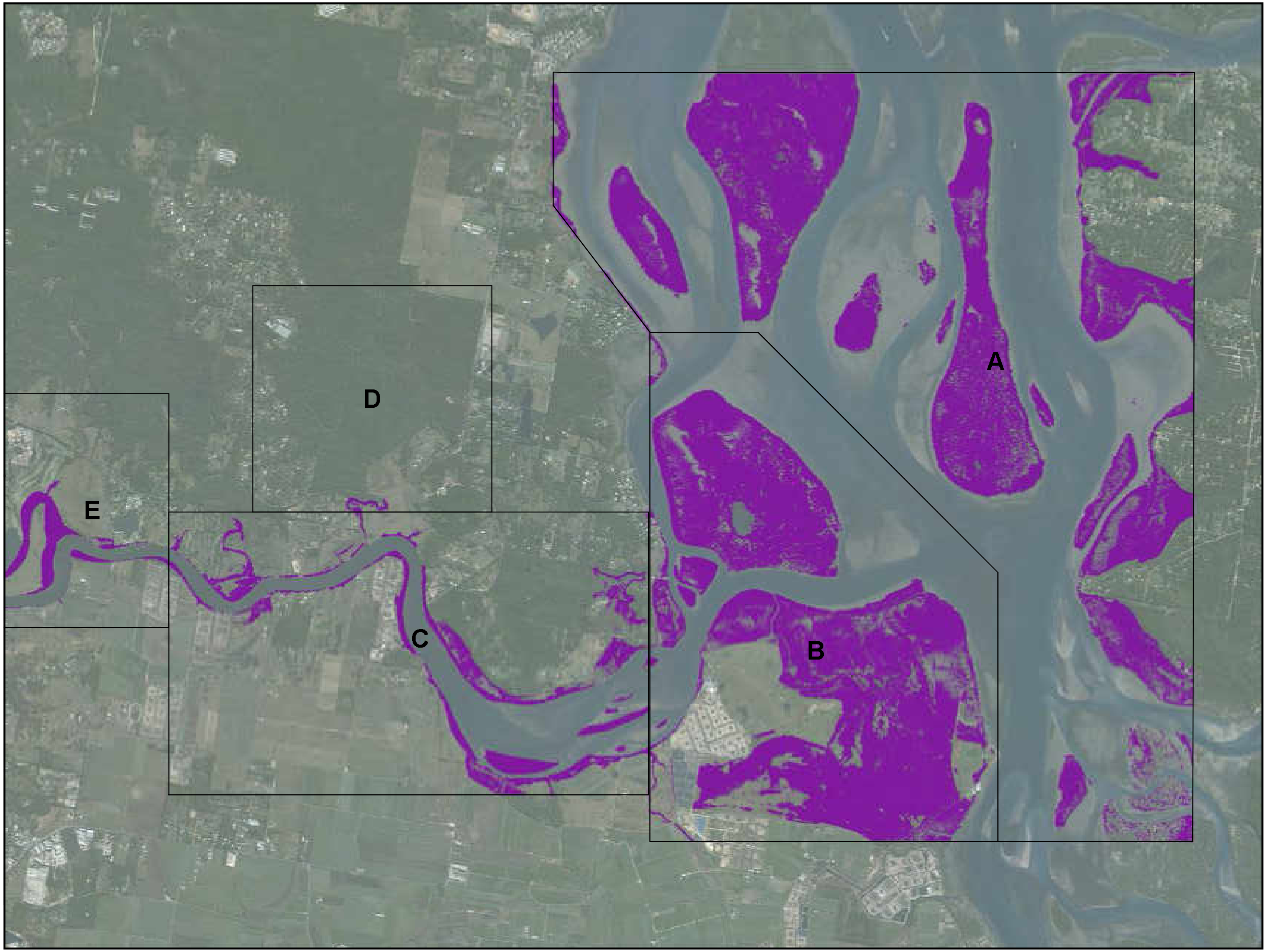
2011 LINEAR LENGTH (Zone A to E)



LEGEND

A Reporting Zone

Mangrove and Intertidal Habitat

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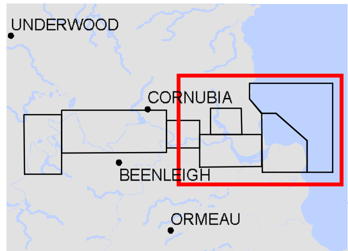

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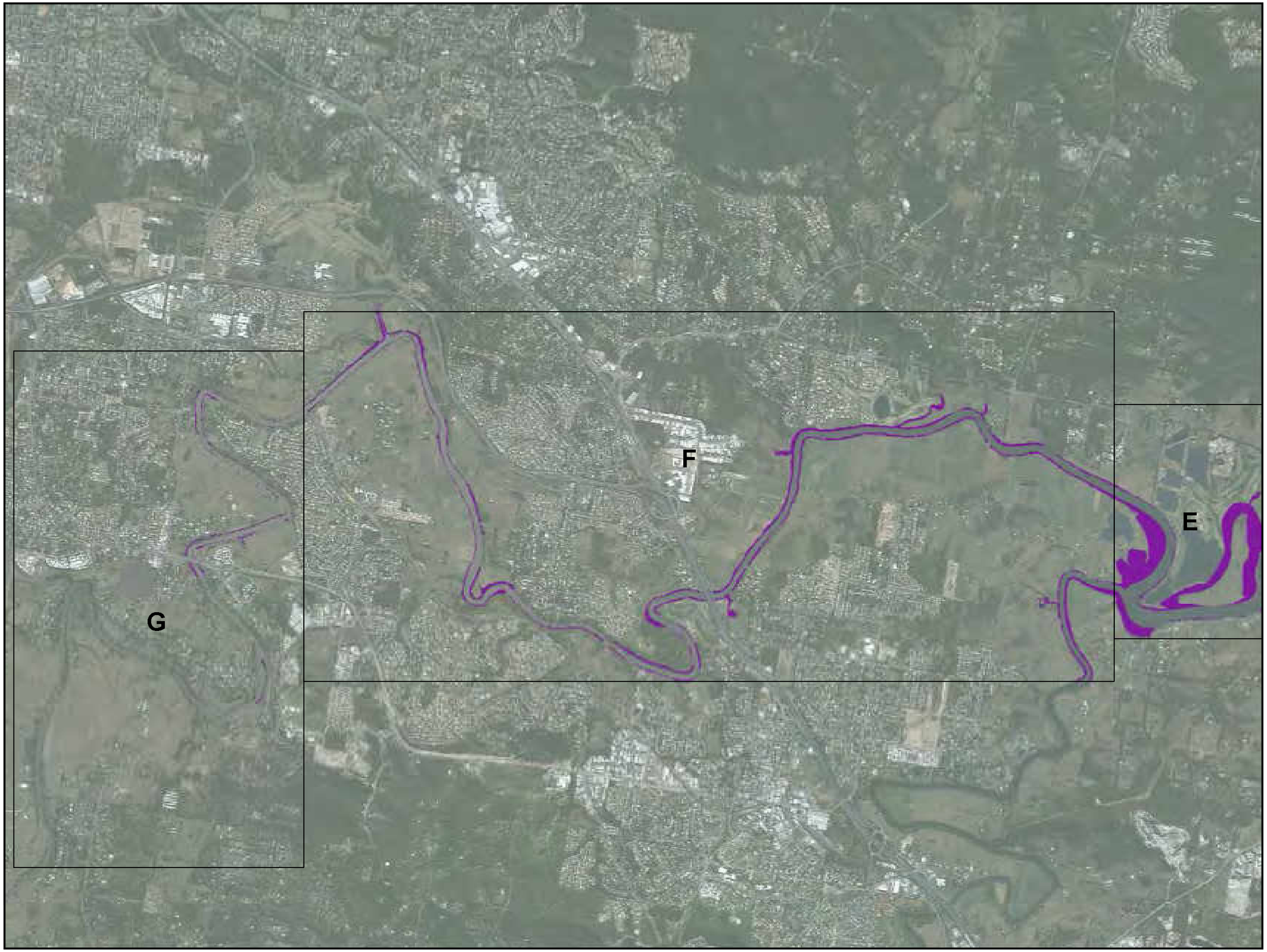
WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

I:\QENV2\Projects\QE06804\Spatial\LinearLengthFigures\mxd\IH013500_WyaralongEEMP_LinearLength_2011_r1v1.mxd | Date: 8/11/2016

2011 LINEAR LENGTH (Zones E to G)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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GDA94
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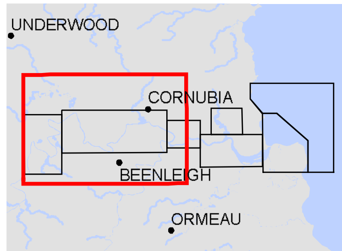

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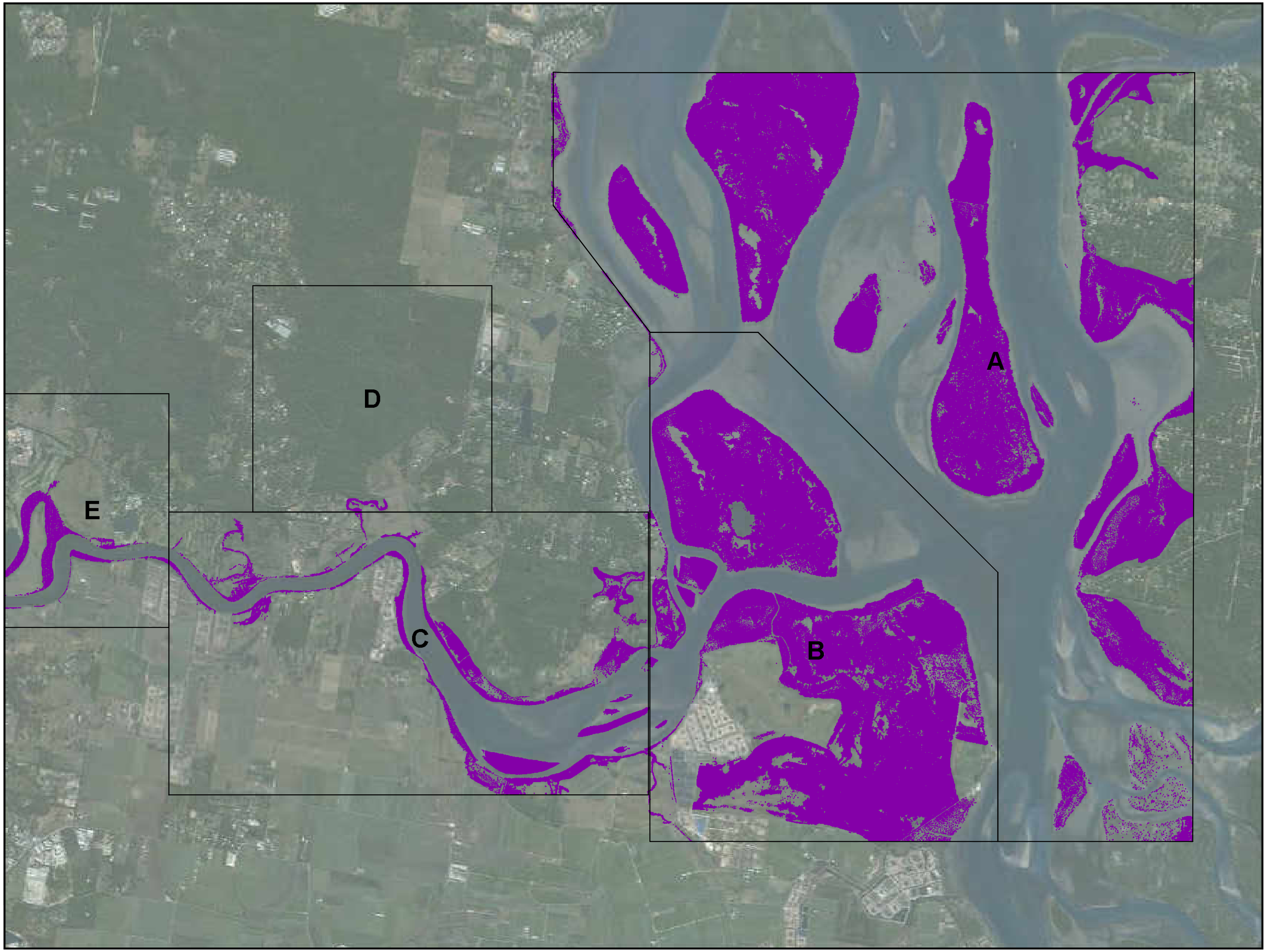
2012 LINEAR LENGTH (Zone A to E)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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GDA94
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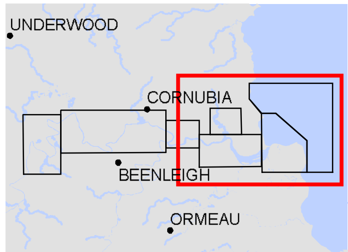

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WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

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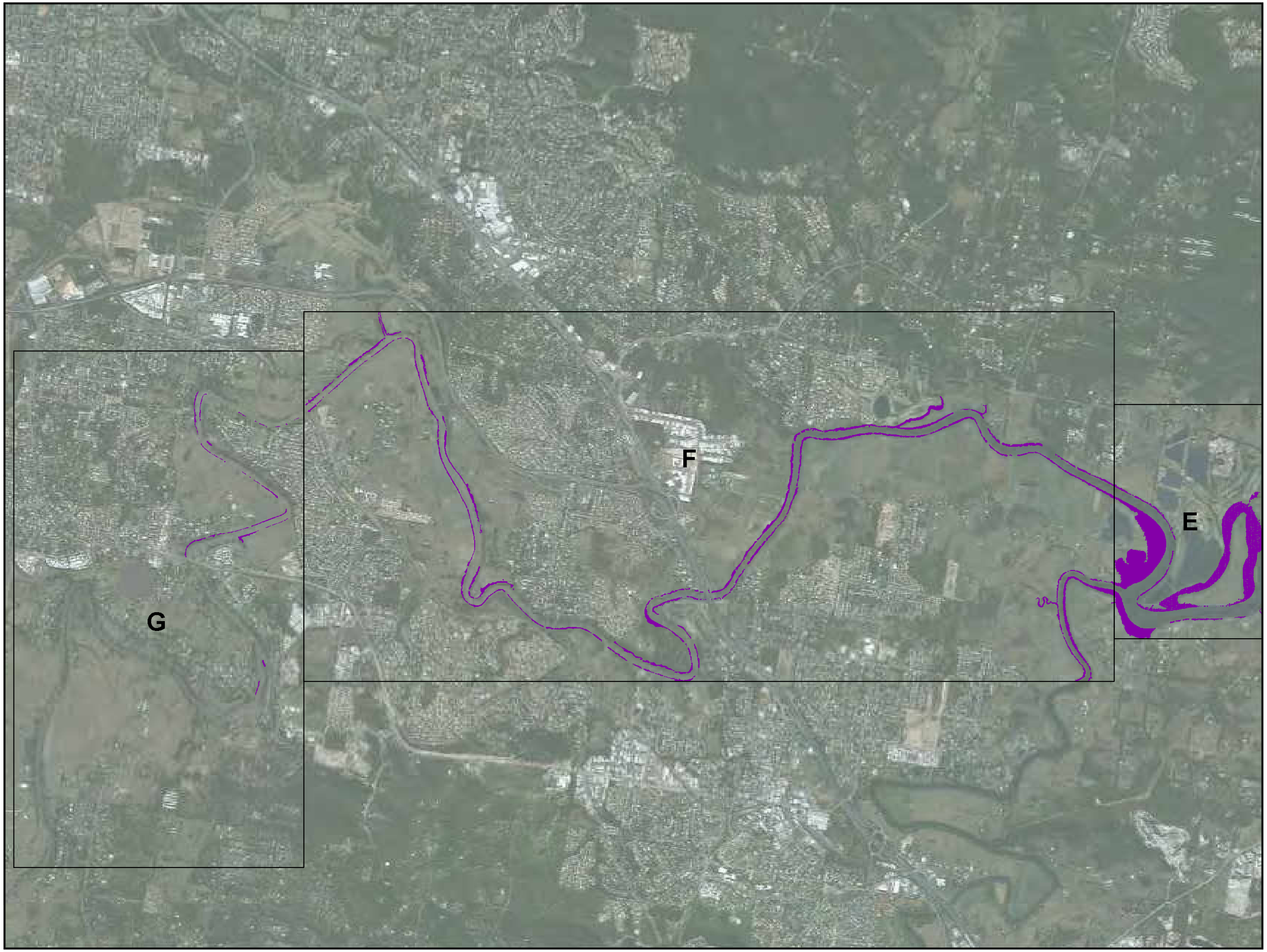
2012 LINEAR LENGTH (Zones E to G)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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GDA94
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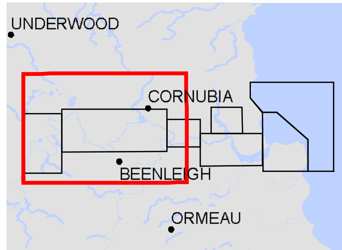
Kilometres



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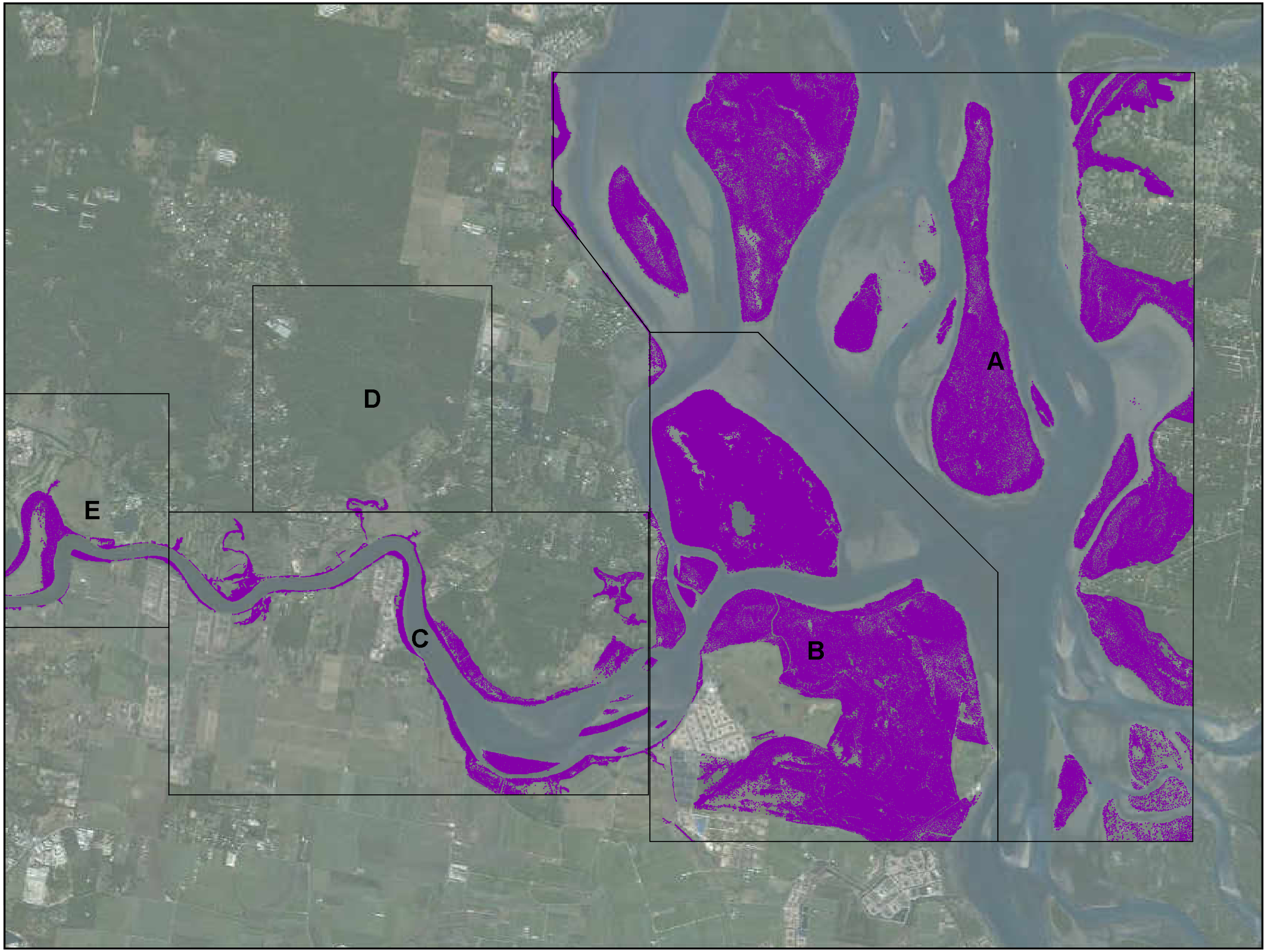
2013 LINEAR LENGTH (Zone A to E)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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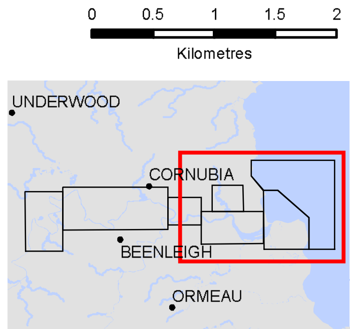

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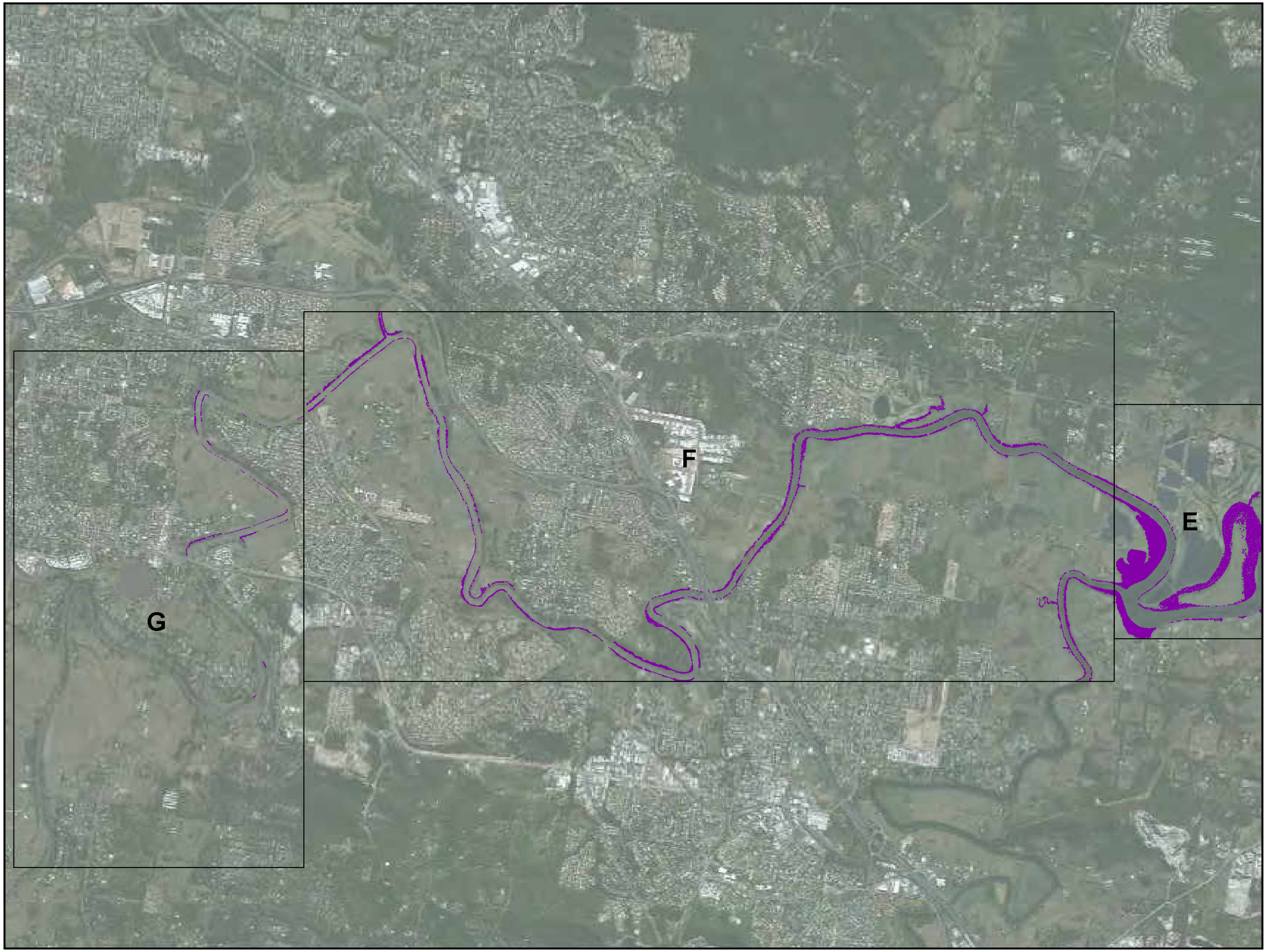
2013 LINEAR LENGTH (Zones E to G)



LEGEND

A Reporting Zone
Mangrove and Intertidal Habitat

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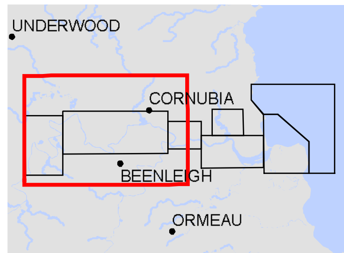
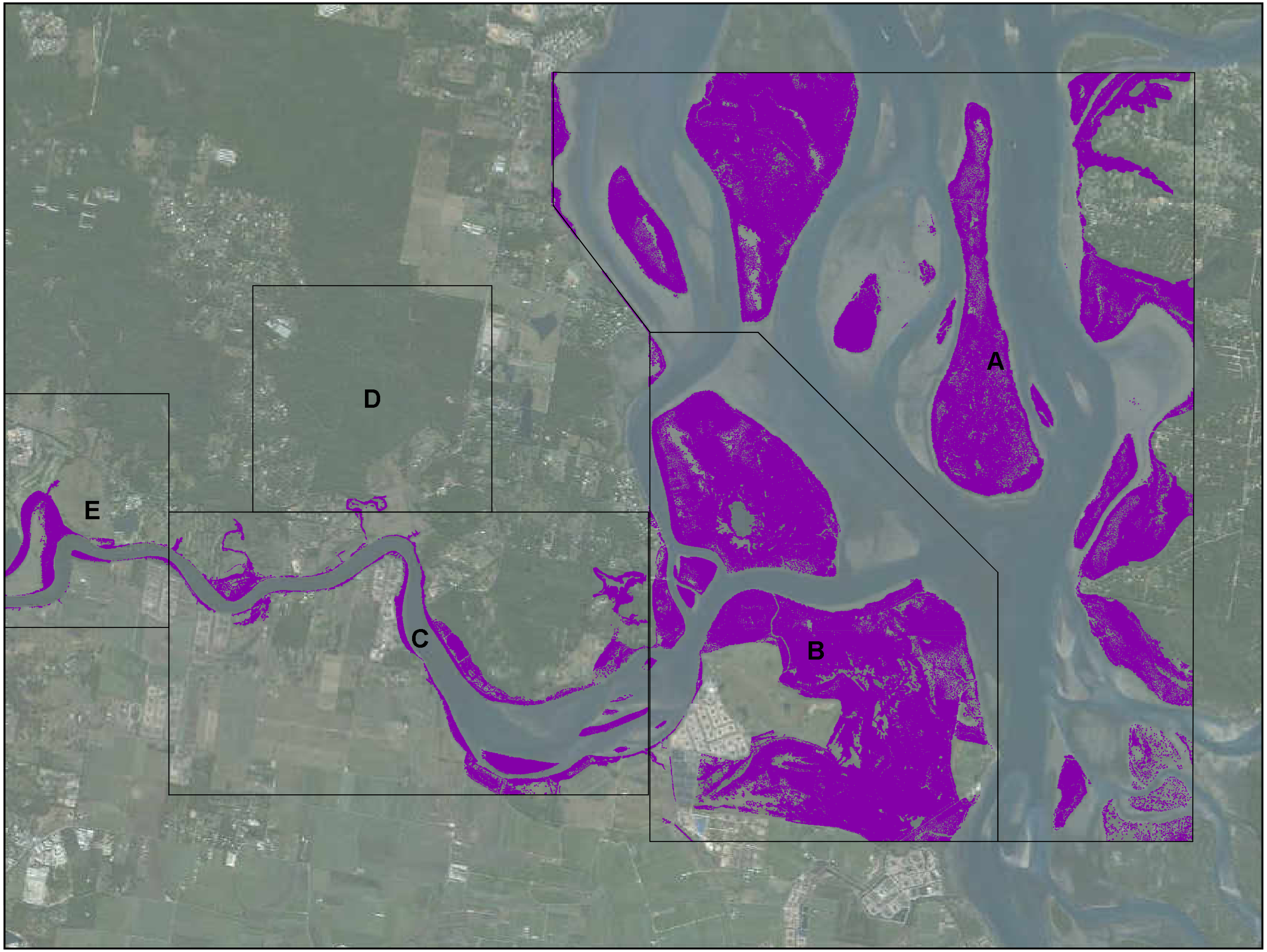


WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

2014 LINEAR LENGTH (Zone A to E)



LEGEND

A Reporting Zone

Mangrove and Intertidal Habitat

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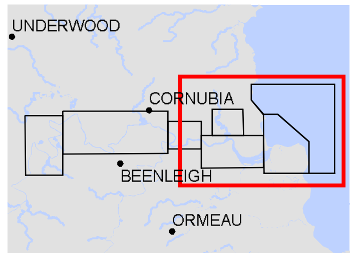

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WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

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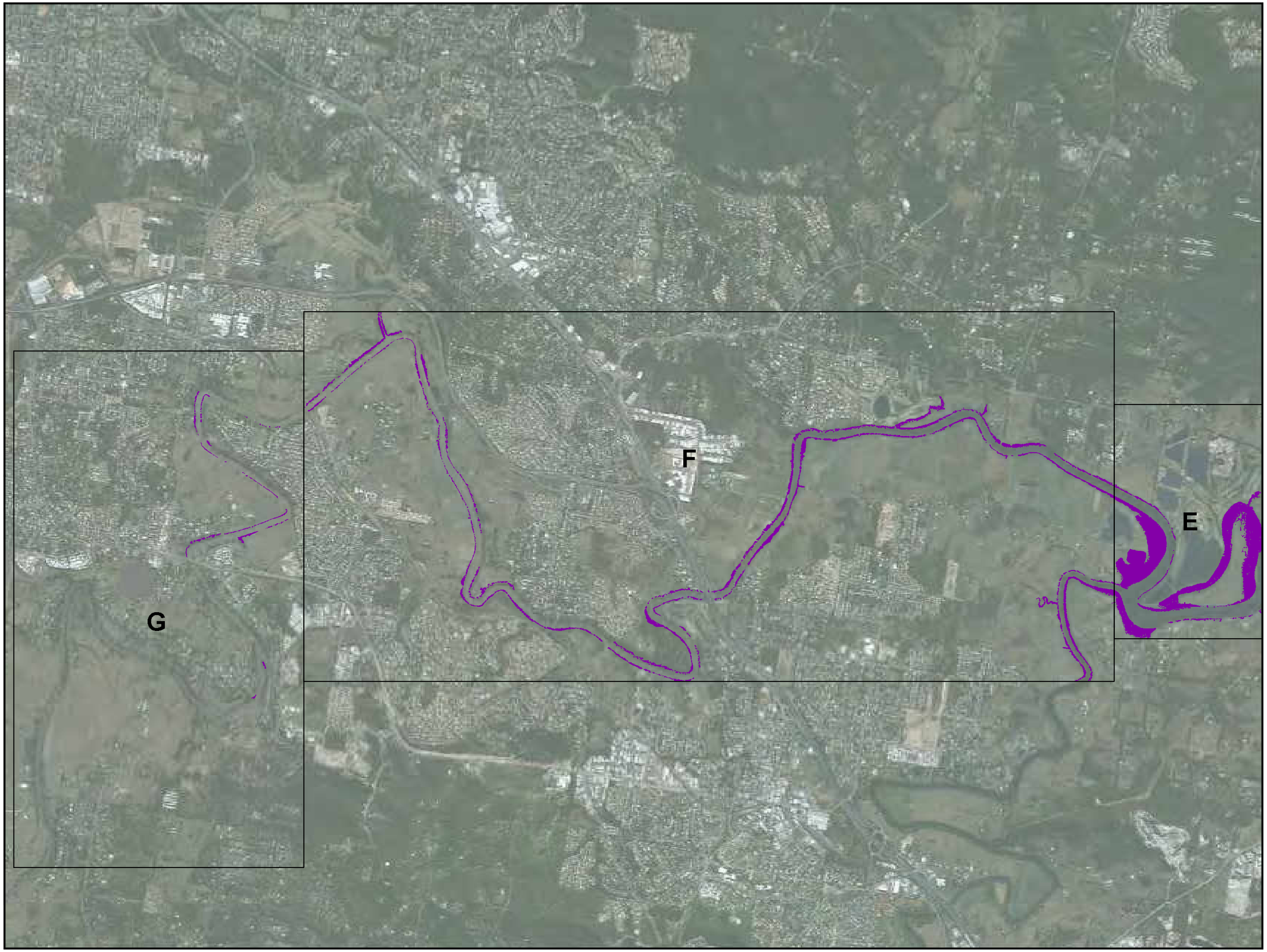
2014 LINEAR LENGTH (Zones E to G)



LEGEND

- A — Reporting Zone
- Mangrove and Intertidal Habitat

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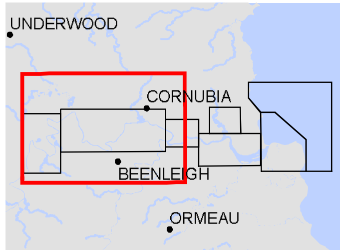
0 0.5 1 1.5 2
Kilometres



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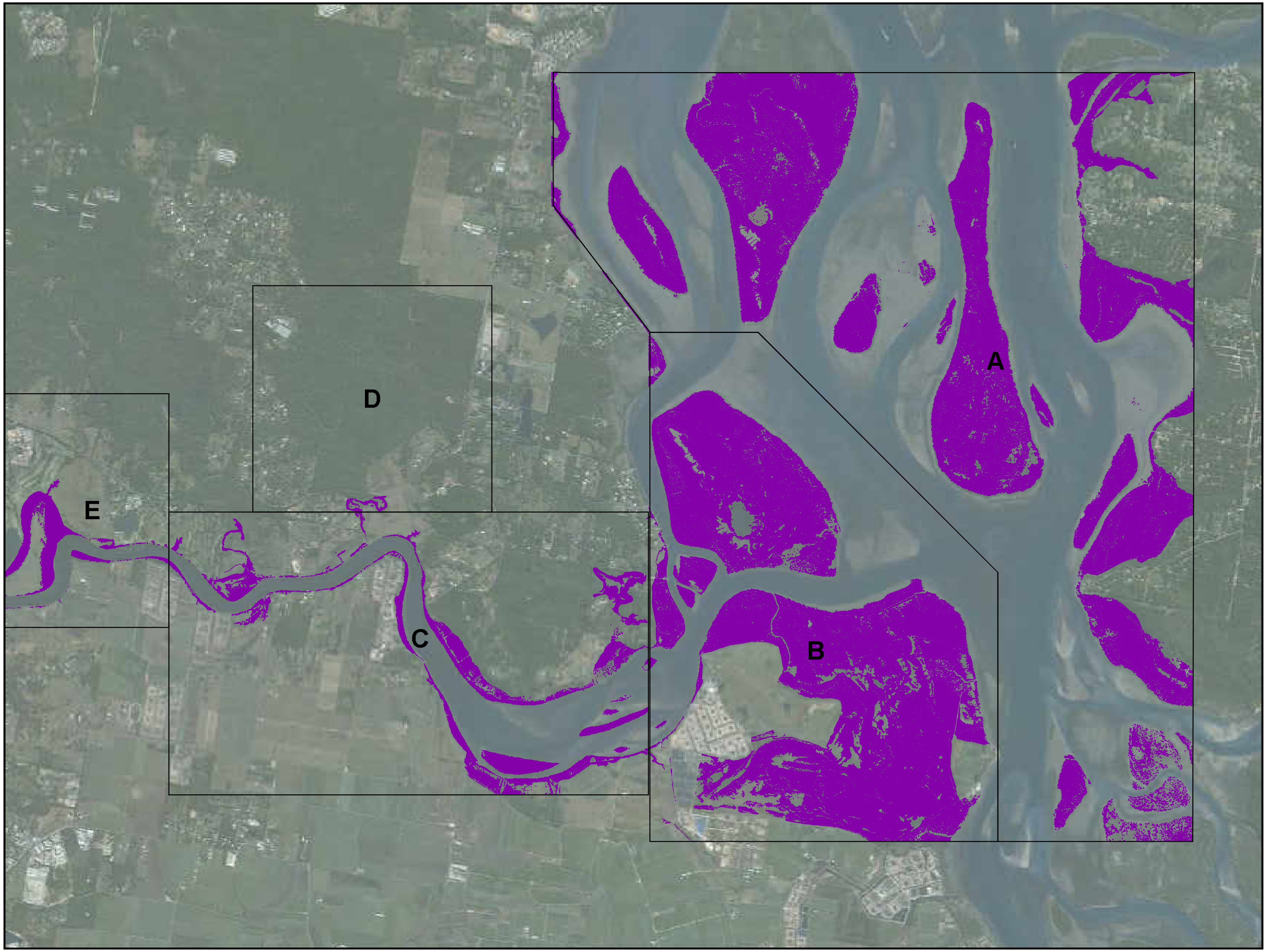
WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

I:\QENV2\Projects\QE06804\Spatial\LinearLengthFigures\mxd\IH013500_WyaralongEEMP_LinearLength_2014_r1v1.mxd | Date: 9/11/2016

2015 LINEAR LENGTH (Zone A to E)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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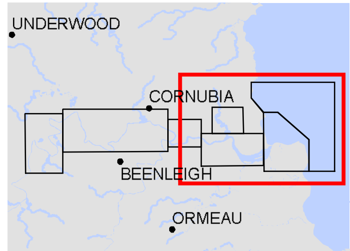
Kilometres



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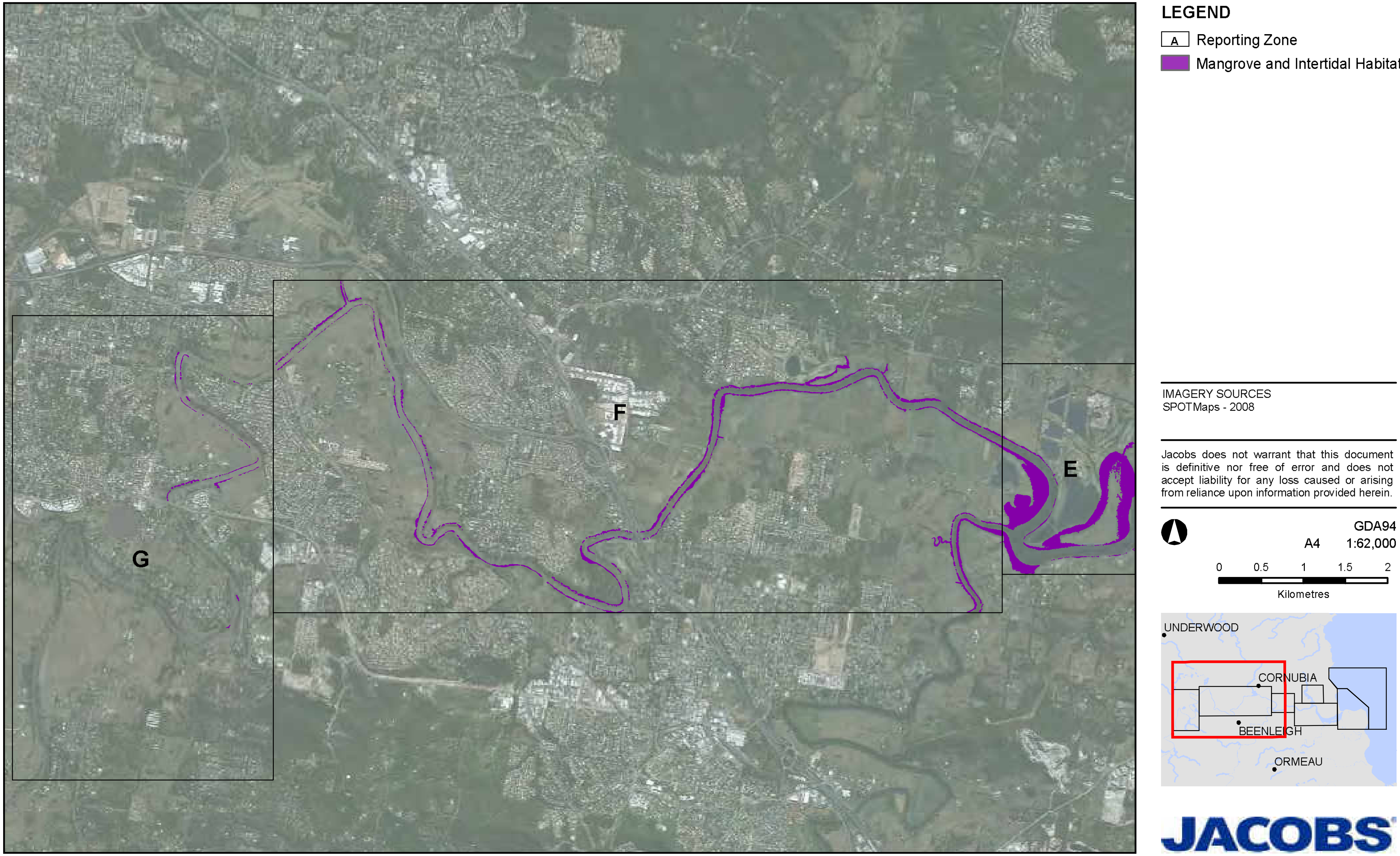
2015 LINEAR LENGTH (Zones E to G)



LEGEND

- A — Reporting Zone
- Mangrove and Intertidal Habitat

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GDA94
A4 1:62,000
0 0.5 1 1.5 2
Kilometres

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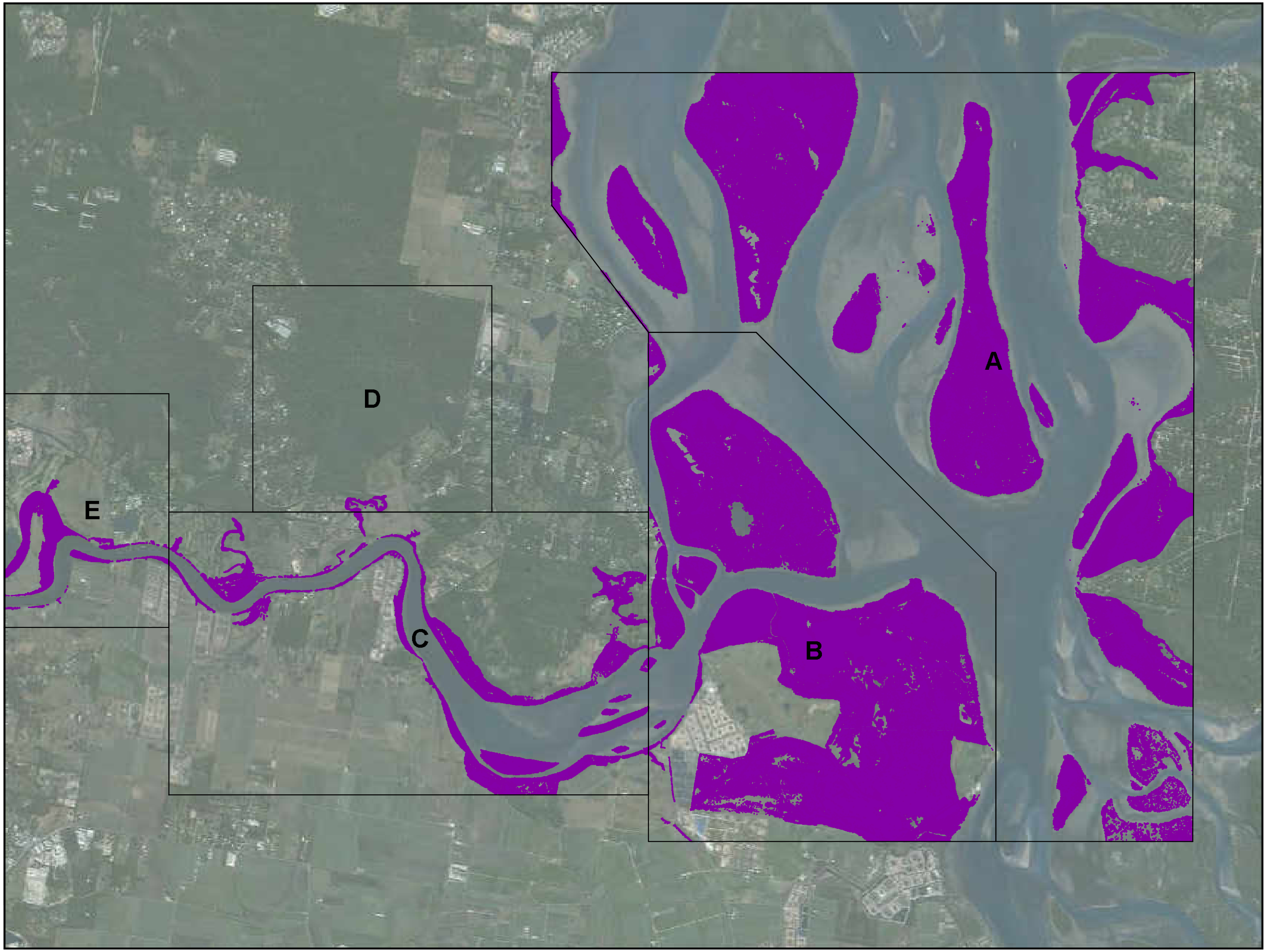
WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

2016 LINEAR LENGTH (Zone A to E)



LEGEND

A Reporting Zone

Mangrove and Intertidal Habitat

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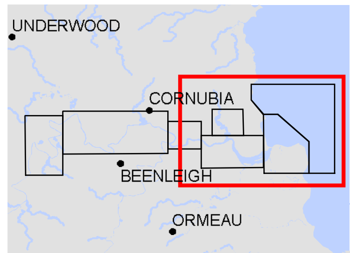
GDA94
A4 1:62,000

0 0.5 1 1.5 2
Kilometres



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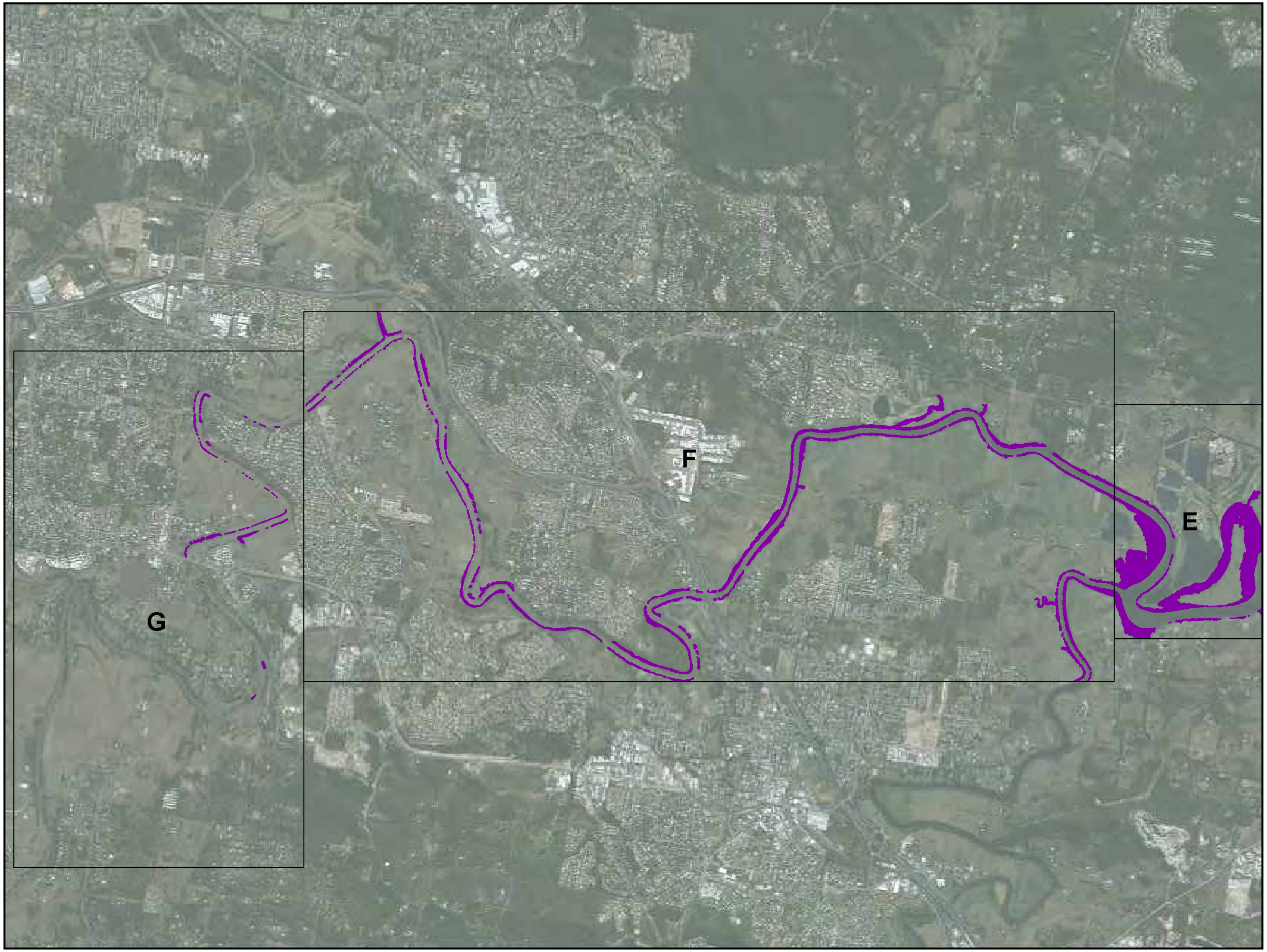
WYARALONG DAM ESTUARINE ECOLOGY MANAGEMENT PLAN

I:\QENV2\Projects\QE06804\Spatial\LinearLengthFigures\mxd\IH013500_WyaralongEEMP_LinearLength_2016_r1v1.mxd | Date: 31/05/2017

2016 LINEAR LENGTH (Zones E to G)



LEGEND

- A Reporting Zone
- Mangrove and Intertidal Habitat

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GDA94
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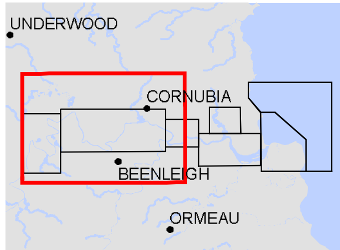
Kilometres



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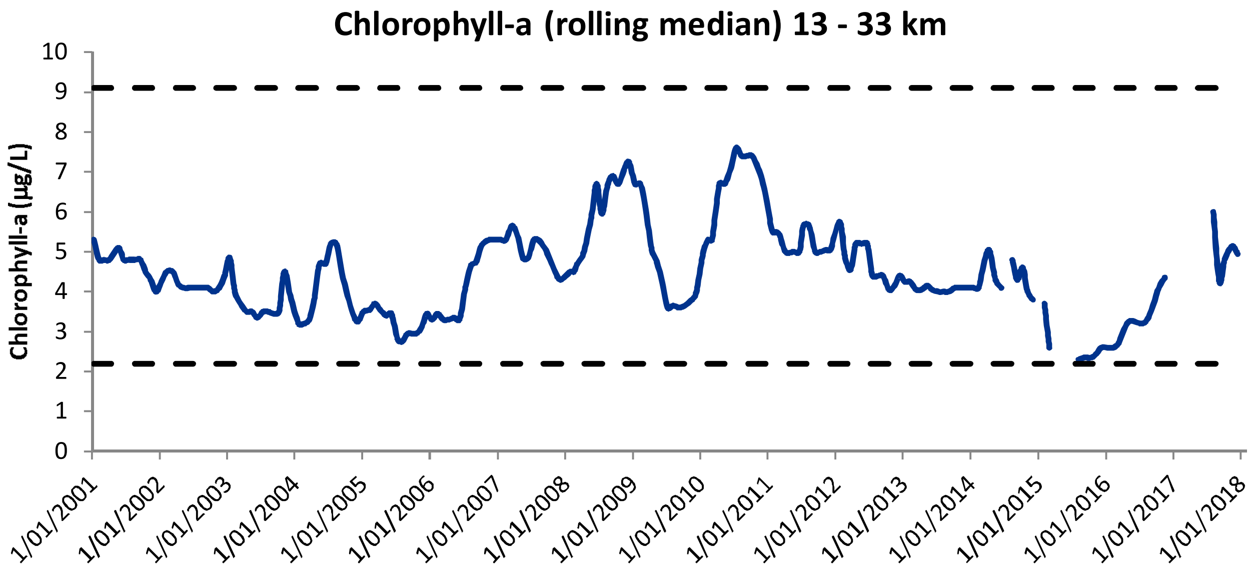
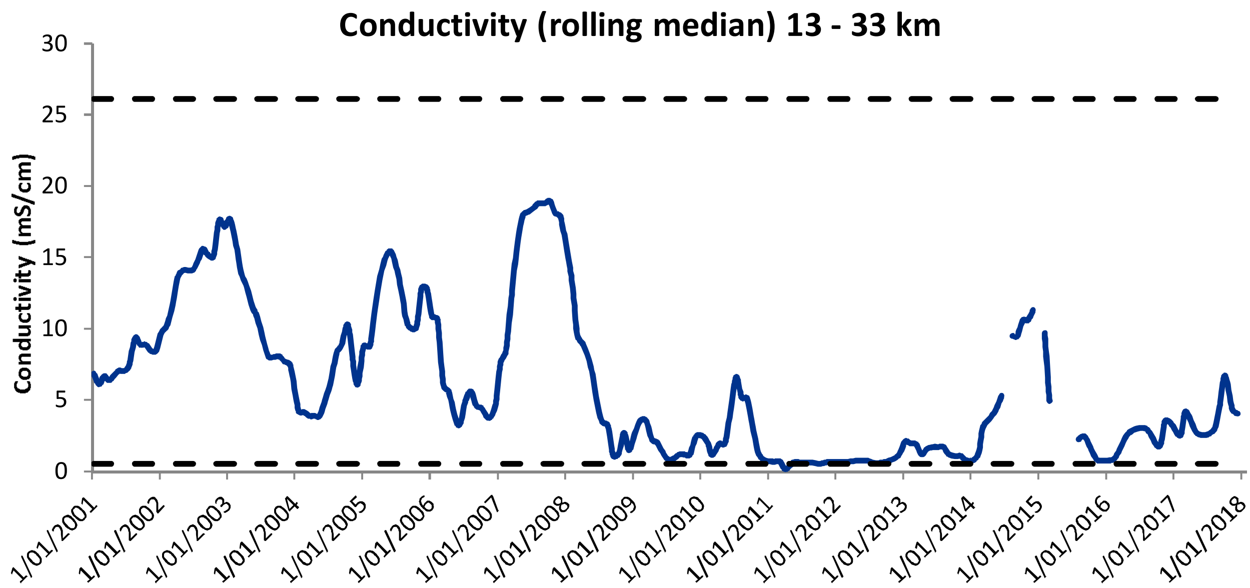
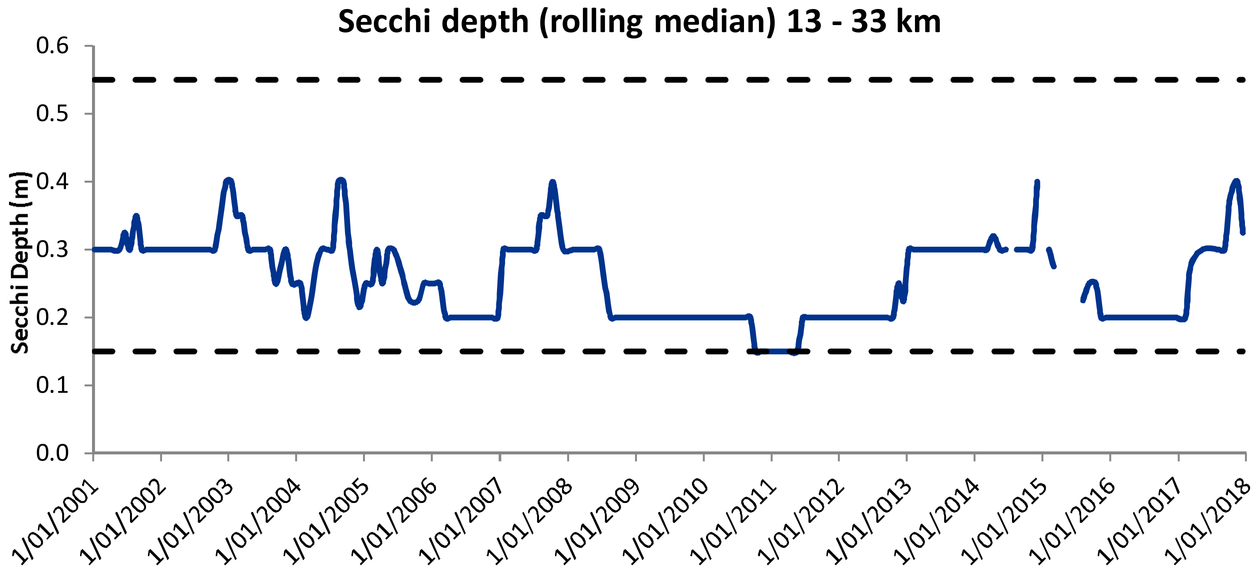
Appendix D. Logan River water quality – annual rolling medians

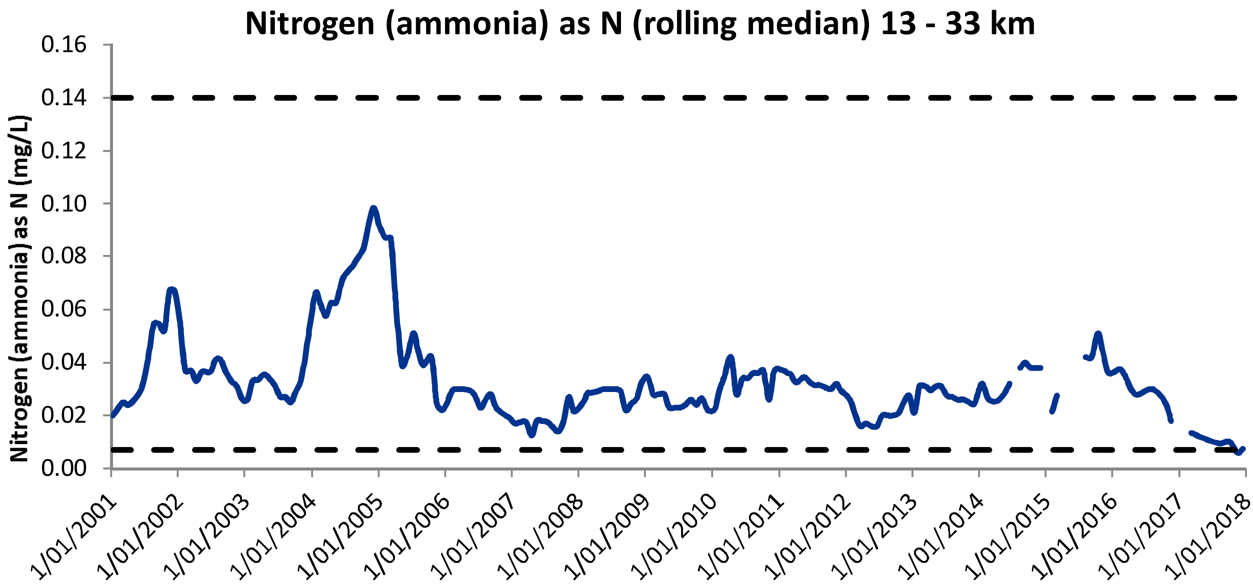
D.1 Above Albert River confluence - 13-33 km AMTD

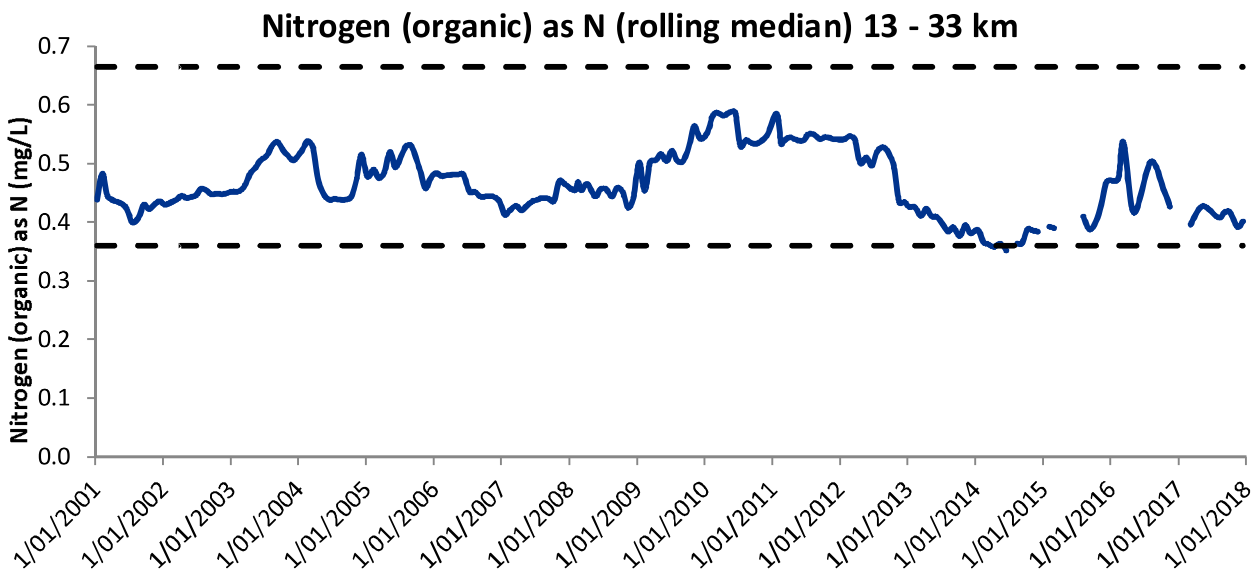
Horizontal dashed lines = Lower and upper trigger values to be applied after the first year of dam operation.

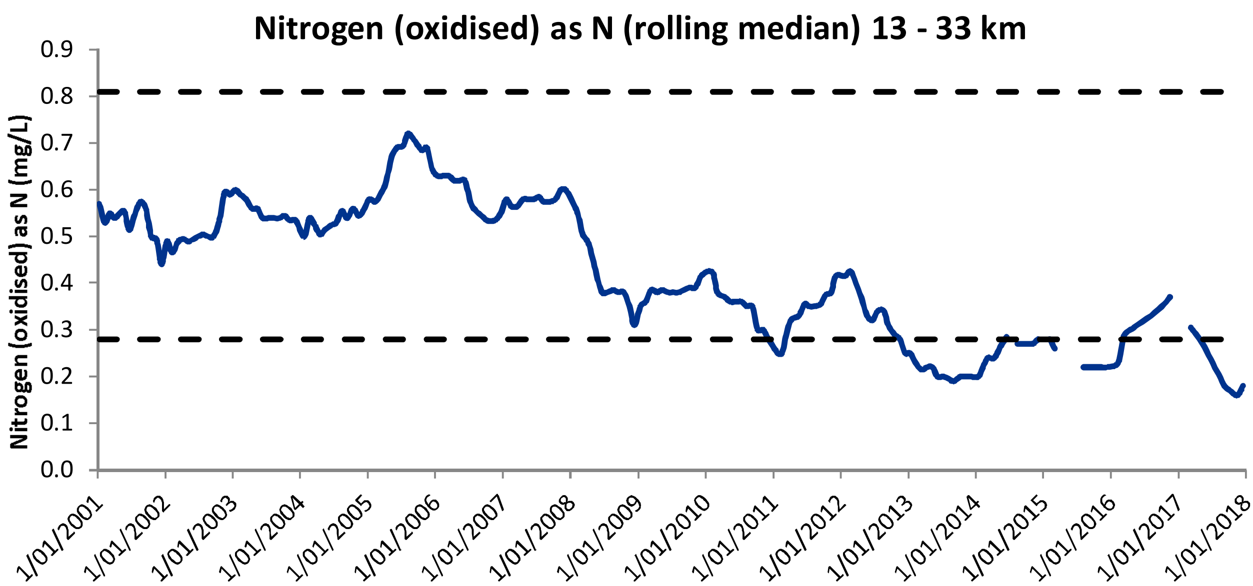


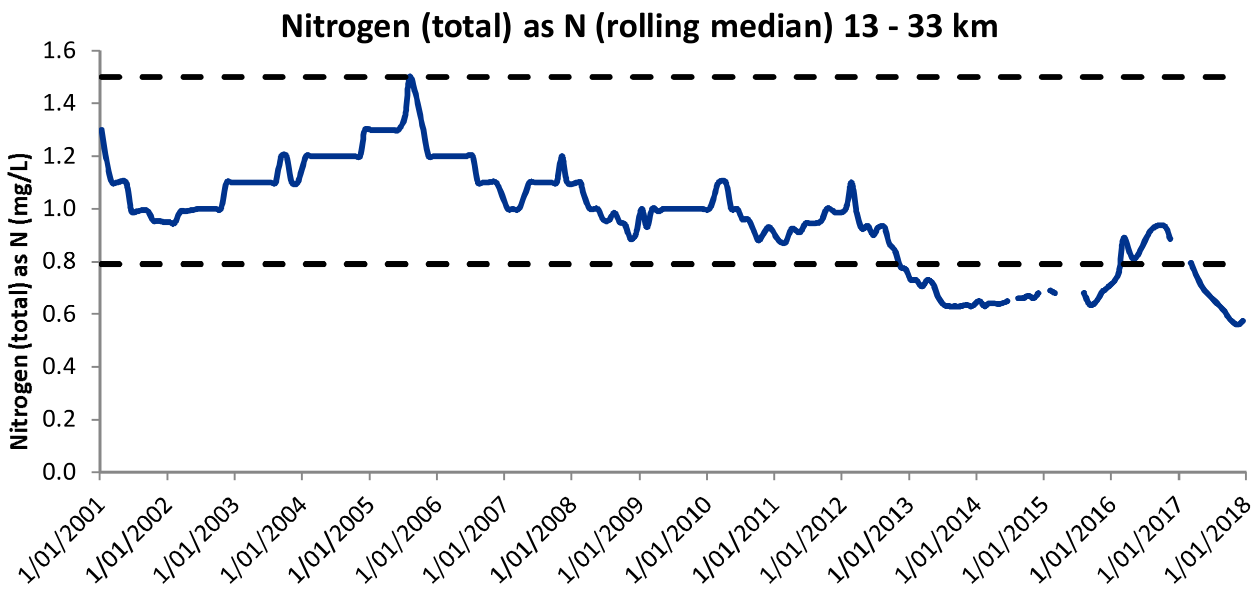



Secchi depth (rolling median) 13 - 33 km
Secchi Depth (m)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Nitrogen (ammonia) as N (rolling median) 13 - 33 km
Nitrogen (ammonia) as N (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Nitrogen (organic) as N (rolling median) 13 - 33 km
Nitrogen (organic) as N (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Nitrogen (oxidised) as N (rolling median) 13 - 33 km
Nitrogen (oxidised) as N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Nitrogen (total) as N (rolling median) 13 - 33 km
Nitrogen (total) as N (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
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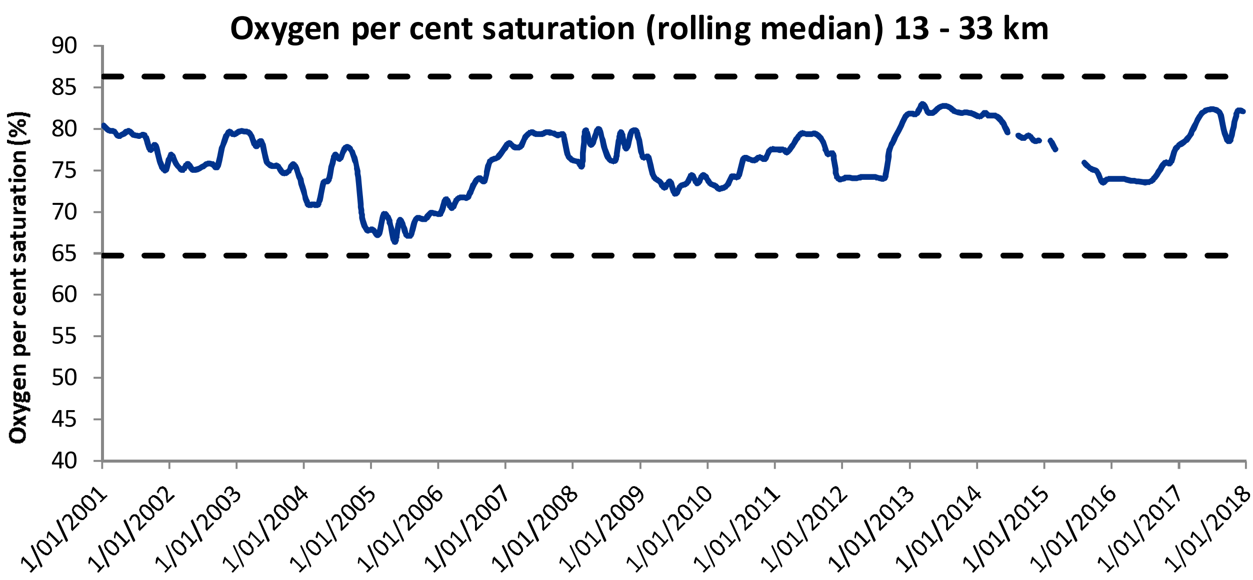
1/01/2016
1/01/2017
1/01/2018


Oxygen per cent saturation (rolling median) 13 - 33 km
Oxygen per cent saturation (%)
90
85
80
75
70
65
60
55
50
45
40
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
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1/01/2014
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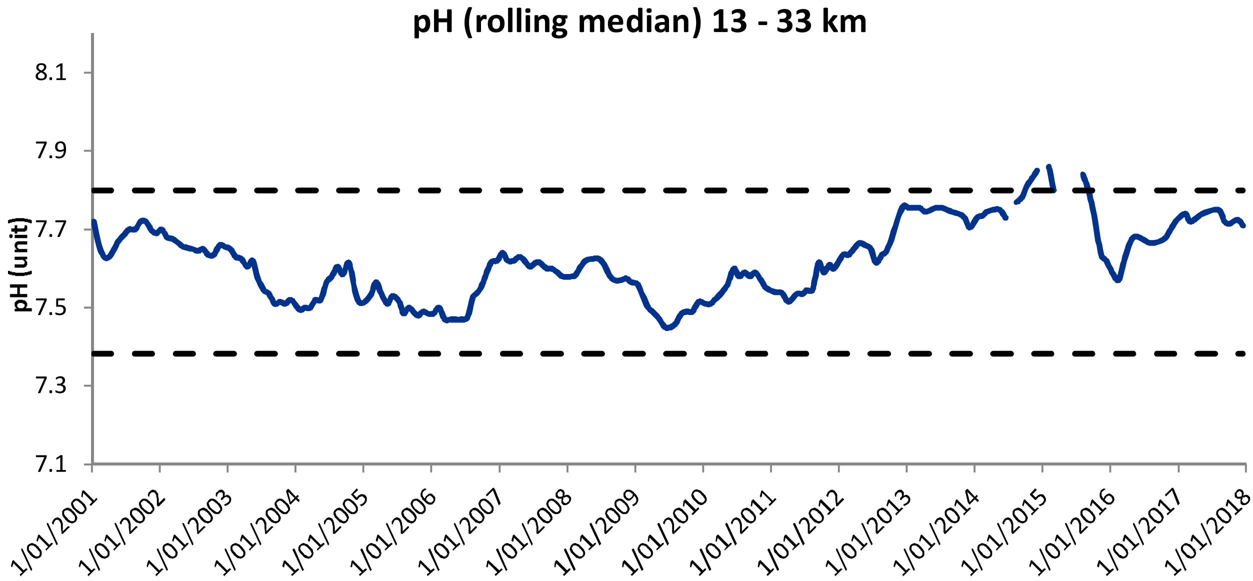
1/01/2016
1/01/2017
1/01/2018


pH (rolling median) 13 - 33 km
pH (unit)
8.1
7.9
7.7
7.5
7.3
7.1
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
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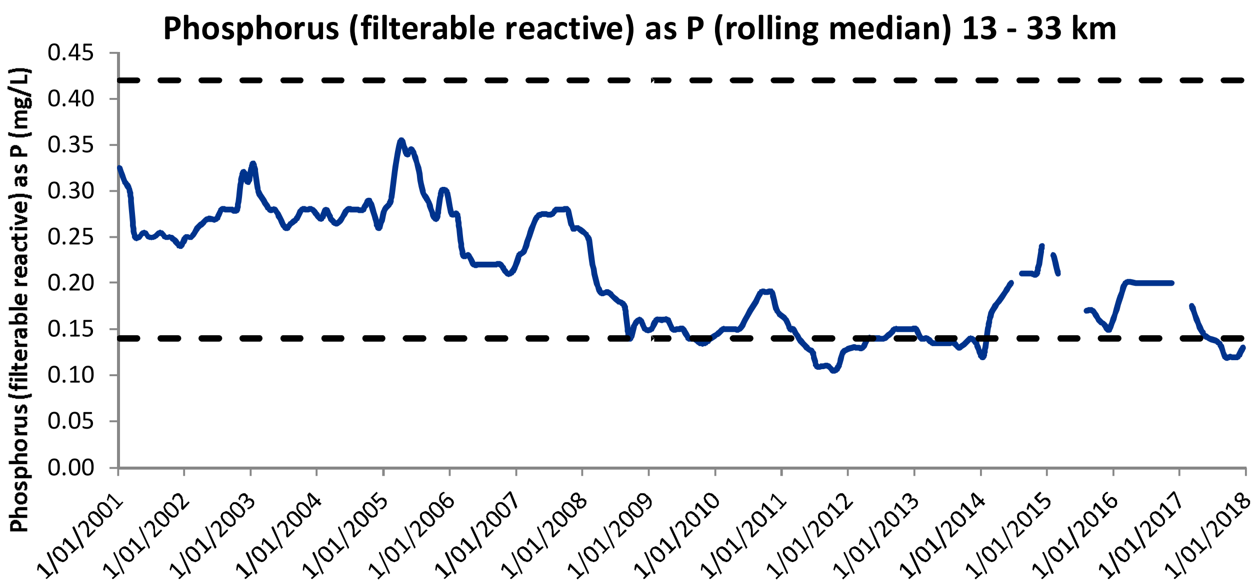
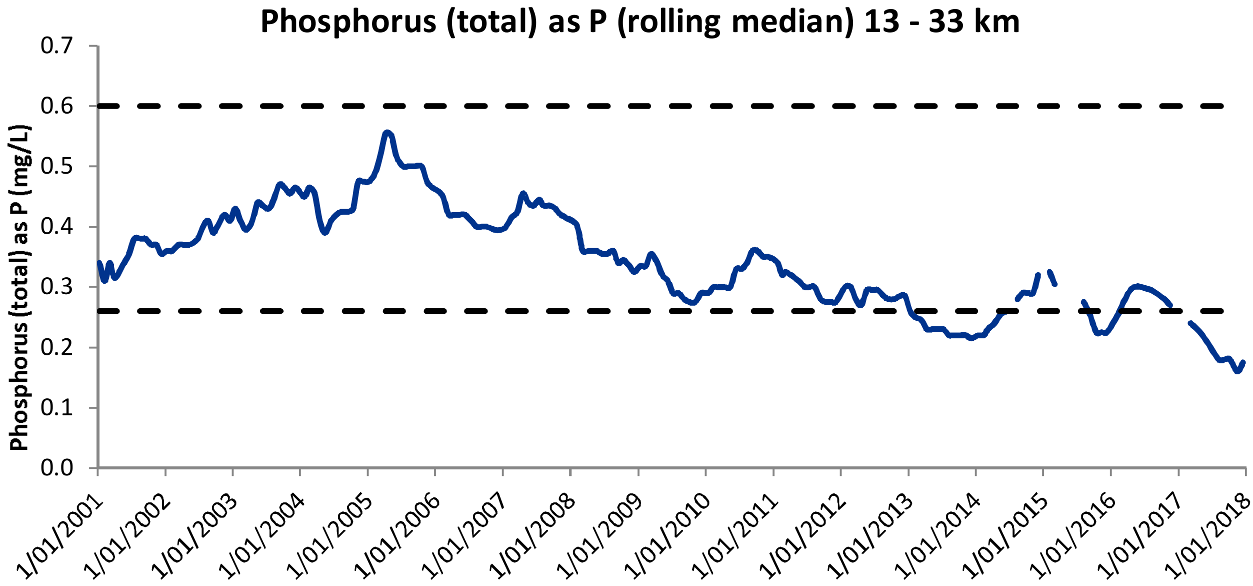
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Phosphorus (filterable reactive) as P (rolling median) 13 - 33 km
Phosphorus (filterable reactive) as P (mg/L)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Phosphorus (total) as P (rolling median) 13 - 33 km
Phosphorus (total) as P (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
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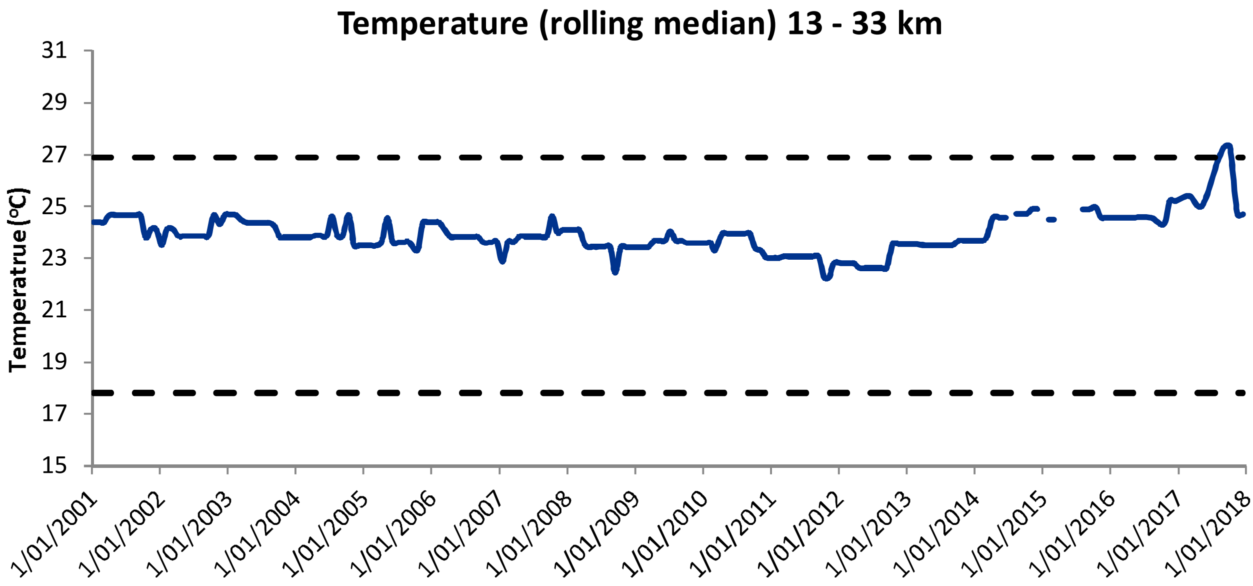
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Temperature (rolling median) 13 - 33 km
Temperatrue (ºC)
15
17
19
21
23
25
27
29
31
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
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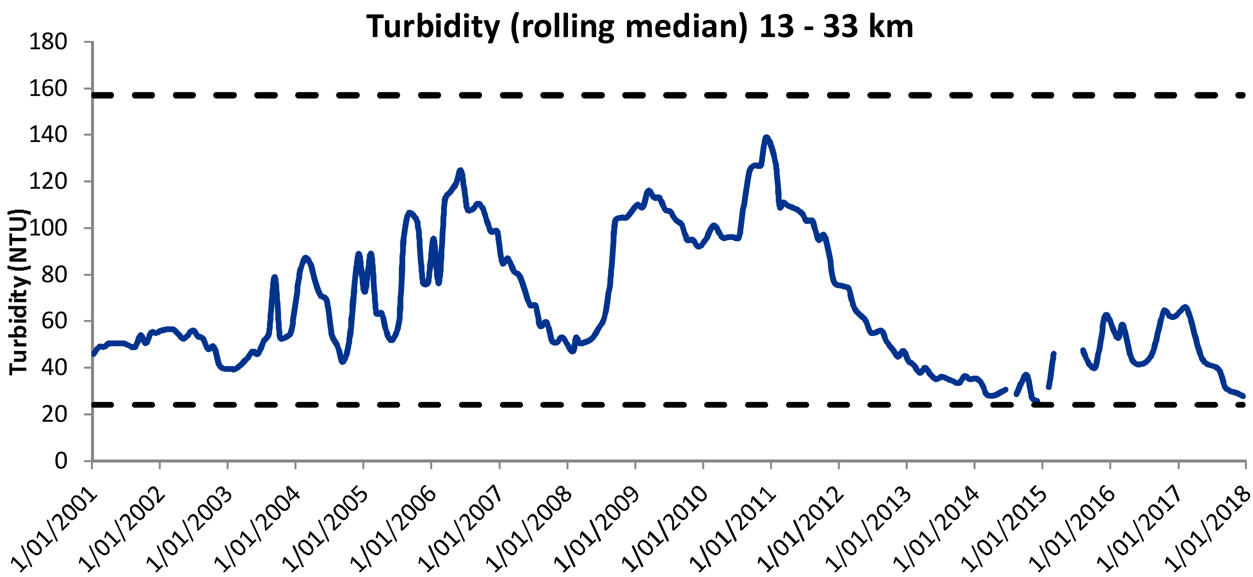
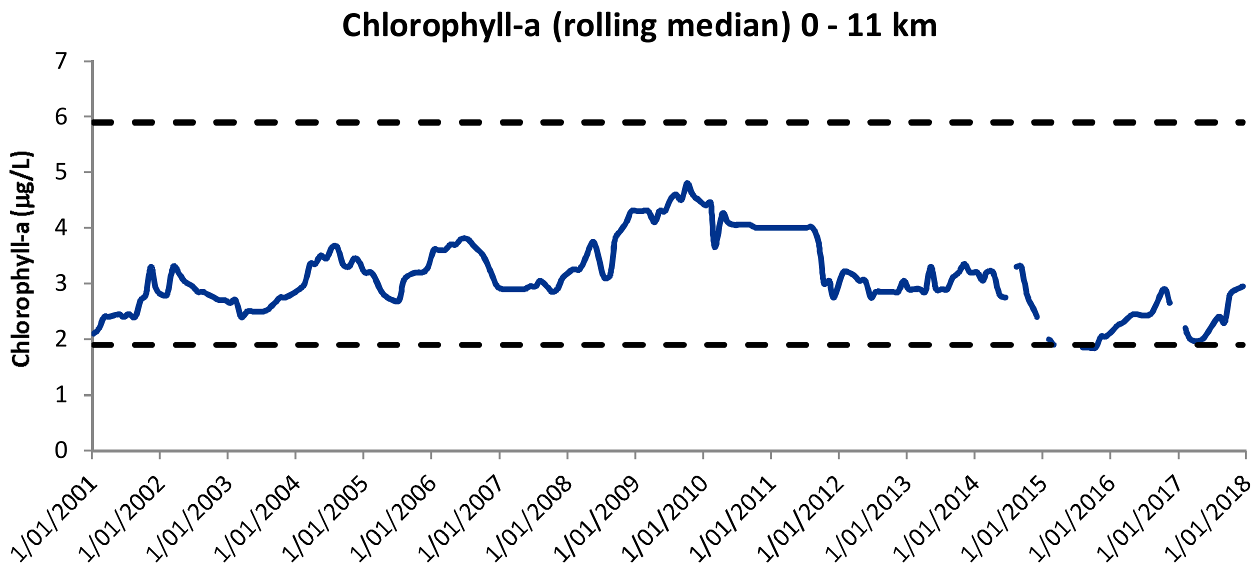
1/01/2017
1/01/2018

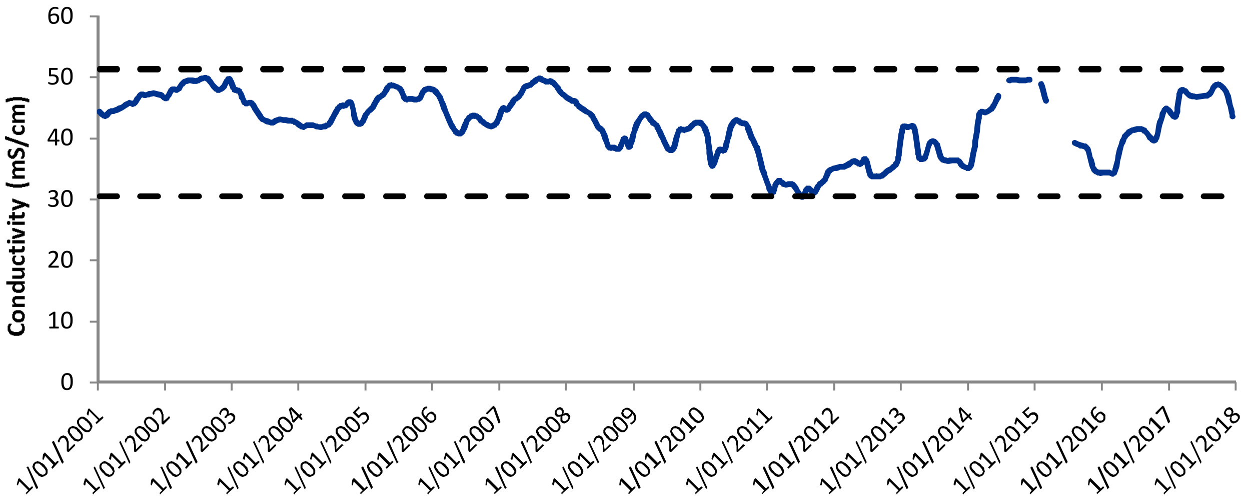


D.2 Below Albert River confluence – 0-11 km AMTD

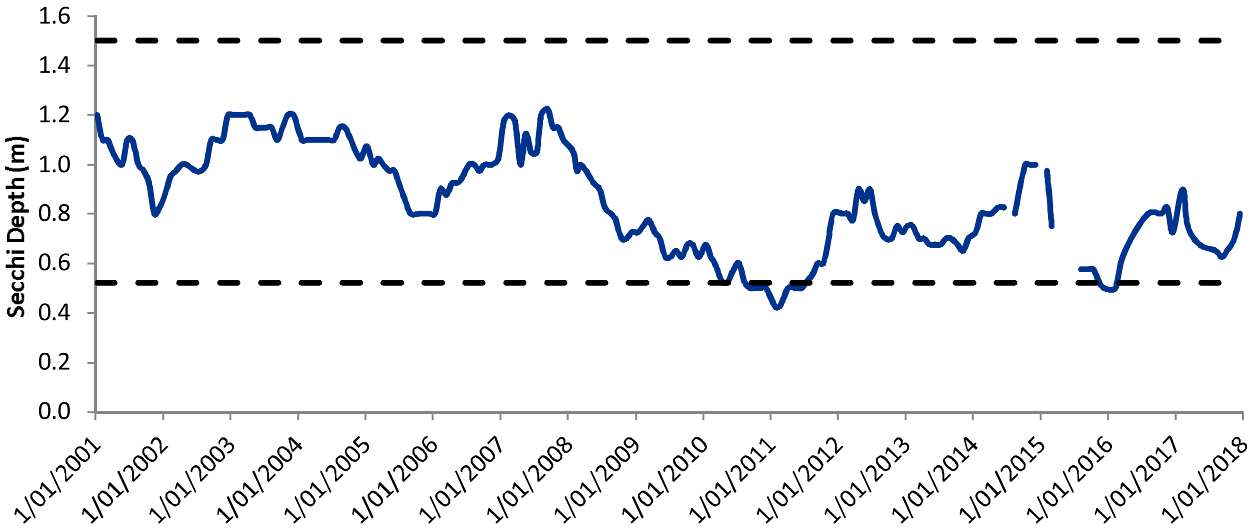
Horizontal dashed lines = Lower and upper trigger values to be applied after the first year of dam operation.

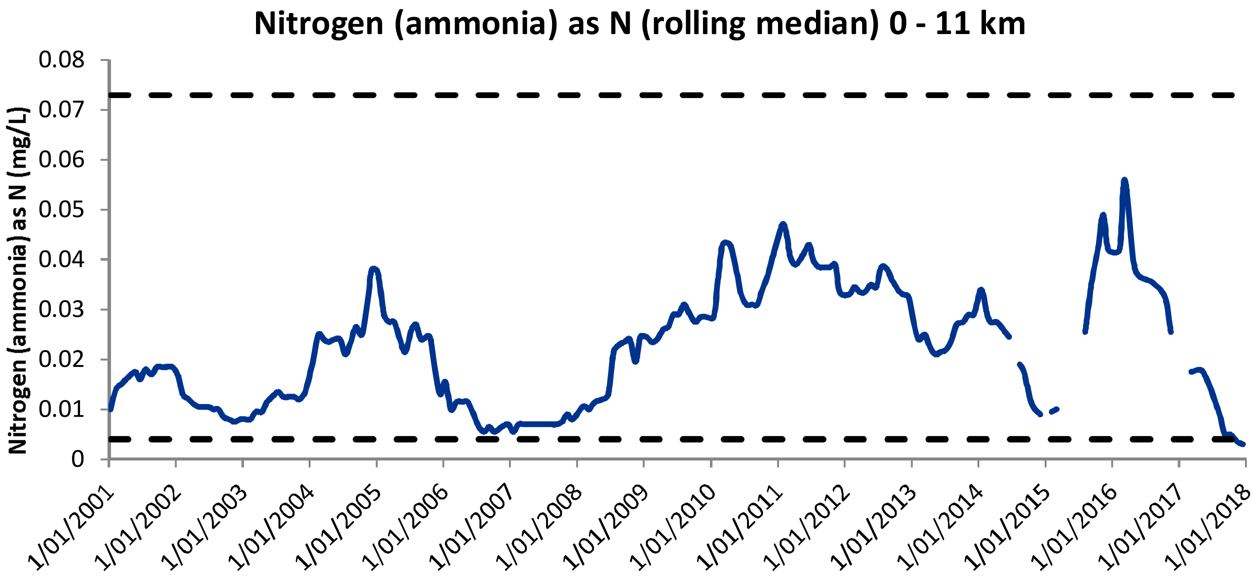


Conductivity (rolling median) 0 - 11 km

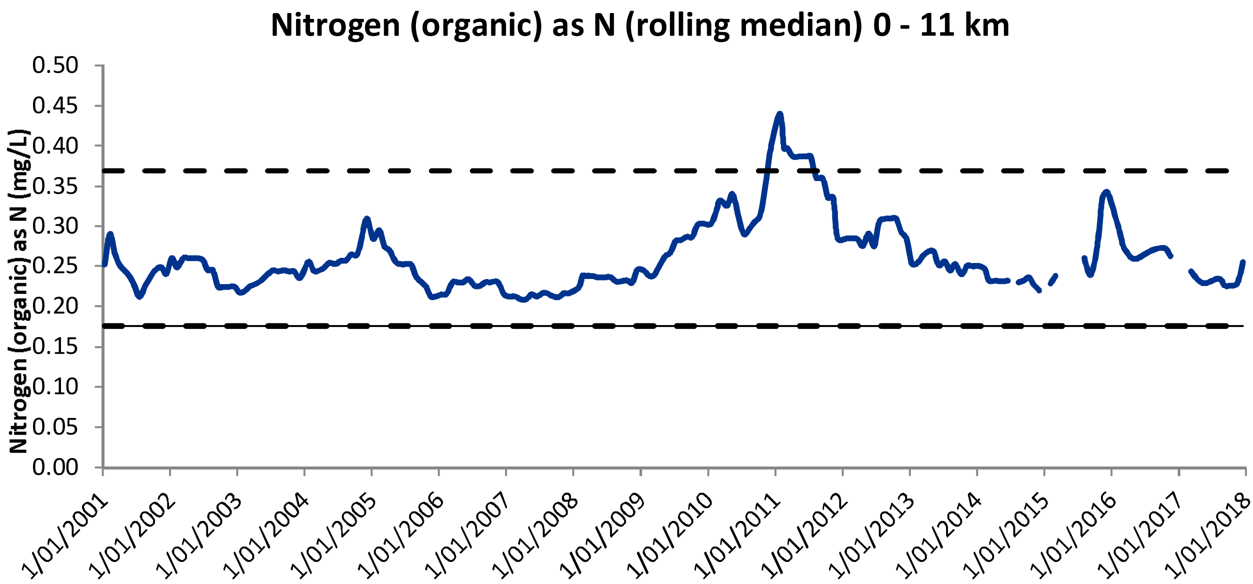


Secchi Depth (rolling median) 0 - 11 km





Nitrogen (ammonia) as N (rolling median) 0 - 11 km
Nitrogen (ammonia) as N (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018



Nitrogen (organic) as N (rolling median) 0 - 11 km
Nitrogen (organic) as N (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
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1/01/2013
1/01/2014
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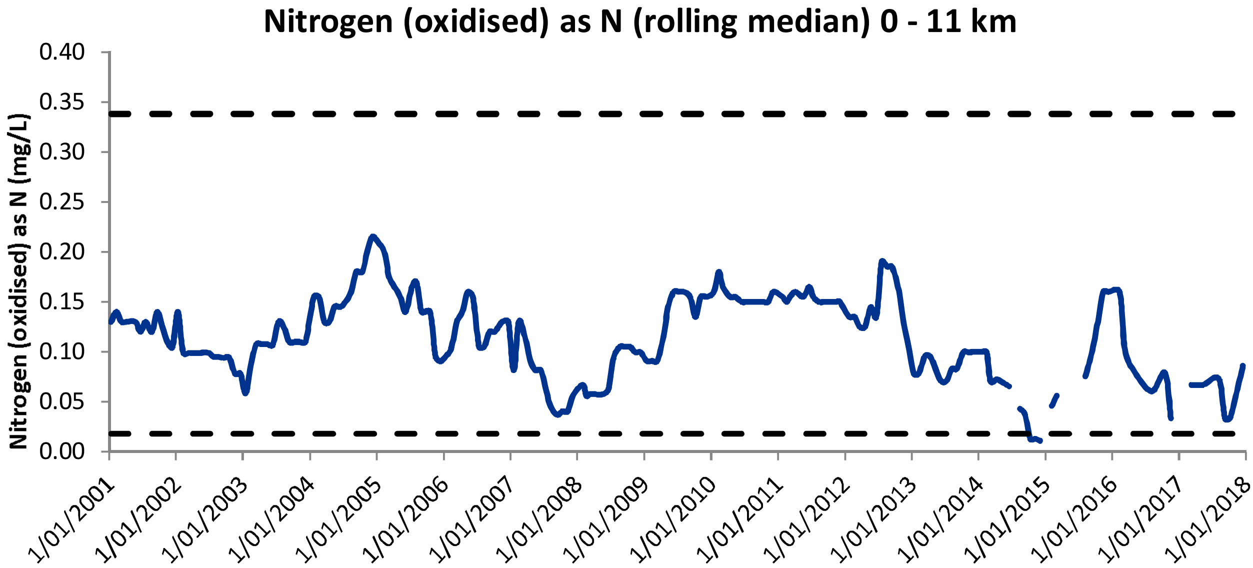
1/01/2016
1/01/2017
1/01/2018


Nitrogen (oxidised) as N (rolling median) 0 - 11 km
Nitrogen (oxidised) as N (mg/L)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
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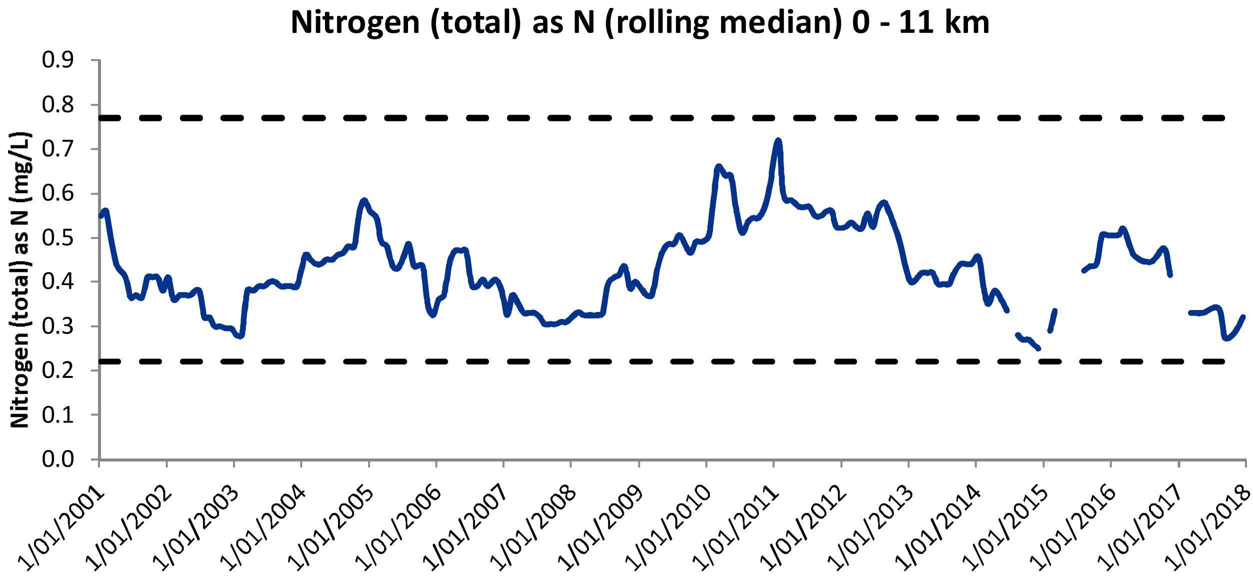
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Nitrogen (total) as N (rolling median) 0 - 11 km
Nitrogen (total) as N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
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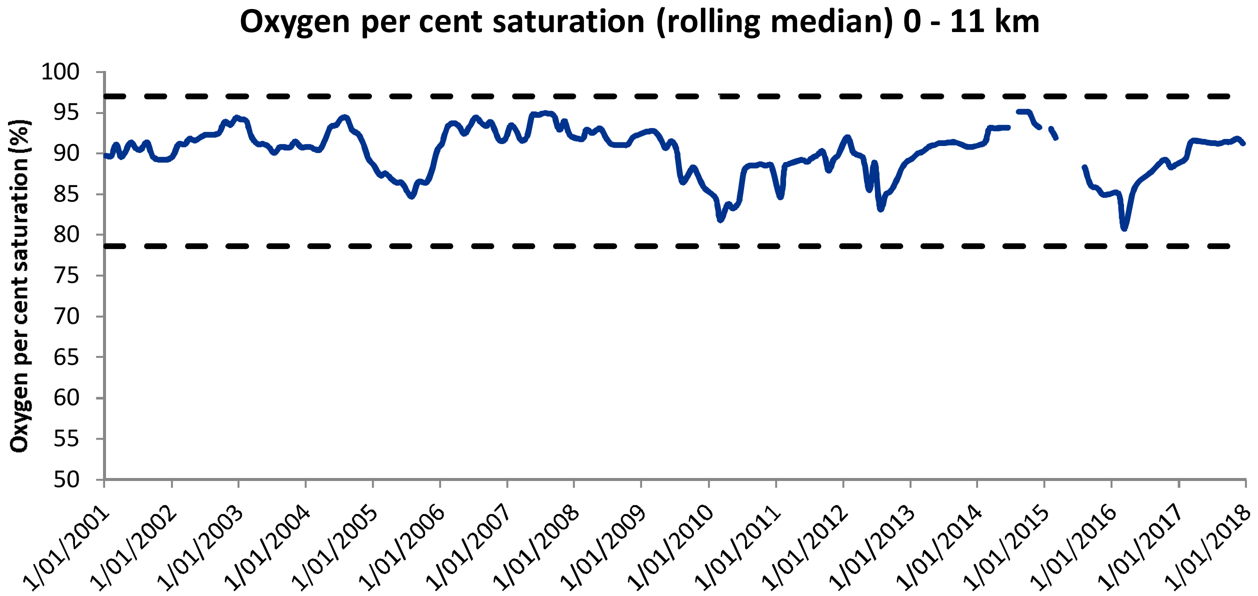
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018



Oxygen per cent saturation (rolling median) 0 - 11 km
Oxygen per cent saturation (%)
100
95
90
85
80
75
70
65
60
55
50
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
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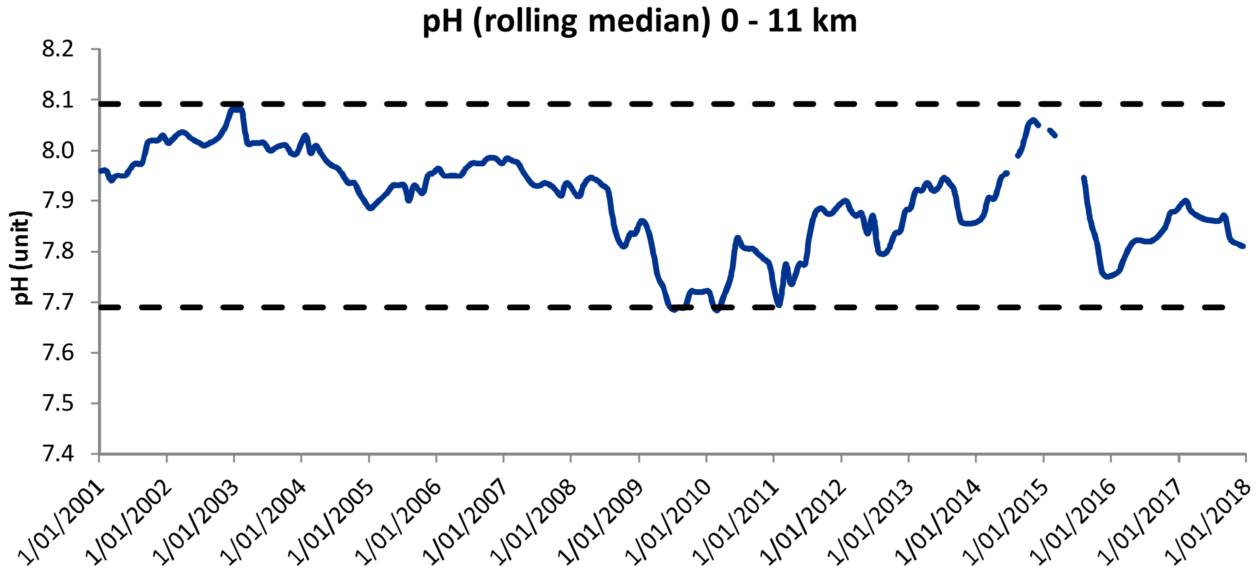
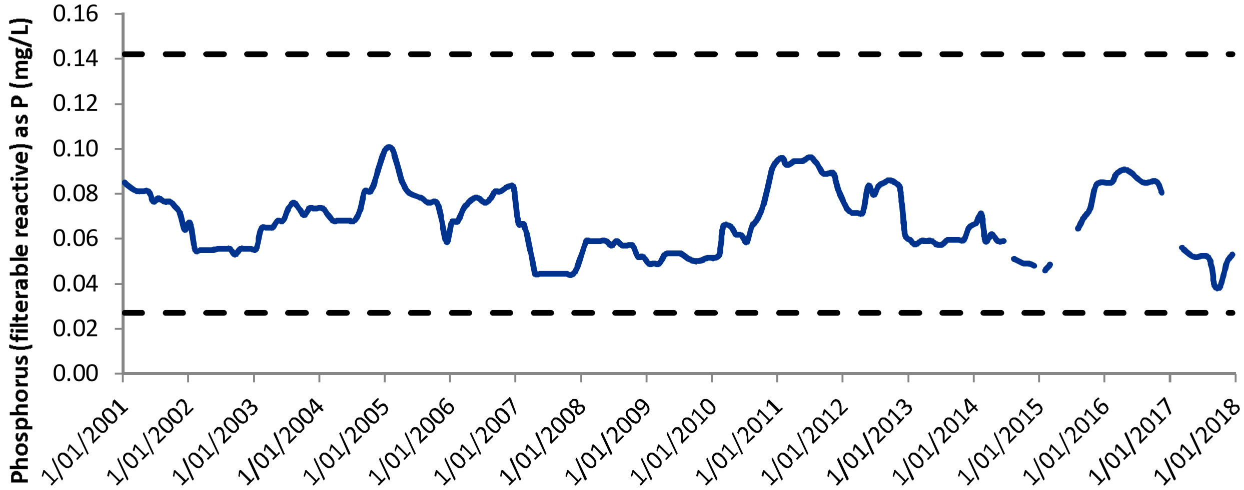
1/01/2016
1/01/2017
1/01/2018

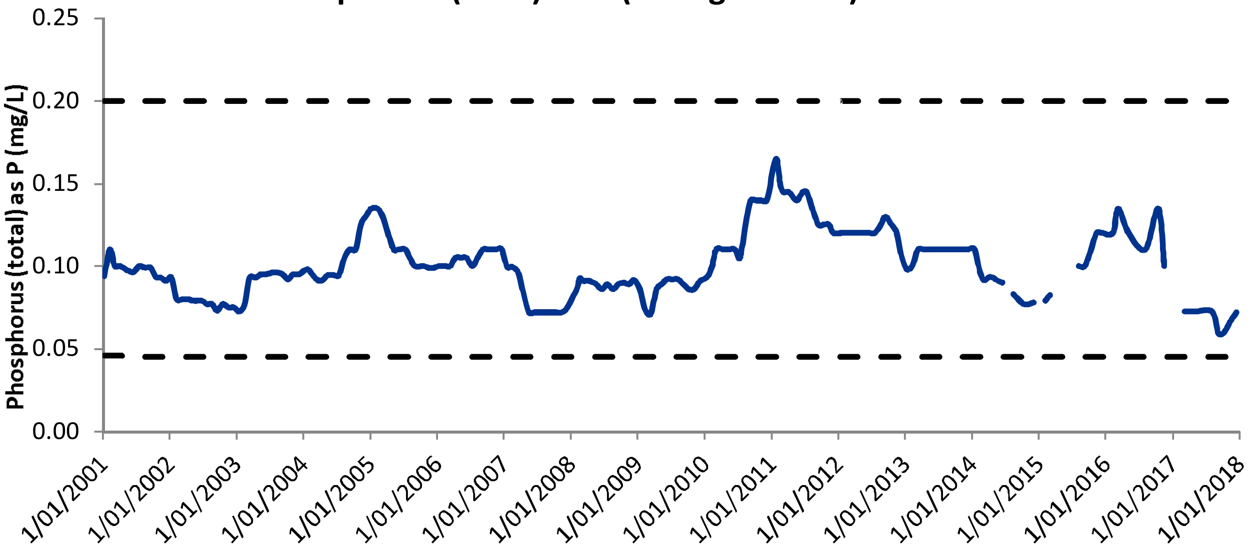


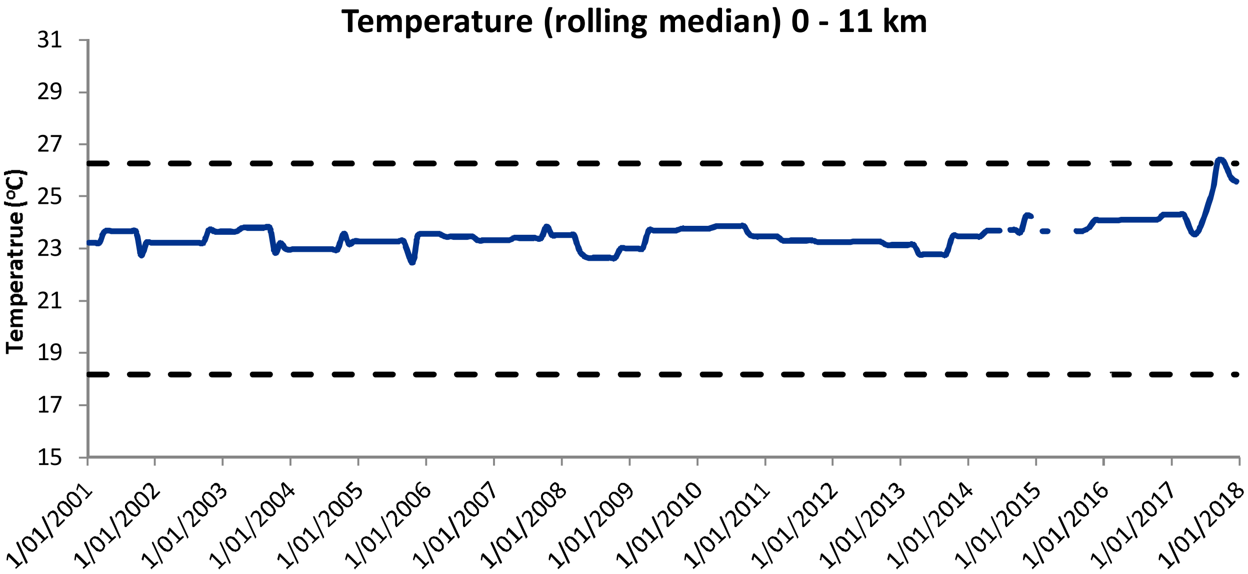
pH (rolling median) 0 - 11 km
pH (unit)
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018

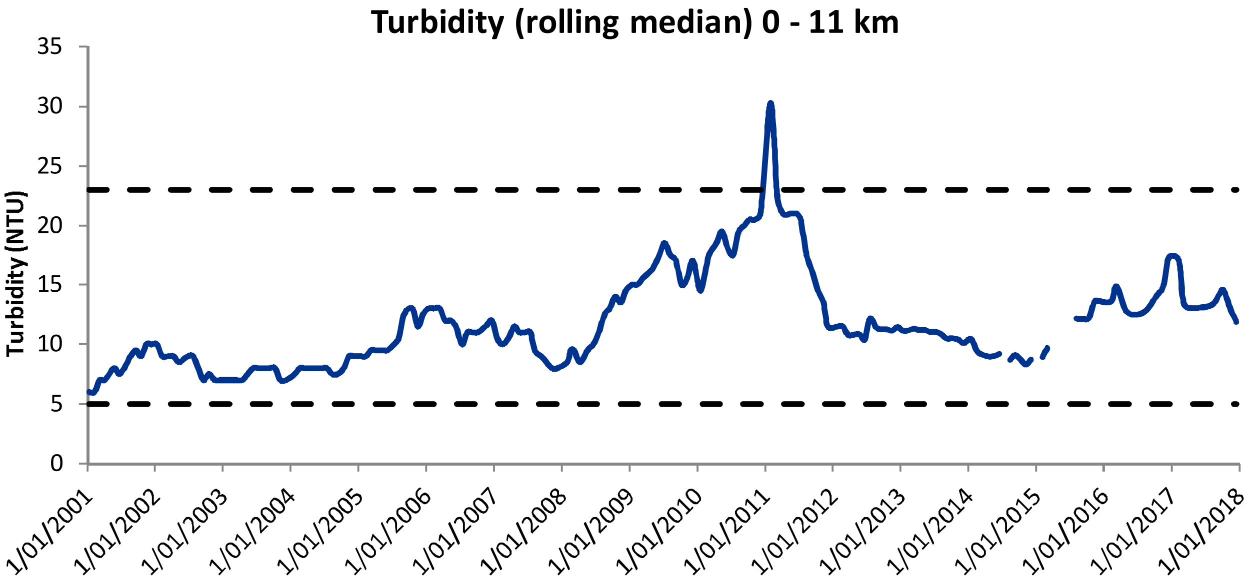
Phosphorus (filterable reactive) as P (rolling median) 0 - 11 km



Phosphorus (total) as P (rolling median) 0 - 11 km




Temperature (rolling median) 0 - 11 km
Temperatrue (ºC)
31
29
27
25
23
21
19
17
15
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018


Turbidity (rolling median) 0 - 11 km
Turbidity (NTU)
35
30
25
20
15
10
5
0
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
1/01/2013
1/01/2014
1/01/2015
1/01/2016
1/01/2017
1/01/2018