



Port of Brisbane Satellite Derived Turbidity Monitoring

Historical Assessment 2011- 2025

Final

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Indigenous artist



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Executive Summary

Background and Approach

Turbidity indicates suspended sediment behaviour in the lower Brisbane River and western Moreton Bay and informs dredging, sediment management and port operations. Interpretation is complicated by natural variability from river discharge, catchment runoff and other physical processes. This assessment establishes a 2011-2025 satellite-derived turbidity baseline for the lower Brisbane River and western Moreton Bay. It characterises turbidity range, variability and spatial distribution to help distinguish system-scale responses from localised sediment disturbance relevant to Port of Brisbane operations.

MODIS, Landsat and Sentinel-2 imagery was analysed across seven reporting zones spanning the Brisbane River estuary, port-adjacent waters, western Moreton Bay embayments and offshore bay environments. Satellite patterns were interpreted with rainfall information and compared with 2025 continuous in situ turbidity measurements.

Findings

A persistent land-to-sea turbidity gradient was evident. Turbidity and variability were greatest in the Brisbane River estuary and port-adjacent waters and decreased offshore. Median turbidity declined from approximately 9 FNU in the Brisbane River estuary and 8 FNU near the river mouth to 4 FNU in Central Bay and 2 FNU in Spitfire Channel.

The largest responses occurred during major rainfall and flood periods. During the January 2011 flood, turbidity exceeded 1,460 FNU near the river mouth. The February-March 2022 flood produced maxima above 500 FNU in multiple zones. Response magnitude varied, but major floods consistently produced substantial turbidity increases across reporting zones.

Despite episodic increases, turbidity repeatedly returned to characteristic background ranges. No consistent long-term increase or decrease was evident, with behaviour dominated by short-duration events superimposed on a relatively stable spatial structure.

Results Validation and Method Limitations

Satellite-derived turbidity was compared with continuous in situ measurements. Satellite observations captured broad near-surface spatial patterns, relative temporal variability and major events at the system scale. Agreement was strongest at shallow turbid nearshore sites and weaker at clearer deeper sites, where fixed-depth measurements are less comparable with surface optical observations. Differences also reflect unit differences, surface optical retrieval versus point measurement, atmospheric correction uncertainty and the positive local bias. Offshore field measurements generally below 1 NTU are therefore broadly consistent with satellite-derived values of approximately 2 FNU within method uncertainty. This small absolute offset confirms low-turbidity offshore conditions rather than precise one-to-one agreement at low concentrations.

Conclusion

The turbidity record shows a persistent spatial gradient and substantial short-term variability during major rainfall and flood periods. The baseline provides a defensible framework for assessing broad patterns in background turbidity variability, distinguishing typical environmental variability from conditions warranting further investigation, and supporting the future development of operational dredge management approaches.

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1 Introduction

1.1 Background

Western Moreton Bay and the lower Brisbane River form a dynamic estuarine-coastal system influenced by catchment inputs, hydrodynamic processes and port-related activities. Turbidity is a key indicator of suspended sediment behaviour because it affects light availability, primary productivity, benthic habitat condition and ecosystem health. Understanding spatial and temporal turbidity patterns is therefore important for interpreting environmental condition, assessing the context for port operations and supporting evidence-based coastal management.

Turbidity in estuarine and coastal waters is shaped by river discharge, tidal mixing, wind driven resuspension and catchment land use. In the lower Brisbane River and western Moreton Bay, fluvial inputs transport fine sediments and nutrients from a large, modified catchment, particularly following high-rainfall and flood events. Previous studies show that suspended sediment loads from the Brisbane River influence turbidity gradients extending into Moreton Bay, with elevated turbidity and reduced light near the river mouth and progressively clearer conditions toward open coastal waters (e.g., Cox 1998a; Dennison & Abal 1999; Tibbetts *et al.* 1998). Wind driven resuspension is also important in the shallow embayments of western Moreton Bay, where unconsolidated sediments can be mobilised during strong wind conditions.

Catchment modification has increased sediment and nutrient delivery to Moreton Bay. Land clearing, urban development, waterway erosion and streambank erosion have increased sediment runoff, while approximately 150 million tonnes of mud have accumulated in the bay over the past ~70 years, with sedimentation rates increasing after catchment clearing and during major floods (Capelin *et al.* 1998; Coates-Marnane *et al.* 2016b). These processes have contributed to progressive infilling and “muddification” of western Moreton Bay, where the spatial extent of muddy, easily resuspended sediment has more than doubled since the 1970s (Coates-Marnane *et al.* 2016).

Consistent with these catchment and sediment processes, Port of Brisbane monitoring has documented strong water-quality gradients across the lower estuary and western Moreton Bay, with higher turbidity, nutrients and metals in Brisbane River sites and progressively clearer conditions toward Waterloo Bay (BMT WBM 2014). Despite extensive local monitoring, long-term assessment of baseline turbidity across western Moreton Bay and the lower Brisbane River remains constrained by the spatial and temporal limitations of field sampling. Satellite remote sensing addresses these constraints by providing synoptic, long-term observations across the region. Multispectral sensors, including Sentinel-2, can resolve turbidity gradients, suspended sediment dynamics and event scale plumes in estuarine and coastal environments.

This assessment uses satellite-derived turbidity observations to examine spatial and temporal patterns across western Moreton Bay and the lower Brisbane River for the period 2011–2025, incorporating major flood events, contrasting rainfall regimes and multiple ENSO phases. Satellite observations are interpreted alongside rainfall, river discharge and wind conditions to support assessment of background variability and event scale response.

By integrating satellite observations, environmental drivers and regulatory management zones, the assessment provides supporting information for the future derivation of turbidity triggers for dredging operations. The baseline is intended to help distinguish background turbidity behaviour from unusual observations and to inform future operational dredge management in the Port of Brisbane region.

1.1 Aim and Objectives

The aim of this assessment is to characterise historical baseline turbidity conditions across western Moreton Bay and the lower Brisbane River adjacent to the Port of Brisbane. The assessment is intended to provide the background information needed to support the future derivation of turbidity triggers for dredging operations by describing how turbidity varies naturally through space and time, and how it responds to key environmental drivers including rainfall and river discharge associated with flood events.

The specific objectives of this assessment are to:

- Characterise spatial patterns in turbidity, including comparisons among reporting regions.
- Describe temporal variability in turbidity, across multiple timescales, including event scale, seasonal and inter-annual behaviour.
- Examine relationships between observed turbidity patterns and key environmental drivers, including rainfall and flooding.
- Evaluate satellite-derived turbidity estimates using in situ turbidity measurements and evaluate the accuracy and reliability of the remote-sensing dataset.

1.2 Study Area

The Study Area shown in Figure 1.1 has been structured to align with the *Environmental Protection (Water and Wetland Biodiversity) Policy (EPP Water) 2019* management zones and water types for the Moreton Bay region. These water types reflect ecological values, management intent and natural physical characteristics, and provide the basis for reporting spatial turbidity patterns and establishing baseline conditions. The EPP classifies western Moreton Bay as slightly disturbed (SD) to moderately disturbed (MD) open/enclosed coastal waters, and the lower Brisbane River as moderately disturbed (MD) lower-estuary waters.

Western Moreton Bay is a shallow, semi-enclosed embayment in Southeast Queensland, separated from the Coral Sea by Moreton and North Stradbroke Islands. The tidal lower Brisbane River discharges into the western bay, forming a dynamic estuarine-coastal system with semi-diurnal tides, strong mixing and localised stratification during elevated freshwater inflow and wet-season conditions (Dennison & Abal 1999; BMT WBM 2014; Yu *et al.* 2014). Major rainfall and flood events deliver freshwater and fine sediment from the Brisbane River catchment into western Moreton Bay, temporarily increasing turbidity over broad areas (Dennison & Abal 1999; Coates-Marnane *et al.* 2016; Healthy Land & Water 2020). The shallow western bay is also susceptible to wind- and wave-driven resuspension of bottom sediments, whereas deeper, more ocean-influenced areas generally experience greater flushing and clearer water conditions (Dennison & Abal 1999; BMT WBM 2014).

Port of Brisbane operations are concentrated at the mouth of the Brisbane River and occur within an environment that is already naturally turbid and variable. Navigation channel maintenance, land reclamation, vessel movements, dredged-material placement and port infrastructure can generate localised turbidity through sediment disturbance, propeller wash, modified flow paths and runoff from developed port land during heavy rainfall (BMT WBM 2014; BMT 2023). Long-term monitoring indicates that these port-related effects are typically localised and occur against a background of larger catchment-driven turbidity associated with floods and wind driven resuspension (BMT WBM 2014; Healthy Land & Water 2020). This setting creates the need for a regional baseline that can inform future turbidity trigger development by distinguishing expected background variability from observations that may warrant operational review or further investigation during dredging.

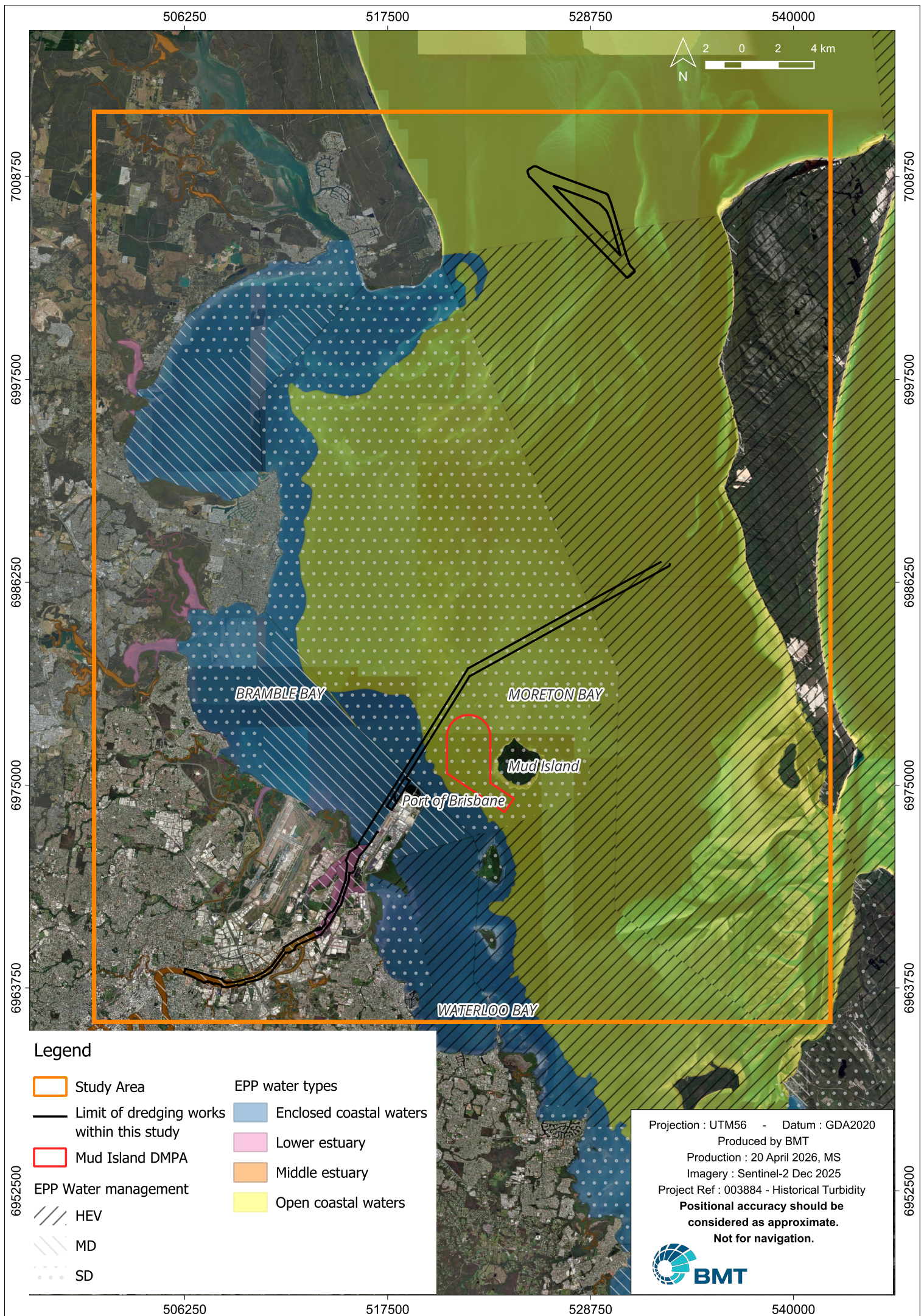


Figure 1.1 Monthly Turbidity Distribution for Z1 (2011–2025)

2 Methods

2.1 Overview of Datasets

This assessment draws on multiple complementary datasets to characterise turbidity dynamics across the lower Brisbane River estuary and adjacent waters of Moreton Bay between 2011 and 2025. The primary dataset comprises satellite-derived turbidity observations, which provide consistent long-term spatial coverage across all reporting zones and enable assessment of both estuarine and marine turbidity patterns over a range of hydrological and environmental conditions. These observations support the evaluation of spatial gradients, seasonal variability, long-term trends, and the response of the system to episodic disturbance events.

To assist interpretation of the satellite-derived turbidity record, rainfall data from multiple Bureau of Meteorology monitoring stations within the Brisbane River catchment were incorporated into the analysis. Rainfall information provides important hydrological context for understanding periods of elevated turbidity associated with catchment runoff, river discharge, and flood-related sediment transport. The combined datasets allow turbidity patterns to be examined within the context of short-term rainfall events over the 15-year (2011–2025) assessment period.

In addition, targeted in situ turbidity measurements were collected between September and December 2025. Given the short monitoring duration and the fact that satellite observations reflect near-surface conditions while in situ sensors sample at depth (below ~3 m), this comparison is intended to evaluate relative agreement and temporal alignment between the datasets rather than serve as a formal correlation exercise.

2.2 Satellite Data and Turbidity Products

2.2.1 Satellite Imagery

Satellite imagery from MODIS, Landsat and Sentinel-2 was used to develop a long-term turbidity record for the Study Area between 2011 and 2025 (0). MODIS imagery was used for 2011 and 2012, while Landsat and Sentinel-2 provided higher-resolution observations from 2013 and 2015 onwards.

Each satellite platform provides different strengths. MODIS provides frequent long-term observations over large areas at 250 m resolution, Landsat provides multi-decadal continuity at 30 m resolution, and Sentinel-2 provides finer spatial detail at 10 m resolution for estuarine and nearshore waters. Combining these datasets provides a near-continuous satellite record that supports assessment of long-term turbidity patterns and shorter-term turbidity events.

Table 2.1 Satellite Constellation Used

Satellite	Start Date	End Date	Band Resolution	Retrieved Time for Study
MODIS Terra	Dec 1999	Operational	250 m	2011-2012
MODIS Aqua	Jul 2002	Operational	250 m	2011-2012
Landsat 8	Feb 2013	Operational	30 m	2013-2025
Landsat 9	Sep 2021	Operational	30 m	2021-2025
Sentinel-2A	Jun 2015	Operational	10 m	2015-2025
Sentinel-2B	Mar 2017	Operational	10 m	2017-2025
Sentinel-2C	Sep 2024	Operational	10 m	2024-2025

A total of 4,259 satellite images were downloaded and reviewed across the 2011-2025 study period. 1,713 scenes were excluded due to unsuitable image conditions (i.e., cloud cover, cloud shadow, sun glint, atmospheric contamination) or unsuccessful turbidity retrievals following image processing. The final analysis was therefore based on 2,546 valid satellite images, which were used to derive and assess turbidity patterns and long-term trends across Western Moreton Bay.

The combined use of MODIS, Landsat and Sentinel-2 imagery improves temporal coverage across Western Moreton Bay, while recognising that differences in sensor resolution, spectral response, acquisition timing and processing characteristics may introduce residual sensor-related variability within the time series.

2.3 Image Processing, Quality Control and Cloud Screening

All satellite images were processed through a quality-control workflow before turbidity values were calculated. This workflow was designed to remove or minimise factors that can interfere with the water-quality signal, including cloud cover, cloud shadow, haze, sun glint, land interference and other image artefacts. This ensured that turbidity estimates were based only on valid water pixels suitable for analysis.

2.3.1 Atmospheric Correction

Atmospheric correction procedures appropriate to each satellite sensor were applied to derive water-leaving reflectance from top-of-atmosphere imagery. Supporting atmospheric and meteorological datasets were incorporated where required to support atmospheric characterisation and promote consistency of reflectance retrievals across the satellite image dates.

2.3.2 Masking and Artefact Removal

Image screening was applied to identify and remove pixels that were not suitable for turbidity analysis. This included screening out land, cloud-affected areas, bright image artefacts, high-altitude atmospheric interference and pixels with unrealistic reflectance values.

These screening steps reduce the likelihood that non-water features or image artefacts influence the turbidity results. Only valid water pixels were retained for turbidity calculation and spatial analysis.

2.3.3 Sun Glint Correction

Sun glint occurs when sunlight reflects directly from the water surface and affects the satellite signal. Where present, sun glint was reduced using correction procedures based on short-wave infrared bands. This helped minimise the influence of surface reflection on the turbidity estimates.

2.3.4 Turbidity Derivation

Turbidity was estimated from atmospherically corrected satellite imagery using established semi-analytical algorithms that relate water-leaving reflectance¹ to turbidity (Nechad *et al.*, 2010; Nechad *et al.*, 2016; Dogliotti *et al.*, 2015). The approach uses different wavelength bands depending on the water conditions. For low to moderately turbid waters, turbidity was derived from red-band reflectance using the Nechad algorithm. Under increasing turbid conditions, where red-band reflectance can become less sensitive due to saturation effects, an alternative formulation incorporating near-infrared reflectance was applied following the approach of Dogliotti *et al.* (2015). Near-infrared wavelengths remain responsive over a wider turbidity range and are therefore better suited to highly turbid waters. This

¹ Water leaving reflectance is the reflection signal of solar radiation that leaves from the water surface after being absorbed by a water body (Hong *et al.*, 2025)

combined approach allowed turbidity to be estimated across the range of water conditions observed in the lower Brisbane River and Western Moreton Bay

Satellite-derived turbidity is reported in Formazin Nephelometric Units (FNU). These values represent area-averaged surface optical conditions and are not directly equivalent to depth-specific in situ turbidity measurements, which are commonly reported in NTU. Therefore, comparisons between satellite and field measurements should focus on relative patterns, timing and event response rather than exact one-to-one agreement.

2.4 Spatial Aggregation and Reporting Regions

To support spatial interpretation, the Study Area was subdivided into seven (7) zones representing various hydrodynamic settings and levels of exposure to catchment influence and anthropogenic activity, ranging from inner estuarine waters to offshore bay water as illustrated in Figure 2.1 and summarised in Table 2.2.

For each valid satellite image, turbidity was summarised within each zone using valid water pixels only. This approach reduces the influence of isolated pixels and provides a consistent basis for comparing turbidity conditions among zones.

Table 2.2 Reporting zones used for spatial aggregation of satellite derived turbidity

Zone ID	Zone name	EPP water type	Hydrodynamic setting and characteristics	Role in assessment
Z1	Middle Estuary (Brisbane River)	Middle to Lower Estuary (MD)	Tidal Brisbane River upstream of the port precinct; river-dominated with high background turbidity and rapid response to freshwater inflows and tidal resuspension	Inner-estuary baseline
Z2	Port of Brisbane / Bulwer Island / Crab and Lytton Creeks	Enclosed Coastal to Lower Estuary (MD)	Shallow port and industrial creeks with restricted flushing and very high baseline turbidity	Disturbance-influenced inner estuary
Z3	Outer Bar – Lower Estuary	Enclosed Coastal (MD) to Open Coastal Waters (SD)	Shallow embayment seaward of the river mouth with elevated turbidity influenced by fine sediments and wind driven resuspension	Estuary–bay transition
Z4	Waterloo Bay (seagrass meadows) – Lower Estuary	Enclosed Coastal Waters (MD with HEV sub-zone)	Shallow embayment with partial marine influence and lower, more variable turbidity	Ecologically sensitive zone
Z5	Moreton Bay – Open Coastal (Mud Island DMPA)	Open Coastal (SD)	Deeper, ocean-influenced waters surrounding the dredged material placement area	Offshore impact zone
Z6	Moreton Bay – Open Coastal (Central Bay, outside DMPA)	Open Coastal (SD)	Open coastal waters removed from direct estuarine and dredging influence	Open coastal reference
Z7	Spitfire Channel	Open Coastal (SD)	Open coastal waters removed from direct estuarine and dredging influence	Open coastal reference



Figure 2.1 Zones within Study Area

2.5 Environmental Driver Data

Daily rainfall data were sourced from Bureau of Meteorology monitoring stations considered representative of catchment and regional rainfall conditions, including Brisbane Airport (Station 040842), Helidon TM (Station 040829) and Wivenhoe Dam (Station 040763). The locations of these monitoring stations are shown in Figure 2.2. To support interpretation of rainfall-related turbidity responses, rainfall events were classified based on cumulative rainfall totals as low (≥ 20 to < 40 mm), medium (≥ 40 to < 100 mm), or high (≥ 100 mm). The timing and classification of rainfall events recorded at each station are presented in Figure 2.3.

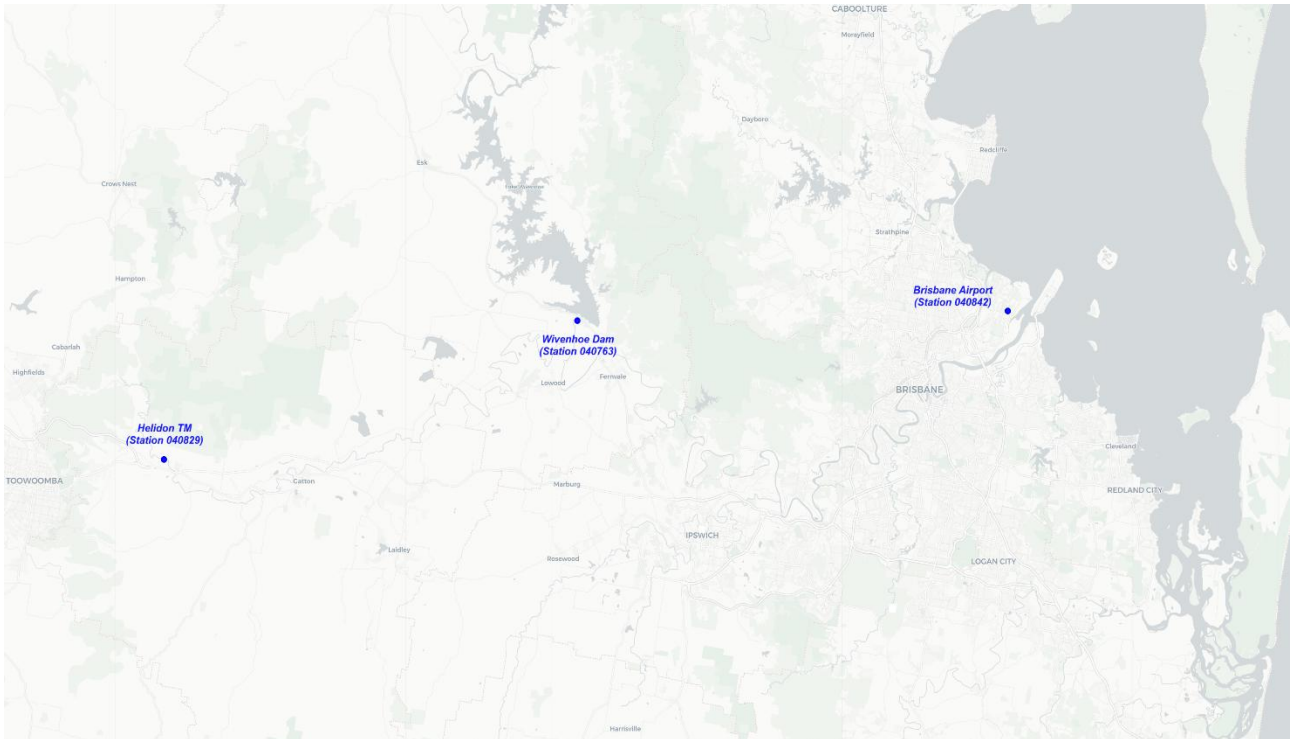


Figure 2.2 Locations of Bureau of Meteorology rainfall monitoring stations used in the study

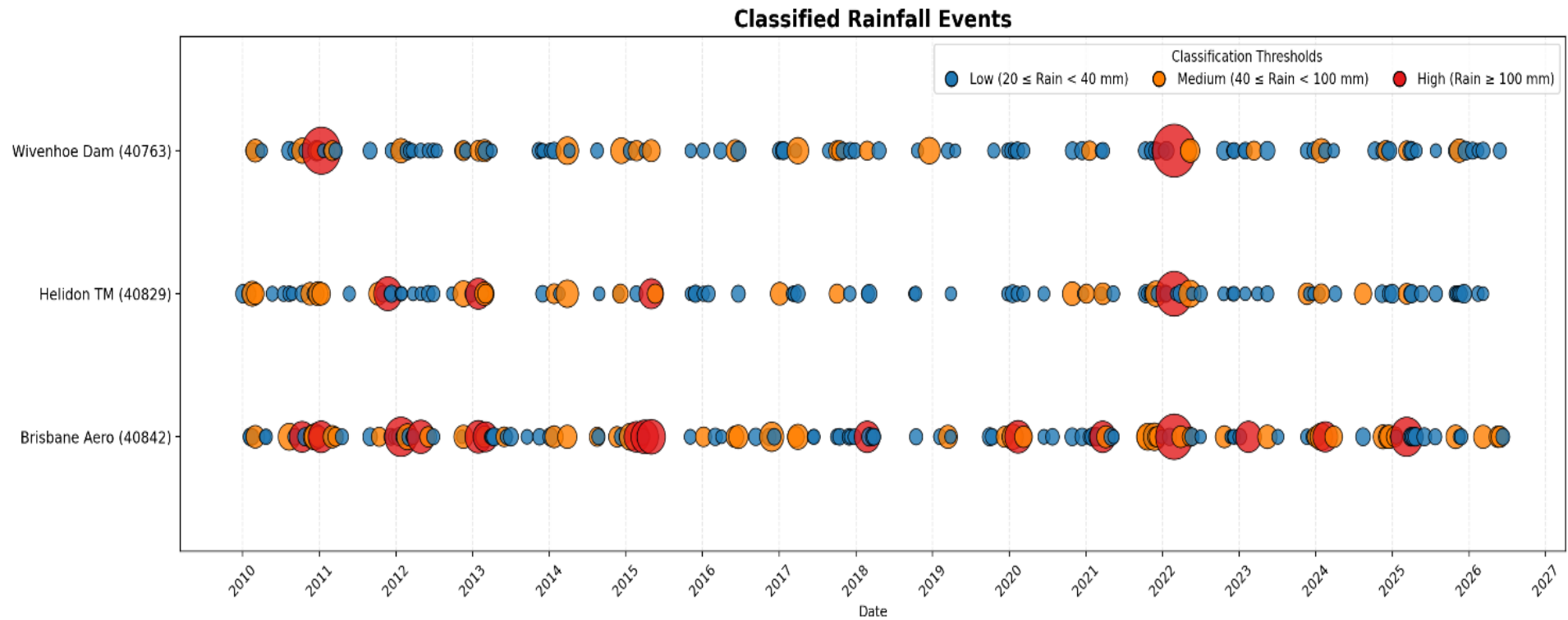


Figure 2.3 Classification of rainfall events recorded at Brisbane Airport, Helidon TM and Wivenhoe Dam between 2010 and 2025 based on cumulative rainfall thresholds.

2.6 Statistical Analyses of Spatial and Temporal Patterns

Statistical analyses were exploratory and descriptive, with the purpose of describing how turbidity varies spatially and temporally rather than formally testing predefined hypotheses. The analysis focused on identifying patterns, ranges and relative differences in turbidity between locations and over different time periods.

Turbidity behaviour was summarised using a range of complementary graphical and statistical summaries. These included box and whisker plots to describe the spread of turbidity values, rolling mean time series to show changes through time, percentile envelopes to illustrate typical ranges and variability through time and probability-of-exceedance curves to examine how often higher turbidity conditions occurred.

To support comparison among seasons and locations, seasonal turbidity thresholds (described above) were applied to calculate the proportion of observations exceeding these thresholds within each zone and year.

2.6.1 Validation Using In-situ Turbidity Data (September–December 2025)

Satellite-derived turbidity was evaluated using continuous in situ turbidity measurements collected from 8 September to 31 December 2025 at four representative sites (CEP01 (2.0 m depth), CEP06 (3.0 m depth), CEP07 (13.0 m depth), and CEP09 (15.0 m depth) as illustrated in Figure 2.4 (SWASH, 2026). In situ sensors recorded turbidity at fixed depths spanning shallow to deeper conditions.

Satellite–in situ comparisons were conducted using temporally matched observations on satellite acquisition dates to evaluate agreement in event timing, relative magnitude and transitions between background and elevated conditions. It can be noted that satellite retrievals represent surface optical conditions averaged over spatial footprints while in situ sensors provide depth-specific point measurements. The following metrics were applied:

- **Event detection metric:** Event detection performance was quantified using Probability of Detection (POD), a standard hit-rate metric describing the proportion of observed events that are successfully identified by the satellite record.
 - A “hit” occurs when an in situ–defined turbidity event is also detected in the satellite time series on at least one satellite acquisition date within the event window
 - A “miss” occurs when an in situ–defined event occurs but no corresponding satellite observation indicates elevated turbidity during that window (e.g., due to cloud cover or revisit timing)

POD was calculated as $POD = \frac{hits}{hits+miss}$

- **Mean bias metric:** For temporally matched satellite and in situ observations (i.e., pairs taken on satellite acquisition dates), systematic offset was summarised using mean bias, defined as the average difference (‘satellite’ minus ‘in situ’) across all matched pairs during the validation period. Mean bias is reported in FNU; positive values indicate satellite-derived turbidity is higher on average than the in-situ sensor, and negative values indicate the satellite-derived turbidity is lower on average.

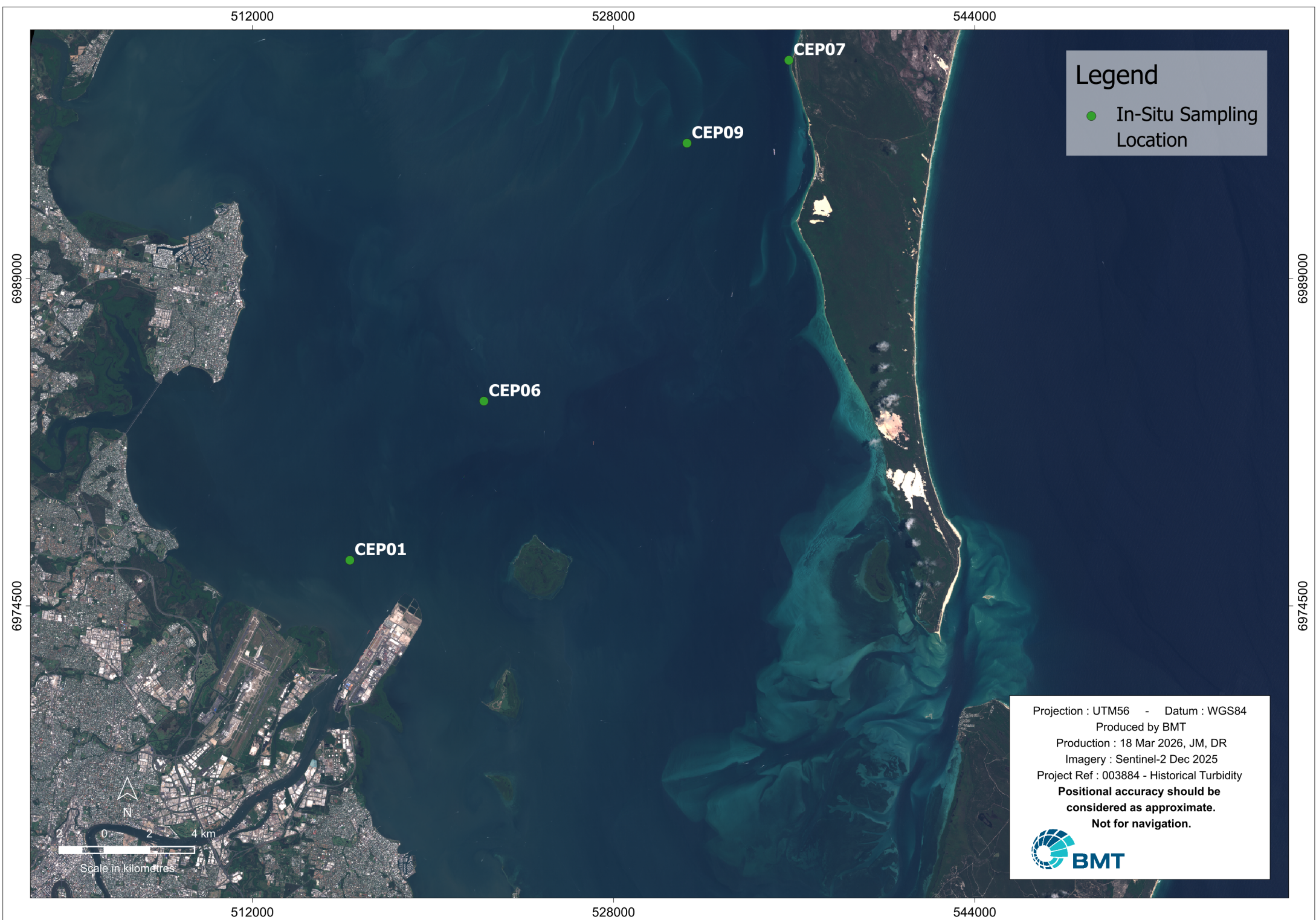


Figure 2.4 Locations of continuous in situ turbidity monitoring sites (CEP 01, CEP 06, CEP 07, and CEP 09).

2.7 Limitations and Uncertainties

The interpretation of satellite-derived turbidity is subject to several limitations and sources of uncertainty that should be considered when assessing the results:

- Satellite observations represent discrete snapshots in time, capturing water quality conditions only at the time of satellite overpass. Short-duration turbidity events occurring between acquisitions may not be detected.
- Cloud cover, cloud shadow, haze, sun glint and other atmospheric effects can reduce image availability and may limit the observation of some rainfall-driven turbidity events despite the application of quality-control procedures.
- Satellite-derived turbidity represents surface optical conditions, whereas in situ measurements are typically collected at fixed depths within the water column. Differences between satellite-derived and field-measured values may therefore occur where vertical stratification or mixing influences turbidity distributions.
- The spatial resolution of the satellite imagery influences the ability to resolve fine-scale turbidity patterns. While Sentinel-2 (10 m) and Landsat (30 m) provide relatively detailed observations of estuarine and nearshore environments, the coarser 250 m MODIS imagery used during 2011 and 2012 may not fully capture spatial variability within narrow waterways such as the lower Brisbane River. As a result, turbidity estimates within Zone 1 may be less representative during the MODIS period than during subsequent Landsat and Sentinel-2 observations.
- The use of multiple satellite missions introduces inherent differences in sensor design, spectral response functions, radiometric characteristics and revisit frequencies. While consistent processing and harmonisation procedures were applied, some variability between sensors may remain.
- Satellite pixels represent area-averaged conditions, whereas field observations represent point measurements. As a result, comparisons between satellite-derived and in situ datasets should be interpreted primarily in terms of relative patterns, temporal variability and event response rather than exact one-to-one correspondence.
- Atmospheric correction and turbidity retrieval algorithms introduce uncertainty, particularly under challenging environmental conditions such as highly turbid waters, strong sun glint, adjacency effects near shorelines, or complex atmospheric conditions.
- Rainfall is an important driver of turbidity but does not fully explain observed variability. Additional processes such as tidal exchange, river discharge dynamics, wind-wave resuspension, sediment availability, and marine dispersion processes can influence turbidity patterns and are not explicitly isolated within this assessment.
- The in-situ validation dataset covers a relatively short monitoring period (September-December 2025) and may not capture the full range of hydrological, seasonal and turbidity conditions observed across the 2011-2025 assessment period. Consequently, validation results should be interpreted as representative of the monitoring period rather than a comprehensive assessment of performance under all conditions.

While these limitations should be considered when interpreting the results, the combined use of multiple satellite platforms, rigorous quality-control procedures, and independent in situ validation provides a robust basis for assessing spatial and temporal turbidity patterns across Western Moreton Bay. The analysis is therefore considered suitable for identifying broad-scale trends, relative differences between zones, and turbidity responses to rainfall over the assessment period.

3 Results

3.1 Overview of Turbidity Patterns

The 2011-2025 satellite-derived turbidity record demonstrates spatial, temporal and seasonal variability across the Brisbane River estuary and Moreton Bay. Long-term patterns indicate that the highest turbidity levels and greatest variability generally occur within the Brisbane River estuary and adjacent lower-estuary environments (Zones 1, 2 and 4), while lower and more stable turbidity conditions are typically observed within the bay environments represented by Zones 5, 6 and 7. Zone 3 occupies an intermediate position between the lower estuary and the broader bay, displaying characteristics of both environments.

Across all zones, turbidity variability is strongly influenced by episodic runoff and flood events. Although typical background conditions remain relatively stable for much of the monitoring period, a small number of major rainfall events generated turbidity concentrations above long-term median conditions and account for several of the highest observations recorded throughout the study area. The influence of these events is evident in both the long-term statistical distributions and the longitudinal turbidity record.

Four major flood periods were identified as key drivers of turbidity variability during the monitoring period:

- **January 2011:** High rainfall occurred across the Brisbane River catchment during the January 2011 flood period (10–12 January). In the upper catchment, Wivenhoe Dam recorded 248.8 mm on 11 January and 133.4 mm on 12 January. In the western catchment, Helidon TM recorded 57.0 mm on 10 January, noting that data were unavailable during part of the peak flood period. Downstream Brisbane River recorded 112.4 mm on 10 January (Brisbane Aero). Figure 3.1—Figure 3.2 illustrate the progression of the January 2011 flood event and associated turbidity plume. Elevated turbidity is evident throughout the Brisbane River and adjacent western Moreton Bay immediately following the flood event, with subsequent imagery showing a progressive reduction in turbidity and plume extent as floodwaters receded and suspended sediments dispersed throughout Moreton Bay.
- **May 2015:** High rainfall occurred across the Brisbane River catchment during the flood period (1–3 May 2015), with the highest daily totals recorded in the lower and western catchments. Downstream Brisbane Aero recorded 134.2 mm on 2 May, while in the western catchment, Helidon TM recorded 101.0 mm on 2 May. Rainfall was lower in the upper catchment, with Wivenhoe Dam recording 54.8 mm on 2 May. Figure 3.3 illustrates turbidity conditions several days after the rainfall event (5 May 2015), with subsequent imagery showing near-complete dissipation of the turbidity plume within approximately 15 days across the lower Brisbane River and western Moreton Bay.
- **February-March 2022:** High rainfall occurred across the Brisbane River catchment during the late February–early March 2022 with particularly intense rainfall between 26 and 28 February. Daily totals exceeded 300 mm at Wivenhoe Dam, 200 mm at Helidon TM and 200 mm at Brisbane Aero. Figure 3.5 and Figure 3.6 illustrate turbidity several days after the rainfall events (2, 5 and 7 March), with subsequent imagery 10 days after showing near complete dissipation of the turbidity plume across Brisbane River and Moreton Bay.
- **March 2025:** High rainfall occurred during the March 2025 flooding event associated with Tropical Cyclone Alfred (approximately 6–11 March), with the most intense rainfall concentrated in the lower catchment. Brisbane Aero recorded 163.4 mm on 9 March and 172.8 mm on 10 March, substantially higher than totals recorded at Wivenhoe Dam and Helidon TM. Figure 3.7 and Figure 3.8 illustrates elevated turbidity one day after the rainfall event (11 March 2025) across parts of western Moreton Bay, with turbidity progressively dissipating in subsequent imagery (14 and 16 March). A secondary turbidity response is evident in the upper Brisbane River on 31 March.

The representative flood event imagery demonstrates the strong influence of major rainfall and flood events on turbidity conditions throughout the Brisbane River estuary and western Moreton Bay. While the magnitude and spatial extent of individual events vary, a consistent pattern is evident whereby elevated turbidity originates within the Brisbane River and lower estuary before progressively attenuating seaward through Moreton Bay.

Across the monitoring period, long-term turbidity patterns indicate a clear land-to-sea gradient, with both background turbidity conditions and event magnitudes decreasing from the river-dominated environments of the lower Brisbane River to the more marine-influenced waters of Moreton Bay. During major runoff and flood events, turbidity becomes elevated across much of the Study Area and considerable overlap occurs between zones, demonstrating the capacity for flood-derived sediment plumes to influence broad areas of the estuary and bay system. Outside these events, the characteristic spatial gradient re-establishes, with background turbidity conditions decreasing progressively from the Brisbane River to offshore Moreton Bay.

Temporal analysis indicates that turbidity variability is strongly event driven and closely aligned with seasonal rainfall patterns. Variability is generally greatest during summer and early autumn when the largest rainfall, runoff and flood events occur within the Brisbane River catchment, while winter conditions are typically characterised by lower turbidity and reduced variability. Despite differences in magnitude between zones, the influence of major wet-season runoff events is evident throughout the estuary and bay system.

Detailed assessment of turbidity distributions, spatial gradients and temporal variability is provided in Sections 3.1 and 3.2. Detailed annual turbidity time-series plots for each monitoring zone are provided in Annex A.

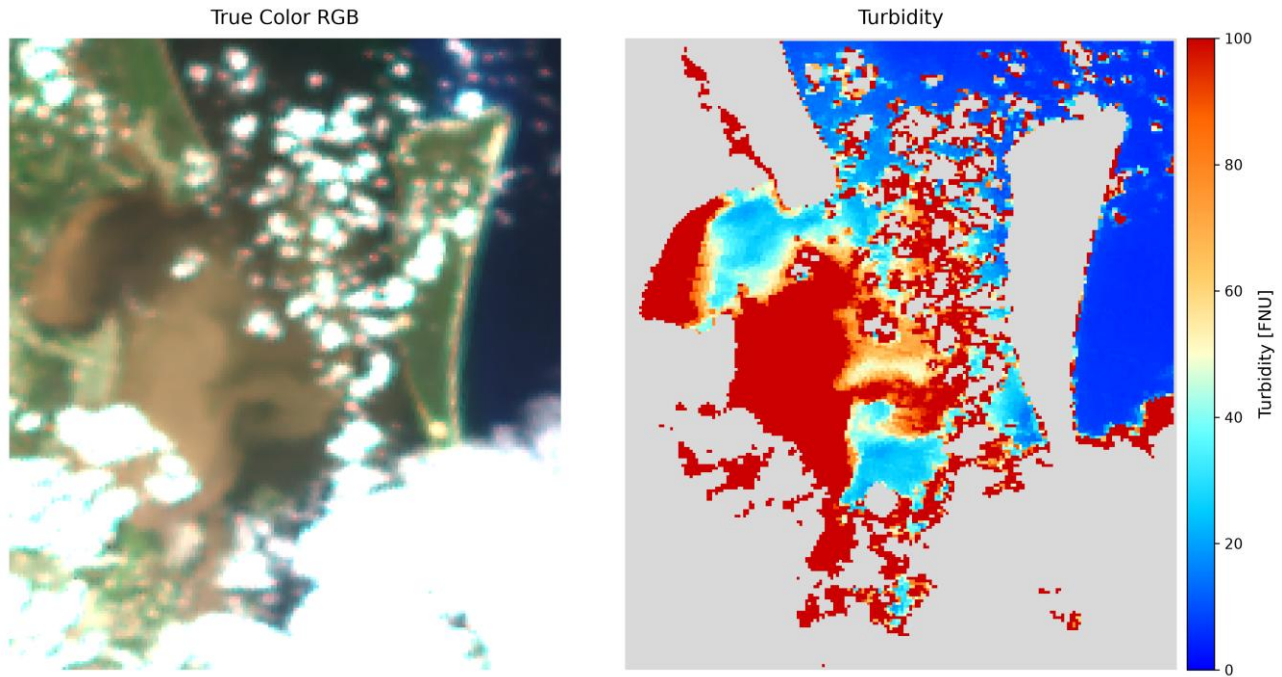
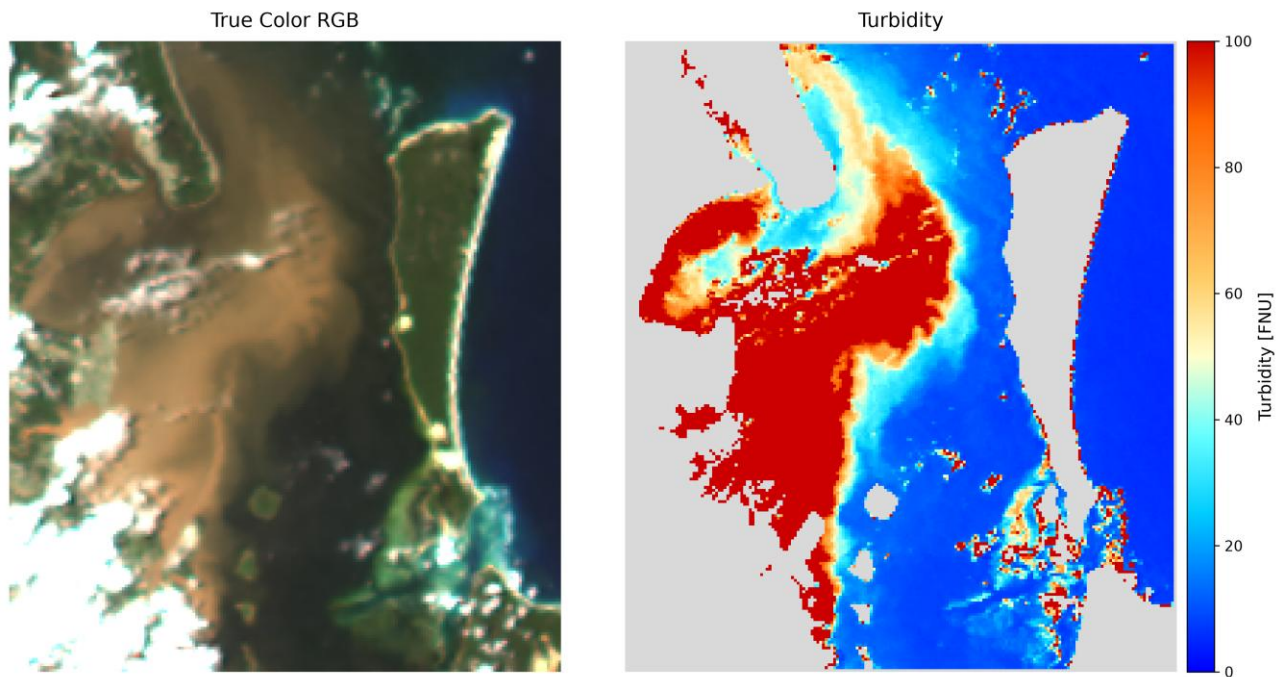
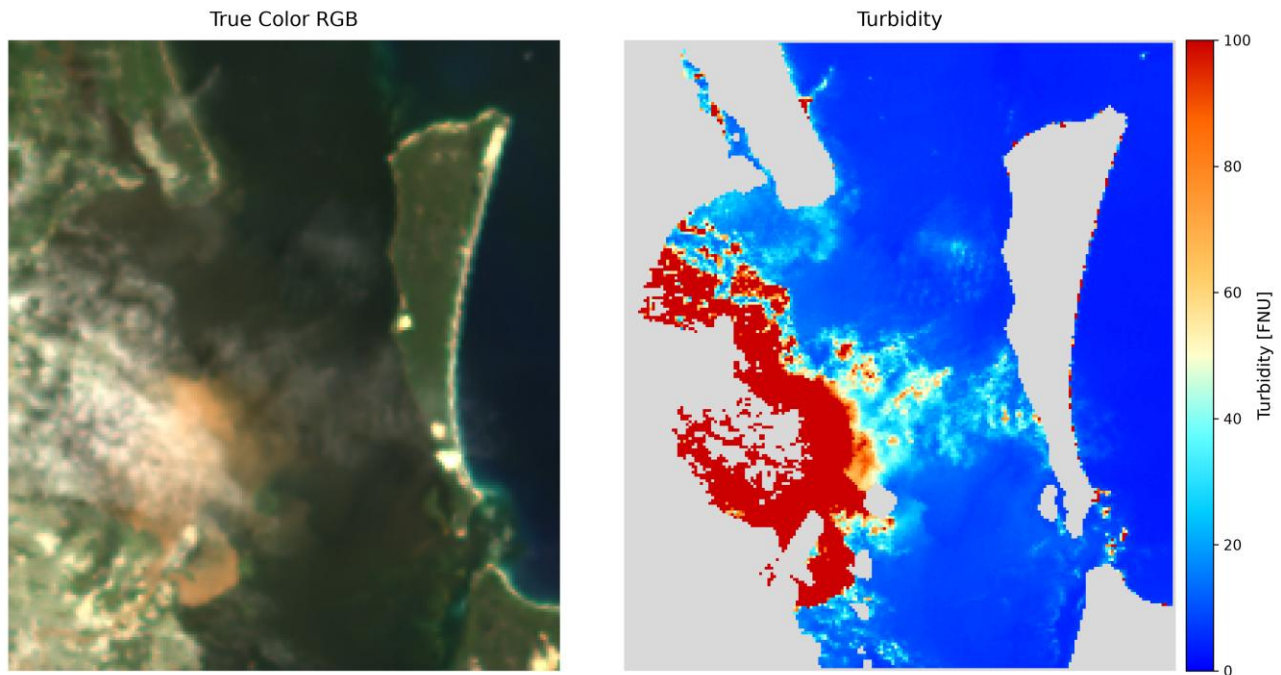
Sensor: Terra MODIS | Local Time: 2011-01-13 09:30:00 AEST

Sensor: Aqua MODIS | Local Time: 2011-01-15 13:40:00 AEST


Figure 3.1 Representative turbidity conditions during the flooding event (January 2011) derived from MODIS (250 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: Terra MODIS | Local Time: 2011-01-18 09:50:00 AEST



Sensor: Terra MODIS | Local Time: 2011-01-25 09:55:00 AEST

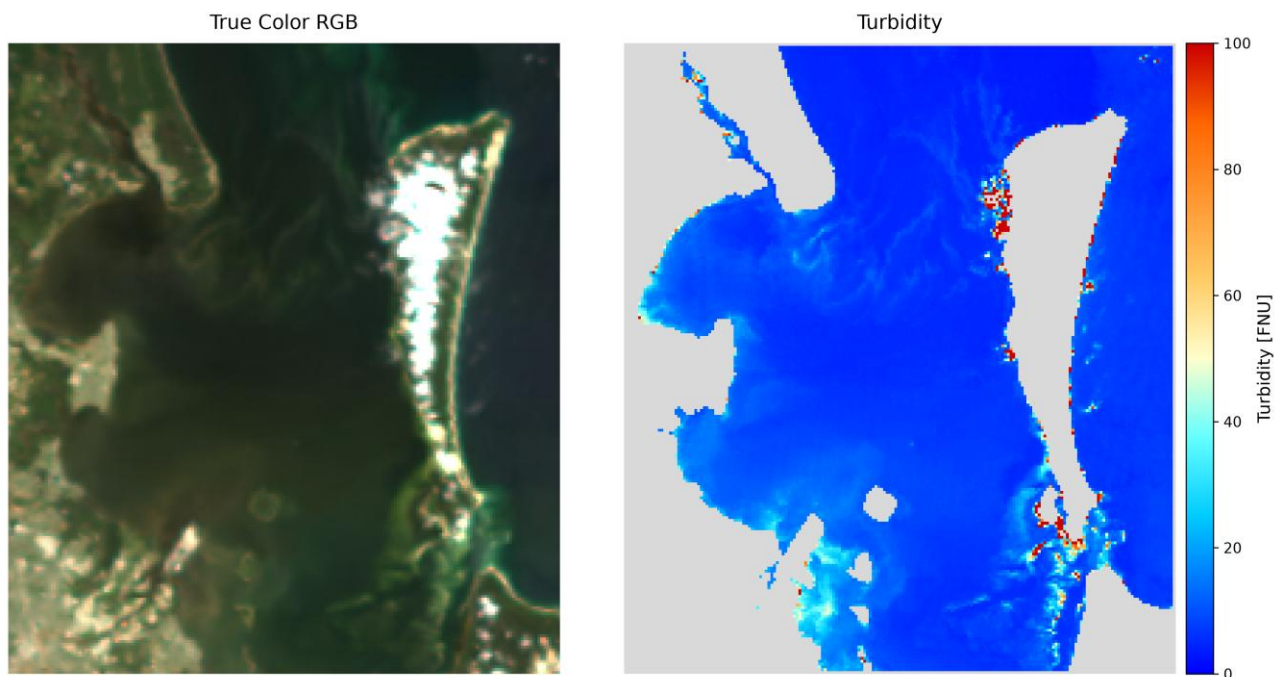


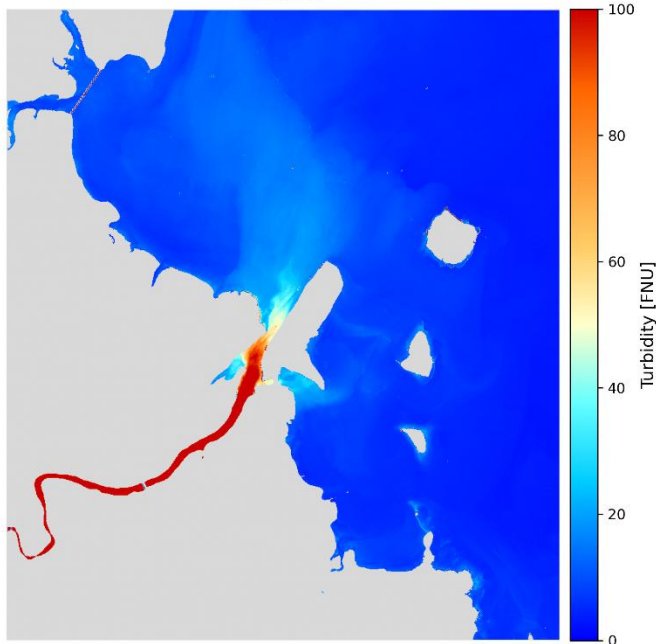
Figure 3.2 Representative turbidity conditions during the flood event (January 2011) derived from MODIS (250 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2015-05-04 09:41:17 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2015-05-20 09:41:09 AEST

Surface Reflectance RGB



Turbidity

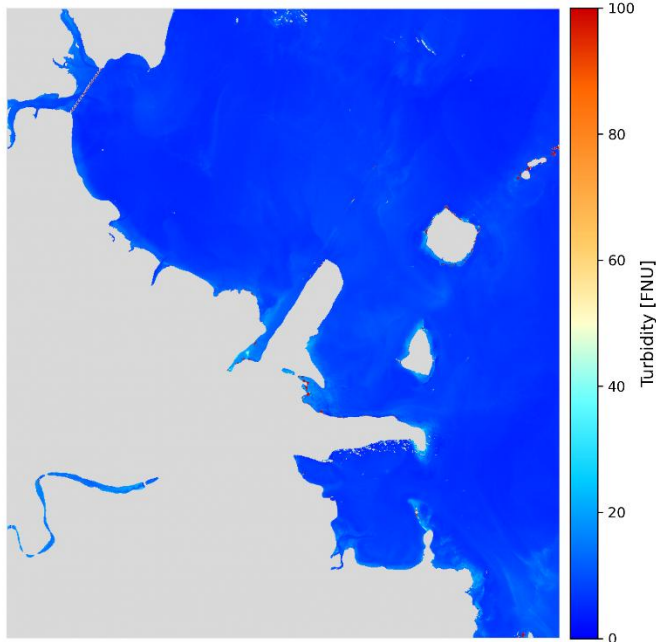


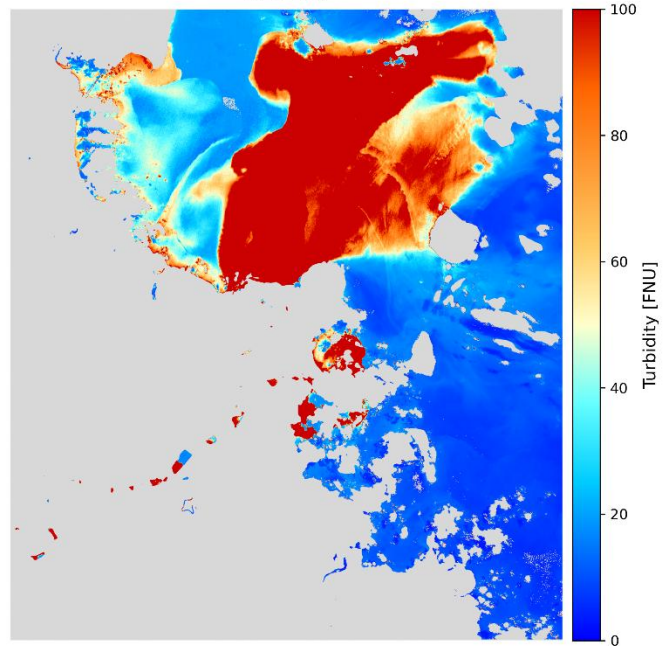
Figure 3.3 Representative turbidity conditions during the May 2015 runoff event derived from Landsat imagery (30 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2022-03-02 09:54:20 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2022-03-05 10:04:16 AEST

Surface Reflectance RGB



Turbidity

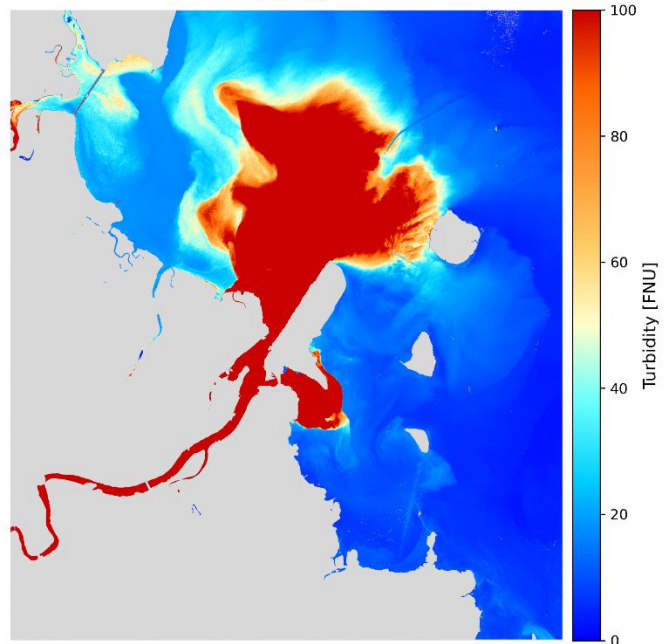
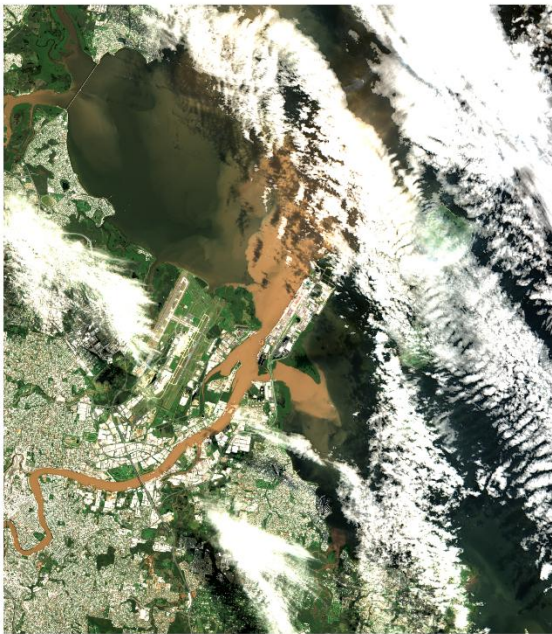


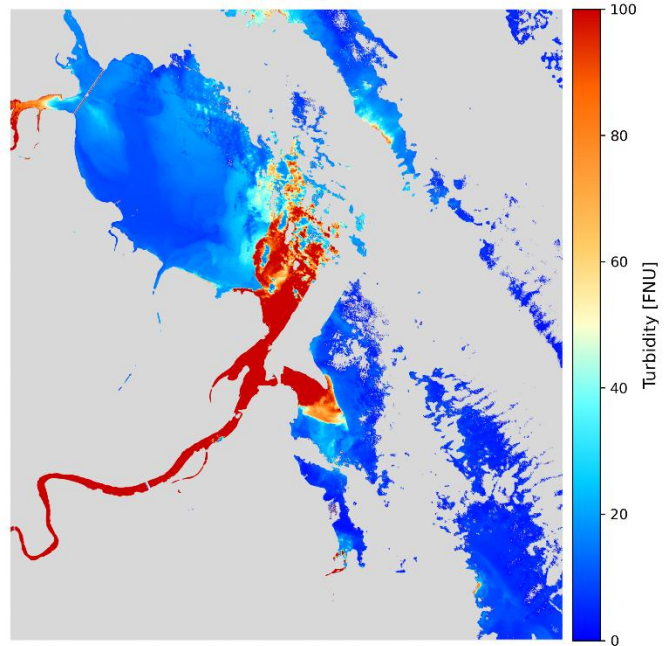
Figure 3.4 Representative turbidity conditions during the March 2022 runoff event derived from Sentinel-2 imagery (10 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2022-03-07 09:54:27 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2022-03-17 09:54:27 AEST

Surface Reflectance RGB



Turbidity

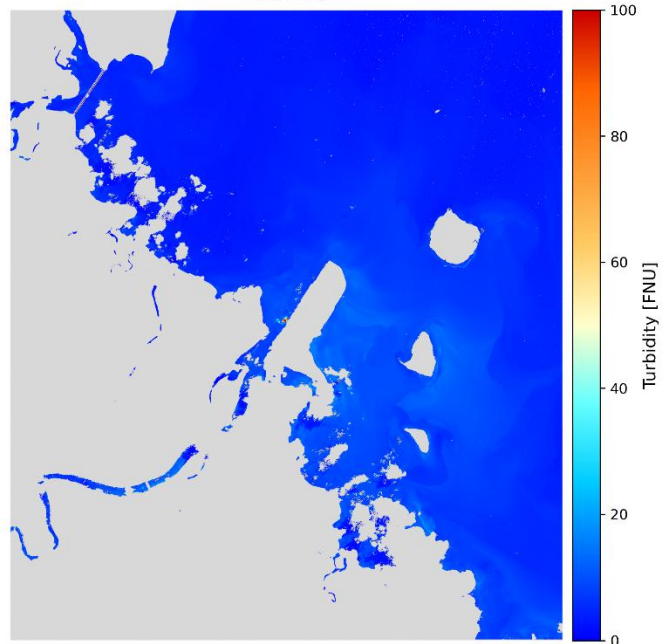


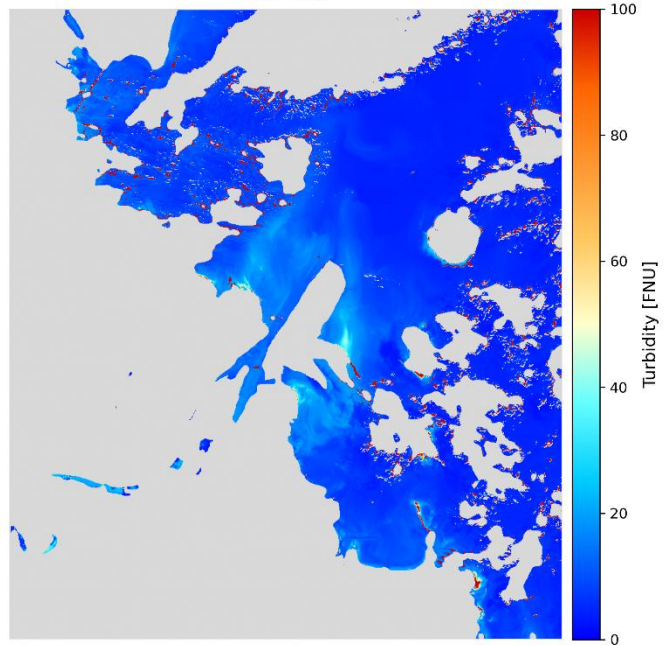
Figure 3.5 Representative turbidity conditions during the March 2022 runoff event derived from Sentinel-2 imagery (10 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L9 OLI | Local Time: 2022-03-12 09:42:09 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2022-03-20 09:42:00 AEST

Surface Reflectance RGB



Turbidity

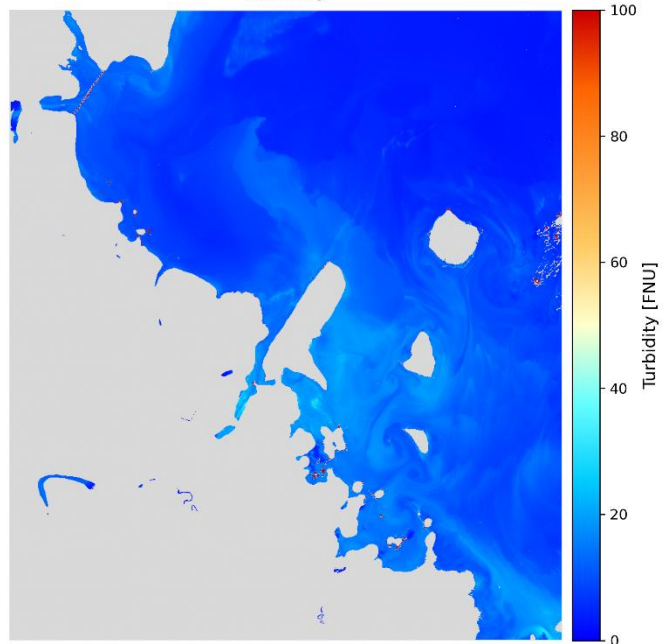
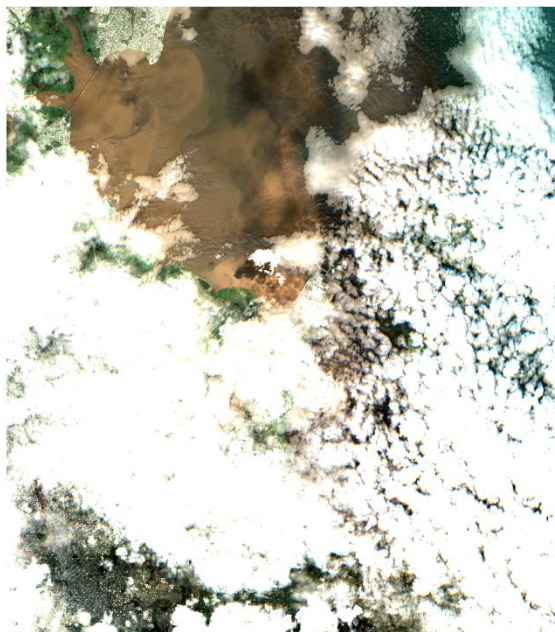


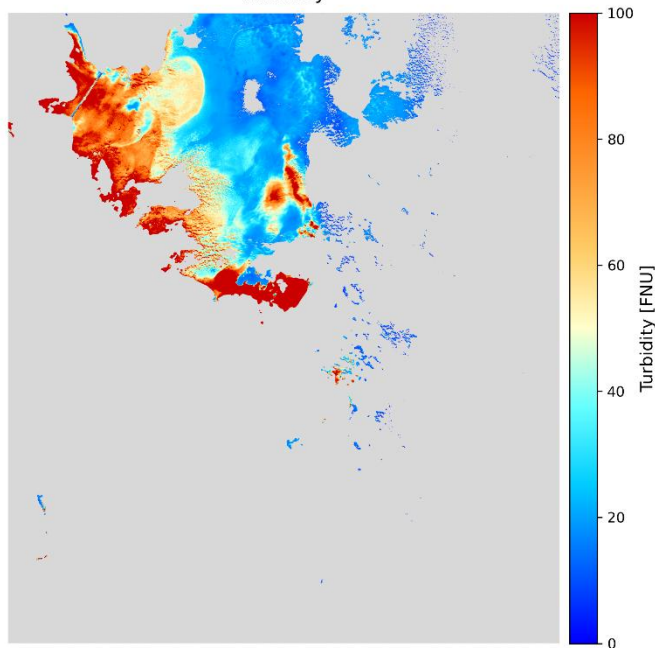
Figure 3.6 Representative turbidity conditions during the March 2022 runoff event derived from Landsat imagery (30 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2C MSI | Local Time: 2025-03-11 09:54:47 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2C MSI | Local Time: 2025-03-14 10:04:42 AEST

Surface Reflectance RGB



Turbidity

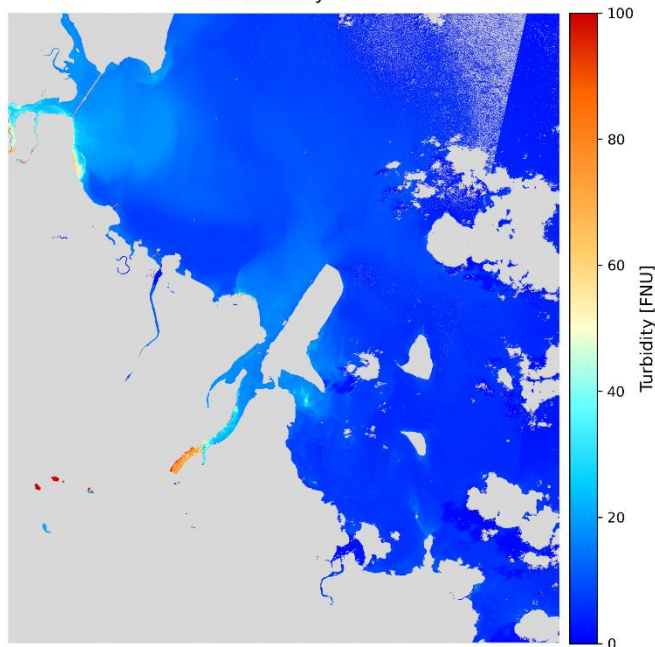
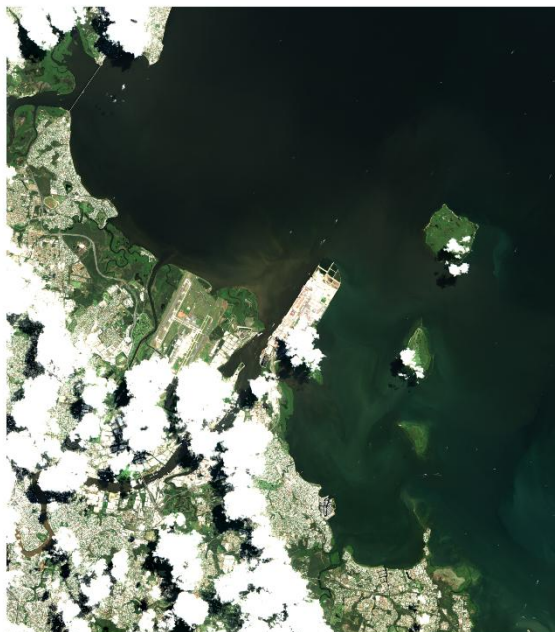


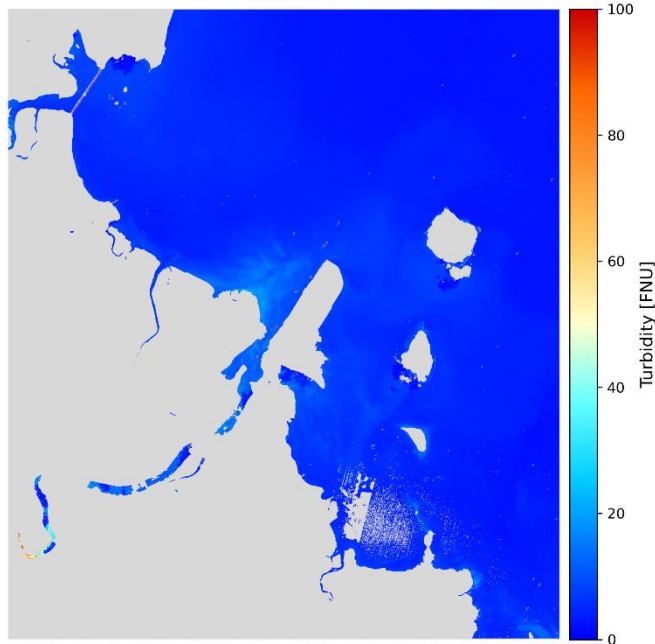
Figure 3.7 Representative turbidity conditions during the March 2025 runoff event derived from Sentinel-2 imagery (10 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2025-03-16 09:54:26 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2C MSI | Local Time: 2025-03-31 09:54:46 AEST

Surface Reflectance RGB



Turbidity

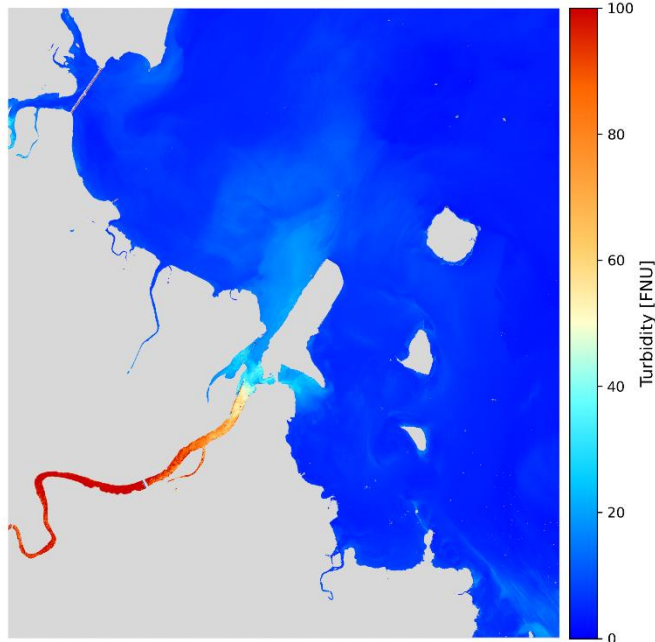


Figure 3.8 Representative turbidity conditions during the March 2025 runoff event derived from Sentinel-2 imagery (10 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

3.1 Spatial Patterns in Turbidity

3.1.1 Long-term Spatial Gradients

Under non-event conditions, turbidity exhibited a clear and persistent spatial gradient across the Study Area:

- Inner estuarine zones (Z1: Middle Estuary (Brisbane River) and Z2: Port of Brisbane/Bulwer Island/Crab and Lytton Creeks) showed elevated and more variable background turbidity
- Transitional zones (Z3: Outer Bar – Lower Estuary and Z4: Waterloo Bay (seagrass meadows) – Lower Estuary) showed moderate background conditions
- Open coastal zones (Z5: Moreton Bay – Open Coastal (Mud Island DMPA), Z6: Moreton Bay – Open Coastal (Central Bay, outside DMPA)) and Z7: Spitfire Channel exhibited low and tightly constrained background turbidity.

These differences were consistent across years and seasons, indicating a stable spatial structure in background turbidity behaviour.

Typical background turbidity ranged from approximately 5–12 FNU in the inner estuary, decreasing progressively seaward to approximately 2–6 FNU in offshore waters. While event-driven periods produced short-duration excursions above these ranges, background conditions remained stable over time and re-established following disturbance.

Long-term turbidity distributions for each reporting zone are illustrated in Figure 3.9 which shows that both central tendency and variability decrease progressively seaward. Zone-specific background ranges and variability envelopes are provided in Table 3.1.

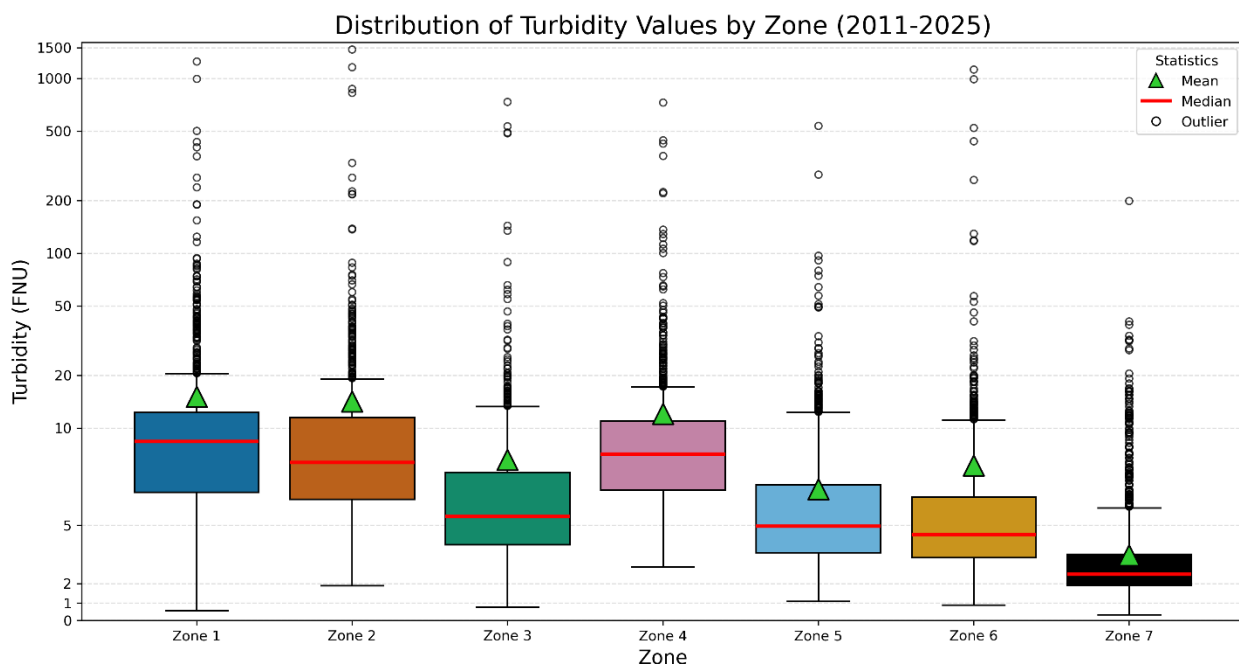


Figure 3.9 Long-term turbidity distributions by reporting zone (2011-2025). Note that the y-axis is presented on a logarithmic scale to improve visualisation of the wide range of turbidity values and extreme event observations.

Table 3.1 Long term turbidity summary by zone (2011–2025)

Zone	Setting	Typical background range (approx.)	P50	P80	P90	P95	P99	Max 2011	Max 2015	Max 2022	Max 2025
			Median turbidity	Turbidity is lower than this 80% of the time	Turbidity exceeded only 10% of the time	Turbidity exceeded only 5% of the time	Turbidity exceeded only 1% of the time				
			FNU								
1	Brisbane River estuary	~5–12	9.3	13.3	17.5	33.7	93.3	1250.5	190.9	502.0	85.7
2	Brisbane River mouth	~6–14	8.2	12.4	15.7	23.1	74.3	1462.7	50.8	826.3	218.0
3	Outer Cutting	~4–9	5.4	8.4	10.6	13.0	36.6	736.1	13.7	143.9	17.1
4	Waterloo Bay seagrass	~6–12	8.7	11.6	14.5	19.3	66.2	729.6	14.5	122.1	46.0
5	Mud Island	~3–8	5.0	7.8	9.9	13.1	28.6	535.7	12.6	97.1	12.6
6	Central Bay	~2–6	4.5	7.0	9.1	11.9	28.0	1125.8	14.1	521.0	20.1
7	Spitfire Channel	~2–4	2.5	3.8	5.6	7.7	16.4	199.1	4.6	18.0	8.3

3.1.2 Spatial Differences in Variability and Extremes

Marked spatial gradients in turbidity were observed across the monitoring zones. Inner estuarine zones exhibited higher median turbidity and broader distributions relative to open coastal zones (Z5–Z7), while open coastal zones were characterised by lower background turbidity and narrower distributions (Figure 3.10).

Zone level turbidity distributions illustrate a progressive reduction in both typical turbidity magnitude and variability with increasing distance from the Brisbane River mouth. Inner estuary and port influenced zones displayed the highest frequency of elevated turbidity observations, whereas open coastal zones (Z5–Z7) showed predominantly low turbidity punctuated by infrequent short-term increases.

These differences are integrated in the probability-of-exceedance curves shown in Figure 3.10. Comparisons among zones using probability-of-exceedance probability, indicating comparatively stable offshore conditions.

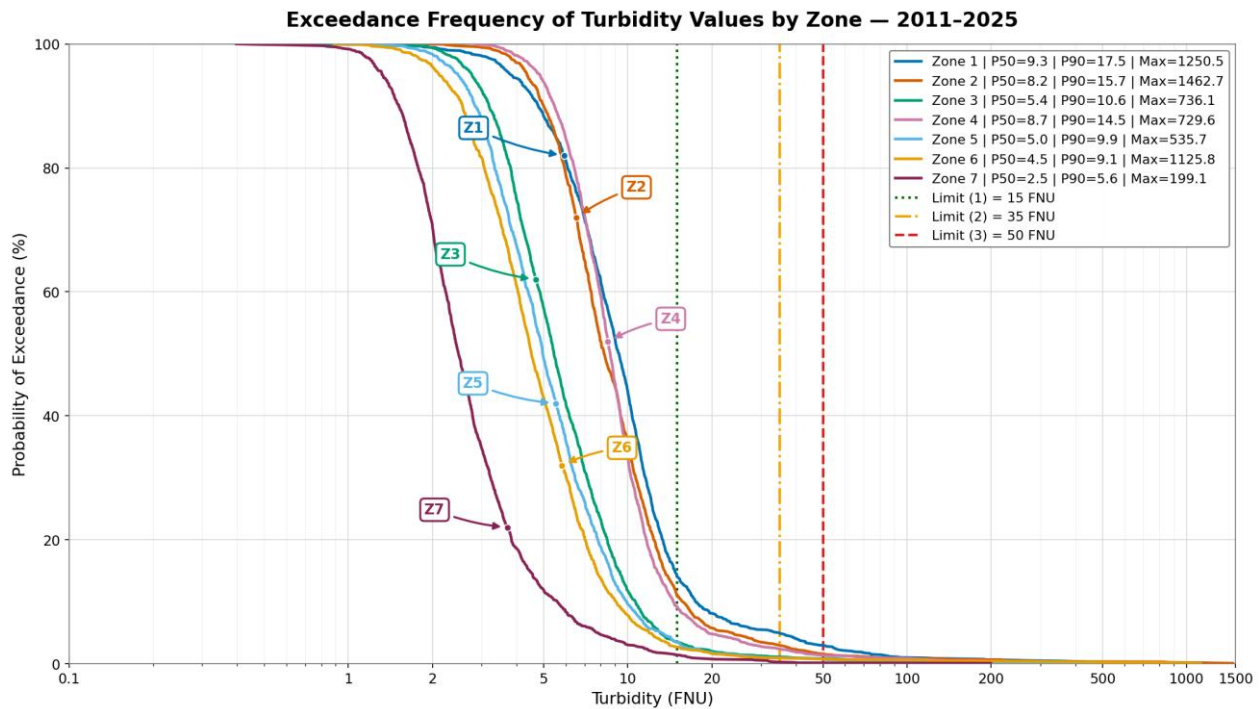


Figure 3.10 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2011-2025). The logarithmic x-axis enables visualisation of both typical background conditions and infrequent high-magnitude turbidity events within a single plot.

3.2 Temporal Patterns in Turbidity

3.2.1 Longitudinal Turbidity Variability and Event Timing

Longitudinal turbidity time-series analysis based on discrete sampling between 2011 and 2025 reveals strongly episodic turbidity behaviour across all seven monitoring zones

Longitudinal turbidity time-series analysis monitoring zones. Rather than sustained shifts in baseline turbidity, the record is dominated by short-duration, high-magnitude events superimposed on relatively stable background conditions. These events frequently occur simultaneously across multiple zones, indicating catchment-scale drivers, but with clear spatial differences in magnitude, variability, and frequency.

Across all zones, background turbidity conditions are typically constrained within a relatively narrow range, while extreme values are expressed as brief excursions well beyond the central distribution. This pattern is clearly illustrated by the 5–95% percentile envelopes, which remain comparatively narrow during quiescent periods but expand sharply during event windows, reflecting both increased variance and the presence of outlier values.

Several multi-zone turbidity episodes are evident in the record, most notably during:

- Late 2010 – early 2011
- Early 2015
- Early 2022
- Early 2025.

These periods are characterised by elevated monthly means, pronounced widening of the 5–95% range, and the occurrence of the highest recorded turbidity values in most zones.

Zone 1 (Z1: Middle Estuary - Brisbane River)

Z1 exhibits the largest absolute range of turbidity values and the most extreme individual events across the monitoring period (Figure 3.11). Median turbidity over the full record is approximately 9.3 FNU, though this value masks substantial episodic variability. During non-event conditions, turbidity commonly falls within the approximate background range of 5–12 FNU. Across the full dataset, the 5th–95th percentile range is approximately 4–34 FNU, with only 5% of observations exceeding approximately 34 FNU.

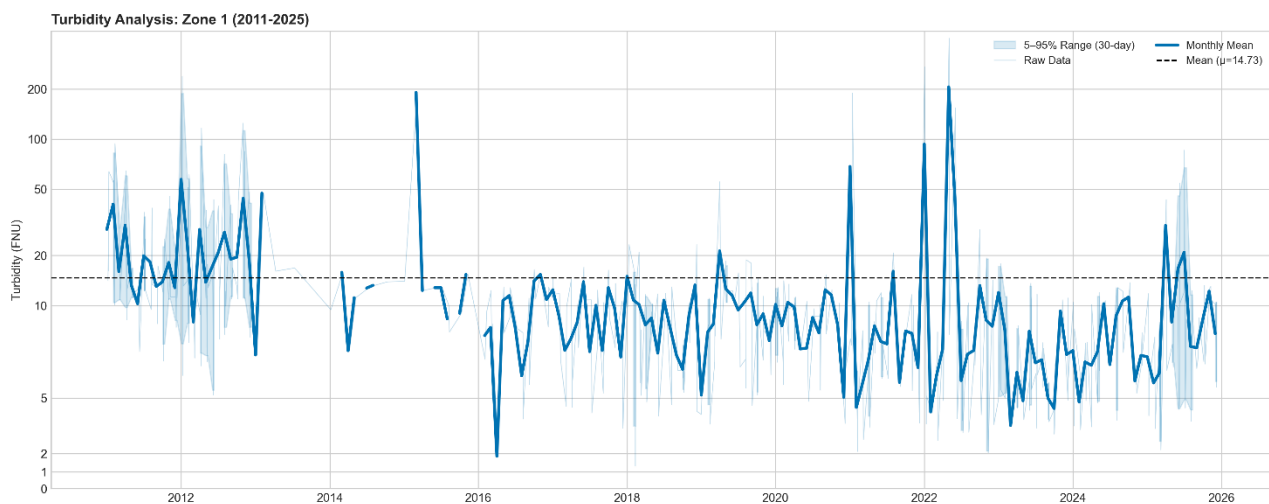


Figure 3.11 Longitudinal Turbidity Analysis for Zone 1 (2011-2025)

Several discrete high-magnitude episodes dominate the upper tail of the distribution. The largest turbidity response occurs in early 2011, when turbidity increases sharply following major rainfall across the Brisbane River catchment and reaches an extreme peak of approximately 1,250 FNU (19 February 2011). A further elevated period is evident in 2015, with turbidity increasing to approximately 190 FNU following rainfall events. The next major response occurs during February–March 2022, when turbidity rises rapidly and remains elevated across multiple observation between approximately 400–500 FNU (–6 March 2022). Renewed elevated conditions are again observed during March–April 2025, with turbidity increasing to approximately 80–85 FNU on 31 March 2025 following successive March rainfall events.

Across all events, the 5th percentile remained close to background levels, even as the upper percentile expands substantially, indicating strongly skewed distributions and short-lived turbidity excursions rather than prolonged elevation.

Zone 2 (Z2: Port of Brisbane / Bulwer Island / Crab and Lytton Creeks)

Z2 displays consistently elevated variability relative to Z3, Z5, Z6 and Z7 (Figure 3.12), with a long-term median turbidity of approximately 8.2 FNU and frequent excursions above 20 FNU. Outside event periods, turbidity typically ranges between 6 and 14 FNU, with the 5–95% envelope spanning approximately 4–23 FNU, indicating that moderate variability persists in Z2 even during background conditions.

Four major periods illustrate Z2's response to catchment rainfall. In January 2011, the largest response in the record followed widespread catchment flooding: turbidity peaked at 1,462.7 FNU on 12 January, and the monthly mean reached 529.2 FNU. In May 2015, turbidity reached 50.8 FNU on 3 May, representing a smaller but notable response to upper-, middle- and lower-catchment rainfall. The

February–March 2022 flood produced the second-largest response, reaching 826.3 FNU on 28 February, followed by 271.5 FNU on 1 March, 328.8 FNU on 5 March and 138.6 FNU on 6 March. In March–April 2025, turbidity peaked at 218.0 FNU on 10 March, with smaller peaks of approximately 28–29 FNU on 4 April.

The frequent expansion of the upper percentile in Z2 indicates a higher frequency of moderate-to-high turbidity events compared to downstream zones, while its relatively stable lower percentile indicates broadly consistent baseline conditions between intermittent high-turbidity events.

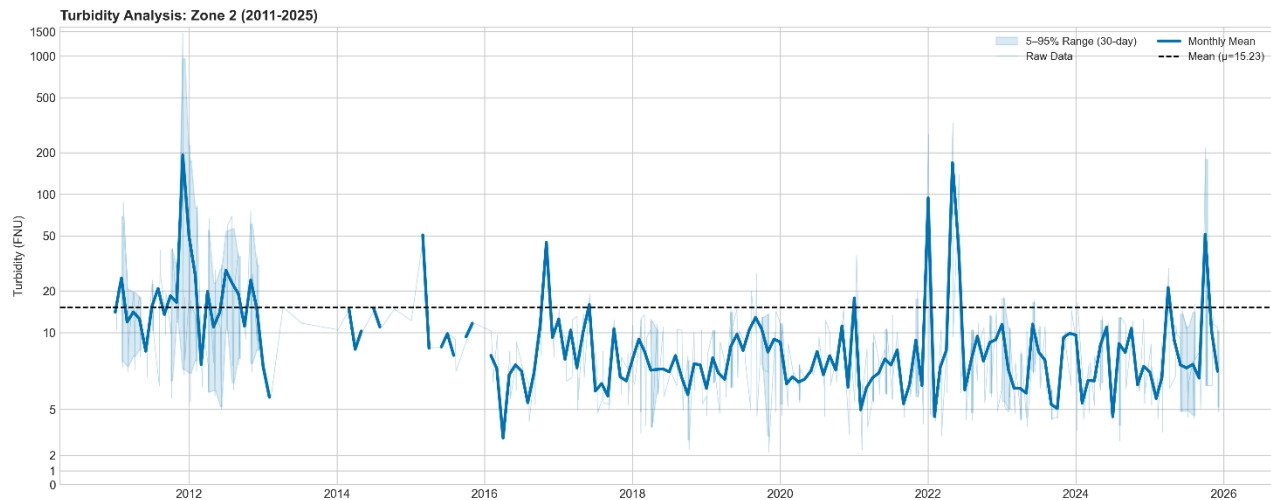


Figure 3.12 Longitudinal Turbidity Analysis for Zone 2 (2011-2025)

Zone 3 (Z3: Outer Bar – Lower Estuary)

Z3 exhibits lower overall turbidity and reduced variability relative to Z1 and Z2, with a long-term median of approximately 5.4 FNU (Figure 3.13). Background turbidity is consistently low, typically between and 9 FNU, with a narrow 5–95% envelope of approximately 3–13 FNU during quiescent periods.

Four periods illustrate Z3's attenuated response to catchment rainfall. In January 2011, the largest response in the record reached 736.1 FNU on 12 January, and the monthly mean increased to 331.9 FNU. In May 2015, turbidity reached only 11.7 FNU, indicating a modest response compared with upstream zones. The February–March 2022 flood produced the largest post-2011 response, reaching 61.8 FNU on 28 February, 134.6 FNU on 1 March and 143.9 FNU on 5 March. In March–April 2025, turbidity remained comparatively moderate, reaching 12.7 FNU on 10 March and 13.6 FNU on 4 April.

Overall, Z3 is characterised by a stable, relatively low turbidity regime punctuated by sharp but infrequent event driven increases. The smaller magnitude and frequency of elevated observations relative to Z1 and Z2 concentrations gradually decrease into downstream zones.

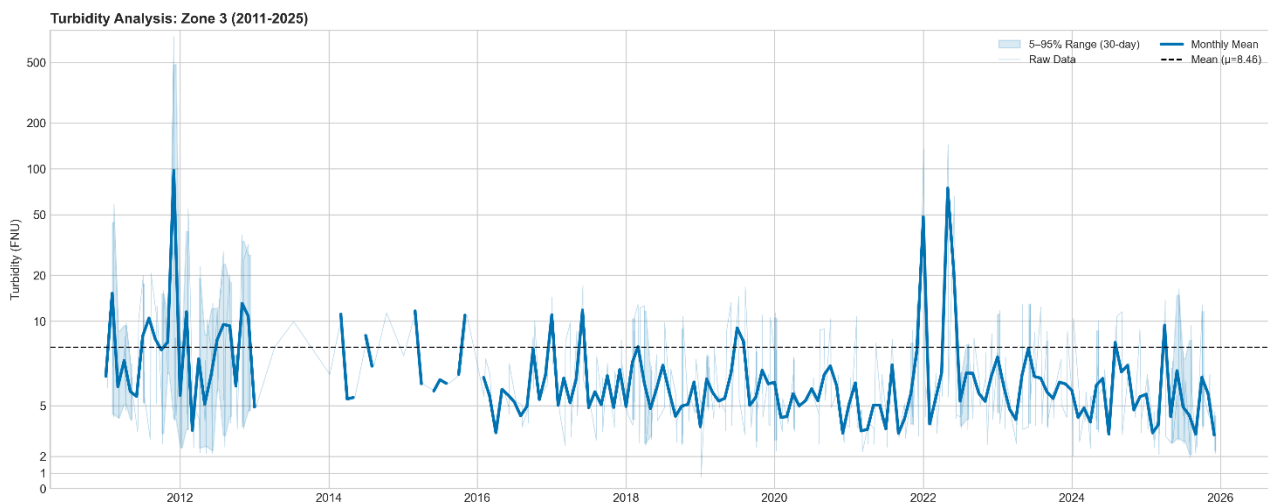


Figure 3.13 Longitudinal Turbidity Analysis for Zone 3 (2011-2025)

Zone 4 (Z4: Waterloo Bay (seagrass meadows) – Lower Estuary)

Z4 shows higher long-term turbidity than Z3, Z5, Z6 and Z7 Z4 with a median of 8.7 FNU (Figure 3.14). Background turbidity generally ranges from 6 to 12 FNU, while the 5–95% envelope typically spans 4–19 FNU, indicating greater overall variability than Z3, Z5, and Z6.

Turbidity reflects both Brisbane River discharge and local resuspension in shallow Waterloo Bay, with major floods producing short-lived peaks, including 730 FNU in 2011 and 122 FNU in 2022. A shorter-duration response reached 46.0 FNU on 10 March 2025, consistent with a moderate event rather than a prolonged catchment-wide sediment pulse.

The relatively elevated 5th percentile during some event periods suggests slower return to baseline and greater persistence of elevated turbidity in Z4 compared to upstream zones.

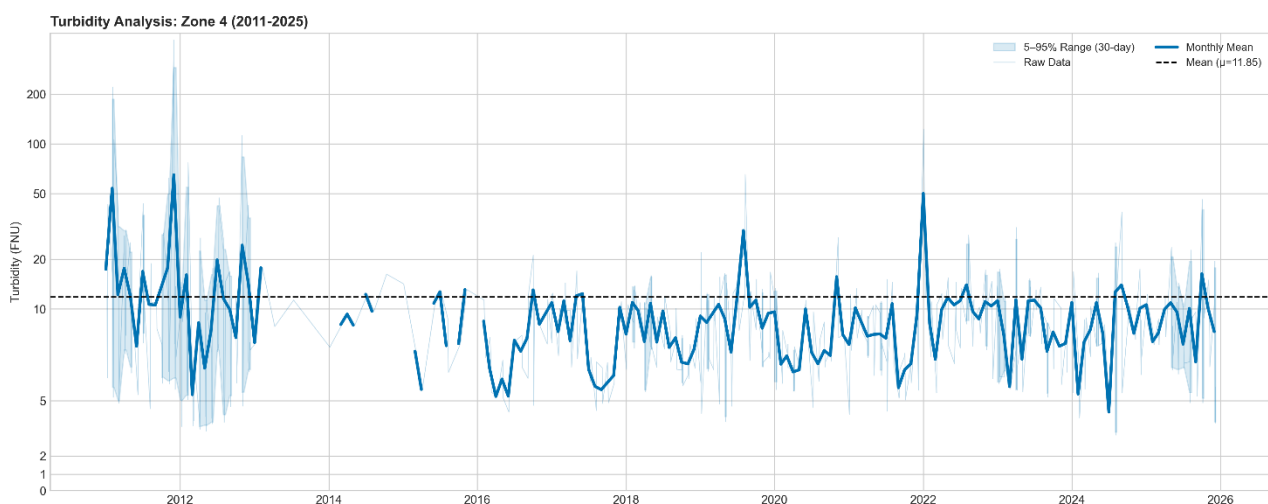


Figure 3.14 Longitudinal Turbidity Analysis for Zone 4 (2011-2025)

Zone 5 (Z5: Moreton Bay – Open Coastal (Mud Island DMPA))

Z5 is a relatively low-turbidity, marine-influenced zone, with a long-term median of approximately 5.0 FNU (Figure 3.15). Background values typically range between 4 and 7 FNU, with a narrow 5–95% envelope of approximately 2–13 FNU.

Major excursions were largely confined to exceptional flood events, reaching 536 FNU in 2011 and 97 FNU in 2022, compared with only 13 FNU in both 2015 and 2025 flooding events, indicating generally stable conditions interrupted by infrequent, short-lived events.

The rapid expansion and subsequent contraction of the 5–95% envelope indicates high sensitivity to disturbance events but limited persistence of elevated turbidity.

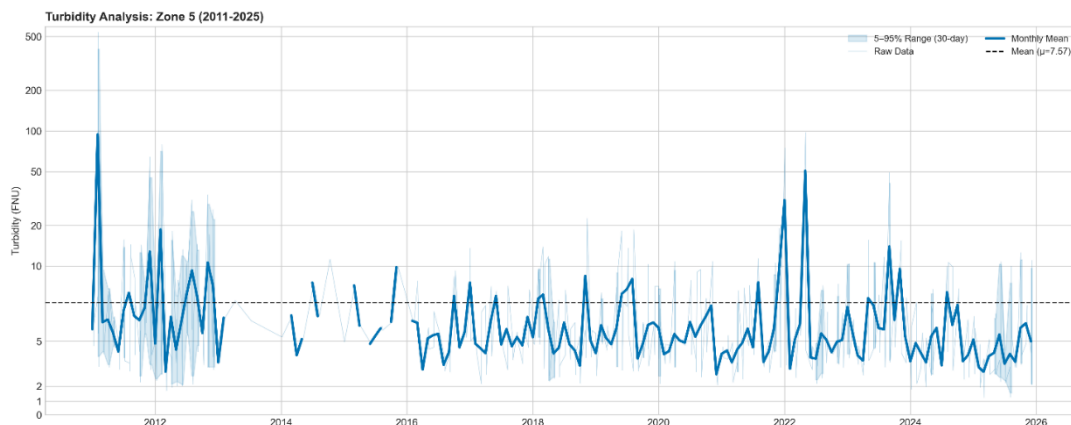


Figure 3.15 Longitudinal Turbidity Analysis for Zone 5 (2011-2025)

Zone 6 (Z6: Moreton Bay – Open Coastal (Central Bay, outside DMPA))

Z6 exhibits the lowest median turbidity across the monitoring network, approximately 4.5 FNU, and the most constrained background variability (Figure 3.16). Non-event turbidity typically remains between 3 and 6 FNU, with a consistently narrow 5–95% envelope of approximately 2–12 FNU.

Major floods produced peaks of 1,126 FNU in 2011 and 521 FNU in 2022, whereas annual maxima were only 14 FNU in 2015 and 20 FNU in 2025. The rapid contraction of the rolling percentile envelope after major events indicates that elevated turbidity was generally short-lived, reflecting strong attenuation outside the main estuarine system.

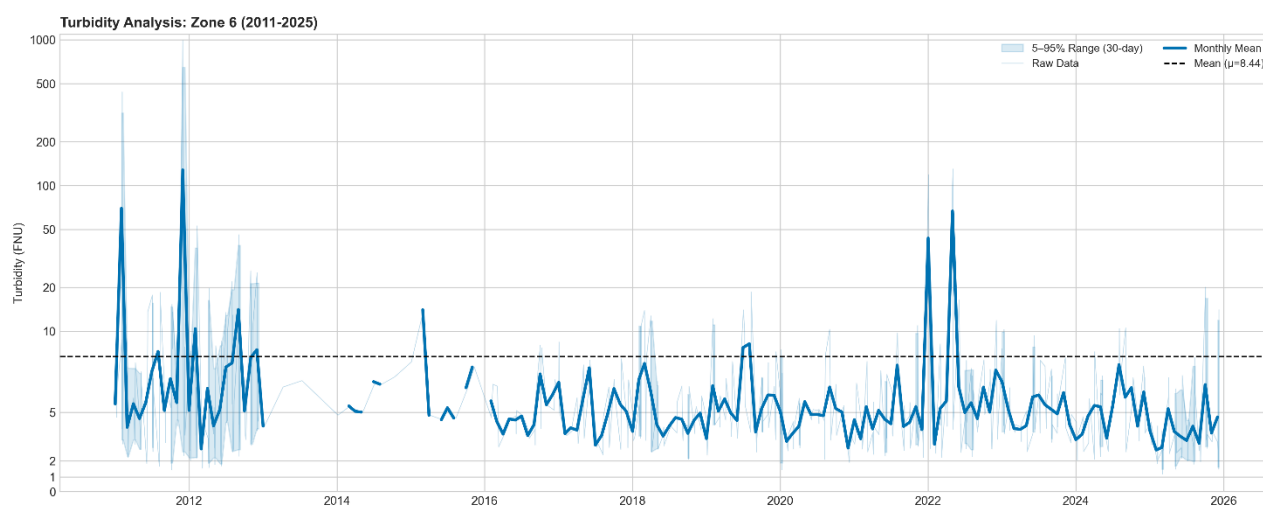


Figure 3.16 Longitudinal Turbidity Analysis for Zone 6 (2011-2025)

Zone 7 (Z7: Spitfire Channel)

Z7 exhibits the lowest turbidity in the monitoring network, with a long-term median of approximately 2.5 FNU and a full-record 5th–95th percentile range of 1–8 FNU (Figure 3.17).

Flood responses were strongly attenuated compared with other zones. Turbidity reached 199 FNU in 2011 but only 18 FNU in 2022, while annual maxima were approximately 5 FNU in 2015 and 8 FNU in 2025. Overall, Z7 remained consistently clear, with notable excursions largely confined to major bay-wide events.

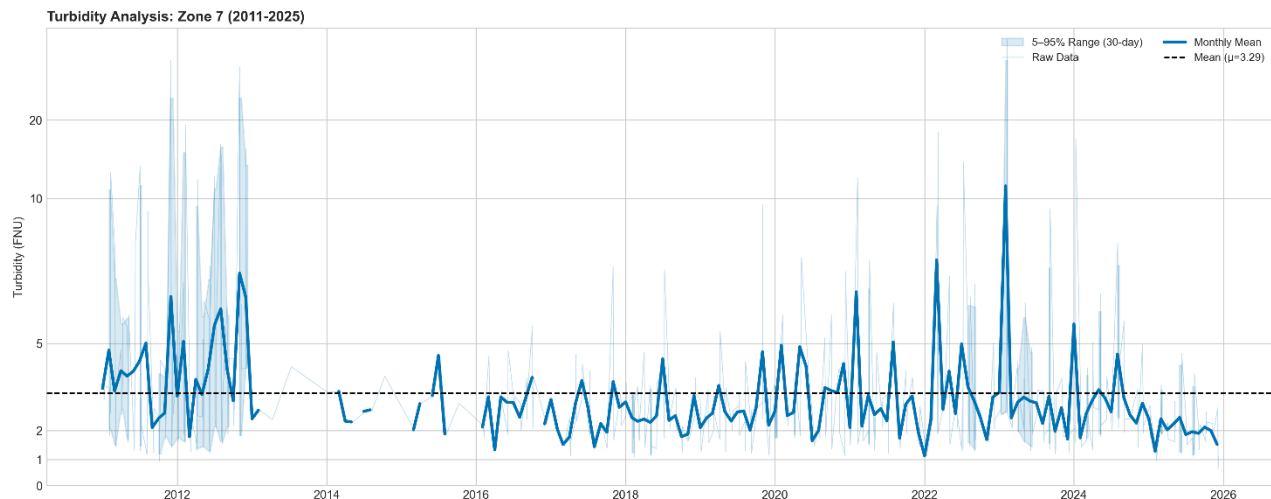


Figure 3.17 Longitudinal Turbidity Analysis for Zone 7 (2011–2025)

3.2.2 Seasonal Variability

Figure 3.18 to Figure 3.24 shows month-by-month turbidity values for each zone. Turbidity showed a repeatable seasonal structure, with higher turbidity and broader distributions during the wet season (November–March) and lower, more stable conditions during the dry season (April–October). Seasonal contrasts were strongest in Z1–2 and weakest in Z5–6.

Mean turbidity exceeded median turbidity in most zones and months, with the largest differences generally occurring between January and March. High-value outliers were also recorded during the dry season. Z7 had the lowest monthly turbidity and narrowest distributions, while Z6 recorded several extreme observations despite generally low median turbidity.

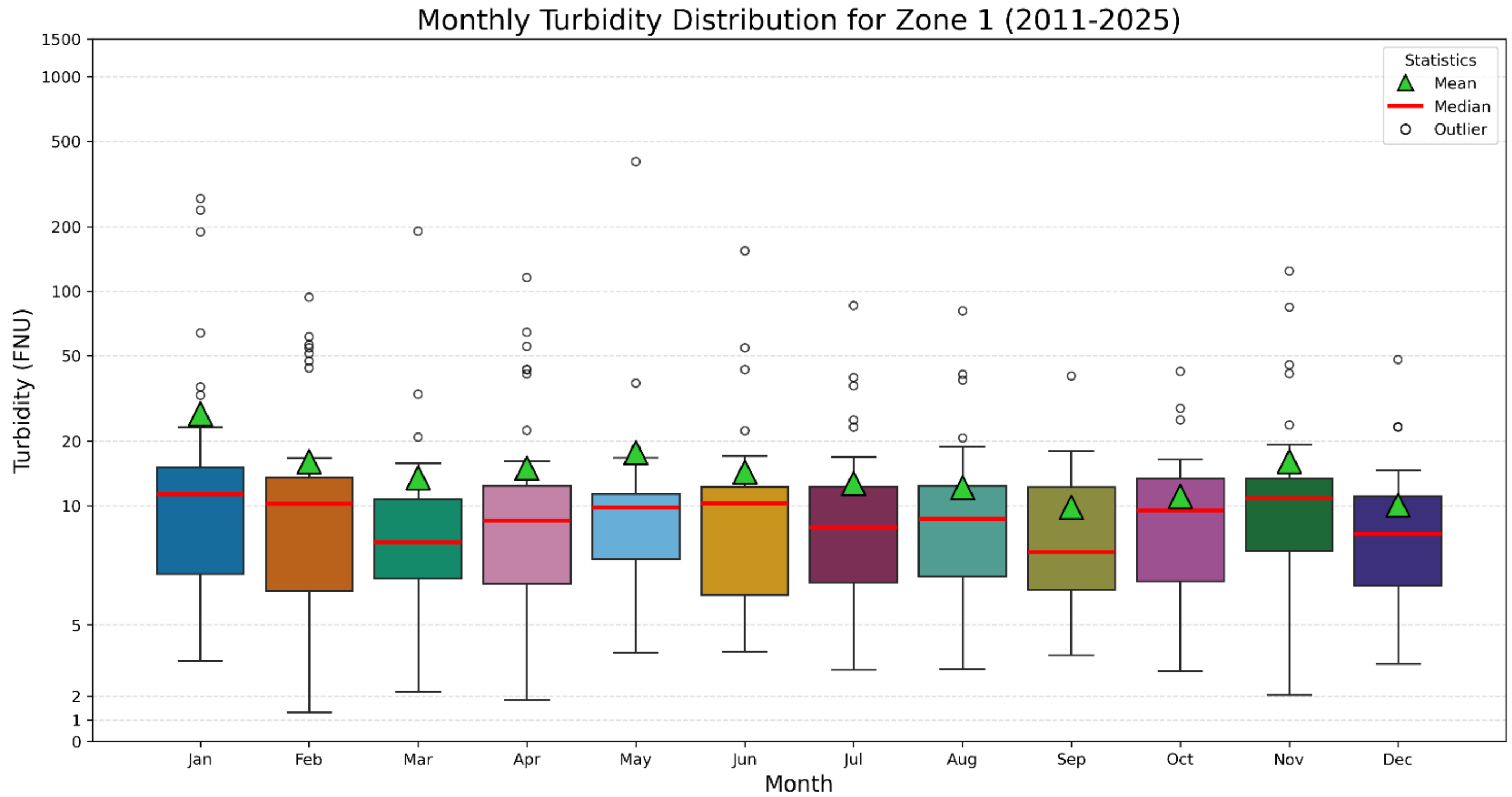


Figure 3.18 Monthly Turbidity Distribution for Z1 (2011–2025)

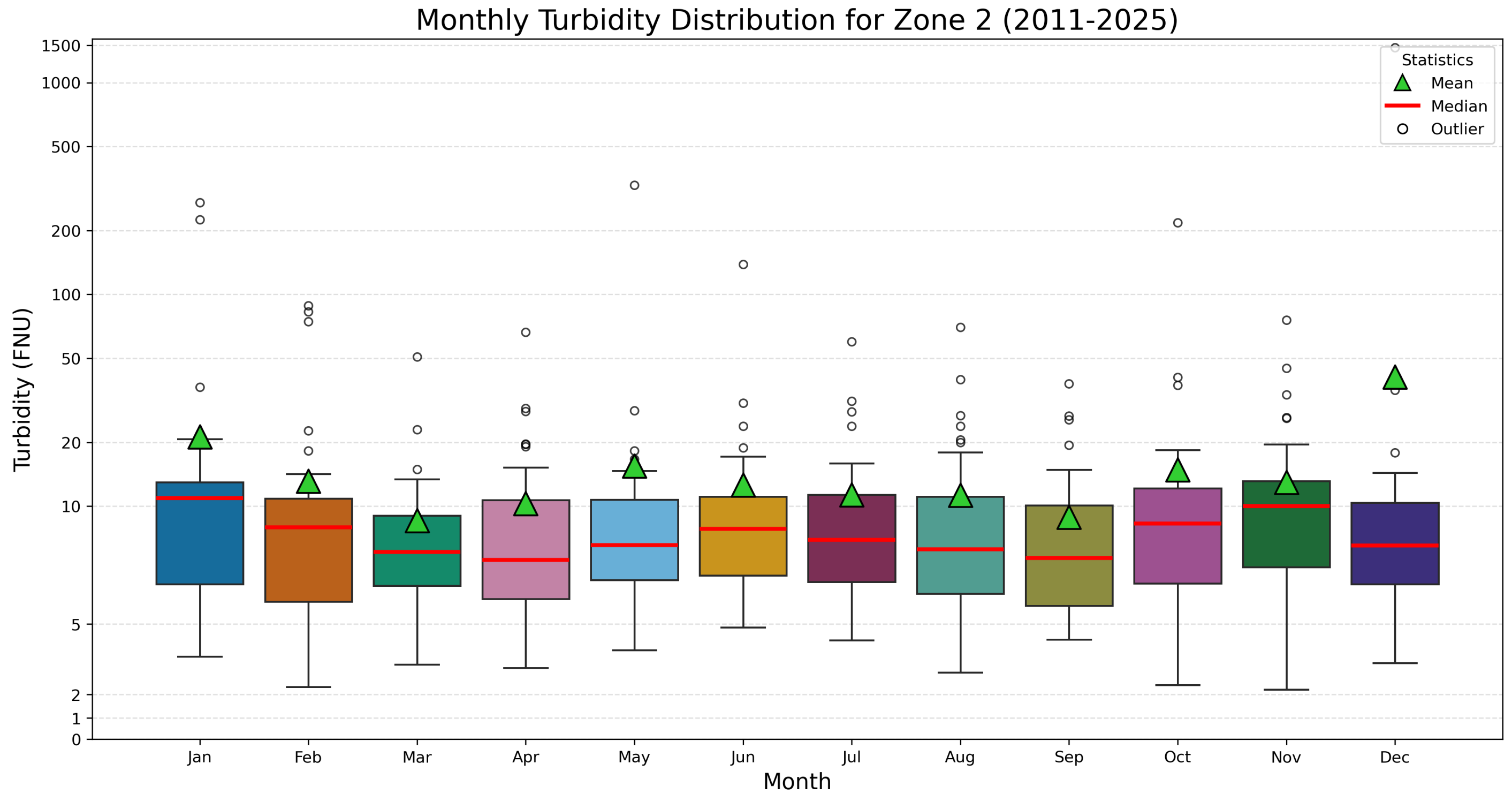


Figure 3.19 Monthly Turbidity Distribution for Z2 (2011–2025)

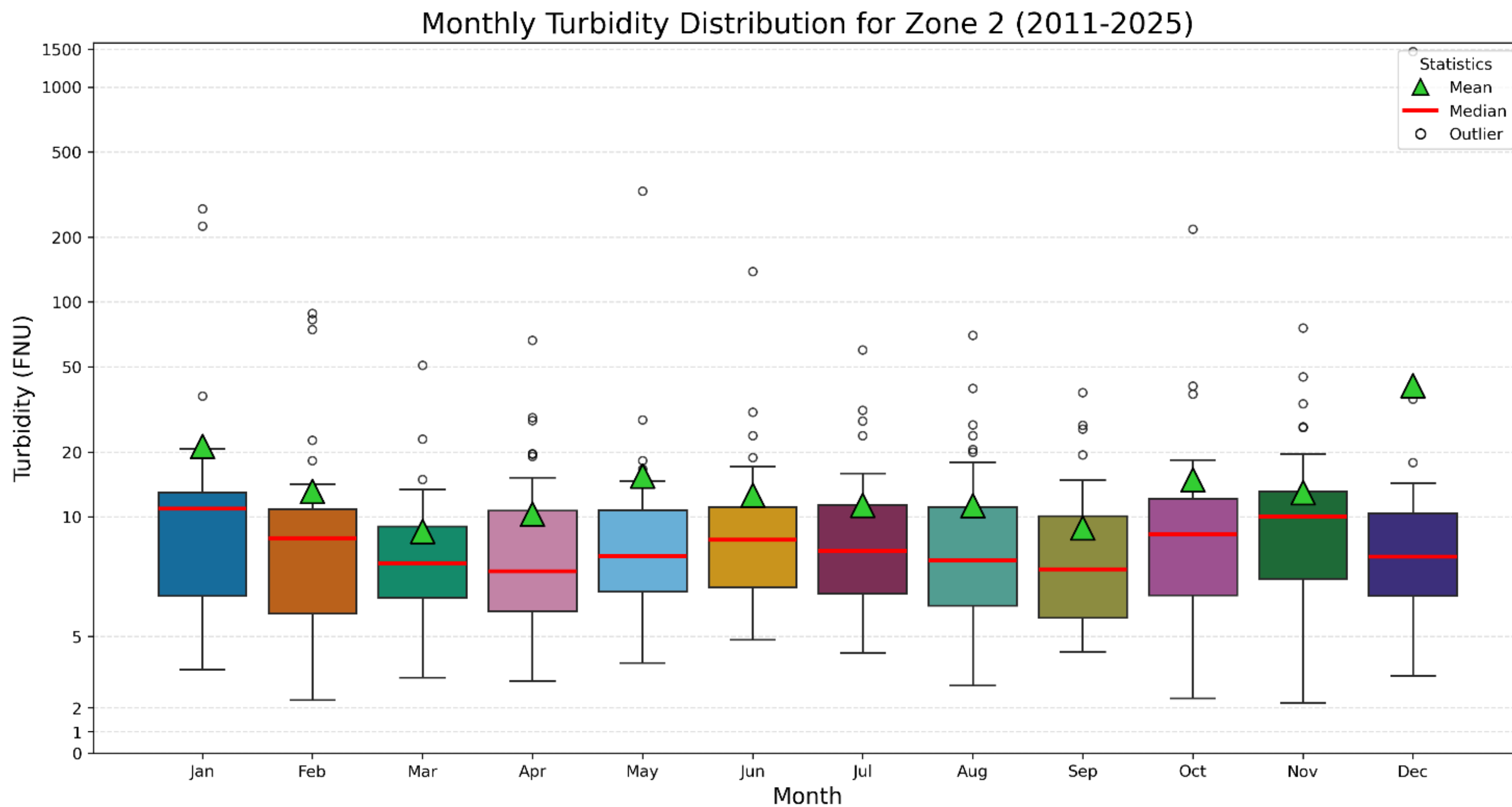


Figure 3.20 Monthly Turbidity Distribution for Z3 (2011–2025)

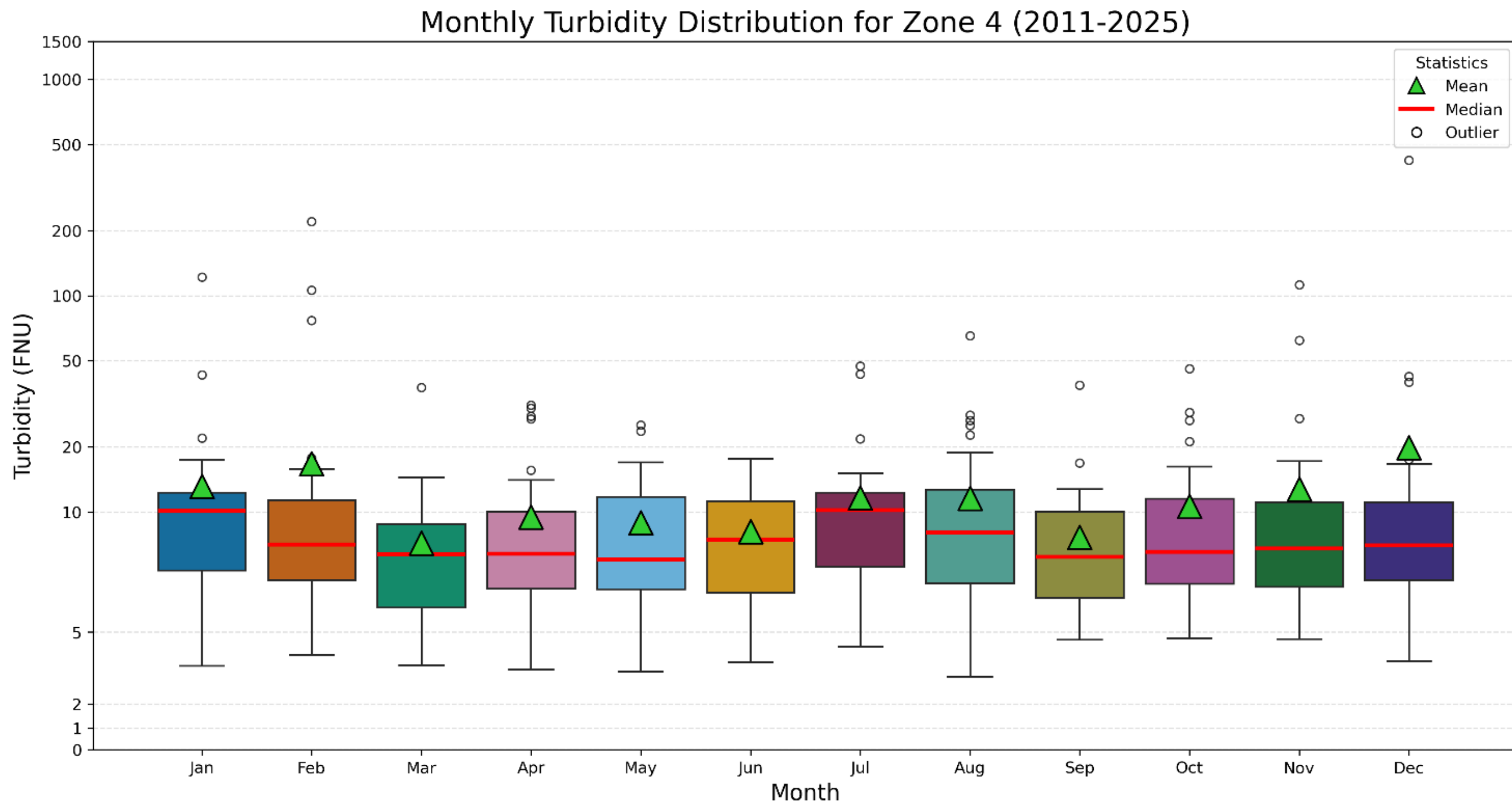


Figure 3.21 Monthly Turbidity Distribution for Z4 (2011–2025)



Figure 3.22 Monthly Turbidity Distribution for Z5 (2011–2025)

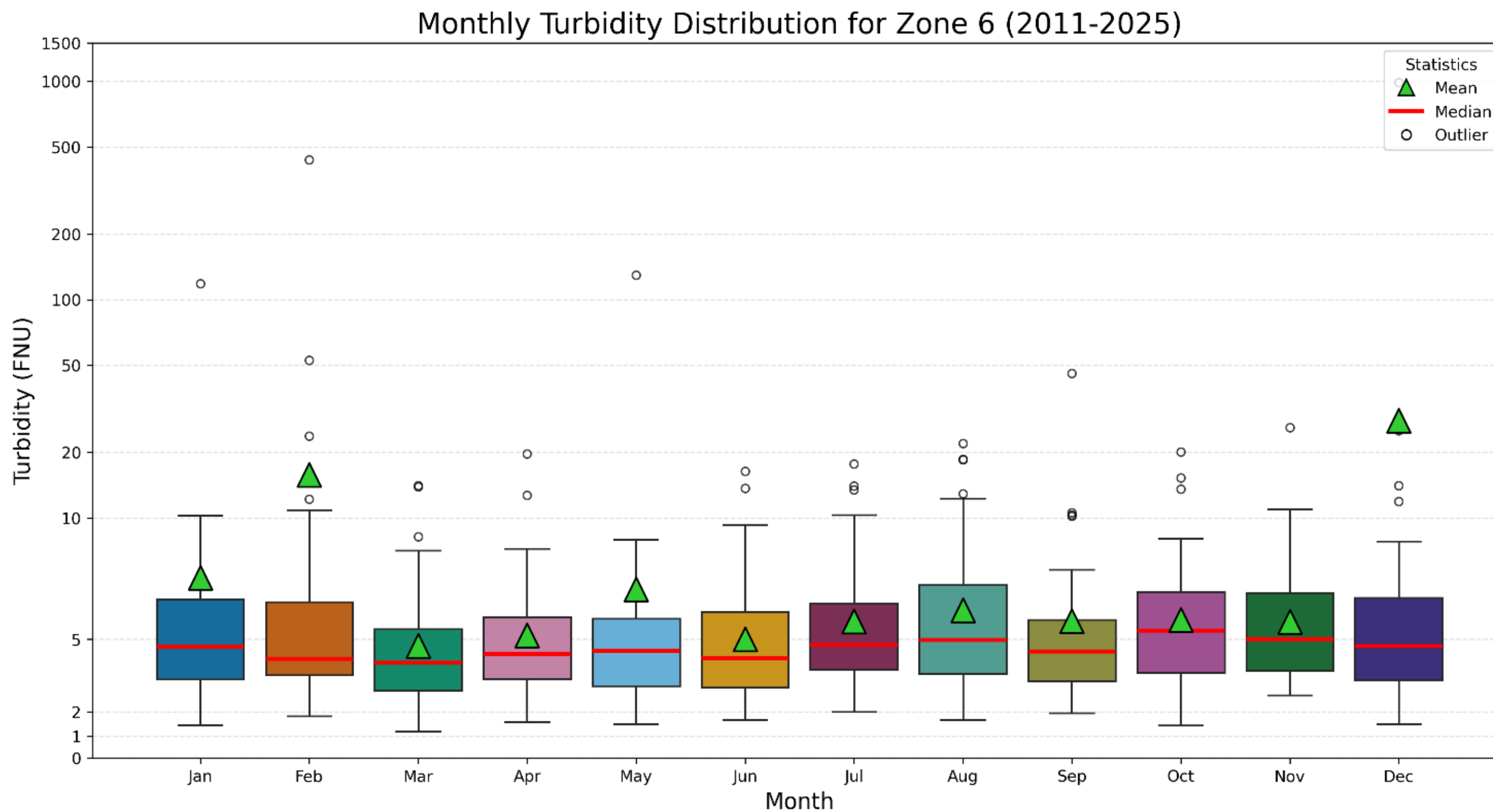


Figure 3.23 Monthly Turbidity Distribution for Z6 (2011–2025)

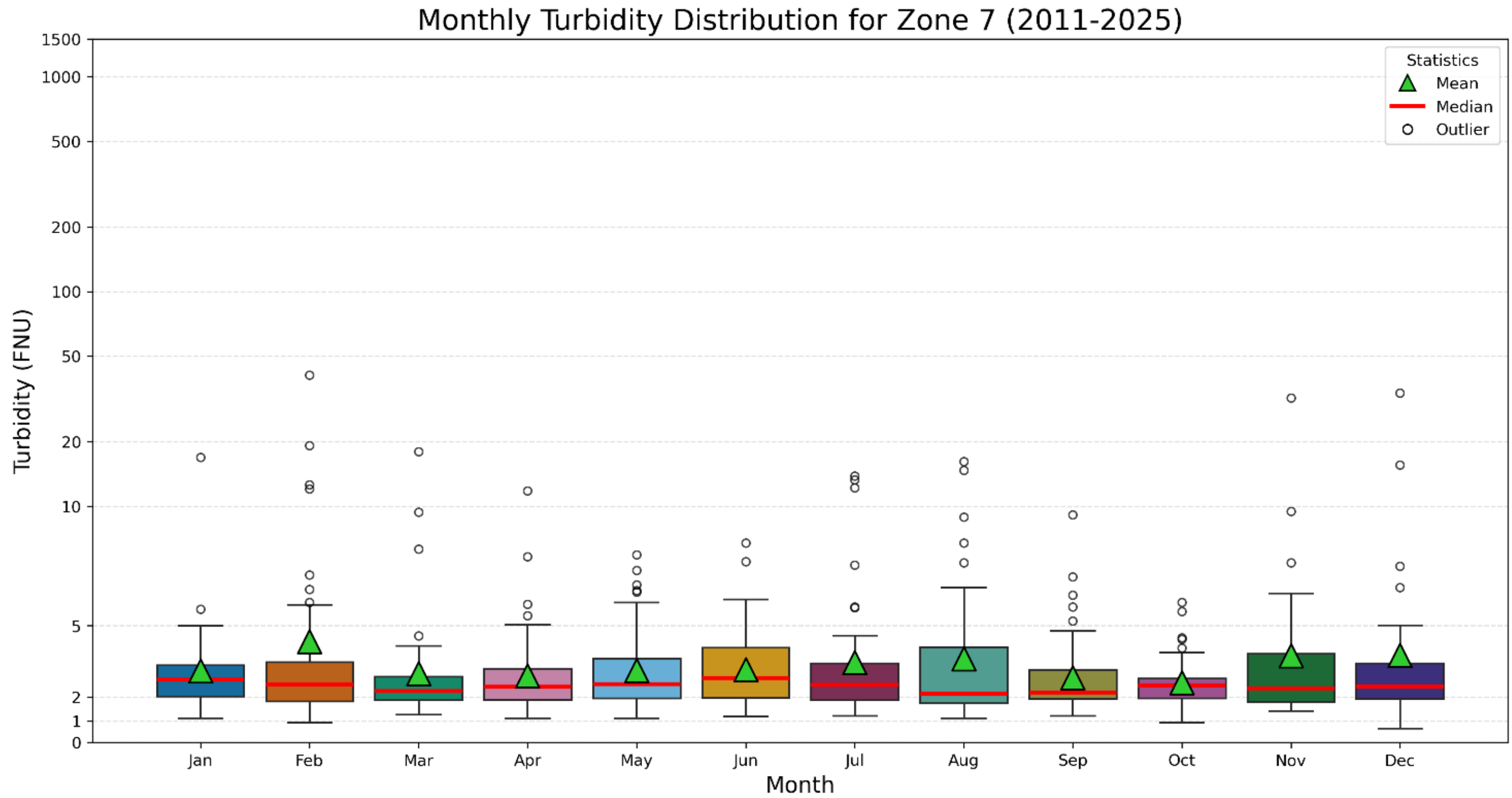


Figure 3.24 Monthly Turbidity Distribution for Z7 (2011–2025)

3.2.3 Interannual Variability

Time-series plots in Figure 3.11 to Figure 3.17 show mean monthly mean over time and rolling 5th–95th percentile ranges for Zones 1–7. Inter-annual variability was strongly associated with major rainfall and flood periods rather than gradual shifts in background behaviour. The strongest multi-zone responses occurred in 2011 and 2022, while responses in 2015 and 2025 were smaller and more spatially variable.

Zone responses differed systematically across the selected event years. The riverine zones, Z1–Z2, showed frequent moderate elevations and pronounced upper tails, with 2011 maxima of 1,251 and 1,463 FNU, respectively. Z3, the estuarine transition zone, and Z4, near the river entrance, showed distinct event-related excursions, reaching 736 and 730 FNU in 2011 and 144 and 122 FNU in 2022, respectively. In the offshore zones, Z5–Z7, turbidity generally remained low outside major events; however, 2011 maxima reached 536 (Z5), 1,126 (Z6) and 199 FNU (Z7), respectively, while 2022 maxima reached 97 (Z5), 521 (Z6) and 18 (Z7) FNU. Responses were more spatially limited in 2015, when maxima were concentrated in Z1 (191 FNU) and Z2 (51 FNU), and in 2025, when the largest values occurred in Z2 (218 FNU), Z1 (86 FNU) and Z4 (46 FNU). No consistent monotonic change was evident over 2011–2025.

3.2.4 Event scale Behaviour and Recovery

Major events were characterised by rapid increases in turbidity, expansion of the rolling 5th–95th percentile range and subsequent contraction of satellite-derived surface turbidity toward zone-specific background distributions. The principal examples were:

- **2011:** Widespread high-turbidity observations occurred across all zones, with the largest annual values recorded in Z2 (1,463 FNU), Z1 (1,251 FNU) and Z6 (1,126 FNU).
- **2015:** The response was strongest in Z1 (191 FNU) and Z2 (51 FNU), with limited responses elsewhere.
- **2022:** A multi-zone response occurred during late February and early March, reaching 826 FNU in Z2, 521 FNU in Z6, 502 FNU in Z1, 144 FNU in Z3, 122 FNU in Z4 and 97 FNU in Z5.
- **2025:** The largest response occurred in Z2 (218 FNU), with lower peaks in Z1 (86 FNU), Z4 (46 FNU) and the remaining zones.

Following the major 2011 and 2022 events, monthly means declined and rolling percentile ranges narrowed across the affected zones. Responses were generally largest in Z1–Z2, variable in Z3–Z4 and strongly attenuated in Z5–Z7.

Table 3.2 summarises key rainfall and turbidity event examples used for interpretation with annual rainfall plots illustrated in Annex A.

Table 3.2 Key rainfall and turbidity event examples (2011–2025)

Event window	Rainfall indicator (Brisbane Aero)	Zones with documented turbidity response examples	Turbidity examples
Jan–Feb 2011	112.4 mm on 10 Jan 2011	System-wide response; largest in Z1, Z2 and Z6	Z2: 1,463 FNU (12 Jan); Z6: 1,126 FNU (17 Jan); Z1: 1,251 FNU (18 Feb); Z7: 199.1 FNU (17 May)
May 2015	134.2 mm on 2 May 2015	Response concentrated in Z1–Z2; limited elsewhere	Z1: 191 FNU (3 May); Z2: 51 FNU (3 May); all other zones: ≤14 FNU
Feb–Mar 2022	23 Feb–3 Mar 2022: peak 228.4 mm; total 835.4 mm	System-wide signal across zones	Z2: 826 FNU (28 Feb); Z6: 521 FNU (28 Feb); Z1: 502 FNU (28 Feb); Z3–Z5: 97–144 FNU; Z7: 11 FNU
Mar–Apr 2025	10 Mar 2025: 172.8 mm daily rainfall	Strongest in Zones 1–2; attenuated seaward	Z2: 218 FNU (10 Mar); Z1: 82 FNU (30 Mar); Z4: 46 FNU (10 Mar); Z3 and Z5–Z7: ≤20 FNU

3.3 Validation of Satellite-derived Turbidity

3.3.1 Temporal Agreement

A logarithmic time-series comparison was undertaken to evaluate whether the satellite-derived and in situ observations responded similarly to changes in environmental conditions throughout the monitoring period as illustrated in Figure 3.25.

Temporal agreement was strongest at the shallow stations, CEP01 (2 m) and CEP06 (3 m), where increases and decreases in satellite turbidity generally coincided with changes in the in situ record. Agreement was weaker at CEP07 (13 m) and CEP09 (15 m), where in situ turbidity remained comparatively low and stable while satellite observations showed greater variability and several elevated values.

In-situ Turbidity with Sentinel-2 FNU Overlay (UTC)

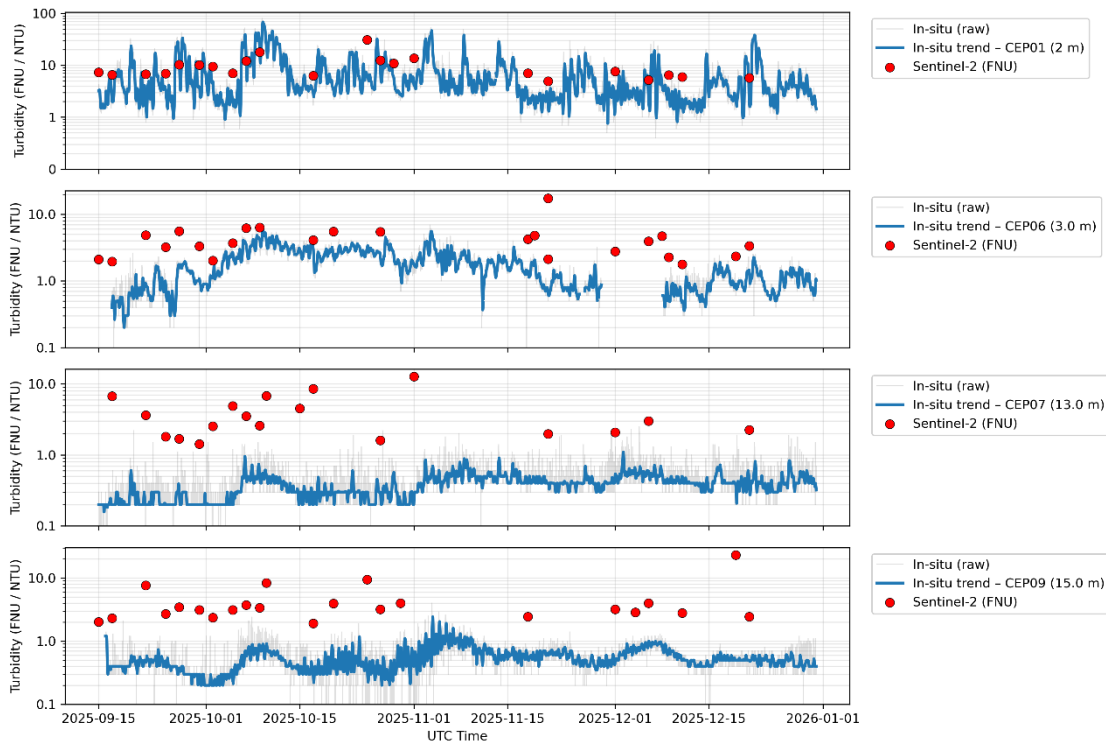


Figure 3.25 Logarithmic time-series comparison of in situ NTU and satellite-derived FNU across all stations, highlighting temporal alignment of turbidity events.

3.3.2 Near Surface Comparison

Satellite-derived FNU values were compared with coincident in situ NTU measurements at four monitoring stations (Figure 3.24). CEP01 showed the closest positive relationship, although satellite values were generally above the 1:1 line and several observations showed larger positive differences. CEP06 also showed a positive fitted relationship, with most observations concentrated at low turbidity and one positive outlier (in-situ: 0.6 NTU and satellite:17.5 FNU).

At CEP07 and CEP09, in situ measurements were concentrated within a narrow low-turbidity range, while satellite values were higher and more dispersed. The fitted relationships showed greater departure from the 1:1 line at these deeper stations, with CEP09 displaying the weakest correspondence between increasing in situ and satellite turbidity.

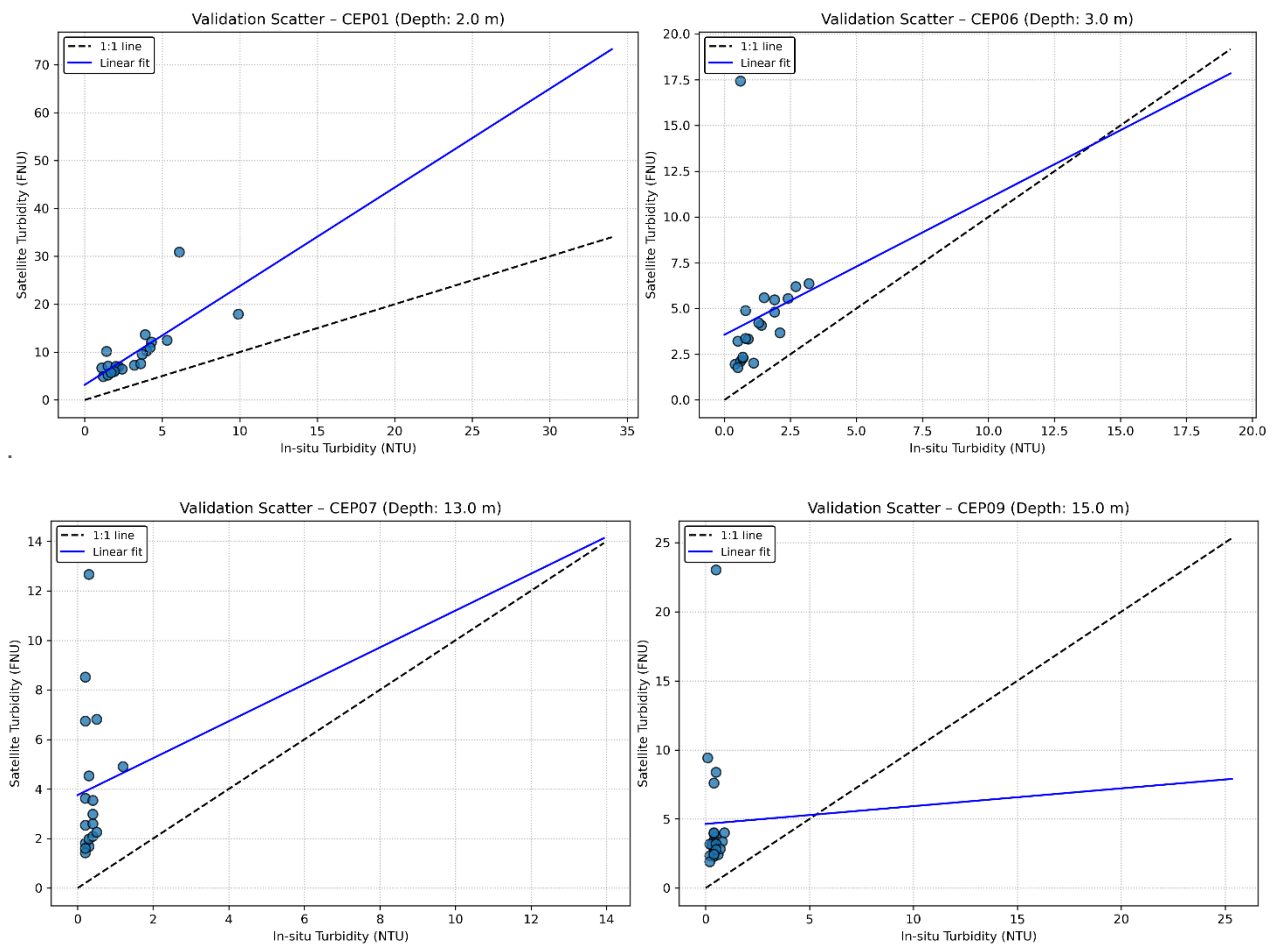


Figure 3.26 Validation scatter plots comparing satellite-derived FNU and in situ NTU across all four monitoring stations (CEP01, CEP06, CEP07, and CEP09).

3.3.3 Systematic Bias Offset

Difference analysis confirmed a positive mean bias at every station summarised in Table 3.3 and illustrated in Figure 3.27.

Table 3.3 Mean bias for each in-situ site

Site	Depth	Mean bias (satellite – in situ)
CEP01	2 m	+6.492 FNU
CEP06	3 m	+3.234 FNU
CEP07	13 m	+3.665 FNU
CEP09	15 m	+4.264 FNU

Most paired observations fell within the plotted $\pm 2\sigma$ limits of agreement, indicating that the positive offset was broadly consistent across the validation dataset. However, each station contained at least one relatively large positive difference, and disagreement generally increased for some higher-magnitude observations. This was most evident at CEP01, CEP07 and CEP09, while CEP06 showed a more compact difference distribution apart from one outlier.

The regression residuals were generally clustered around zero after accounting for the fitted relationship, but isolated large residuals remained. CEP01 showed increasing residual spread at higher turbidity, CEP06 had comparatively compact residuals, and CEP07–CEP09 showed greater relative scatter because most in situ measurements were concentrated within a narrow low-turbidity range.

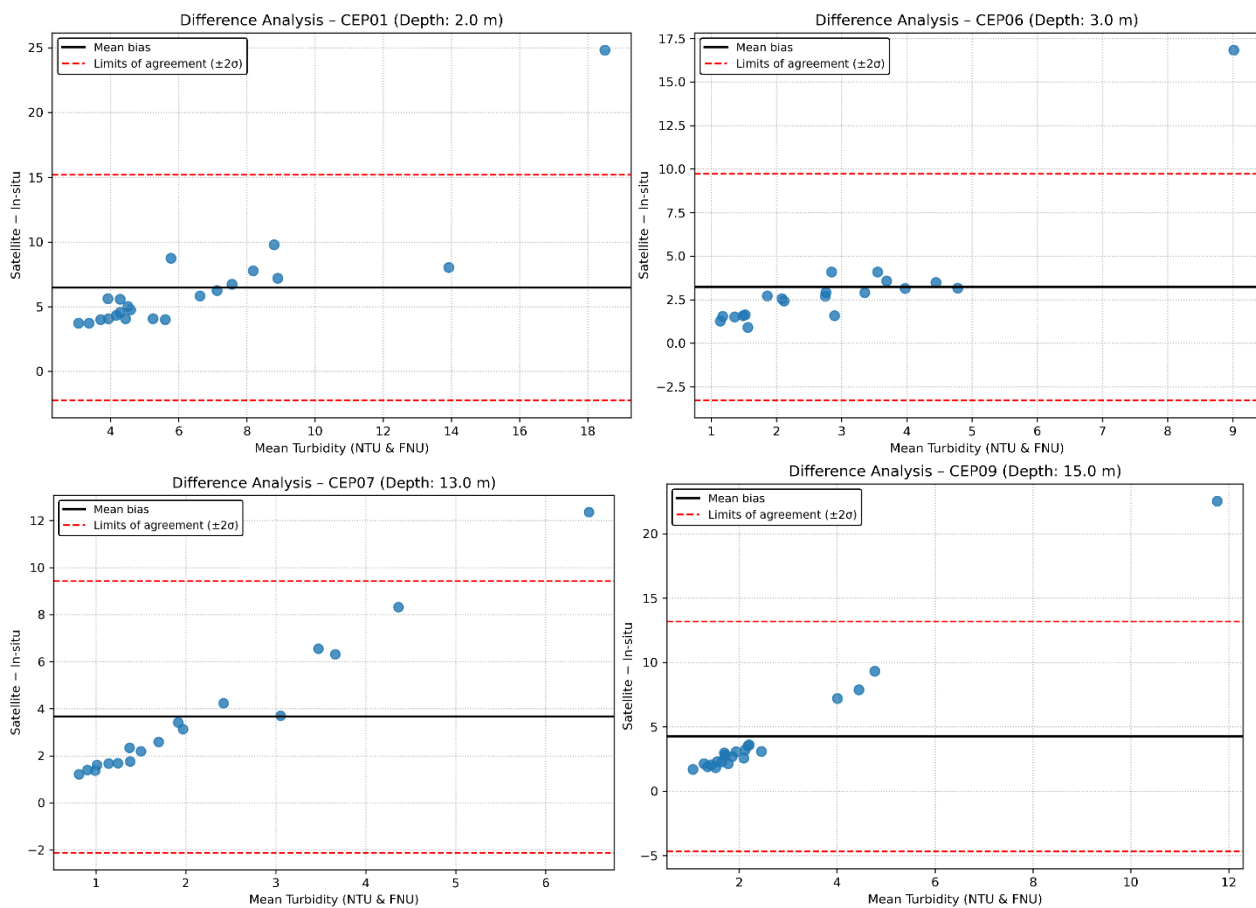


Figure 3.27 Validation scatter plots comparing satellite-derived FNU and in situ NTU across all four monitoring stations (CEP01, CEP06, CEP07, and CEP09).

3.3.4 Overall Validation Finding

The satellite and in situ measurements were not directly equivalent, with satellite turbidity consistently higher on average. The results support using satellite observations to assess near-surface spatial patterns and broad temporal changes, particularly at shallow stations. Greater caution is required when comparing absolute satellite values with measurements from deeper sensors, where agreement was weaker and surface-to-depth differences were more pronounced.

4 Discussion

4.1 Overall Synthesis

Turbidity in the lower Brisbane River and western Moreton Bay exhibits a persistent land-to-sea gradient and strongly episodic variability through time. The results show elevated and more variable conditions in inner estuarine and port-adjacent waters, transitional behaviour in western Moreton Bay embayment's, and low, tightly constrained background conditions in offshore waters. This spatial structure persists across seasons and years and provides a stable framework for interpreting short-term turbidity excursions across the system.

These patterns align with established conceptual and empirical understanding of the Brisbane River–Moreton Bay system, which emphasises strong catchment influence near the river mouth, progressive offshore attenuation, and episodic system-wide responses during major rainfall and flood conditions (Tibbetts *et al.* 1998; Dennison & Abal 1999; Cox 1998a, 1998b). They are also consistent with regional syntheses indicating that year-to-year water-quality behaviour in Moreton Bay is strongly influenced by climate variability and episodic flow events, rather than a consistent directional trend (Saeck *et al.* 2019; Healthy Land & Water 2020).

4.2 Spatial Patterns in Context of Previous Studies and WQOs

4.2.1 Comparison with Previous Studies and Monitoring Programs

Major rainfall and flood events dominate the upper tails of turbidity distributions across the Study Area, producing rapid increases in turbidity within the lower Brisbane River and western Moreton Bay, with decreasing magnitude and duration seaward. This behaviour is consistent with established understanding that fine sediments accumulate during low-flow periods and are mobilised during short, high-magnitude floods, generating elevated turbidity and downstream gradients (Cox 1998a; Yu *et al.* 2014).

Sediment and contaminant studies following major Brisbane River floods demonstrate that these events deliver substantial quantities of fine material to Moreton Bay and influence sediment distributions over broad spatial scales (Coates-Marnane *et al.* 2016a). Longer-term sedimentary records further show that the persistence of event-derived deposits varies spatially across the bay (Coates-Marnane *et al.* 2016b). The present results show that, although event responses can be system-wide, their persistence is strongly zone and depth-dependent.

Following major events, satellite-derived surface turbidity distributions contracted toward zone-specific background ranges rather than remaining elevated. This repeated escalation–contraction behaviour indicates observed surface turbidity returning toward background distributions after event scale disturbance. As the assessment is based on surface turbidity observations, this interpretation relates specifically to turbidity behaviour rather than broader ecological or sediment-system condition.

4.2.2 Interpretation Relative to EPP Water Management Zones and WQOs

Interpretation relative to the EPP needs to recognise two key issues: (i) units and (ii) the statistical context of objectives. Under Queensland's EPP framework, WQOs are set as long-term receiving-water goals, not instantaneous limits, and are used in planning, reporting and decision contexts rather than as direct point-source emission objectives. Guidance supporting the EPP framework emphasises that objectives are derived from guideline methods and are interpreted using appropriate decision criteria and temporal aggregation, including distribution-based approaches consistent with modern guidelines (e.g. median and percentile-based criteria depending on the indicator and level of protection).

In this assessment, turbidity is derived from satellite reflectance and reported in FNU, representing a surface-optical proxy. EPP turbidity objectives are expressed in NTU and are typically assessed using long-term statistical measures (DES 2022a). Although NTU and FNU are often closely related for many nephelometric applications, they are not strictly interchangeable, particularly under very clear offshore conditions and under extreme high turbidity where sensor/optical effects can diverge. The practical implication is that the satellite-derived FNU record in this assessment provides strong spatial and temporal context but should not be treated as a direct surrogate for compliance-grade NTU datasets without site- and method-specific validation.

Accordingly, the results are best interpreted in the management-intent sense: whether turbidity patterns and variability observed within each reporting region are consistent with the expected behaviour of the water type (inner estuarine vs offshore open coastal), and whether short-duration excursions are consistent with system-wide climatic forcing versus more localised disturbance. This is consistent with the EPP and guideline framework approach, which recognises that naturally dynamic systems can experience episodic departures during high-magnitude events, with assessment focused on long-term distributional behaviour and recovery toward typical conditions.

4.2.3 Implications of Spatial Patterns for Interpreting Elevated Turbidity

The spatial structure identified in this assessment means that turbidity values have different significance across the system. Inner estuarine and port-adjacent waters zones commonly exhibit moderate to elevated turbidity associated with persistent sediment availability and resuspension, whereas offshore waters are characterised by low, tightly constrained background turbidity and infrequent elevation outside major forcing events. This contrast provides a clear basis for distinguishing expected spatial patterns from anomalous turbidity responses.

4.3 Temporal Variability and Trends

4.3.1 Seasonal Patterns

The results show a repeatable seasonal signal across the Study Area, with higher turbidity and broader distributions during the wet season and lower, more stable conditions during the dry season. Seasonal contrasts are strongest in inner riverine and shallow western bay zones and become progressively weaker in outer areas, particularly Zones 5 and 7, reflecting reduced direct catchment influence and the increasing dominance of marine exchange seaward. This behaviour is consistent with Brisbane River estuary observations showing wet–dry differences in the estuarine turbidity maximum and stronger tidal structuring downstream than upstream (Yu *et al.* 2014).

4.3.2 Event-Scale Dynamics and Recovery

Event-scale dynamics dominate the upper tails of turbidity distributions across zones. Major rainfall and flood periods produce rapid increases in turbidity, with the largest magnitudes and greatest persistence generally occurring in inner estuarine waters and strong attenuation seaward. The inclusion of 2011 demonstrates the importance of major flood events in defining long-term extremes, while the response recorded in Zone 7 confirms that severe events can also generate anomalous turbidity in normally clear offshore waters. Sediment and contaminant studies in Moreton Bay show that such events can deliver substantial fine material and influence sediment composition and contaminant patterns (Dennison & Abal 1999; Yu *et al.* 2014; Coates-Marnane *et al.* 2016a).

A consistent outcome across event windows is observed surface turbidity returned toward zone-specific background envelopes following disturbance. Turbidity distributions contract after event periods rather than remaining broadly elevated, indicating repeated return toward typical background behaviour.

4.3.3 Inter-Annual Variability and Trends

Inter-annual variability is pronounced across the 2011–2025 assessment period and reflects shifts between wetter and drier phases and the timing of major events. Years with major rainfall and flood conditions, particularly 2011 and 2022, show broader distributions and stronger upper tails whereas drier years exhibit more constrained turbidity distributions.

Once this variability is accounted for, the results do not indicate a consistent monotonic trend in background turbidity over 2011–2025. This is consistent with regional summaries showing strong climate-linked year-to-year variability in bay condition and water quality, with outcomes influenced by rainfall/runoff and flushing conditions (Saeck *et al.* 2019; Healthy Land & Water 2020).

This finding does not contradict longer-term evidence of sediment accumulation or historical infilling. Rather, it indicates that over the assessment period, the dominant turbidity signal is event sequencing and climatic variability, with any underlying progressive change difficult to distinguish from this variability at the spatial and temporal scales assessed.

4.4 Role of Environmental Drivers

Driver interpretation is framed around rainfall-related response mechanisms rather than linear correlations, recognising the non-linear nature of turbidity responses. High and extreme turbidity is closely associated with short-duration, high-intensity rainfall and flood events. This relationship becomes more selective seaward: inner zones respond to a wider range of runoff conditions, whereas substantial responses in outer areas, including Zone 7, generally require major events capable of transporting sediment across the bay.

Wind-driven resuspension is recognised as an important secondary process in shallow bay environments and is well established in prior studies (Dennison & Abal 1999). Tides contribute to mixing and resuspension locally, with expression varying across the system (Yu *et al.* 2014). However, neither wind or tides were not explicitly included in the present attribution framework and are therefore interpreted here as a plausible contributing factor rather than a quantified predictor.

4.5 Validation and Confidence in Interpretation

Comparison between satellite-derived turbidity and in situ observations indicates that the satellite product is useful for interpreting near-surface spatial patterns and broad temporal changes, but the two measurement types are not directly equivalent. Validation outcomes should be considered in light of the relatively small number of concurrent observations, the limited turbidity range captured during the September–December 2025 validation period and differences between surface satellite observations and sensors positioned at depth.

Agreement was strongest at the shallow stations, particularly CEP01 (2.0 m) and CEP06 (3.0 m), and weaker at CEP07 (13.0 m) and CEP09 (15.0 m). Satellite estimates showed a systematic positive bias across the stations, with mean offsets of approximately +3.2 to +6.5 FNU. This indicates that satellite turbidity was generally higher than the corresponding depth-specific in situ measurements, with greater caution required at deeper stations where surface-to-depth differences were more pronounced.

Satellite data captured the timing of several turbidity events where overpass dates coincided with observed increases, but this capability is constrained by revisit frequency, cloud cover, and episodic in situ sampling.

Mean bias between satellite and in situ turbidity was comparable to background turbidity levels under relatively clear conditions, indicating that the satellite product is not suitable for quantitative interpretation of low-level absolute turbidity. Although empirical calibration or bias correction may be

feasible with an expanded in situ dataset spanning a broader turbidity range, such approaches were not considered robust for general application here. Accordingly, satellite turbidity was interpreted on a relative basis, focused on spatial patterns, temporal variability, and event timing. This approach is consistent with previous Brisbane River studies (Yu *et al.* 2014).

4.6 Implications for Environmental Management

Taken together, the results support interpretation of turbidity in the Port of Brisbane region that recognises strong spatial differences in background behaviour. Inner estuarine and port-adjacent waters are naturally more turbid and variable, reflecting persistent sediment availability and hydrodynamic confinement, while offshore waters maintain low, stable background conditions with infrequent elevation during major catchment-scale events.

The satellite record provides value by placing turbidity observations within a spatially explicit baseline and event context, supporting distinction between system-wide climatic responses and more localised disturbance in a naturally dynamic environment. In particular, the long temporal coverage allows individual events and short-term excursions to be interpreted against zone-specific background envelopes, rather than as isolated exceedances.

A key practical limitation for quantitative application is the restricted size and scope of the concurrent in situ validation dataset, particularly under higher-turbidity conditions. The available match-ups primarily represent relatively clear conditions and do not fully span the range of turbidity observed during major events. As a consequence, satellite-derived turbidity values are most reliable for relative interpretation of patterns, gradients and changes through time, rather than precise estimation of low-level absolute turbidity.

With an expanded in situ monitoring dataset capturing a broader range of turbidity conditions, it may be feasible in future to explore empirical calibration or bias-correction approaches to improve quantitative agreement between satellite reflectance and in-water measurements. Such approaches have been applied successfully in other estuarine systems using regression-based relationships between satellite bands and in situ turbidity, often with separate treatment of low- and high-turbidity regimes to address dynamic-range limitations and band saturation effects (e.g. Chowdhury *et al.* 2023). Any calibration undertaken for the Port of Brisbane region would need to be site-specific, supported by sufficient concurrent data, and carefully constrained to the turbidity range over which it is developed.

Within these constraints, the satellite dataset is most appropriately applied as a system-scale interpretive tool, complementary to in situ NTU monitoring. Its strengths lie in describing spatial gradients, identifying event timing and footprint, characterising the return of observed surface turbidity toward background distributions following event scale disturbance, and providing long-term context for turbidity observations across management zones. It is not intended to replace depth-specific point measurements or to support compliance assessment in isolation, but rather to improve understanding of how turbidity behaves across the system under different forcing condition.

5 Conclusions

This assessment characterises turbidity behaviour in the lower Brisbane River and western Moreton Bay over the period 2011–2025 using consistent spatial coverage and long-term observation. The results describe how turbidity varies spatially across the estuary–bay continuum and temporally in response to climatic and hydrological forcing, providing a coherent basis for interpreting turbidity conditions in a highly dynamic system.

Turbidity exhibits a persistent land-to-sea gradient across the Study Area. Inner estuarine and port-adjacent waters consistently show higher and more variable turbidity, transitional bay areas exhibit intermediate conditions, and offshore waters maintain low and tightly constrained background turbidity. This spatial structure is stable through time and forms an appropriate reference for interpreting short-term turbidity excursions within different management zones.

Temporal variability is dominated by episodic disturbance rather than sustained elevation. Major rainfall and flood events generate the largest turbidity excursions and are responsible for most upper-tail behaviour in the record. These events produce system-wide responses with magnitudes and persistence that decrease progressively seaward. Outside major event periods, turbidity generally remains within zone-specific background ranges.

Following disturbance, turbidity consistently returns toward typical background conditions within each zone. Although event-driven turbidity can be severe and spatially extensive, the repeated contraction of turbidity distributions after events indicates recovery rather than persistent elevation or regime shift over the assessment period. Inter-annual variability is strong and reflects the sequencing of wet and dry years rather than a monotonic long-term trend.

Interpretation of environmental drivers shows a clear severity-dependent pattern. Lower-level turbidity elevations commonly occur under background conditions, particularly in inner estuarine zones where fine sediments are readily available for resuspension. High and extreme turbidity is strongly associated with short-duration, high-intensity rainfall events that generate catchment-scale sediment delivery. In shallow bay environments, post-event variability reflects the interaction between recently deposited sediments and wind-driven resuspension, while offshore waters exhibit strong attenuation of both frequency and magnitude of elevated turbidity.

Taken together, the results establish a spatially explicit, long-term baseline that describes typical turbidity behaviour, event responses and recovery characteristics across western Moreton Bay and the lower Brisbane River. This baseline supports interpretation of turbidity observations in terms of background variability, spatial context and event history, rather than isolated values, and provides a consistent framework for understanding turbidity dynamics in a naturally variable estuarine–coastal system.

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Annex A Annual Turbidity Pattern

A.1 Turbidity Pattern 2011

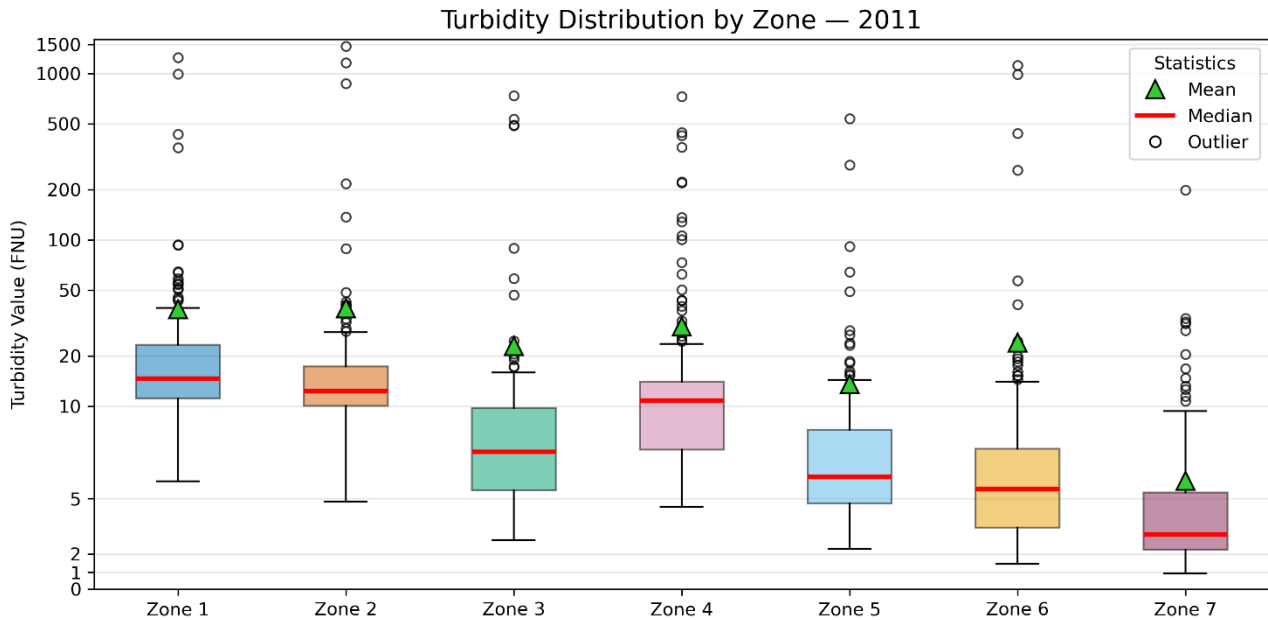


Figure A.1 Turbidity distributions by reporting zone (2011).

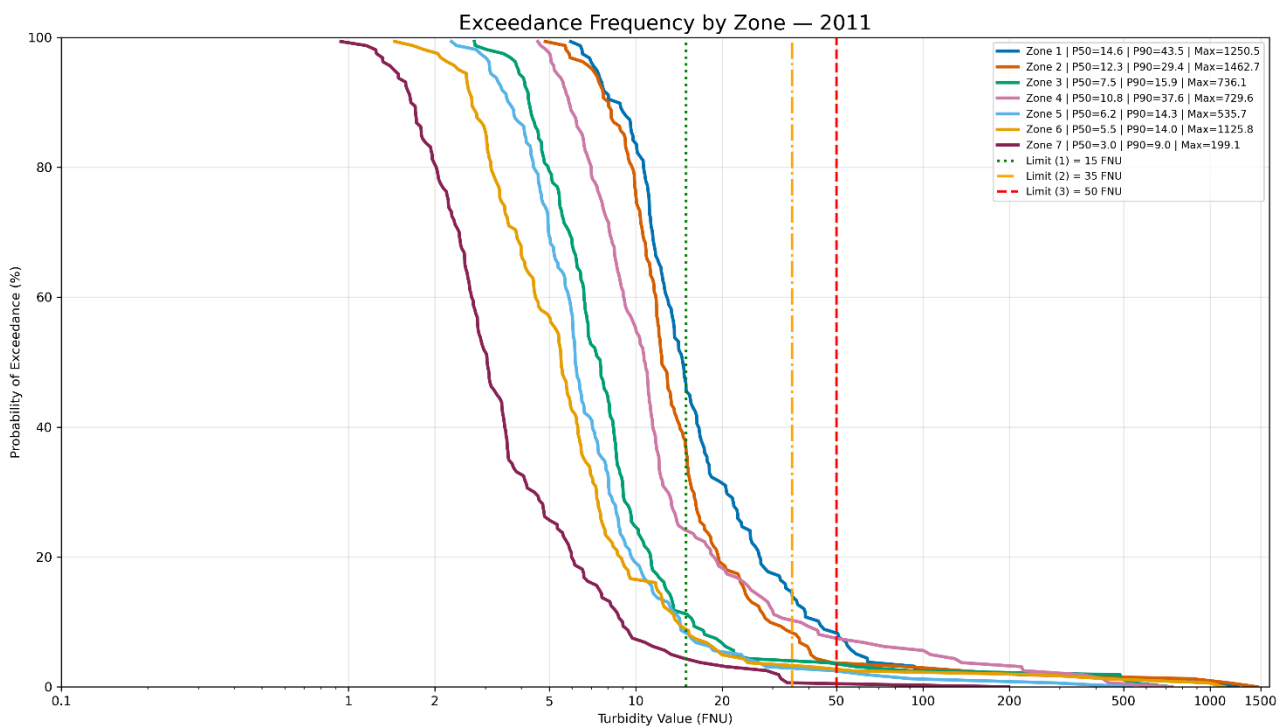


Figure A.2 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2011).

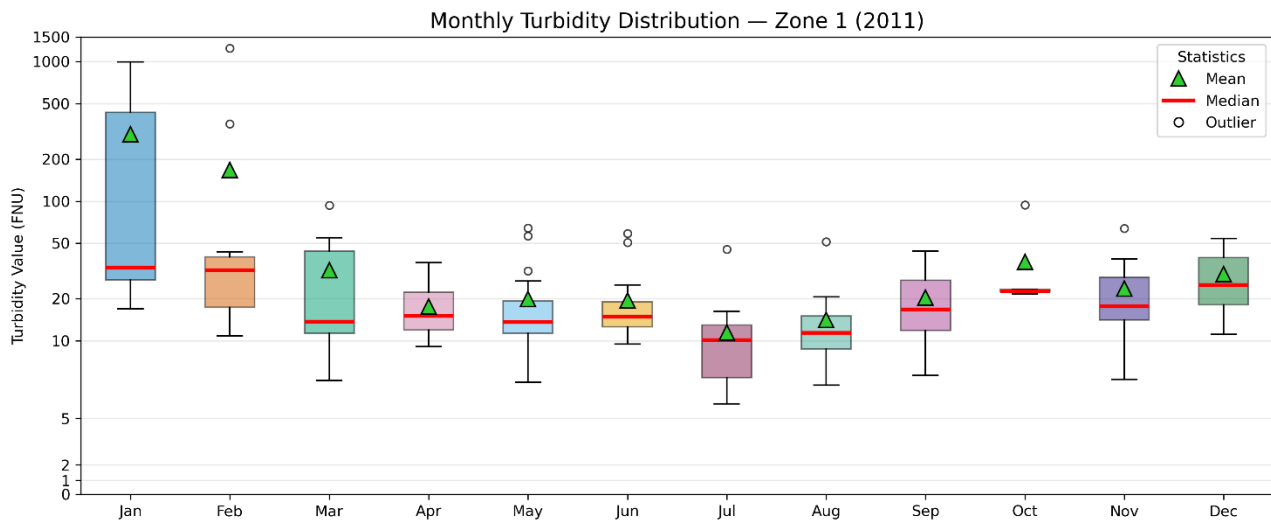


Figure A.3 Monthly Turbidity Distribution by Month for Zone 1 (2011)

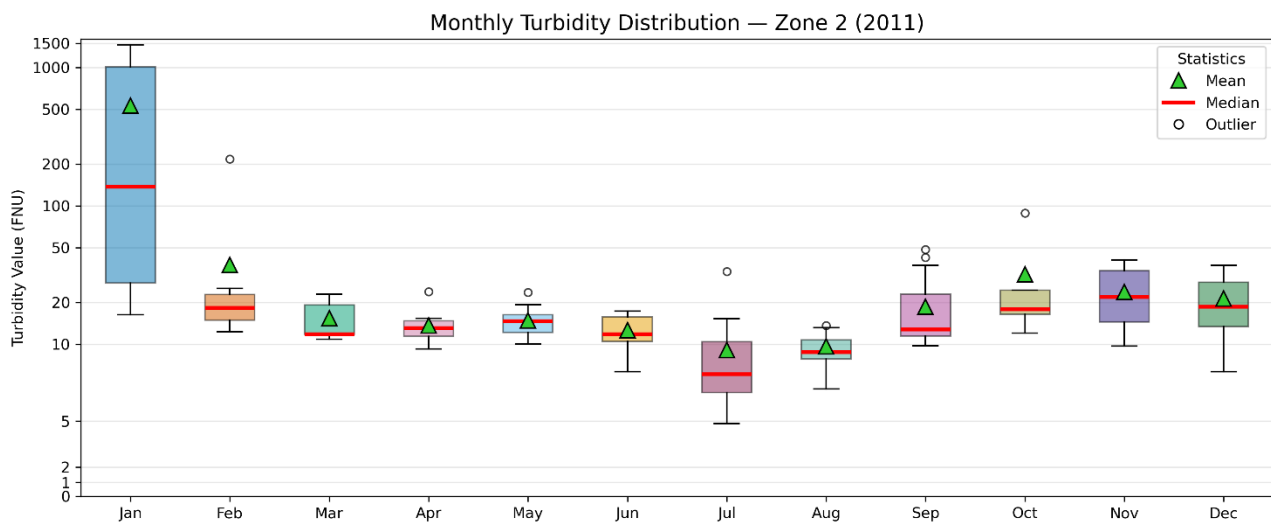


Figure A.4 Monthly Turbidity Distribution by Month for Zone 2 (2011)

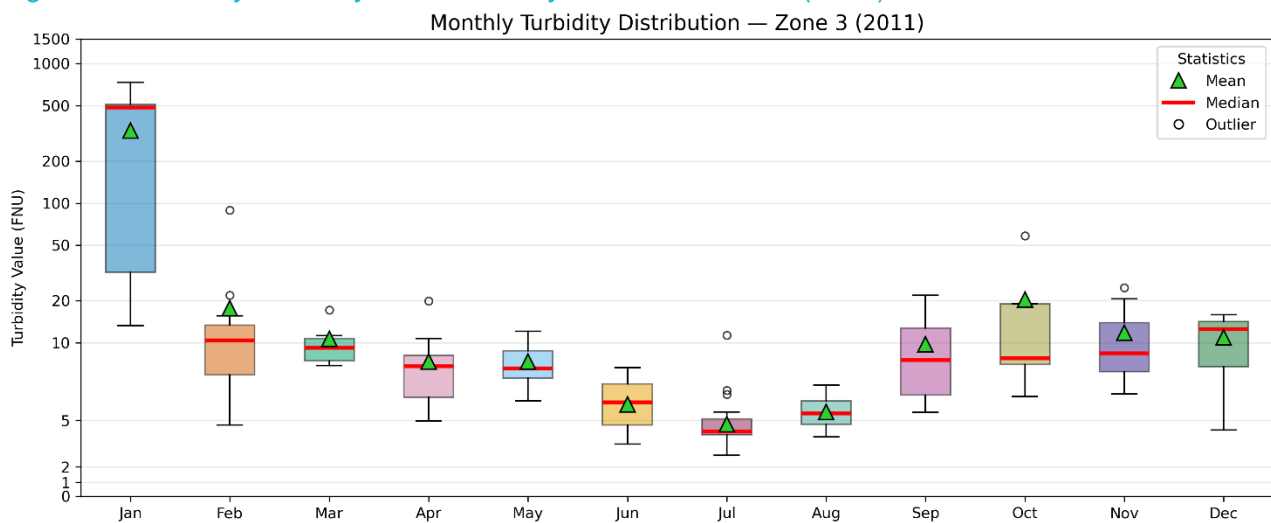


Figure A.5 Monthly Turbidity Distribution by Month for Zone 3 (2011)

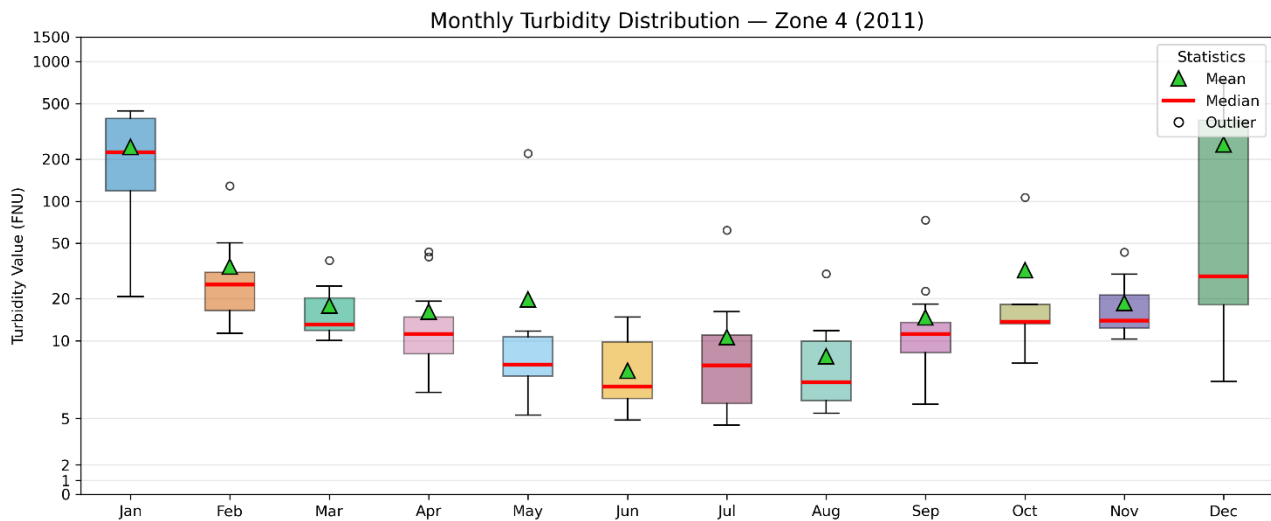


Figure A.6 Monthly Turbidity Distribution by Month for Zone 4 (2011)

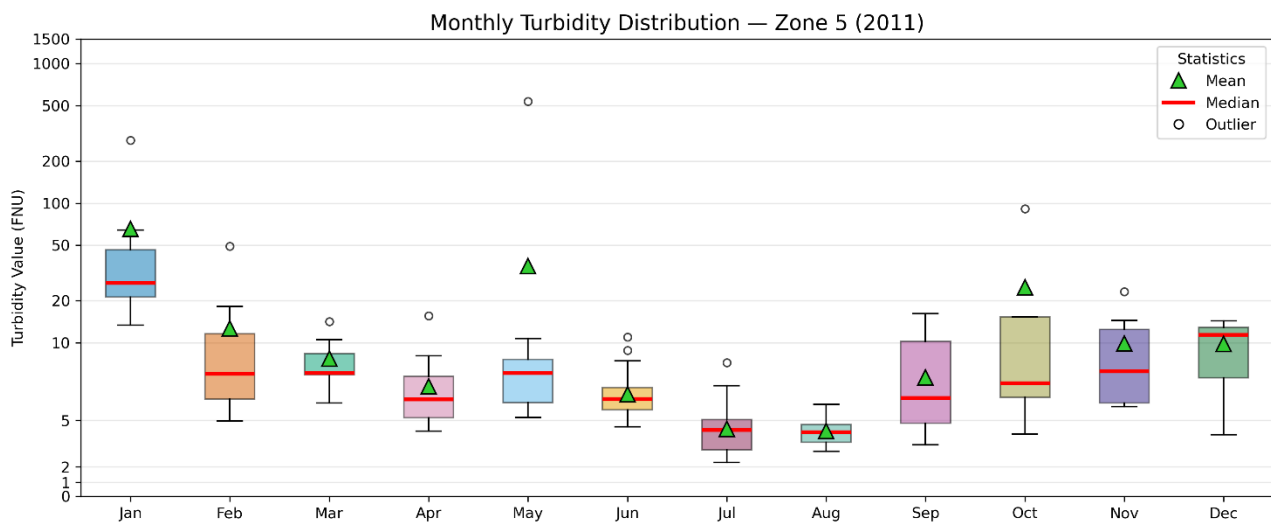


Figure A.7 Monthly Turbidity Distribution by Month for Zone 5 (2011)

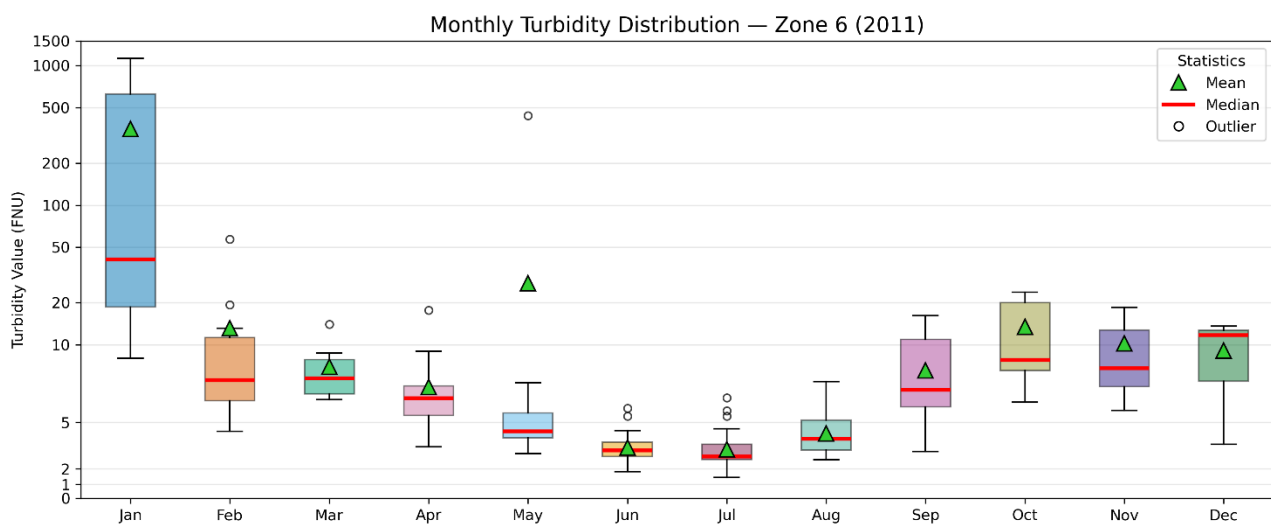


Figure A.8 Monthly Turbidity Distribution by Month for Zone 6 (2011)

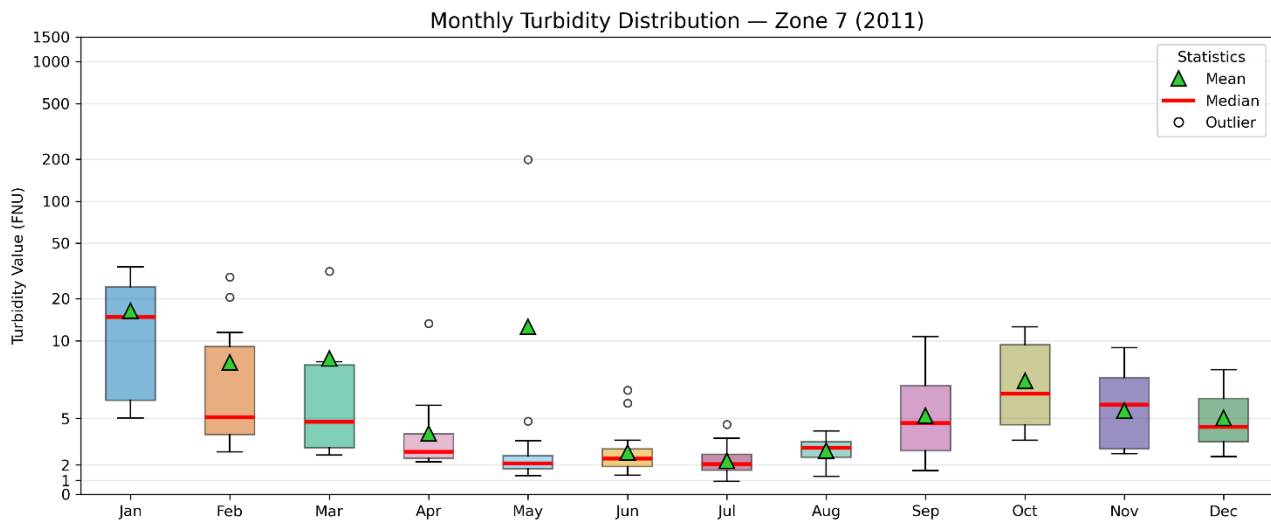


Figure A.9 Monthly Turbidity Distribution by Month for Zone 7 (2011)

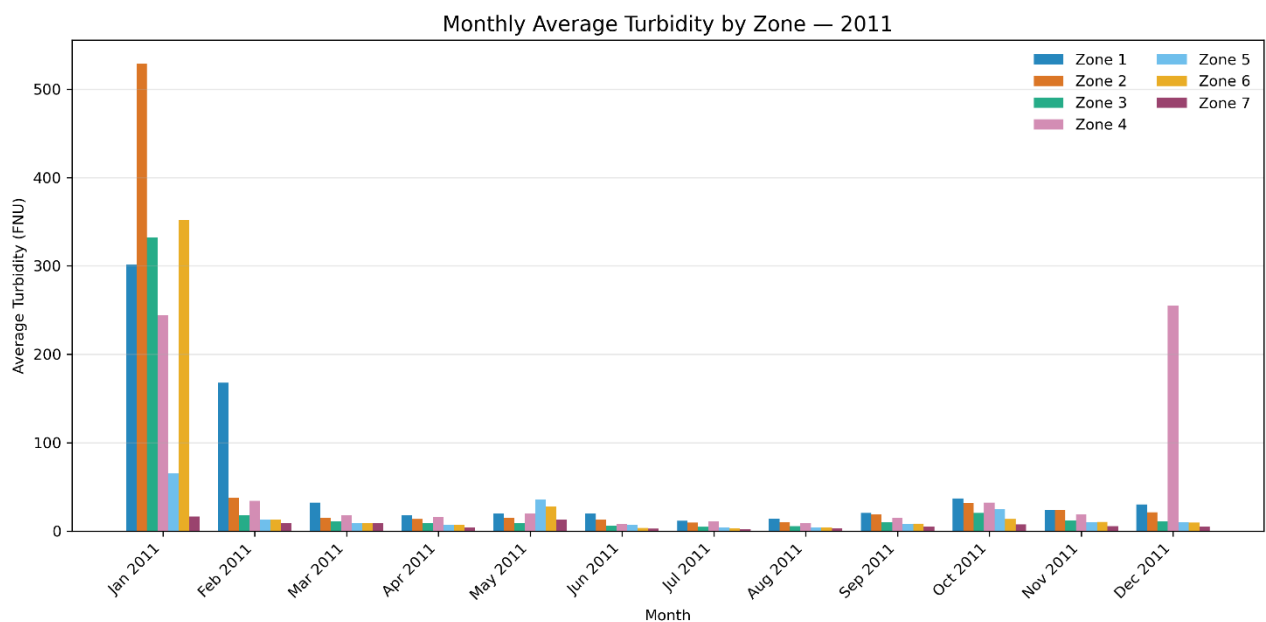
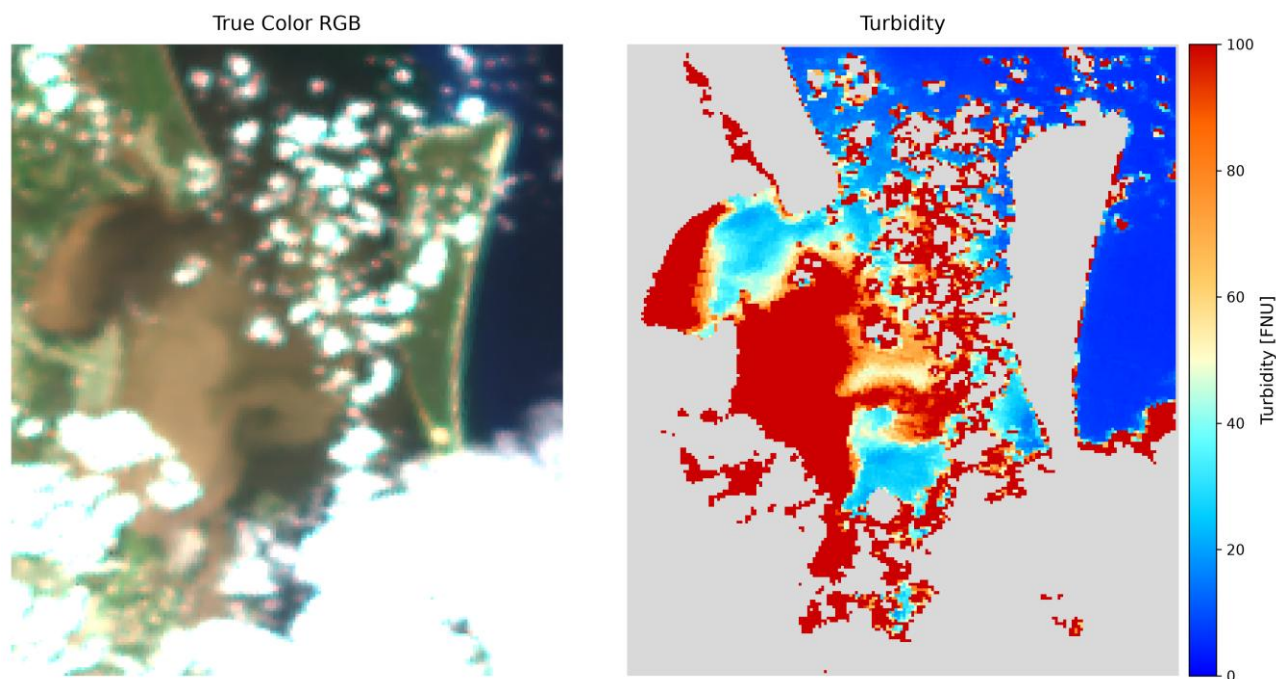


Figure A.10 Monthly Turbidity Distribution by Month (2011)

Sensor: Terra MODIS | Local Time: 2011-01-13 09:30:00 AEST



Sensor: Aqua MODIS | Local Time: 2011-01-15 13:40:00 AEST

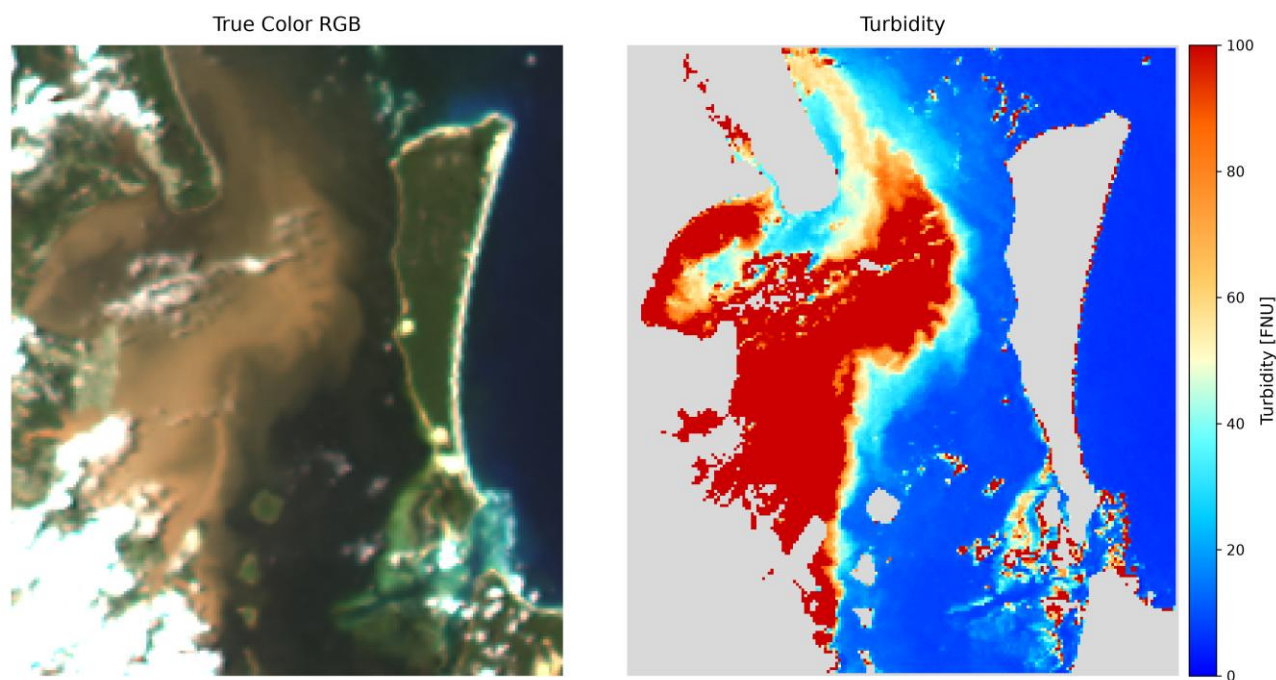
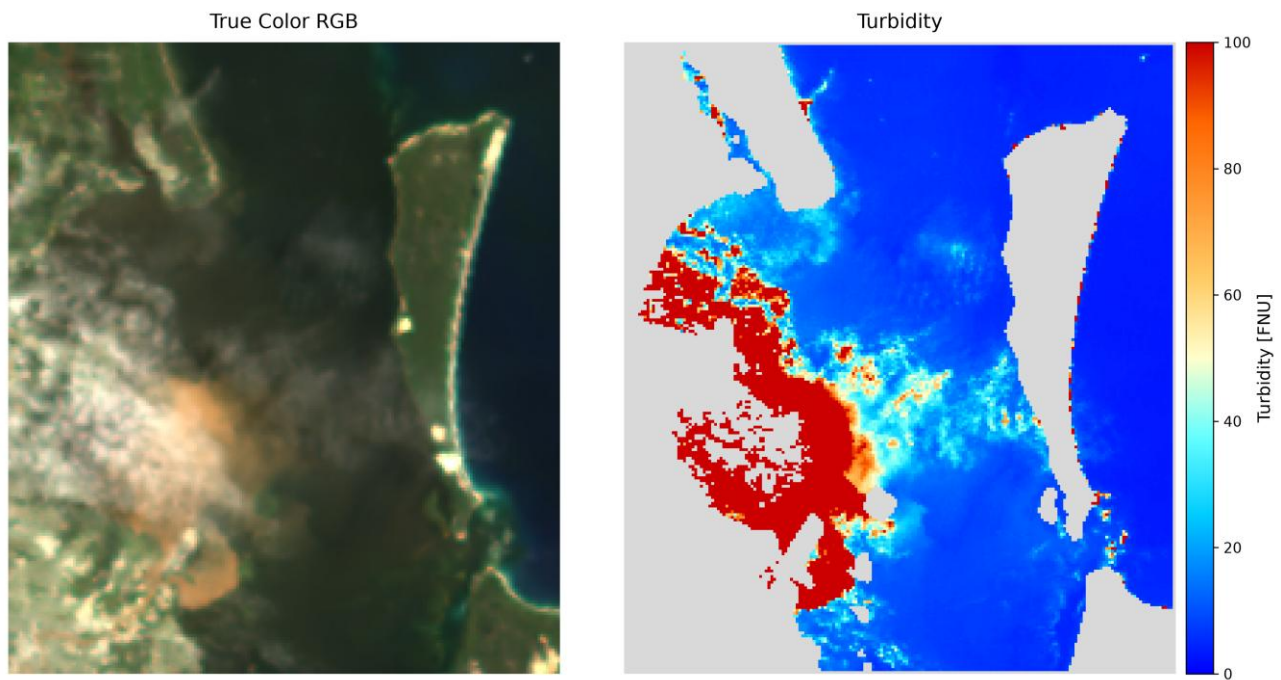


Figure A.11 Representative turbidity conditions during the January 2011 runoff event derived from Modis imagery (250 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: Terra MODIS | Local Time: 2011-01-18 09:50:00 AEST



Sensor: Terra MODIS | Local Time: 2011-01-25 09:55:00 AEST

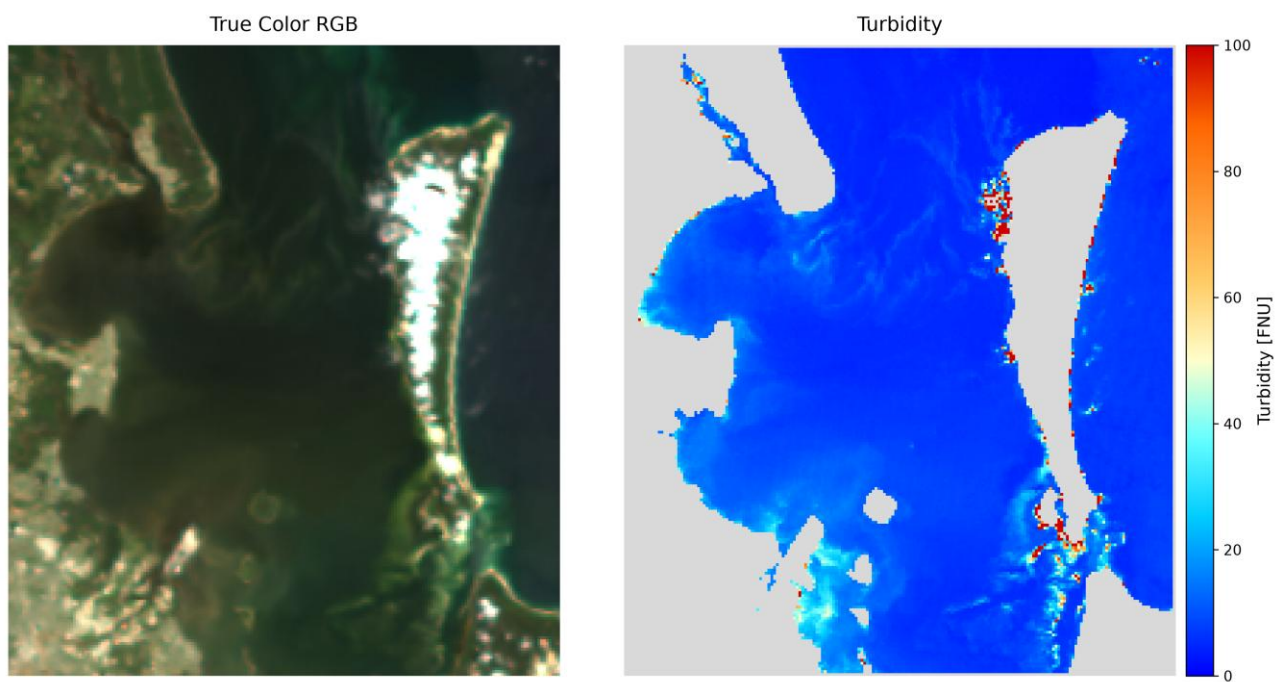
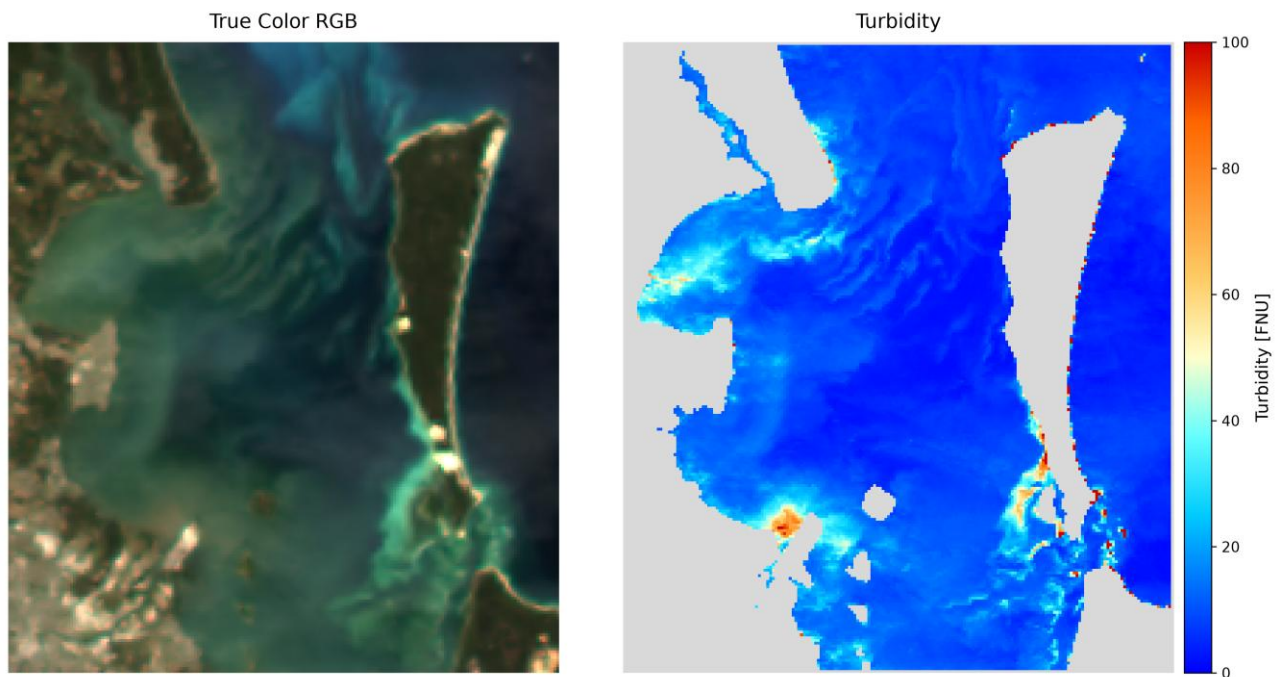


Figure A.12 Representative turbidity conditions during the January 2011 runoff event derived from Modis imagery (250 m spatial resolution). Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: Aqua MODIS | Local Time: 2011-09-30 13:25:00 AEST



Sensor: Terra MODIS | Local Time: 2011-06-20 09:45:00 AEST

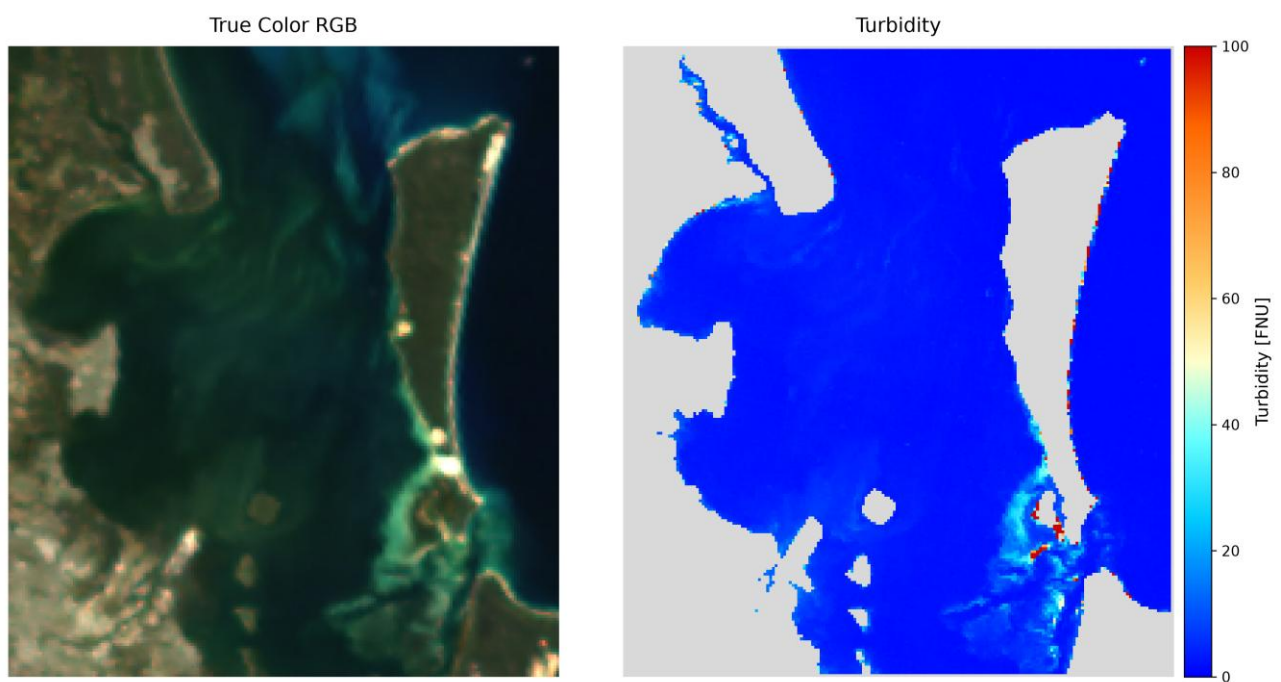


Figure A.13 Representative turbidity conditions in 2011. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.2 Turbidity Pattern 2012

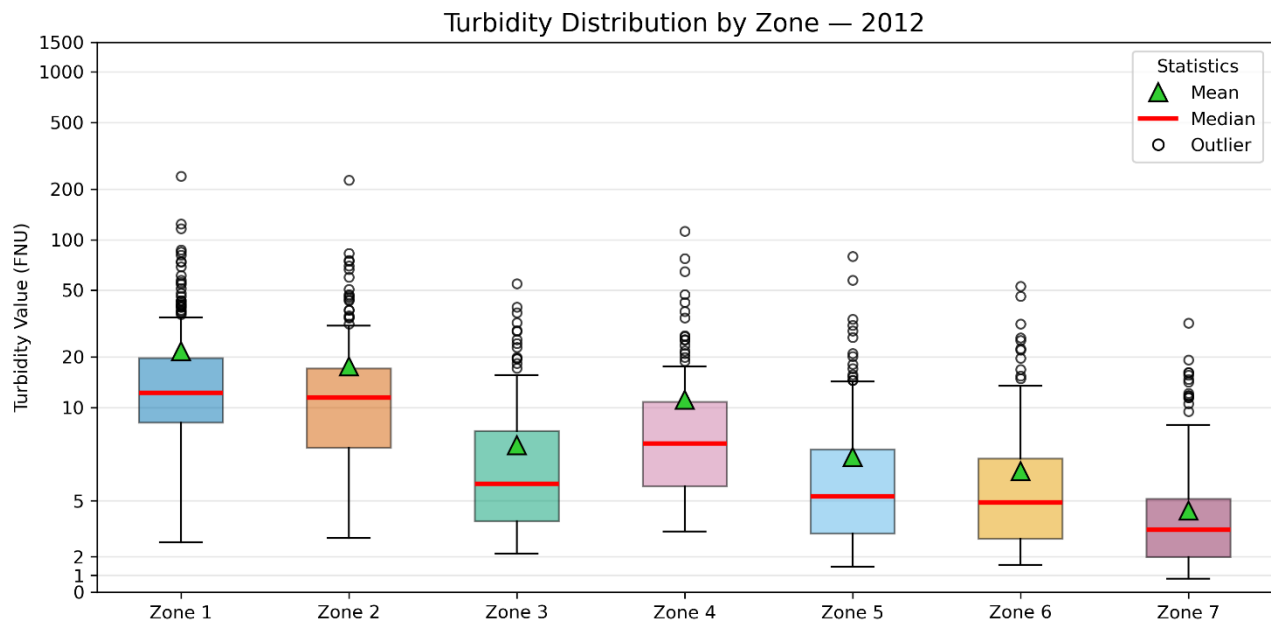


Figure A.14 Turbidity distributions by reporting zone (2012).

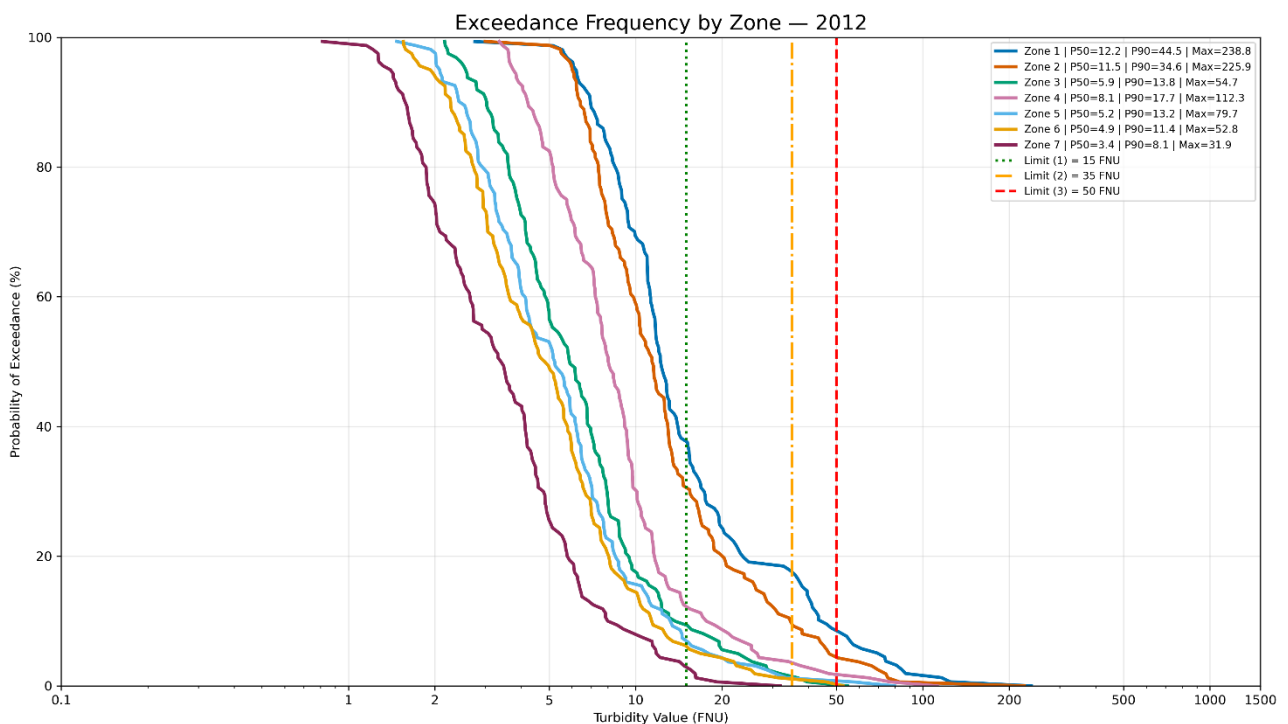


Figure A.15 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2012).

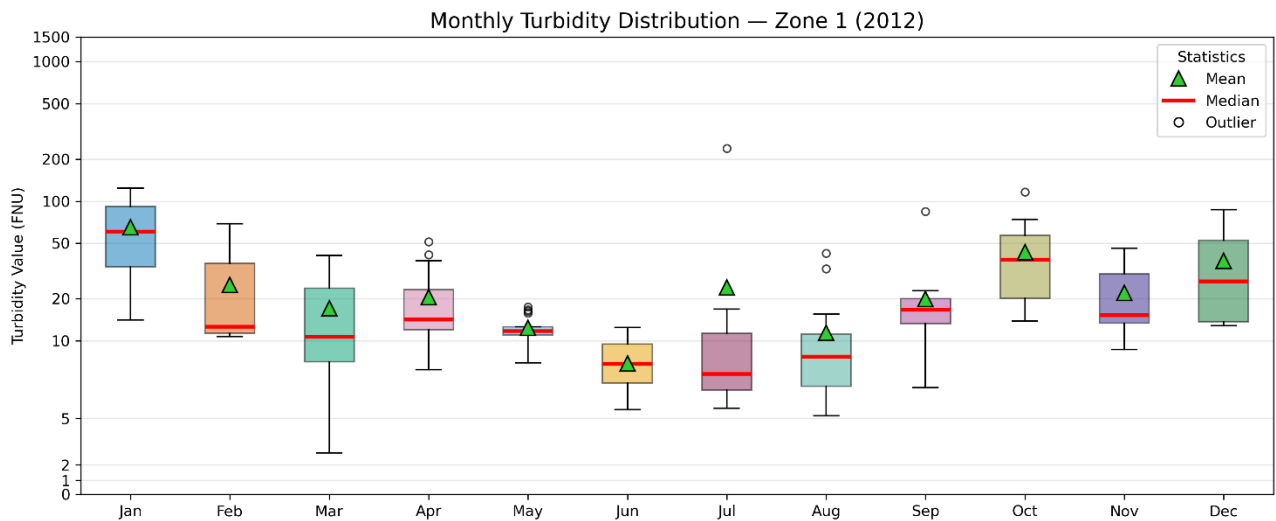


Figure A.16 Monthly Turbidity Distribution by Month for Zone 1 (2012)

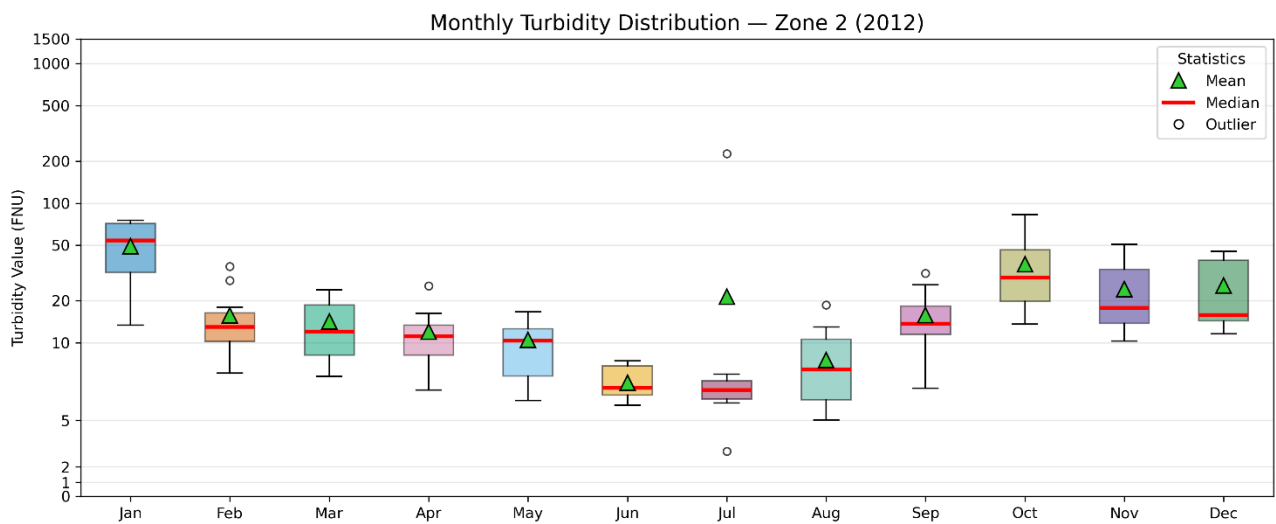


Figure A.17 Monthly Turbidity Distribution by Month for Zone 2 (2012)

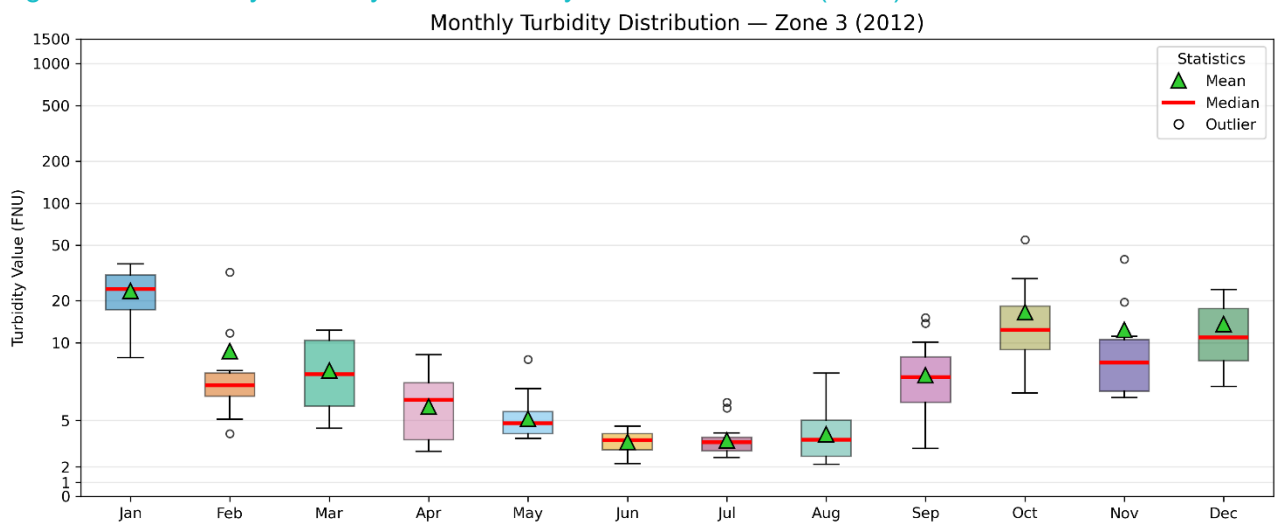


Figure A.18 Monthly Turbidity Distribution by Month for Zone 3 (2012)

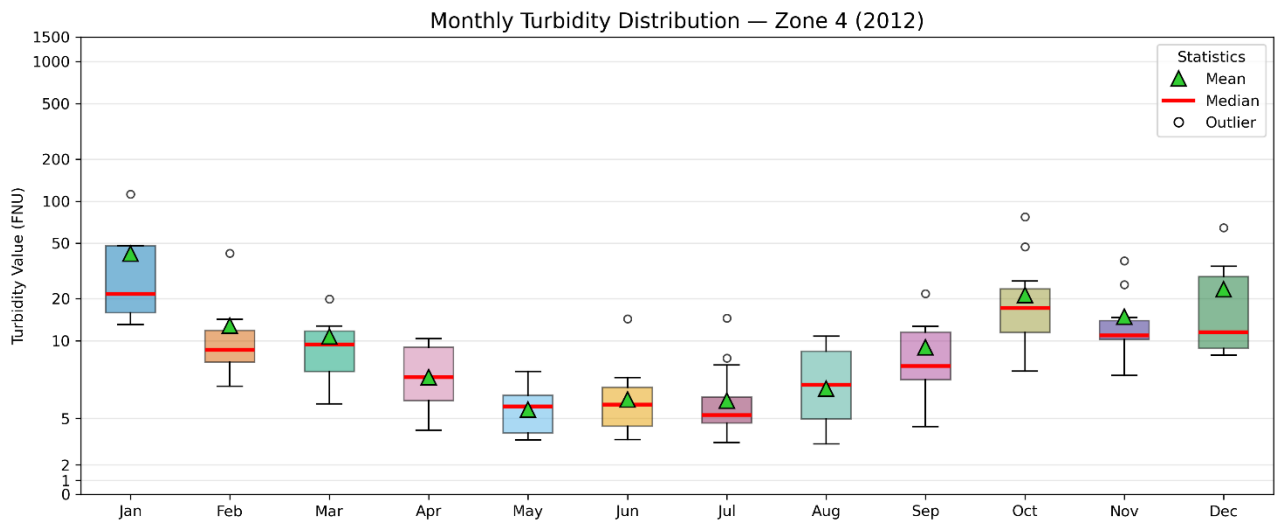


Figure A.19 Monthly Turbidity Distribution by Month for Zone 4 (2012)

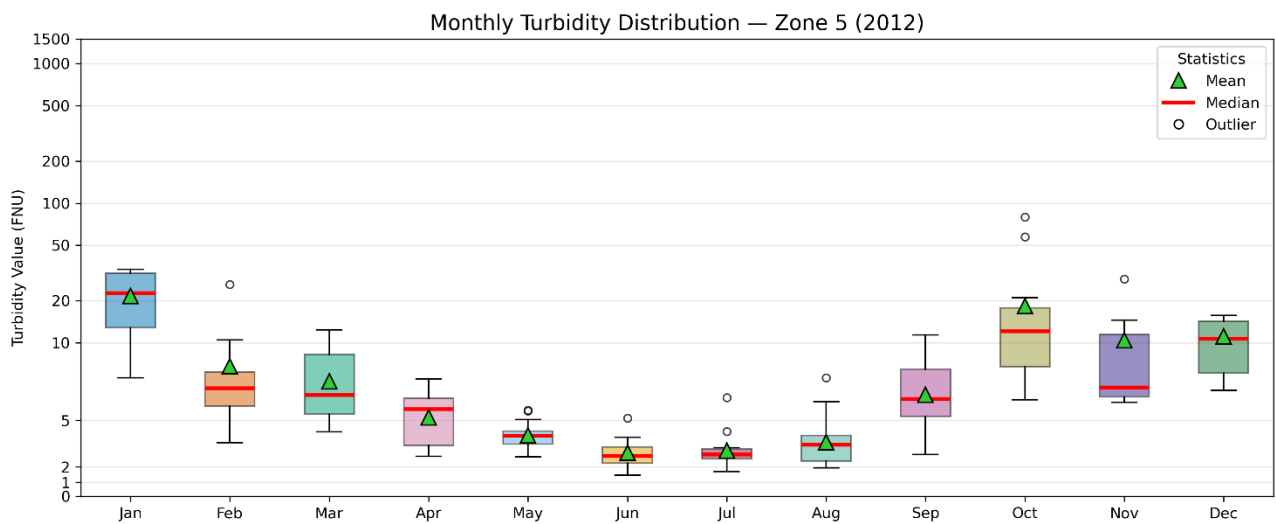


Figure A.20 Monthly Turbidity Distribution by Month for Zone 5 (2012)

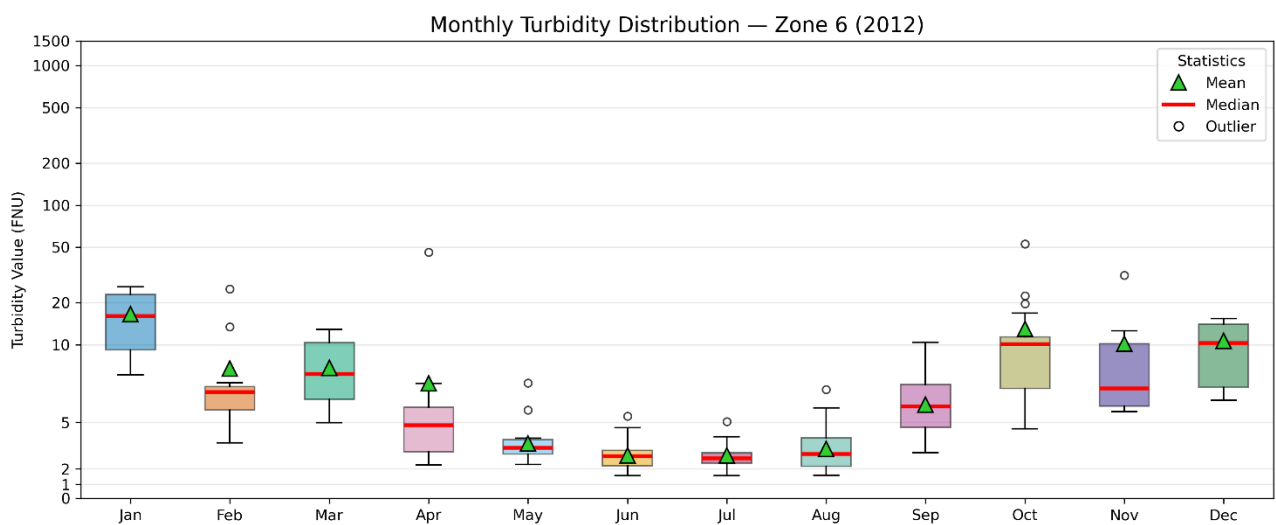


Figure A.21 Monthly Turbidity Distribution by Month for Zone 6 (2012)

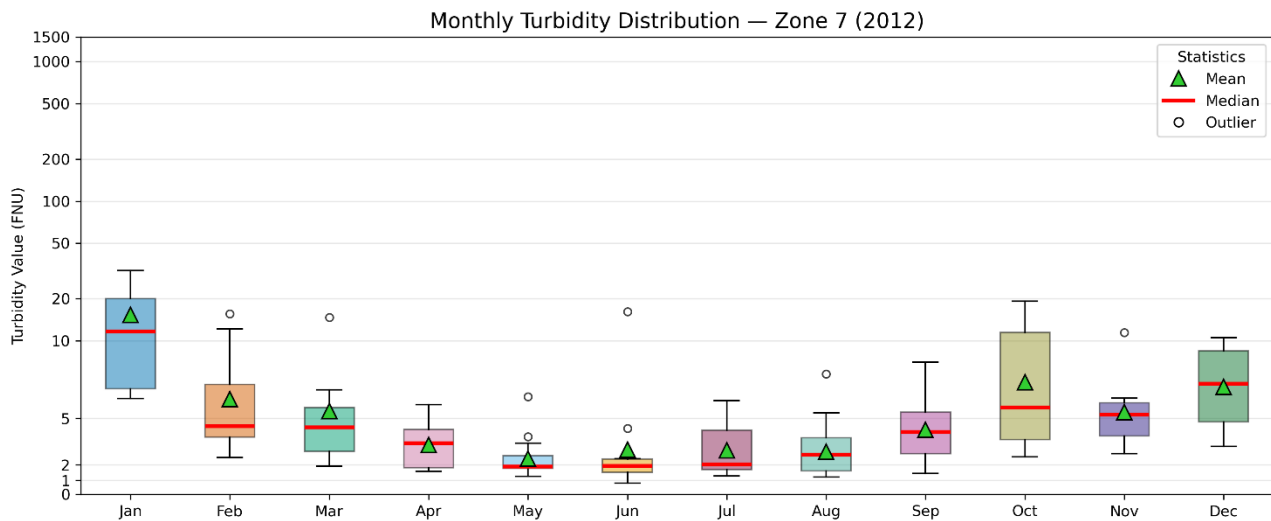


Figure A.22 Monthly Turbidity Distribution by Month for Zone 7 (2012)

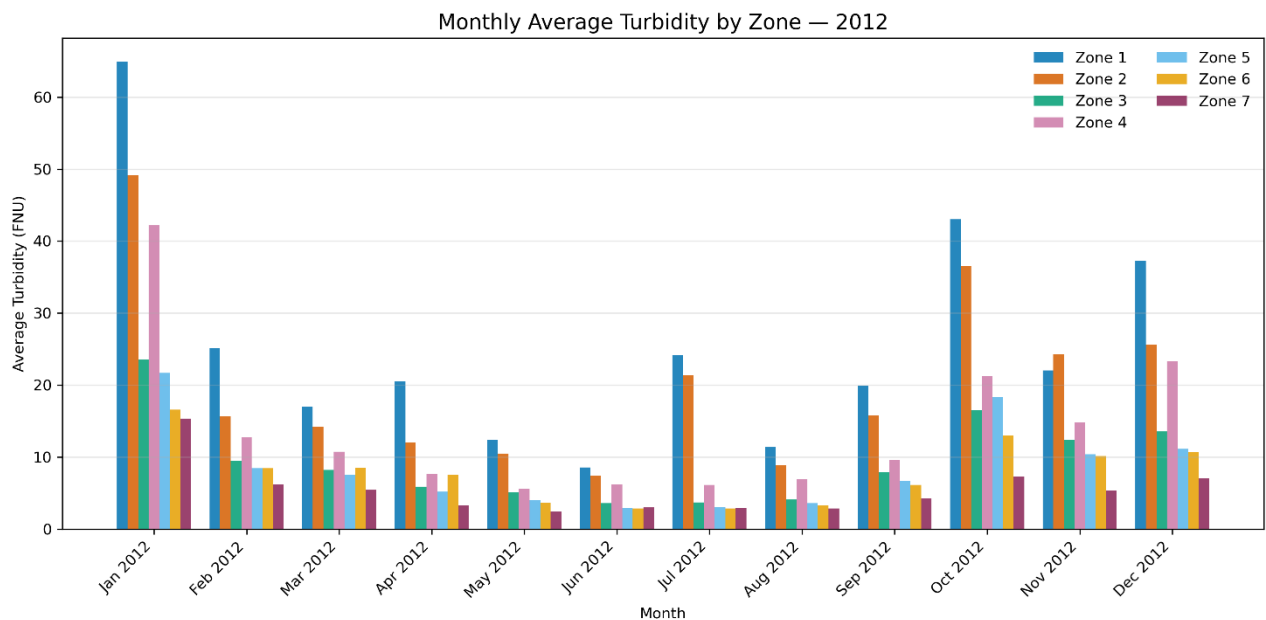
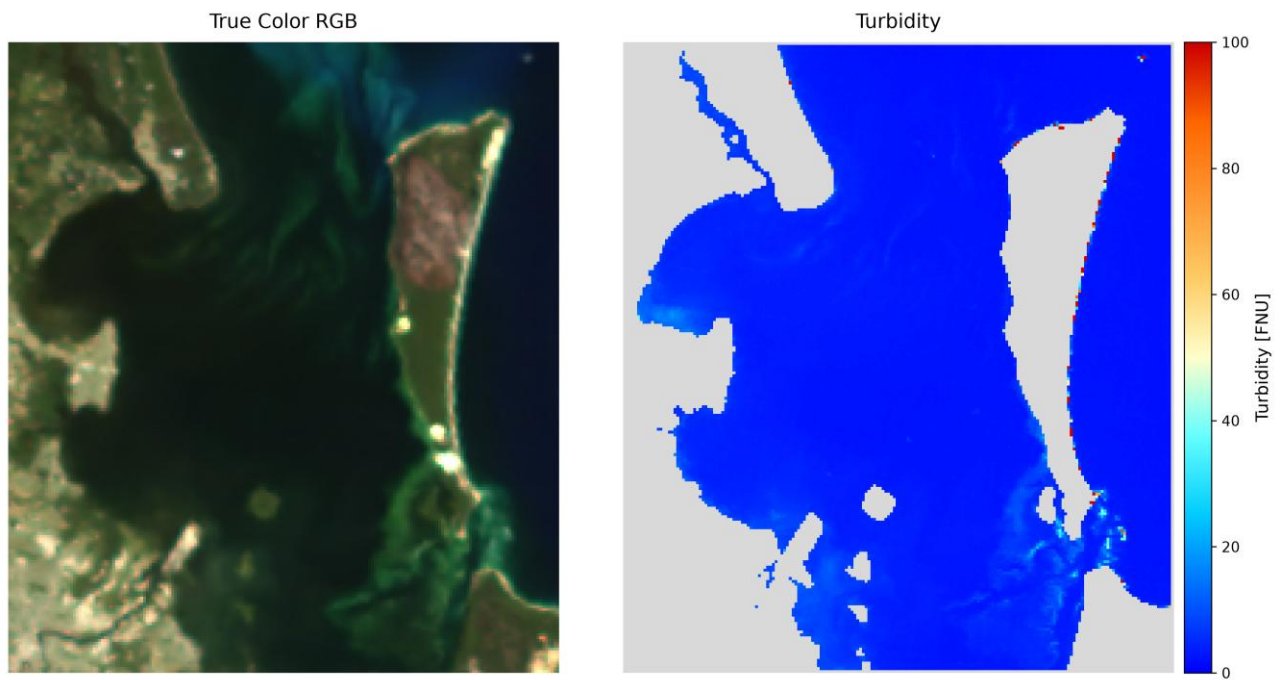


Figure A.23 Monthly Turbidity Distribution by Month (2012)

Sensor: Terra MODIS | Local Time: 2012-02-06 09:50:00 AEST



Sensor: Terra MODIS | Local Time: 2012-05-19 09:55:00 AEST

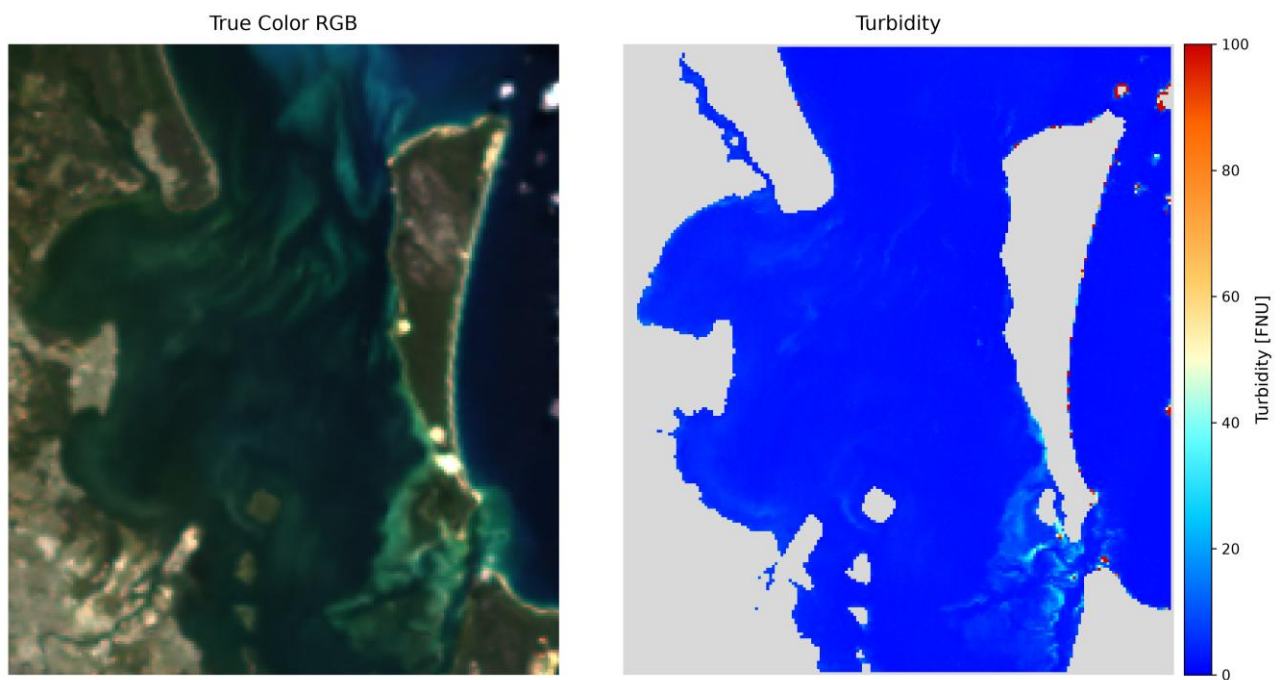
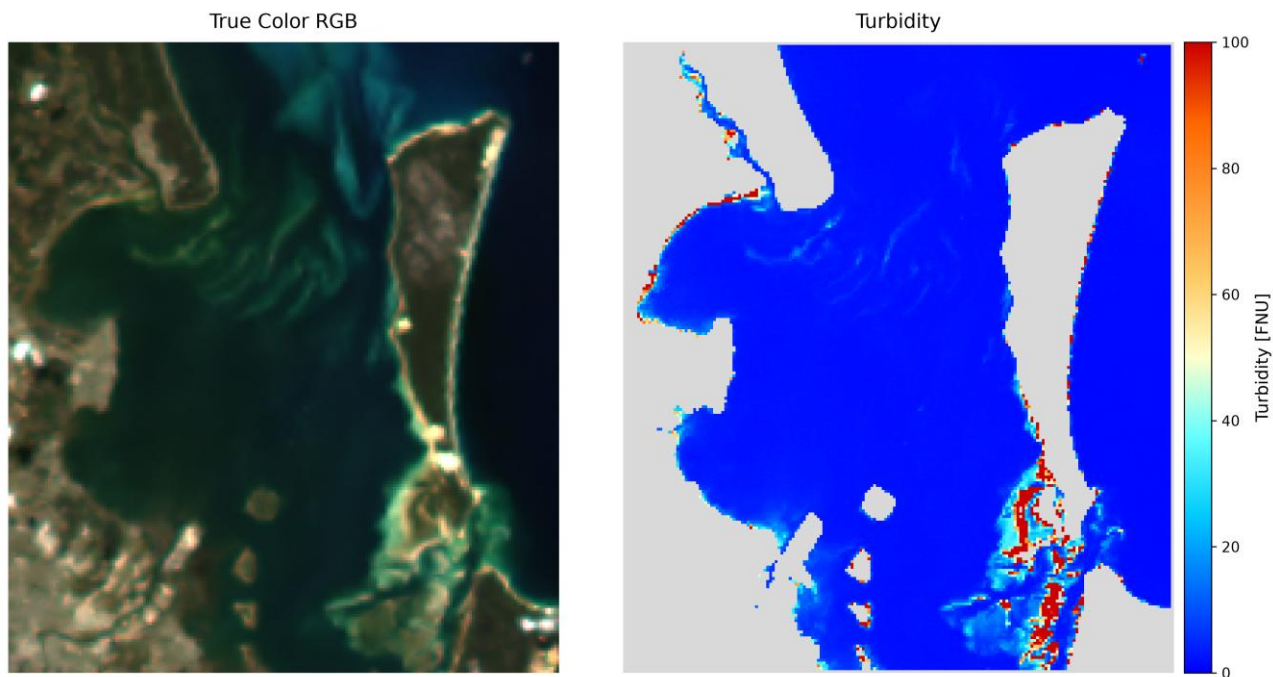


Figure A.24 Representative turbidity conditions in 2012. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: Aqua MODIS | Local Time: 2012-07-30 13:30:00 AEST



Sensor: Aqua MODIS | Local Time: 2012-11-15 13:50:00 AEST

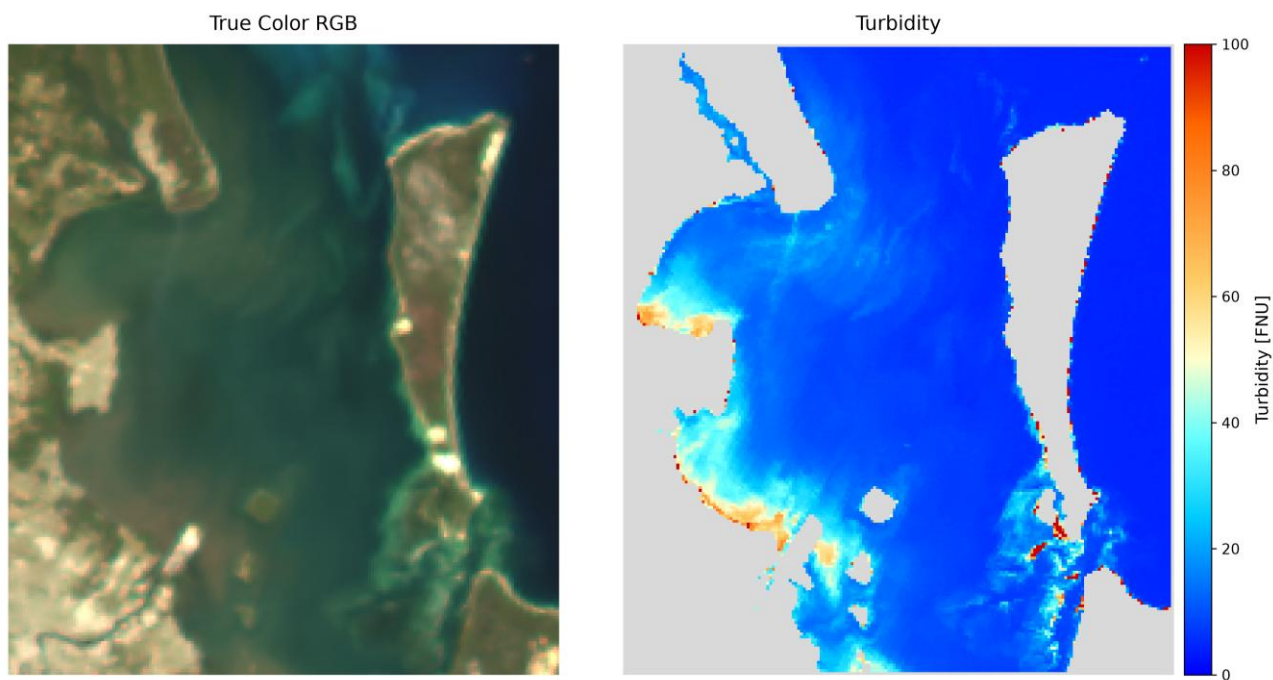


Figure A.25 Representative turbidity conditions in 2012. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.3 Turbidity Pattern 2013

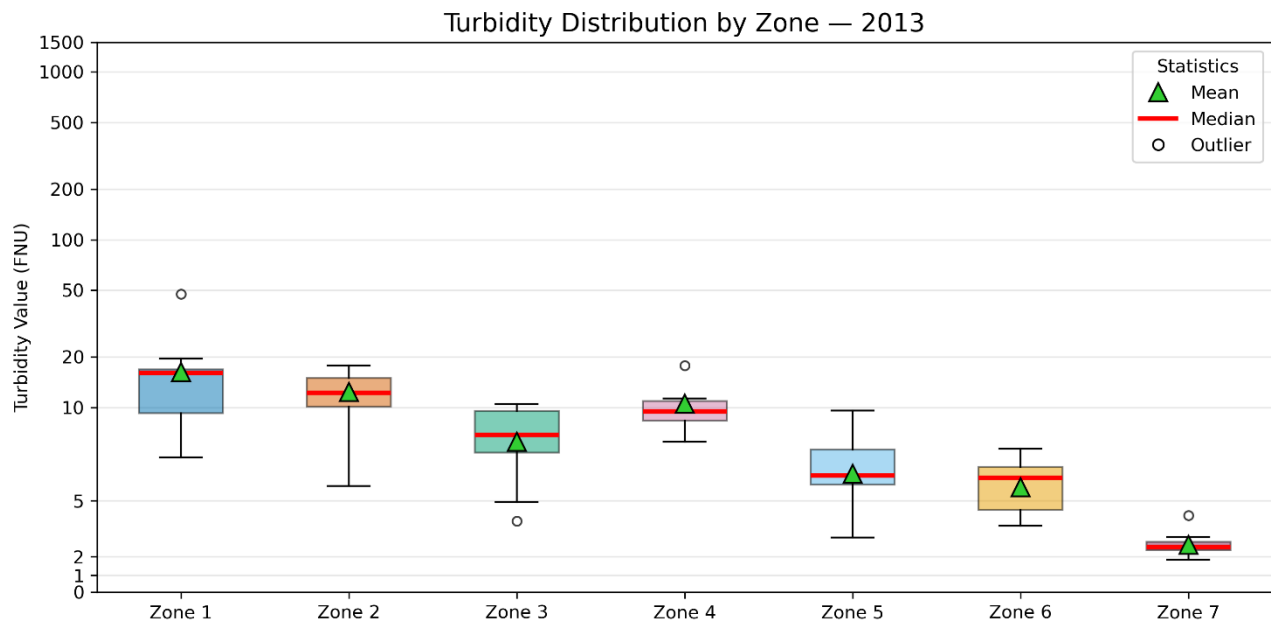


Figure A.26 Turbidity distributions by reporting zone (2013).

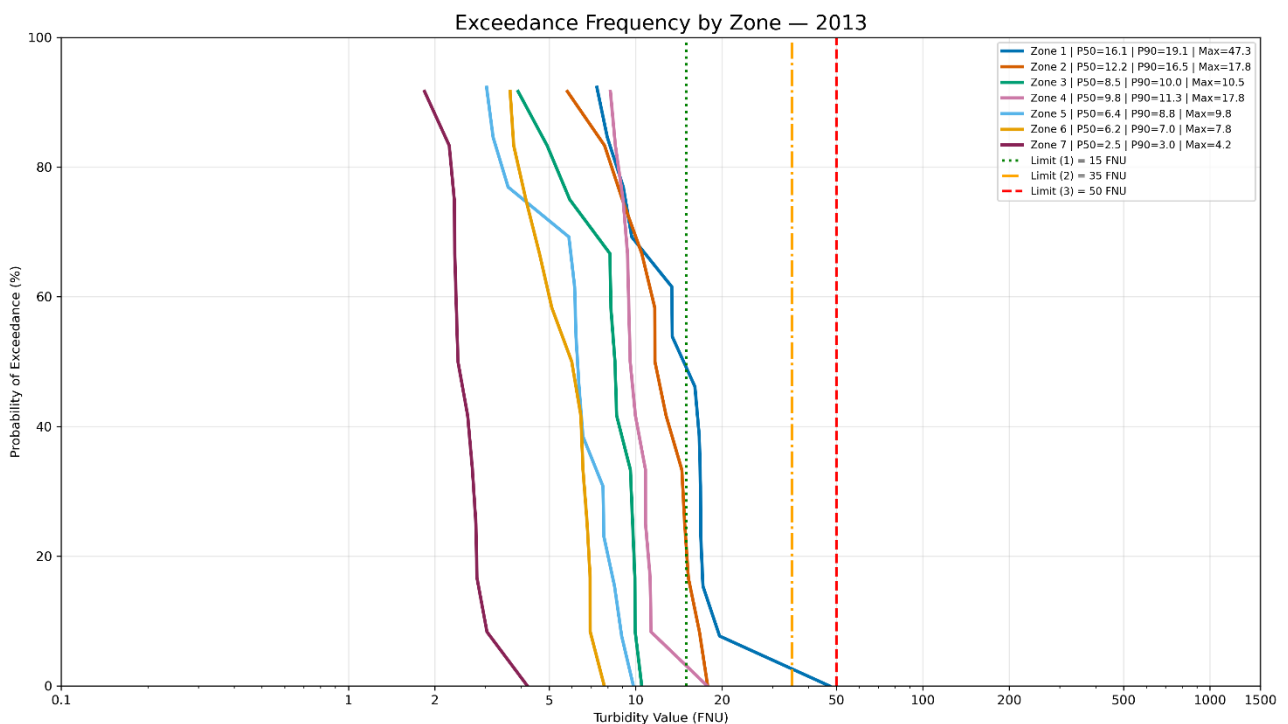


Figure A.27 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2013).

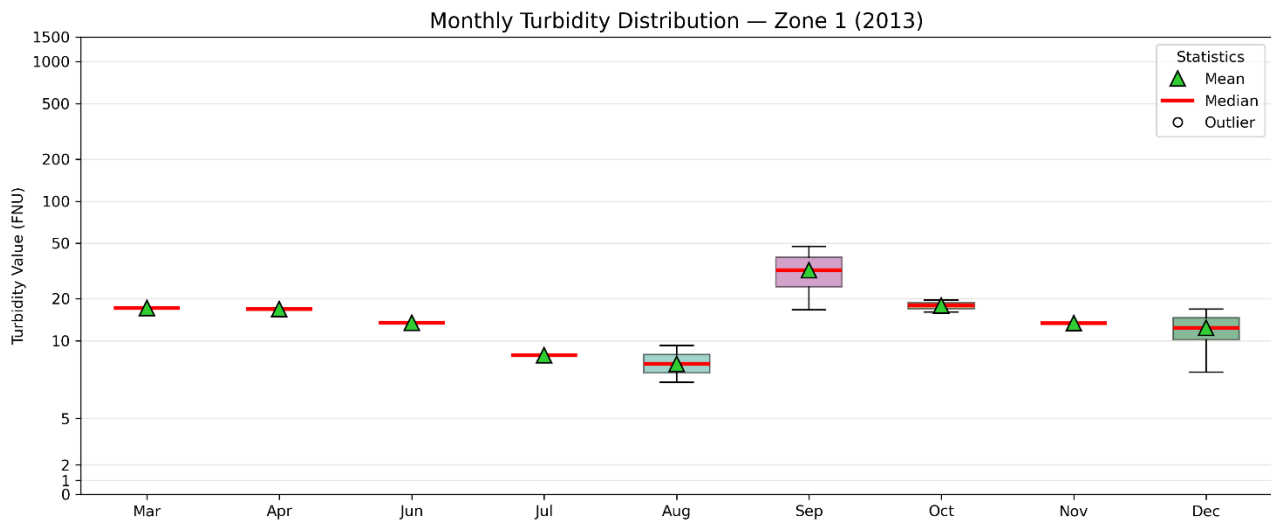


Figure A.28 Monthly Turbidity Distribution by Month for Zone 1 (2013)

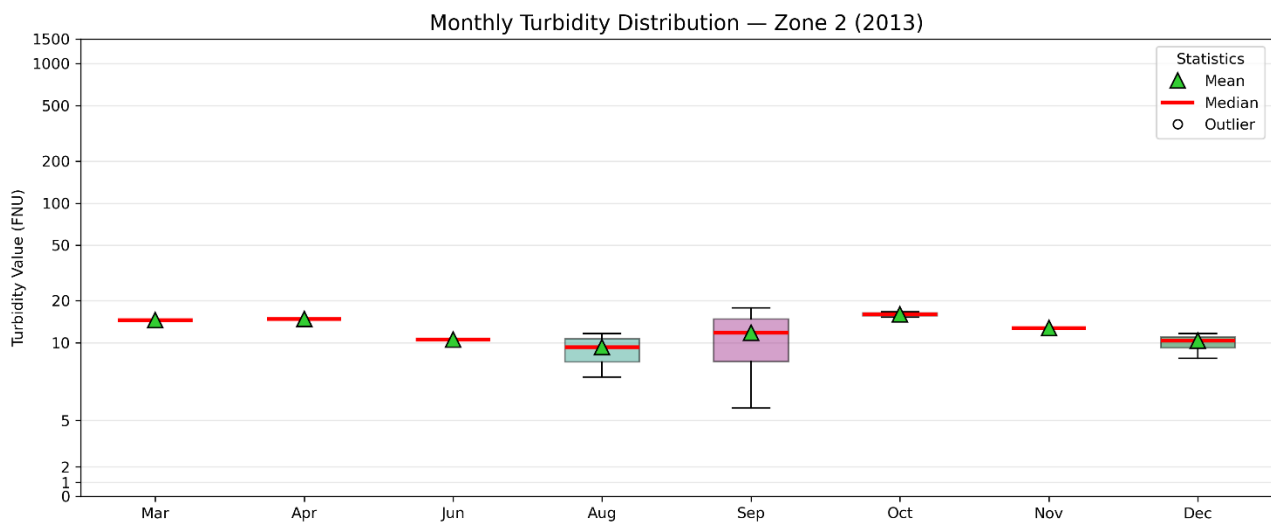


Figure A.29 Monthly Turbidity Distribution by Month for Zone 2 (2013)

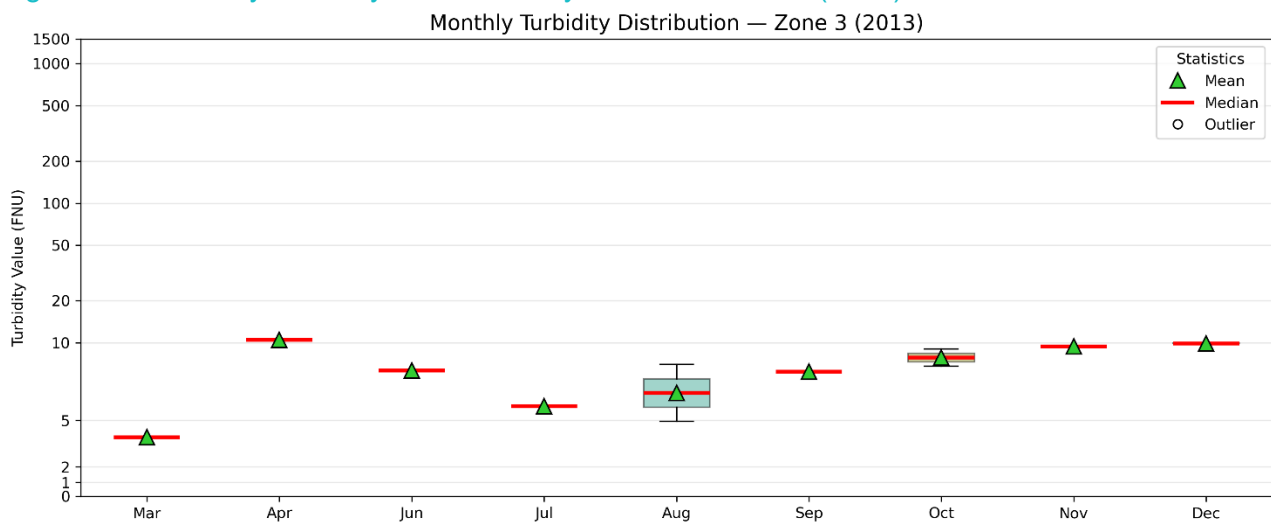


Figure A.30 Monthly Turbidity Distribution by Month for Zone 3 (2013)

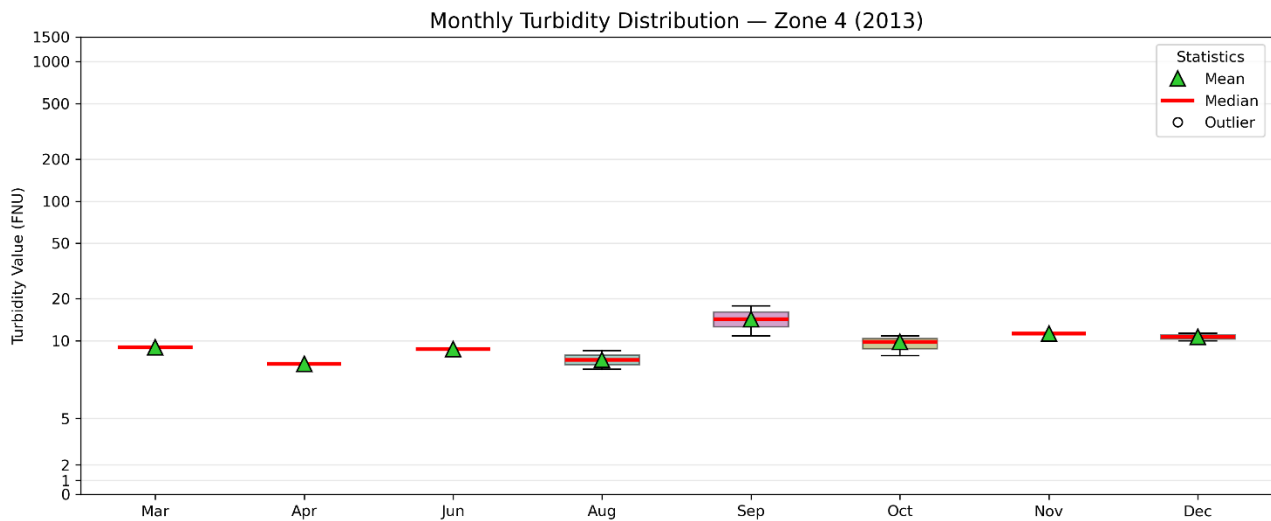


Figure A.31 Monthly Turbidity Distribution by Month for Zone 4 (2013)

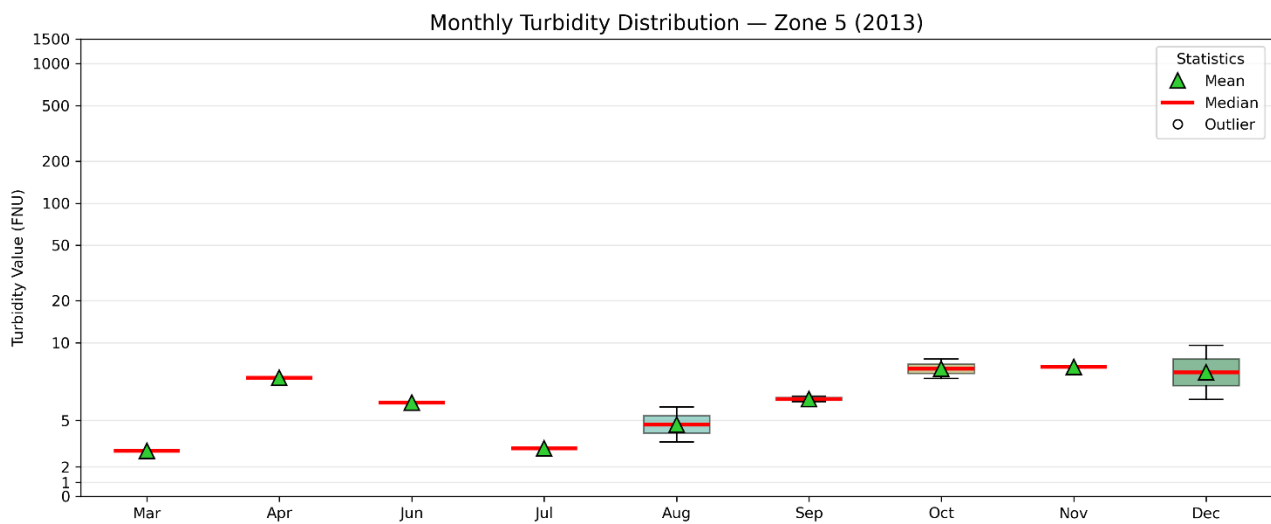


Figure A.32 Monthly Turbidity Distribution by Month for Zone 5 (2013)

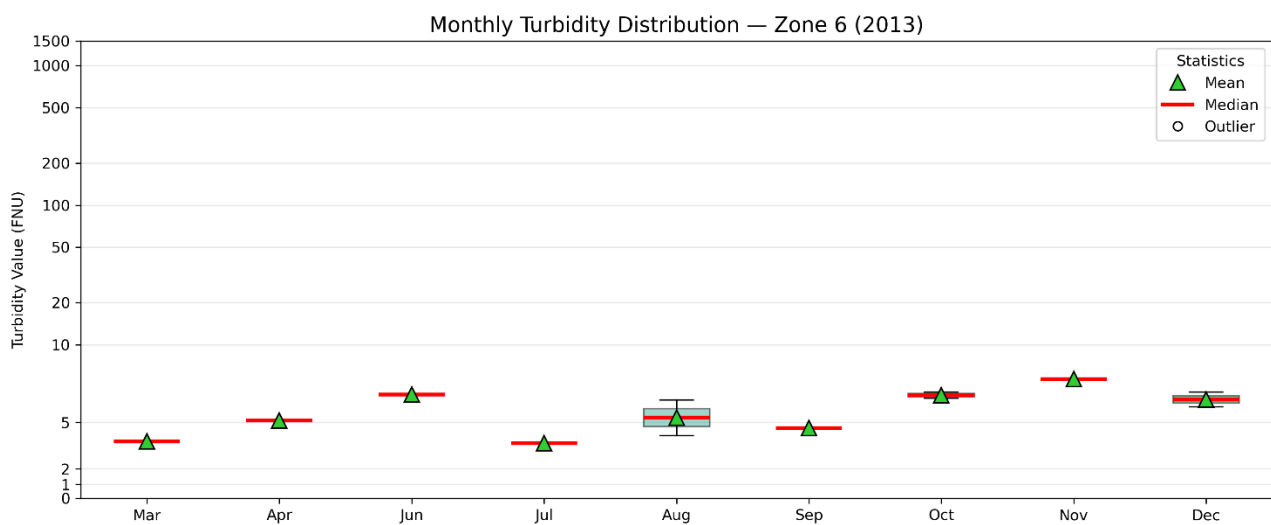


Figure A.33 Monthly Turbidity Distribution by Month for Zone 6 (2013)

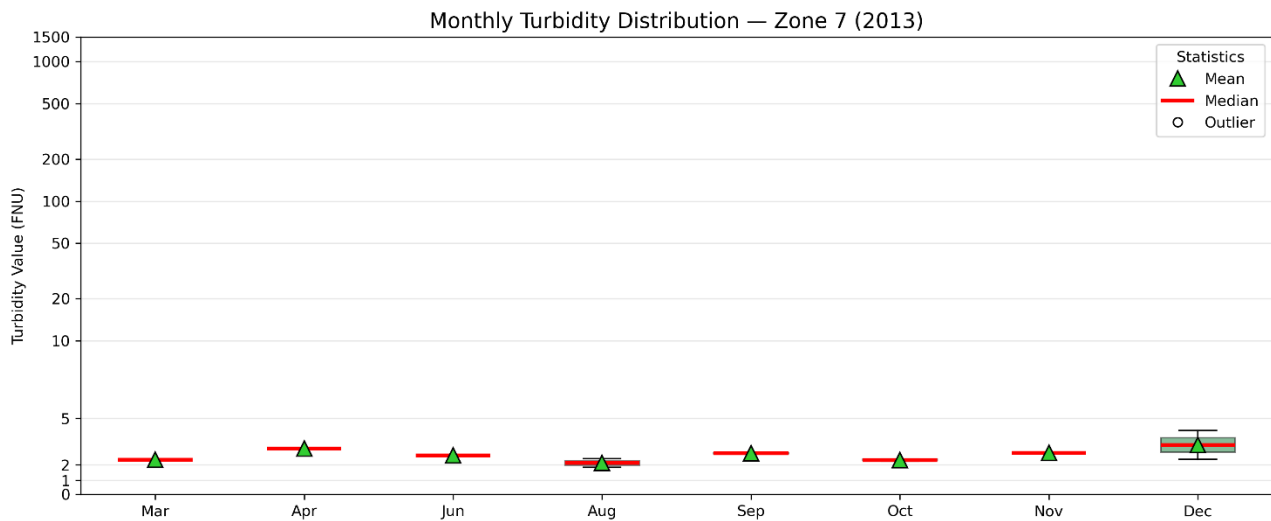


Figure A.34 Monthly Turbidity Distribution by Month for Zone 7 (2013)

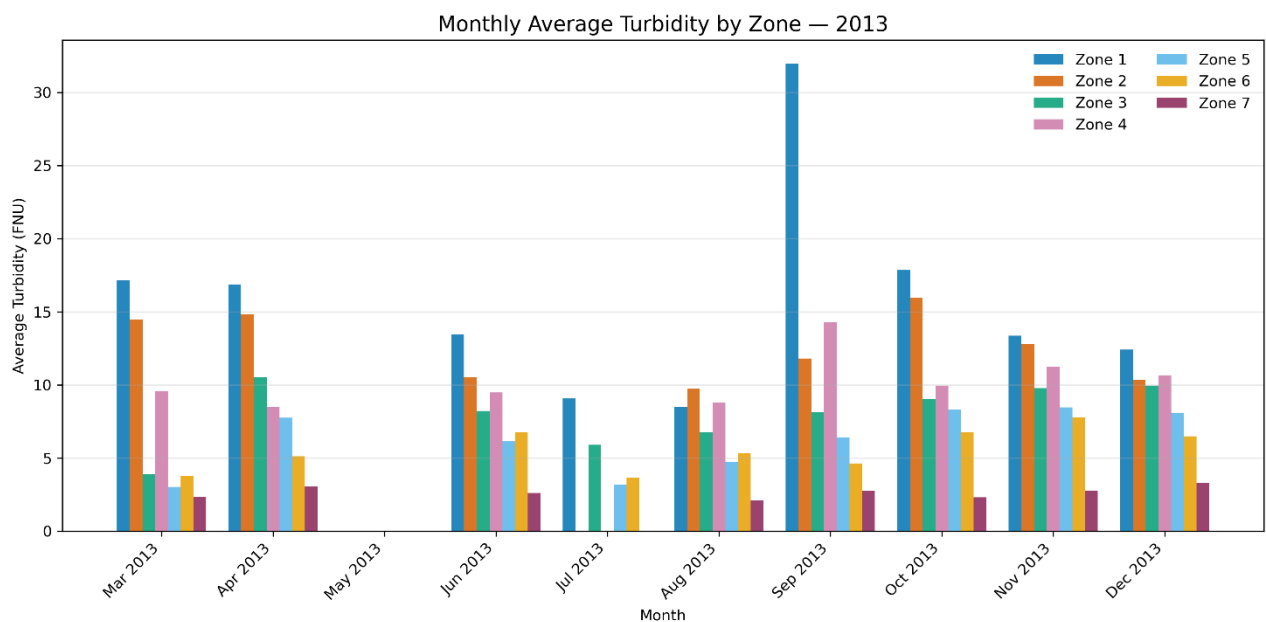


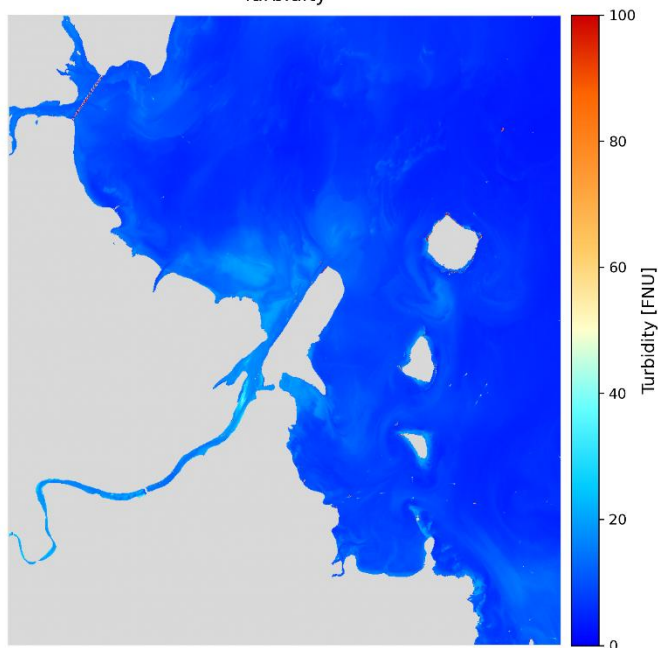
Figure A.35 Monthly Turbidity Distribution by Month (2013)

Sensor: L8 OLI | Local Time: 2013-04-28 09:43:52 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2013-08-18 09:44:08 AEST

Surface Reflectance RGB



Turbidity

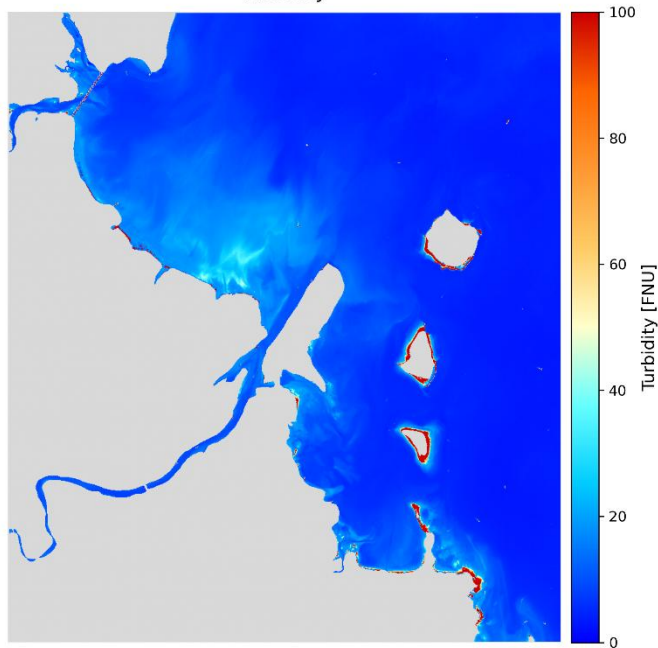


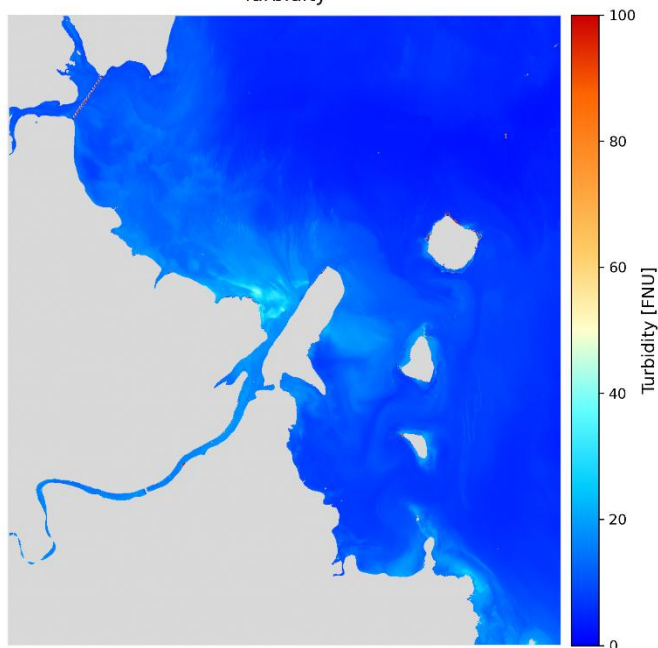
Figure A.36 Representative turbidity conditions in 2013. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2013-09-19 09:44:04 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2013-12-24 09:43:34 AEST

Surface Reflectance RGB



Turbidity

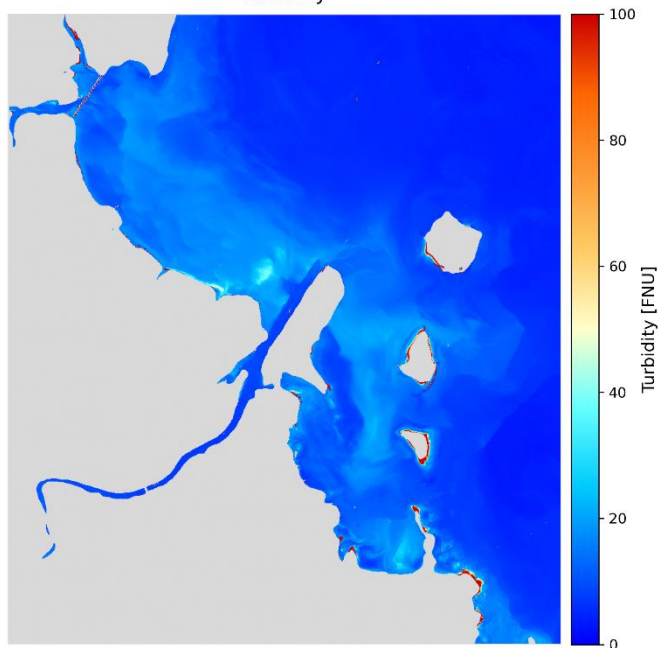


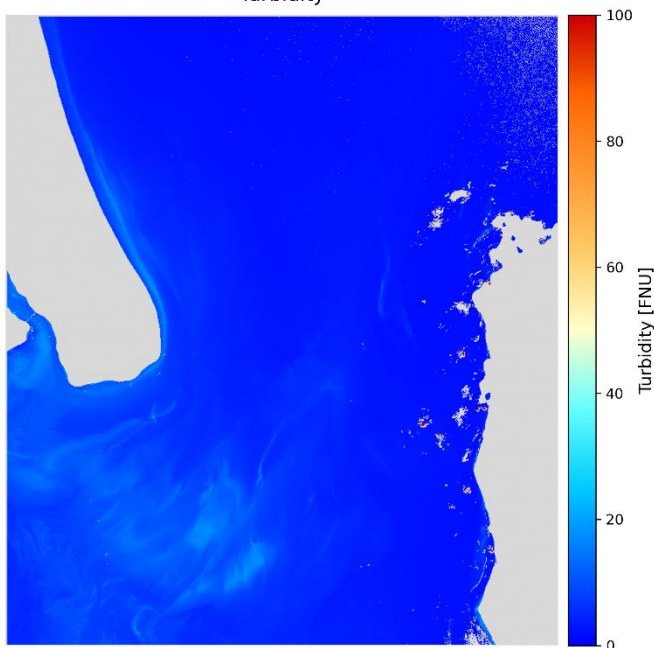
Figure A.37 Representative turbidity conditions in 2013. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2013-04-28 09:43:52 AEST

Surface Reflectance RGB

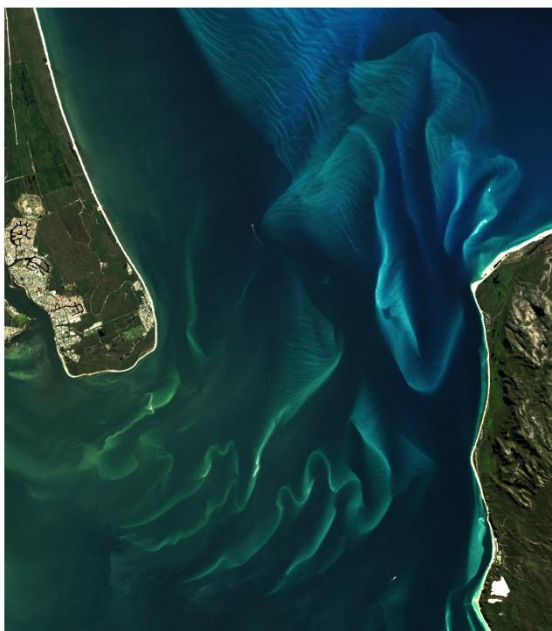


Turbidity



Sensor: L8 OLI | Local Time: 2013-06-15 09:44:05 AEST

Surface Reflectance RGB



Turbidity

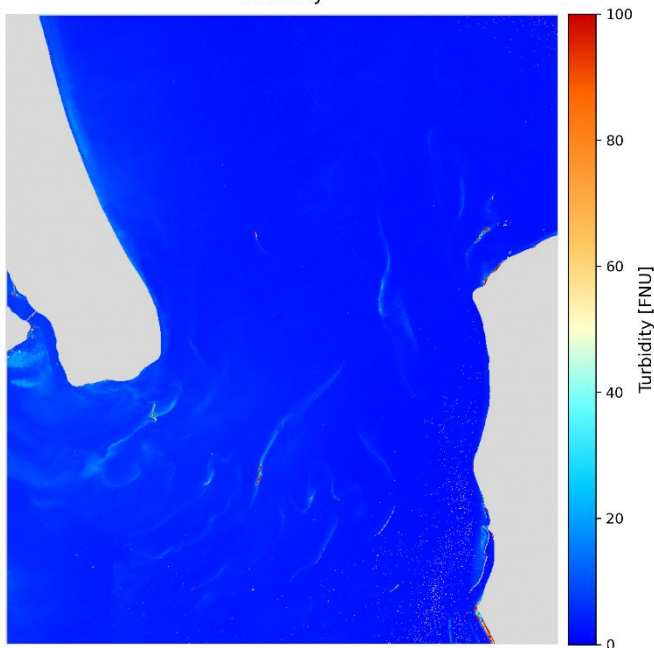
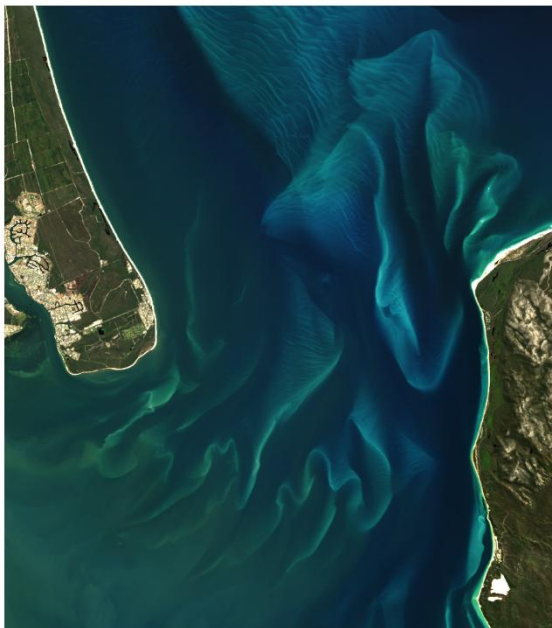


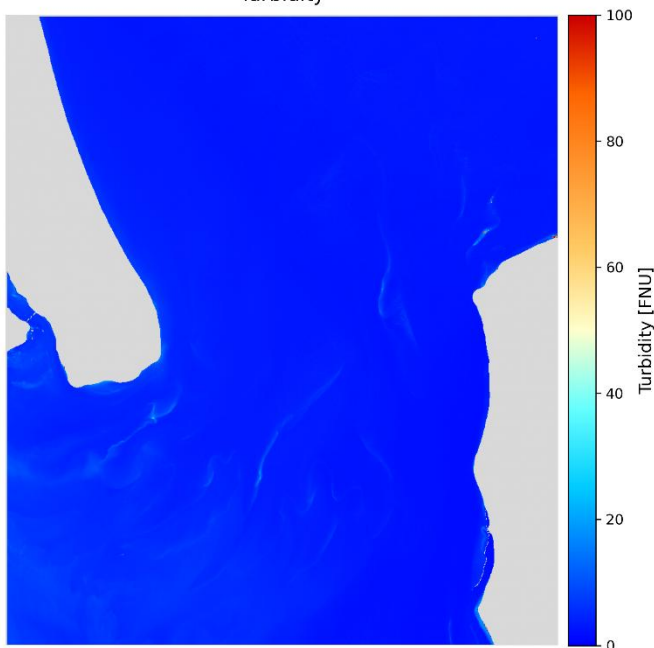
Figure A.38 Representative turbidity conditions in 2013. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2013-09-19 09:44:04 AEST

Surface Reflectance RGB

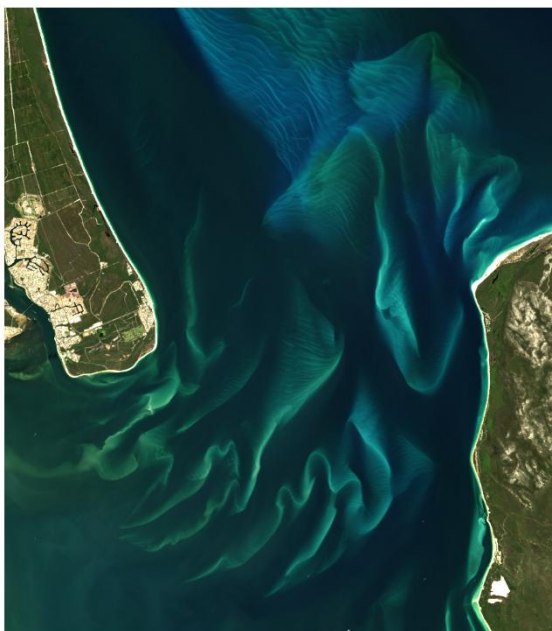


Turbidity



Sensor: L8 OLI | Local Time: 2013-12-24 09:43:34 AEST

Surface Reflectance RGB



Turbidity

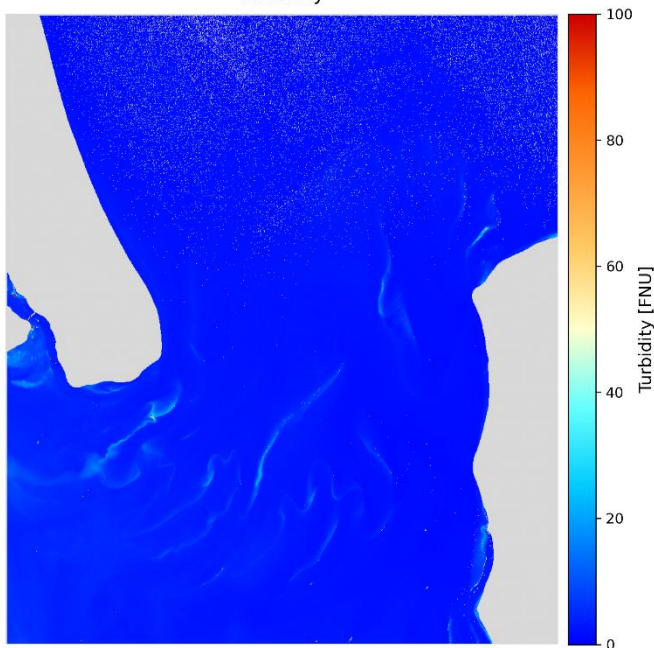


Figure A.39 Representative turbidity conditions in 2013. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.4 Turbidity Pattern 2014

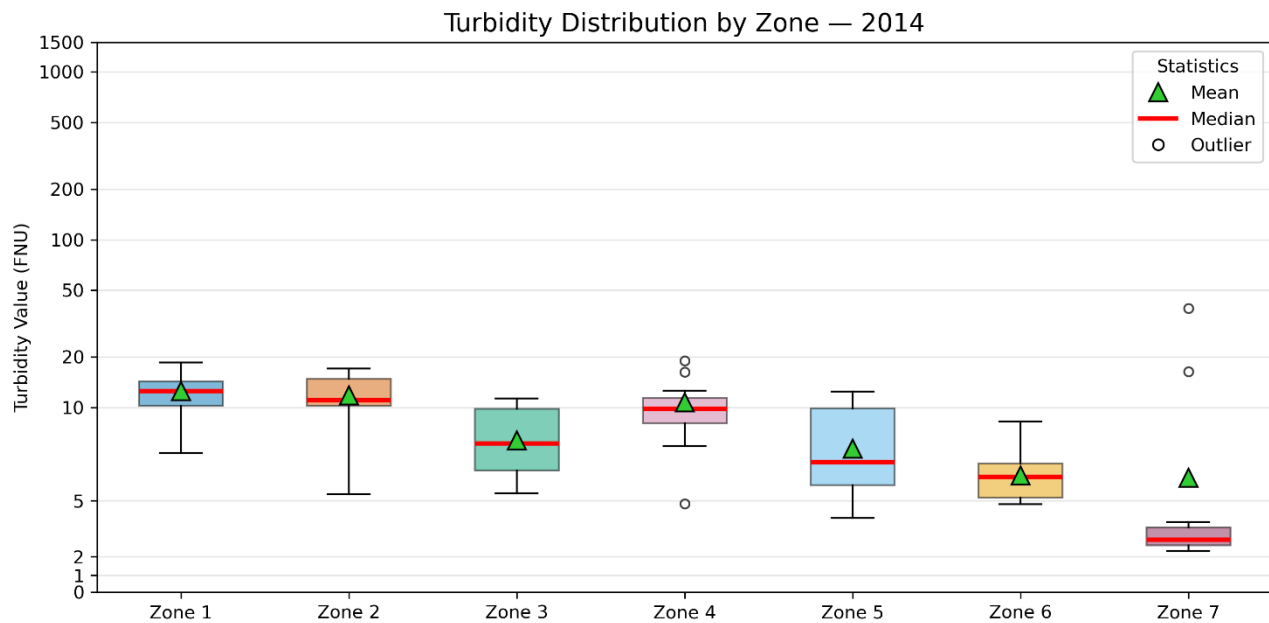


Figure A.40 Turbidity distributions by reporting zone (2014).

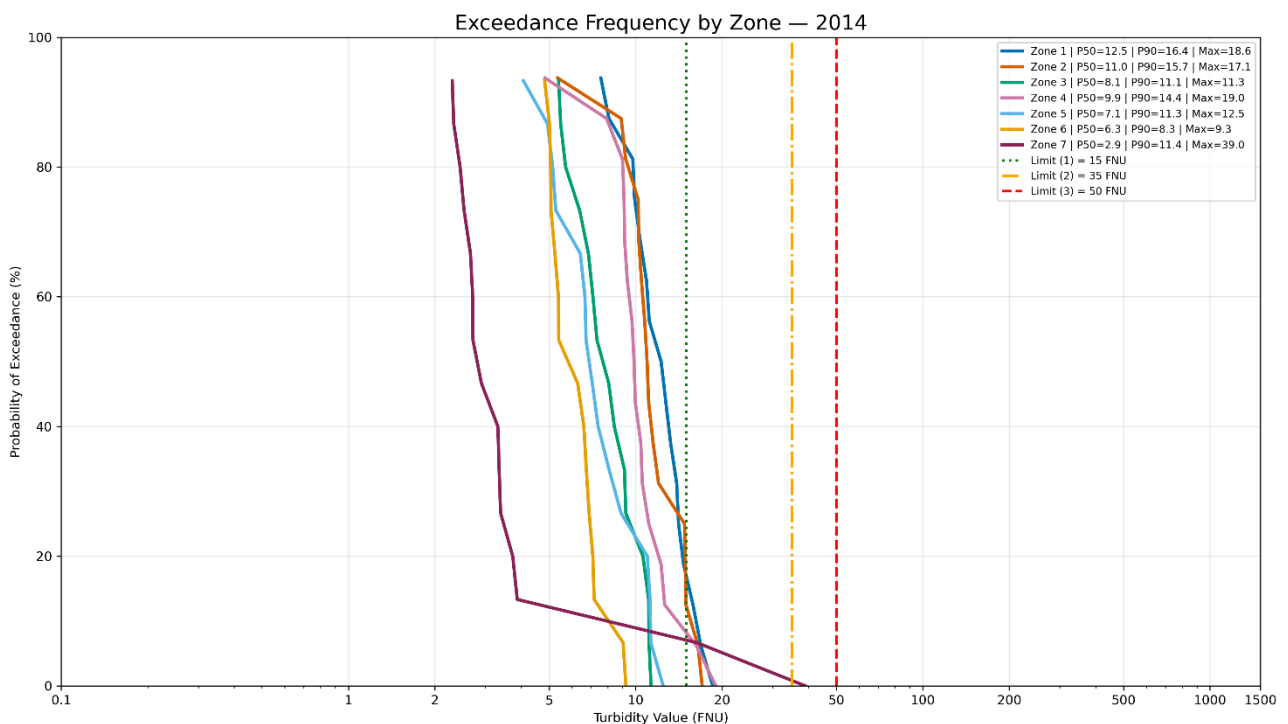


Figure A.41 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2014).

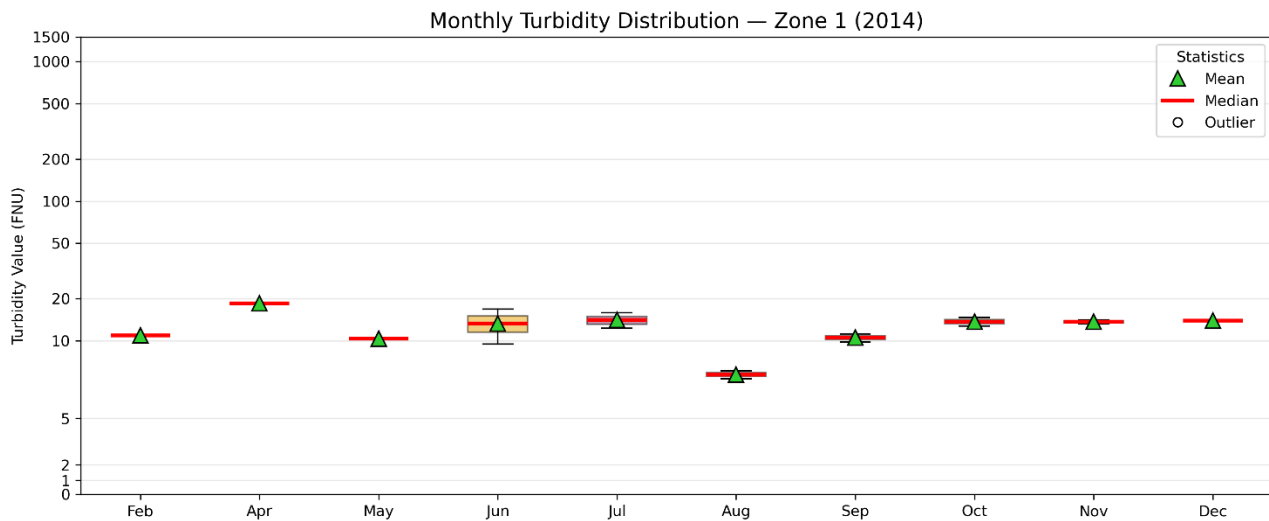


Figure A.42 Monthly Turbidity Distribution by Month for Zone 1 (2014)

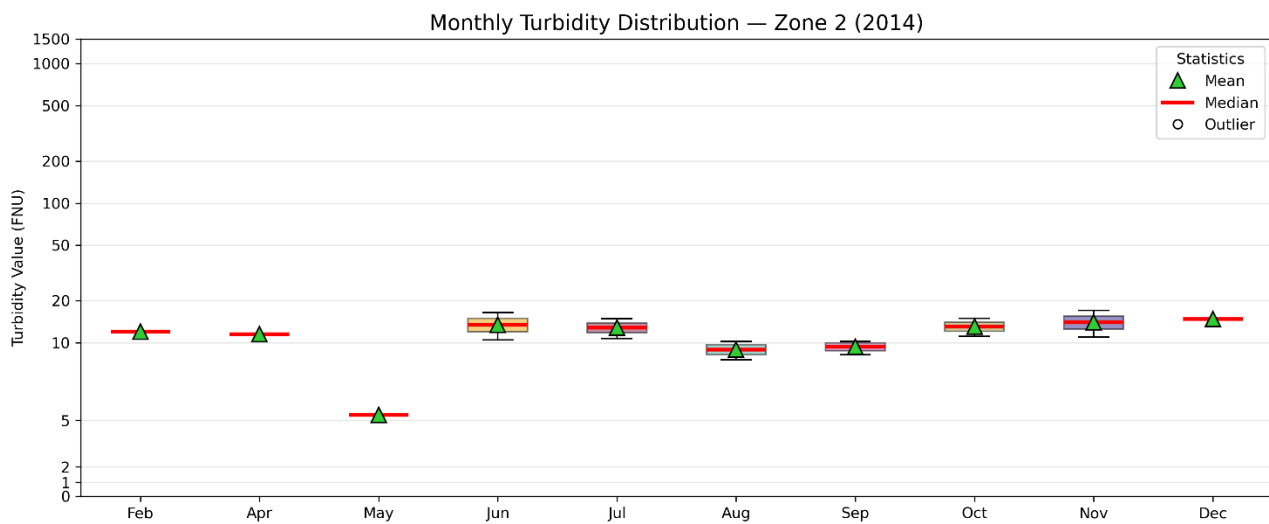


Figure A.43 Monthly Turbidity Distribution by Month for Zone 2 (2014)

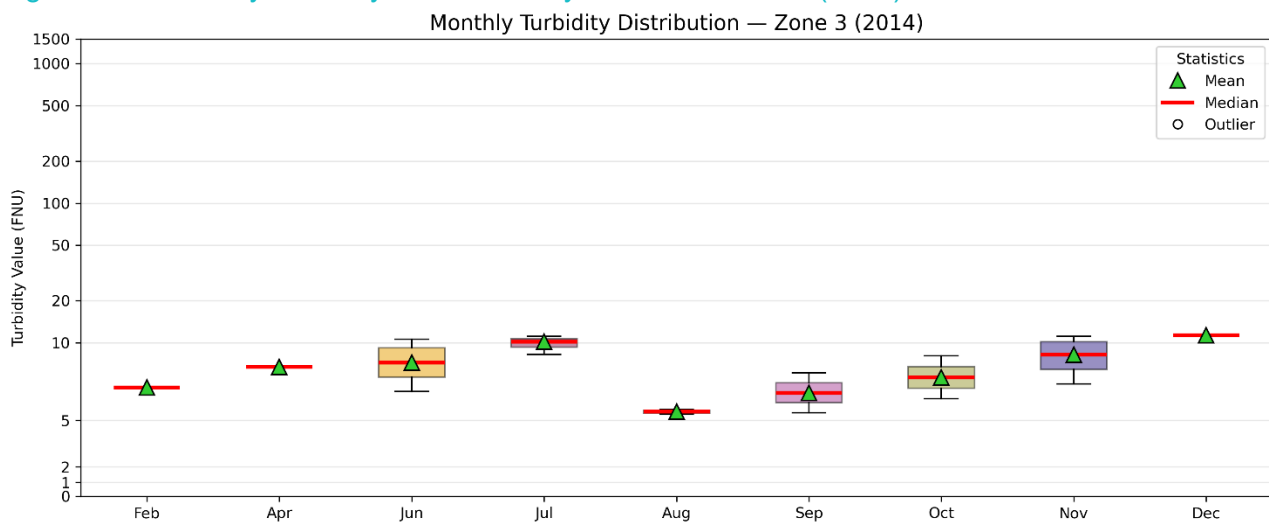


Figure A.44 Monthly Turbidity Distribution by Month for Zone 3 (2014)

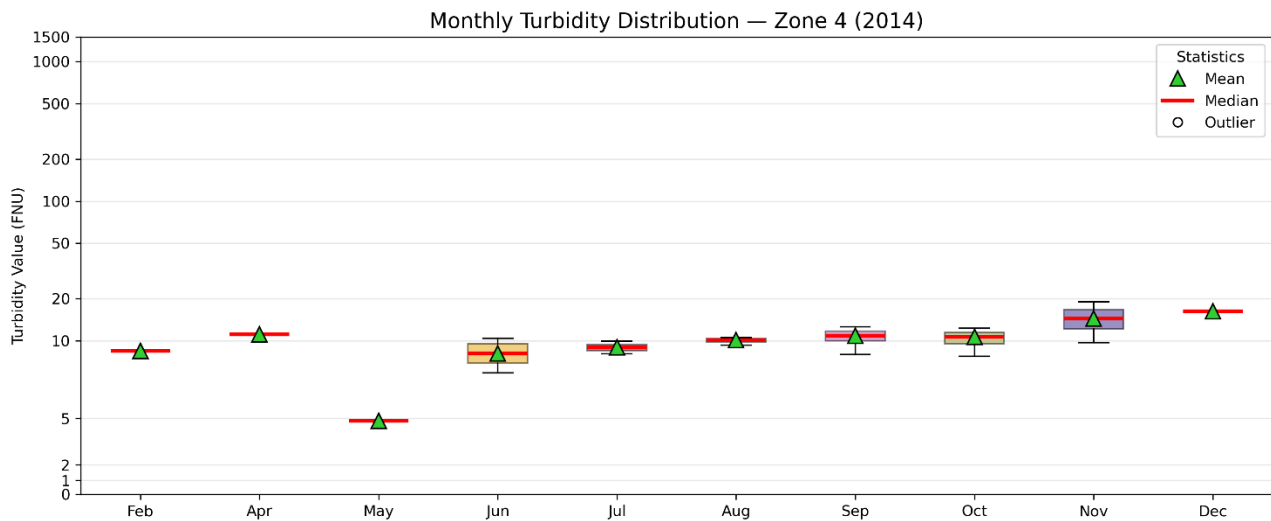


Figure A.45 Monthly Turbidity Distribution by Month for Zone 4 (2014)

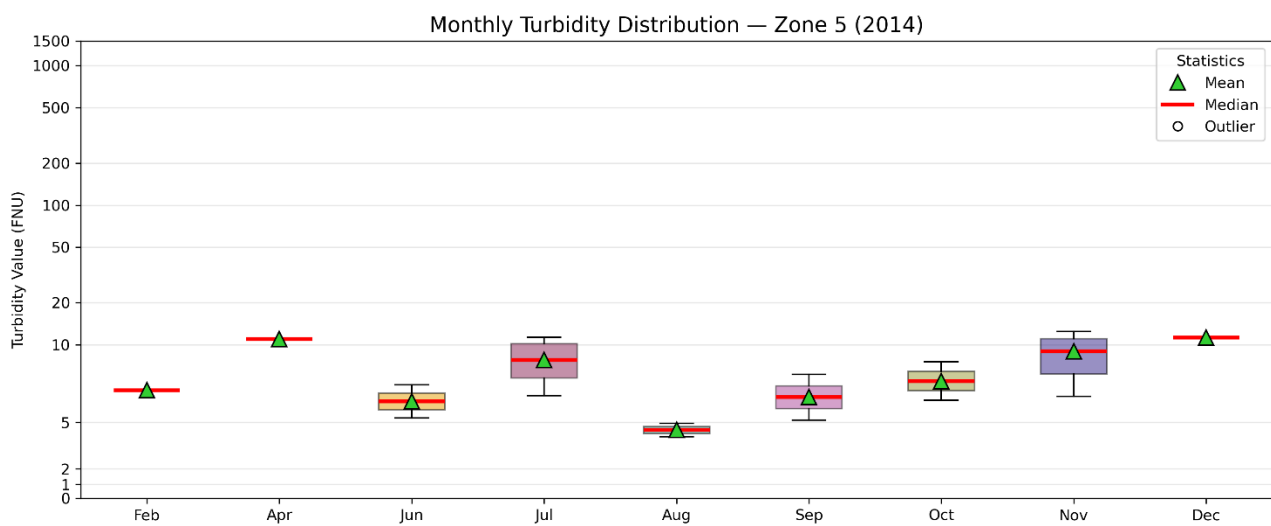


Figure A.46 Monthly Turbidity Distribution by Month for Zone 5 (2014)

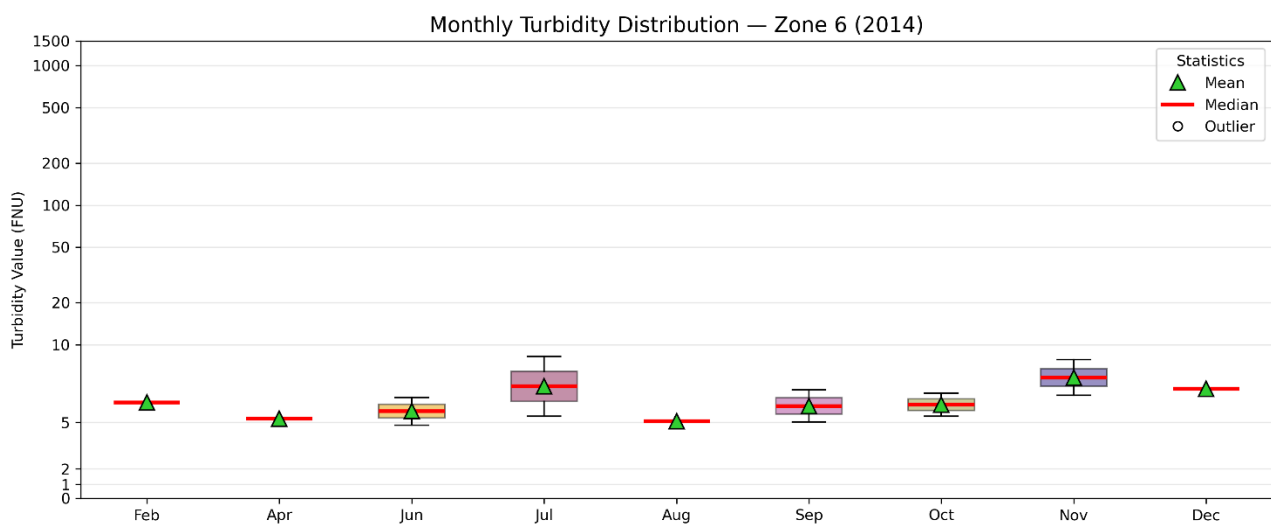


Figure A.47 Monthly Turbidity Distribution by Month for Zone 6 (2014)

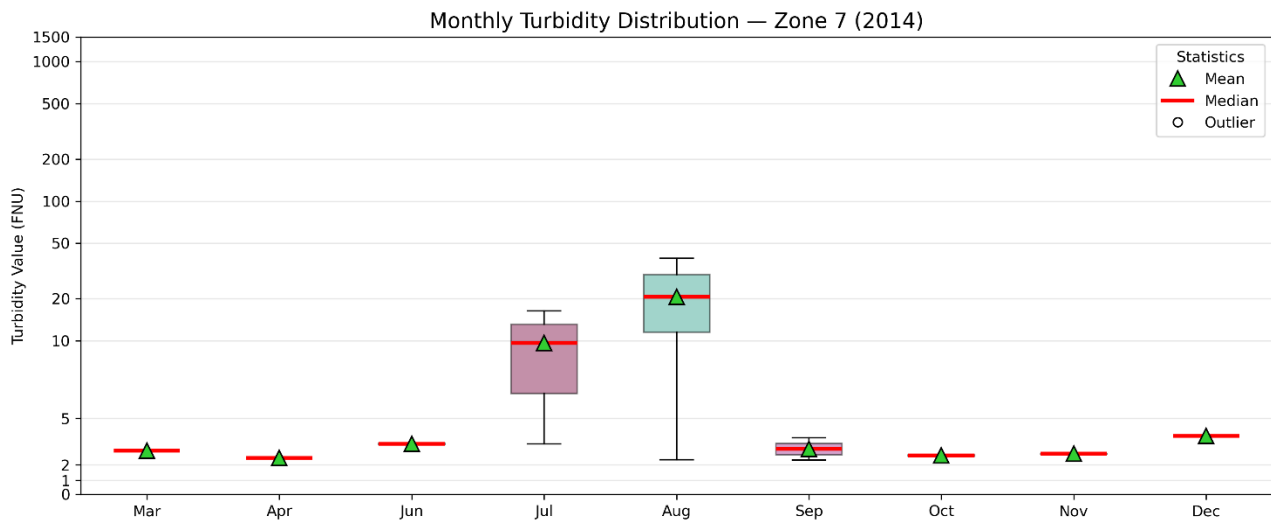


Figure A.48 Monthly Turbidity Distribution by Month for Zone 7 (2014)

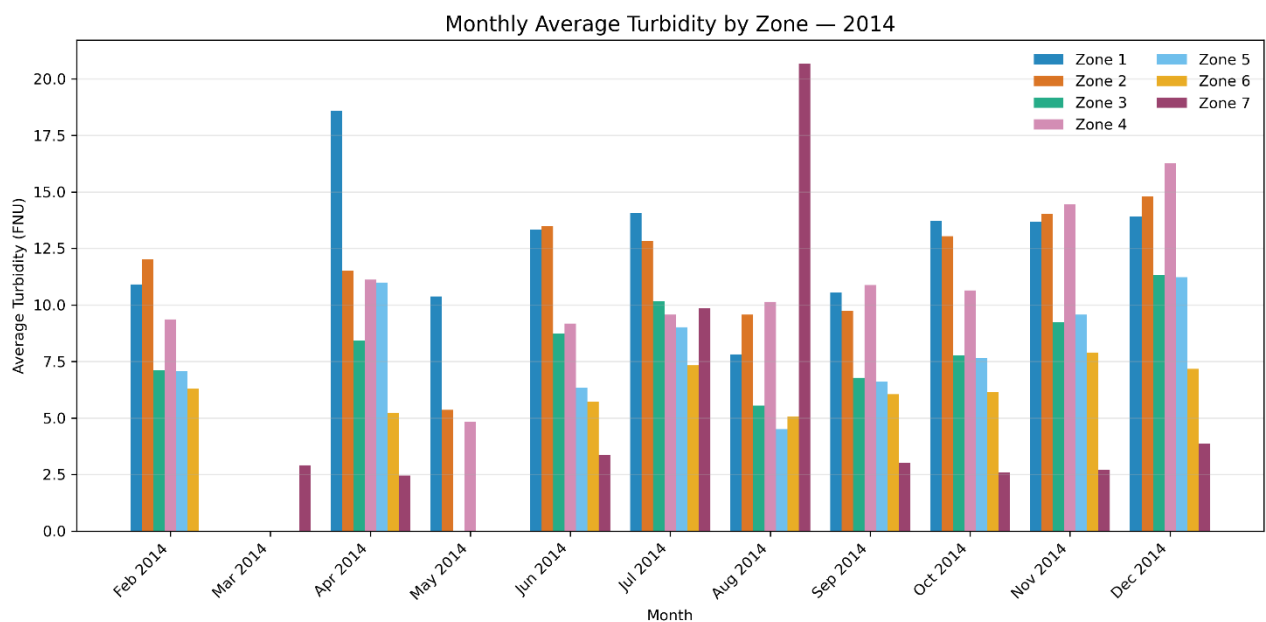


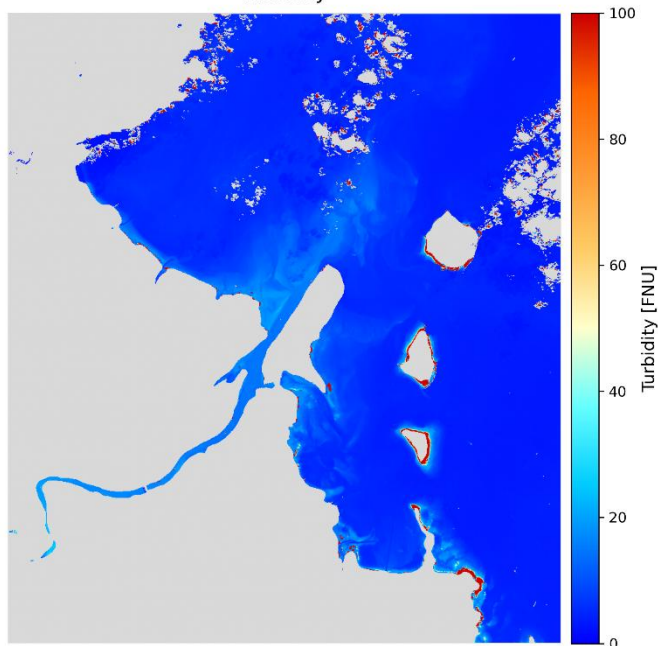
Figure A.49 Monthly Turbidity Distribution by Month (2014)

Sensor: L8 OLI | Local Time: 2014-07-04 09:41:55 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2014-10-08 09:42:19 AEST

Surface Reflectance RGB



Turbidity

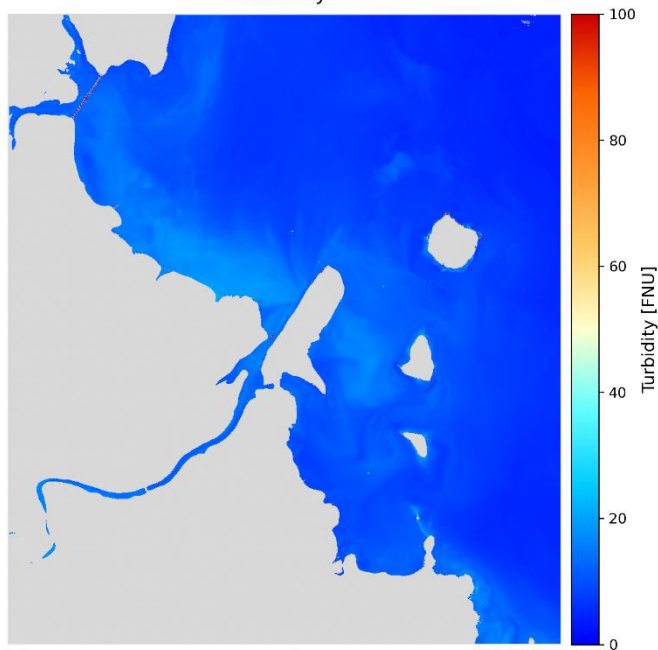


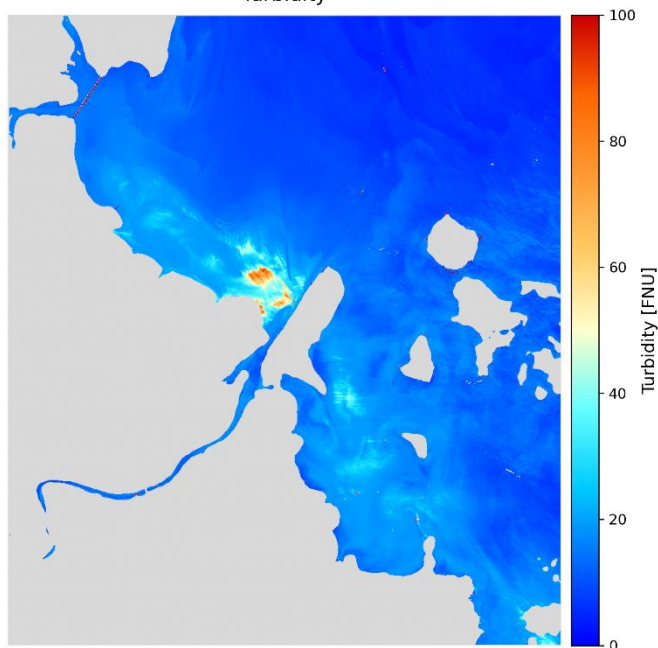
Figure A.50 Representative turbidity conditions in 2014. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2014-11-25 09:42:18 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2014-12-11 09:42:12 AEST

Surface Reflectance RGB



Turbidity

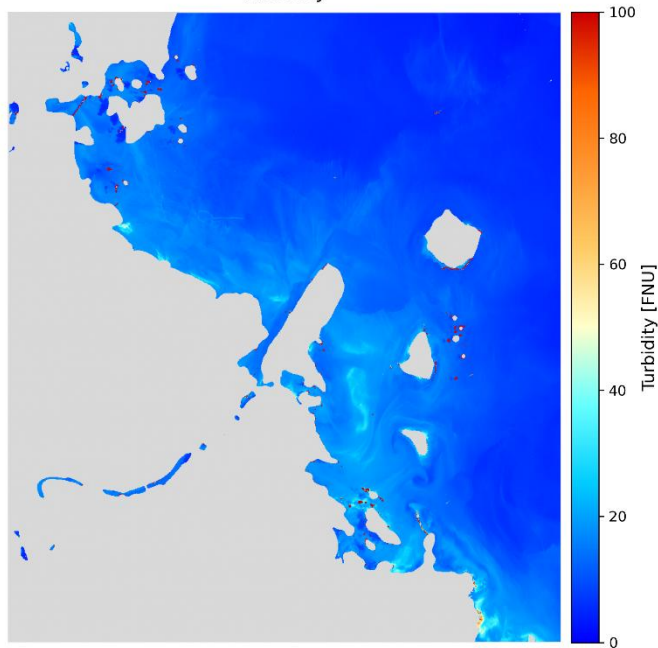


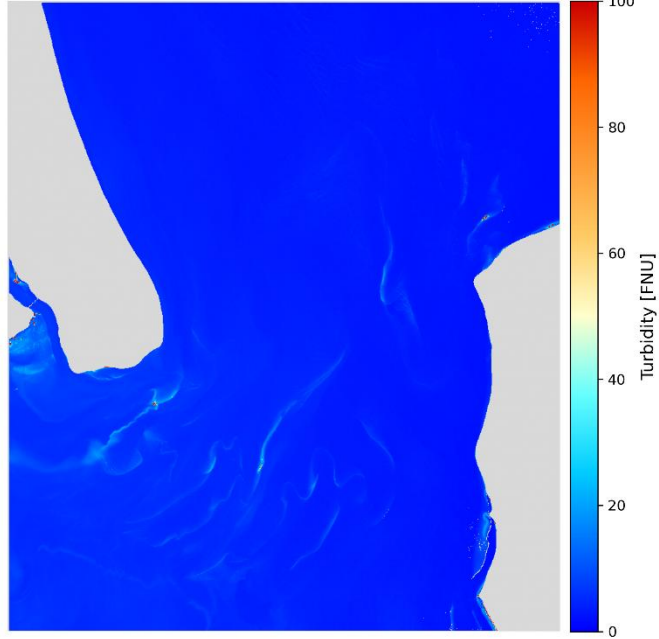
Figure A.51 Representative turbidity conditions in 2014. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2014-06-18 09:41:50 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2014-08-05 09:42:07 AEST

Surface Reflectance RGB



Turbidity

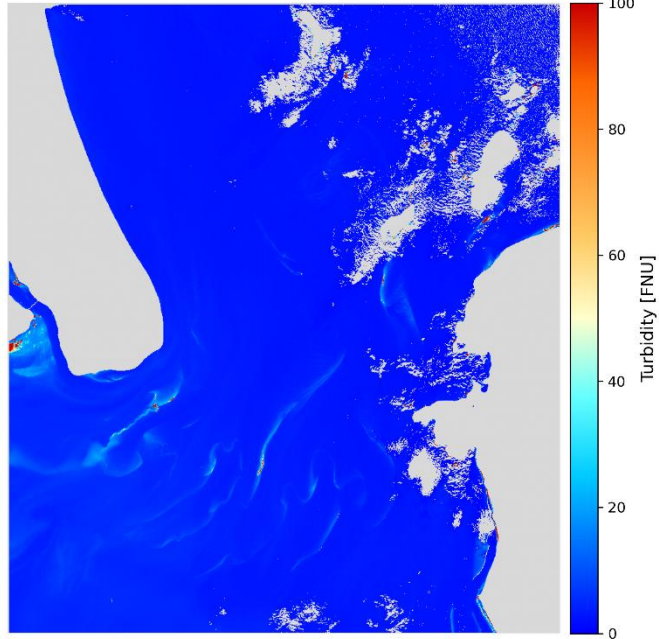


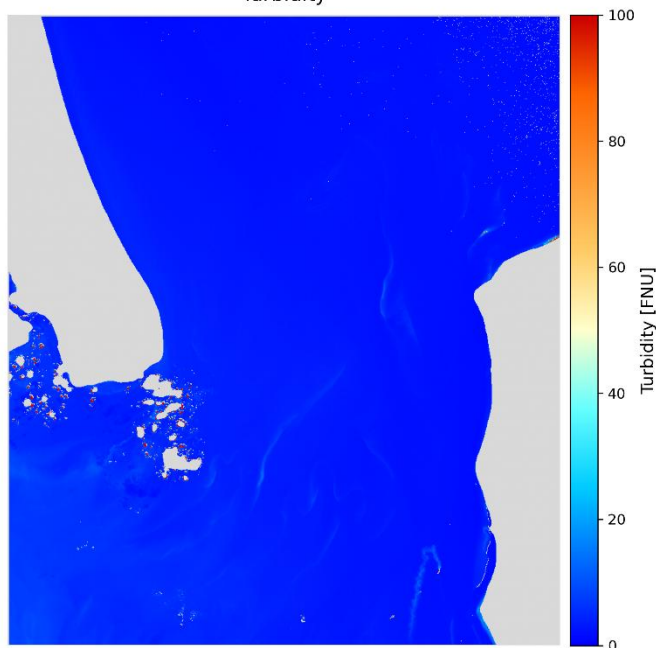
Figure A.52 Representative turbidity conditions in 2014. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2014-10-08 09:42:19 AEST

Surface Reflectance RGB

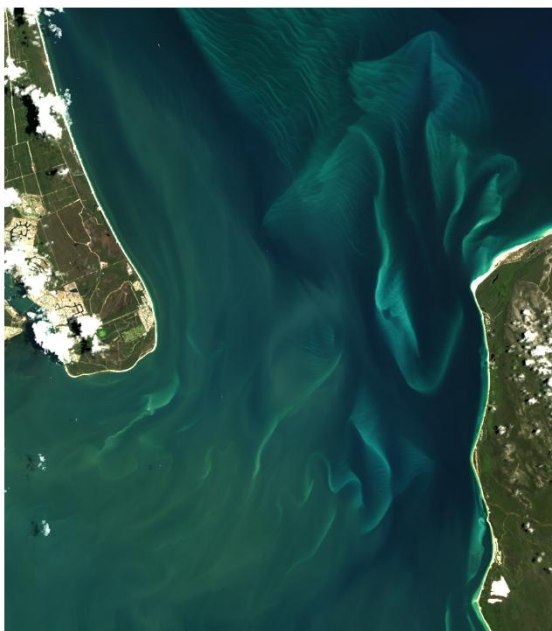


Turbidity



Sensor: L8 OLI | Local Time: 2014-12-11 09:42:12 AEST

Surface Reflectance RGB



Turbidity

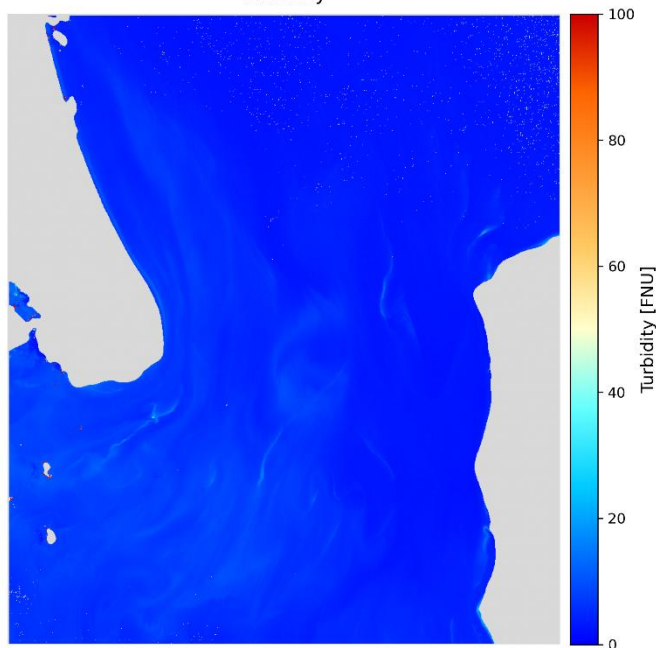


Figure A.53 Representative turbidity conditions in 2014. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.5 Turbidity Pattern 2015

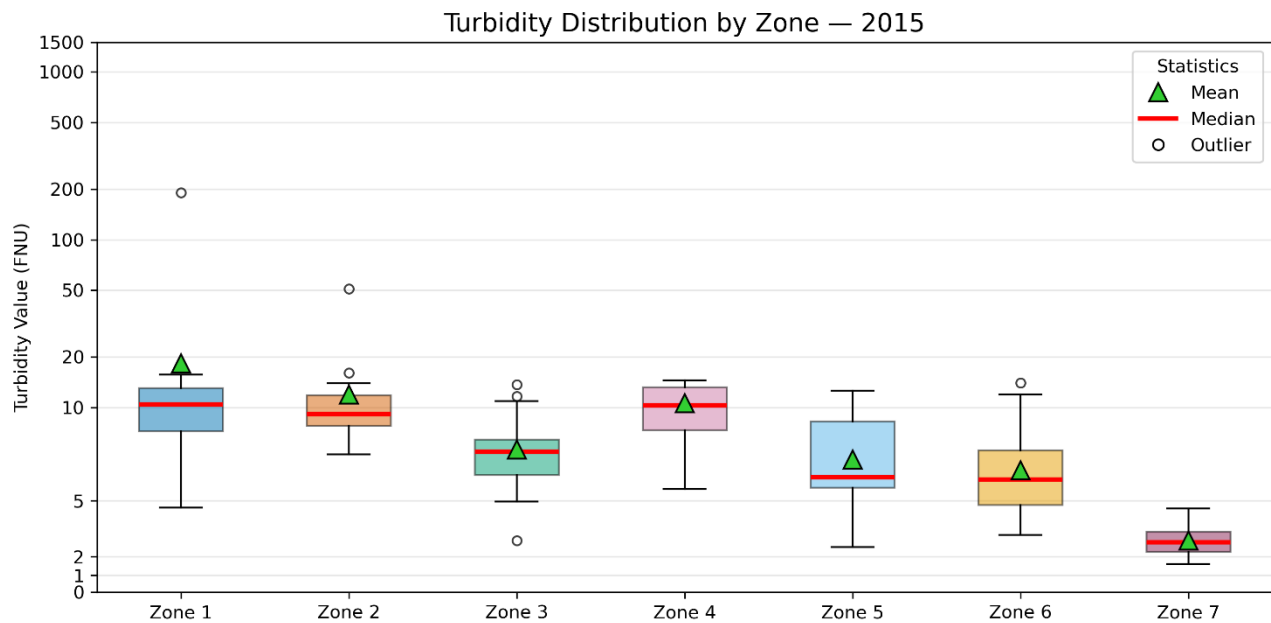


Figure A.54 Turbidity distributions by reporting zone (2015).

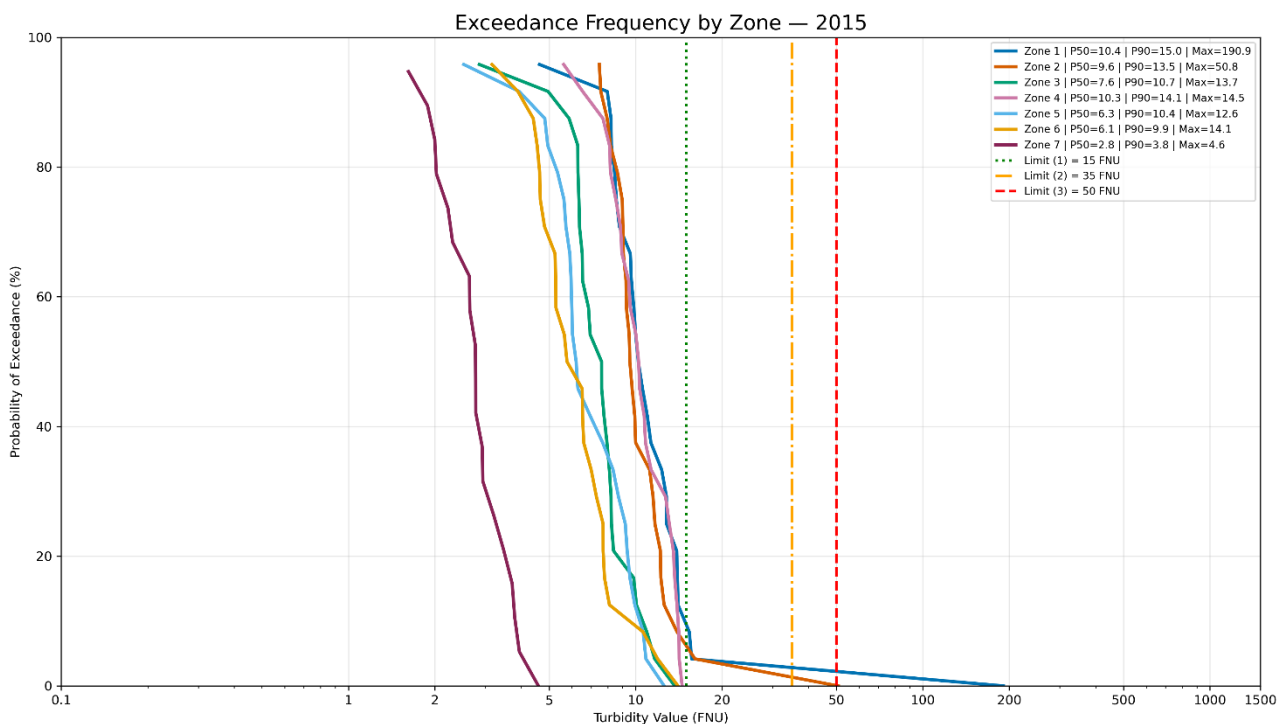


Figure A.55 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2015).

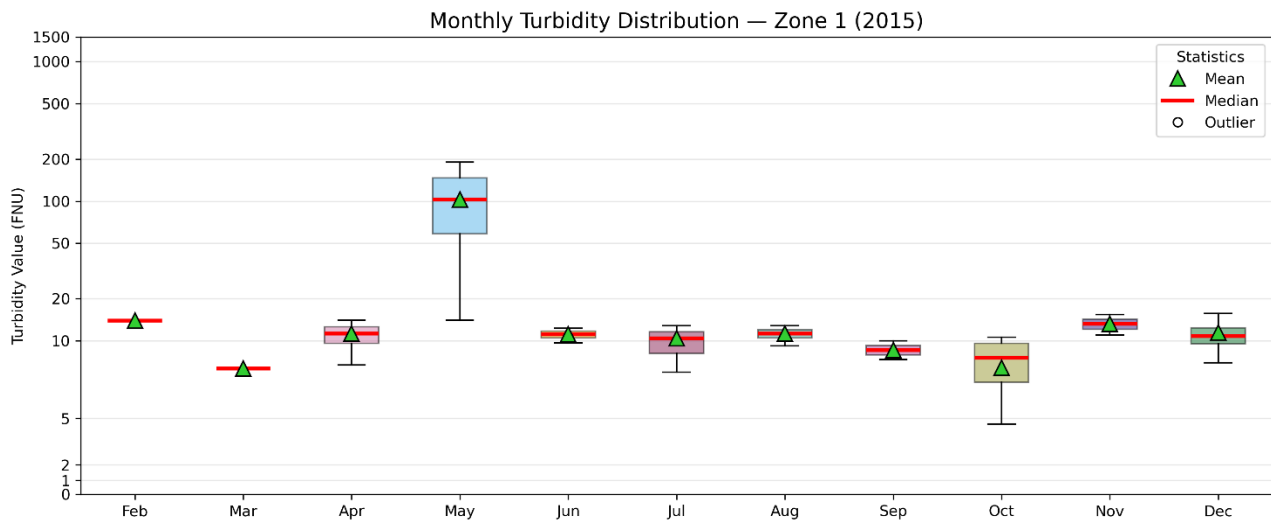


Figure A.56 Monthly Turbidity Distribution by Month for Zone 1 (2015)

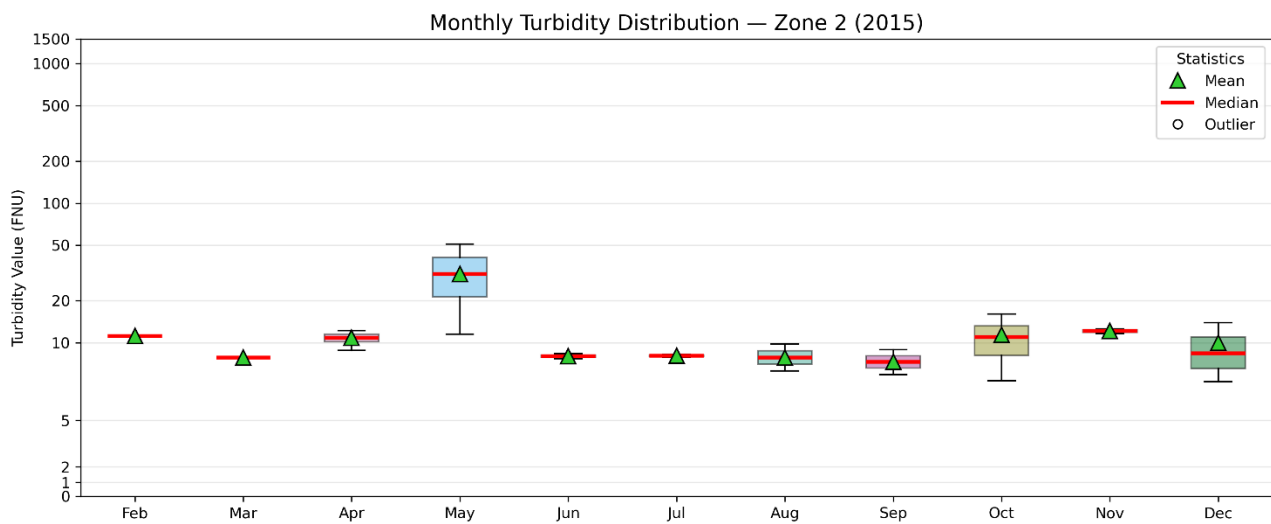


Figure A.57 Monthly Turbidity Distribution by Month for Zone 2 (2015)

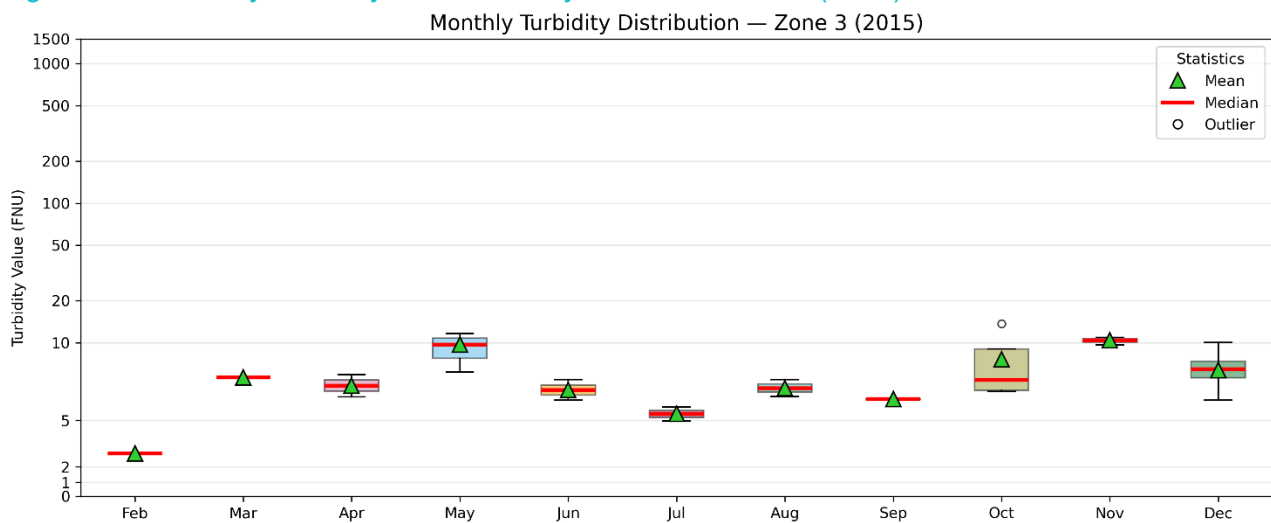


Figure A.58 Monthly Turbidity Distribution by Month for Zone 3 (2015)

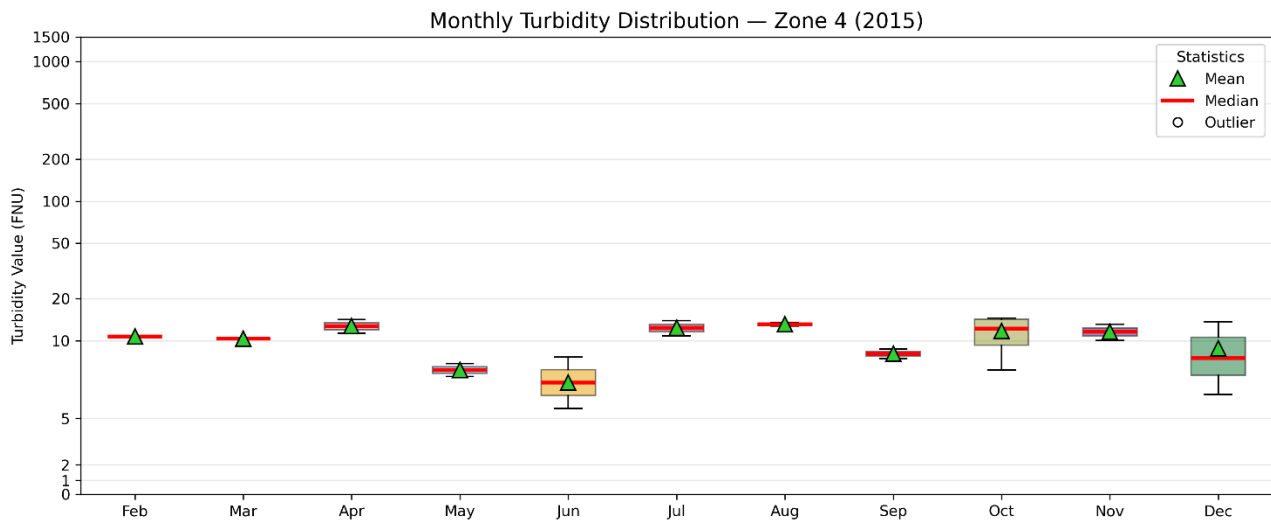


Figure A.59 Monthly Turbidity Distribution by Month for Zone 4 (2015)

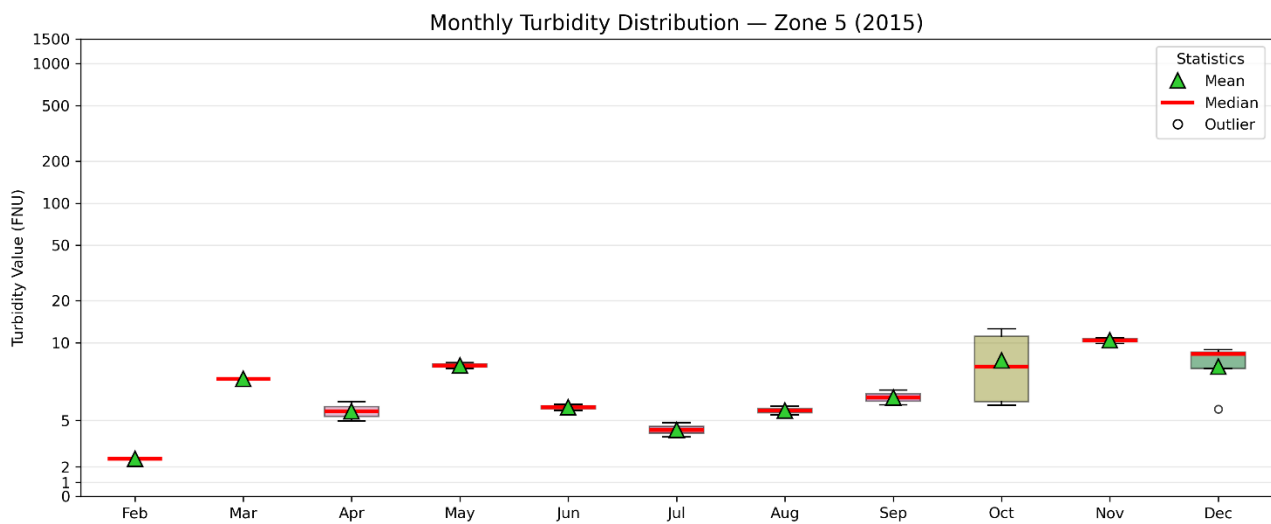


Figure A.60 Monthly Turbidity Distribution by Month for Zone 5 (2015)

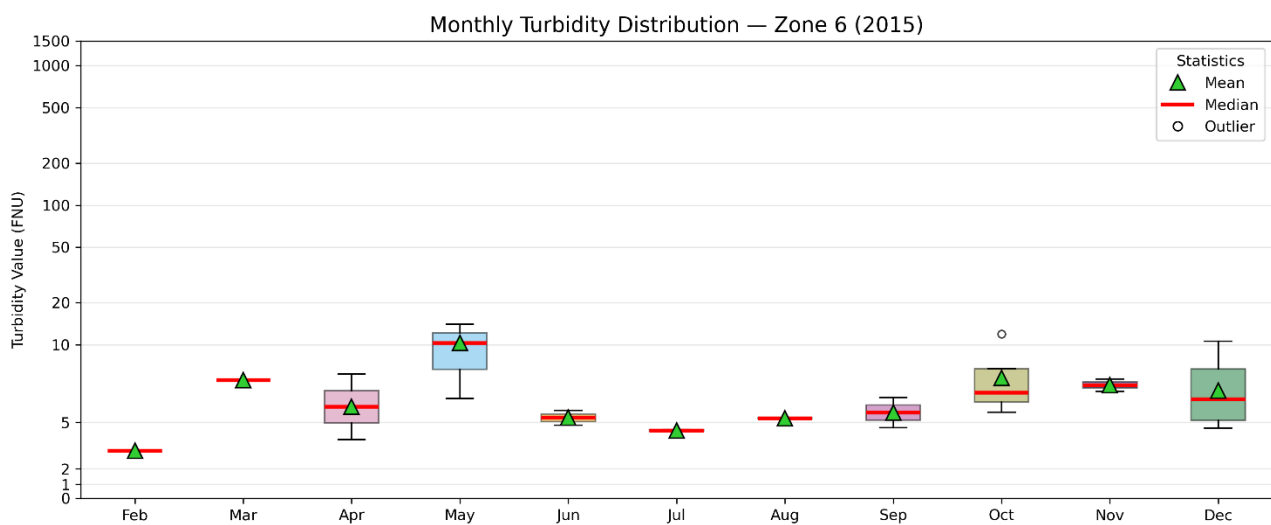


Figure A.61 Monthly Turbidity Distribution by Month for Zone 6 (2015)

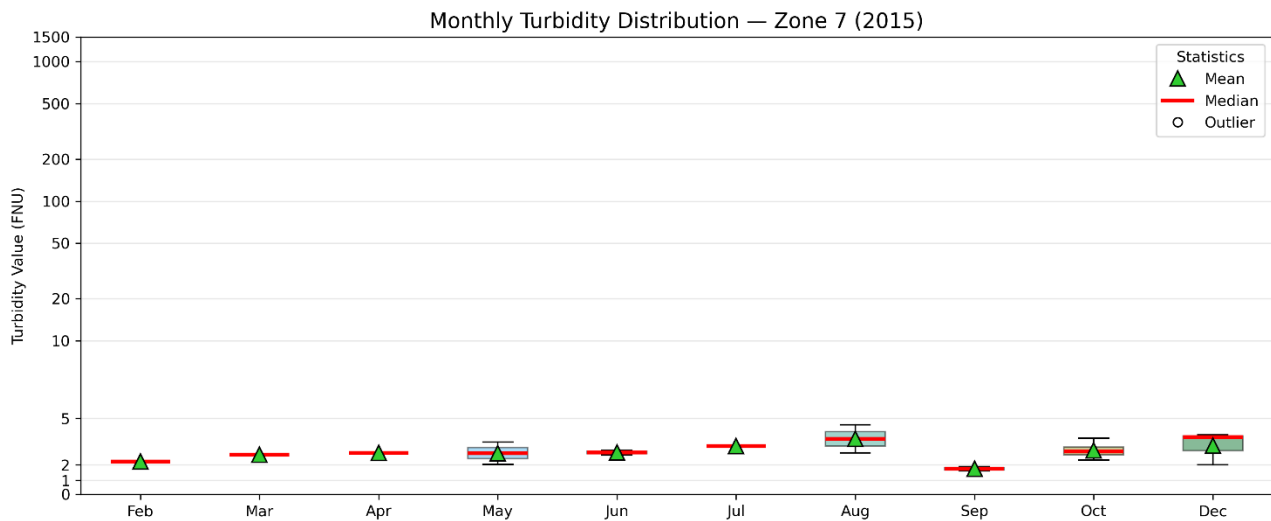


Figure A.62 Monthly Turbidity Distribution by Month for Zone 7 (2015)

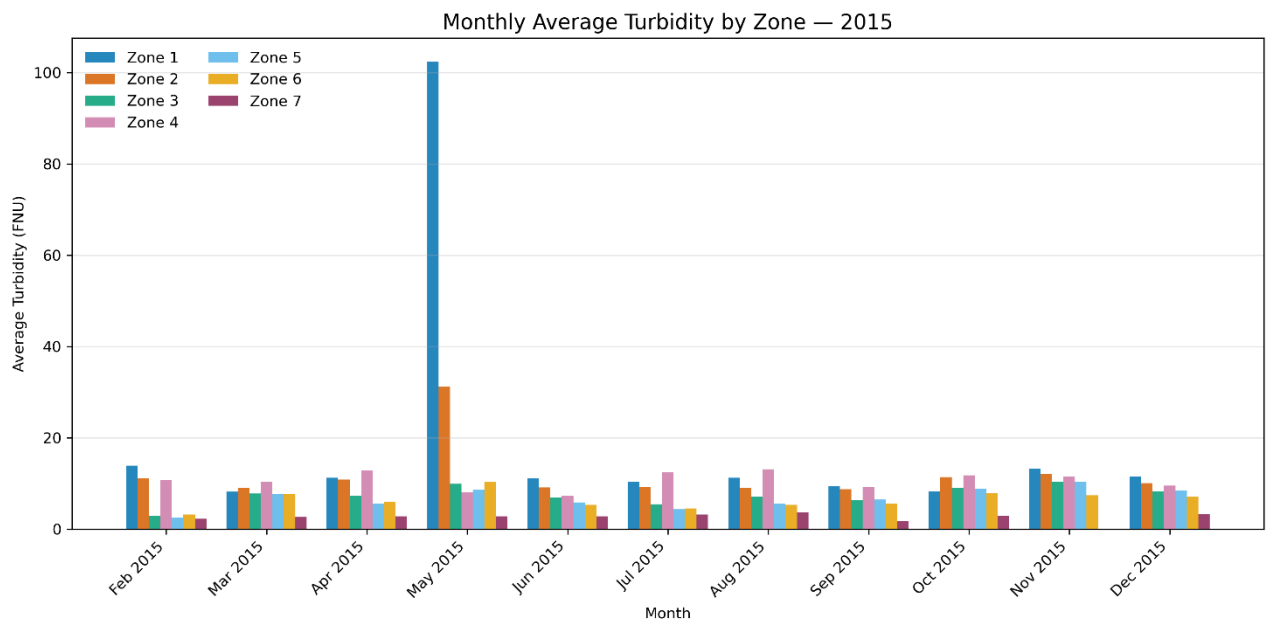


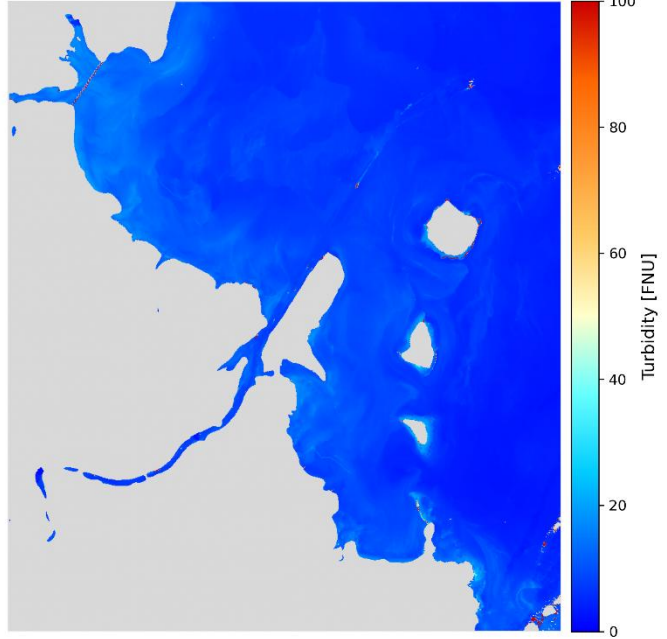
Figure A.63 Monthly Turbidity Distribution by Month (2015)

Sensor: L8 OLI | Local Time: 2015-03-17 09:41:42 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2015-08-24 09:41:53 AEST

Surface Reflectance RGB



Turbidity

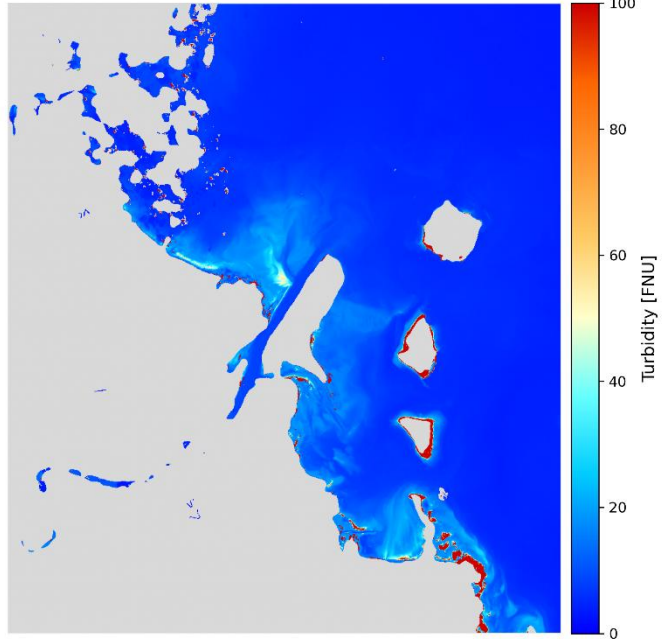


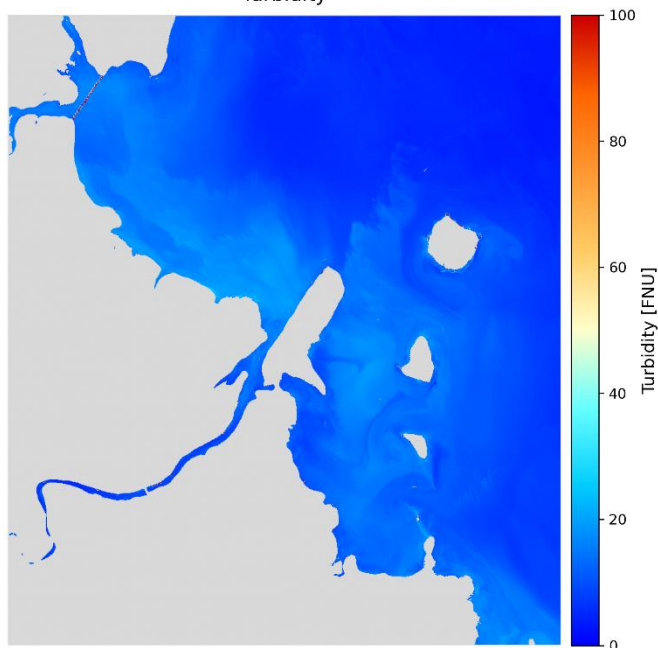
Figure A.64 Representative turbidity conditions in 2015. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2015-10-27 09:42:13 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2015-12-30 09:42:14 AEST

Surface Reflectance RGB



Turbidity

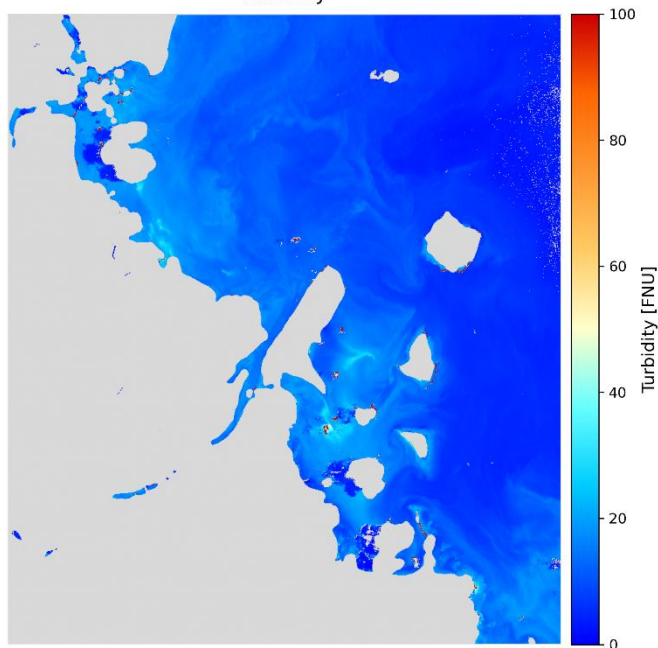
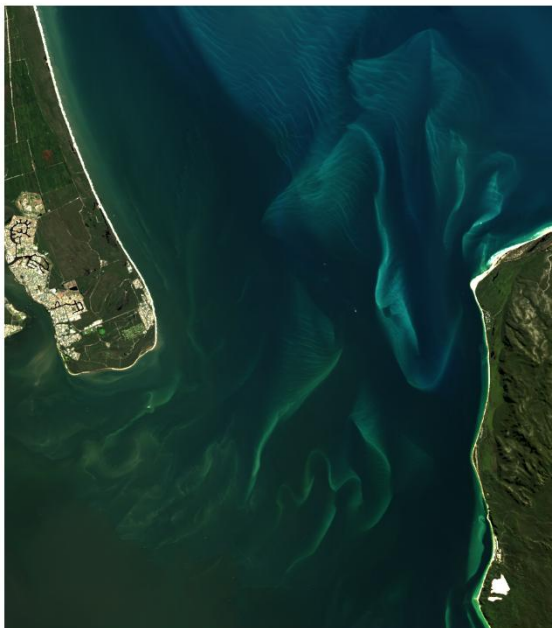


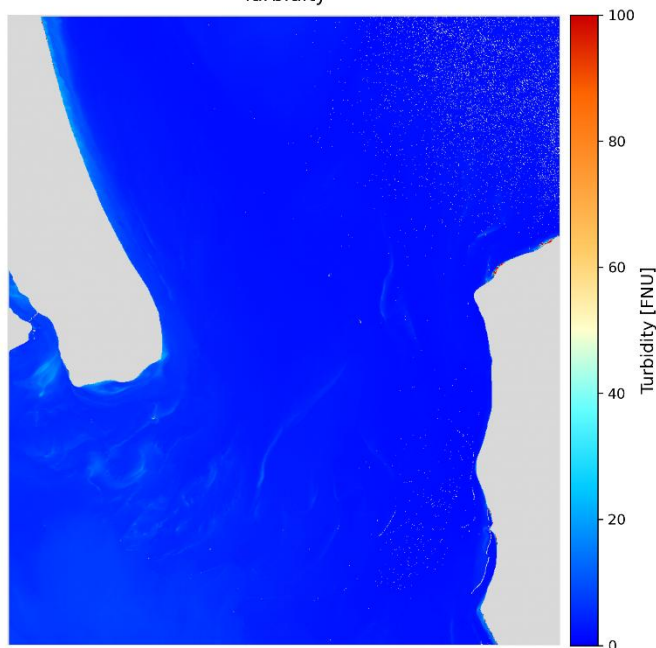
Figure A.65 Representative turbidity conditions in 2015. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2015-05-04 09:41:17 AEST

Surface Reflectance RGB

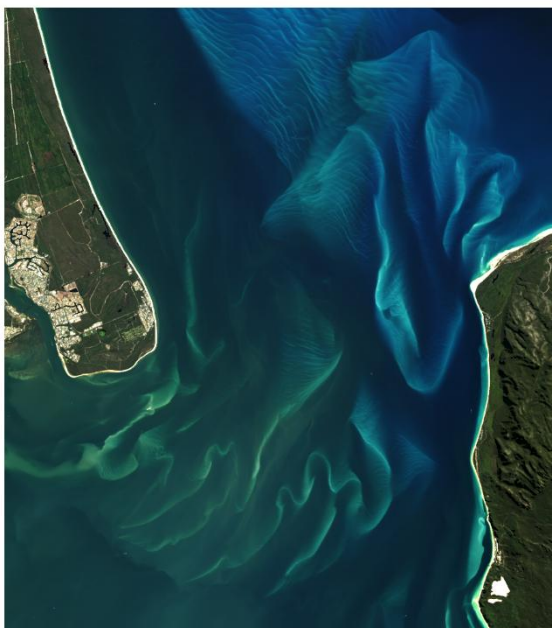


Turbidity



Sensor: L8 OLI | Local Time: 2015-07-07 09:41:35 AEST

Surface Reflectance RGB



Turbidity

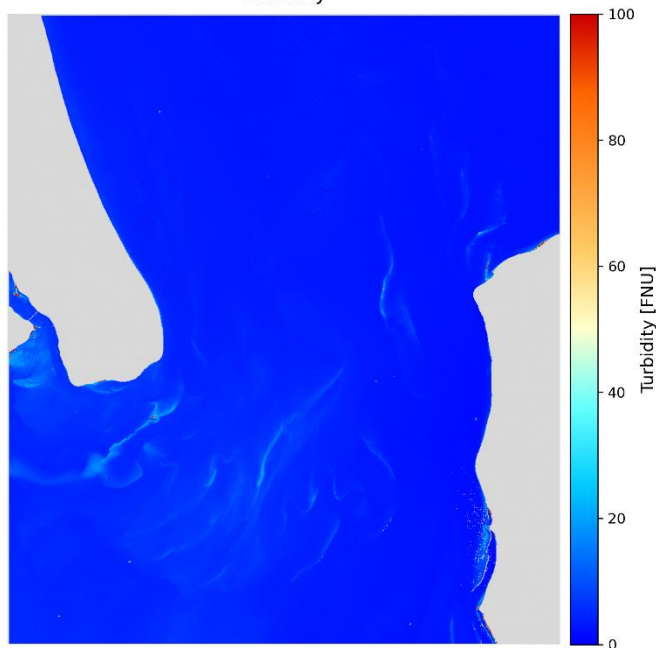
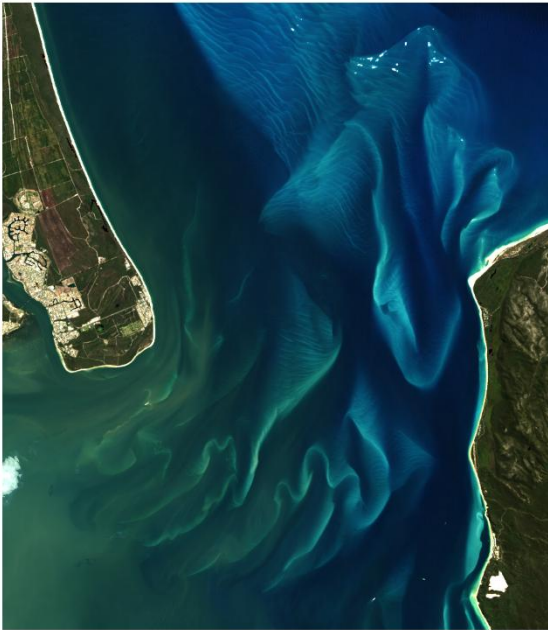


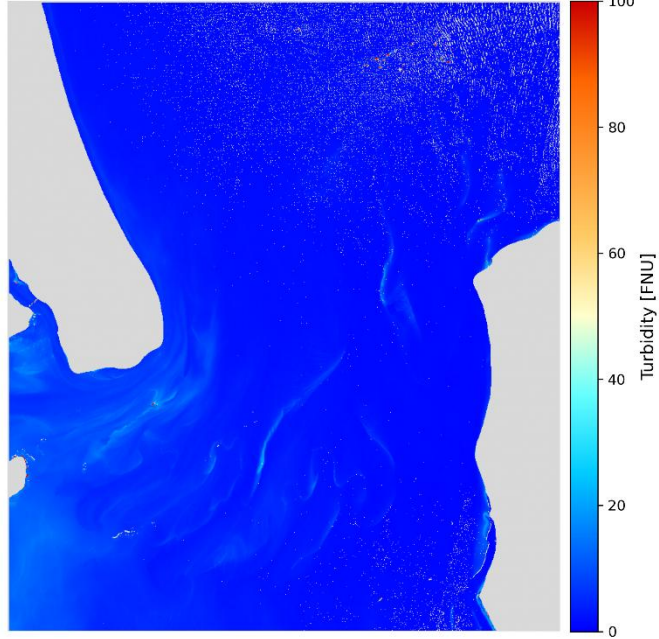
Figure A.66 Representative turbidity conditions in 2015. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2015-09-25 09:42:07 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2015-12-30 09:42:14 AEST

Surface Reflectance RGB



Turbidity

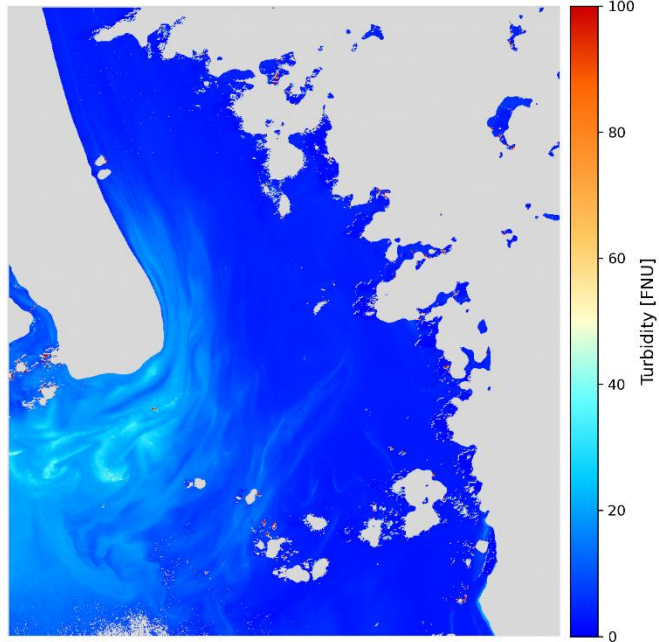


Figure A.67 Representative turbidity conditions in 2015. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.6 Turbidity Pattern 2016

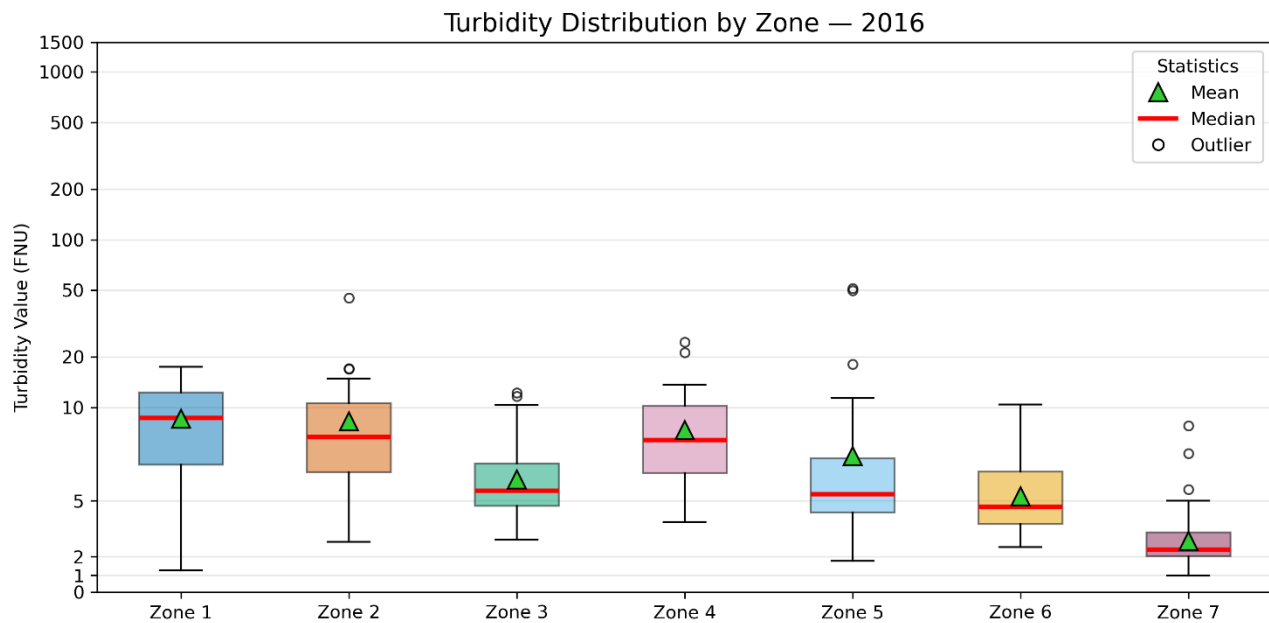


Figure A.68 Turbidity distributions by reporting zone (2016).

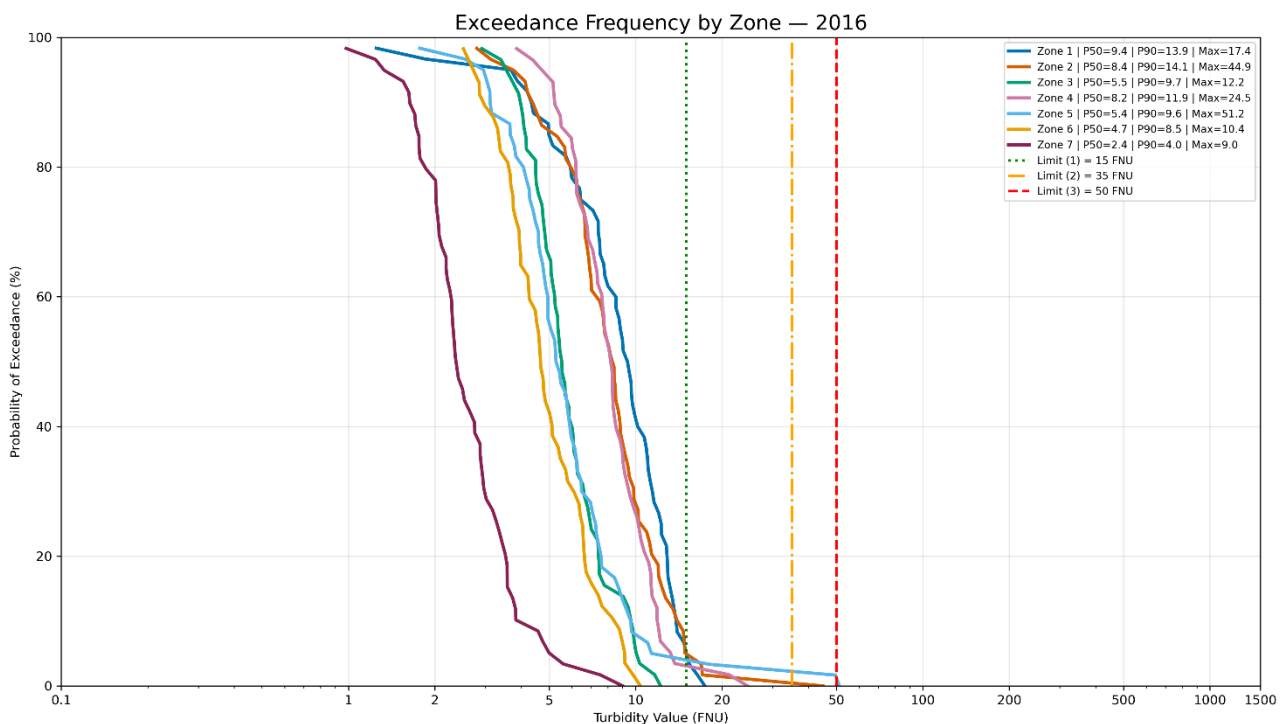


Figure A.69 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2016).

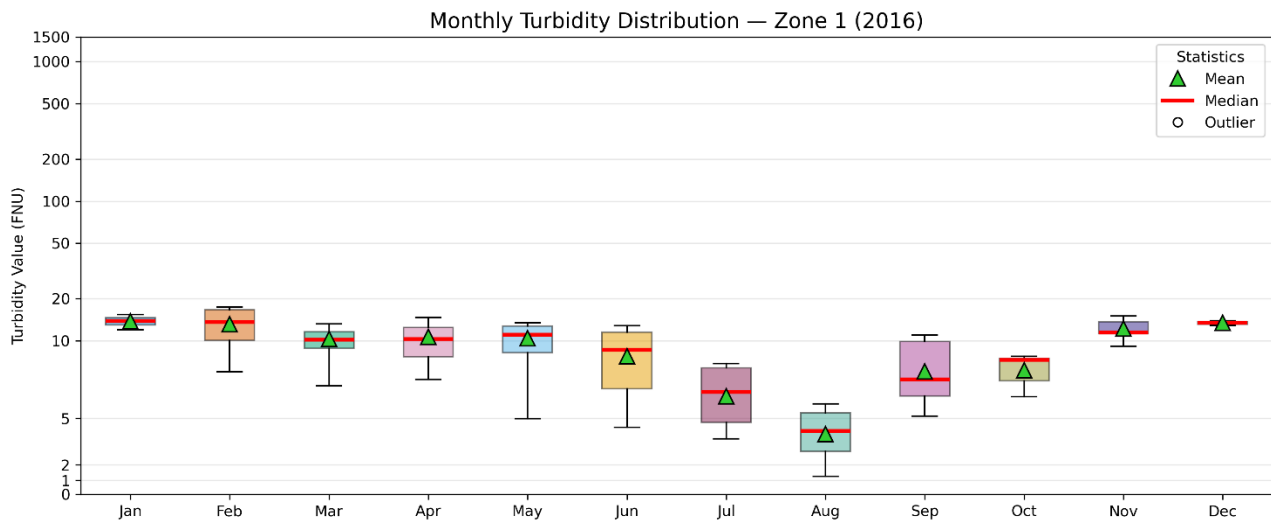


Figure A.70 Monthly Turbidity Distribution by Month for Zone 1 (2016)

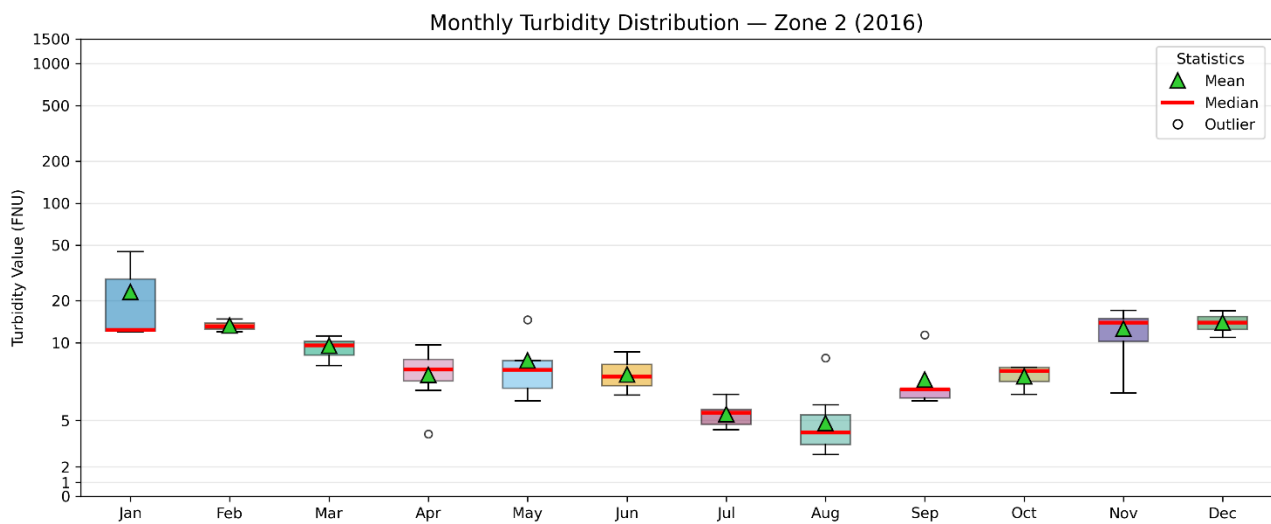


Figure A.71 Monthly Turbidity Distribution by Month for Zone 2 (2016)

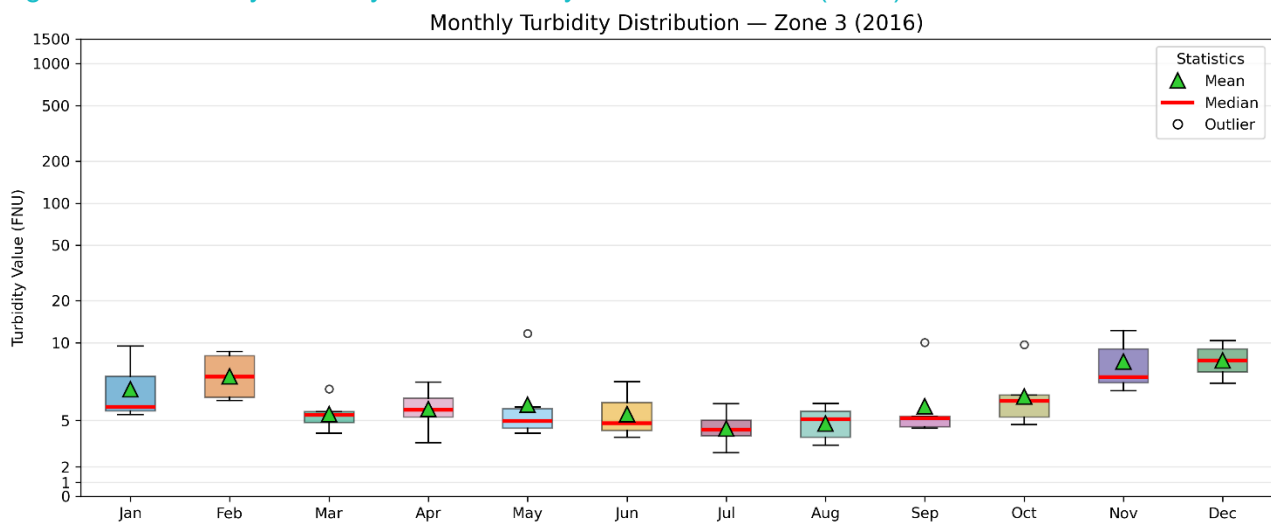


Figure A.72 Monthly Turbidity Distribution by Month for Zone 3 (2016)

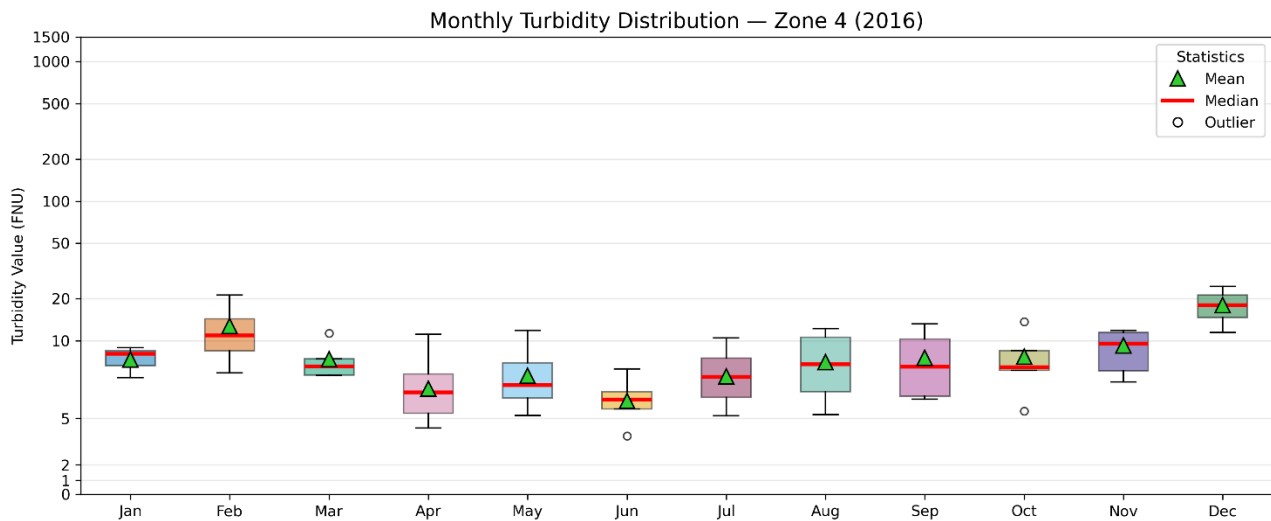


Figure A.73 Monthly Turbidity Distribution by Month for Zone 4 (2016)

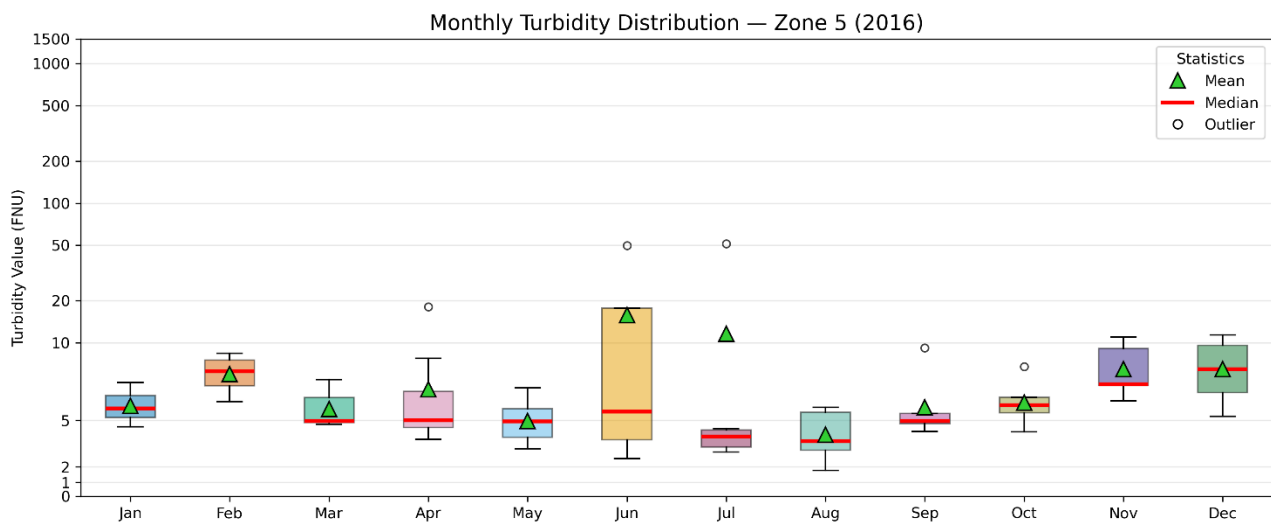


Figure A.74 Monthly Turbidity Distribution by Month for Zone 5 (2016)

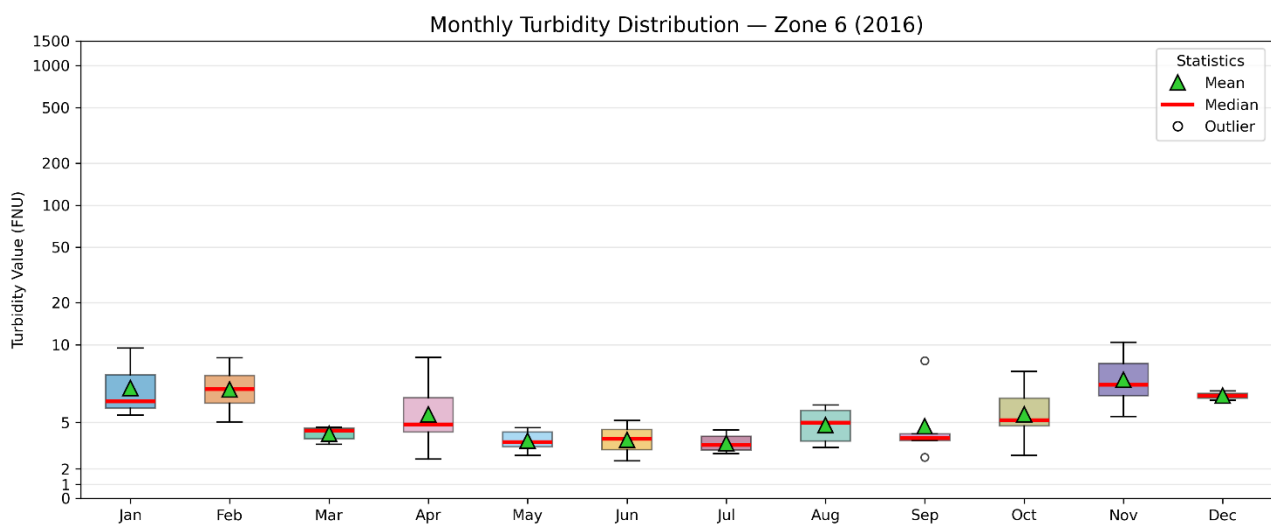


Figure A.75 Monthly Turbidity Distribution by Month for Zone 6 (2016)

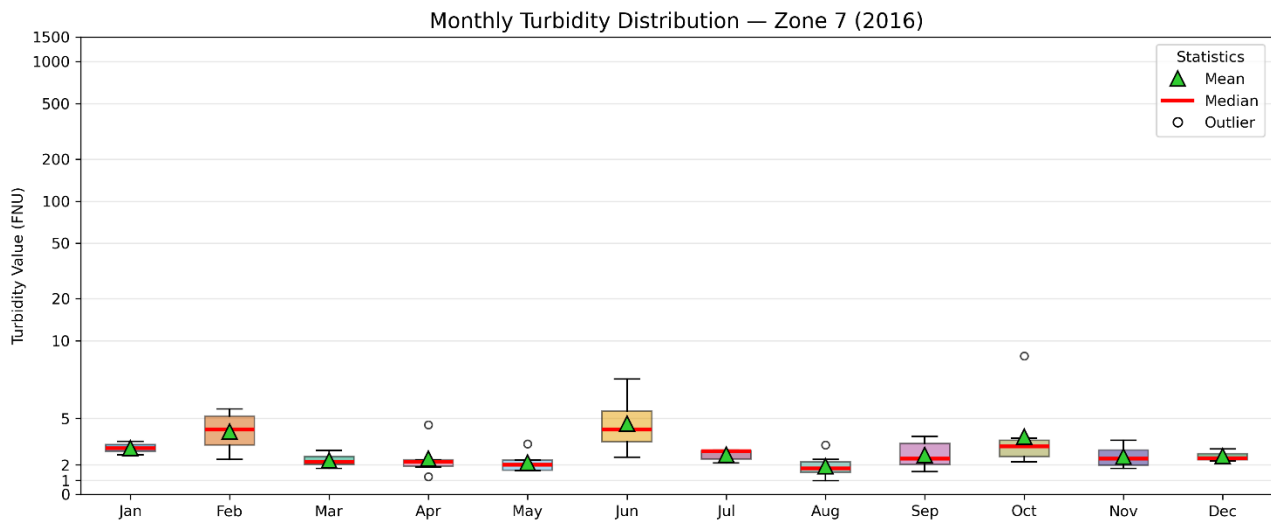


Figure A.76 Monthly Turbidity Distribution by Month for Zone 7 (2016)

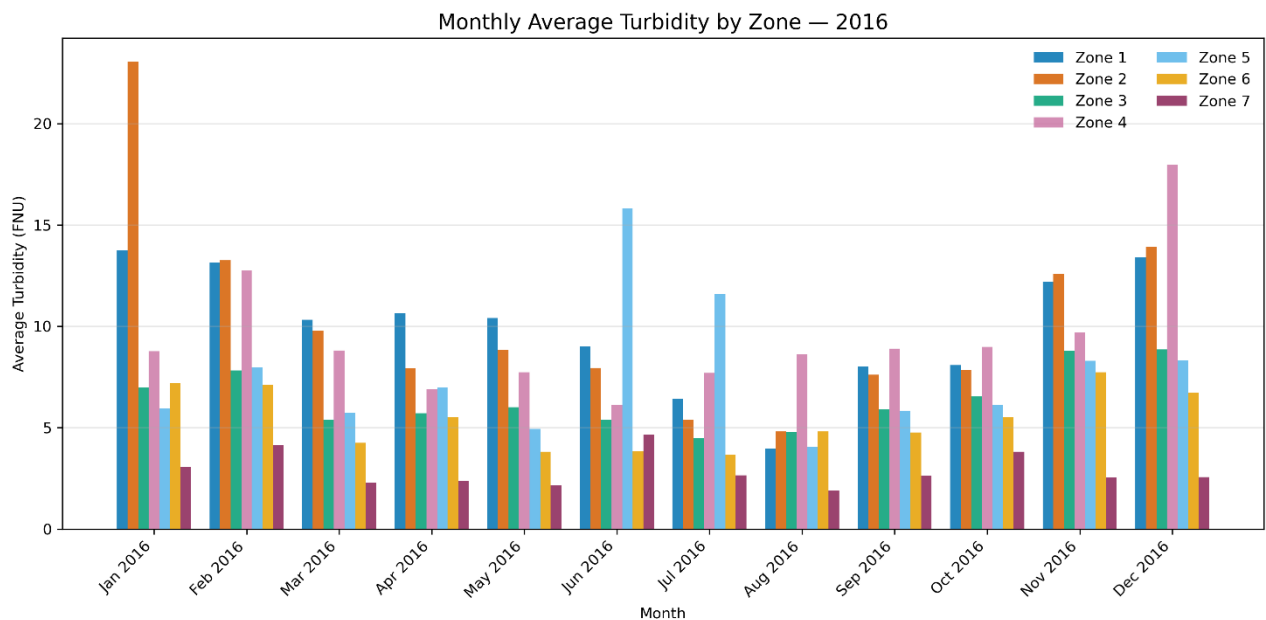


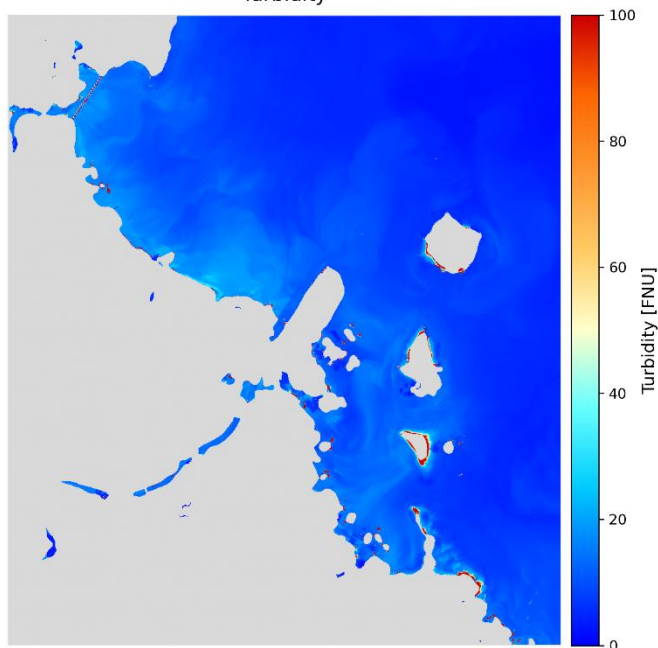
Figure A.77 Monthly Turbidity Distribution by Month (2016)

Sensor: L8 OLI | Local Time: 2016-01-15 09:42:12 AEST

Surface Reflectance RGB



Turbidity



Sensor: L8 OLI | Local Time: 2017-01-01 09:42:21 AEST

Surface Reflectance RGB



Turbidity

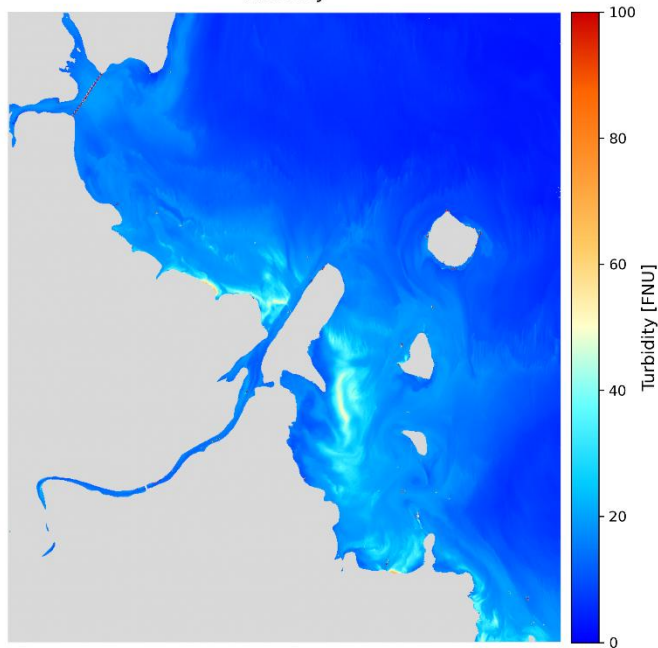
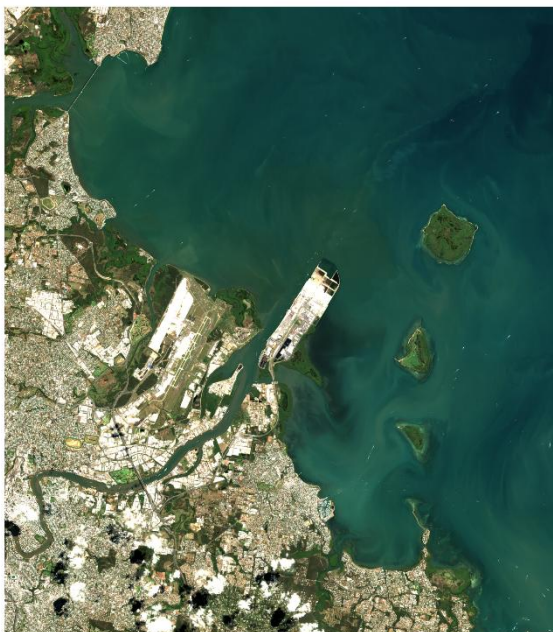


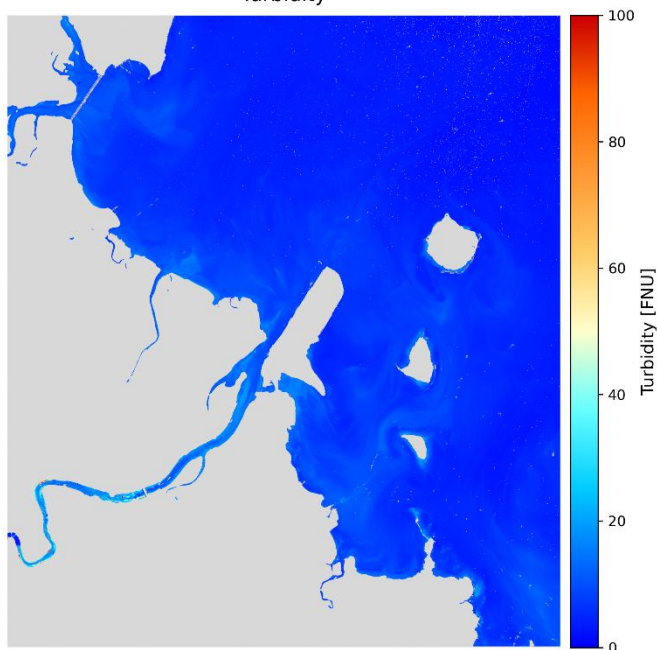
Figure A.78 Representative turbidity conditions in 2016. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2016-04-10 10:04:17 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2016-12-13 09:54:19 AEST

Surface Reflectance RGB



Turbidity

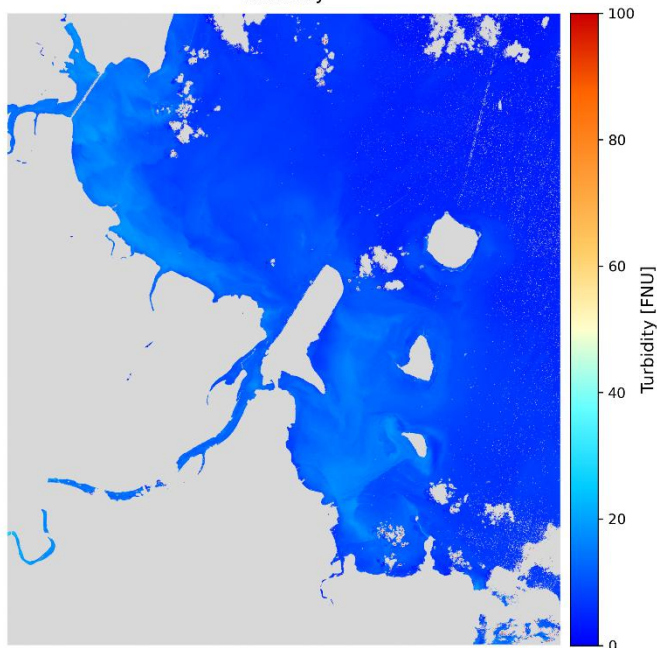
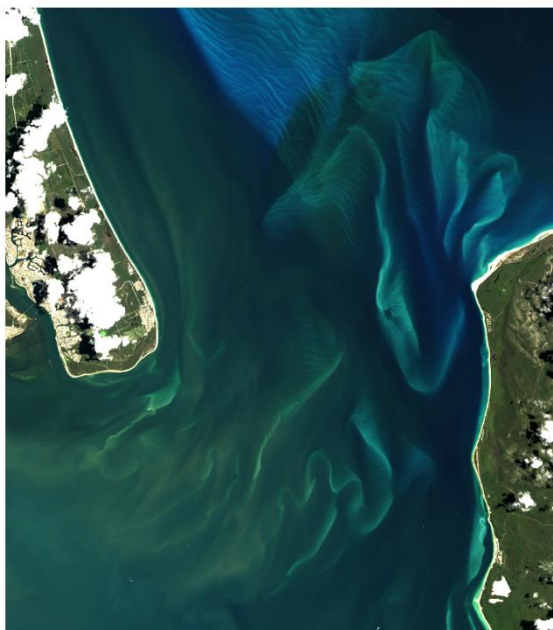


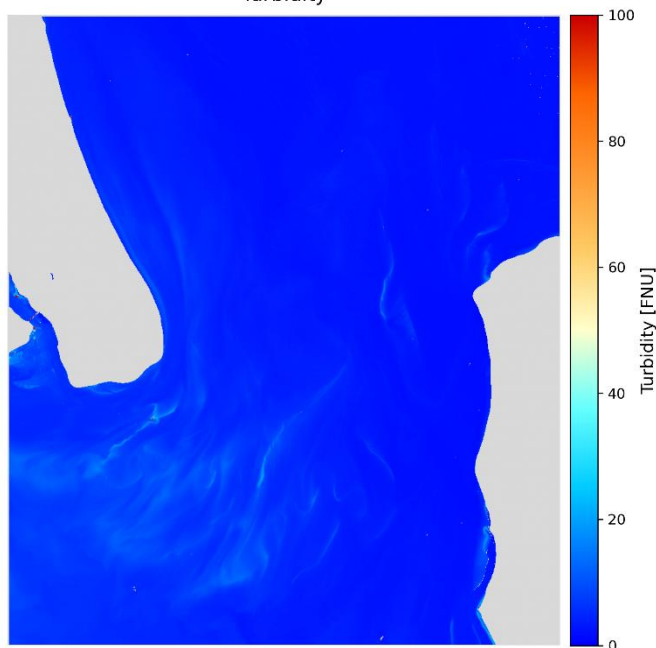
Figure A.79 Representative turbidity conditions in 2016. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: L8 OLI | Local Time: 2016-01-15 09:42:12 AEST

Surface Reflectance RGB

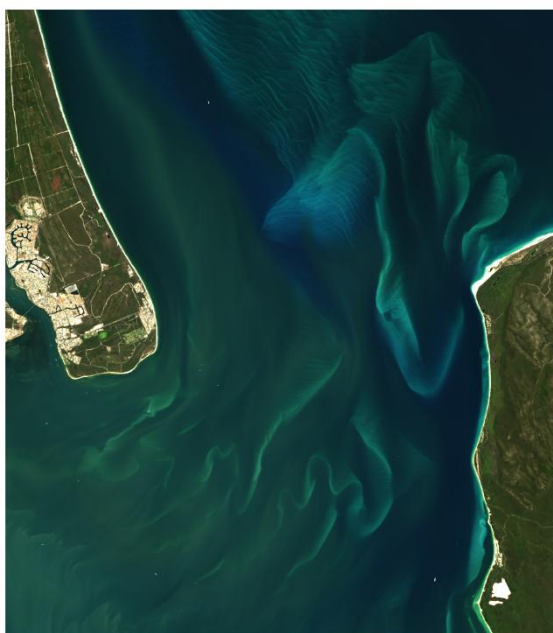


Turbidity



Sensor: L8 OLI | Local Time: 2017-01-01 09:42:21 AEST

Surface Reflectance RGB



Turbidity

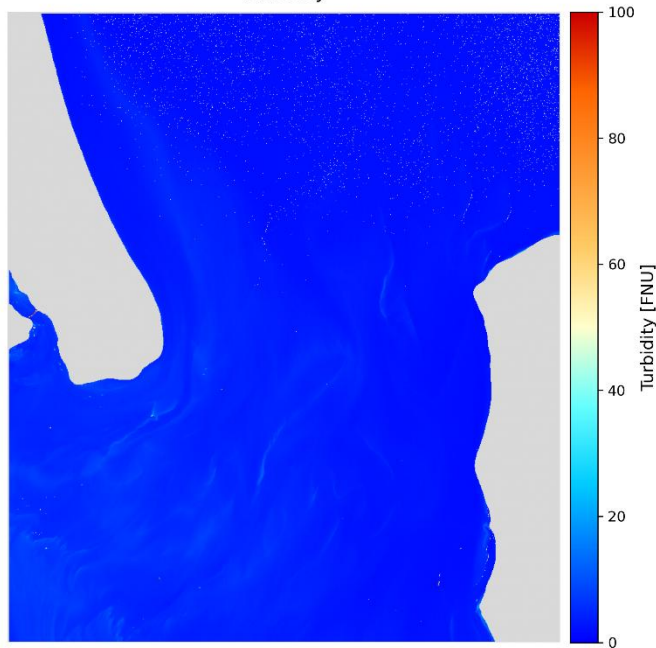


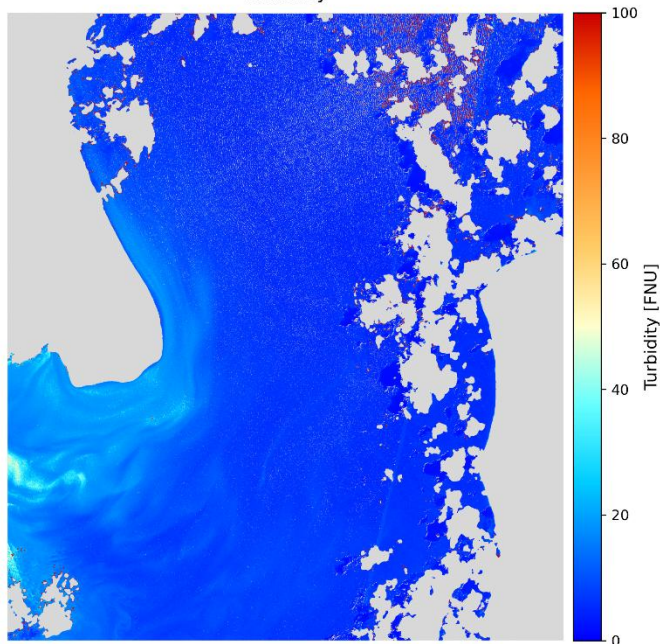
Figure A.80 Representative turbidity conditions in 2016. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2016-02-10 10:04:01 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2016-04-17 09:54:10 AEST

Surface Reflectance RGB



Turbidity

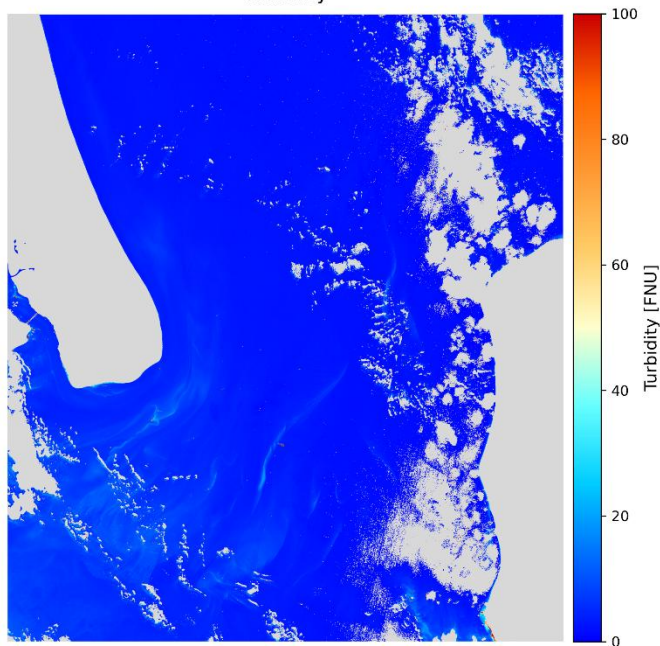


Figure A.81 Representative turbidity conditions in 2016. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.7 Turbidity Pattern 2017

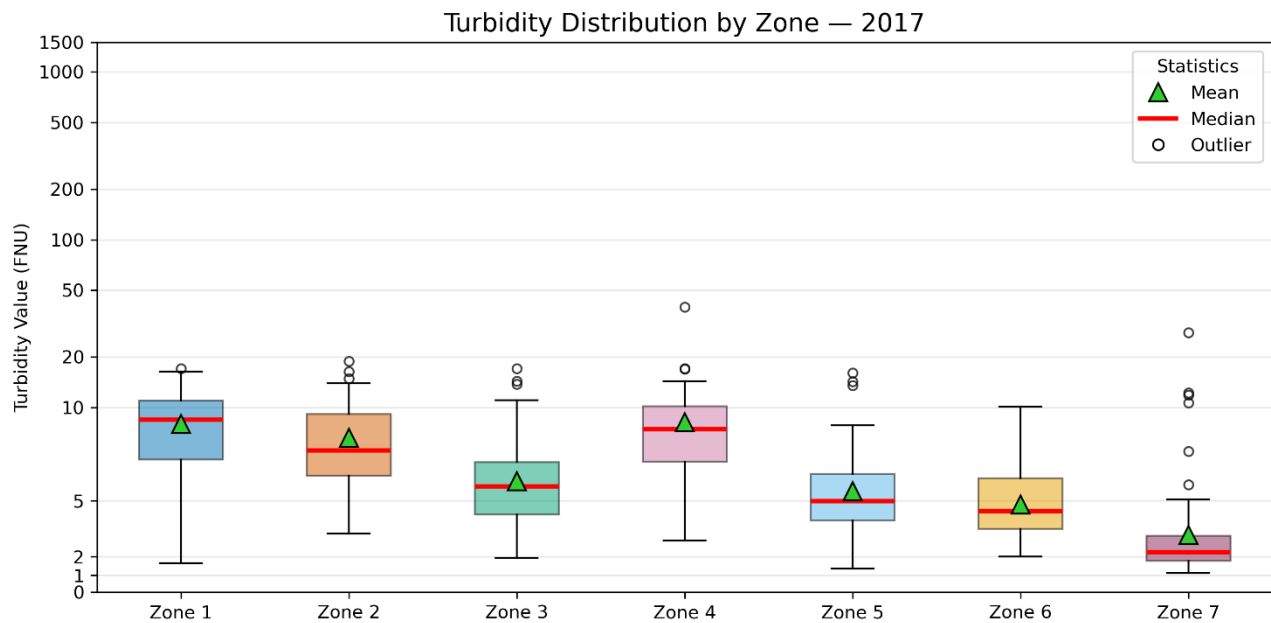


Figure A.82 Turbidity distributions by reporting zone (2017).

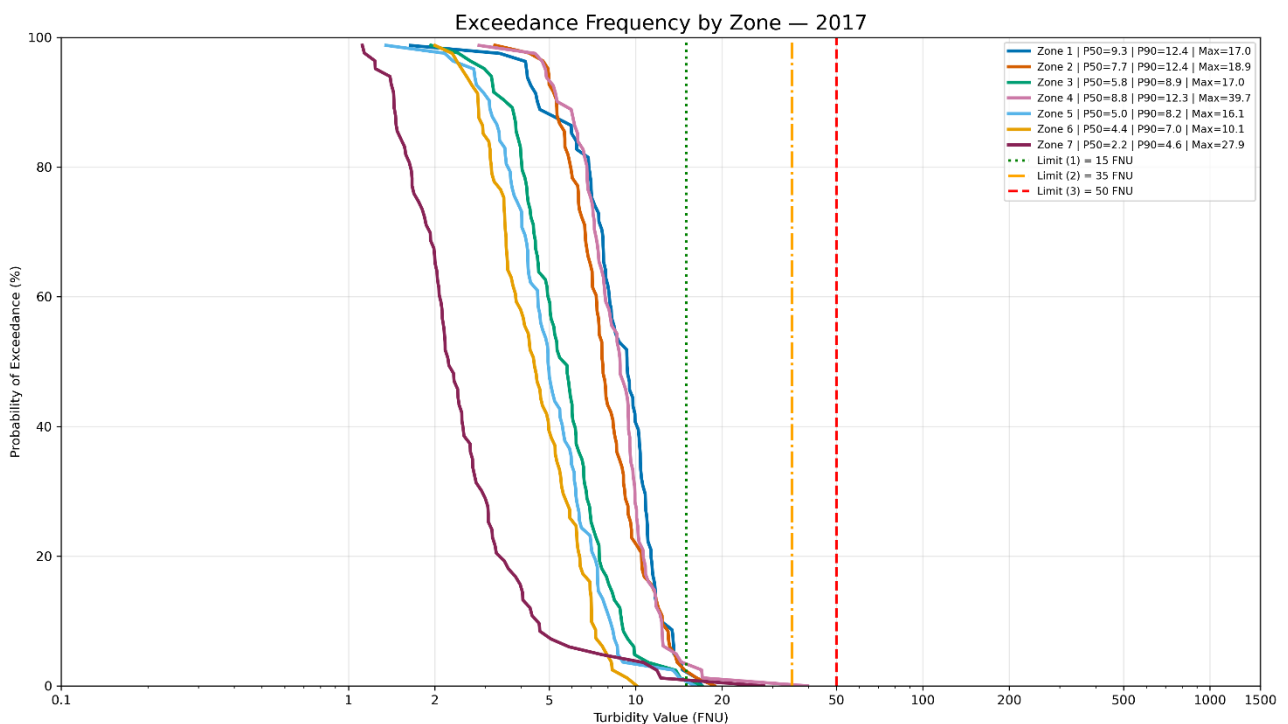


Figure A.83 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2017).

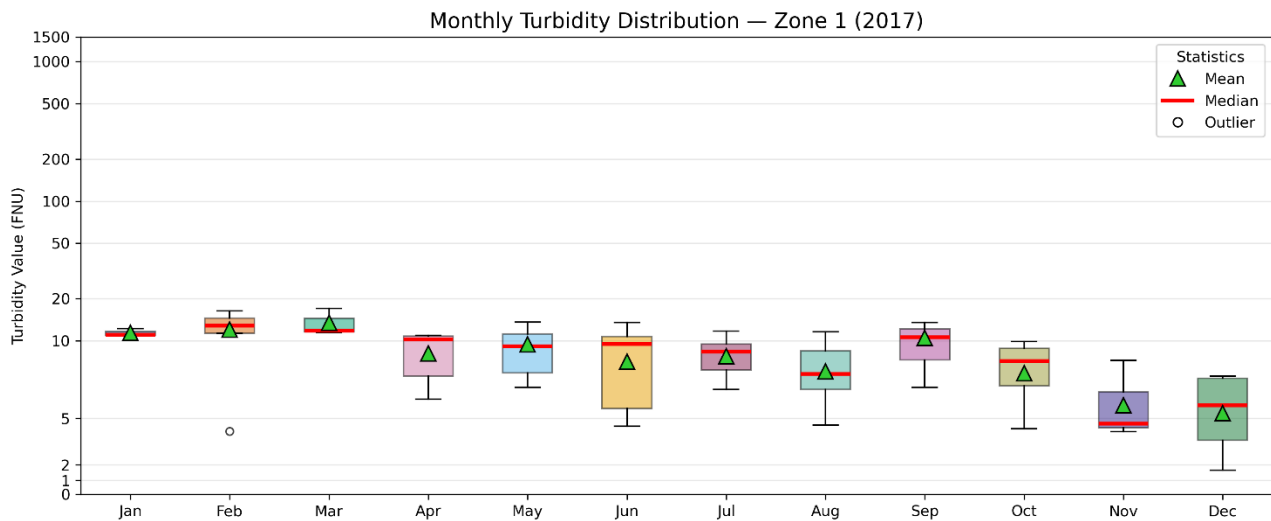


Figure A.84 Monthly Turbidity Distribution by Month for Zone 1 (2017)

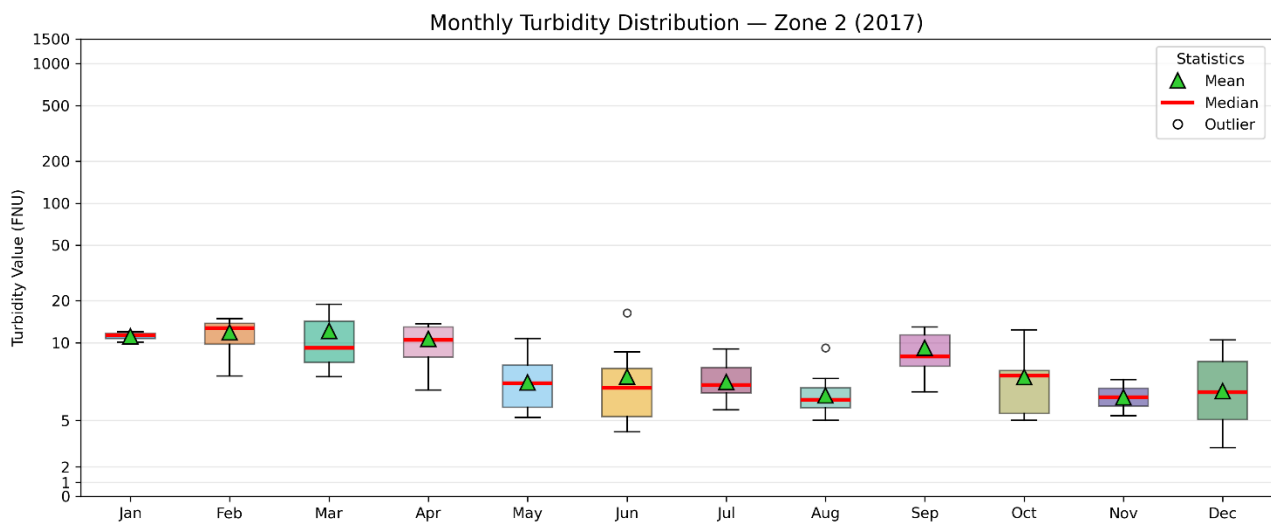


Figure A.85 Monthly Turbidity Distribution by Month for Zone 2 (2017)

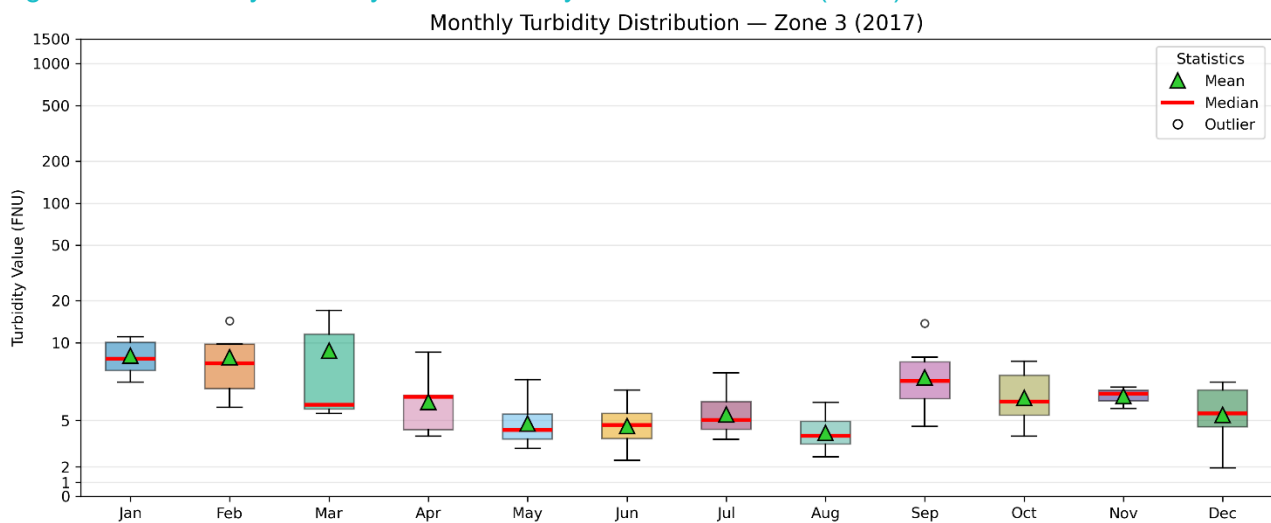


Figure A.86 Monthly Turbidity Distribution by Month for Zone 3 (2017)

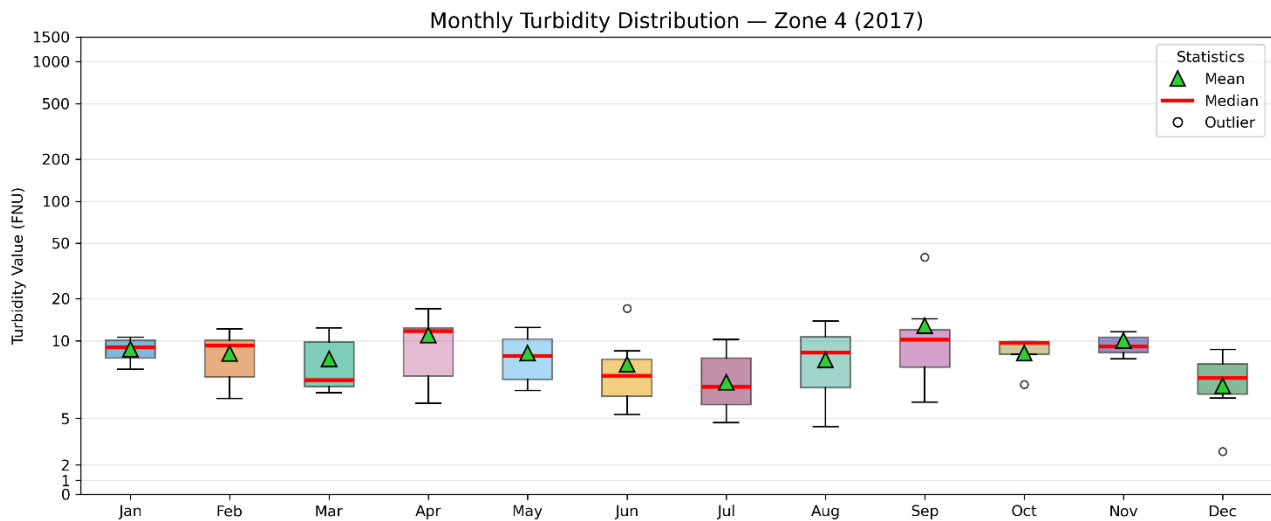


Figure A.87 Monthly Turbidity Distribution by Month for Zone 4 (2017)

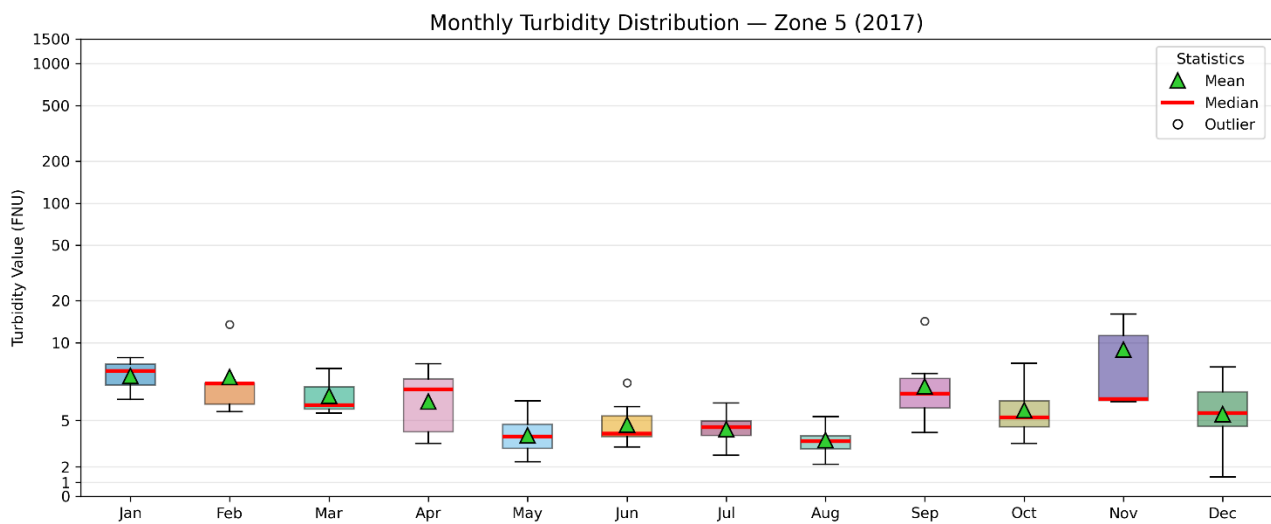


Figure A.88 Monthly Turbidity Distribution by Month for Zone 5 (2017)

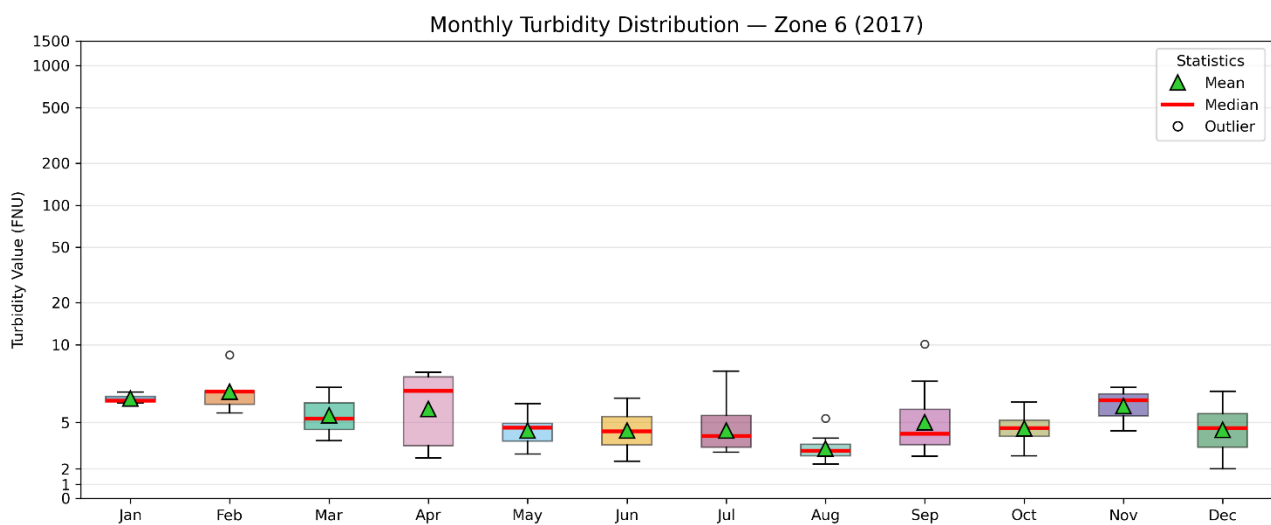


Figure A.89 Monthly Turbidity Distribution by Month for Zone 6 (2017)

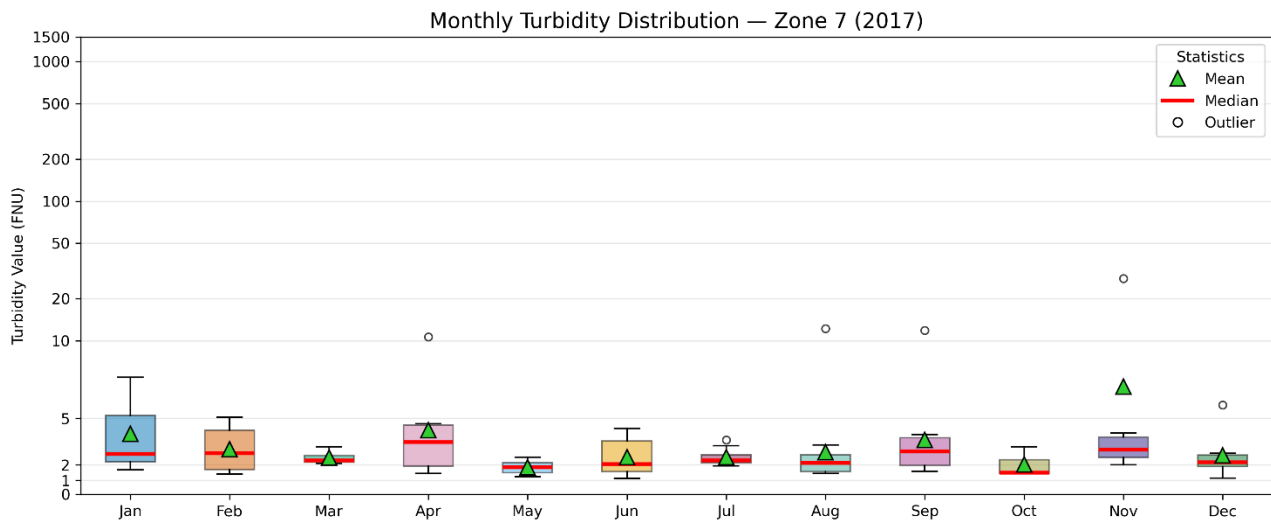


Figure A.90 Monthly Turbidity Distribution by Month for Zone 7 (2017)

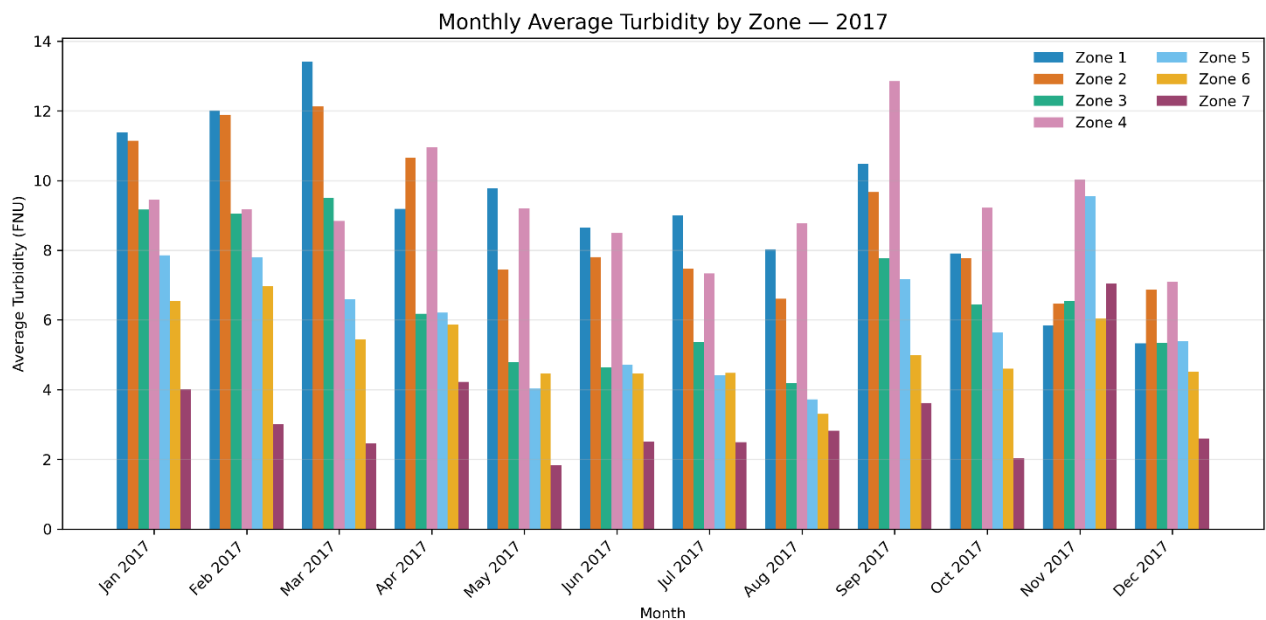


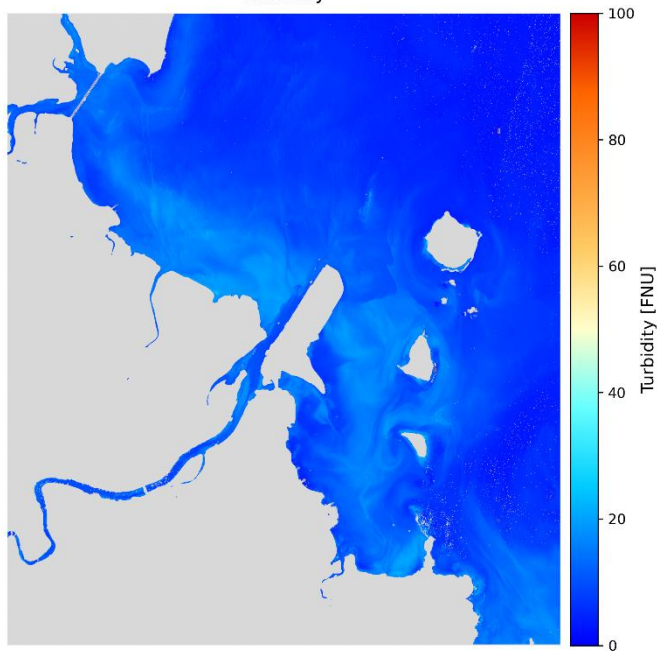
Figure A.91 Monthly Turbidity Distribution by Month (2017)

Sensor: S2A MSI | Local Time: 2017-02-01 09:54:17 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2017-08-20 09:54:24 AEST

Surface Reflectance RGB



Turbidity

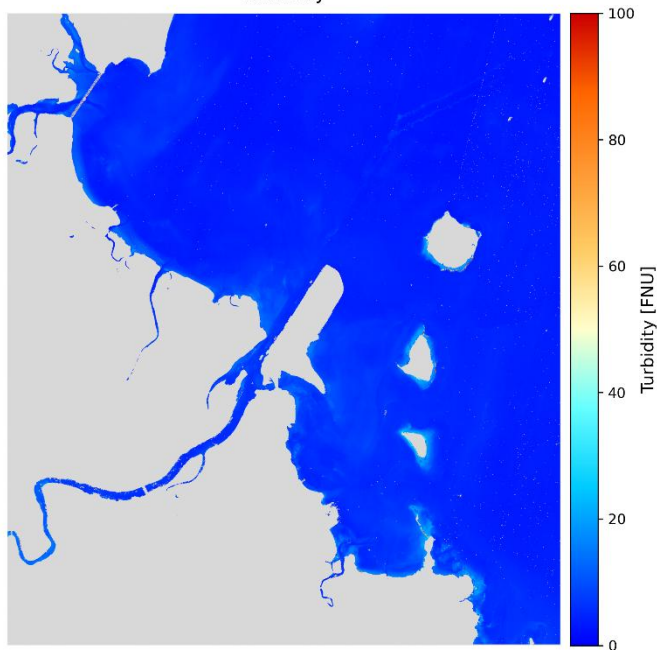


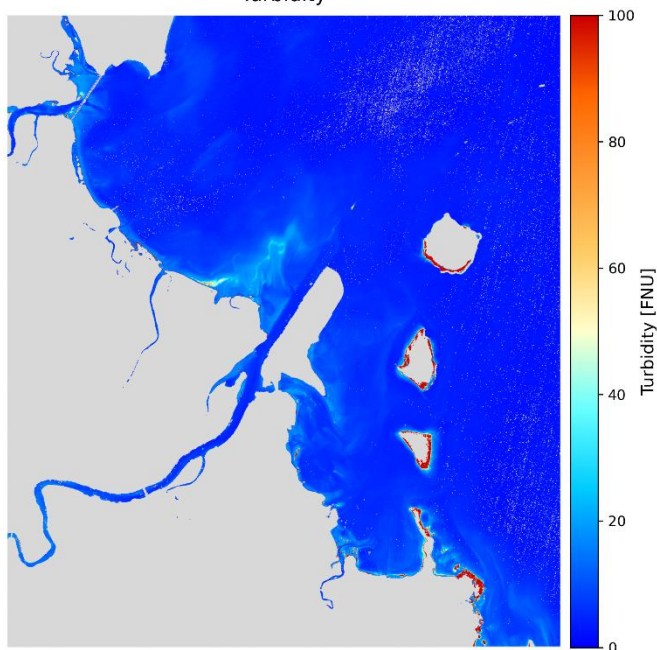
Figure A.92 Representative turbidity conditions in 2017. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2017-08-18 10:04:16 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2017-09-24 09:54:10 AEST

Surface Reflectance RGB



Turbidity

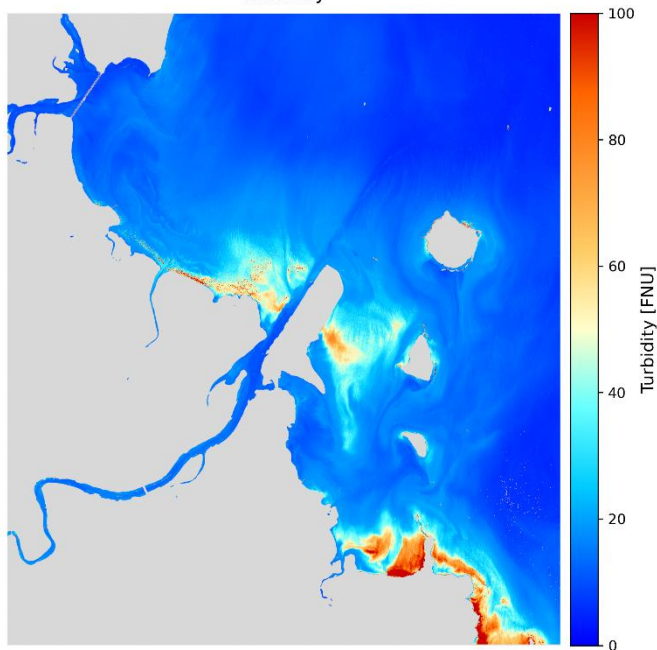
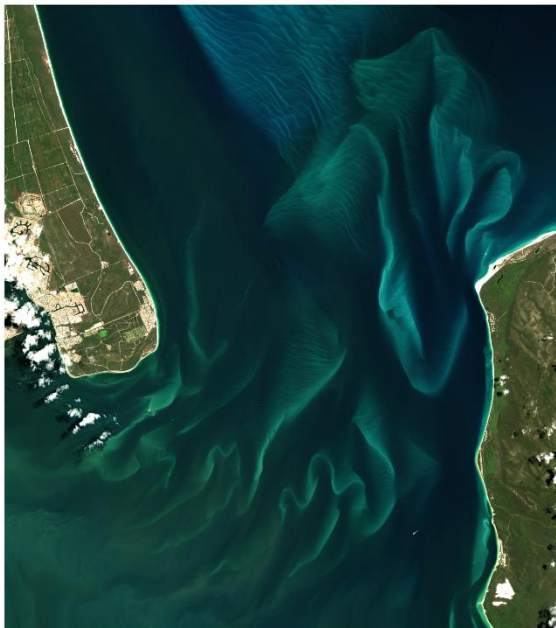


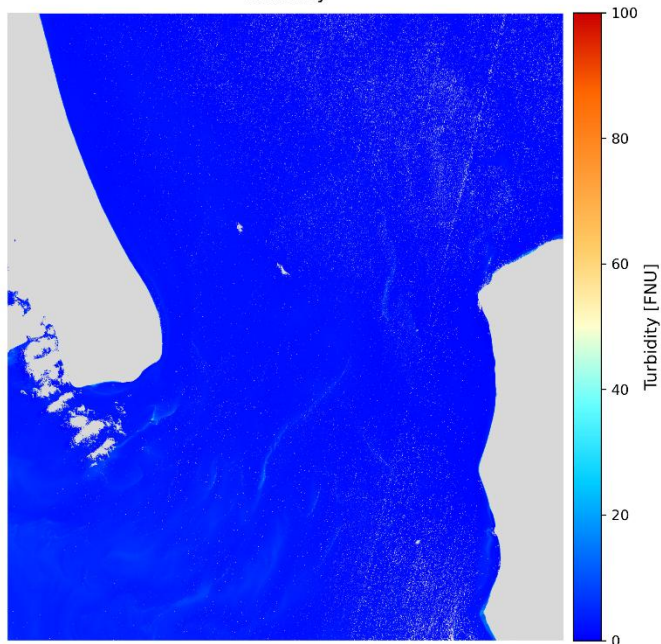
Figure A.93 Representative turbidity conditions in 2017. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2017-02-01 09:54:02 AEST

Surface Reflectance RGB

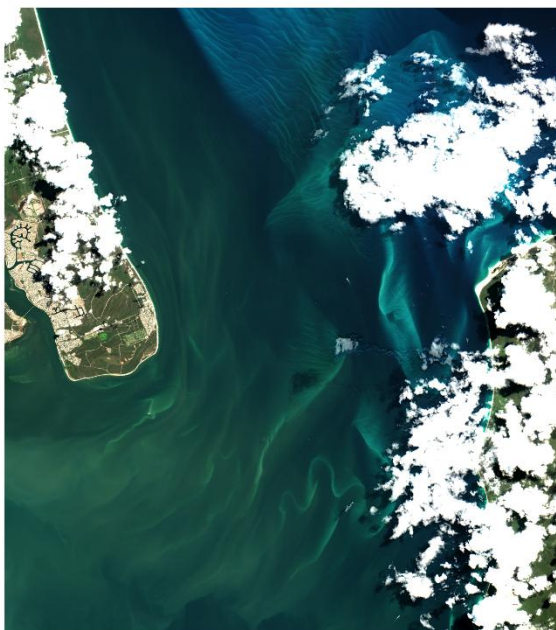


Turbidity



Sensor: S2A MSI | Local Time: 2017-03-03 09:54:02 AEST

Surface Reflectance RGB



Turbidity

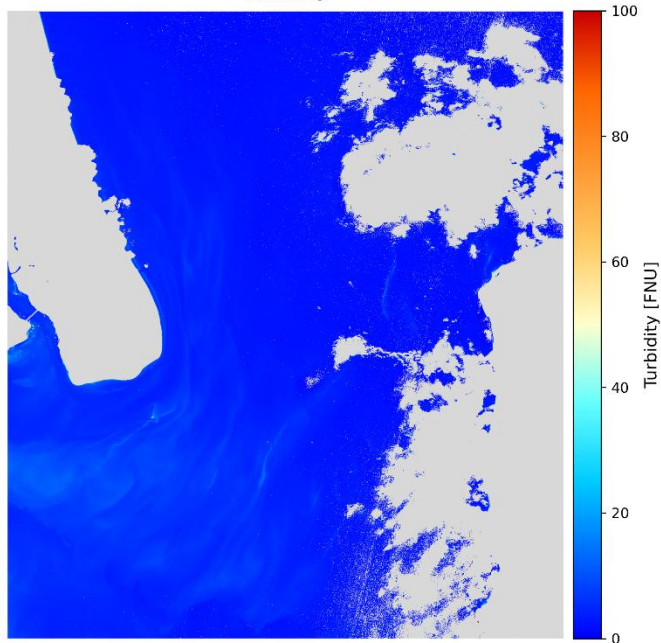
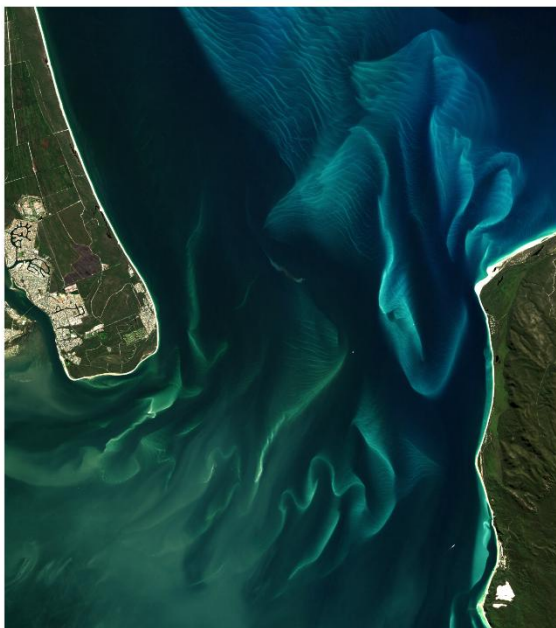


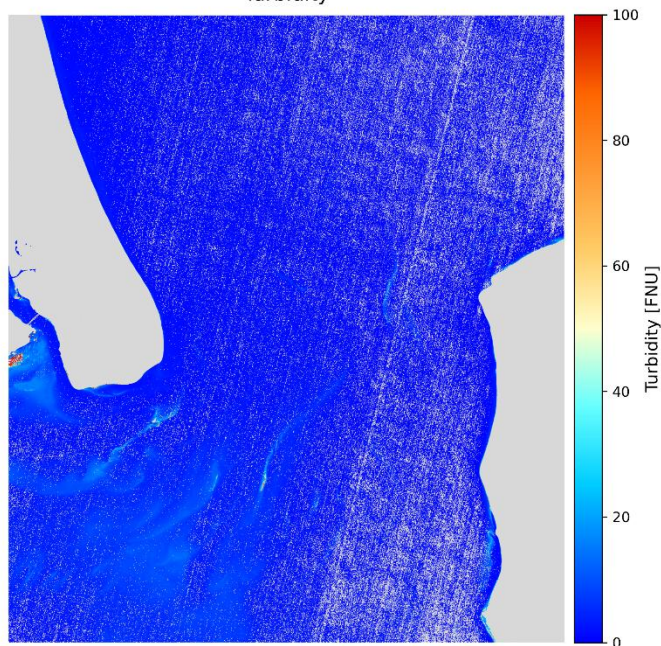
Figure A.94 Representative turbidity conditions in 2017. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2017-06-01 09:54:13 AEST

Surface Reflectance RGB

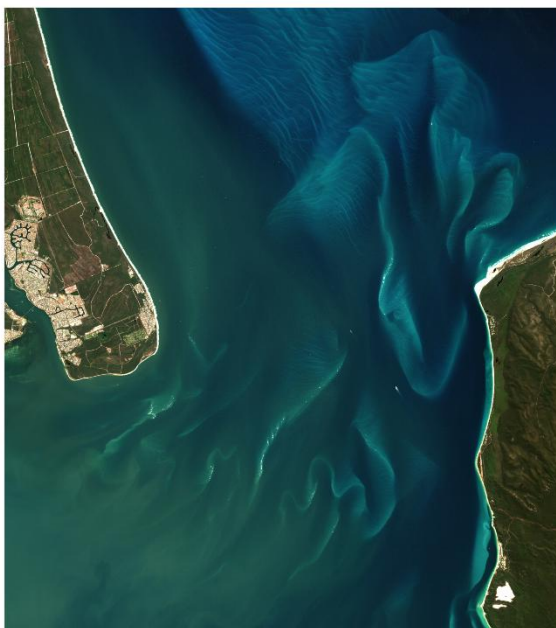


Turbidity



Sensor: S2B MSI | Local Time: 2017-09-24 09:53:56 AEST

Surface Reflectance RGB



Turbidity

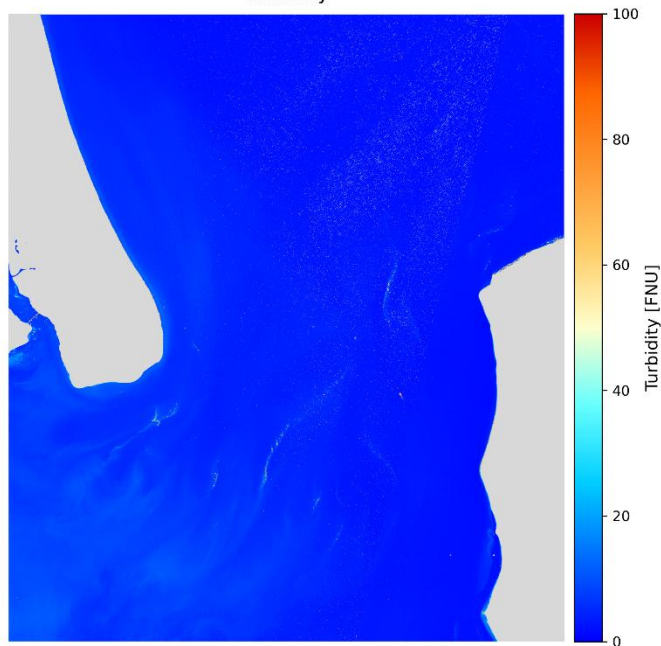


Figure A.95 Representative turbidity conditions in 2017. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.8 Turbidity Pattern 2018

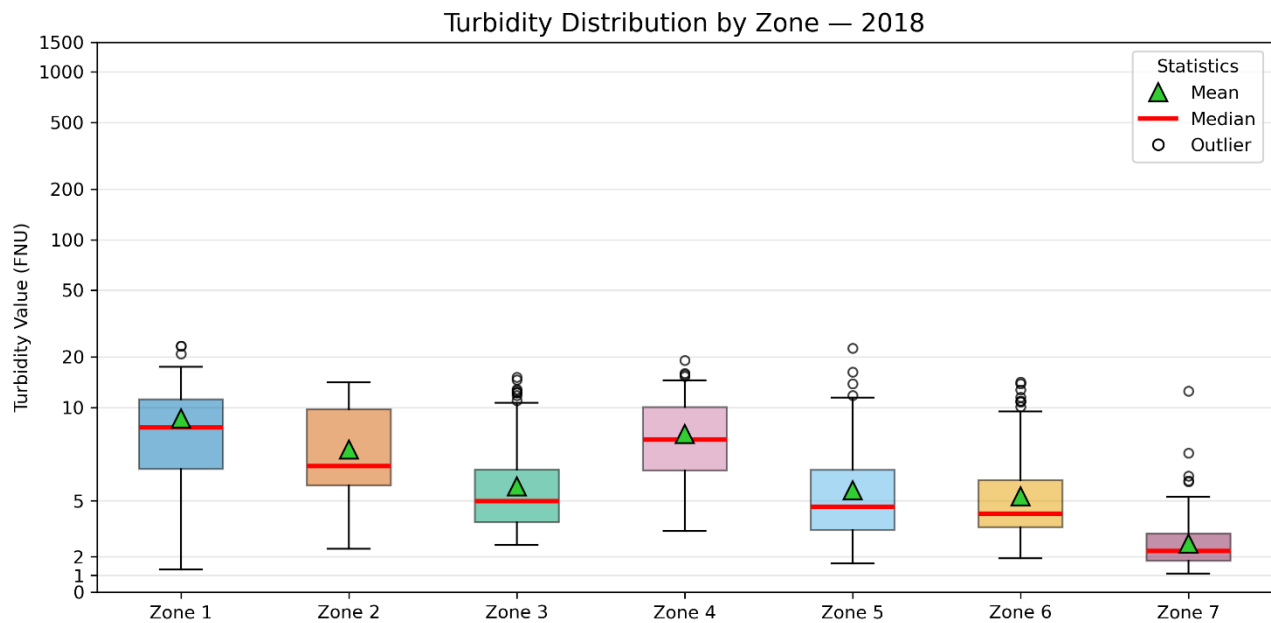


Figure A.96 Turbidity distributions by reporting zone (2018).

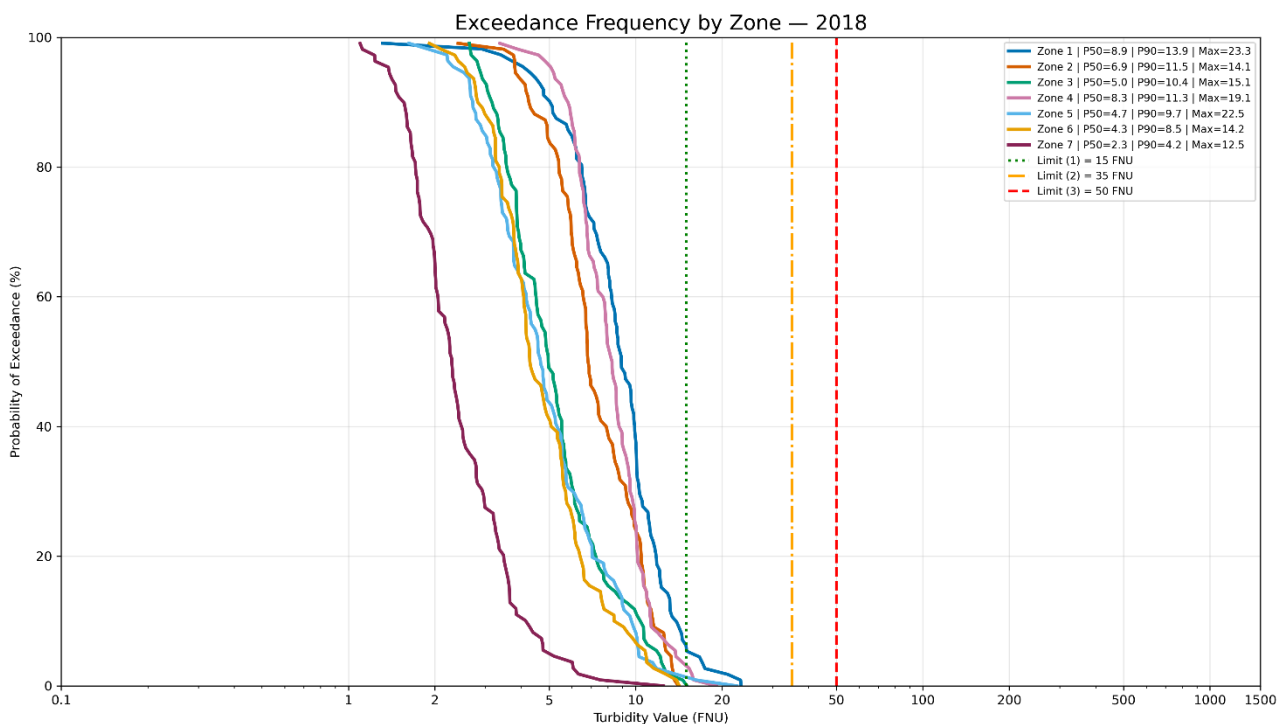


Figure A.97 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2018).

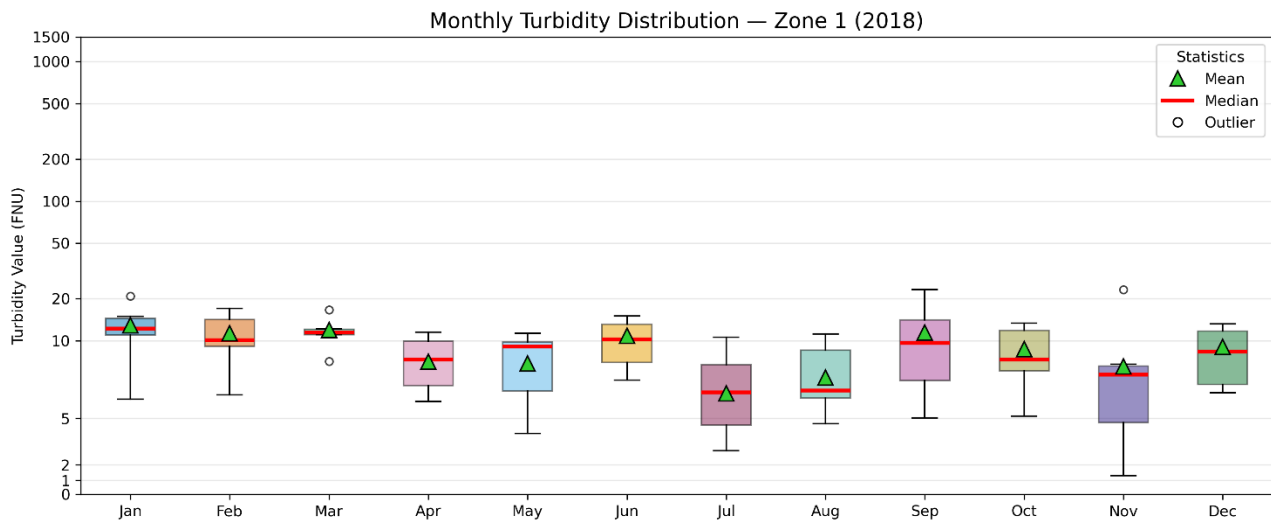


Figure A.98 Monthly Turbidity Distribution by Month for Zone 1 (2018)

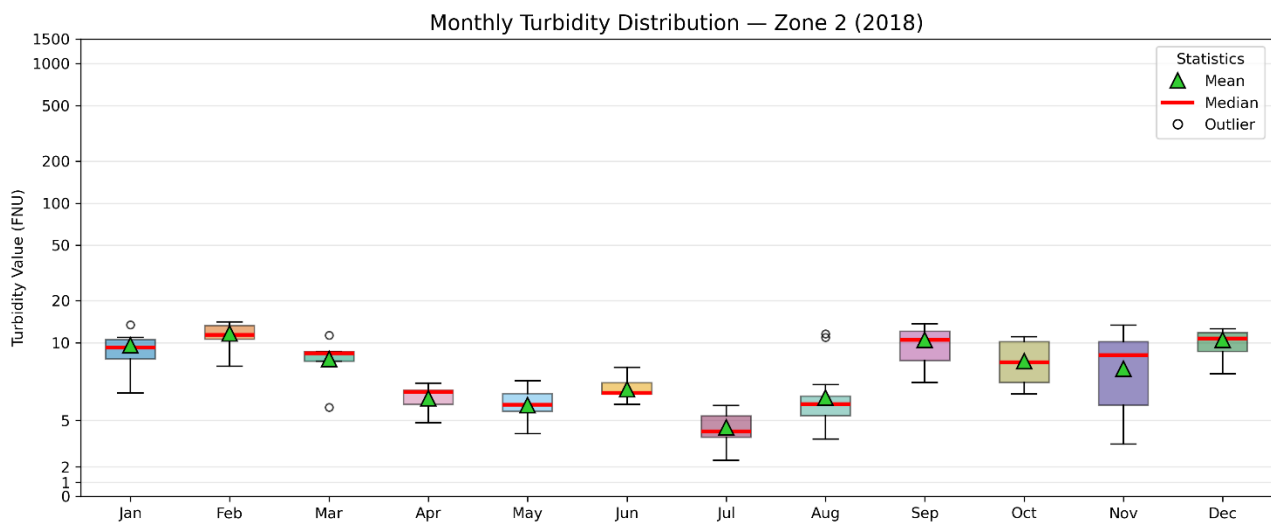


Figure A.99 Monthly Turbidity Distribution by Month for Zone 2 (2018)

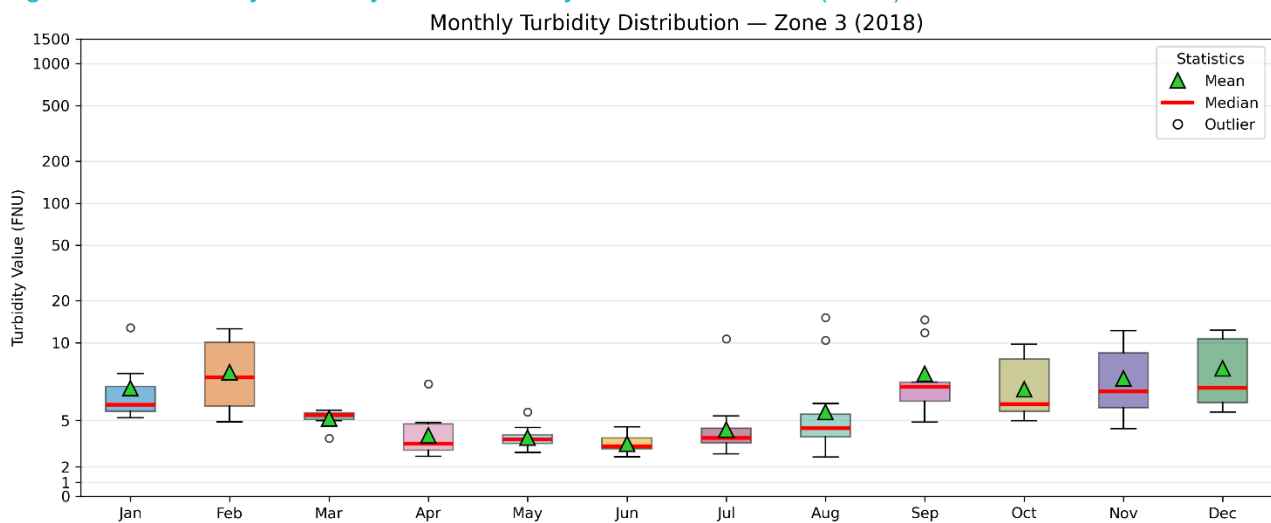


Figure A.100 Monthly Turbidity Distribution by Month for Zone 3 (2018)

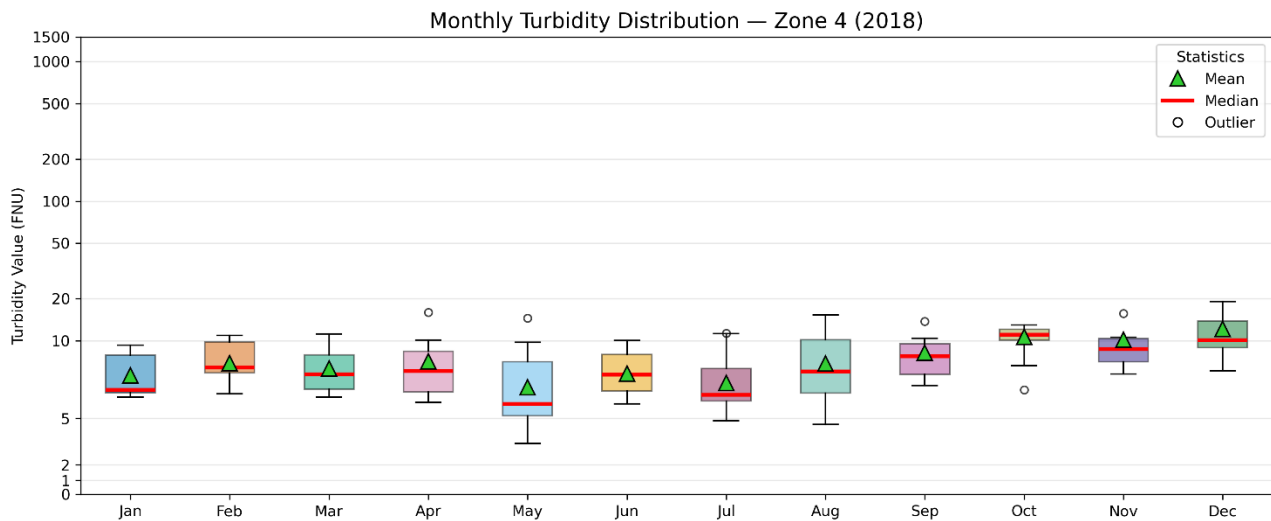


Figure A.101 Monthly Turbidity Distribution by Month for Zone 4 (2018)

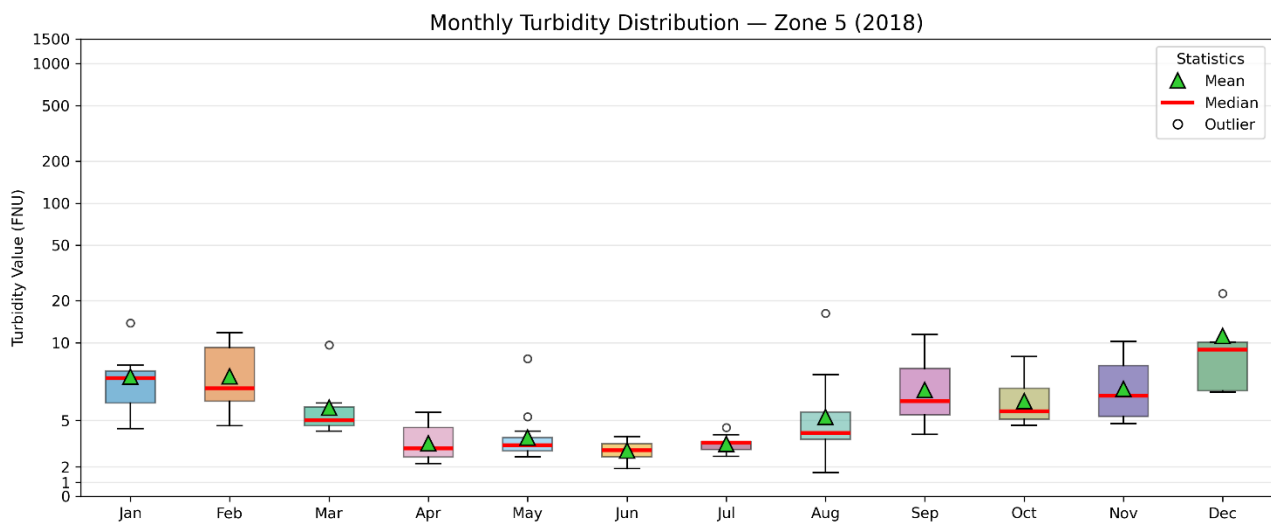


Figure A.102 Monthly Turbidity Distribution by Month for Zone 5 (2018)

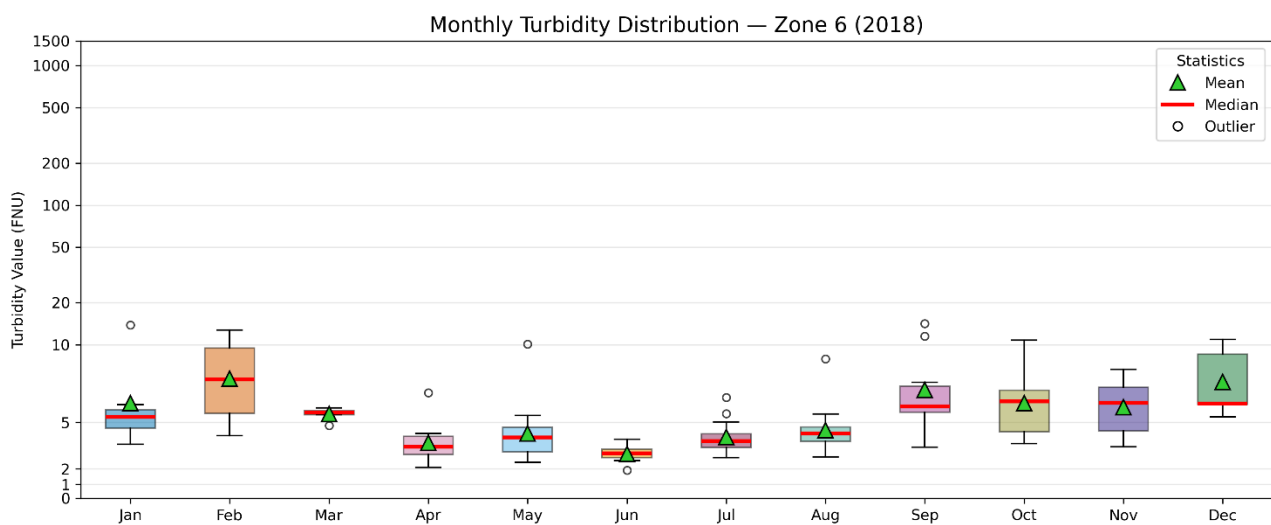


Figure A.103 Monthly Turbidity Distribution by Month for Zone 6 (2018)

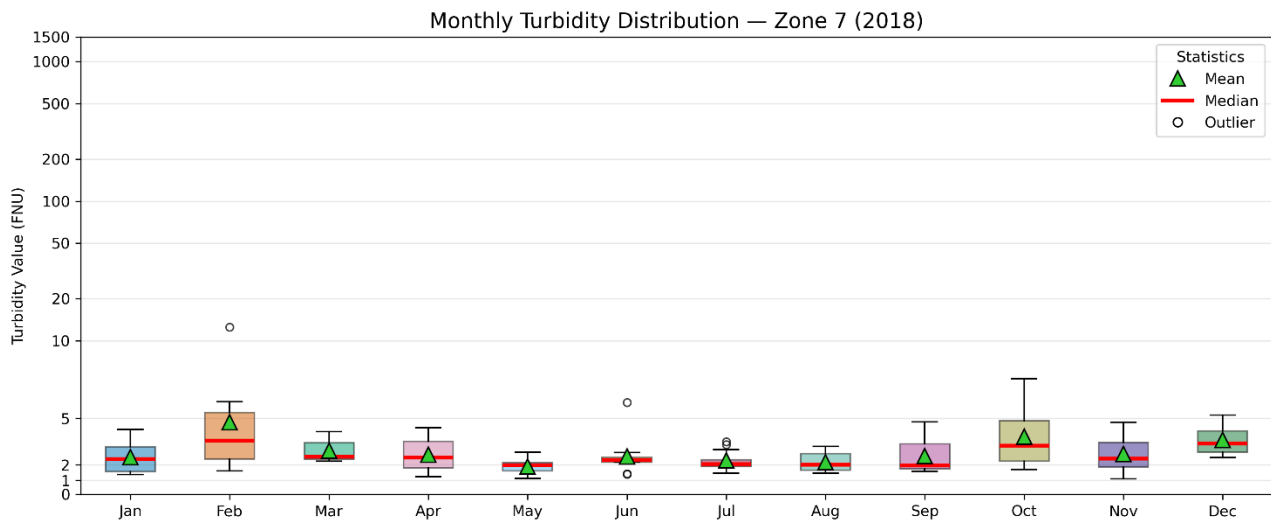


Figure A.104 Monthly Turbidity Distribution by Month for Zone 7 (2018)

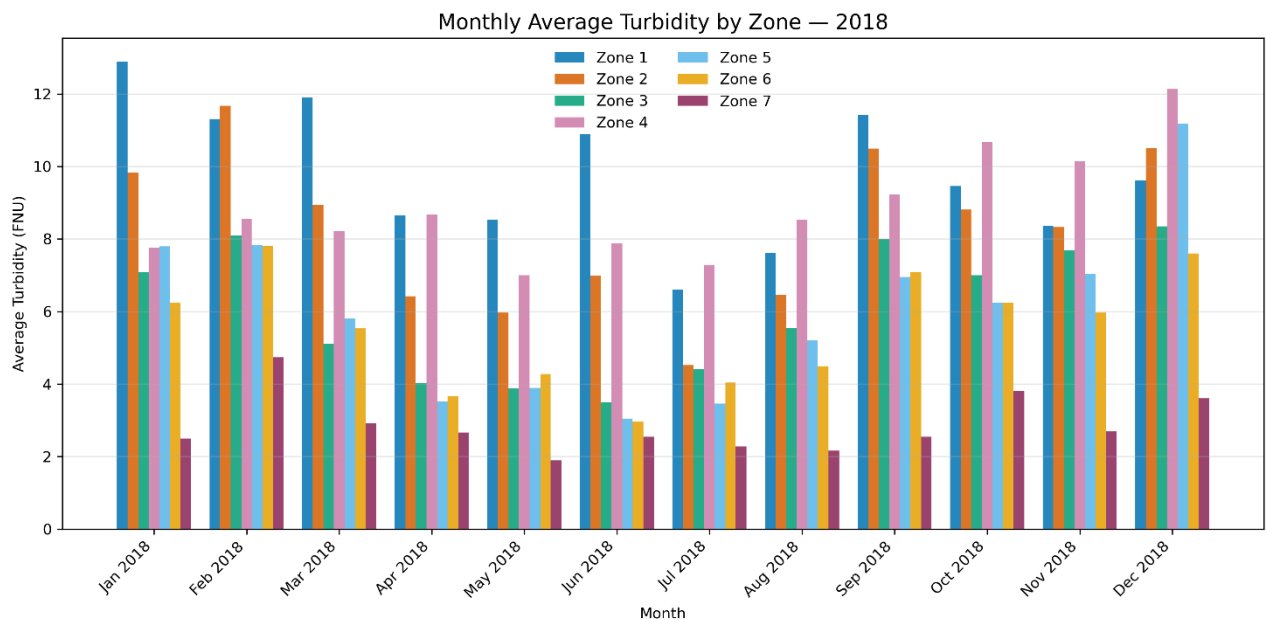


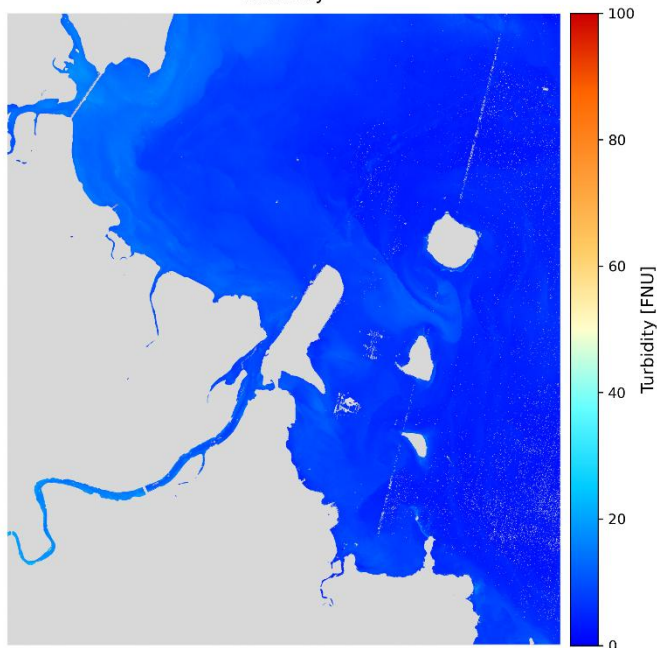
Figure A.105 Monthly Turbidity Distribution by Month (2018)

Sensor: S2A MSI | Local Time: 2018-01-17 09:54:16 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2017-08-20 09:54:24 AEST

Surface Reflectance RGB



Turbidity

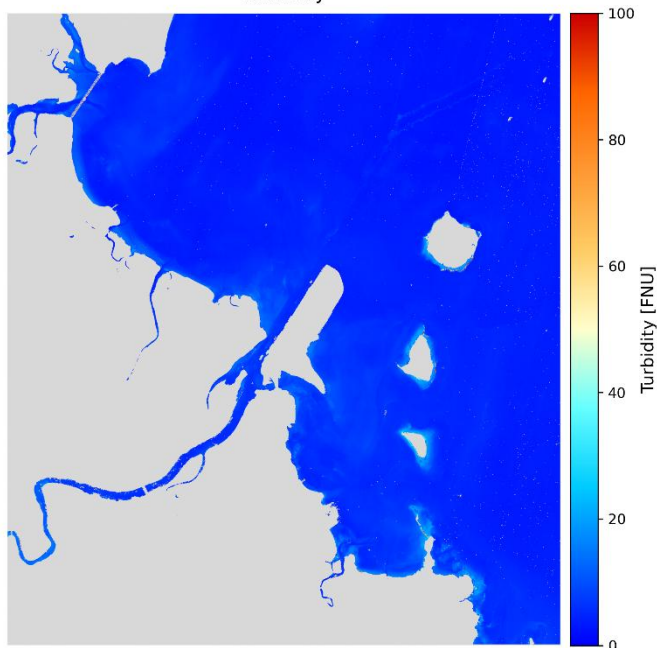


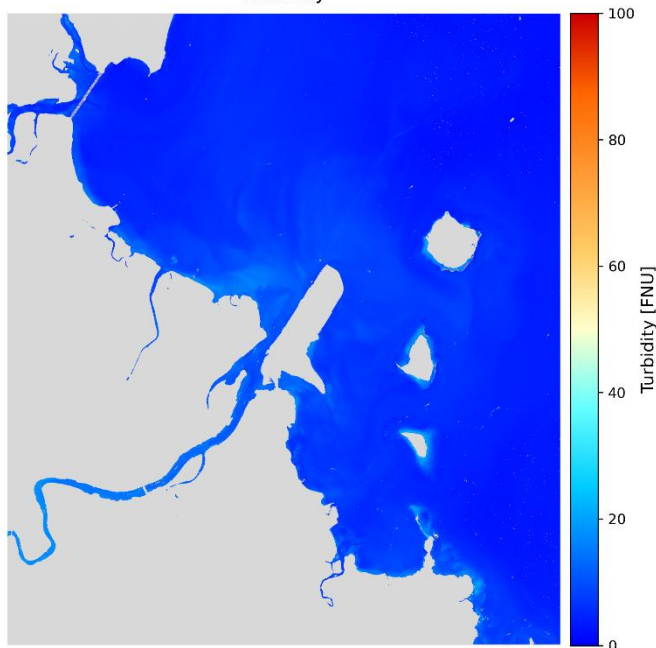
Figure A.106 Representative turbidity conditions in 2018. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2018-09-09 09:54:13 AEST

Surface Reflectance RGB

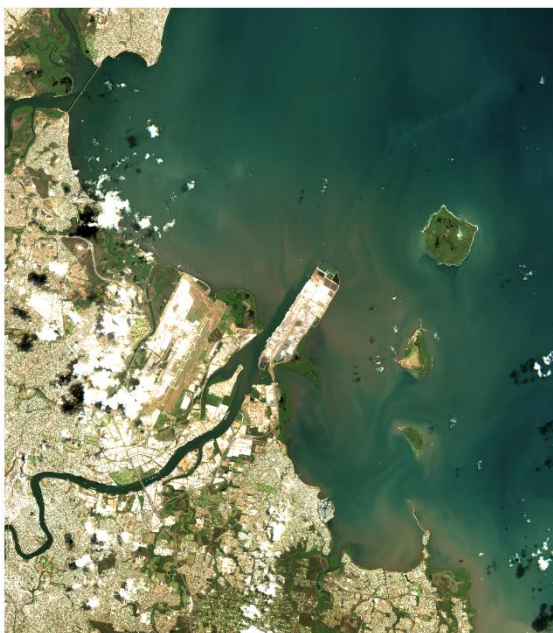


Turbidity



Sensor: S2B MSI | Local Time: 2018-11-28 09:54:20 AEST

Surface Reflectance RGB



Turbidity

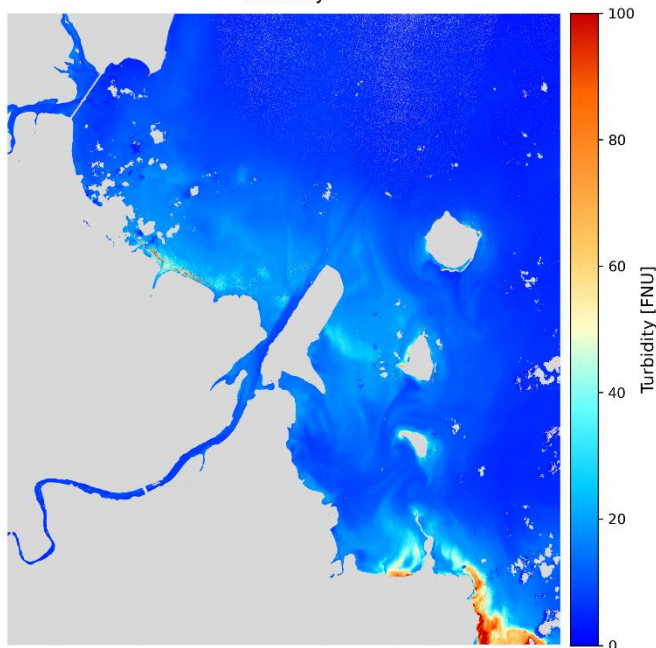


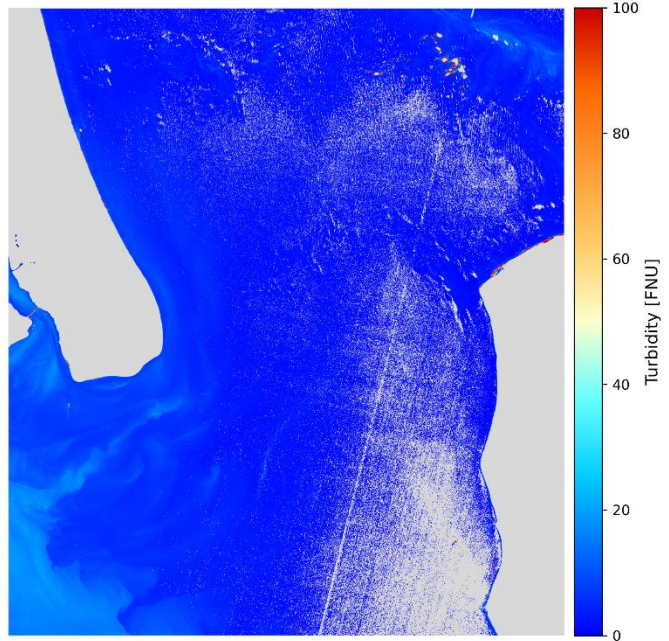
Figure A.107 Representative turbidity conditions in 2018. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2018-01-17 09:54:02 AEST

Surface Reflectance RGB

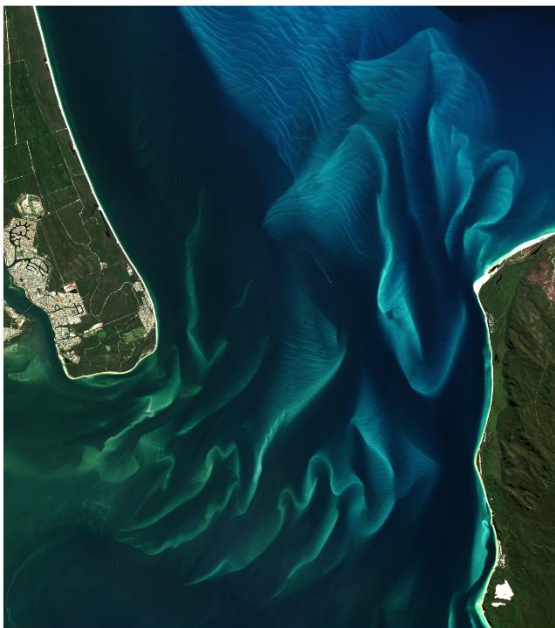


Turbidity



Sensor: S2A MSI | Local Time: 2018-05-10 10:04:07 AEST

Surface Reflectance RGB



Turbidity

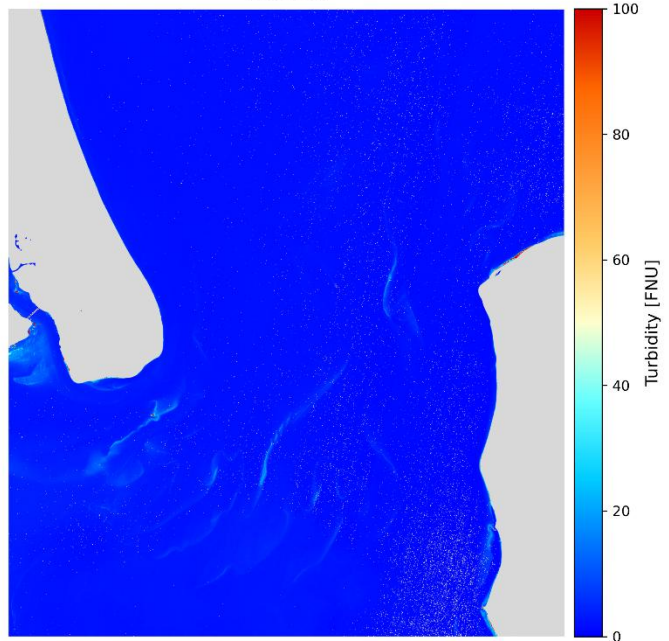
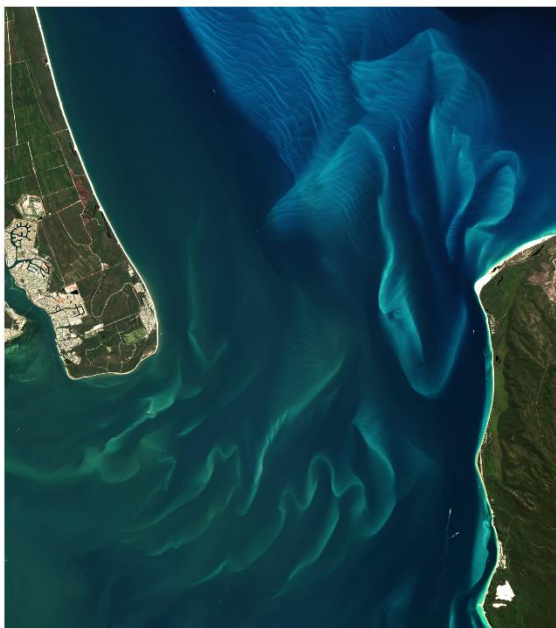


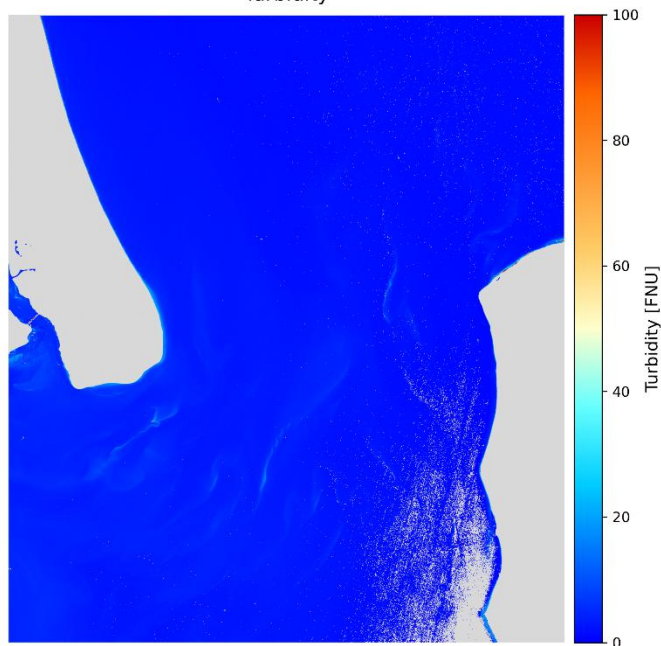
Figure A.108 Representative turbidity conditions in 2018. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2018-09-09 09:54:00 AEST

Surface Reflectance RGB

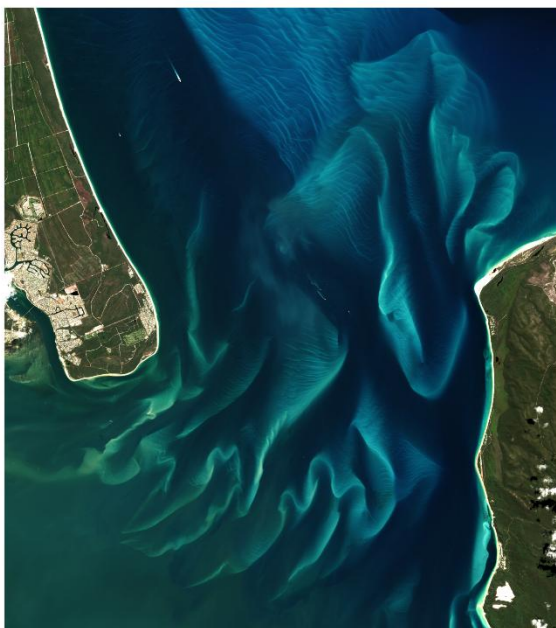


Turbidity



Sensor: S2B MSI | Local Time: 2018-09-19 09:54:01 AEST

Surface Reflectance RGB



Turbidity

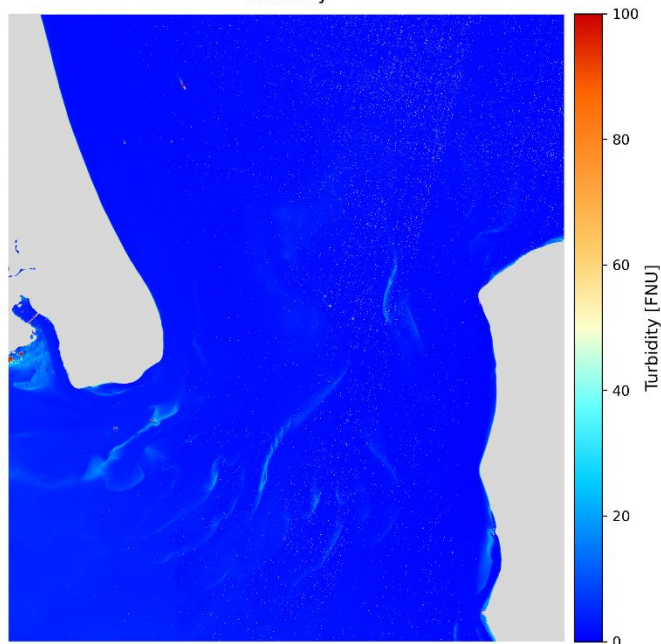


Figure A.109 Representative turbidity conditions in 2018. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.9 Turbidity Pattern 2019

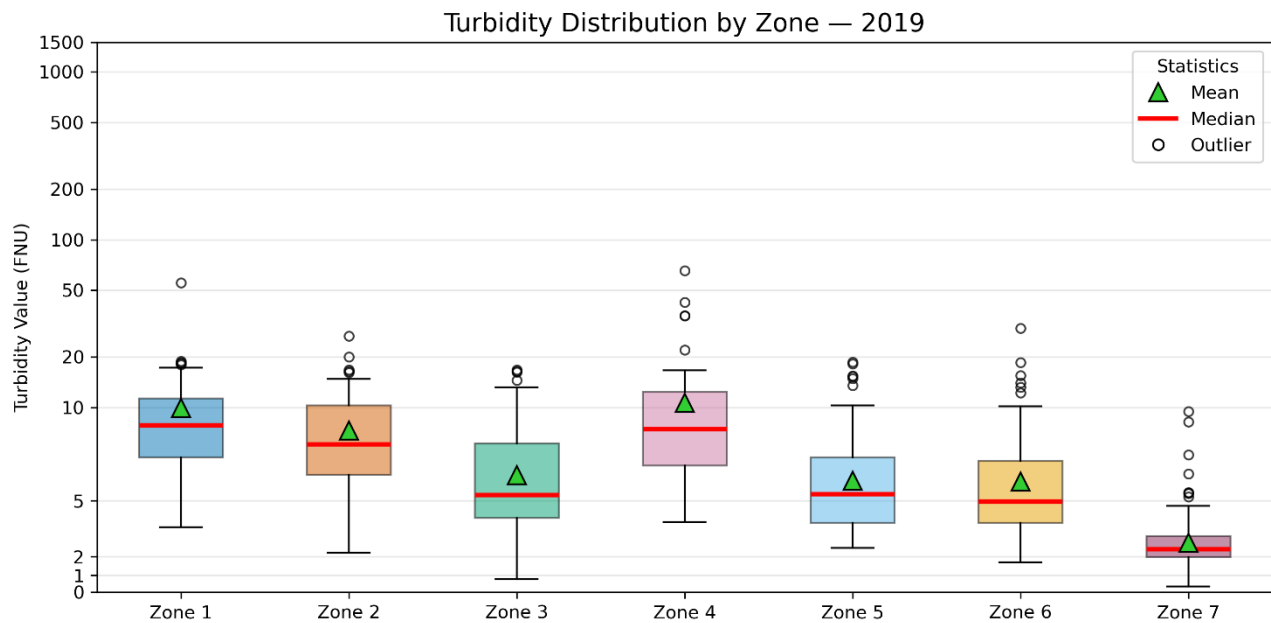


Figure A.110 Turbidity distributions by reporting zone (2019).

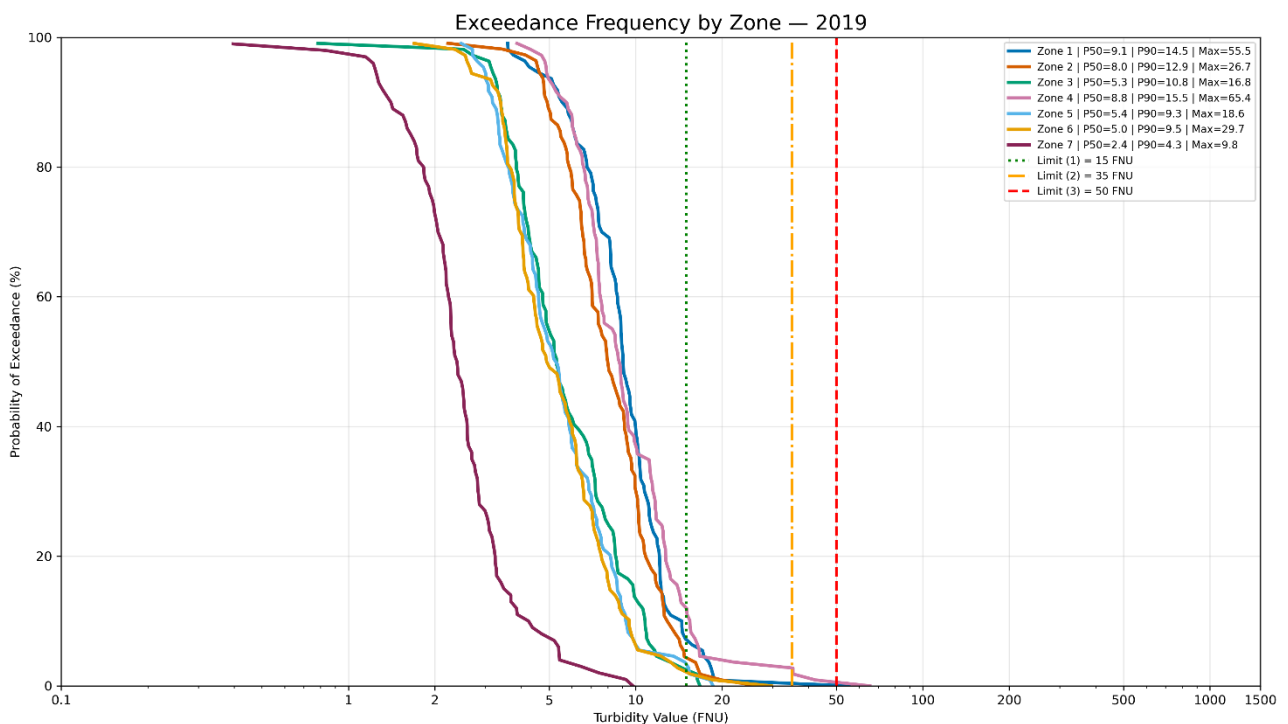


Figure A.111 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2019).

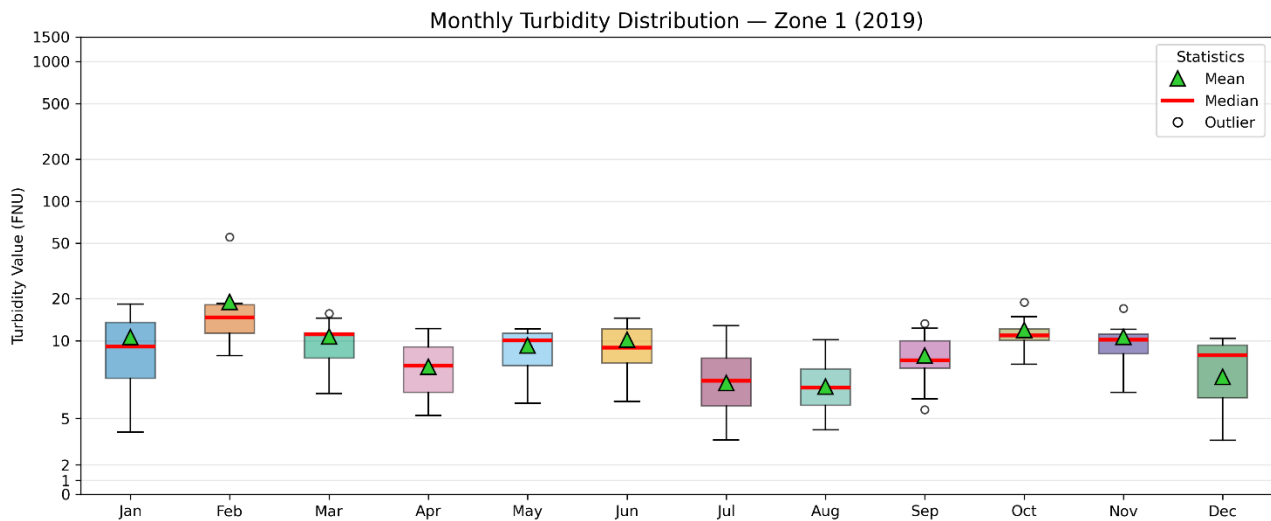


Figure A.112 Monthly Turbidity Distribution by Month for Zone 1 (2019)

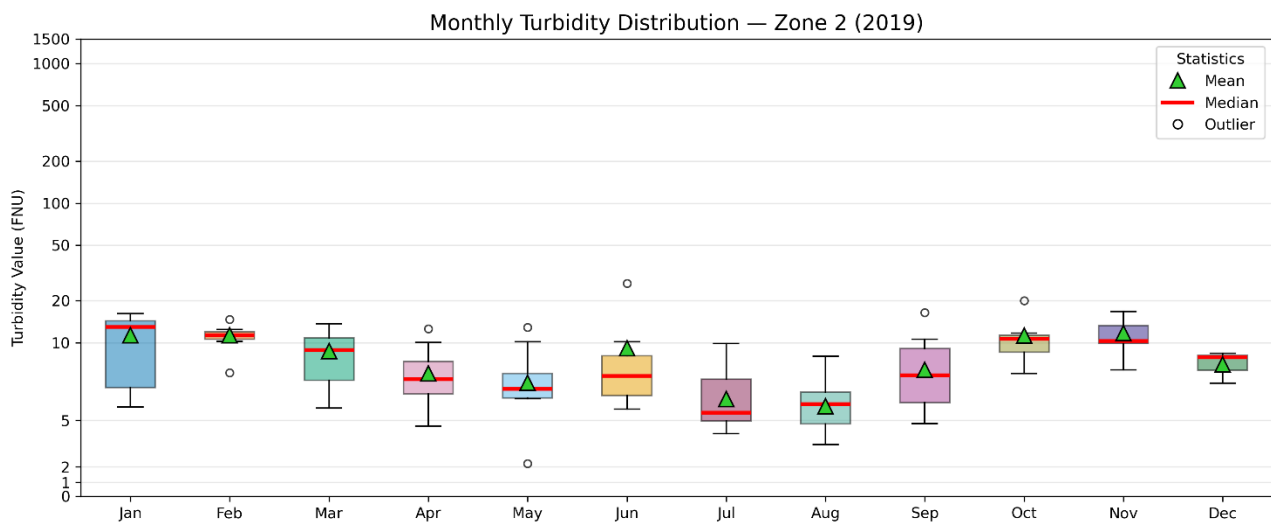


Figure A.113 Monthly Turbidity Distribution by Month for Zone 2 (2019)

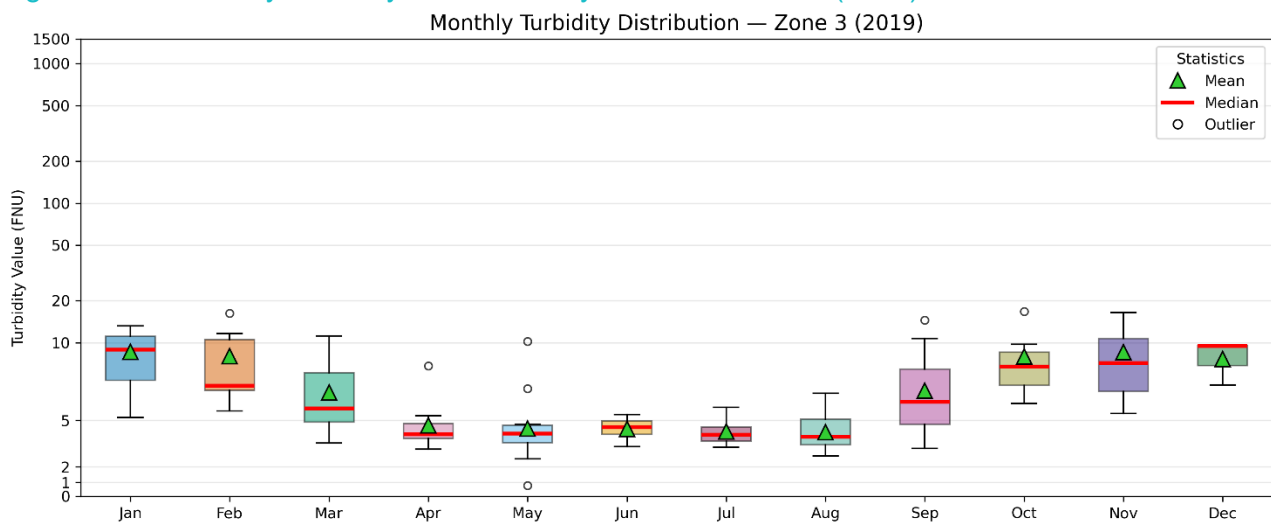


Figure A.114 Monthly Turbidity Distribution by Month for Zone 3 (2019)

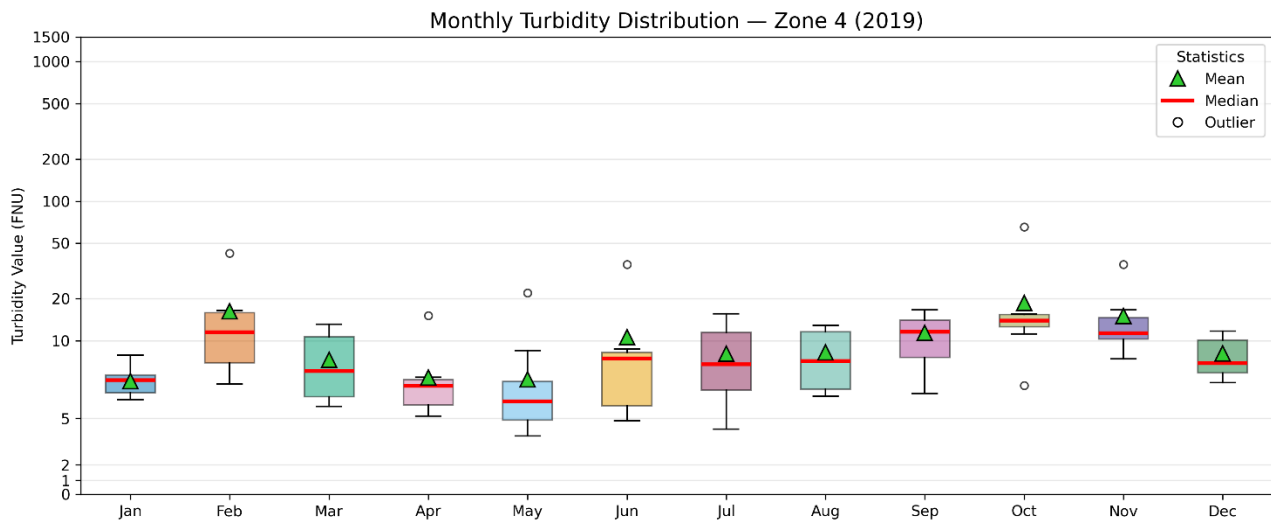


Figure A.115 Monthly Turbidity Distribution by Month for Zone 4 (2019)

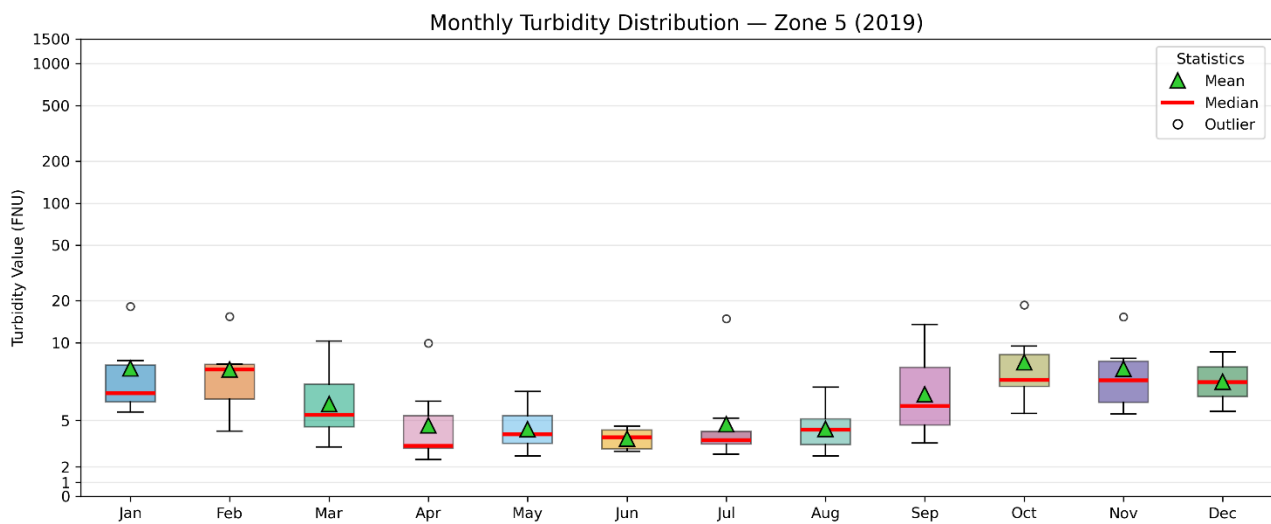


Figure A.116 Monthly Turbidity Distribution by Month for Zone 5 (2019)

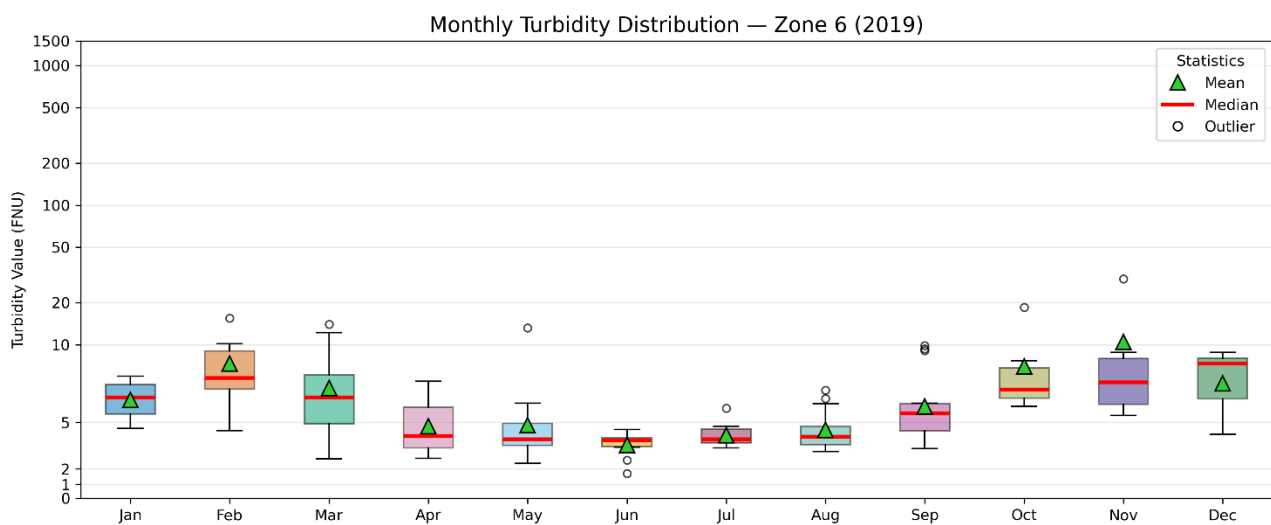


Figure A.117 Monthly Turbidity Distribution by Month for Zone 6 (2019)

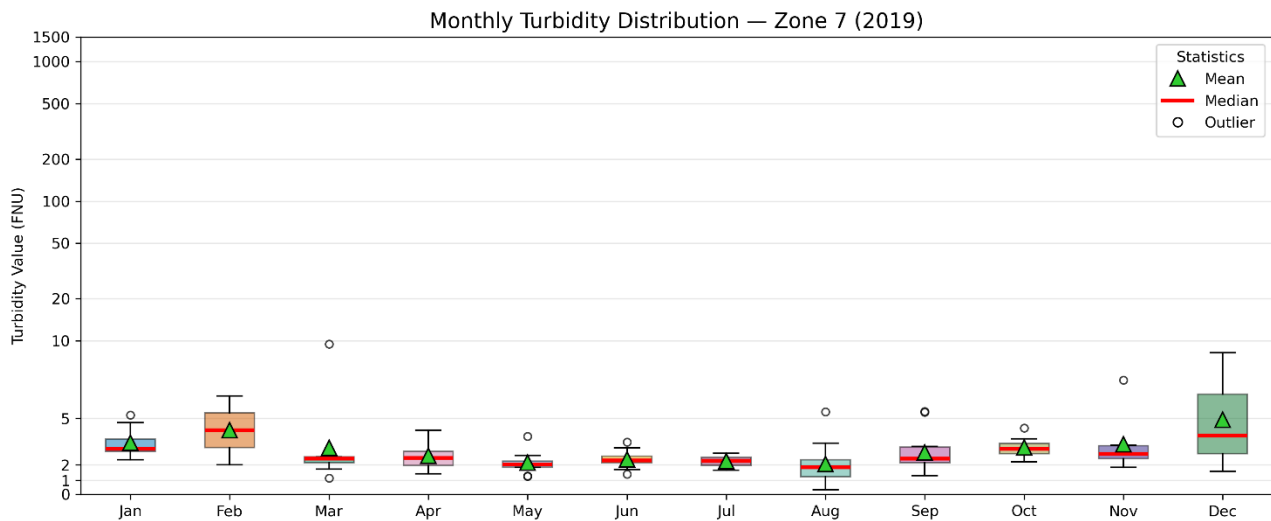


Figure A.118 Monthly Turbidity Distribution by Month for Zone 7 (2019)

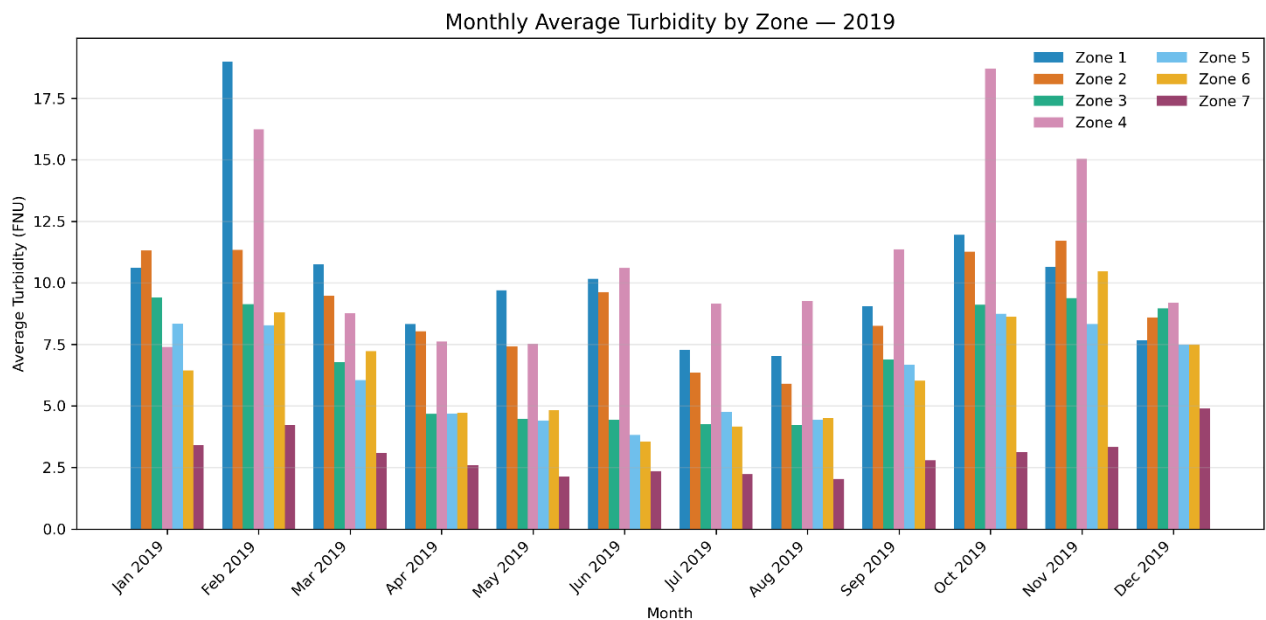


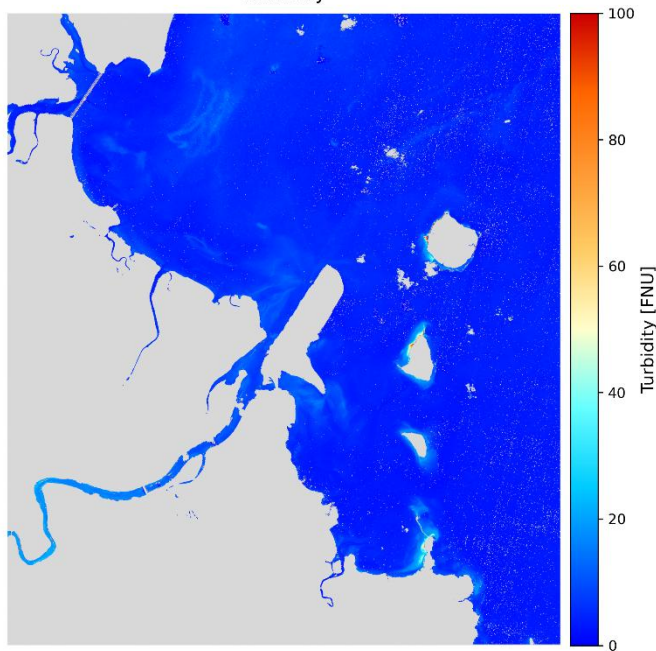
Figure A.119 Monthly Turbidity Distribution by Month (2019)

Sensor: S2A MSI | Local Time: 2019-06-04 10:04:21 AEST

Surface Reflectance RGB

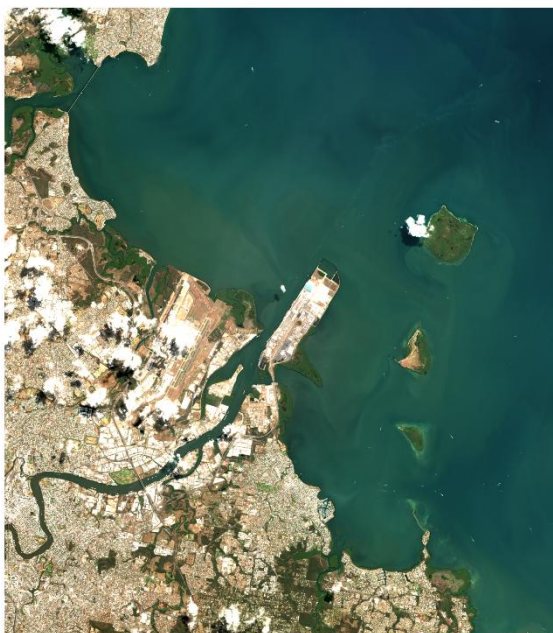


Turbidity



Sensor: S2A MSI | Local Time: 2019-09-29 09:54:25 AEST

Surface Reflectance RGB



Turbidity

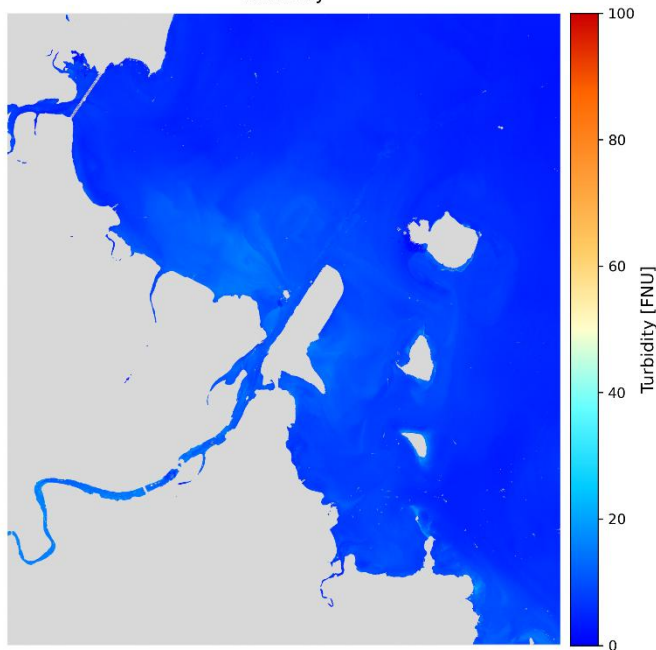


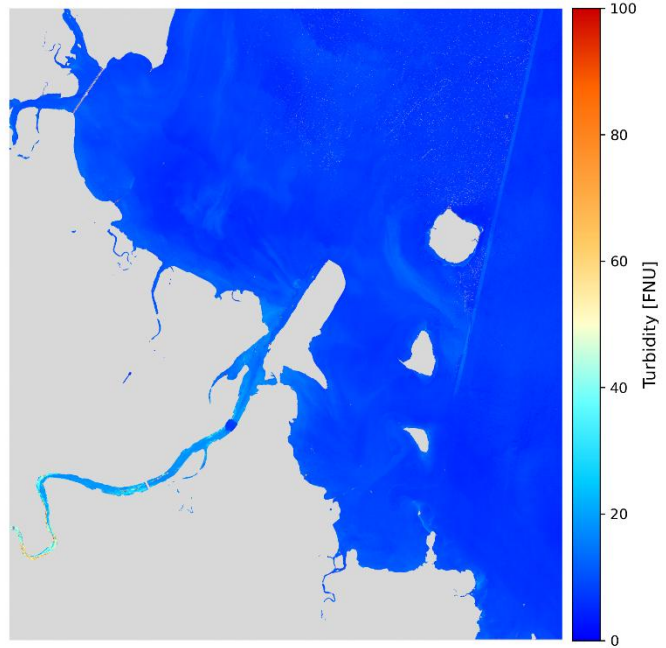
Figure A.120 Representative turbidity conditions in 2019. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2019-02-19 10:04:19 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2019-09-07 10:04:21 AEST

Surface Reflectance RGB



Turbidity

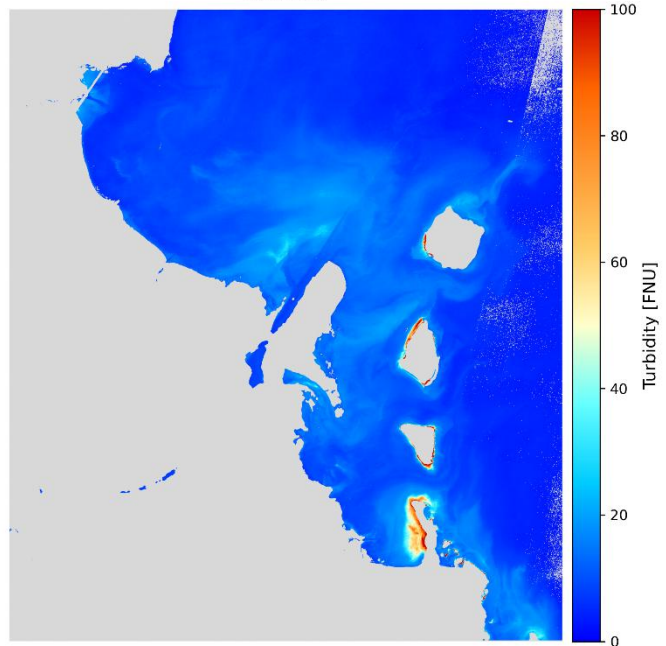
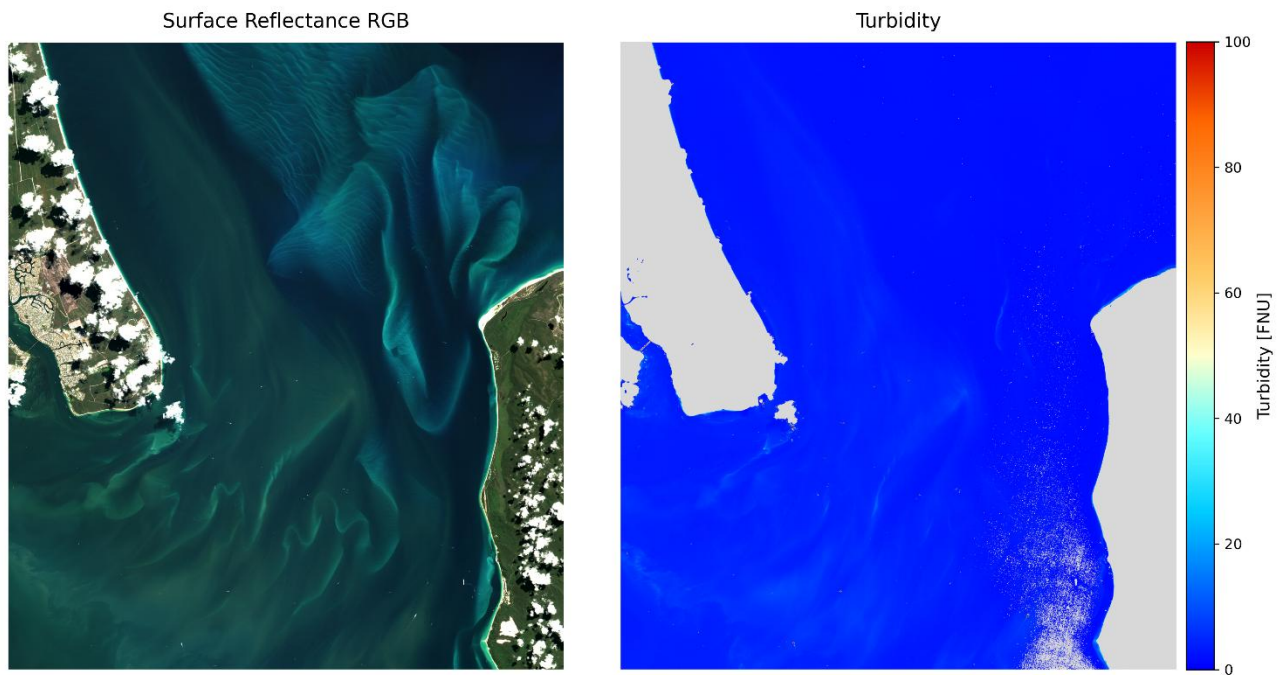


Figure A.121 Representative turbidity conditions in 2019. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2019-03-23 09:54:07 AEST



Sensor: S2A MSI | Local Time: 2019-09-02 10:04:05 AEST

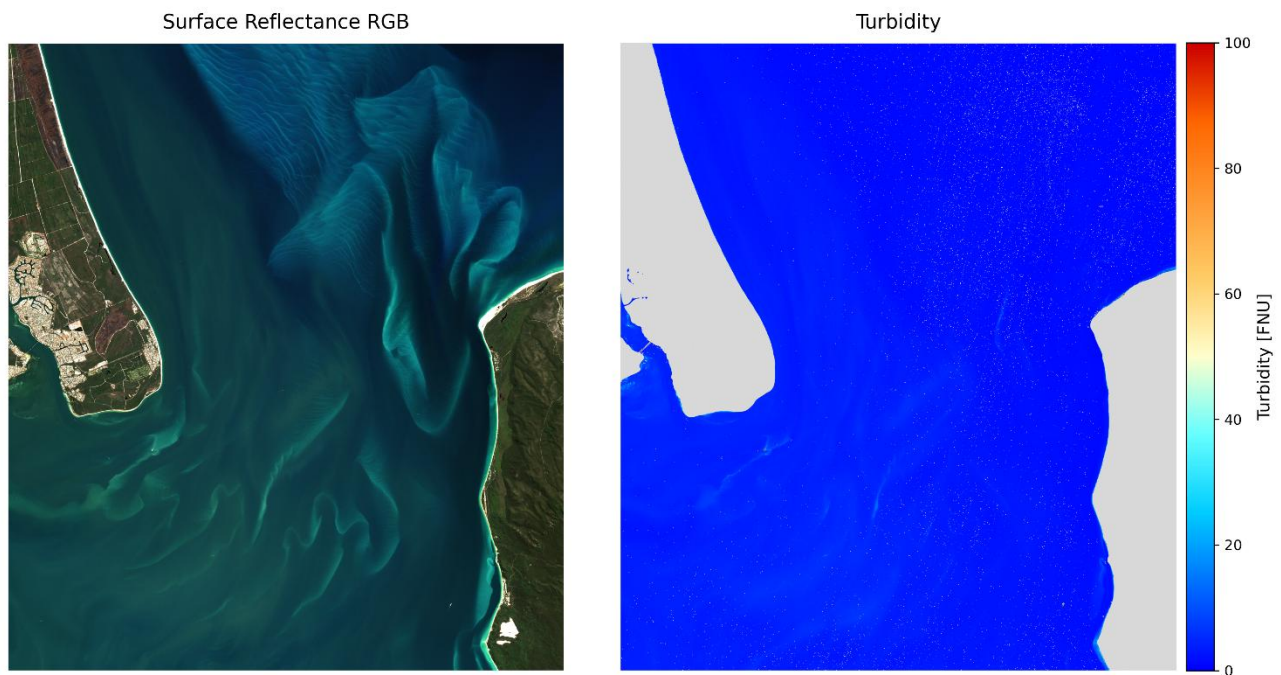


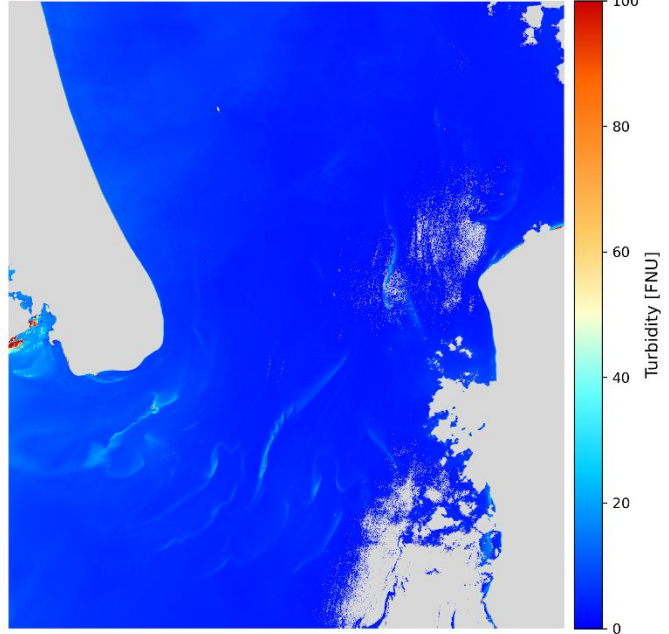
Figure A.122 Representative turbidity conditions in 2019. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2019-10-24 09:54:10 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2019-10-24 09:54:10 AEST

Surface Reflectance RGB



Turbidity

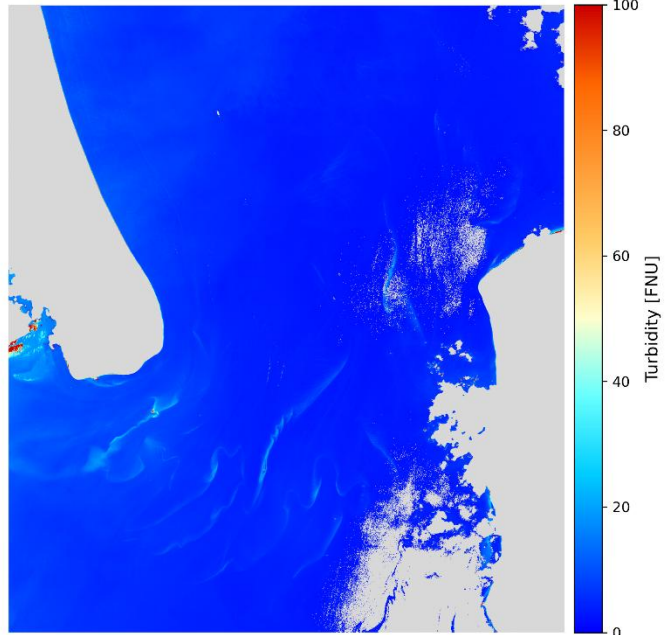


Figure A.123 Representative turbidity conditions in 2019. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.10 Turbidity Pattern 2020

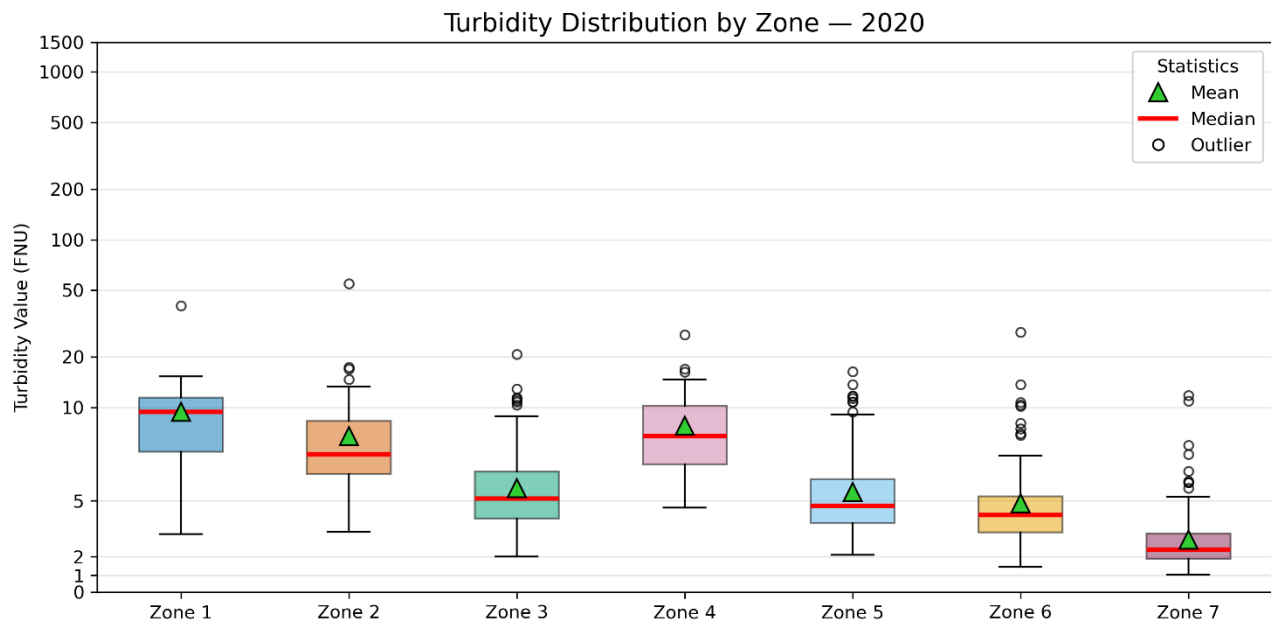


Figure A.124 Turbidity distributions by reporting zone (2020).

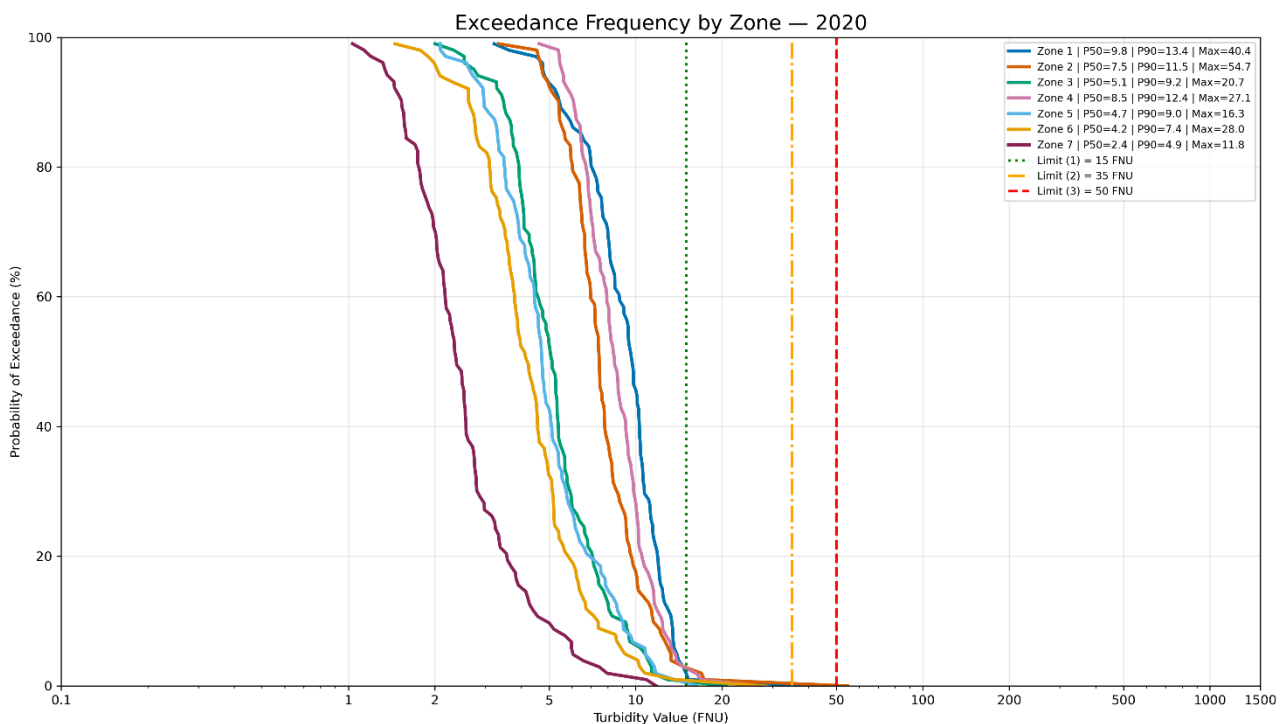


Figure A.125 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2020).

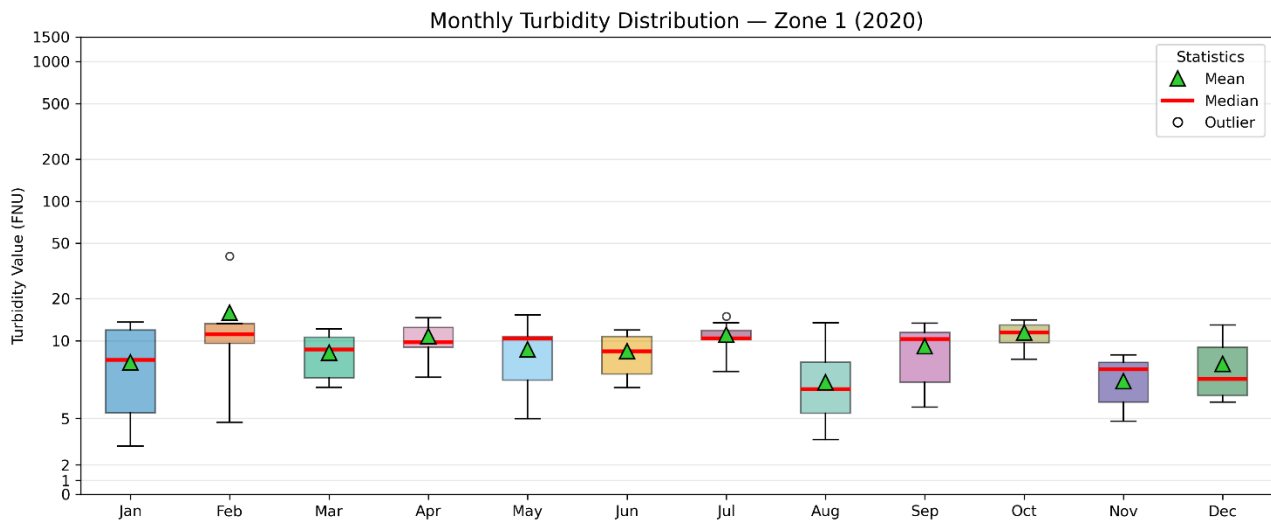


Figure A.126 Monthly Turbidity Distribution by Month for Zone 1 (2020)

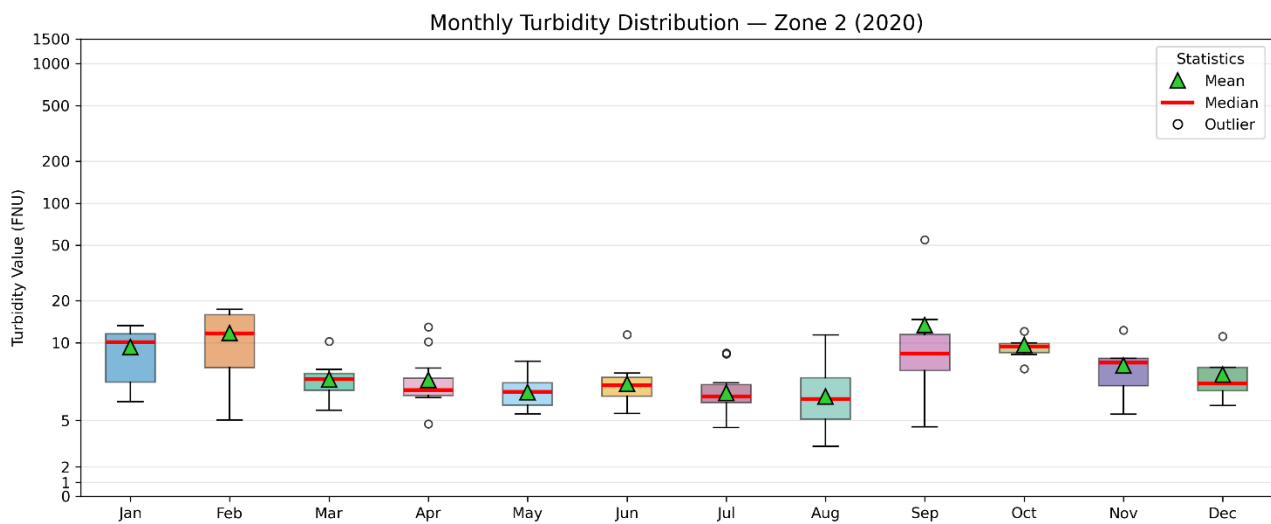


Figure A.127 Monthly Turbidity Distribution by Month for Zone 2 (2020)

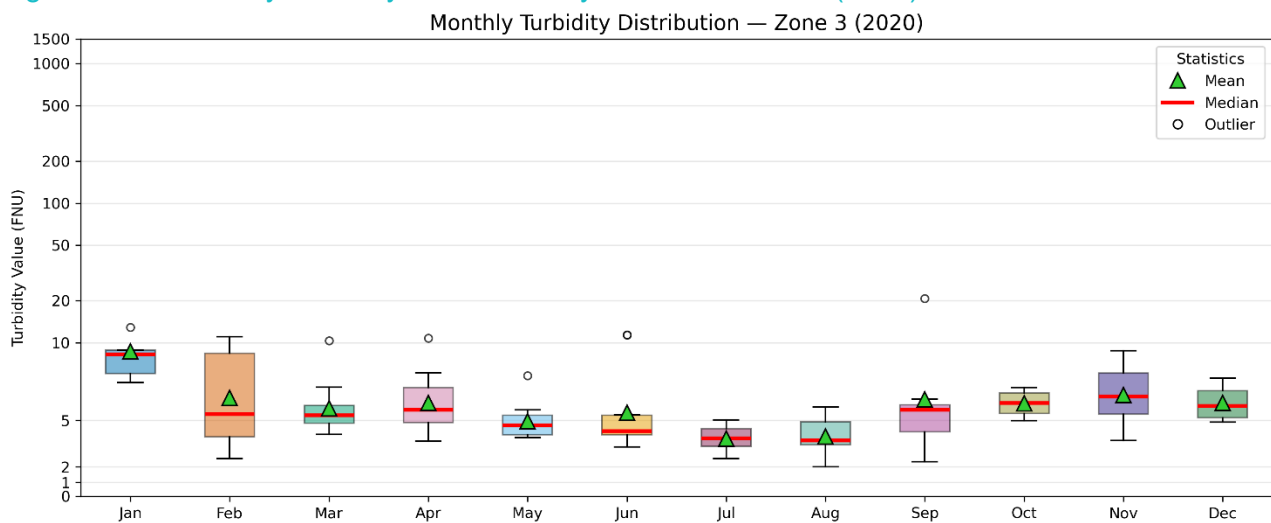


Figure A.128 Monthly Turbidity Distribution by Month for Zone 3 (2020)

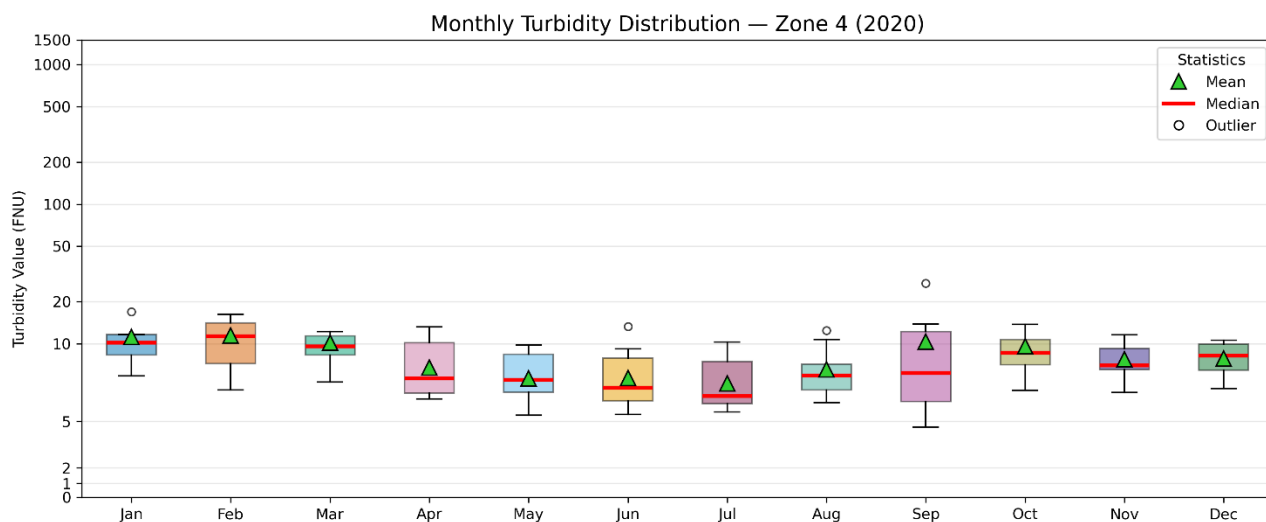


Figure A.129 Monthly Turbidity Distribution by Month for Zone 4 (2020)

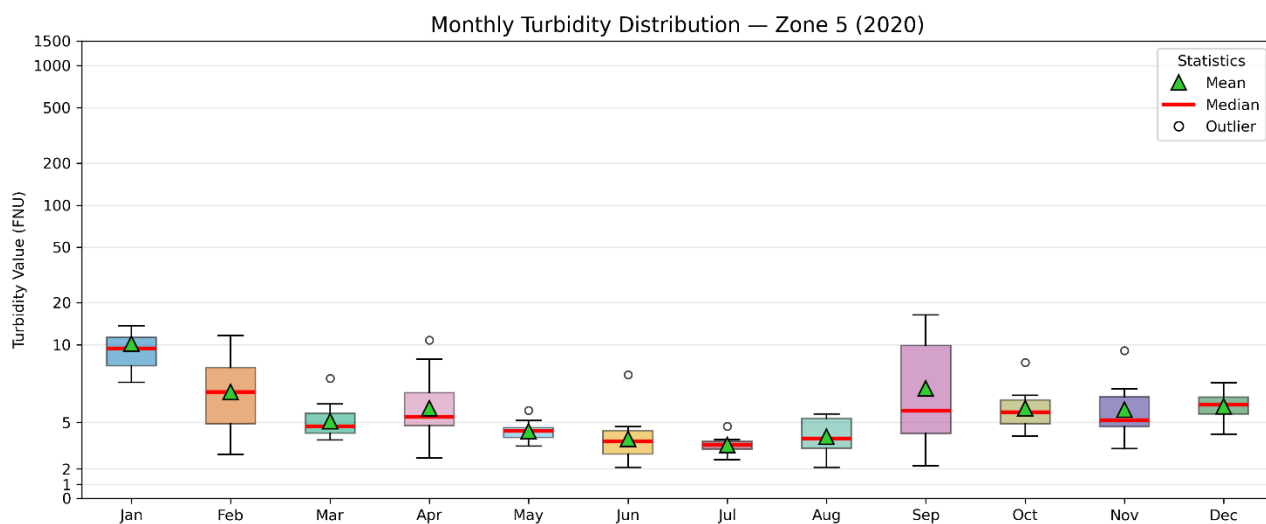


Figure A.130 Monthly Turbidity Distribution by Month for Zone 5 (2020)

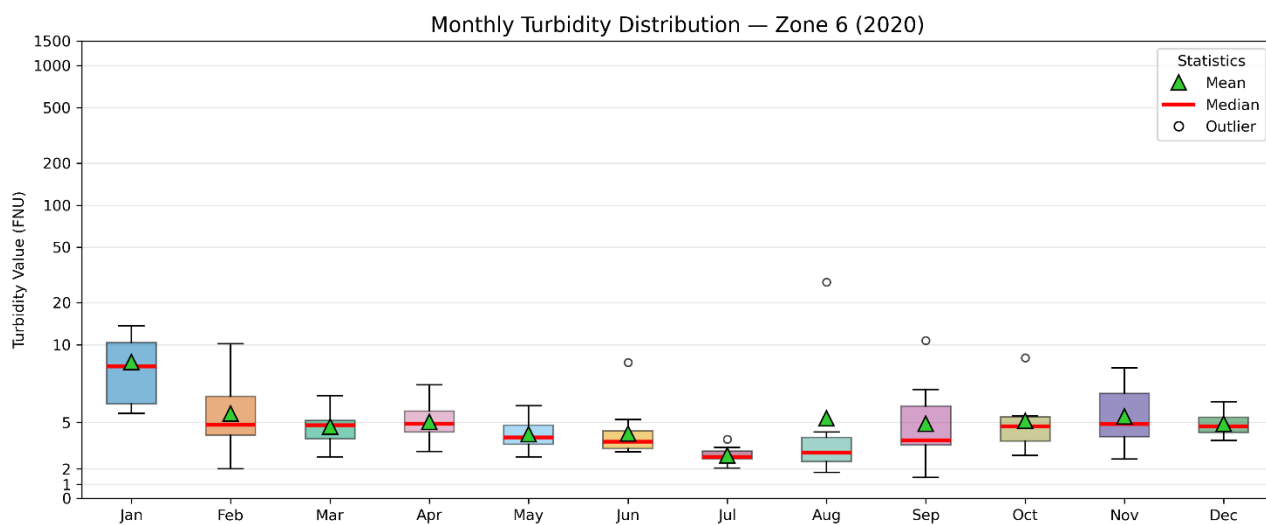


Figure A.131 Monthly Turbidity Distribution by Month for Zone 6 (2020)

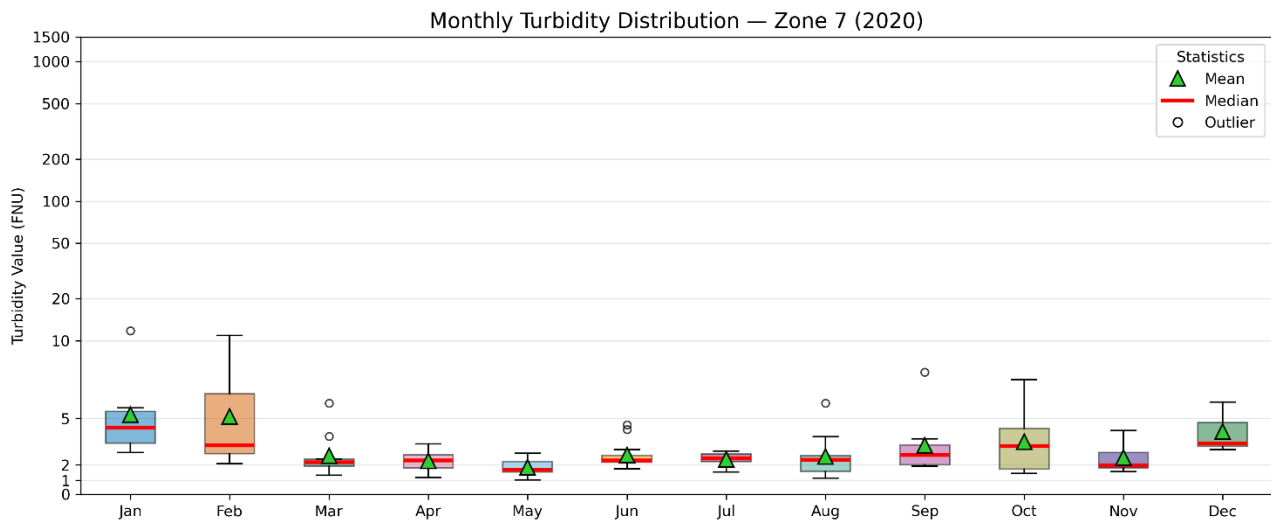


Figure A.132 Monthly Turbidity Distribution by Month for Zone 7 (2020)

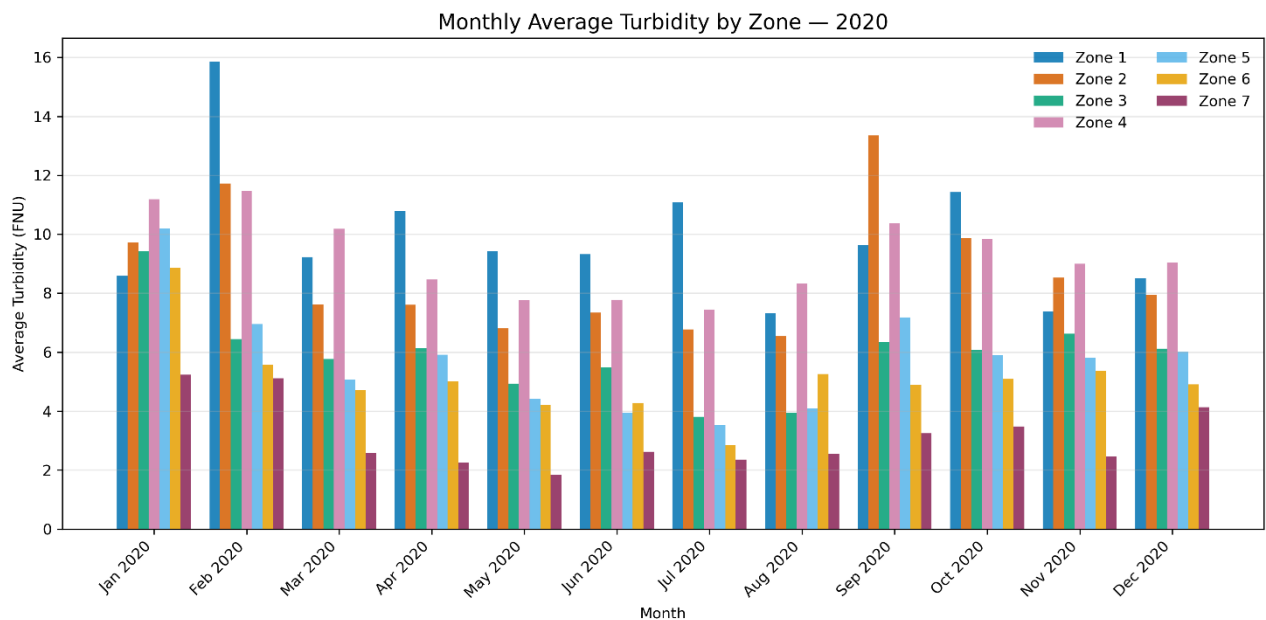
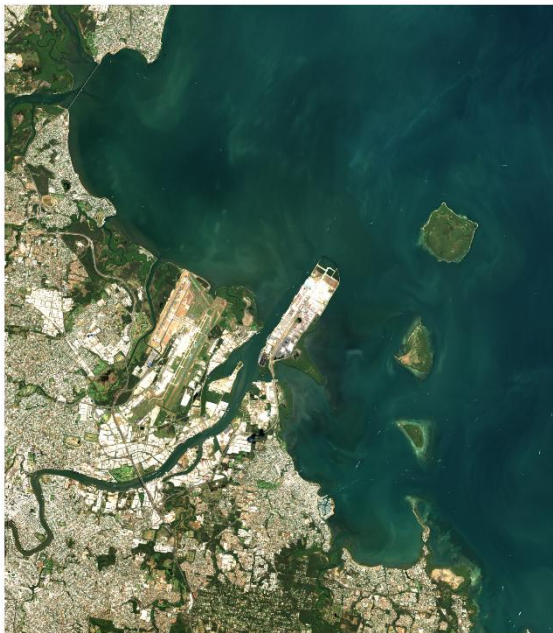


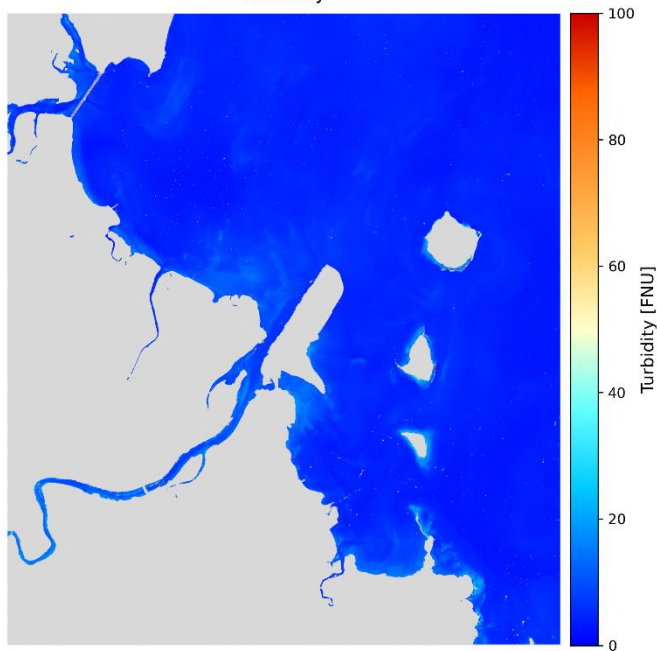
Figure A.133 Monthly Turbidity Distribution by Month (2020)

Sensor: S2A MSI | Local Time: 2020-04-26 09:54:26 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2020-09-26 10:04:25 AEST

Surface Reflectance RGB



Turbidity

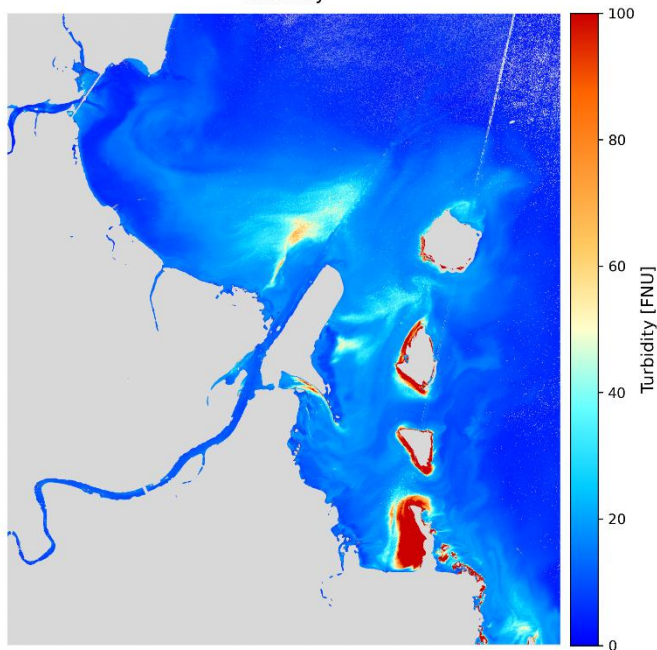


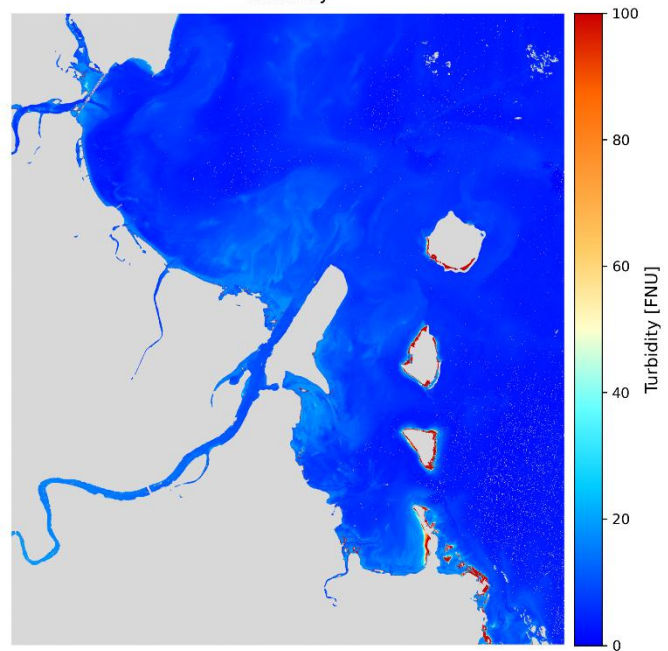
Figure A.134 Representative turbidity conditions in 2020. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2020-05-01 09:54:20 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2020-09-21 10:04:21 AEST

Surface Reflectance RGB



Turbidity

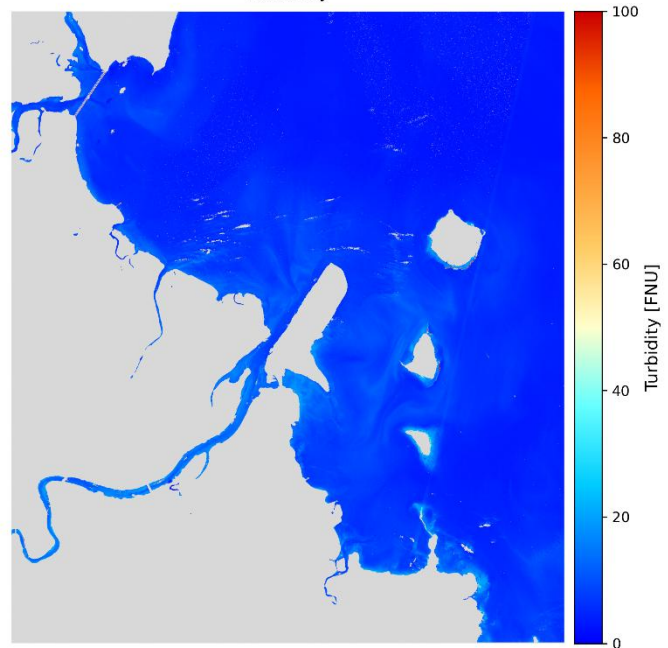
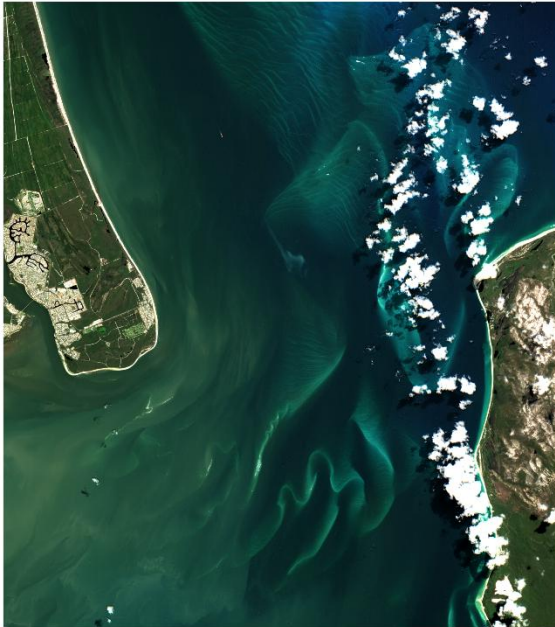


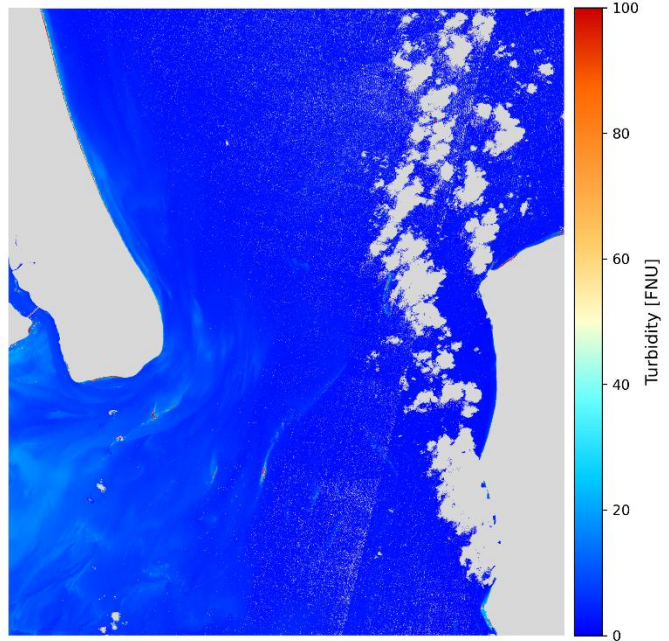
Figure A.135 Representative turbidity conditions in 2020. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2020-03-17 09:54:05 AEST

Surface Reflectance RGB

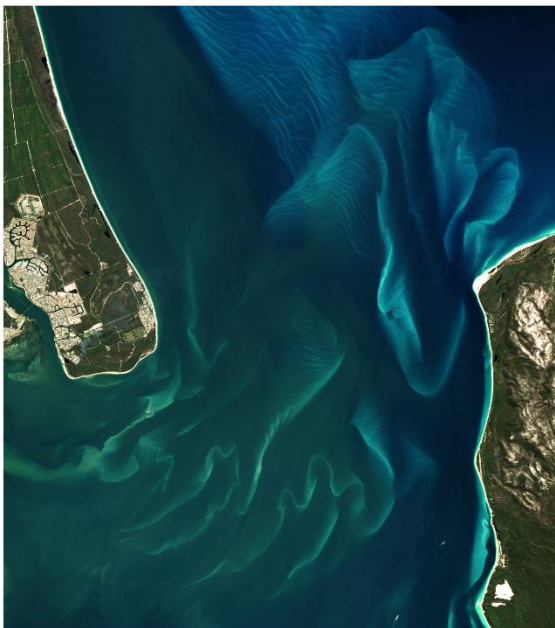


Turbidity



Sensor: S2A MSI | Local Time: 2020-08-24 09:54:15 AEST

Surface Reflectance RGB



Turbidity

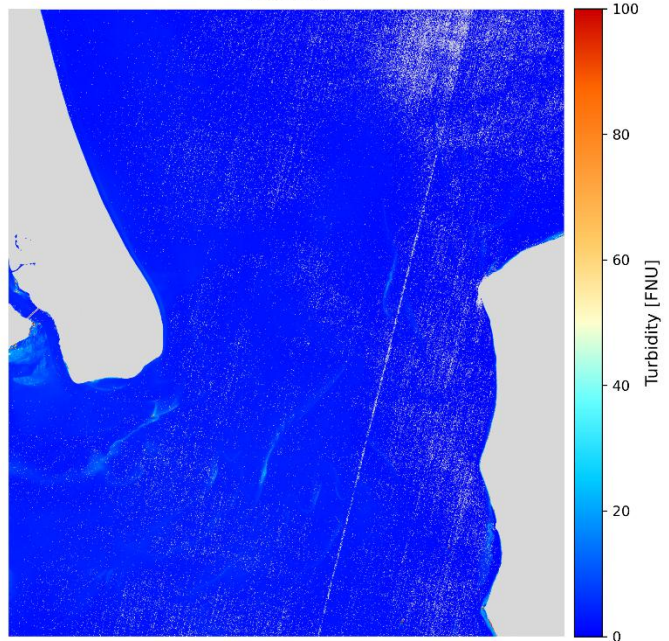


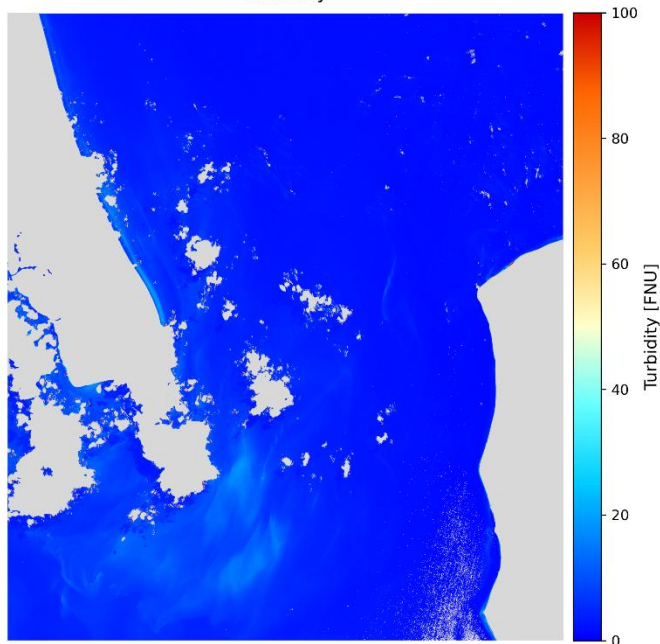
Figure A.136 Representative turbidity conditions in 2020. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2020-04-11 09:54:05 AEST

Surface Reflectance RGB

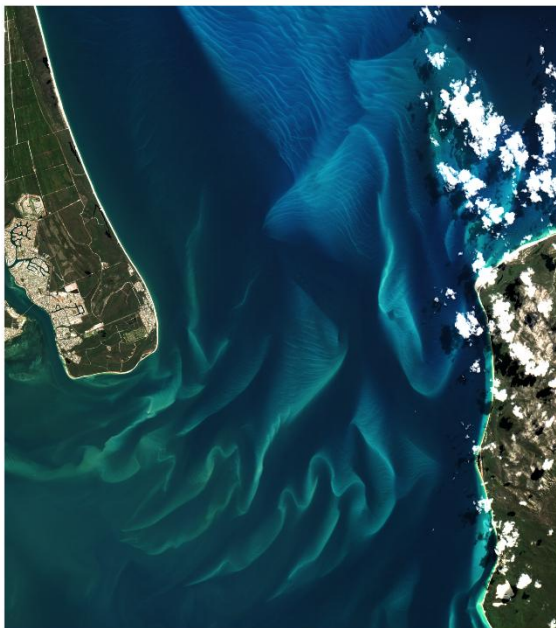


Turbidity



Sensor: S2B MSI | Local Time: 2020-09-01 10:04:08 AEST

Surface Reflectance RGB



Turbidity

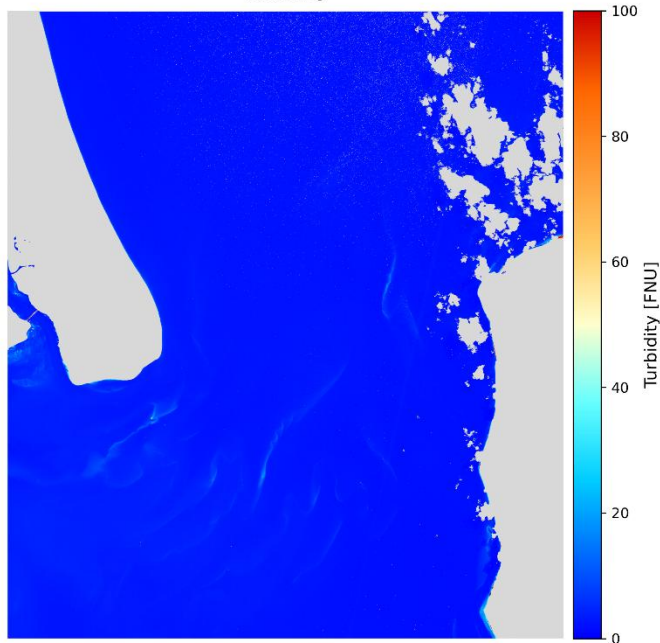


Figure A.137 Representative turbidity conditions in 2020. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.11 Turbidity Pattern 2021

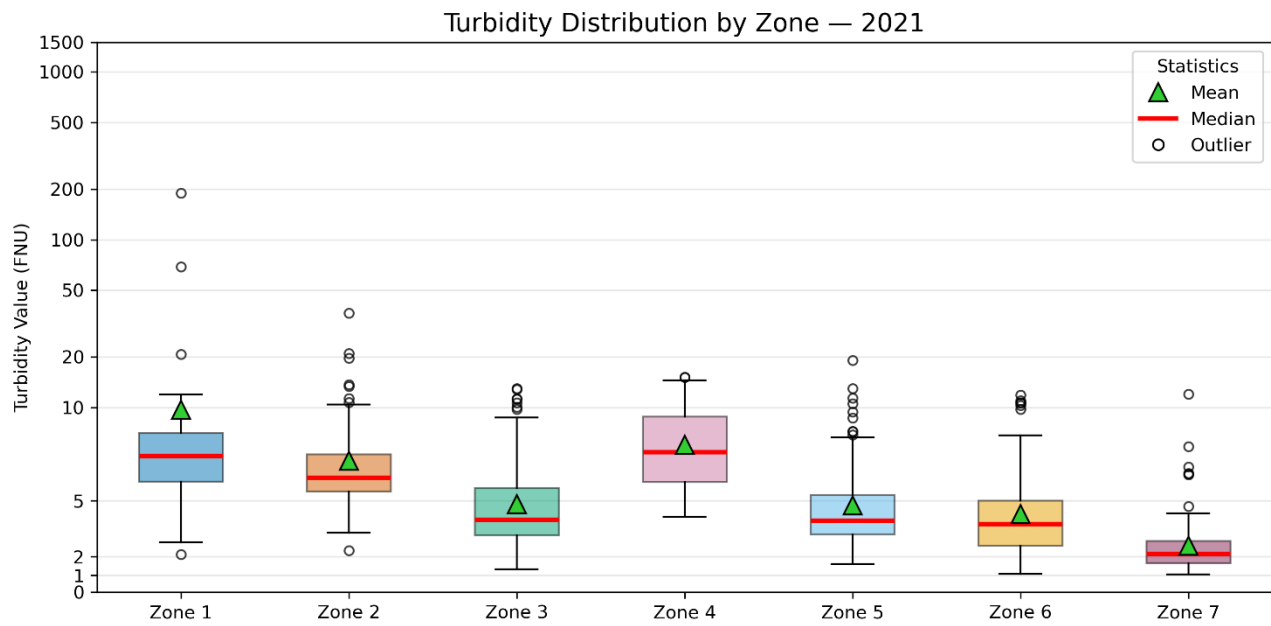


Figure A.138 Turbidity distributions by reporting zone (2021).

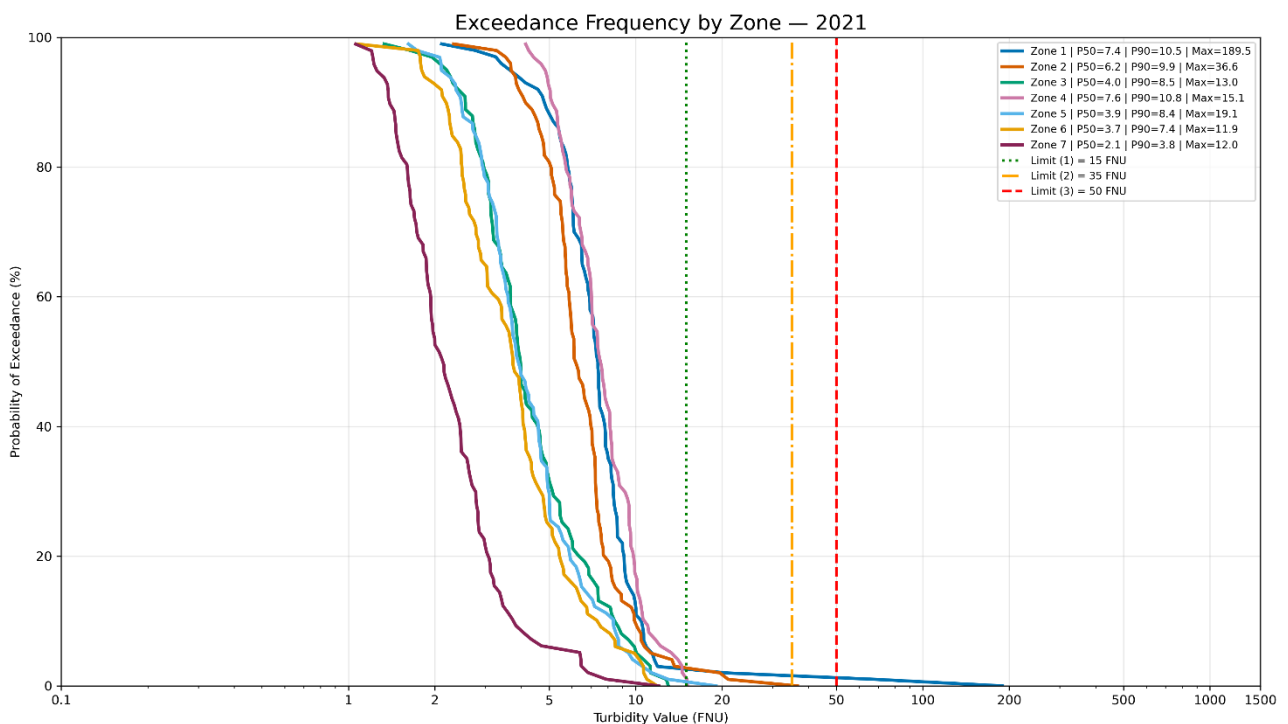


Figure A.139 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2021).

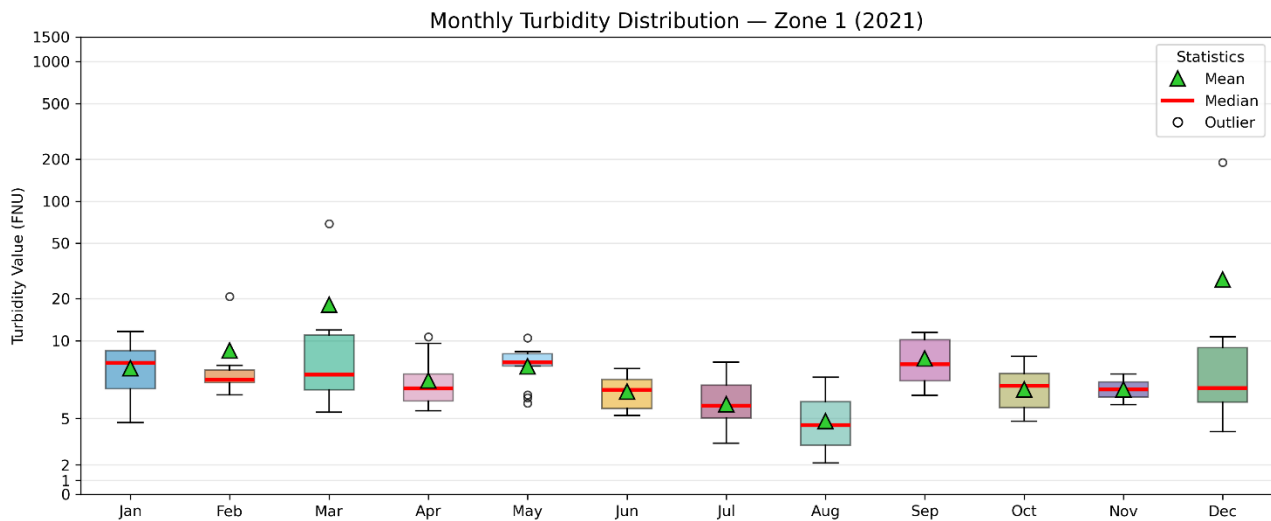


Figure A.140 Monthly Turbidity Distribution by Month for Zone 1 (2021)

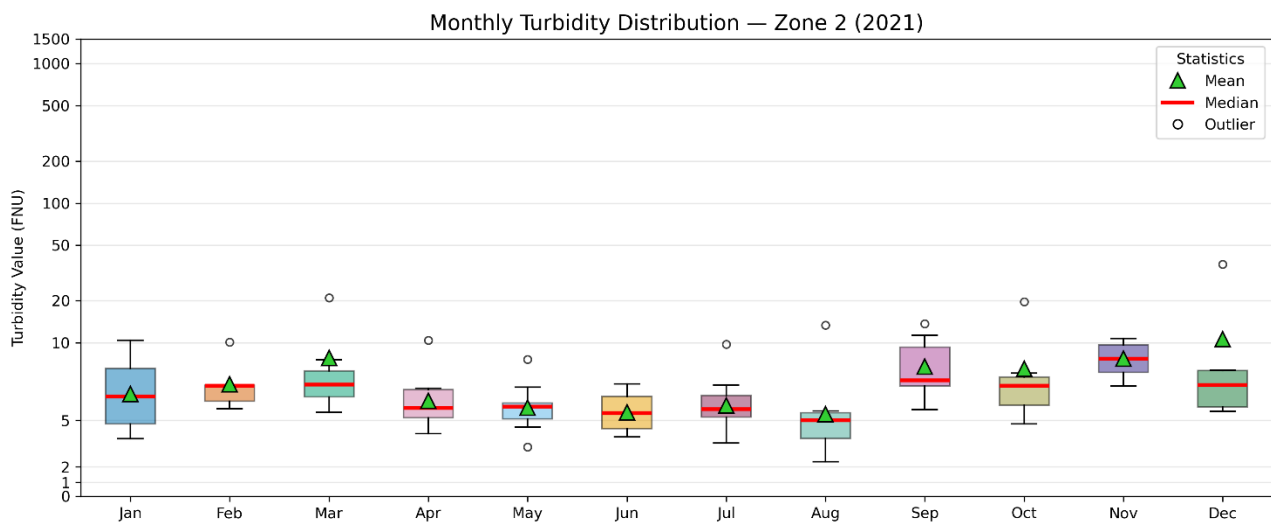


Figure A.141 Monthly Turbidity Distribution by Month for Zone 2 (2021)

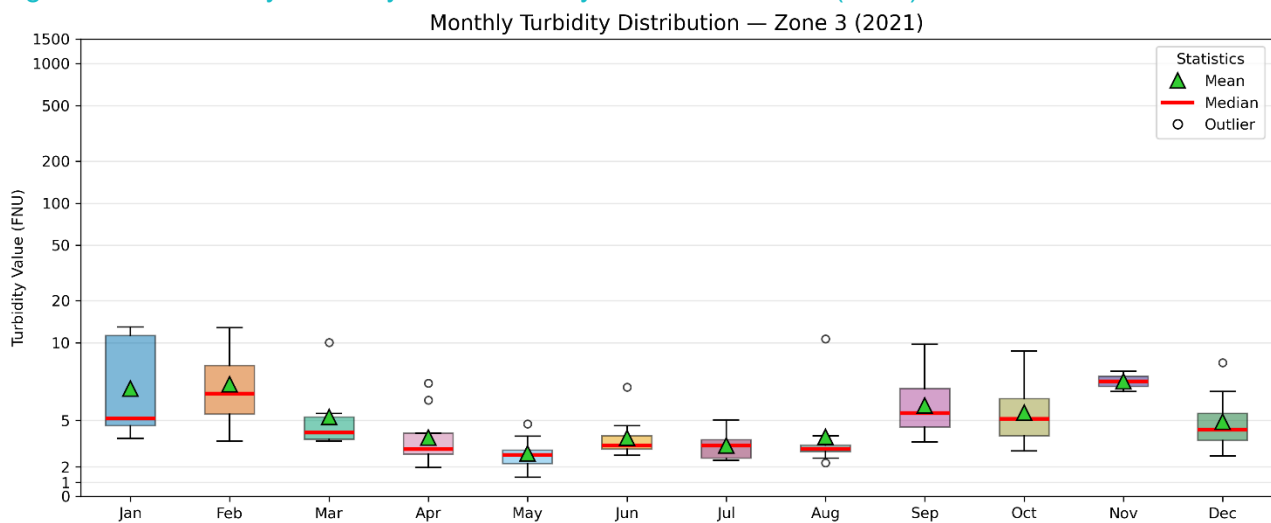


Figure A.142 Monthly Turbidity Distribution by Month for Zone 3 (2021)

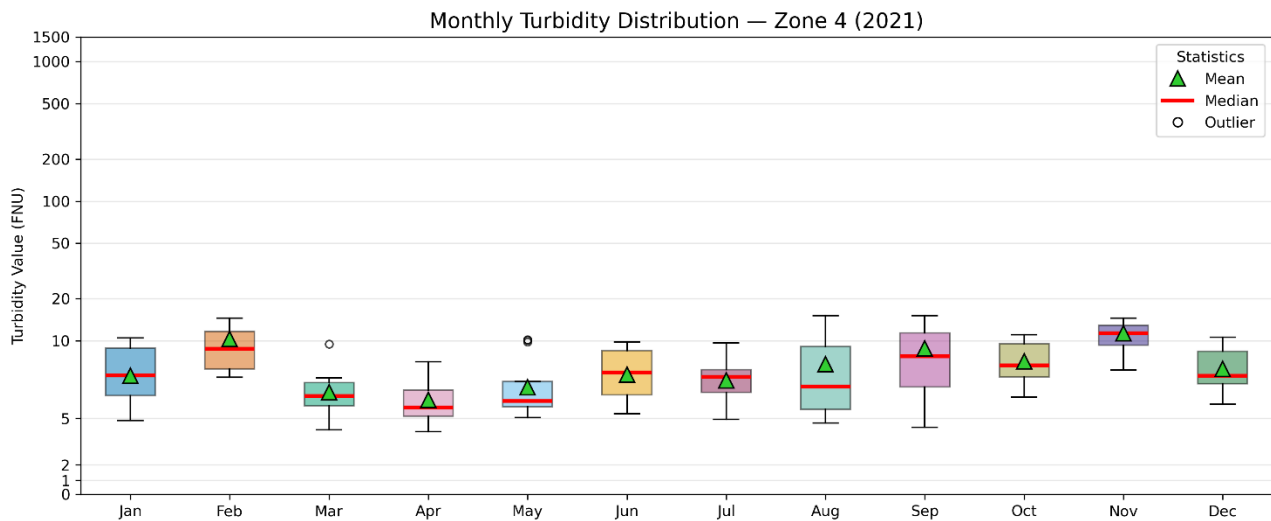


Figure A.143 Monthly Turbidity Distribution by Month for Zone 4 (2021)

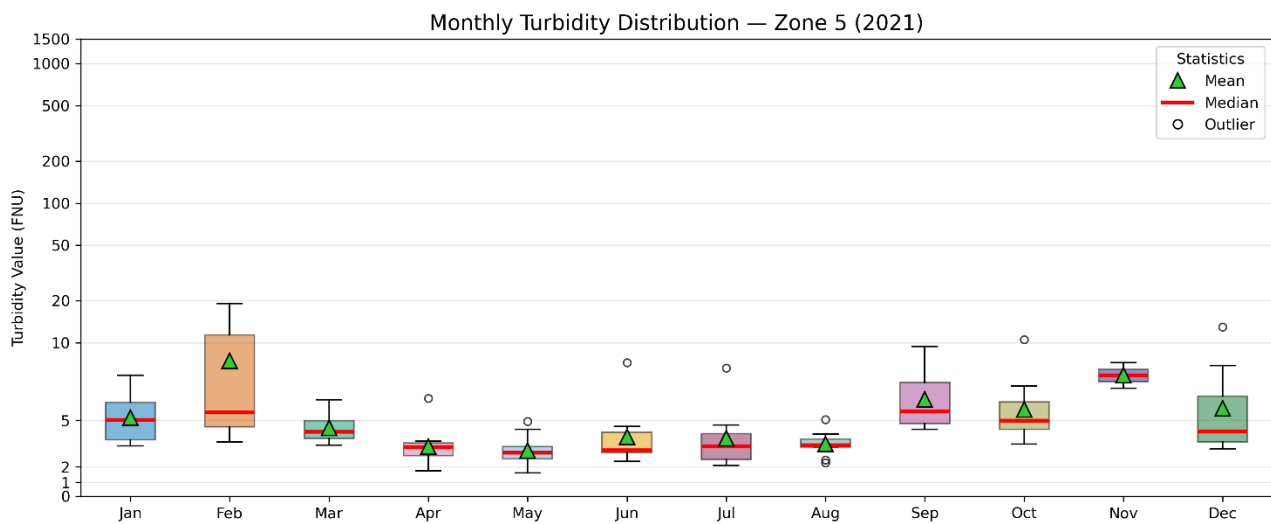


Figure A.144 Monthly Turbidity Distribution by Month for Zone 5 (2021)

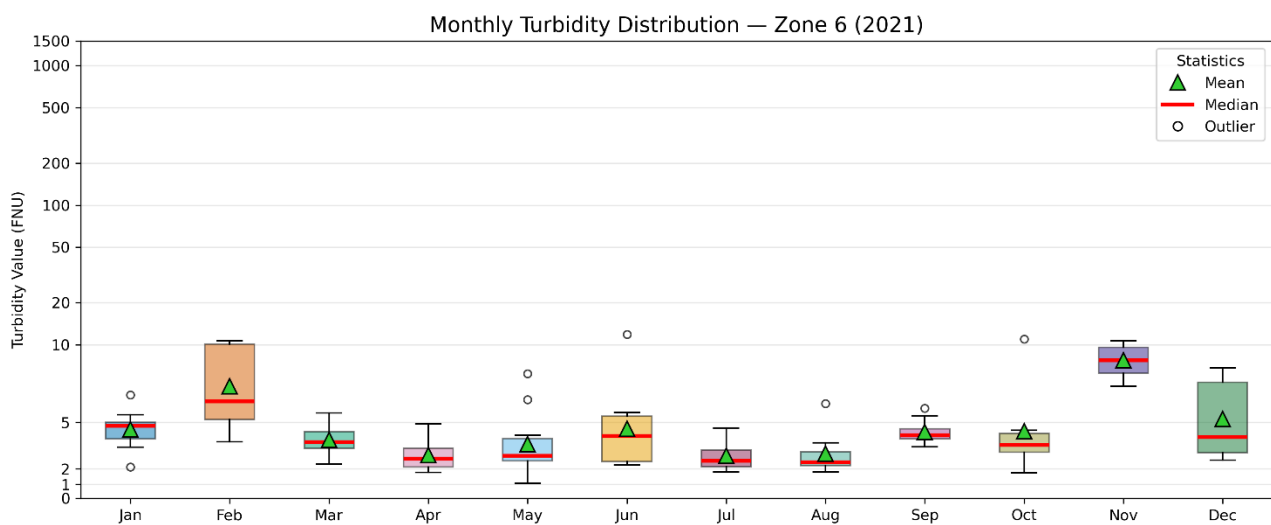


Figure A.145 Monthly Turbidity Distribution by Month for Zone 6 (2021)

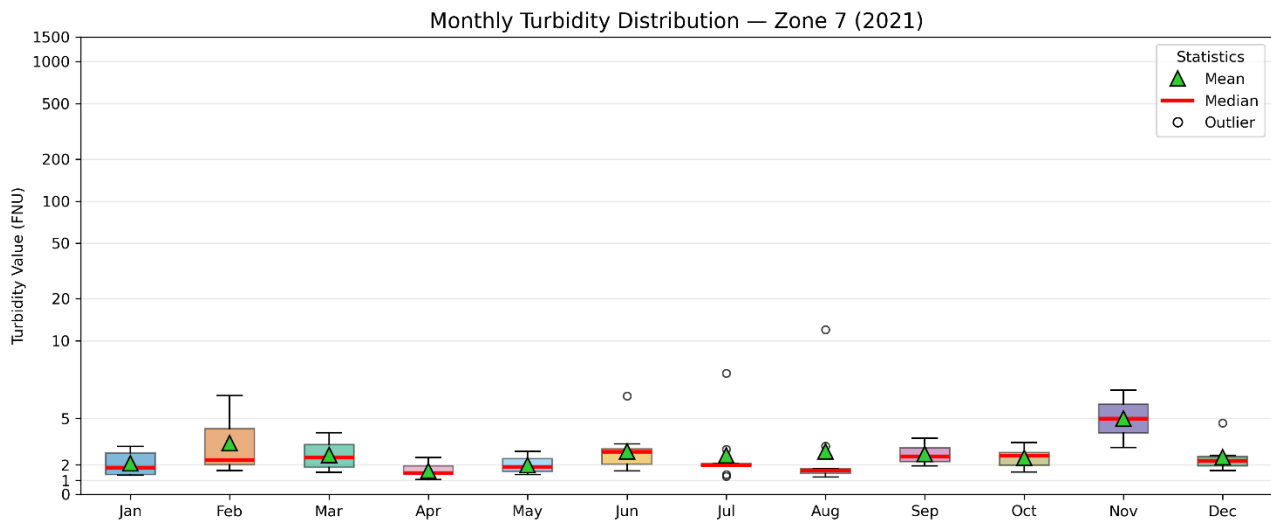


Figure A.146 Monthly Turbidity Distribution by Month for Zone 7 (2021)

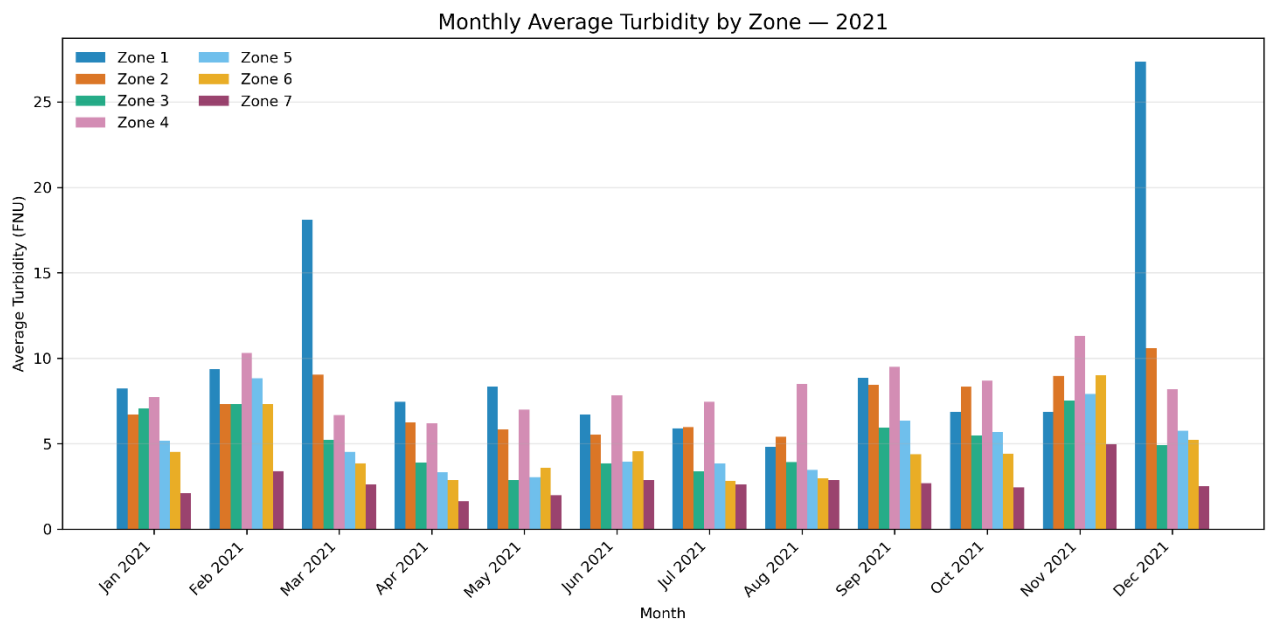


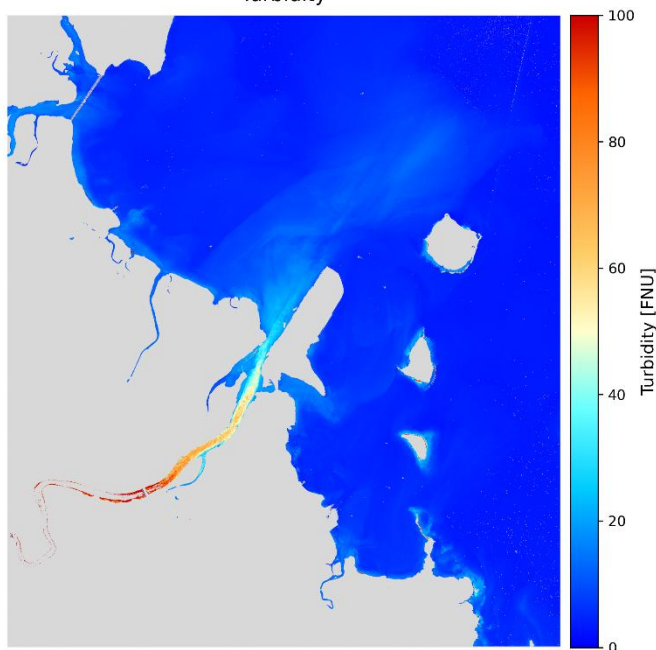
Figure A.147 Monthly Turbidity Distribution by Month (2021)

Sensor: S2A MSI | Local Time: 2021-03-25 10:04:18 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2021-09-21 10:04:22 AEST

Surface Reflectance RGB



Turbidity

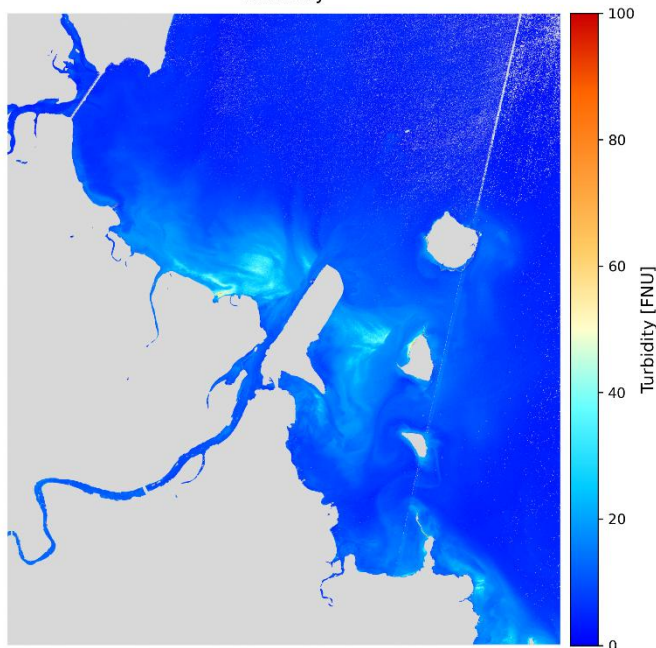


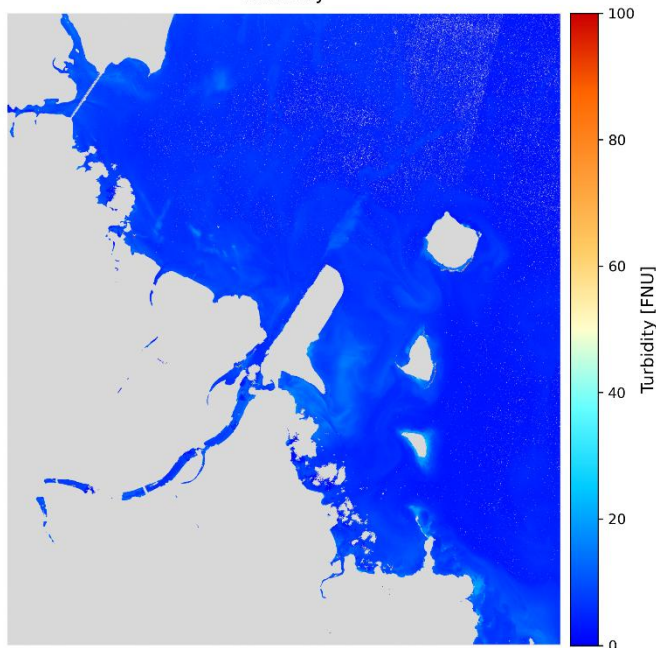
Figure A.148 Representative turbidity conditions in 2021. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2021-02-15 09:54:22 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2021-09-23 09:54:21 AEST

Surface Reflectance RGB



Turbidity

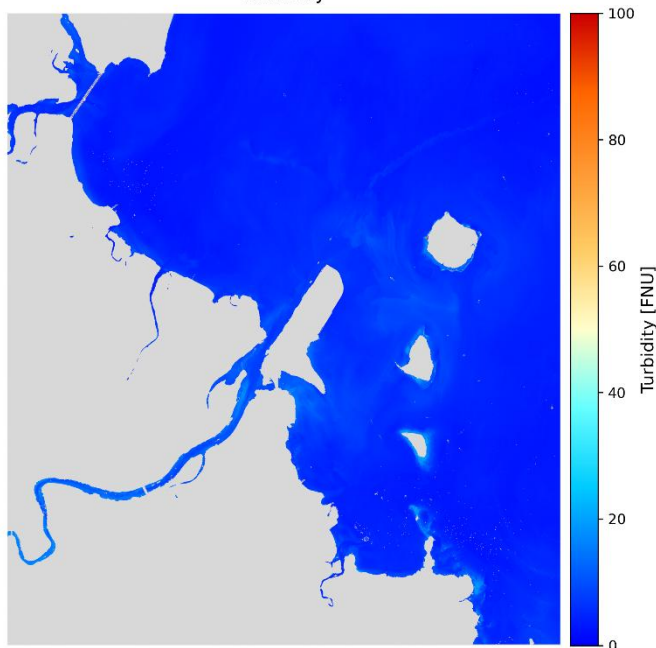
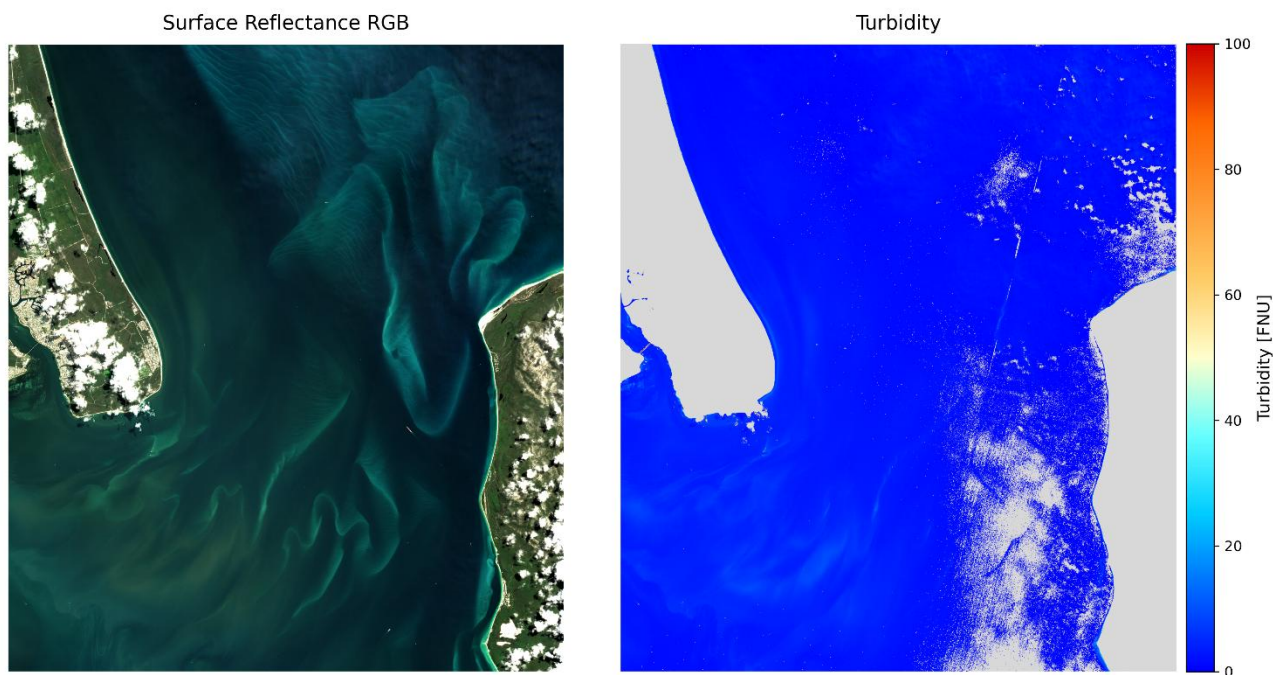


Figure A.149 Representative turbidity conditions in 2021. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2021-03-02 09:54:09 AEST



Sensor: S2B MSI | Local Time: 2021-08-17 10:04:04 AEST

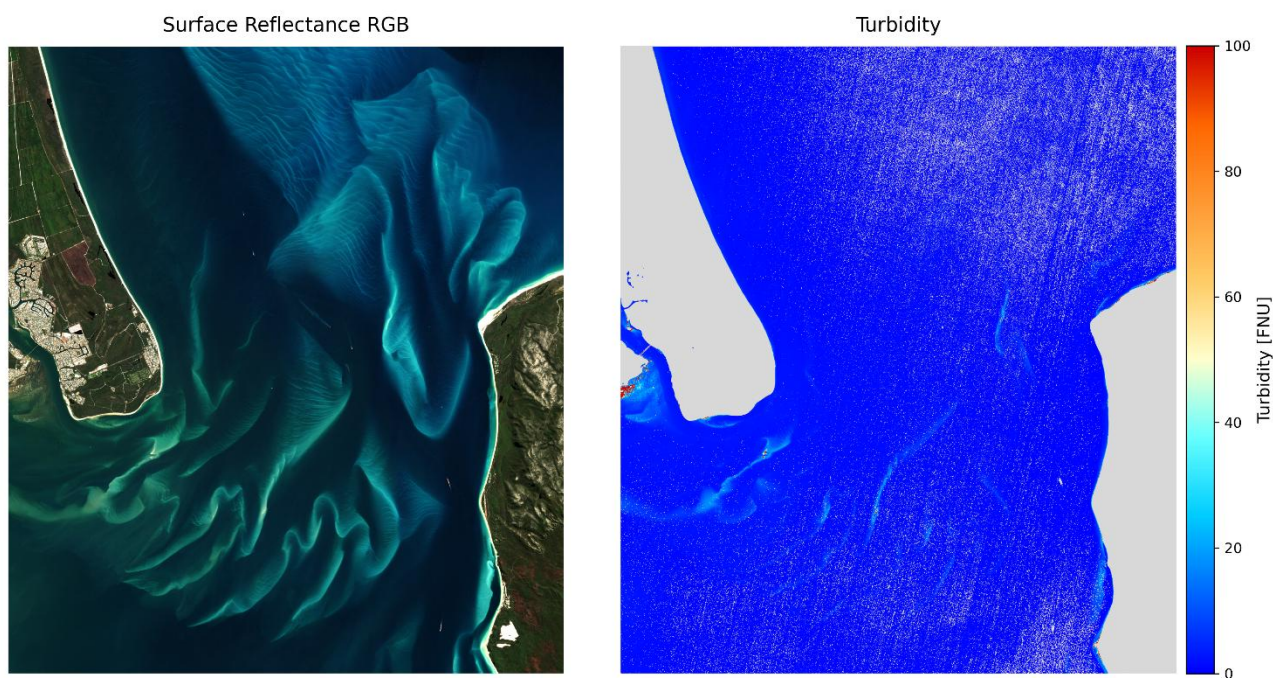


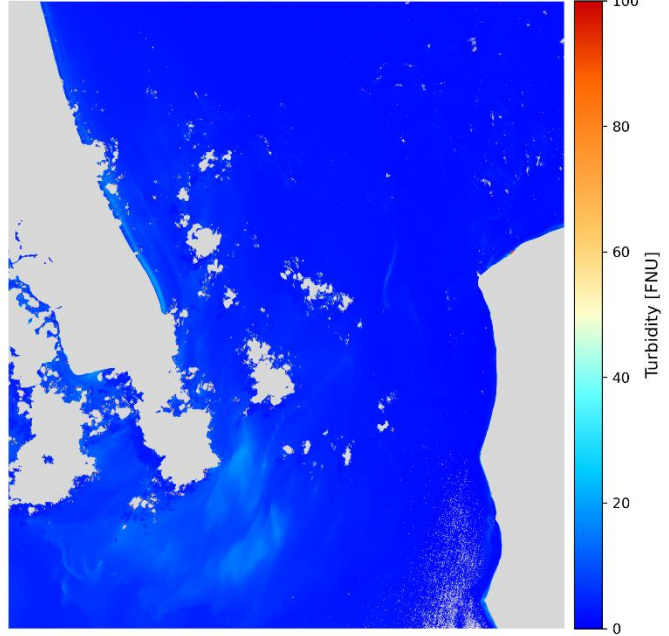
Figure A.150 Turbidity conditions in 2021. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2020-04-11 09:54:05 AEST

Surface Reflectance RGB

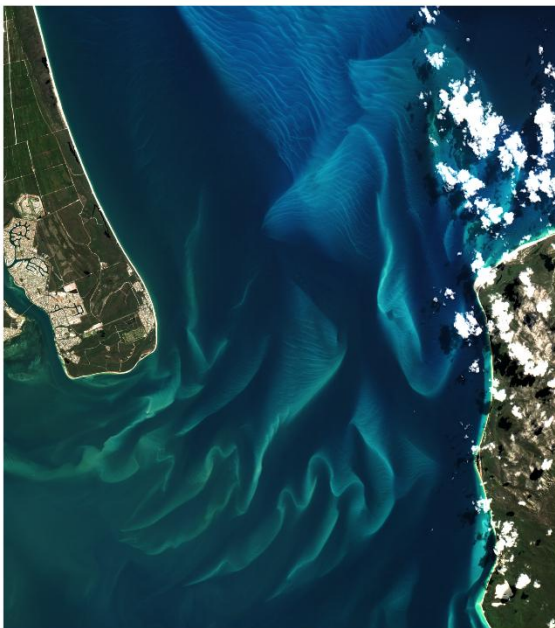


Turbidity



Sensor: S2B MSI | Local Time: 2020-09-01 10:04:08 AEST

Surface Reflectance RGB



Turbidity

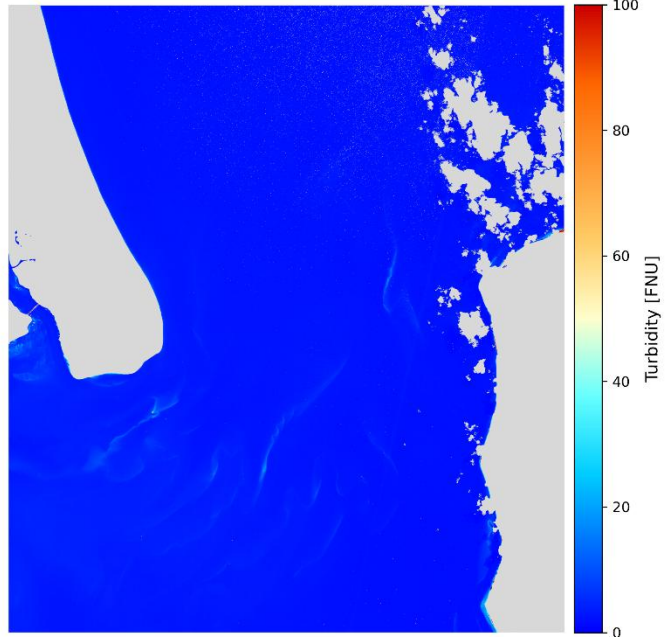


Figure A.151 Representative turbidity conditions in 2021. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.12 Turbidity Pattern 2022

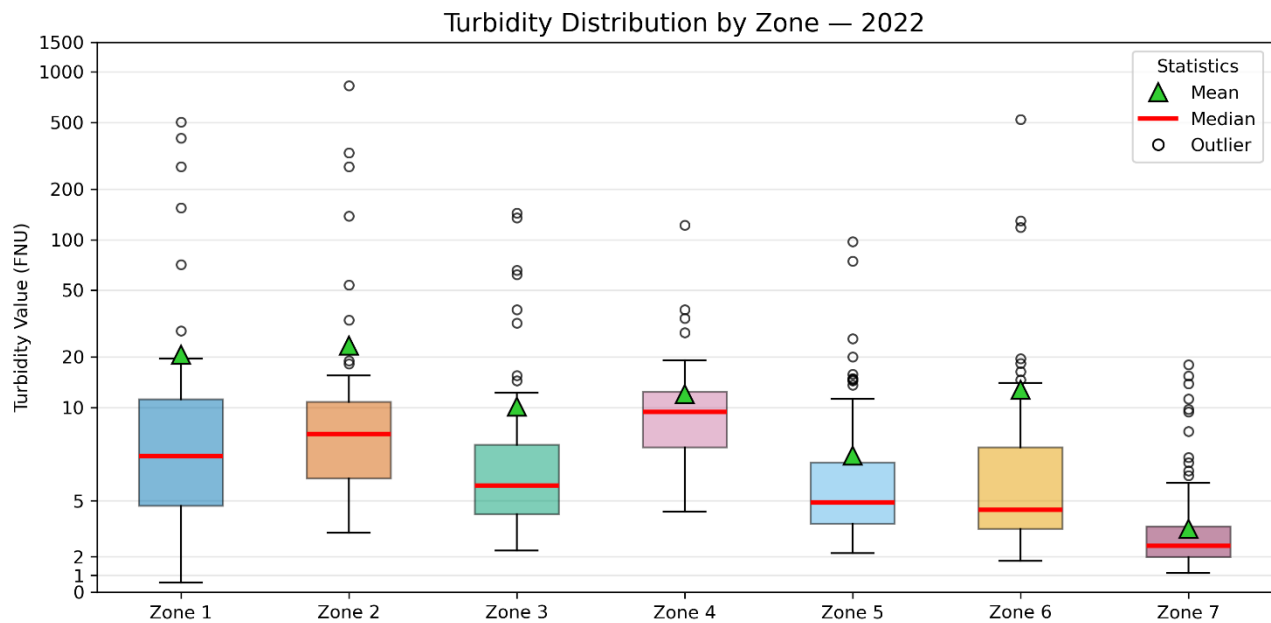


Figure A.152 Turbidity distributions by reporting zone (2022).

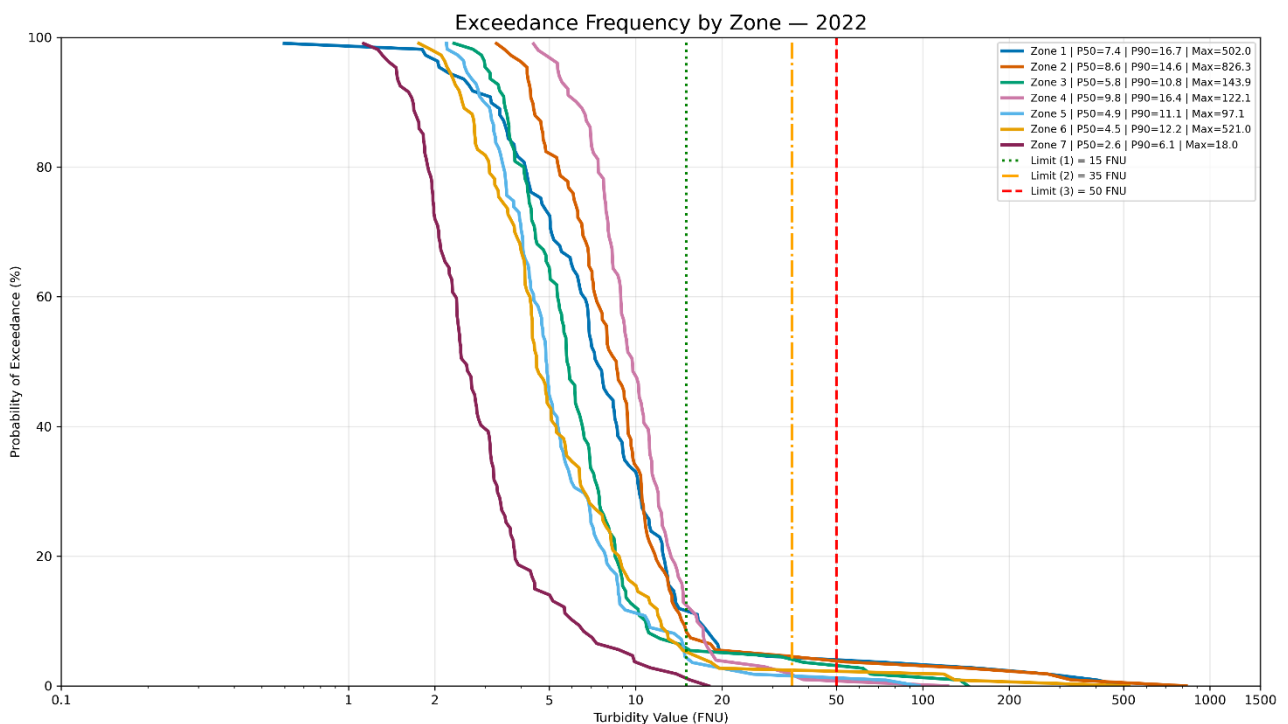


Figure A.153 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2022).

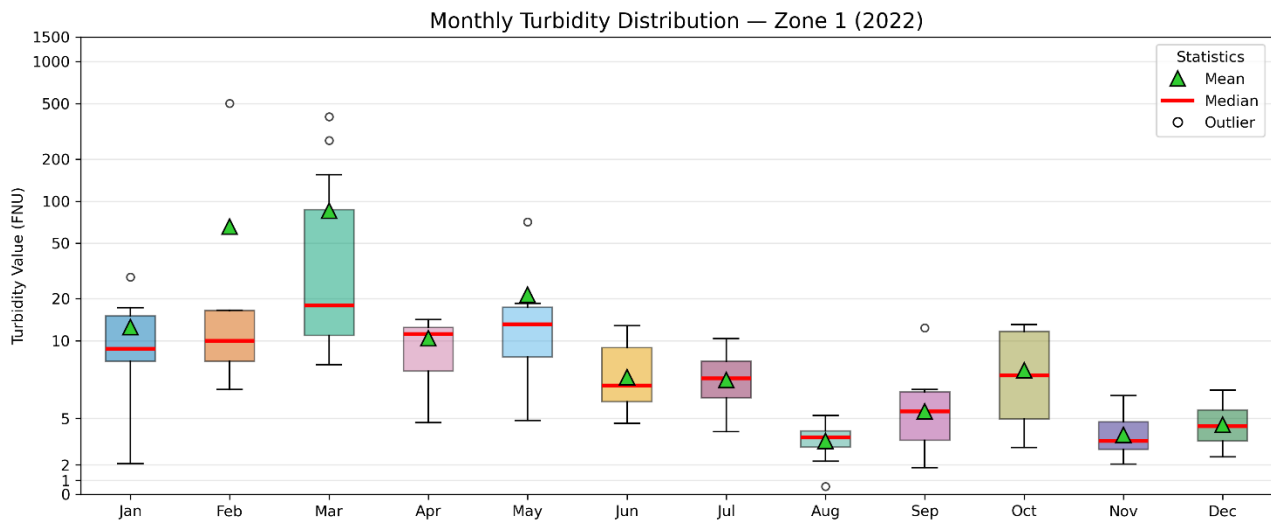


Figure A.154 Monthly Turbidity Distribution by Month for Zone 1 (2022)

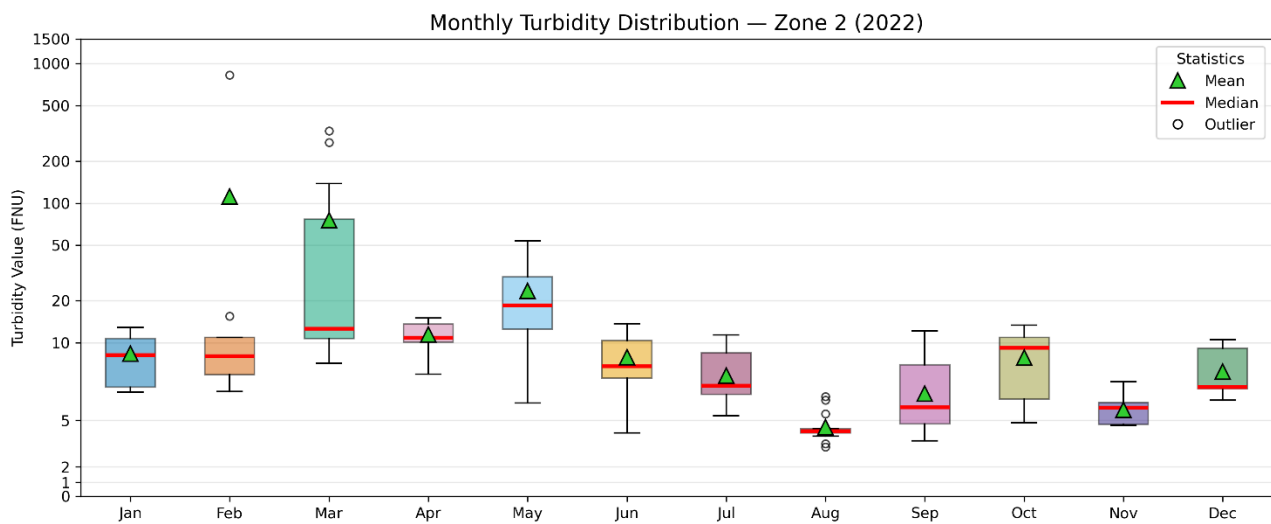


Figure A.155 Monthly Turbidity Distribution by Month for Zone 2 (2022)

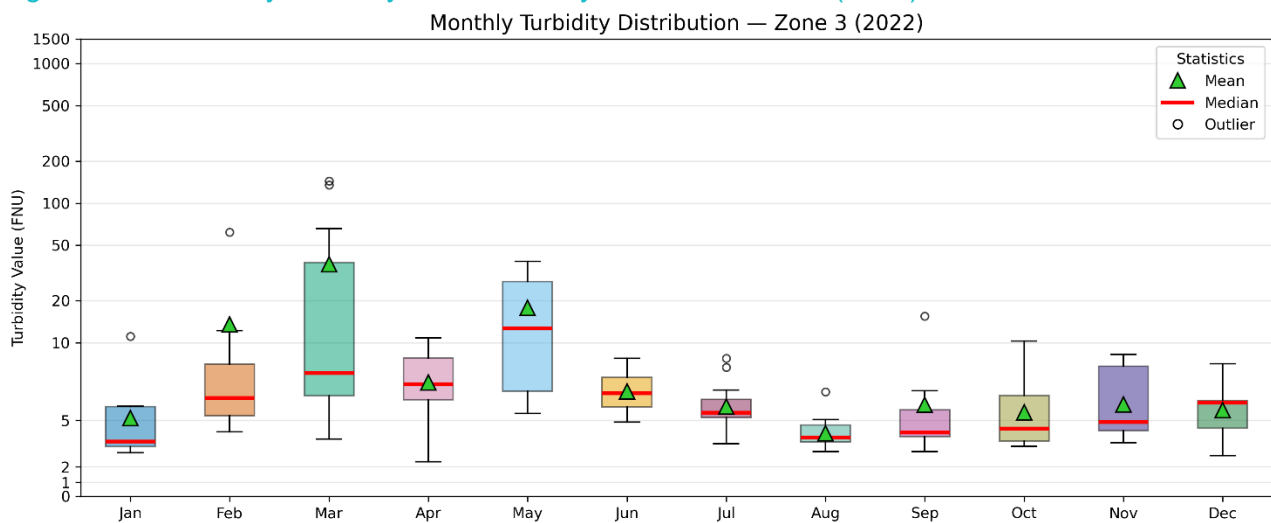


Figure A.156 Monthly Turbidity Distribution by Month for Zone 3 (2022)

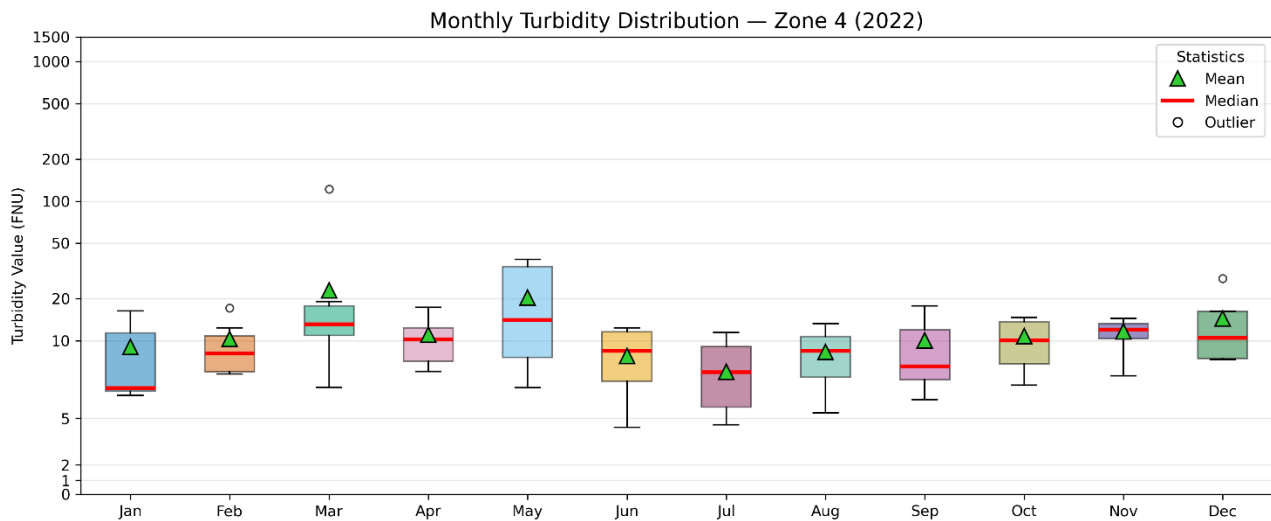


Figure A.157 Monthly Turbidity Distribution by Month for Zone 4 (2022)

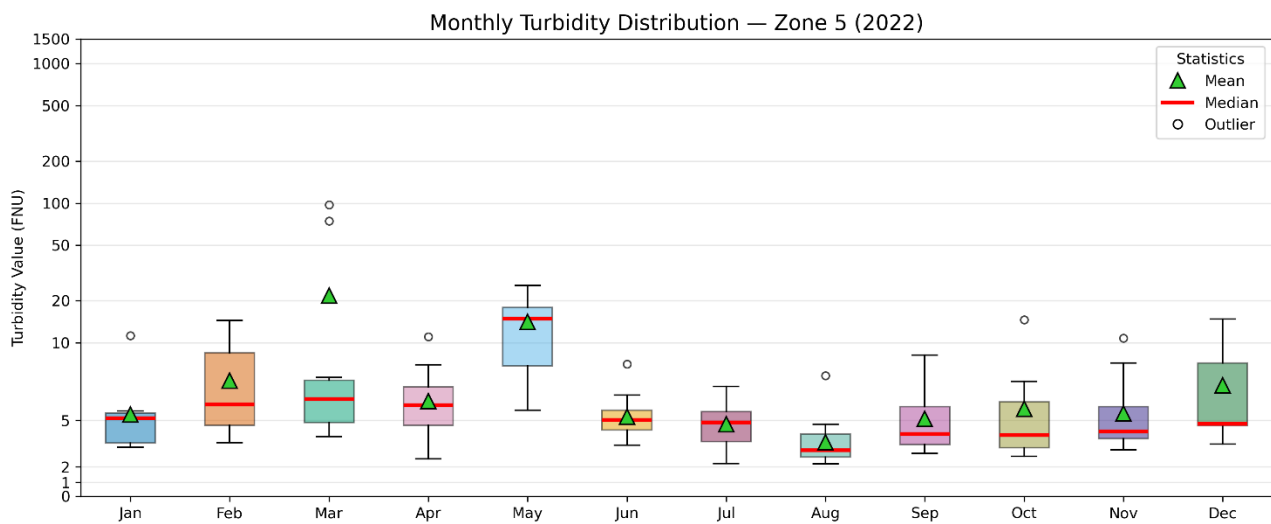


Figure A.158 Monthly Turbidity Distribution by Month for Zone 5 (2022)

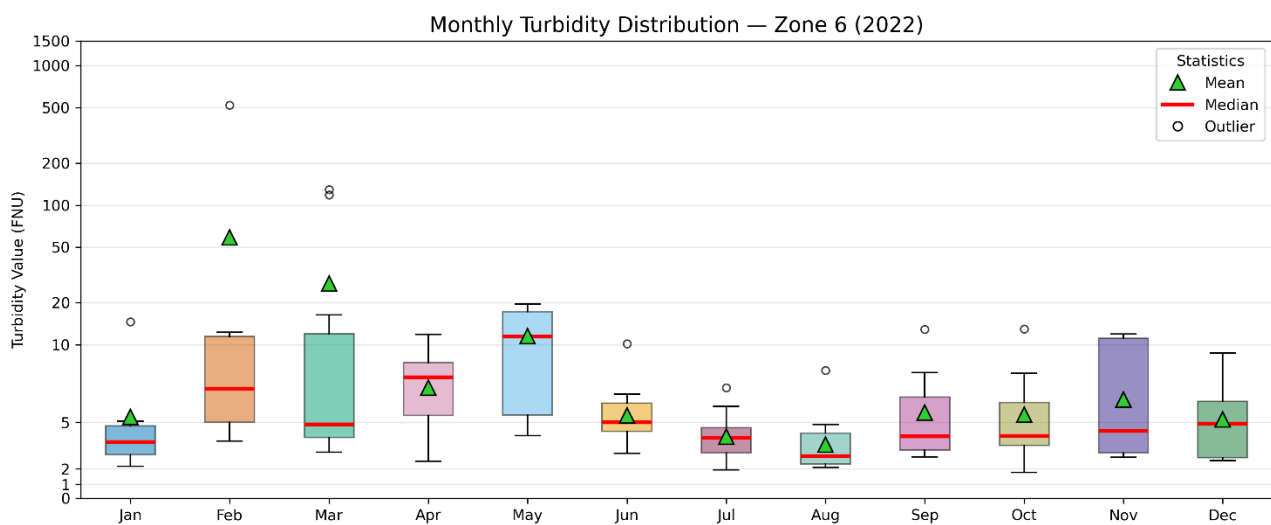


Figure A.159 Monthly Turbidity Distribution by Month for Zone 6 (2022)

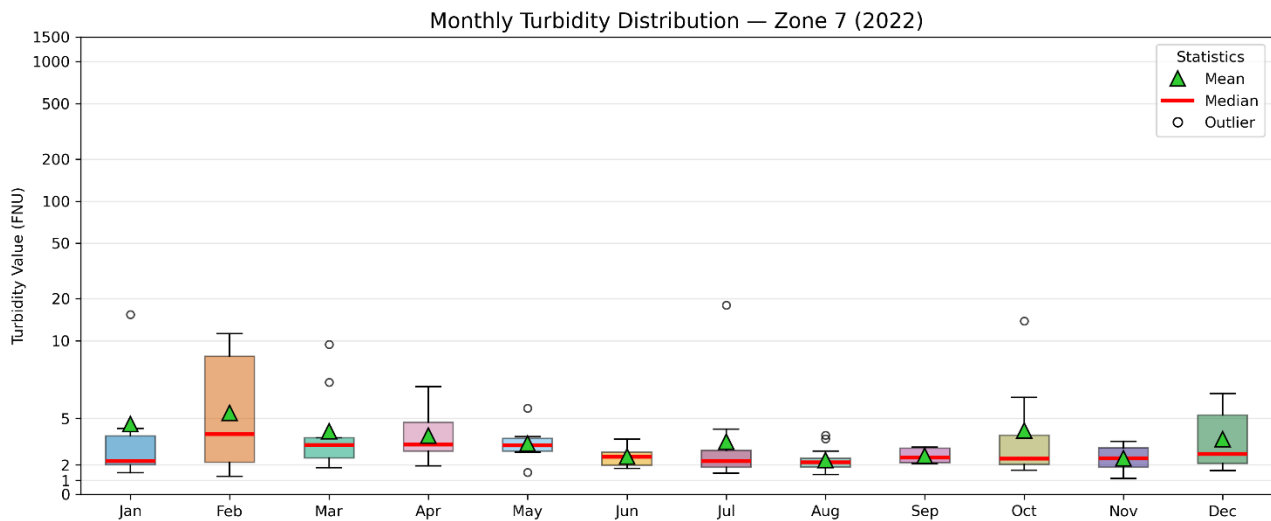


Figure A.160 Monthly Turbidity Distribution by Month for Zone 7 (2022)

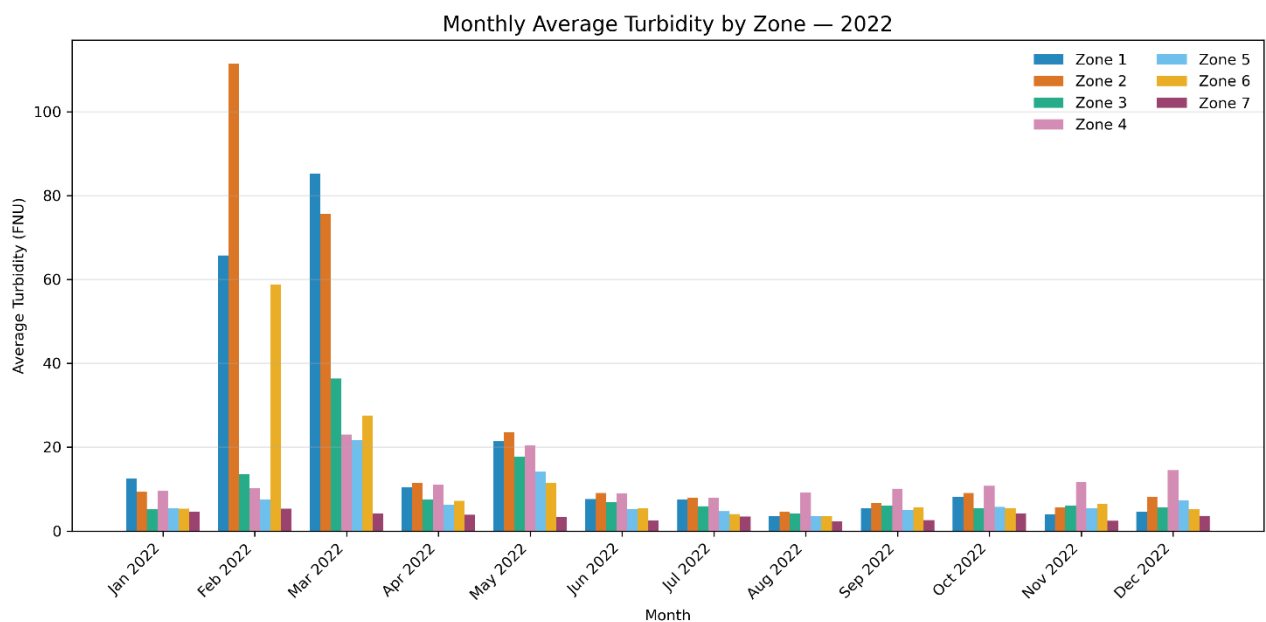
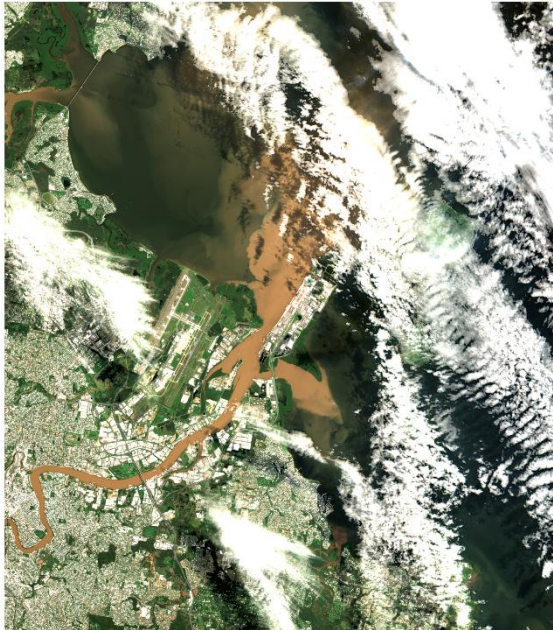


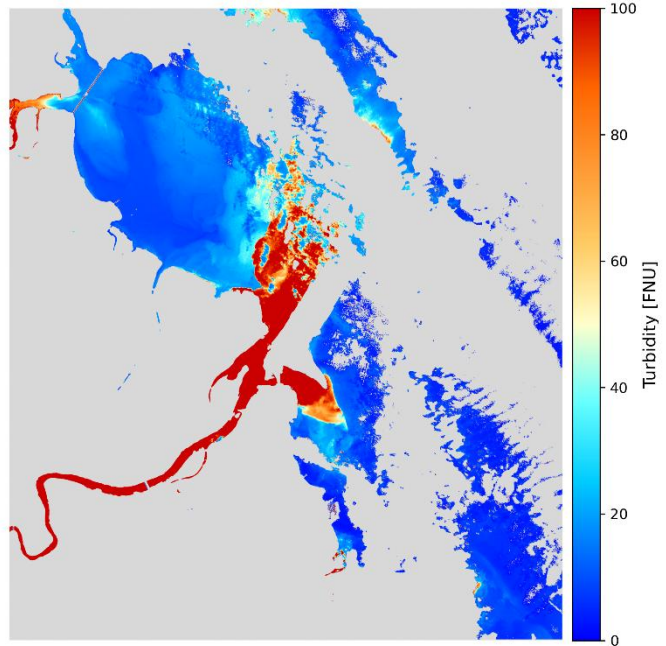
Figure A.161 Monthly Turbidity Distribution by Month (2022)

Sensor: S2A MSI | Local Time: 2022-03-07 09:54:27 AEST

Surface Reflectance RGB

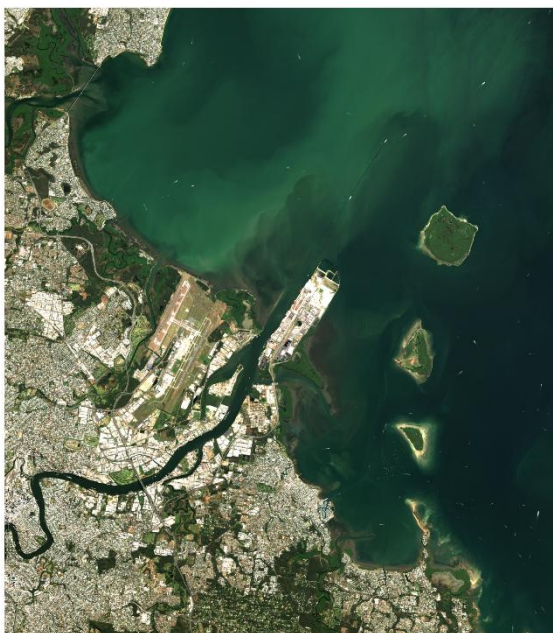


Turbidity



Sensor: S2A MSI | Local Time: 2022-06-25 09:54:36 AEST

Surface Reflectance RGB



Turbidity

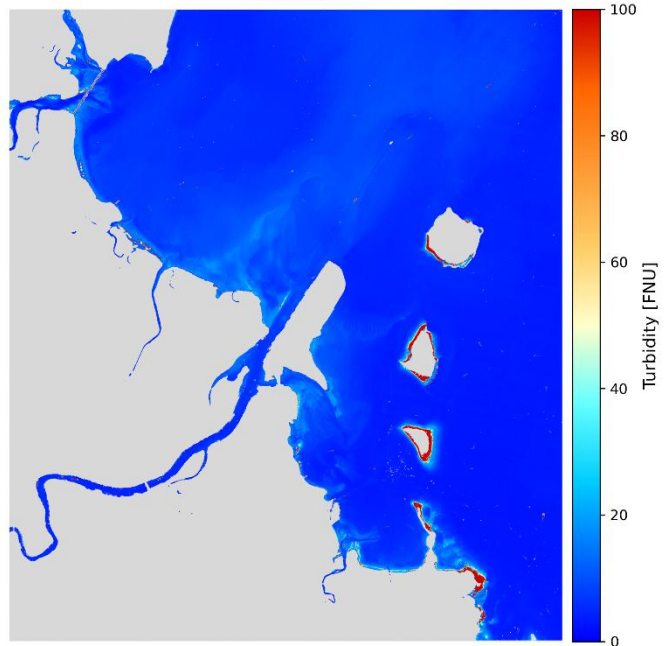


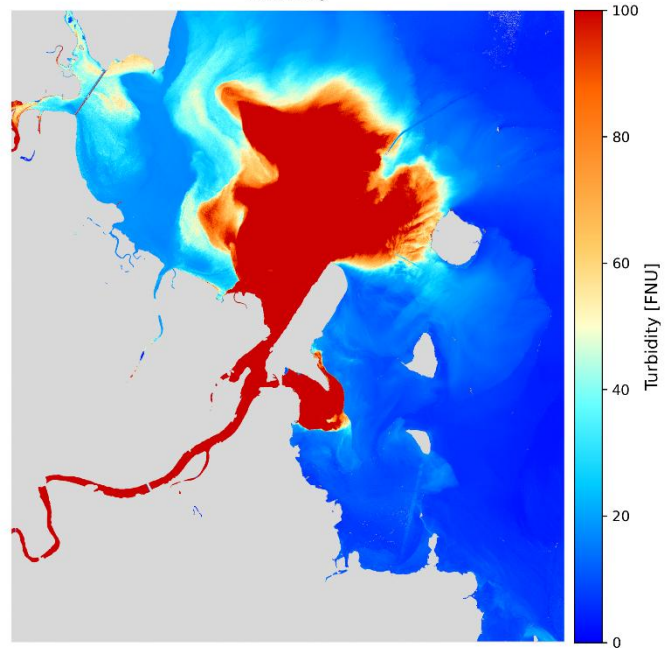
Figure A.162 Representative turbidity conditions in 2022. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2022-03-05 10:04:16 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2022-06-23 10:04:24 AEST

Surface Reflectance RGB



Turbidity

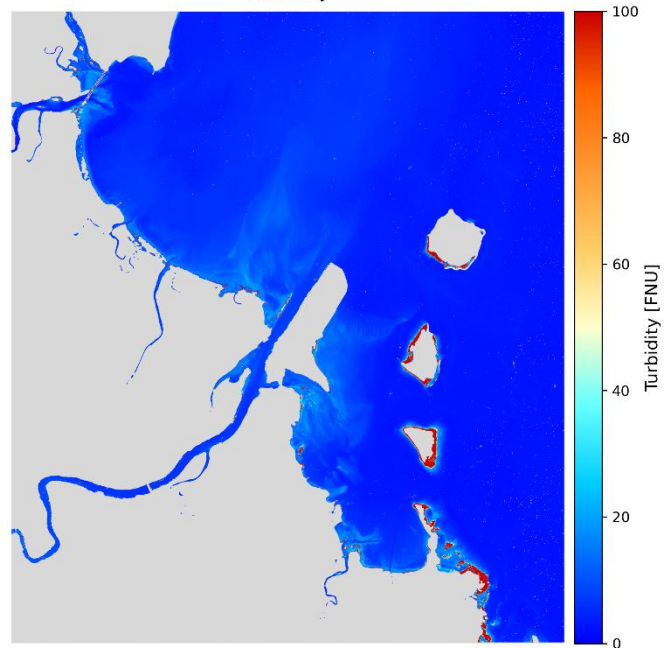
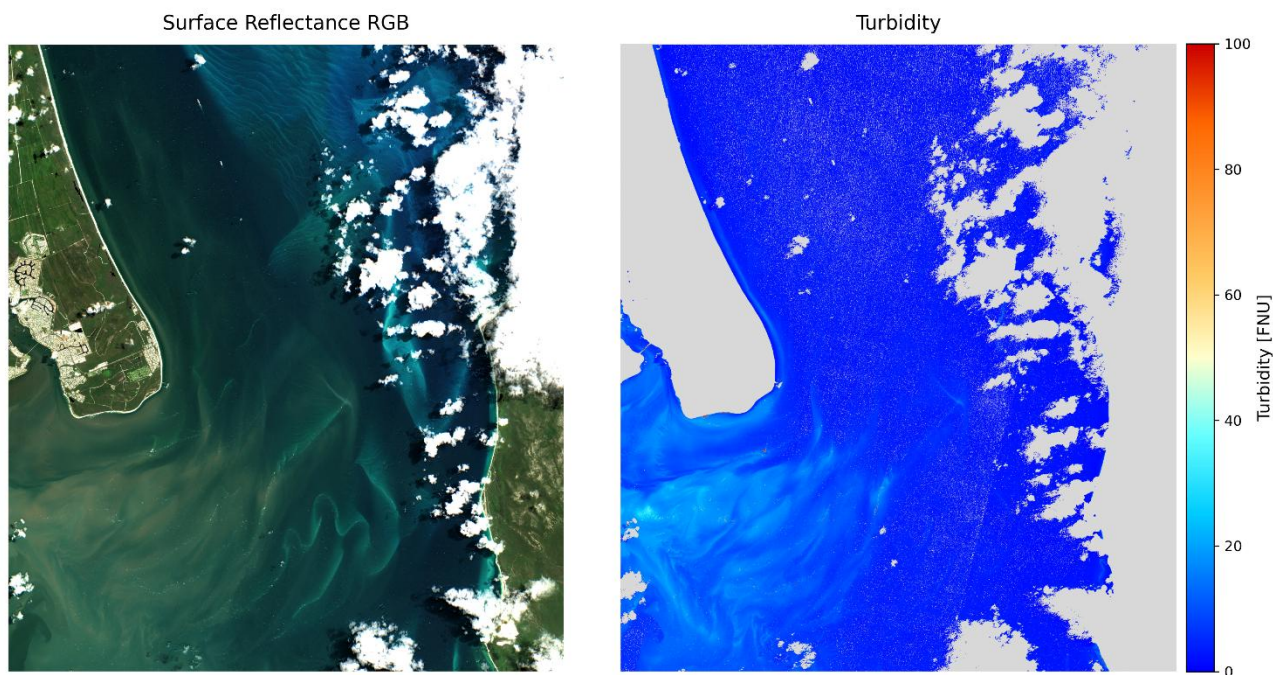


Figure A.163 Representative turbidity conditions in 2022. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2022-02-05 09:54:09 AEST



Sensor: S2A MSI | Local Time: 2022-04-19 10:04:09 AEST

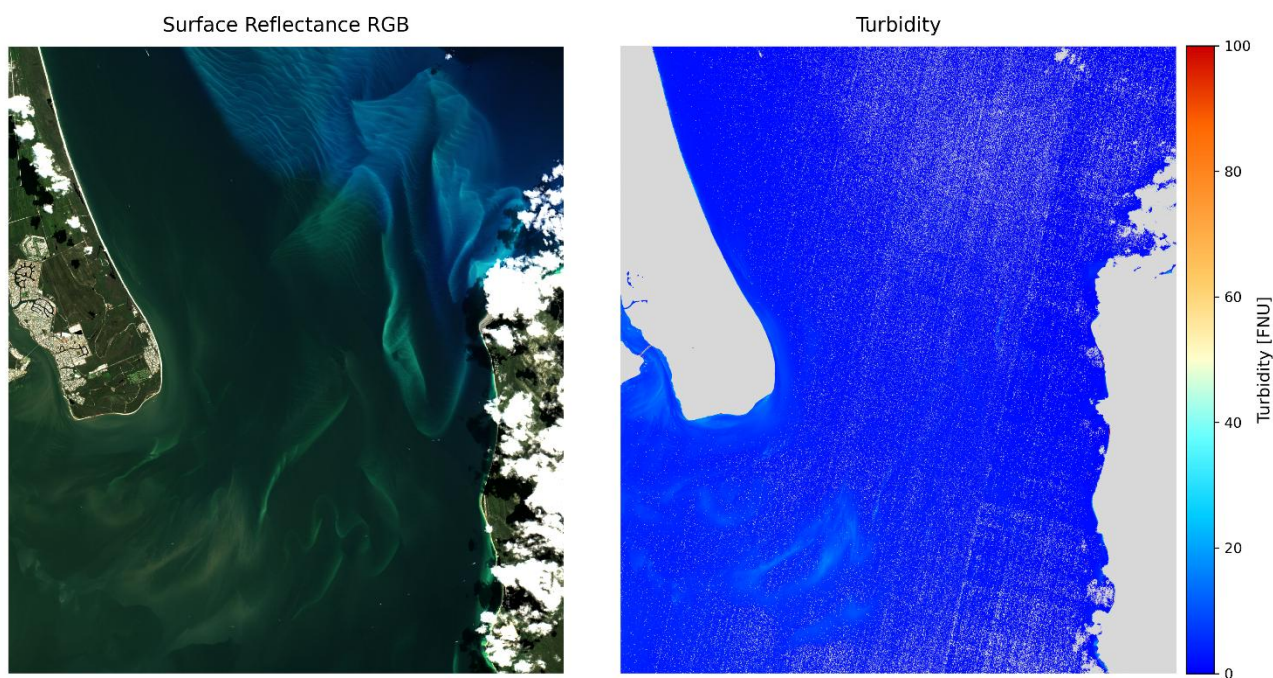
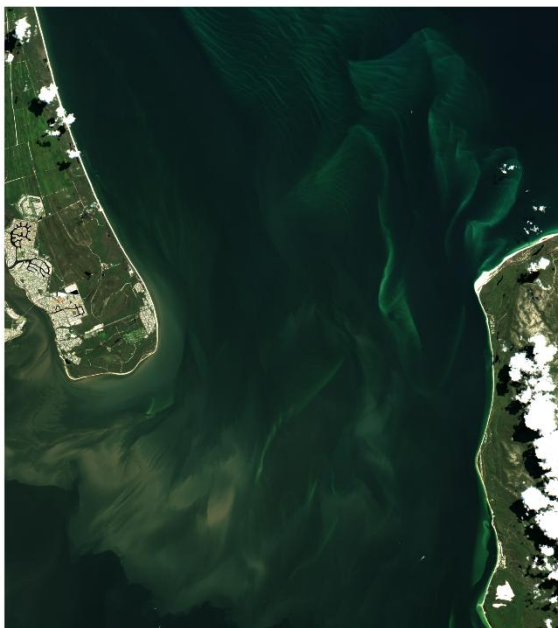


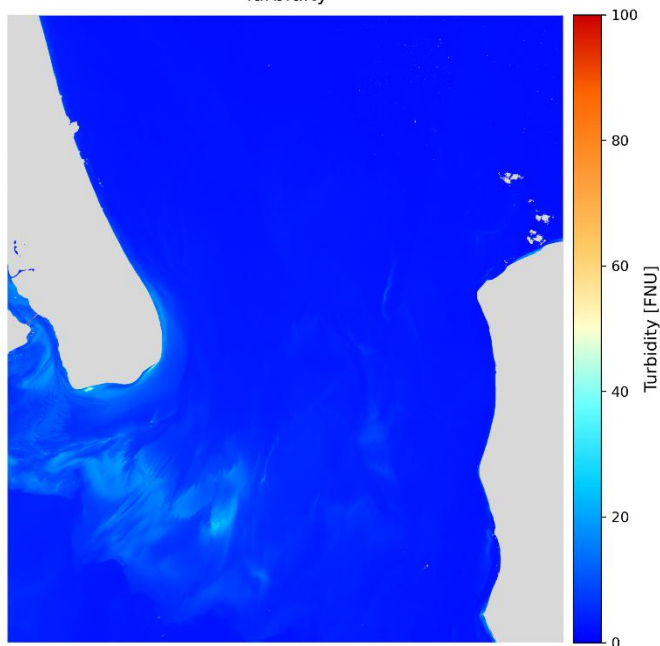
Figure A.164 Turbidity conditions in 2022. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2022-03-22 09:54:07 AEST

Surface Reflectance RGB

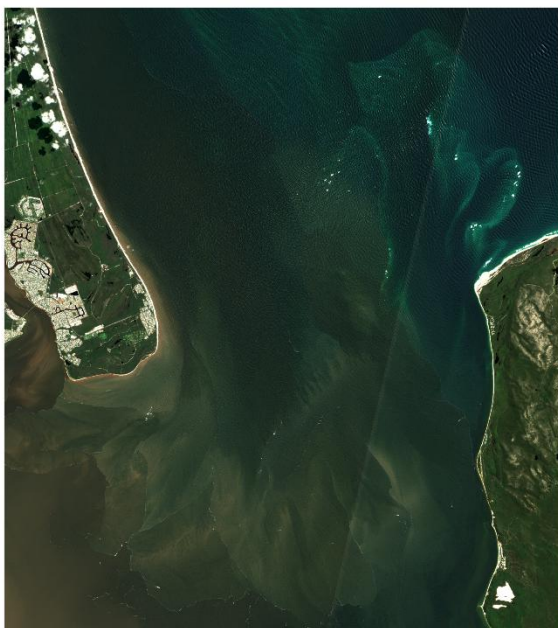


Turbidity



Sensor: S2B MSI | Local Time: 2022-03-05 10:04:02 AEST

Surface Reflectance RGB



Turbidity

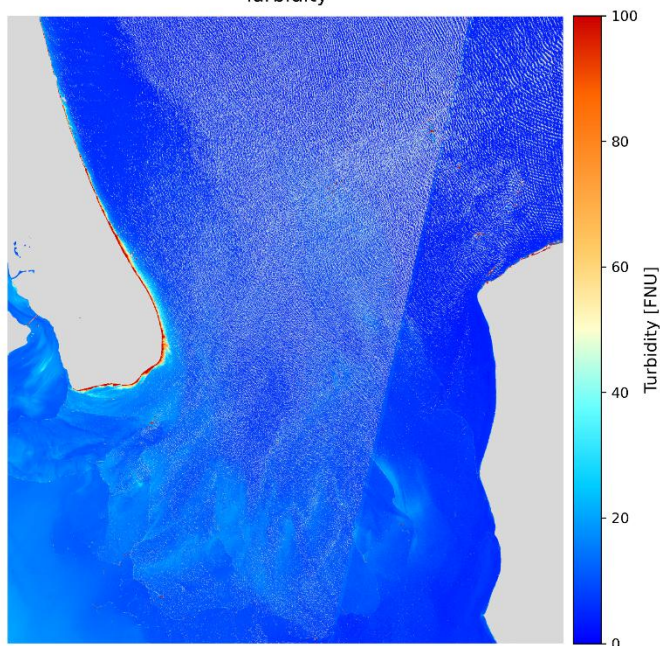


Figure A.165 Representative turbidity conditions in 2022. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.13 Turbidity Pattern 2023

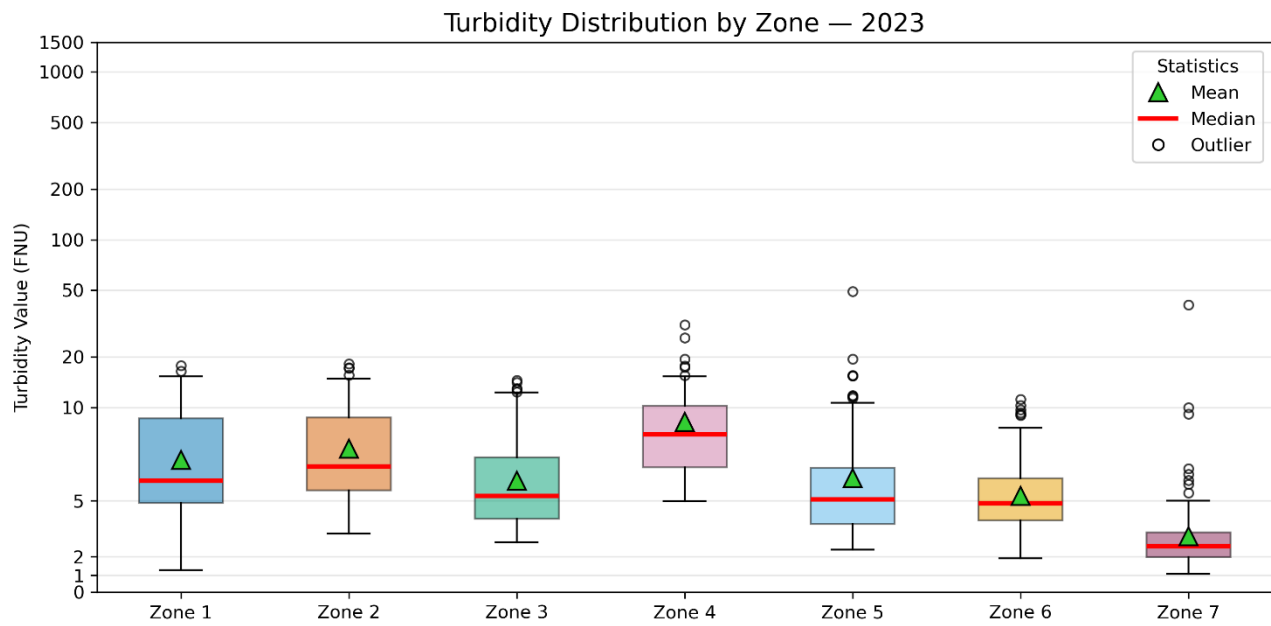


Figure A.166 Turbidity distributions by reporting zone (2023).

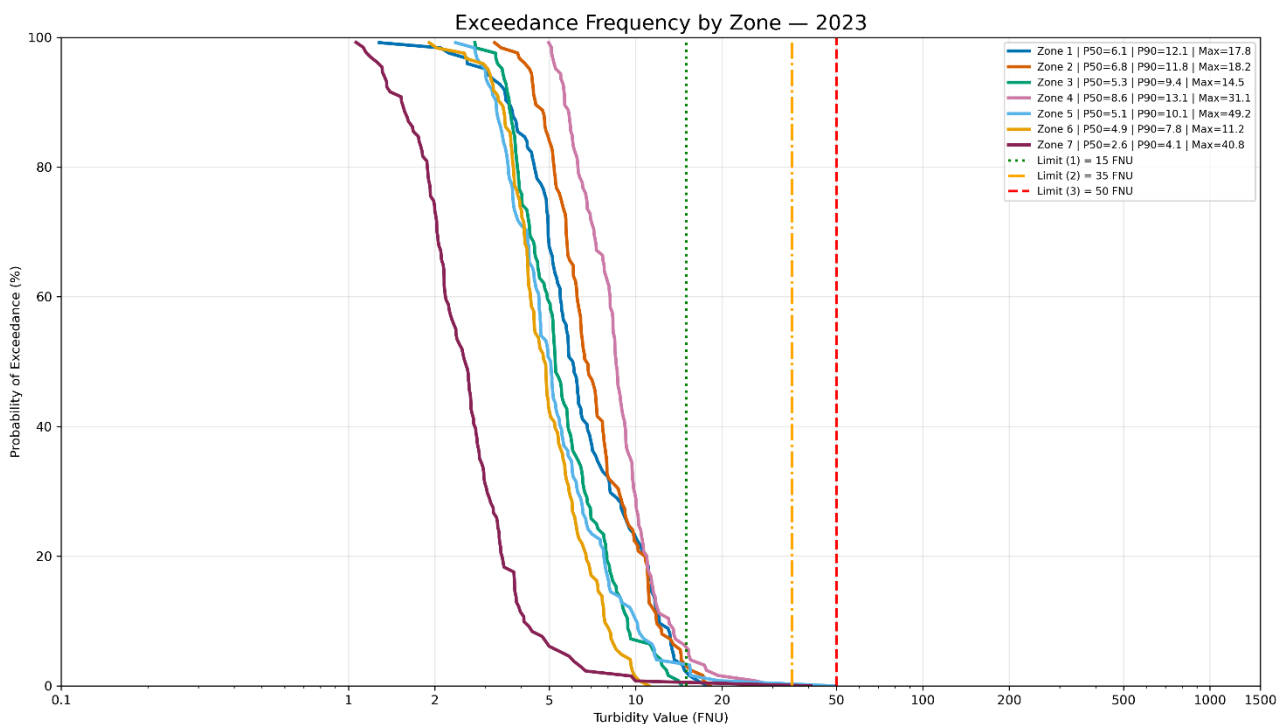


Figure A.167 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2023).

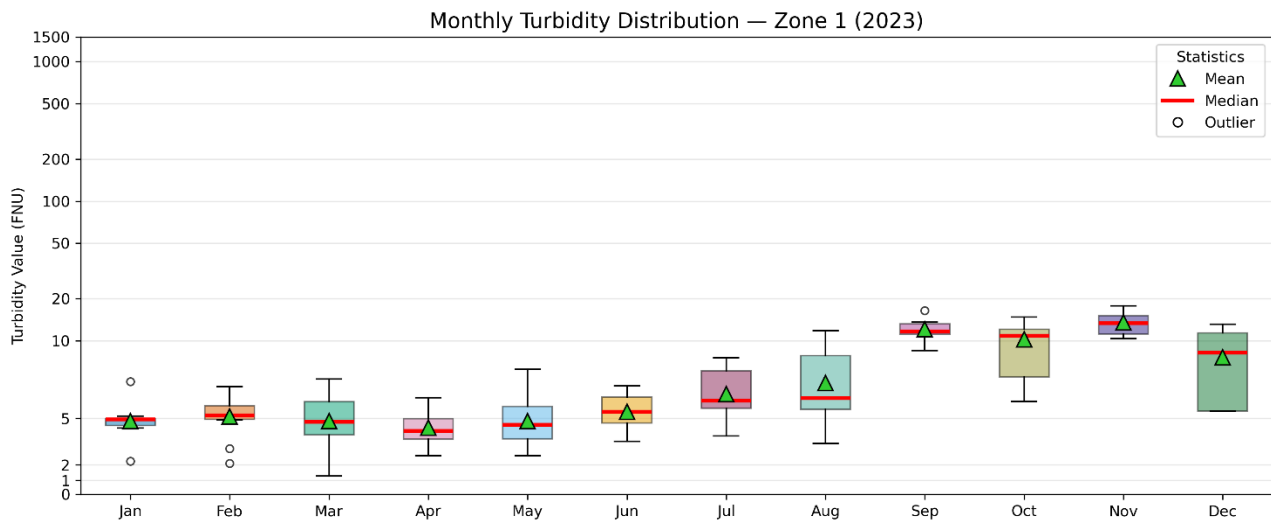


Figure A.168 Monthly Turbidity Distribution by Month for Zone 1 (2023)

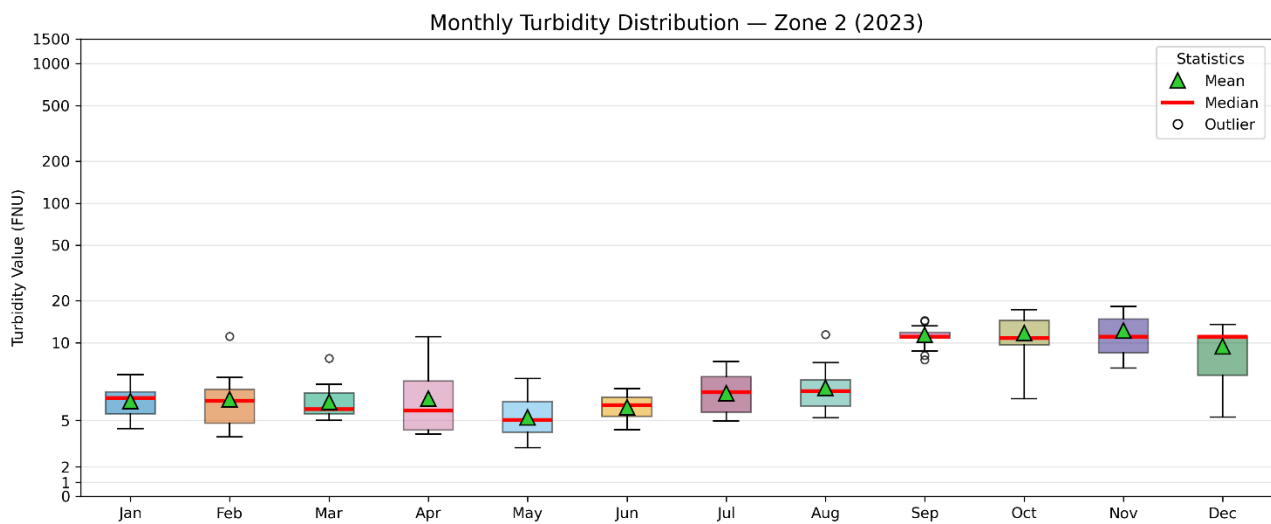


Figure A.169 Monthly Turbidity Distribution by Month for Zone 2 (2023)

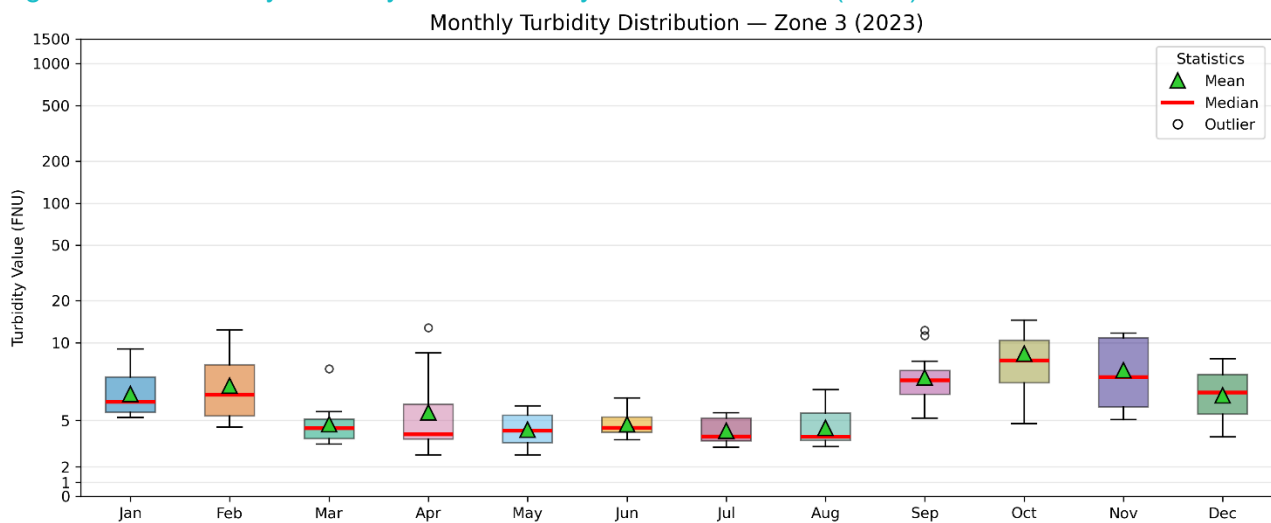


Figure A.170 Monthly Turbidity Distribution by Month for Zone 3 (2023)

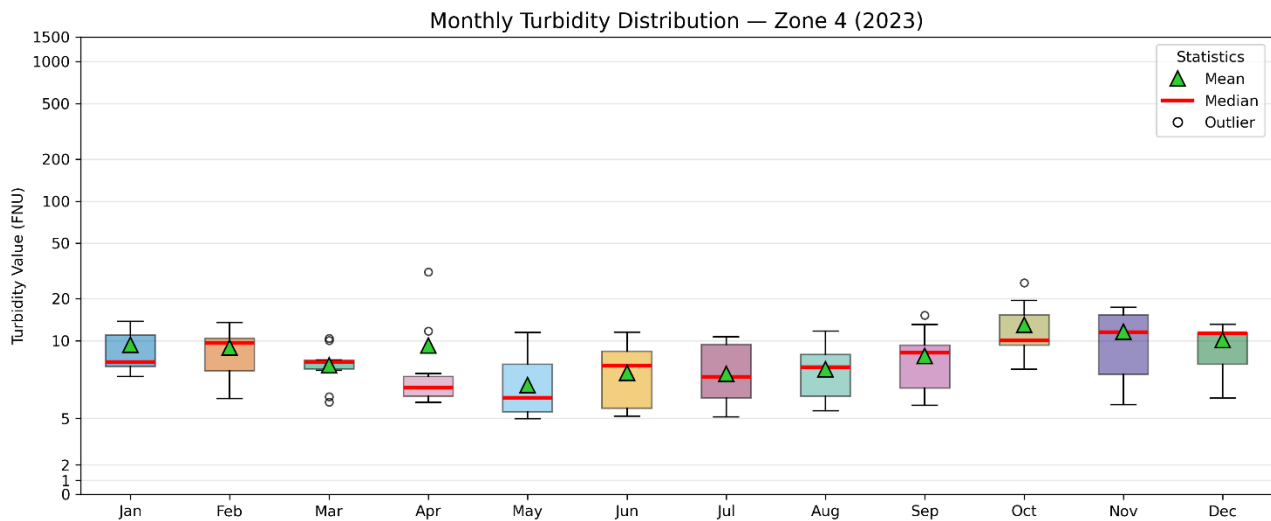


Figure A.171 Monthly Turbidity Distribution by Month for Zone 4 (2023)

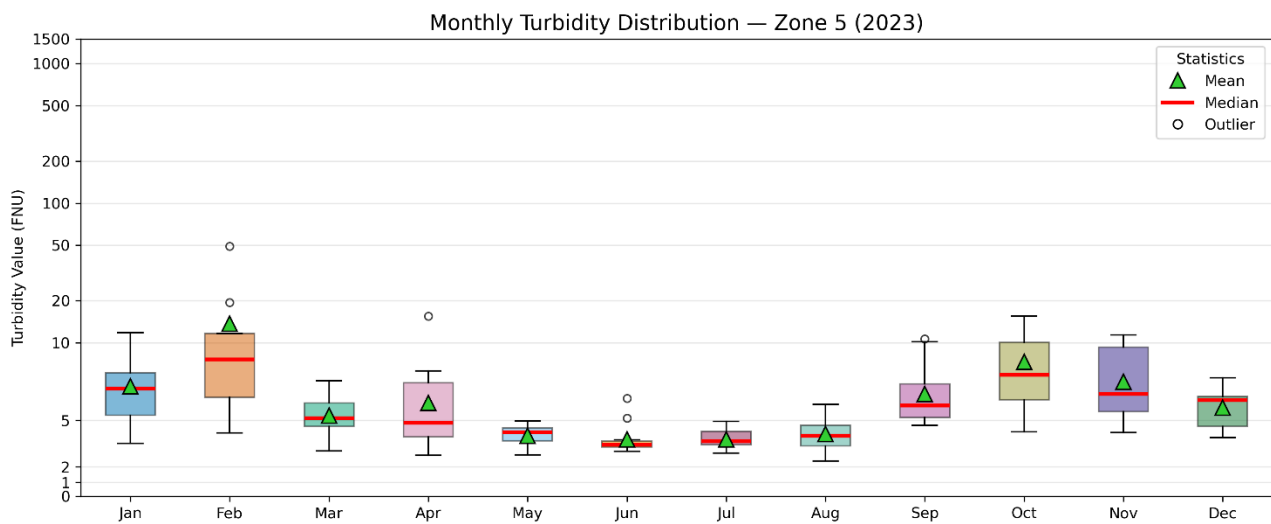


Figure A.172 Monthly Turbidity Distribution by Month for Zone 5 (2023)

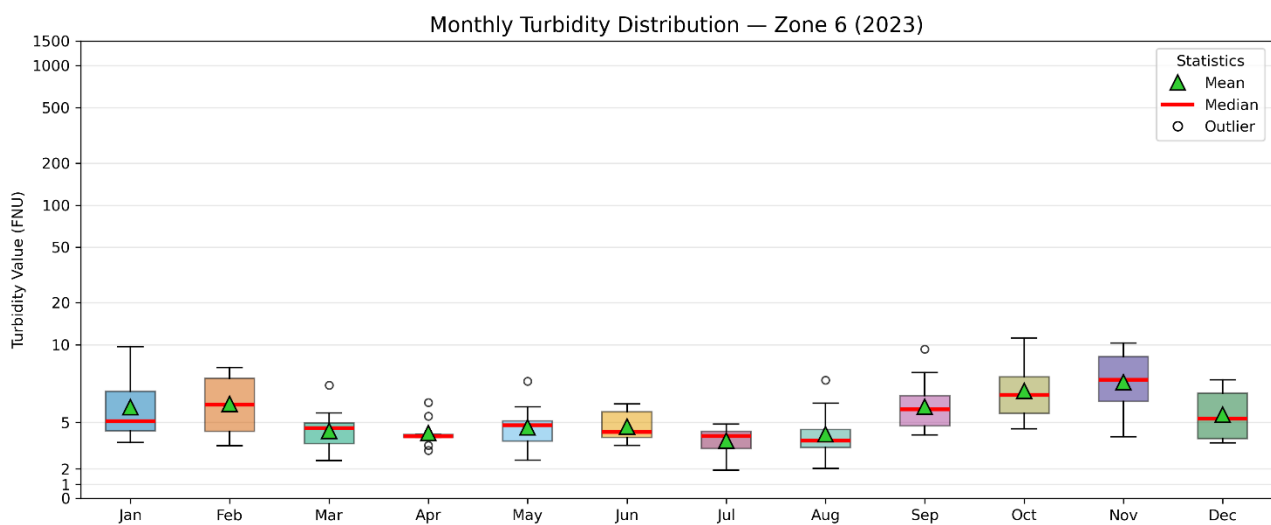


Figure A.173 Monthly Turbidity Distribution by Month for Zone 6 (2023)

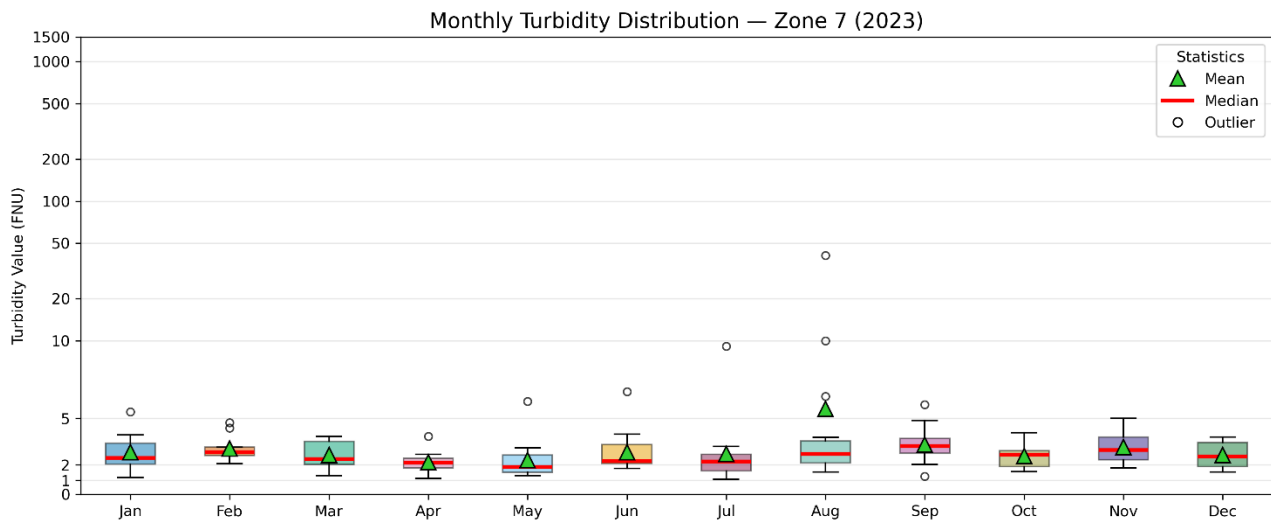


Figure A.174 Monthly Turbidity Distribution by Month for Zone 7 (2023)

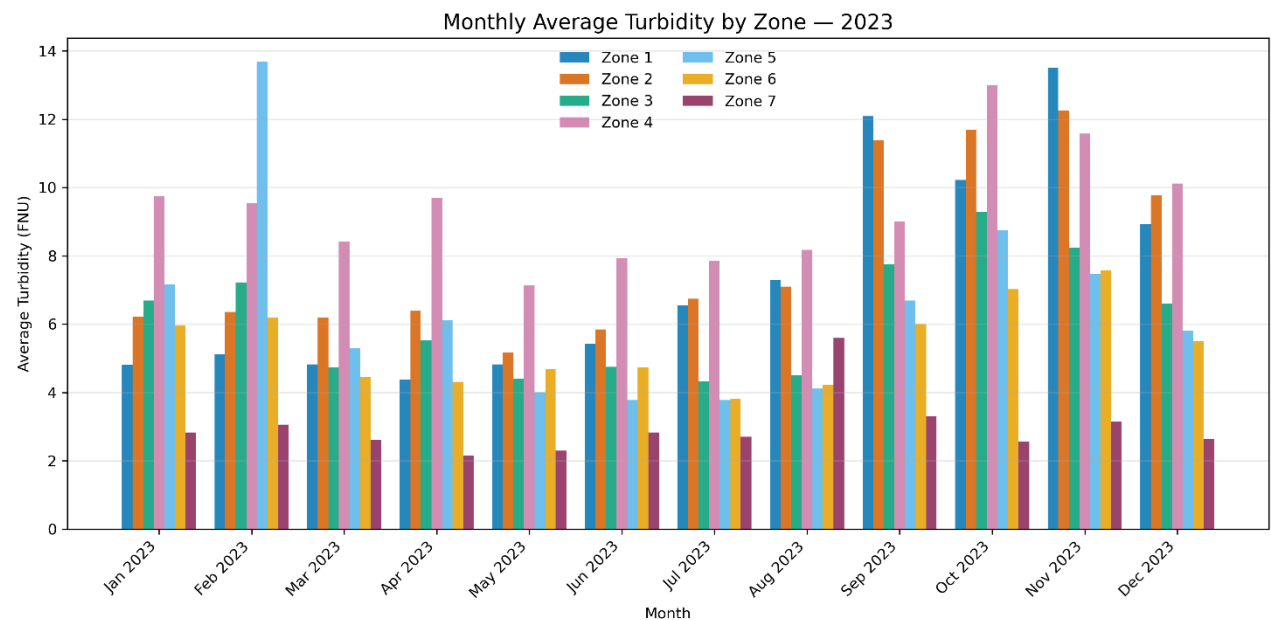


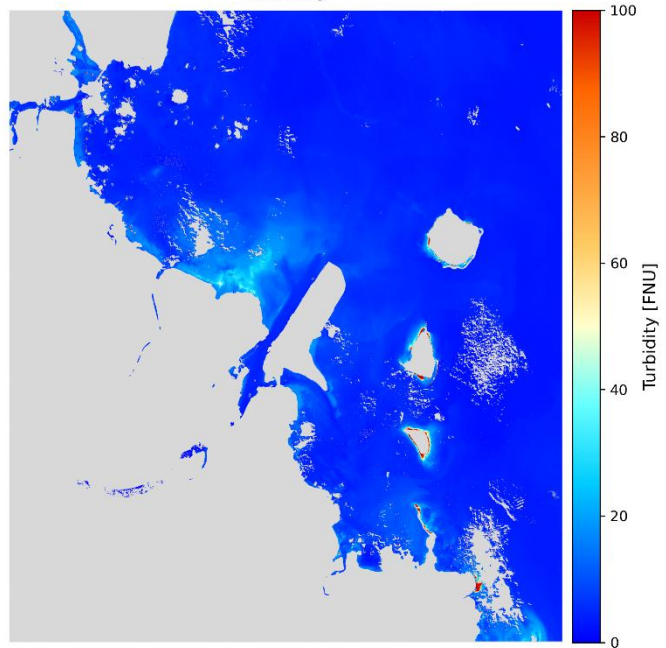
Figure A.175 Monthly Turbidity Distribution by Month (2023)

Sensor: S2A MSI | Local Time: 2023-01-31 09:54:22 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2023-09-28 09:54:26 AEST

Surface Reflectance RGB



Turbidity

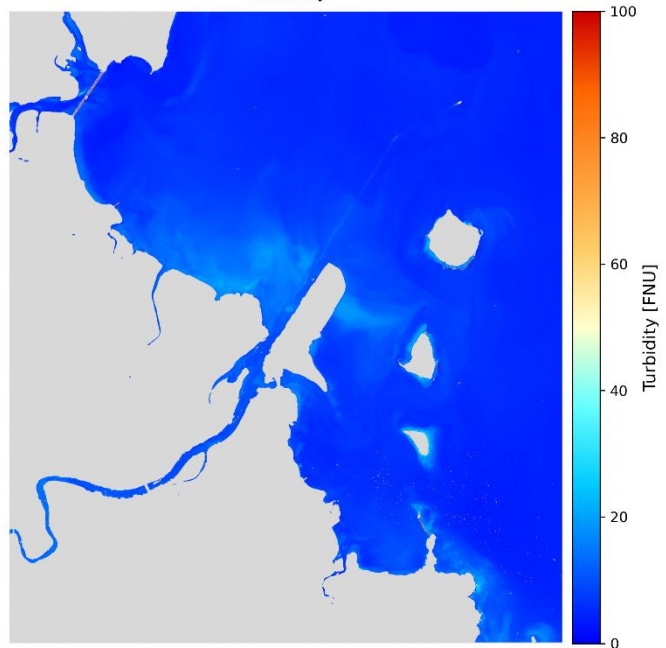
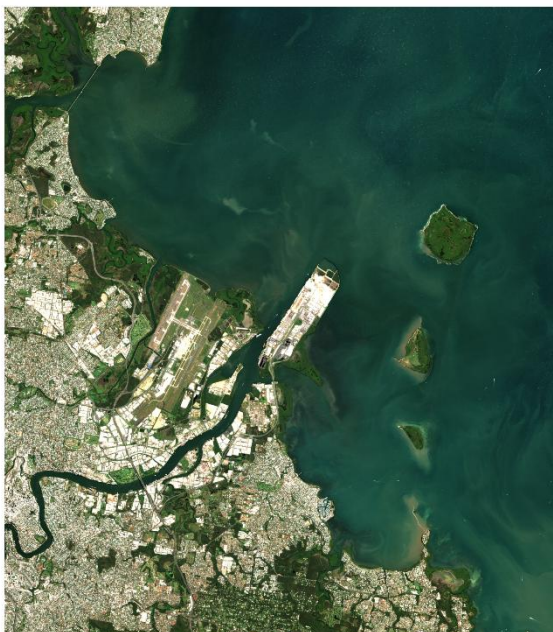


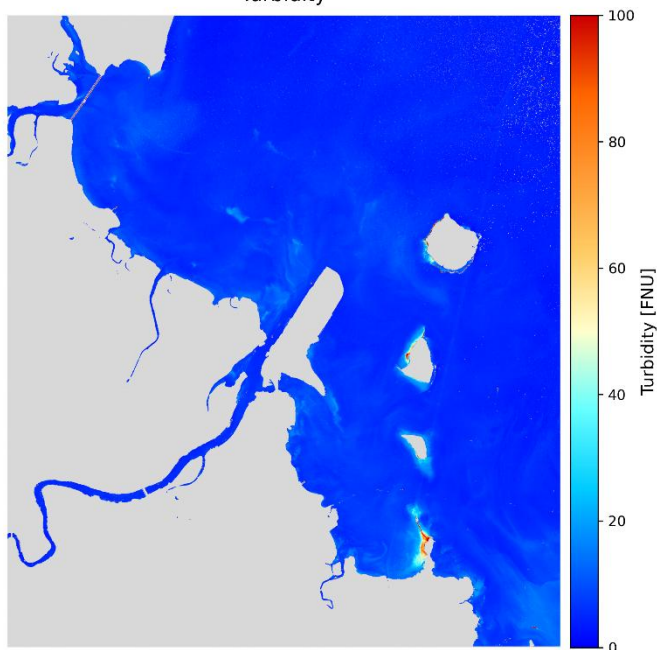
Figure A.176 Representative turbidity conditions in 2023. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2023-04-09 10:04:21 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2023-09-06 10:04:24 AEST

Surface Reflectance RGB



Turbidity

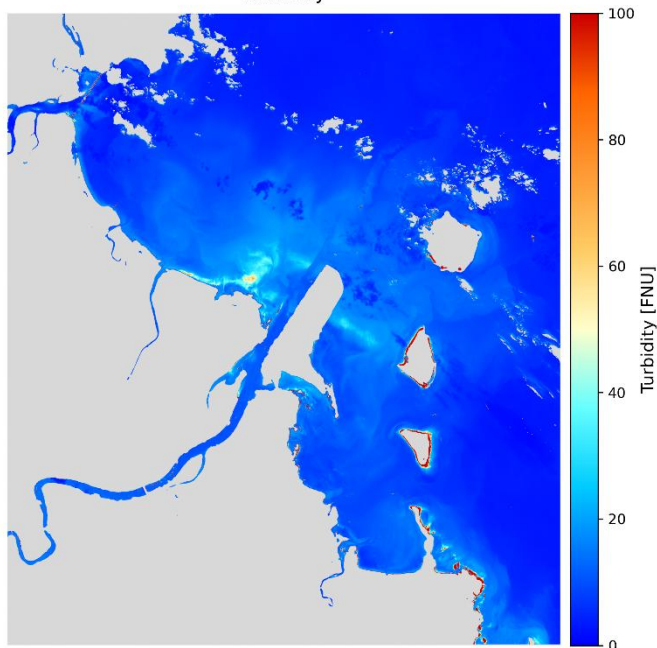
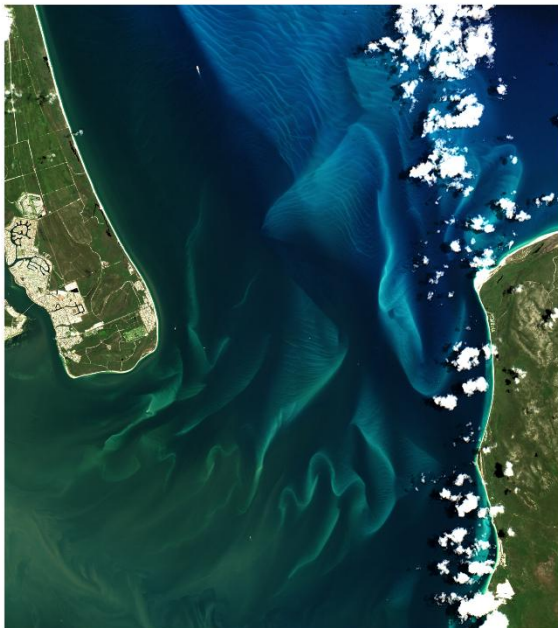


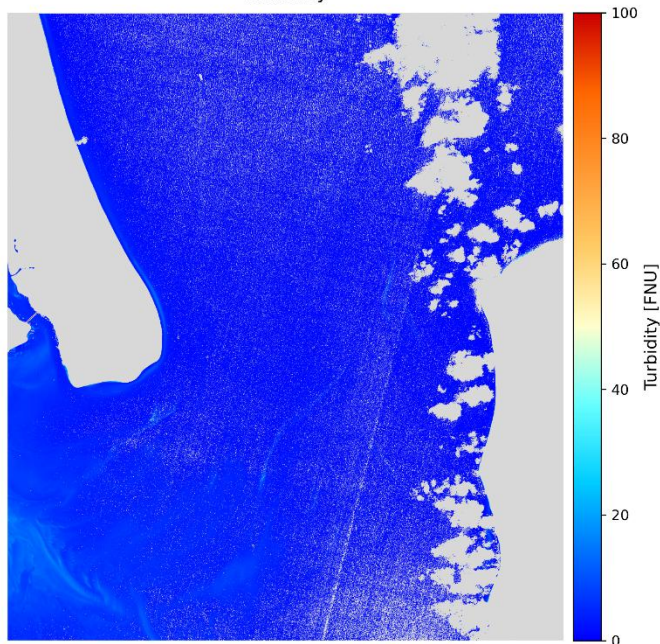
Figure A.177 Representative turbidity conditions in 2023. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2023-01-11 09:54:07 AEST

Surface Reflectance RGB

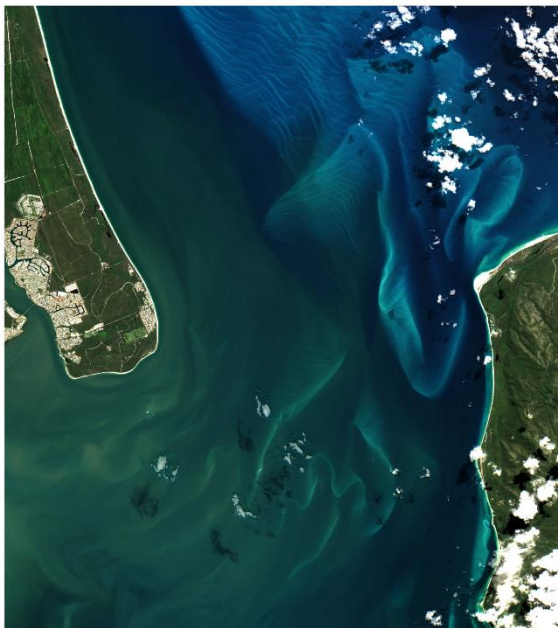


Turbidity



Sensor: S2A MSI | Local Time: 2023-04-21 09:54:08 AEST

Surface Reflectance RGB



Turbidity

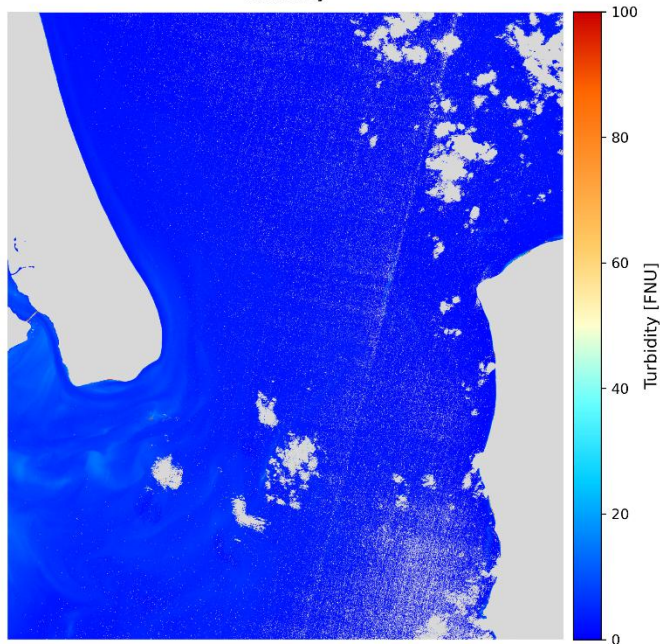
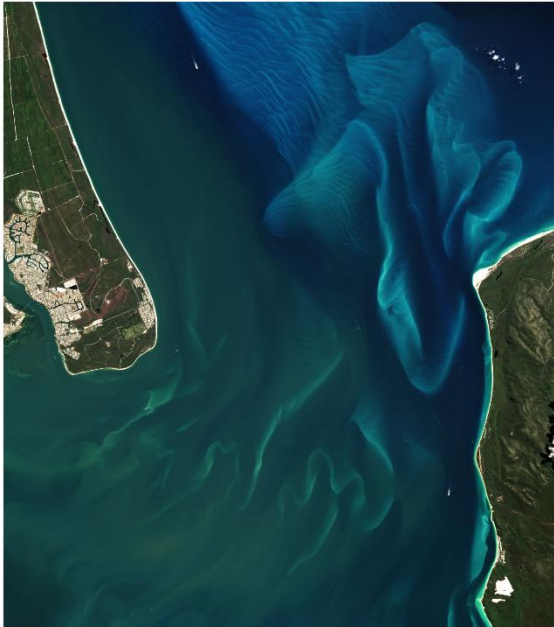


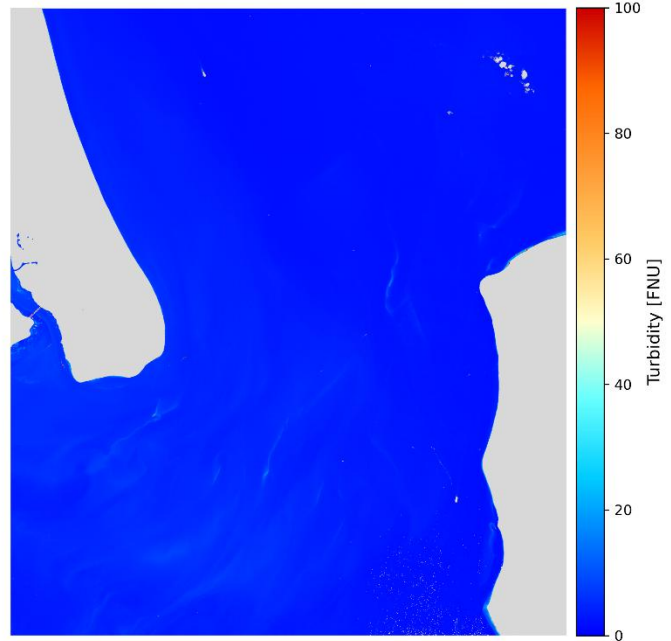
Figure A.178 Turbidity conditions in 2023. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2023-09-01 10:04:10 AEST

Surface Reflectance RGB

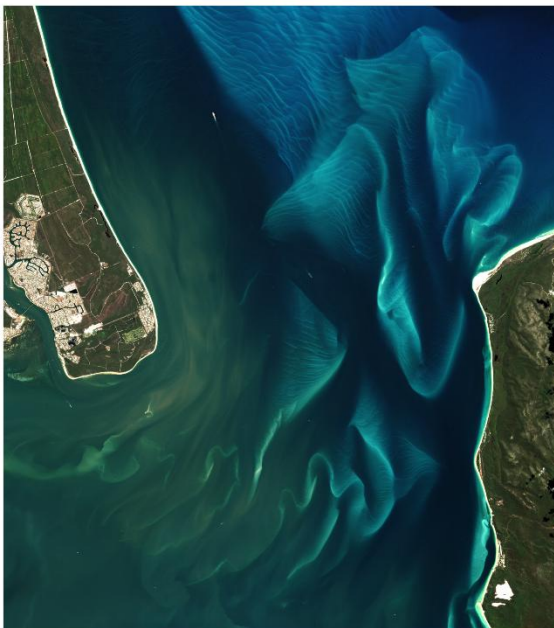


Turbidity



Sensor: S2B MSI | Local Time: 2023-09-26 10:04:08 AEST

Surface Reflectance RGB



Turbidity

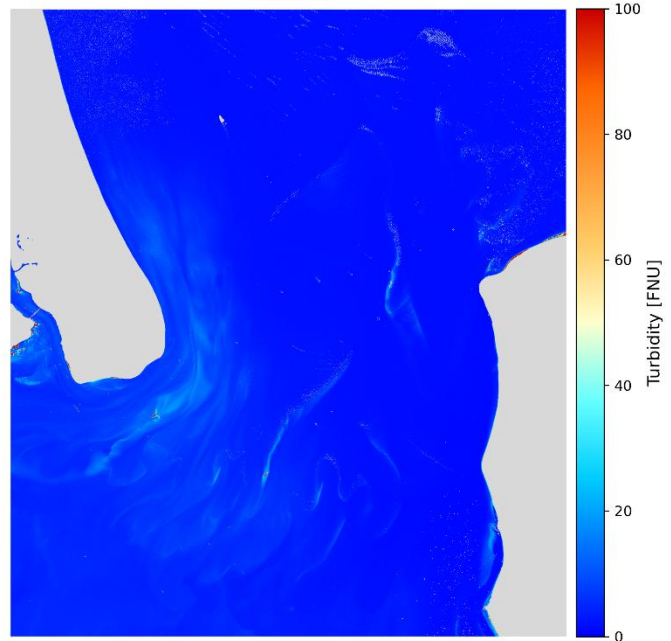


Figure A.179 Representative turbidity conditions in 2023. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.14 Turbidity Pattern 2024

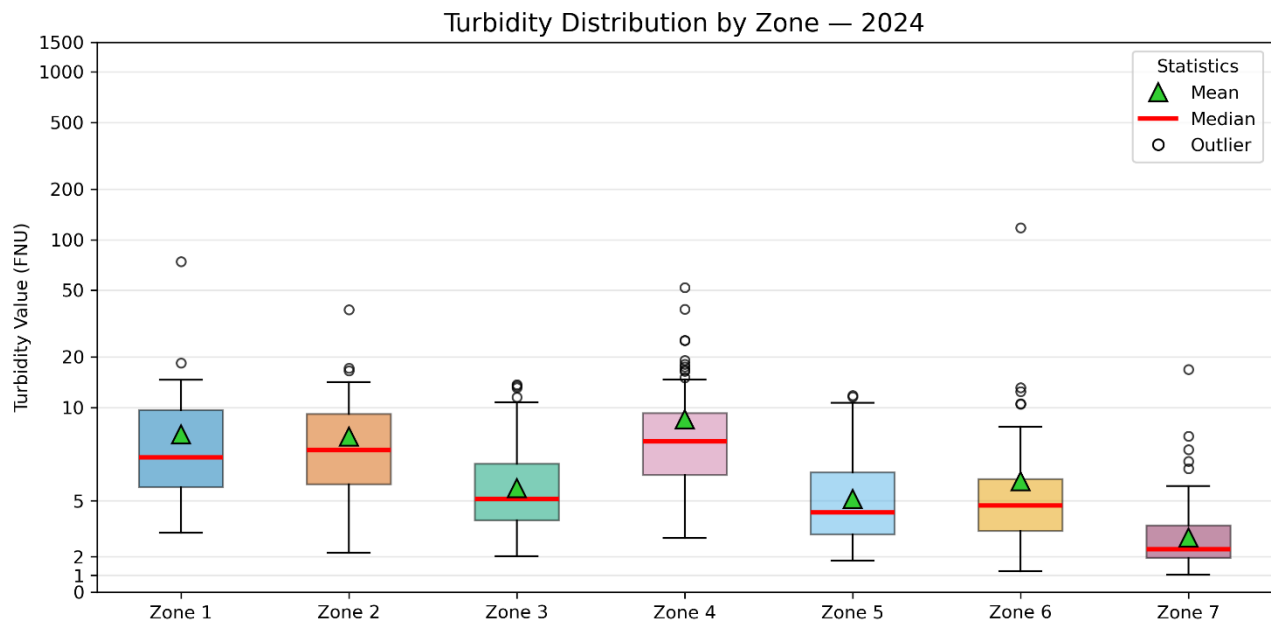


Figure A.180 Turbidity distributions by reporting zone (2024).

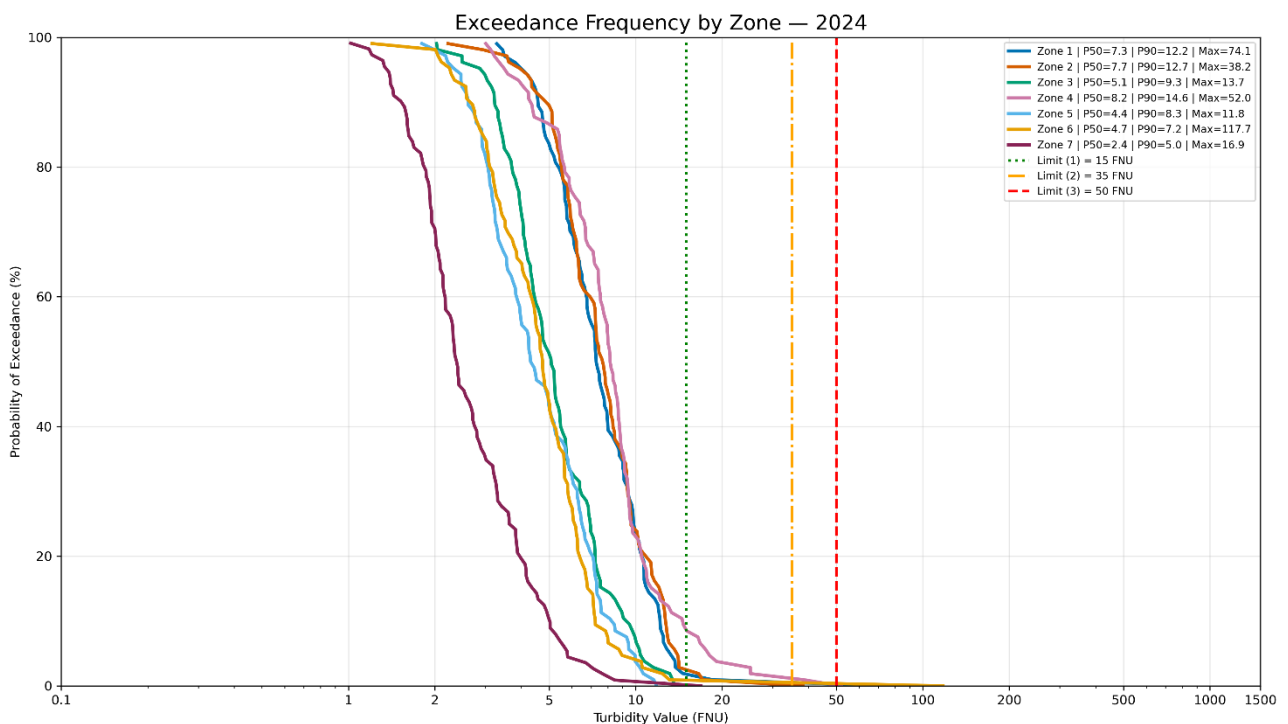


Figure A.181 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2024).

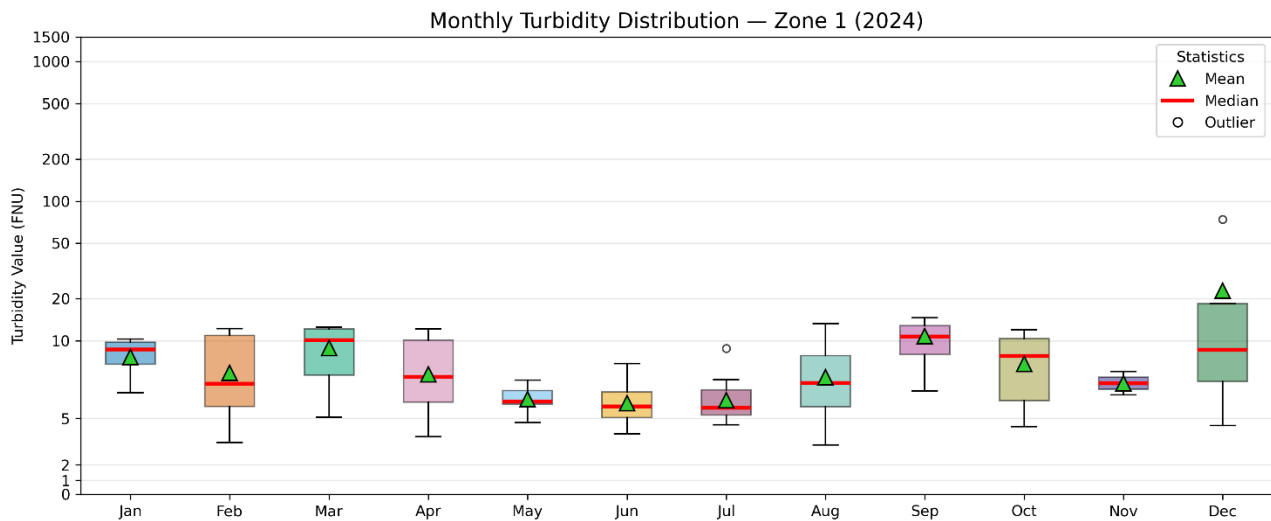


Figure A.182 Monthly Turbidity Distribution by Month for Zone 1 (2024)

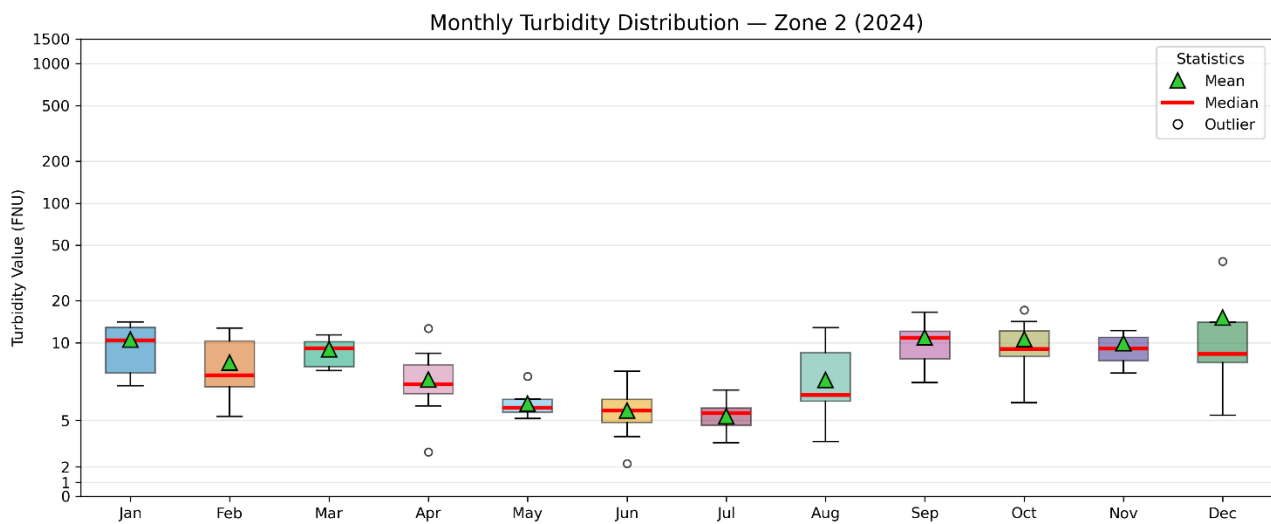


Figure A.183 Monthly Turbidity Distribution by Month for Zone 2 (2024)

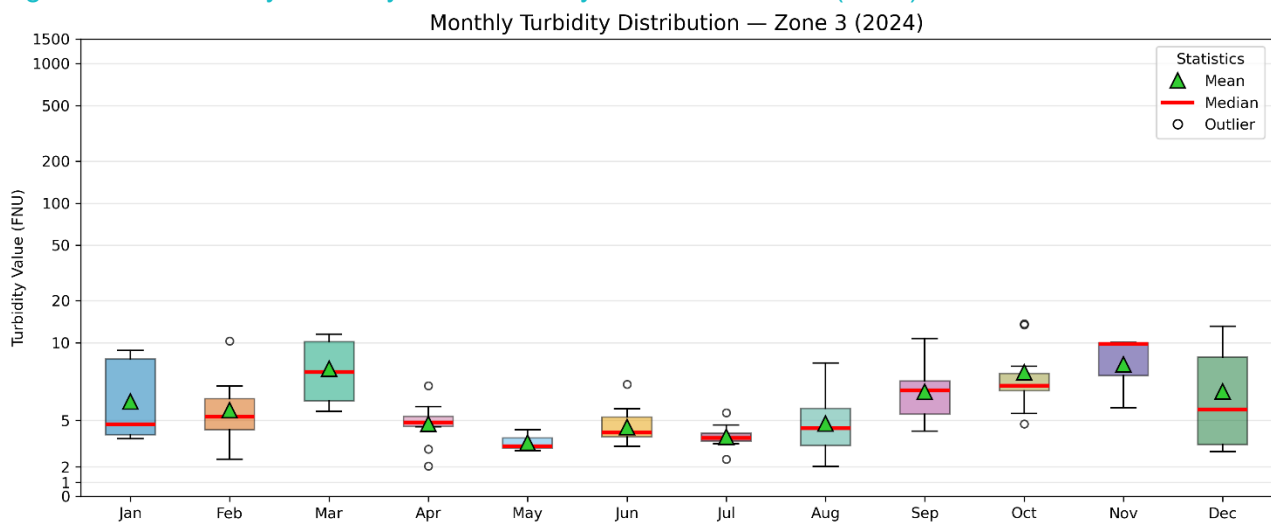


Figure A.184 Monthly Turbidity Distribution by Month for Zone 3 (2024)

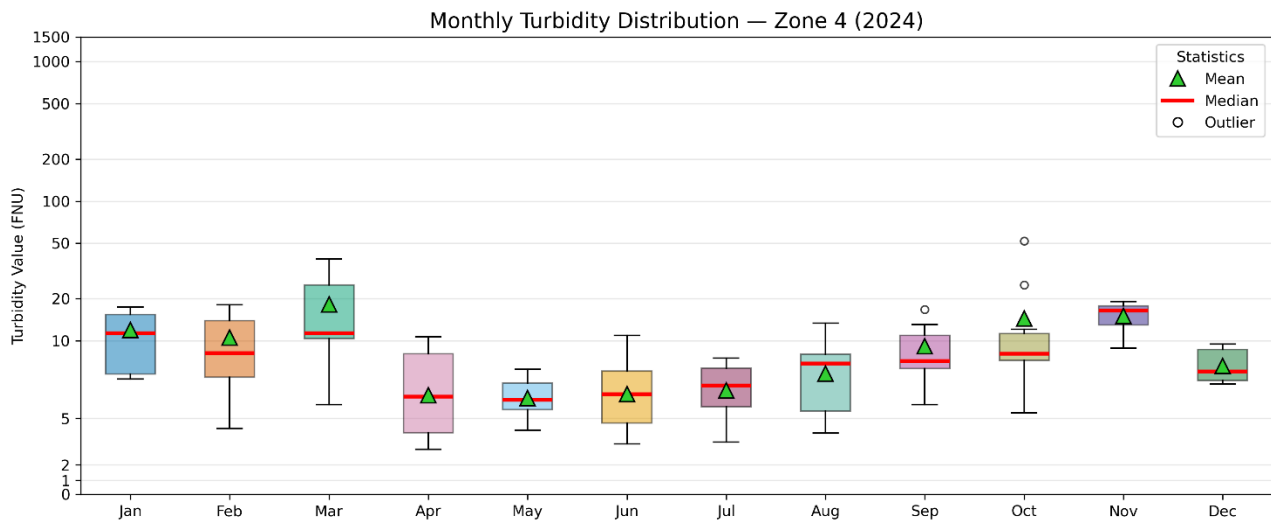


Figure A.185 Monthly Turbidity Distribution by Month for Zone 4 (2024)

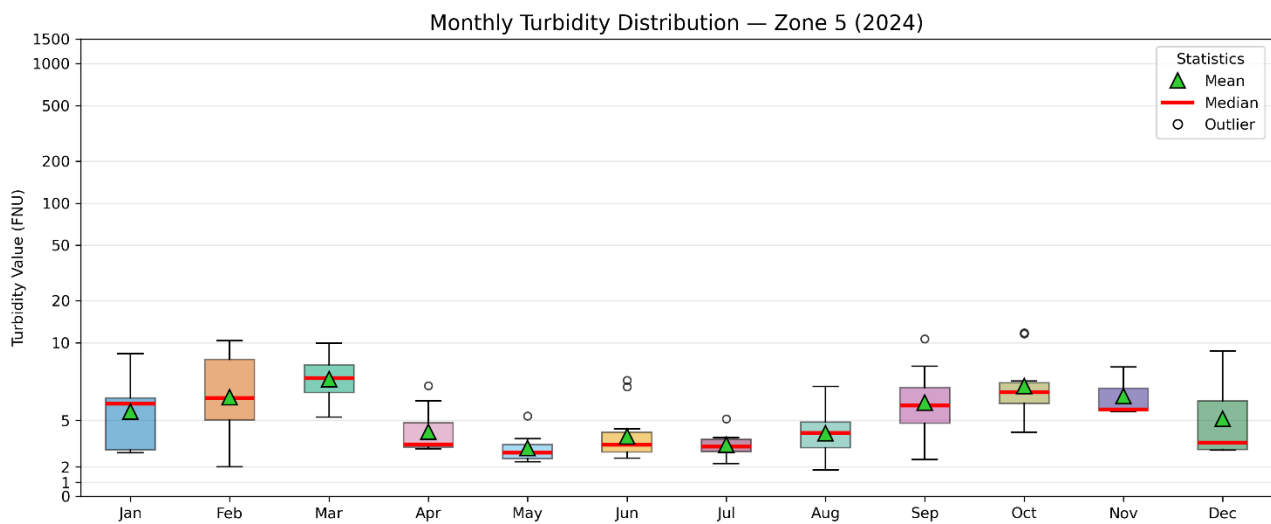


Figure A.186 Monthly Turbidity Distribution by Month for Zone 5 (2024)

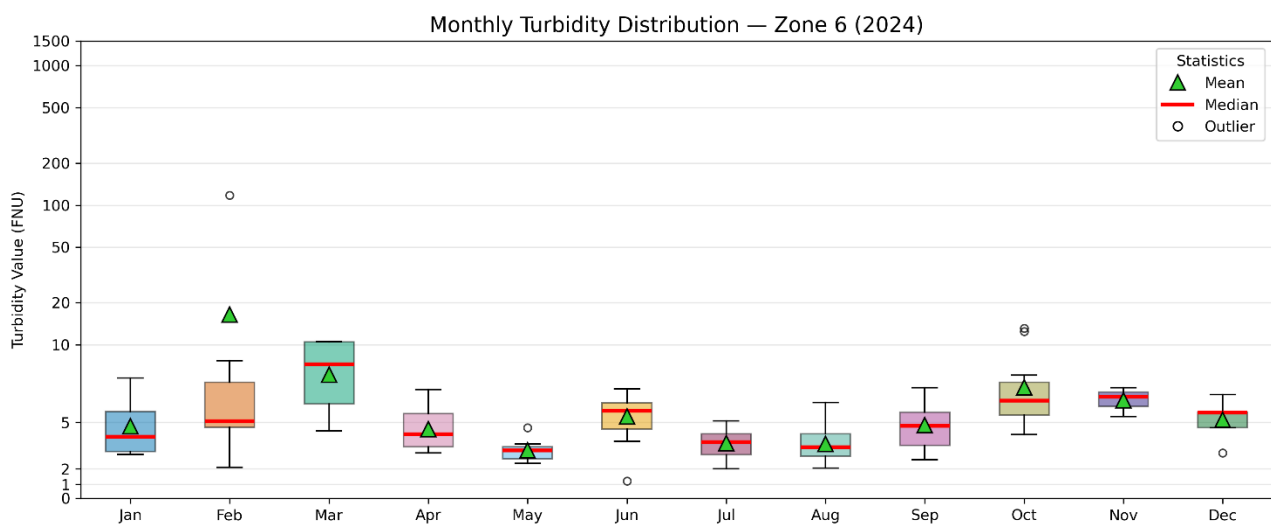


Figure A.187 Monthly Turbidity Distribution by Month for Zone 6 (2024)

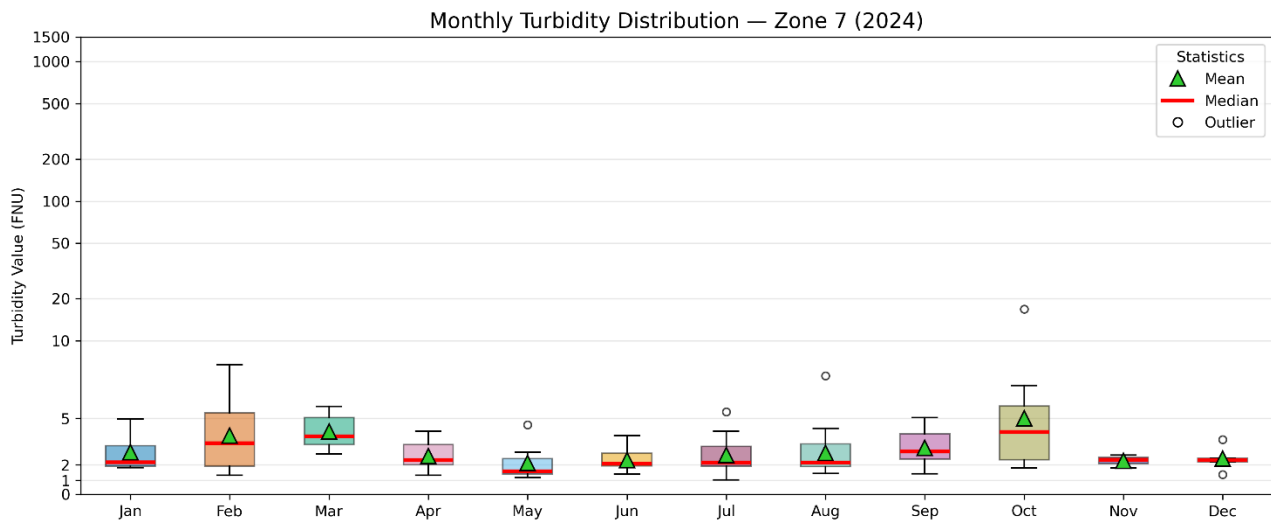


Figure A.188 Monthly Turbidity Distribution by Month for Zone 7 (2024)

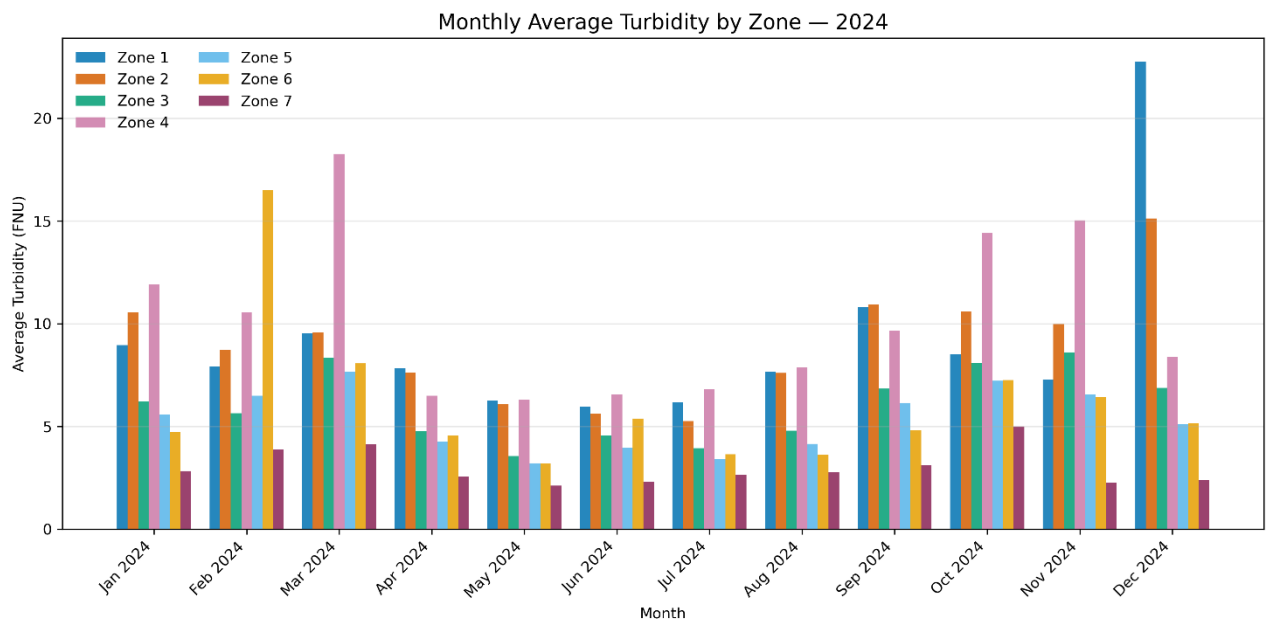


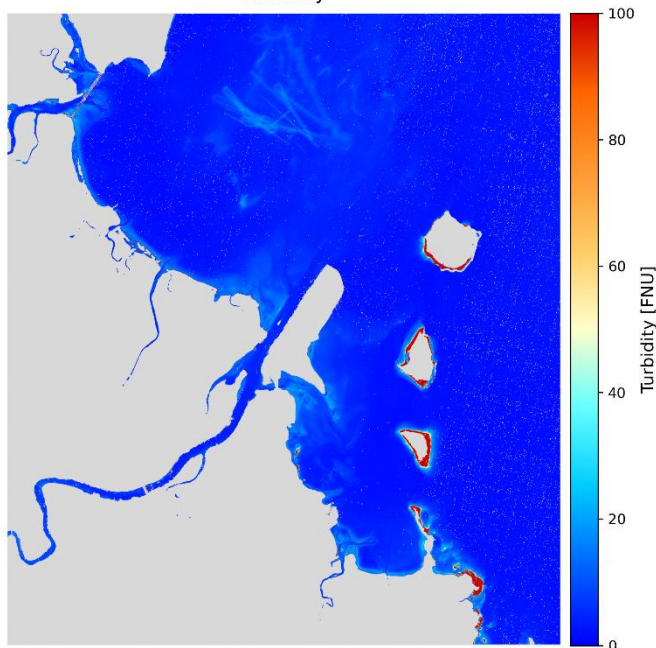
Figure A.189 Monthly Turbidity Distribution by Month (2024)

Sensor: S2A MSI | Local Time: 2024-06-17 10:04:25 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2A MSI | Local Time: 2024-11-01 09:54:23 AEST

Surface Reflectance RGB



Turbidity

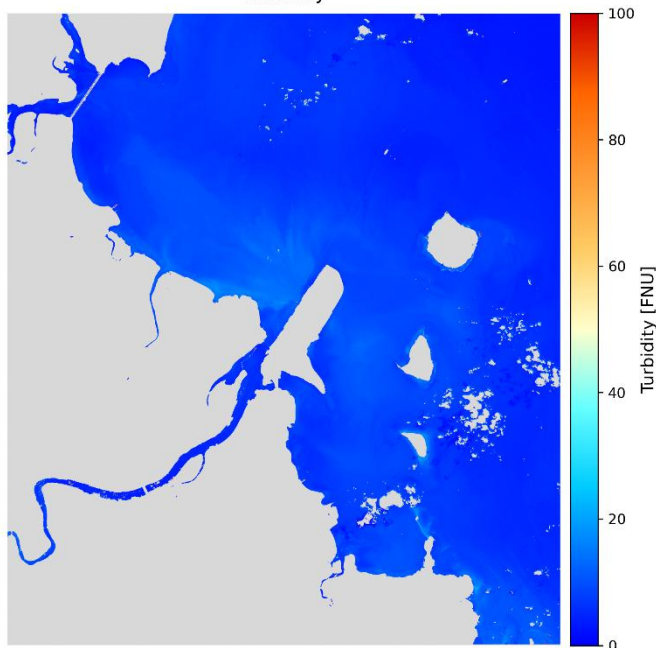


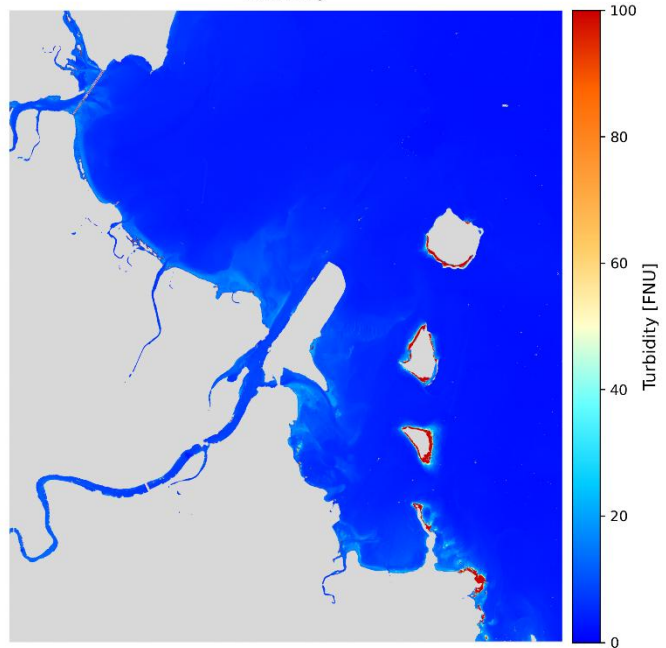
Figure A.190 Representative turbidity conditions in 2024. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2024-04-03 10:04:18 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2024-11-06 09:54:18 AEST

Surface Reflectance RGB



Turbidity

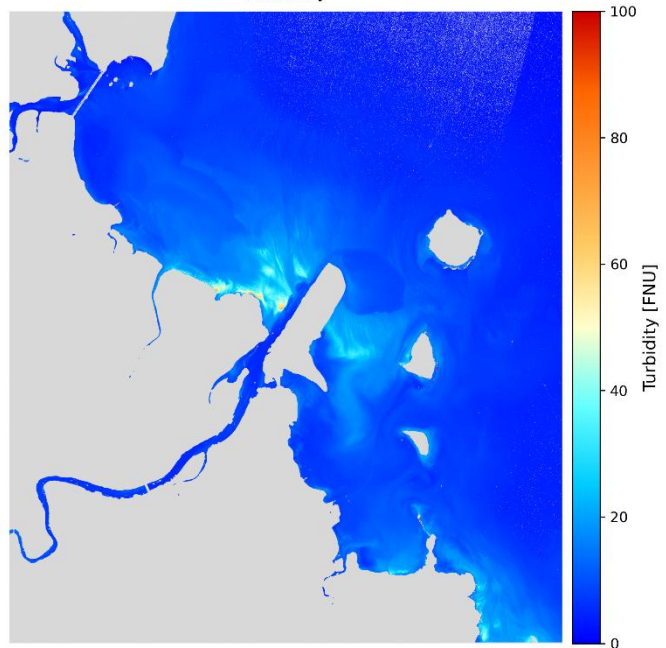


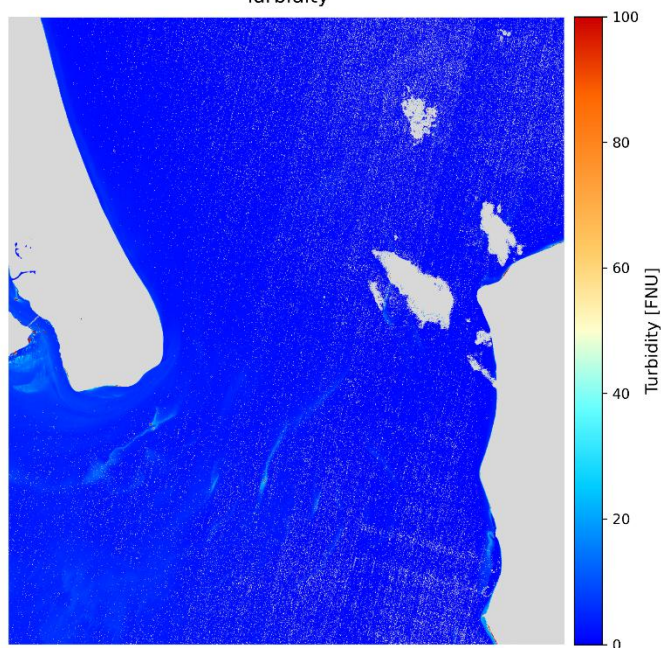
Figure A.191 Representative turbidity conditions in 2024. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2A MSI | Local Time: 2024-05-18 10:04:07 AEST

Surface Reflectance RGB

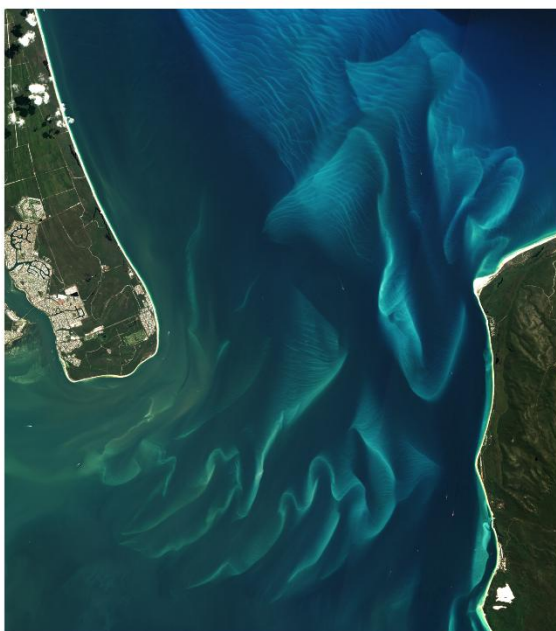


Turbidity



Sensor: S2A MSI | Local Time: 2024-09-15 10:04:03 AEST

Surface Reflectance RGB



Turbidity

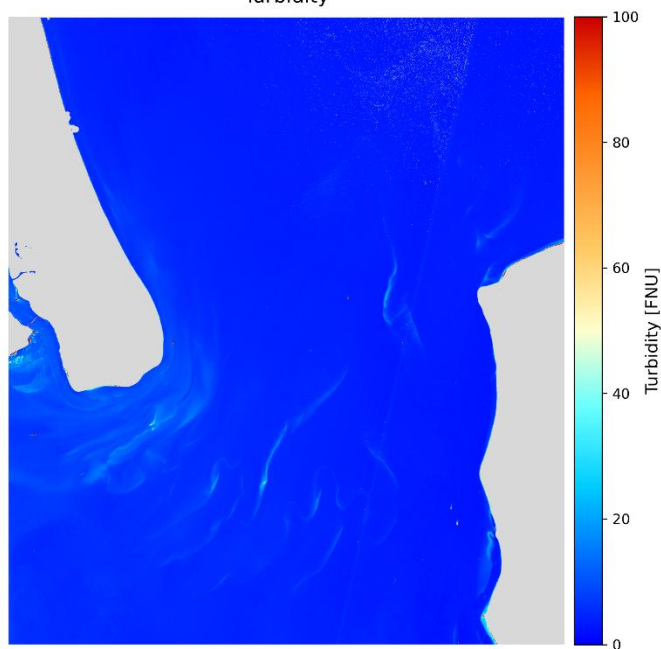
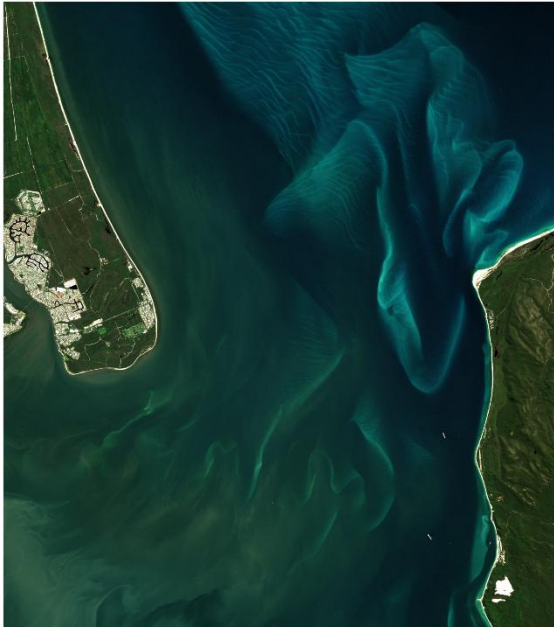


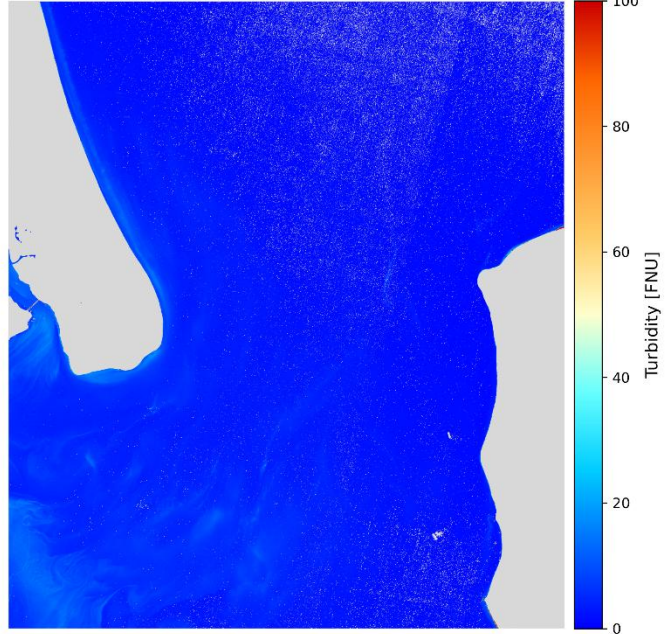
Figure A.192 Turbidity conditions in 2024. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2B MSI | Local Time: 2024-04-10 09:54:09 AEST

Surface Reflectance RGB

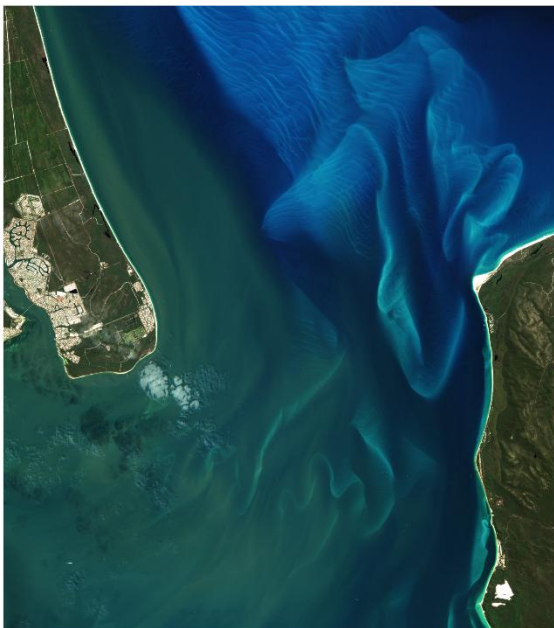


Turbidity



Sensor: S2B MSI | Local Time: 2024-09-20 10:04:00 AEST

Surface Reflectance RGB



Turbidity

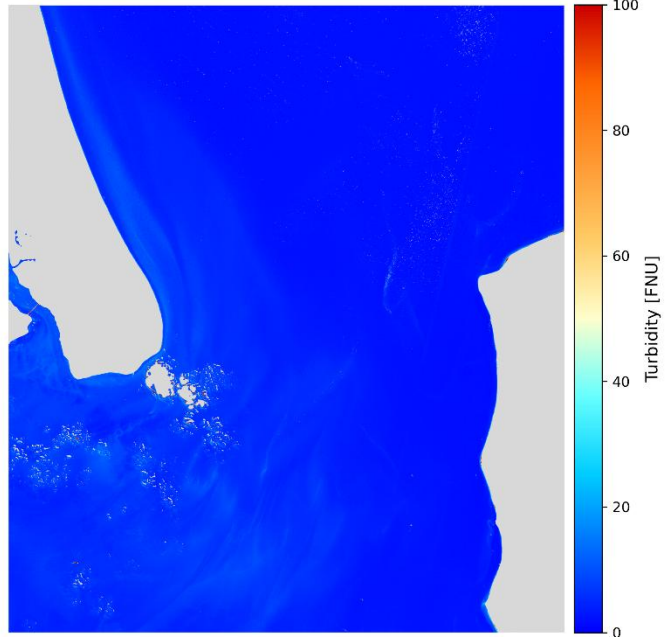


Figure A.193 Representative turbidity conditions in 2024. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

A.15 Turbidity Pattern 2025

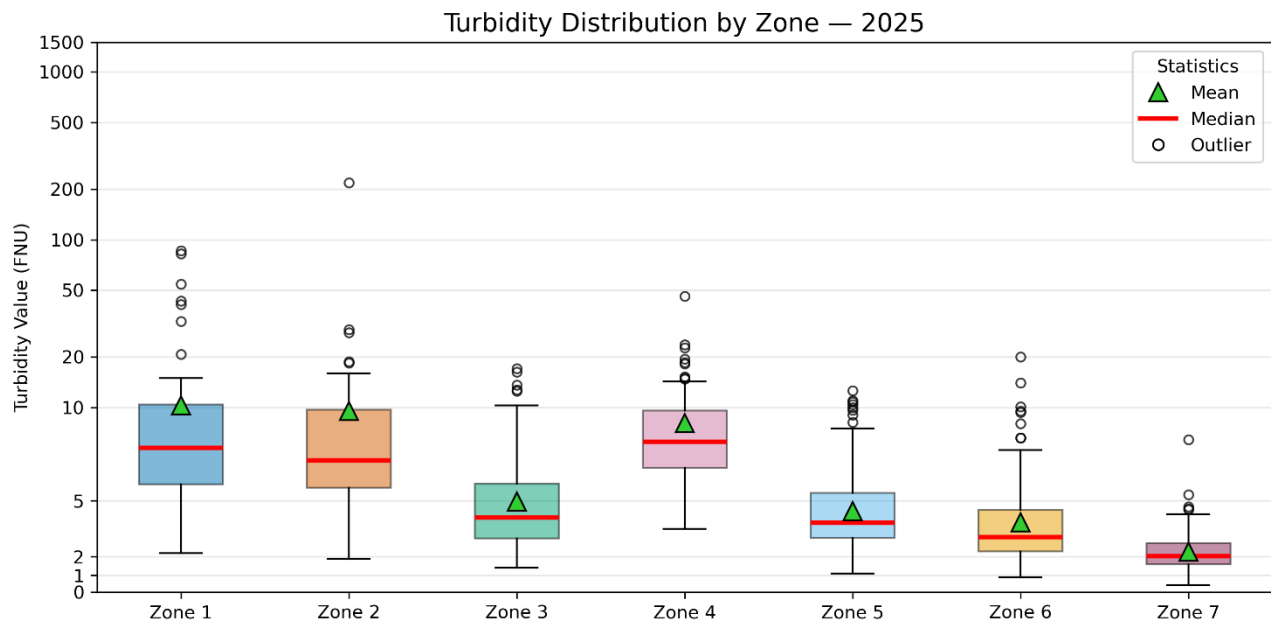


Figure A.194 Turbidity distributions by reporting zone (2025).

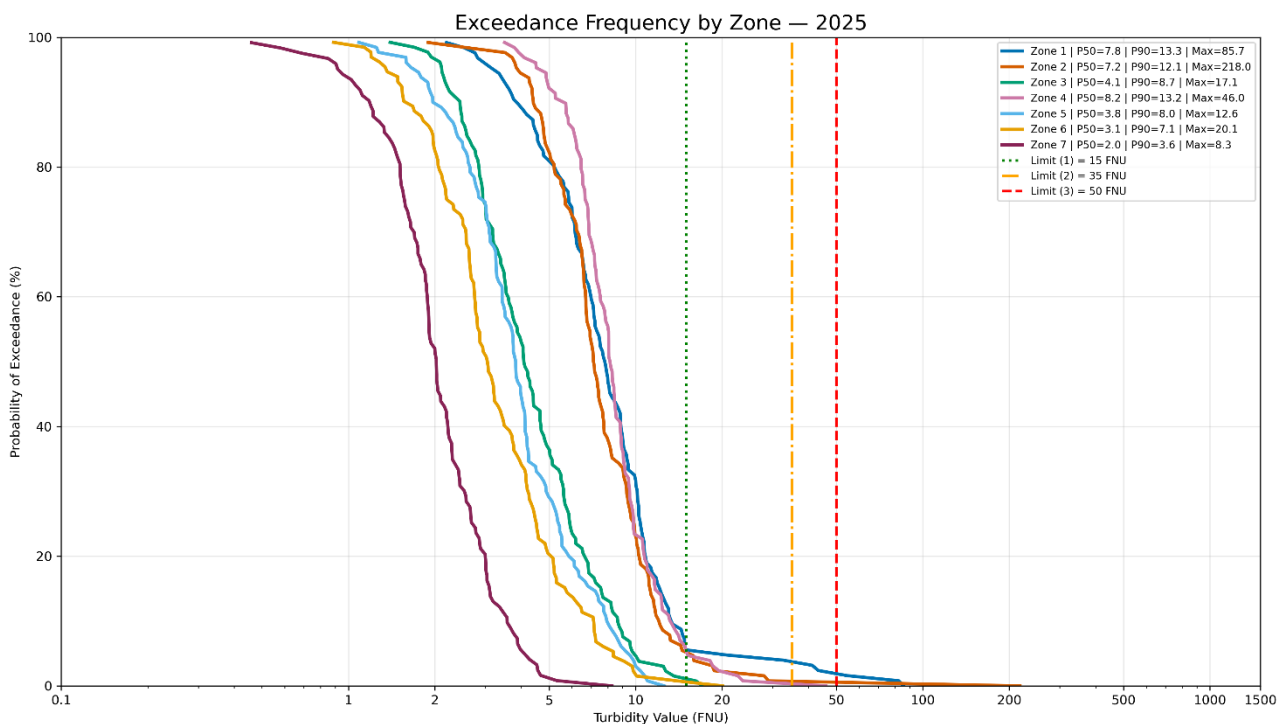


Figure A.195 Probability-of-exceedance curves for satellite-derived turbidity within each monitoring zone (2025).

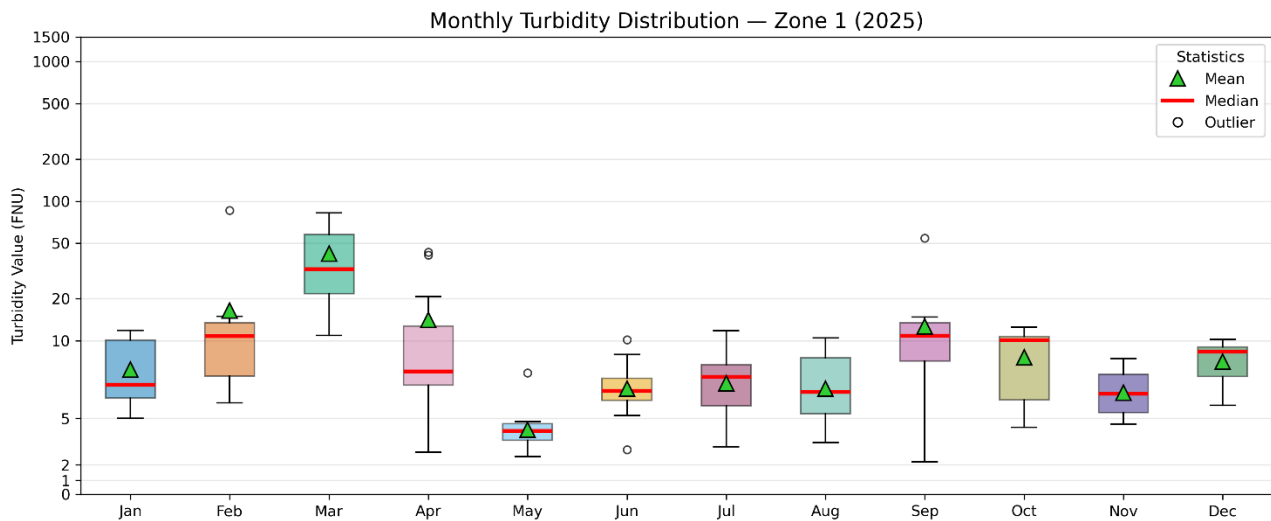


Figure A.196 Monthly Turbidity Distribution by Month for Zone 1 (2025)

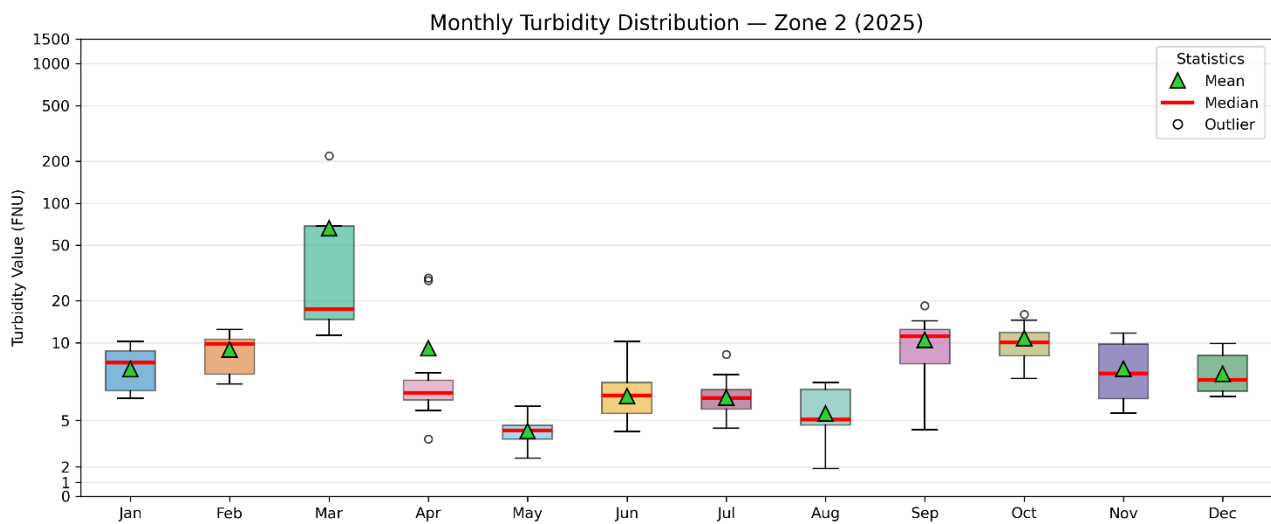


Figure A.197 Monthly Turbidity Distribution by Month for Zone 2 (2025)

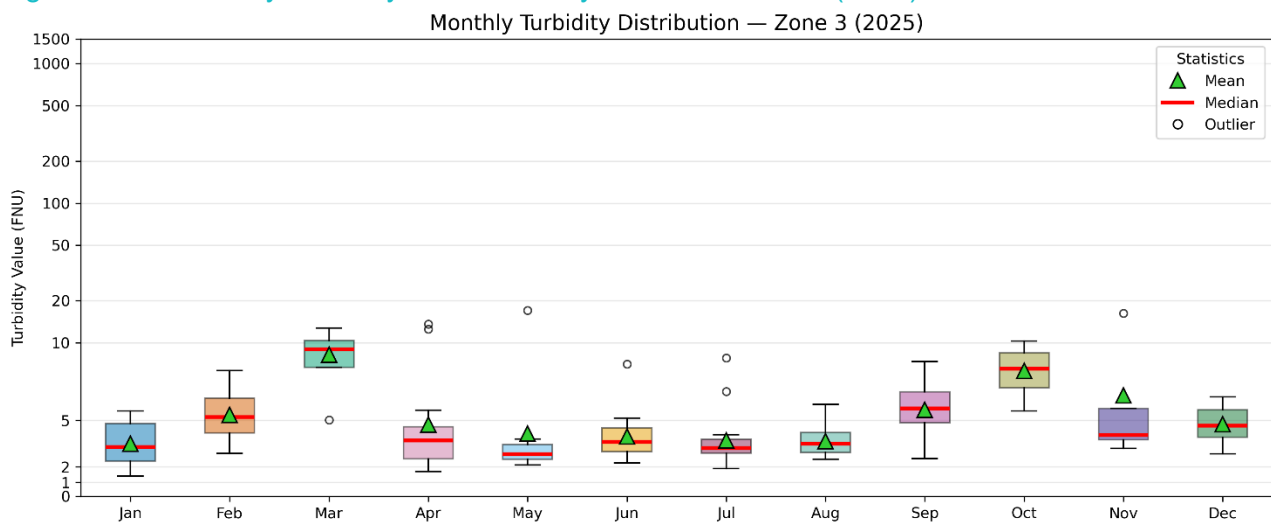


Figure A.198 Monthly Turbidity Distribution by Month for Zone 3 (2025)

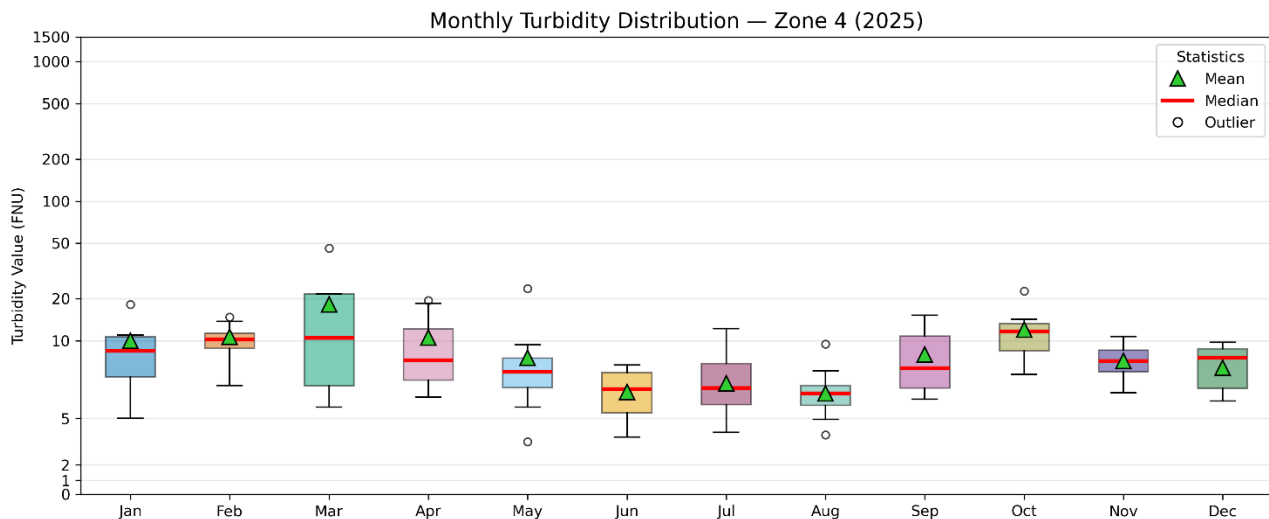


Figure A.199 Monthly Turbidity Distribution by Month for Zone 4 (2025)

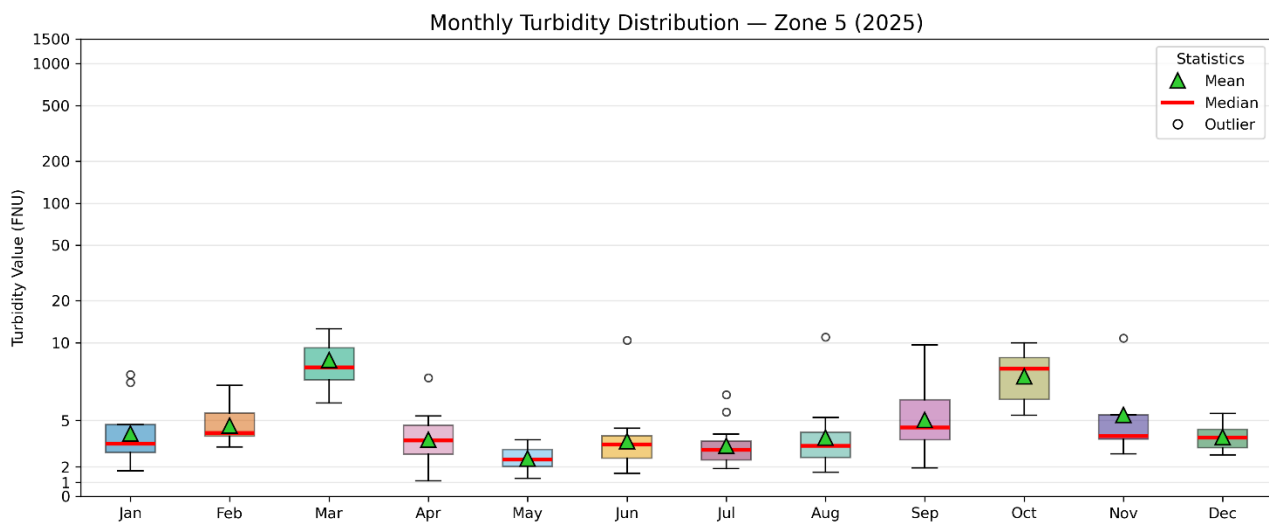


Figure A.200 Monthly Turbidity Distribution by Month for Zone 5 (2025)

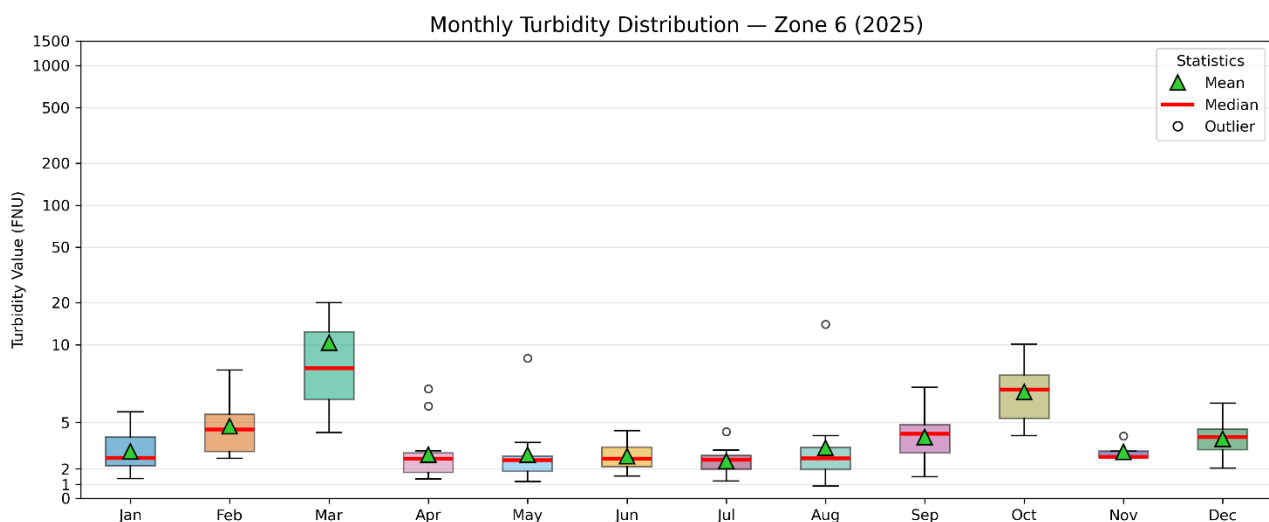


Figure A.201 Monthly Turbidity Distribution by Month for Zone 6 (2025)

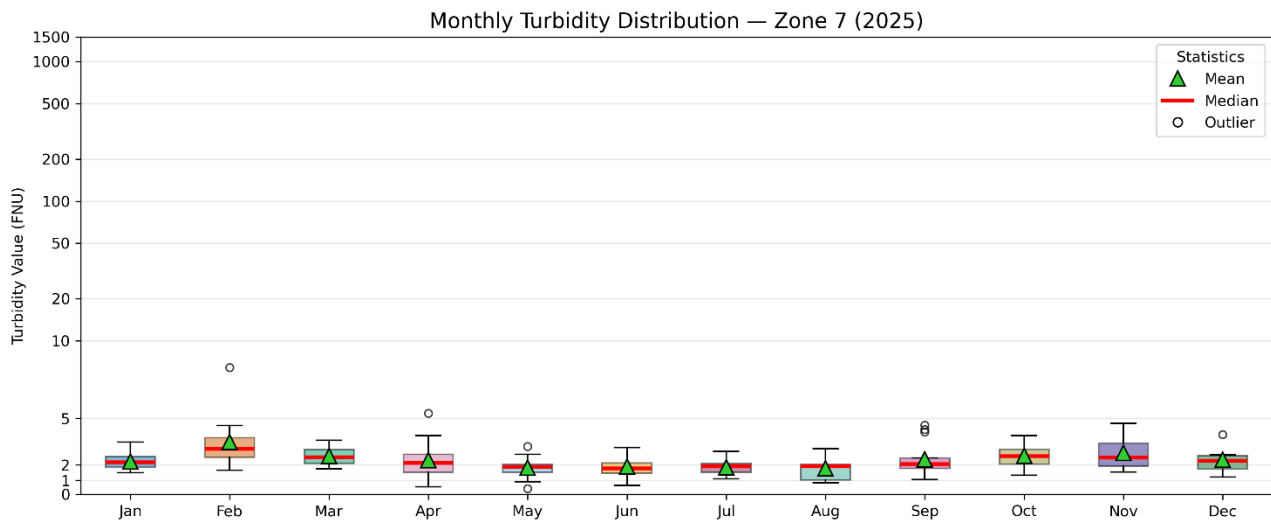


Figure A.202 Monthly Turbidity Distribution by Month for Zone 7 (2025)

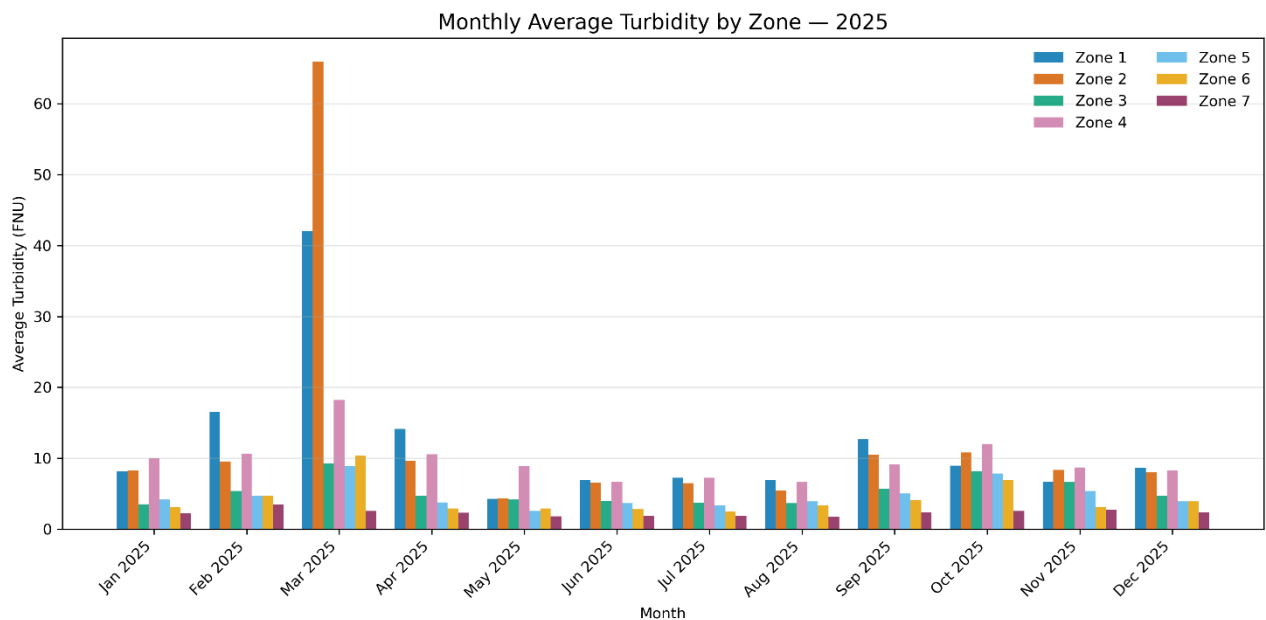
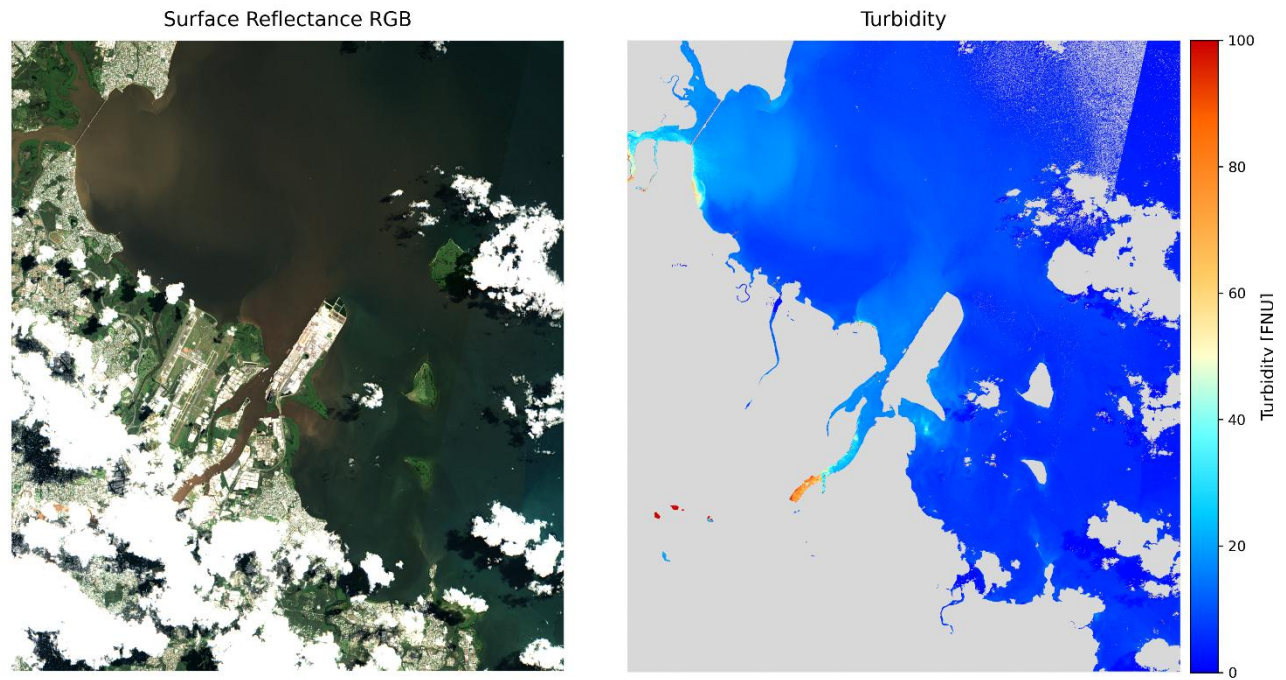


Figure A.203 Monthly Turbidity Distribution by Month (2025)

Sensor: S2C MSI | Local Time: 2025-03-14 10:04:42 AEST



Sensor: S2C MSI | Local Time: 2025-03-11 09:54:47 AEST

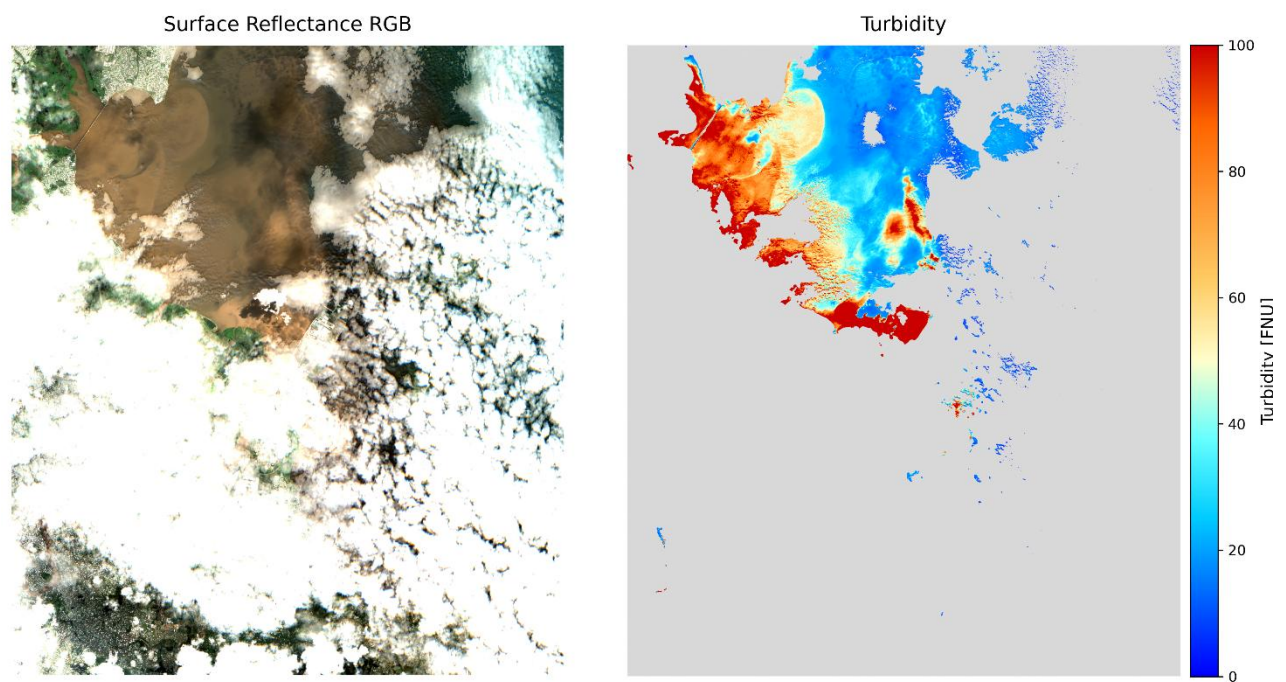


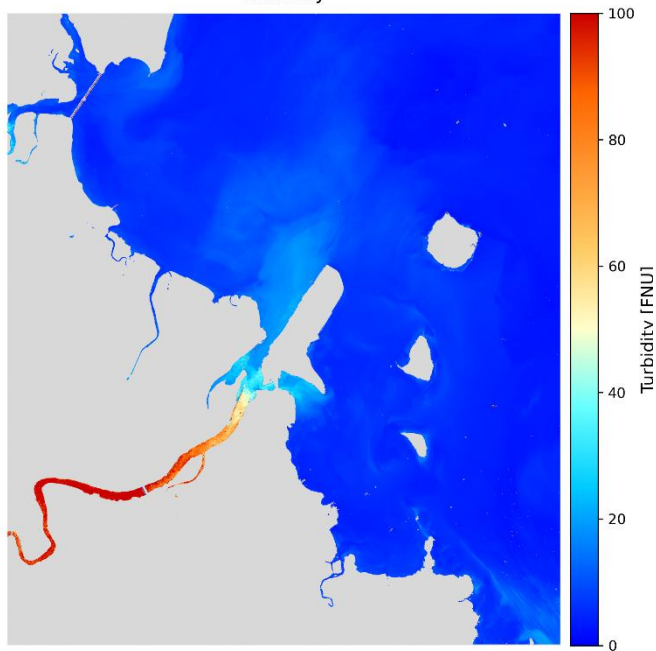
Figure A.204 Representative turbidity conditions in 2025. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2C MSI | Local Time: 2025-03-31 09:54:46 AEST

Surface Reflectance RGB



Turbidity



Sensor: S2B MSI | Local Time: 2025-04-05 09:54:23 AEST

Surface Reflectance RGB



Turbidity

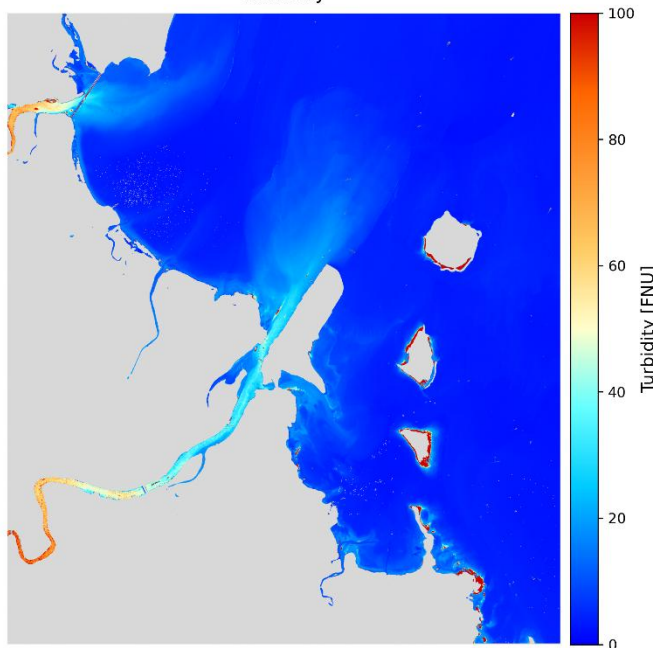
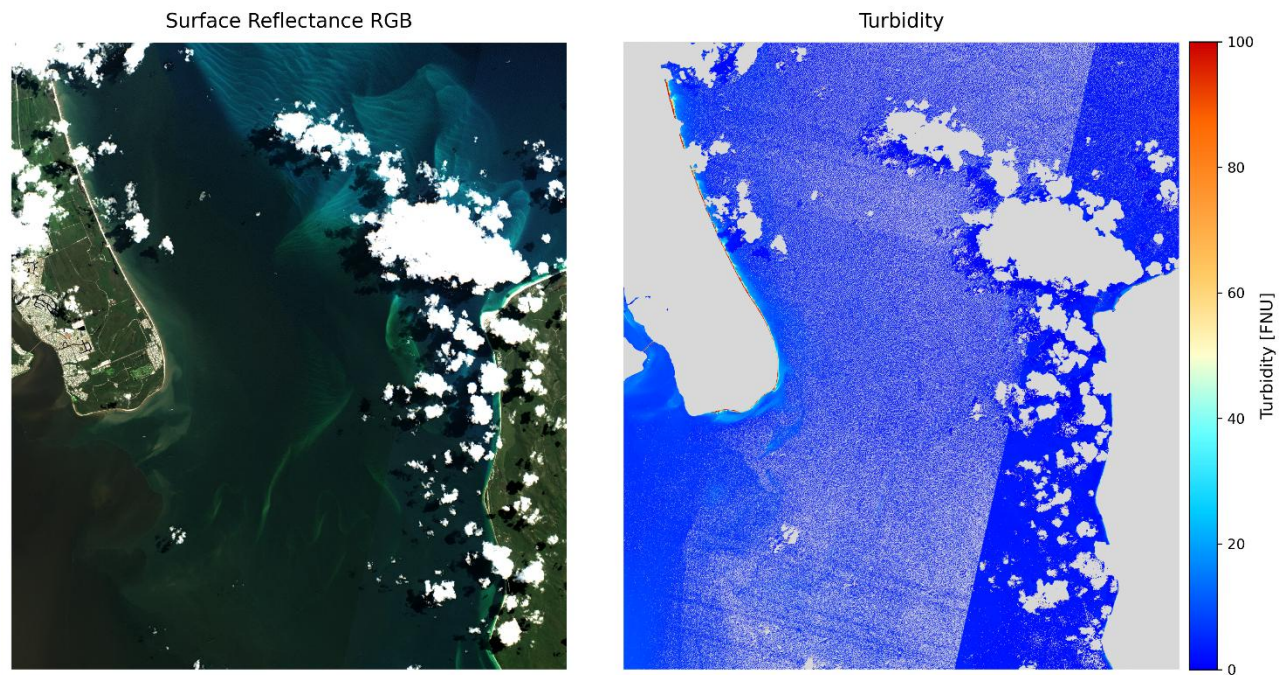


Figure A.205 Representative turbidity conditions in 2025. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2C MSI | Local Time: 2025-03-14 10:04:28 AEST



Sensor: S2B MSI | Local Time: 2025-03-16 09:54:13 AEST

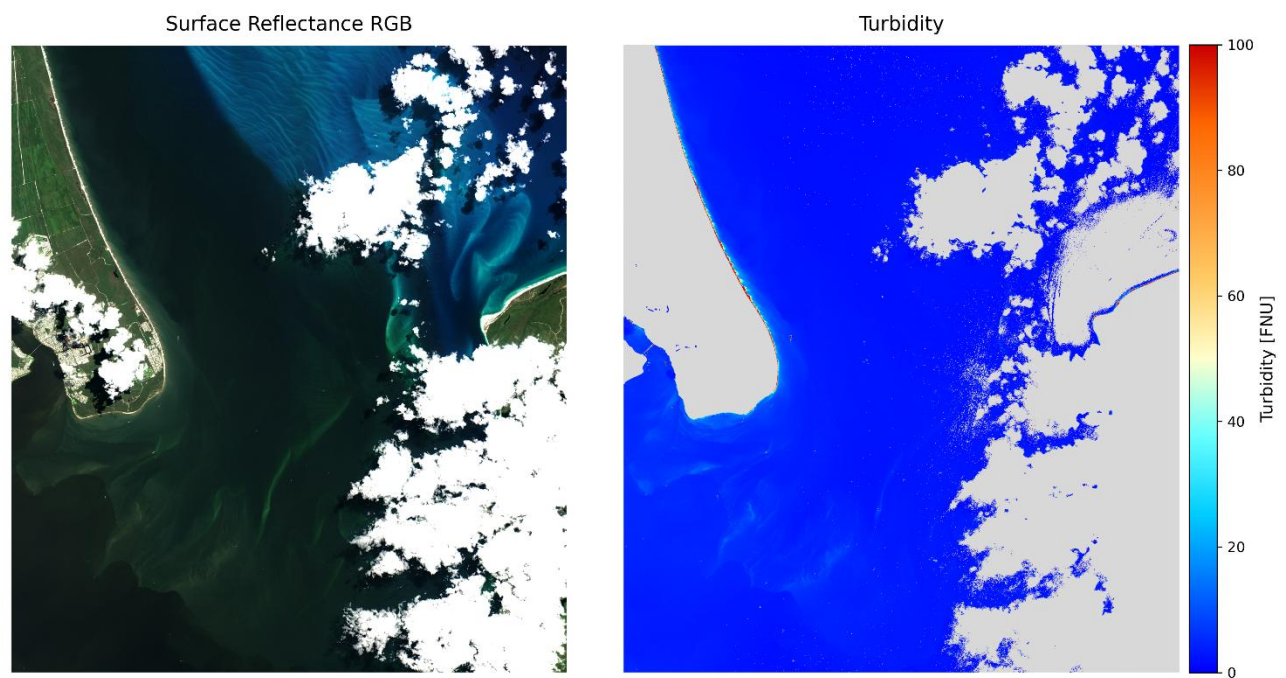
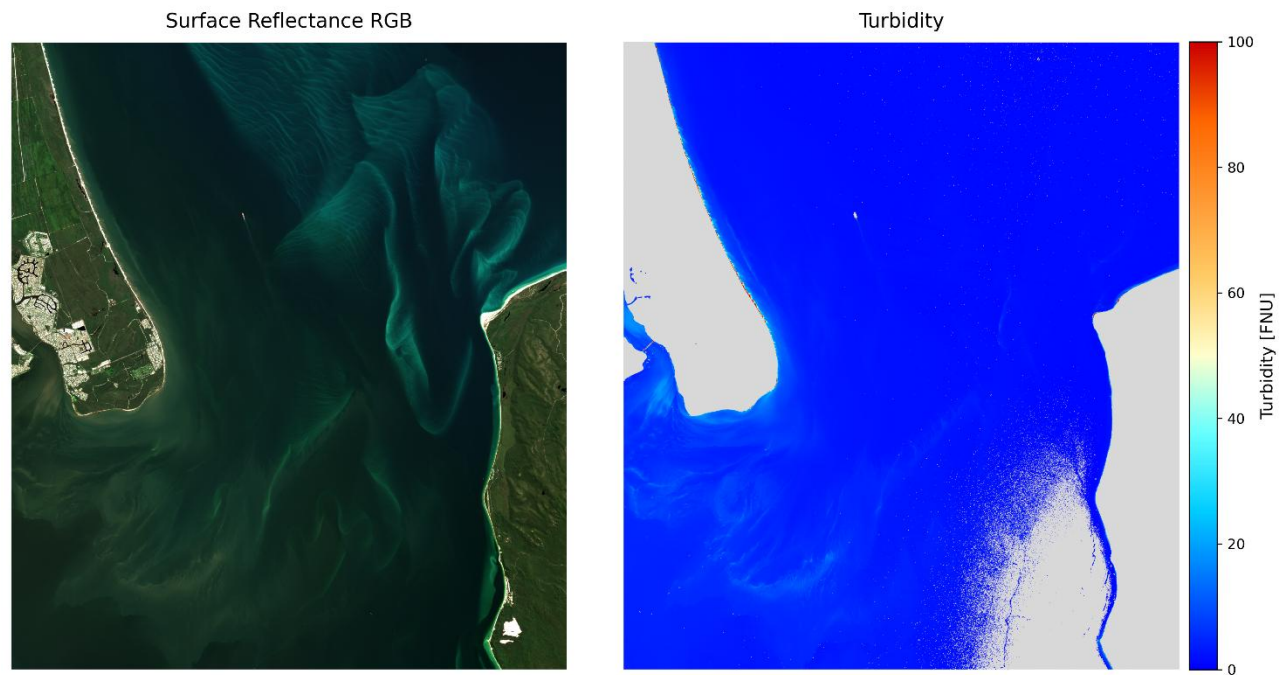


Figure A.206 Turbidity conditions in 2025. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.

Sensor: S2C MSI | Local Time: 2025-03-31 09:54:32 AEST



Sensor: S2B MSI | Local Time: 2025-04-05 09:54:09 AEST

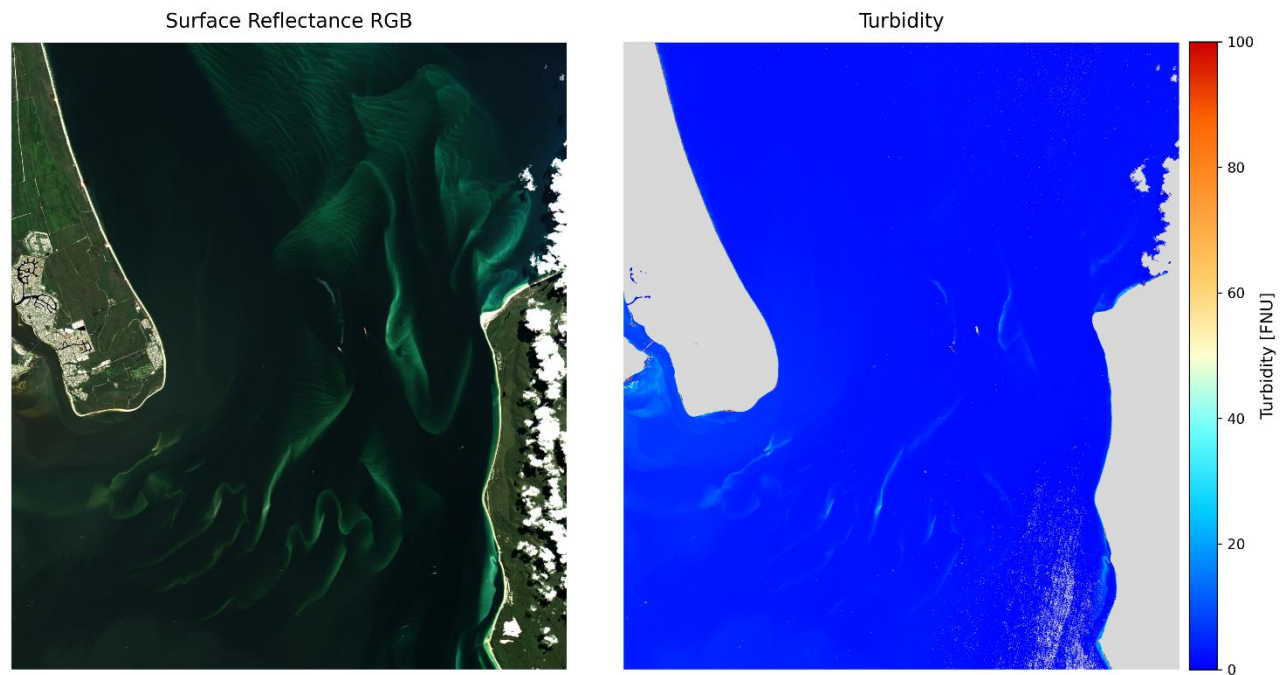
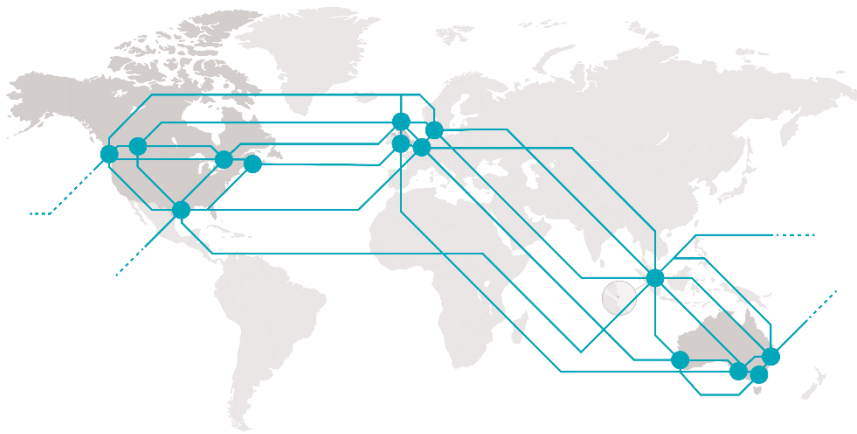


Figure A.207 Representative turbidity conditions in 2025. Turbidity values are displayed with an upper colour scale limit of 100 FNU; areas shown at 100 FNU may represent higher turbidity concentrations.



BMT is a leading design, engineering, science and management consultancy with a reputation for engineering excellence. We are driven by a belief that things can always be better, safer, faster and more efficient. BMT is an independent organisation held in trust for its employees.

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