CLEVELAND BAY SEDIMENT ORIGIN AND DYNAMICS

EXECUTIVE SUMMARY

Cleveland Bay is a naturally sediment-rich environment influenced by regional sediment sources, particularly the Burdekin River, as well as local winds, waves, tides, and currents. Scientific studies show that millions of tonnes of fine sediment move naturally throughout the region each year and that Cleveland Bay acts as a long-term sediment sink. These sediment processes have operated over thousands of years and continue today. Maintenance dredging removes naturally accumulated sediment from Port infrastructure and returns that material to Cleveland Bay via a designated placement area. Understanding these natural sediment dynamics is essential for interpreting environment monitoring results and distinguishing natural variation from localised activities.

WHY SEDIMENT MATTERS

Cleveland Bay is a sediment-rich coastal environment. The bay receives sediment from large regional catchments, particularly the Burdekin River, and is influenced by winds, waves, tides, and coastal currents that continually move sediment throughout the region. Sediment movement plays a critical role in shaping the health of marine ecosystems and maintaining the safe operation of the Port of Townsville's shipping channels and other underwater infrastructure.

THE BURDEKIN RIVER: A MAJOR SOURCE OF SEDIMENT

Townsville is located within the Dry Tropics region of North Queensland and is strongly influenced by the Burdekin River catchment, which covers approximately 130,000 square kilometres—an area similar in size to England. The Burdekin River is Australia's largest river by peak discharge and is the most significant source of fine sediment entering coastal waters in the region.

Whilst the Burdekin Falls Dam captures more than 95% of the sand-sized sediments, the finer particles continue to be transported downstream and out of the river mouth during flood events, as suspended sediment flood plumes. The finer particles originate primarily from sub-surface soil erosion and gully erosion within the catchment. On average, the Burdekin River exports approximately 3.3 million tonnes of fine sediment each year. However, during major flood events sediment loads delivered to coastal waters can increase to as much as 15.74 million tonnes, (Kuhnert et al., 2012).

Figure 1: Burdekin River near Ayr, following heavy rainfall in 2019. Photo: Matt Curnock

These naturally occurring sediment inputs are often orders of magnitude greater than local sediment sources and play a significant role in influencing water quality, turbidity, and sediment distribution within Cleveland Bay. As a result, understanding the interaction between regional sediment processes, local environmental conditions and human activities is essential for effective environmental management, impact assessment, and long-term planning. Continued monitoring, scientific research, and the use of modern tools such as satellite remote sensing help improve understanding of these complex processes and support evidence-based decision-making.

WHAT THIS MEANS:

The amount of sediment delivered to coastal waters by major Burdekin River floods can be significantly greater than sediment movements associated with local activities in Cleveland Bay.

The sea between the North Queensland Coast and the Great Barrier Reef is a shallow lagoon with an average depth of just 35 meters. This shallow marine system plays an important role in the transport and redistribution of sediments throughout the region.

Located approximately 90 kilometres south of Cleveland Bay, the Burdekin River discharges vast volumes of freshwater and suspended sediment during major flood events. The force of these floodwaters can carry fine sediments tens of kilometres offshore in large flood plumes before they become dispersed throughout the wider Great Barrier Reef lagoon.

Once flood flows subside, these fine sediments continue to be redistributed by regional oceanographic processes. Prevailing south-easterly trade winds generate waves and currents that drive a longshore transport system, gradually moving sediments northward along the coastline. Periodic resuspension of previously deposited sediments by wind-driven waves can continue for months after flood events, contributing to naturally elevated turbidity across large areas of the region.

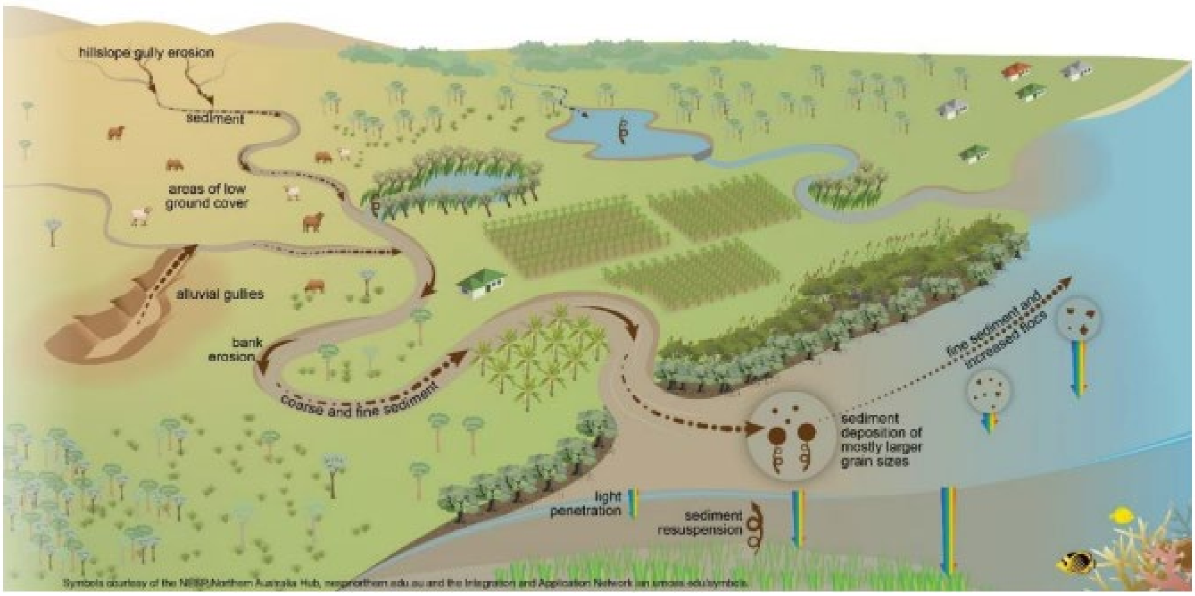


Figure 2: Conceptual understanding of sediment sources and transport across the catchment to marine continuum (Lewis, S. and Bainbridge, Z. 2021)

Within Cleveland Bay, local circulation patterns are further influenced by the interaction of regional trade winds, daily north-easterly sea breezes, tides, and the bay's physical geography. These processes establish a wind-driven circulation system that typically sees water entering the bay near Cape Cleveland and exiting near Magnetic Island. The resulting currents can transport and redistribute suspended sediments throughout the bay, influencing water clarity and sediment deposition patterns. These large-scale natural processes are important considerations when assessing water quality and sediment movement in Cleveland Bay.

The quantity of sediment entering Cleveland Bay through coastal processes can be substantial and often exceeds localised sediment sources. Consequently, understanding regional sediment dynamics is essential for distinguishing natural variability from localised activities and for supporting effective environmental management and monitoring programs.

The image below captures a period when both the Burdekin River and the Ross River were experiencing flood conditions. While flood plumes from both river systems are visible, the scale of the Burdekin River plume is significantly larger than the discharge from the Ross River.

The above image illustrates the dominant pathways by which fine sediments originating from the Burdekin River are transported through the Great Barrier Reef lagoon and ultimately influence sediment conditions in Cleveland Bay. Research has shown that fine sediments from the Burdekin River can be transported northward and accumulate within sheltered coastal embayment's, including Cleveland Bay. These bays are less exposed to the prevailing south-easterly waves, allowing fine sediments to settle and accumulate over extended periods of time.

Historical evidence of this process was identified through the analysis of a 175-year coral core (1813 – 1986) collected from Magnetic Island. The study found chemical signatures indicating that sediments originating from erosion within the Burdekin River catchment had been deposited on Cleveland Bay reefs during and following major flood events (Lewis et al. 2007).

Data from a three-year long field study of fine sediment dynamics in Cleveland Bay found that for present day catchment conditions, the volume of riverine sediments settling in the bay may exceed the volume exported from the bay by approximately 50–75% (Lambrechts et al., 2010). North facing bays act as 'sedimentary sinks' over long periods of time, (Woolfe and Larcombe, 1998). Together, these studies highlight the significant influence of regional sediment sources, particularly the Burdekin River, on the long-term sediment budget and environmental conditions of Cleveland Bay.

WHAT THIS MEANS:

- *Scientific studies indicate that Cleveland Bay receives and retains sediment from regional sources over long time periods.*
- *This means that environmental conditions within Cleveland Bay are influenced not only by local processes, but also by sediment delivered from much larger regional catchments, particularly the Burdekin River.*
- *Scientific studies indicate that Cleveland Bay acts as a **long-term sediment sink**, meaning that more fine sediment enters and settles within the bay than leaves it. As a result, sediments delivered form regional rivers can accumulate within Cleveland Bay over long periods of time, contributing to the naturally sediment-rich conditions observed today.*

CLEVELAND BAY

Cleveland Bay has evolved over thousands of years as sea levels rose following the last ice age, inundating the coastal plain between the present-day mainland and the present-day Great Barrier Reef. When the bay was first formed, it is likely to have been significantly deeper than it is today. Since that time, countless flood events have transported fine sediments from regional catchments into the Great Barrier Reef lagoon. Over millennia, these sediments have been redistributed by waves, tides and coastal currents, creating a substantial store of fine sediment within nearshore marine environments.

As a sheltered, north-facing embayment, Cleveland Bay tends to retain a proportion of these sediments. The gradual accumulation of fine sediment over long periods has contributed to the progressive infilling and shallowing of the bay. This is a natural geological process that has shaped the modern coastal landscape and continues today as sediments are delivered, redistributed and deposited throughout the region. The ongoing accumulation of fine sediments within Cleveland Bay reflects the combined influence of regional river inputs, coastal transport processes and local environmental conditions operating over hundreds to thousands of years.

Recent studies estimate that approximately 2 billion cubic metres of fine sediment are stored on the seabed within Cleveland Bay (BMT 2018). Historical records show that elevated turbidity from suspended sediments occurs on average 220 days of the year in Cleveland Bays due to natural resuspension processes, (Orpin et al., 2004). This is due to a combination of factors:

- Half of the bay is less than 5m deep, allowing wave energy to regularly reach and interact with the sea floor.
- The seabed contains large volumes of fine sized sediment particles which are readily resuspended into the water column under normal environmental conditions.
- Moderate to strong winds occur frequently throughout the year and can generate steep waves in the bay's shallow waters, causing naturally occurring sediment resuspension and increased turbidity.
- Cleveland Bay experiences a large tidal range of 3-4 meters. These tides generate strong currents that can resuspend seabed sediments and transport naturally turbid waters from estuaries, mangrove systems, and intertidal mudflats into deeper parts of the bay, particularly during large outgoing tides.
- Seabed stability is influenced by the presence of coarser sand particles, which help bind finer sediments together. The “binding” role of coarse sediments with fine sediments is a key control on seabed stability, (Alonso et al. 2023). Reductions in the supply of coarse sediments from local and regional river systems, resulting from the construction of weirs and dams, can affect the stability of seabed sediments and increase their susceptibility to resuspension. The construction of weirs and dams on rivers significantly limits the supply of coarse sand to Cleveland Bay, (Gunn, J. & Manning, C. 2010).

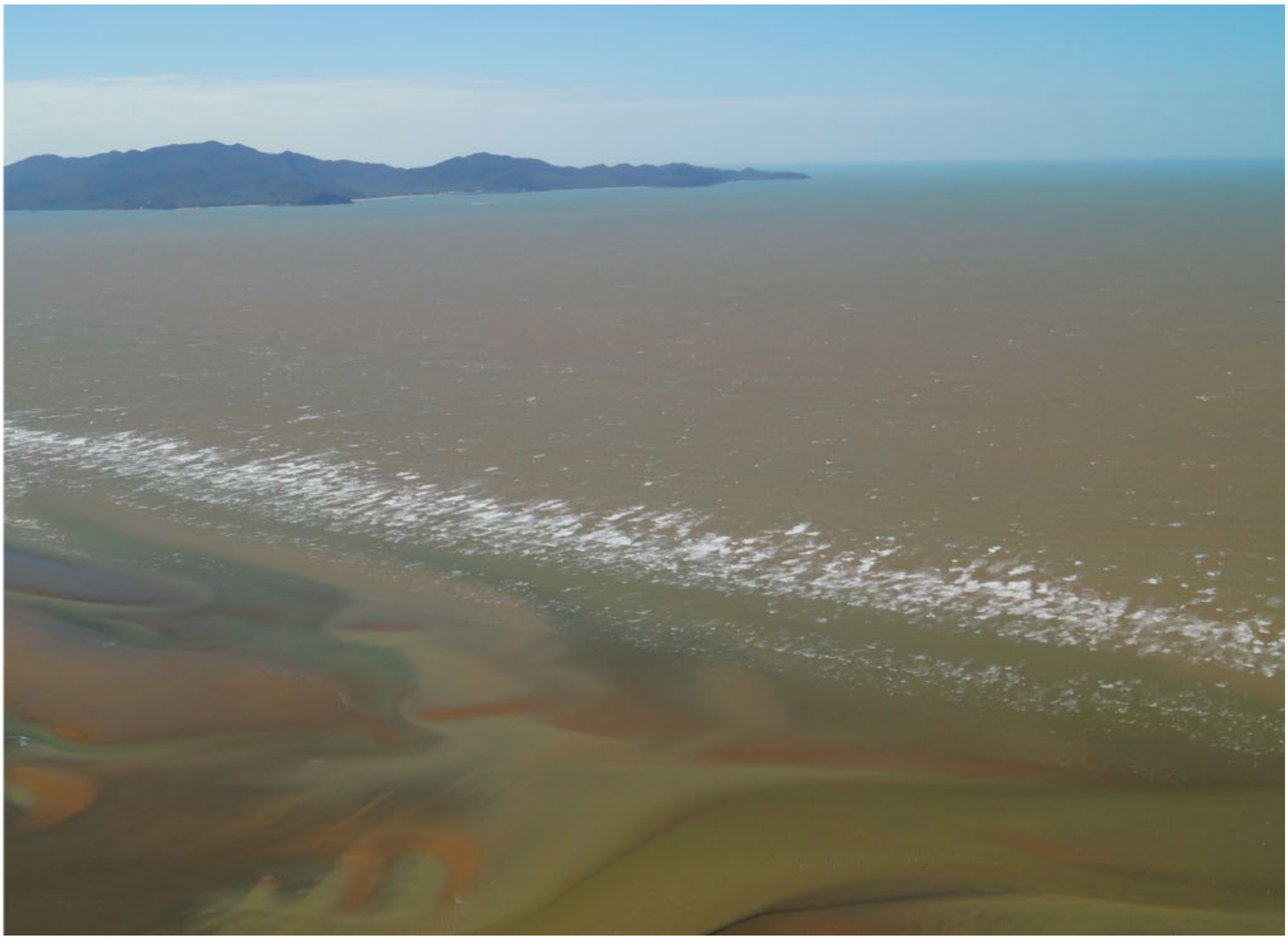


Figure 3: Suspended sediments in Townsville's shallow Cleveland Bay, on an average windy day with no dredging activity, looking towards Magnetic Island

Most studies of Cleveland Bay document the major cause of sediment resuspension in the bay to be waves. The localised waves that frequently occur within Cleveland Bay are short and steep, high-energy waves that regularly suspend fine sediments from the seabed into the water column. While sediment movement within Cleveland Bay varies in response to tides, winds and weather conditions, predominant patterns include:

- Moderate to strong north-easterly winds and incoming tides can transport suspended sediments into Cleveland Bay from surrounding coastal waters.
- Moderate to strong south-easterly and easterly winds, and outgoing tides, generally move sediments from the shallow south-eastern areas of the bay towards the north-western part of the bay.
- Over the long term, Cleveland Bay functions as a sediment sink, with more fine sediment entering and accumulating within the bay than is exported.
- Short-term sediment export can occur during extreme events, such as major floods and cyclones, when strong currents and wave action can transport sediment out of the bay and into the wider Great Barrier Reef lagoon.

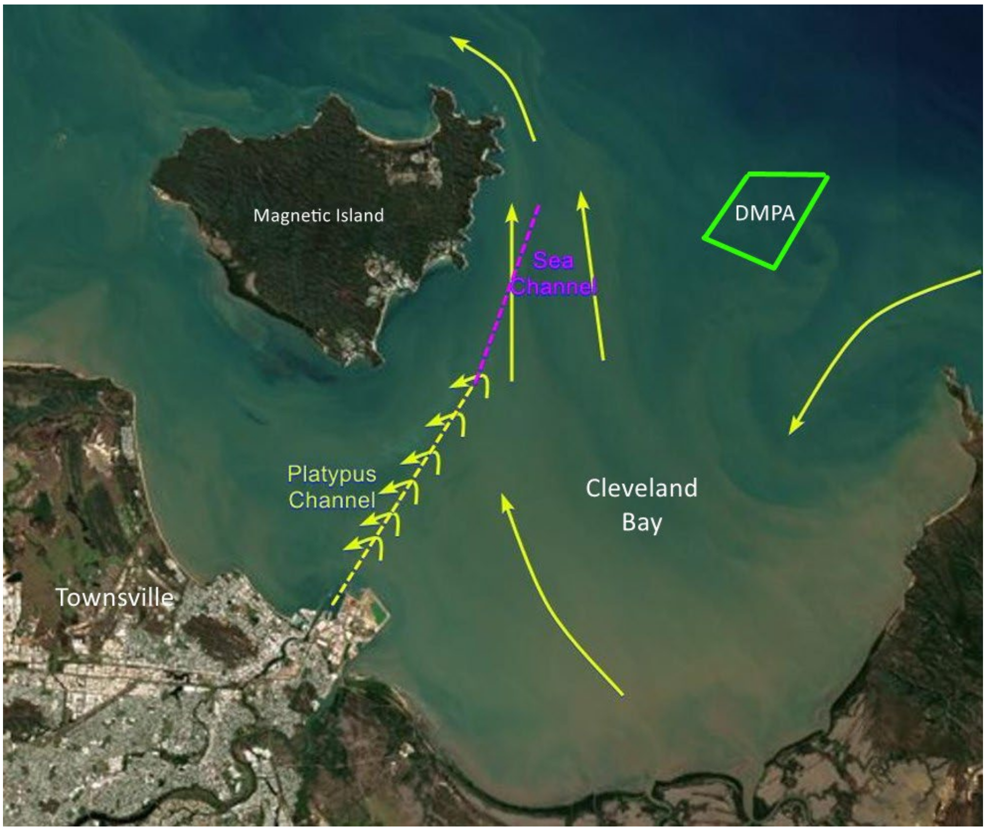
These natural processes continuously redistribute sediment throughout Cleveland Bay and contribute to the naturally variable water clarity and turbidity observed across the region. Understanding these patterns is important for interpreting environmental monitoring results and distinguishing natural variability from localised influences.

WHAT THIS MEANS:

Water clarity in Cleveland Bay is heavily influenced by natural weather and sediment processes

WHY THIS MATTERS FOR MAINTENANCE DREDGING:

- The same natural processes that transport and redistribute sediment throughout Cleveland Bay also contribute to the gradual accumulation of sediment within the Port's shipping channels and harbour areas.
- Because the channels are deeper than much of the surrounding seabed, they act as sediment traps, intercepting sediment moving through the bay. Over time, this naturally occurring accumulation reduces the channel depth and can restrict safe vessel access.
- Maintenance dredging is undertaken to remove this naturally accumulated sediment and maintain safe navigational access to the Port. Understanding how sediment moves through Cleveland Bay is therefore fundamental to understanding why maintenance dredging is required.



This image illustrates a simplified version of the natural circulation and sediment transport pathways within Cleveland Bay. The yellow arrows indicate the general movement of water and suspended sediments through the bay, driven by prevailing south-easterly trade winds, north-easterly sea breezes and tidal currents.

Some of the Port's channel and underwater infrastructure trap sediments moving across Cleveland Bay. The channel is approximately 12 metres deep, making it significantly deeper than much of the surrounding bay. While fine sediments in shallow areas surrounding the channel are regularly resuspended by waves and wind-driven processes, sediments that settle within the deeper channel are less likely to be re-entrained into the water column. As a result, sediment gradually accumulates. To maintain safe access for shipping, the accumulated sediment is periodically removed through maintenance dredging and transferred back to Cleveland Bay via an approved Dredge Material Placement Area (DMPA), located in water approximately 12–16 metres deep. The location of the channel and DMPA is shown in the image above.

The DMPA has been intentionally located in deeper water where wave-driven resuspension is less likely to occur. This allows the dredged sediments to settle onto the seabed, where they are incorporated into the natural seabed sediments through bioturbation, (burrowing of sea floor animals) or the sediment can gradually re-enter the bay's natural sediment transport system through normal oceanographic processes.

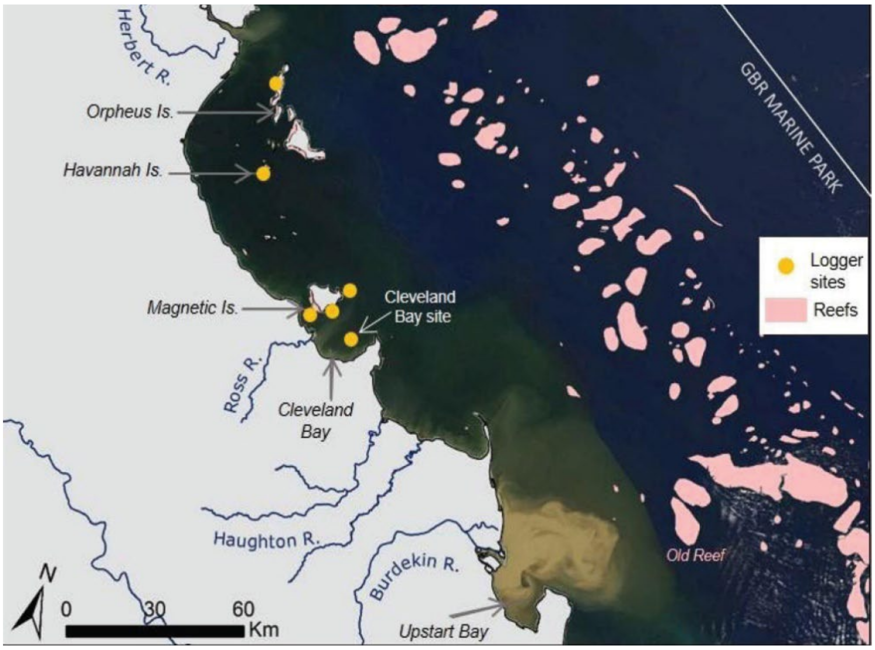
In this way, maintenance dredging does not remove sediment from the regional system but rather returns naturally occurring bay sediments to the marine environment where is it less likely to be suspended while maintaining the safe operation of the Port's navigation channels.

RESEARCH SPOTLIGHT

One of the key questions in Great Barrier Reef water quality science is understanding the extent to which newly delivered sediments from major river floods influence water clarity and light availability in sensitive marine habitats.

To investigate this issue, Lewis et al. (2020) undertook a comprehensive study titled What's Really Damaging the Reef? Tracing the Origin and Fate of the Ecologically Detrimental Sediment and Associated Bioavailable Nutrients. The research examined how sediments and nutrients from the Burdekin River are transported through the coastal marine environment and their potential influence on inshore reef and seagrass ecosystems.

Between June 2016 and March 2020, researchers deployed a network of turbidity sensors, light loggers and sediment traps at strategic locations throughout the central Great Barrier Reef region. These monitoring sites were specifically selected to track the movement of Burdekin River flood plumes and measure their effect on water clarity, light penetration and sediment deposition. Several of these monitoring locations were situated within Cleveland Bay (see image below).



The study found that the most significant reductions in light availability occurred during the three-week period when the 2019 Burdekin River flood plume moved northward through the region. Measurements collected by underwater sensors showed that suspended sediment concentrations peaked during this period, reducing the amount of light reaching coral reefs and seagrass habitats.

Importantly, the effects were not limited to the flood itself. In the months following the event, strong winds and waves repeatedly resuspended newly deposited flood sediments, resulting in prolonged periods of elevated turbidity and reduced water clarity compared with conditions typically experienced in the absence of a major flood.

The research also identified ecological responses associated with these large flood events. Following the arrival of flood-derived sediments, some inshore reefs experienced increased growth of macroalgae, which can compete with young corals for space and resources. The study suggested this response was linked to the delivery of nutrient-rich riverine sediments, which contain substantially higher concentrations of bioavailable nutrients than older marine sediments already present on the seabed.

Key Finding

The study demonstrated that major Burdekin River floods can influence water quality, light availability and ecological conditions across a broad area of the inshore Great Barrier Reef, including Cleveland Bay, with effects that can persist long after floodwaters have receded.

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