

SCOPING AND ENVIRONMENTAL IMPACT REPORTING PROCESS FOR THE DEVELOPMENT OF NEW BERTH 605 AND ASSOCIATED INFRASTRUCTURE TO SUPPORT THE CONTAINER HANDLING FACILITY, PORT OF RICHARDS BAY, KWAZULU-NATAL

Estuarine and Marine Ecology Specialist Study



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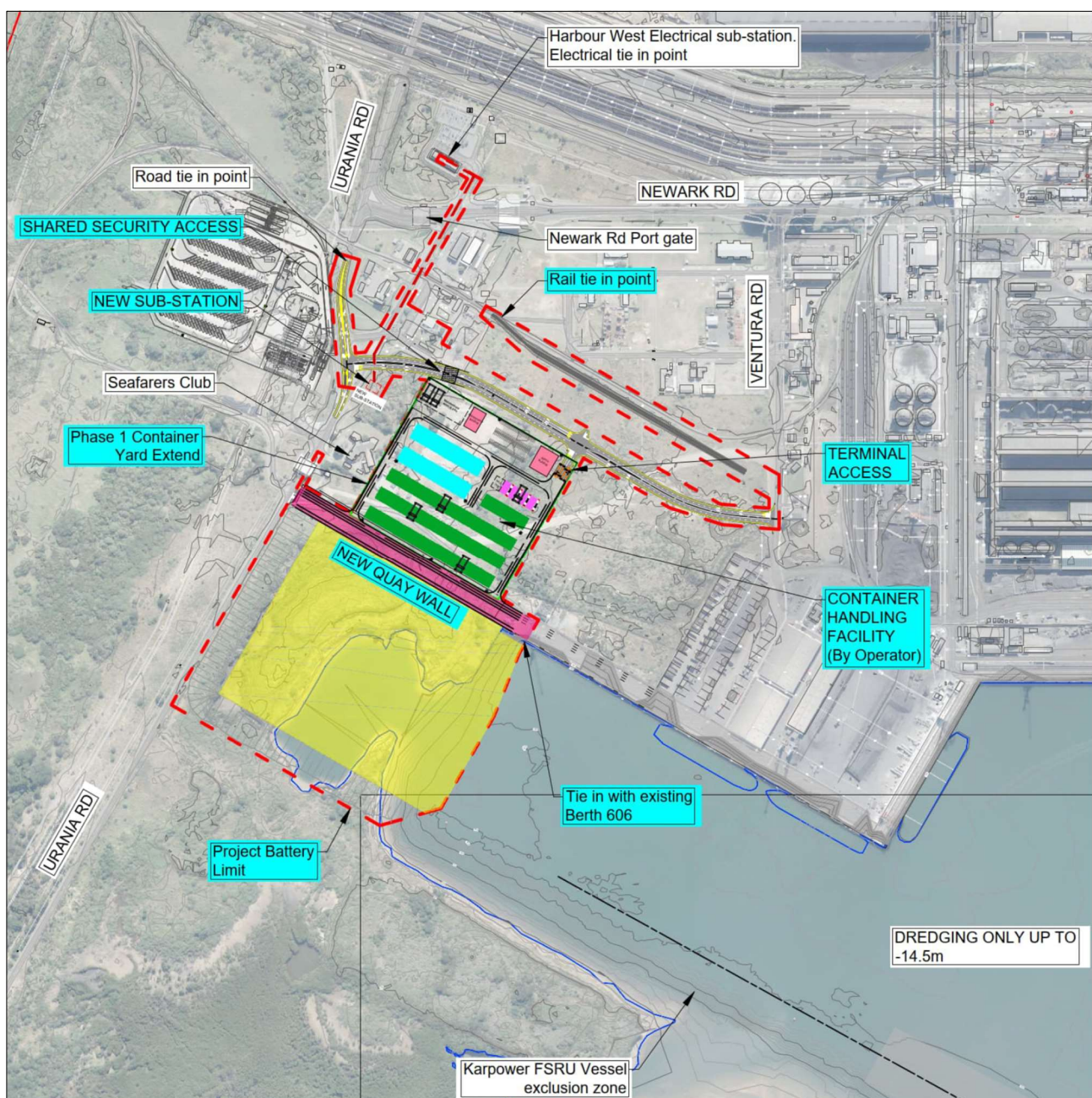
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Executive Summary

Background

Transnet National Ports Authority (TNPA), a Division of Transnet SOC Ltd, has identified the need to develop a new berth (Berth 605) in the 600 Berth Basin in the Port of Richards Bay on the northeast coast of South Africa. The proposed berth layout is outlined in the figure below. The back of berth area will serve as a dedicated Container Handling Facility, alleviating pressure on other parts of the port. Infrastructure that will be developed to support operations at the Container Handling Facility includes a new rail siding, new access road, container storage apron, and the provisioning of electricity, water, sewerage, and stormwater networks. The berth will be constructed by expanding the existing 600 Berth Basin in the port. The extension of the basin will require the dredging and excavation of a large volume of sediment, soil, and rock. Although some of the soil might be beneficially reused on land, the most practical option is to dispose of the material at an authorised open water dredged spoil disposal site off the Richards Bay coast.



Proposed layout of Berth 605 and associated infrastructure.

The nature, scale, and location of activities that will be required for the development of Berth 605 trigger numerous listed activities in terms of the National Environmental Management Act: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008) and thus requires Environmental Authorisation from the Department of Forestry, Fisheries and the Environment. To this end, TNPA appointed WSP Group Africa (Pty) Ltd (WSP) to coordinate an Environmental Impact Assessment process in pursuance of Environmental Authorisation for the development of Berth 605. WSP appointed the Council for Scientific and Industrial Research (CSIR) to perform an Estuarine and Marine Ecology Specialist Study and associated Environmental Impact Assessment for the development of Berth 605. This report presents the findings of the specialist study and impact assessment.

Affected Biophysical Environments

The Port of Richards Bay is situated within the Richards Bay Estuary, which is a large estuarine embayment. The original estuary was extensively modified during the development of the port, with large areas of natural habitat lost to port infrastructure. Further development in the intervening period has led to further, albeit far less pronounced habitat loss. However, there are still large areas of natural habitat in the port, some of which will be adversely affected by the development of Berth 605.

Water and sediment quality across most of the port is good or excellent. Parts of the port, including the area where Berth 605 will be developed, occasionally have slightly impaired water quality, while the sediment is quite significantly metal contaminated. However, the chemical contaminants in the sediment are not in forms and are not released at concentrations when the sediment is disturbed such that they pose a significant ecological risk, as revealed by the results of the toxicity testing of the sediment. The sediment in the Berth 605 development footprint was not toxic to the embryos and larvae of sea urchins under two different testing scenarios, but the soil from small part of the land falling in the footprint was slightly toxic.

The varied natural habitats in the port support a high biodiversity of fauna and flora. Mangrove forests and intertidal and shallow subtidal sediment habitats are particularly important for sustaining biodiversity in the port. While some of the fauna and flora remain permanently in the estuary, the port serves as an important nursery area for many marine fish and shellfish species. The fish and shellfish enter the port as larvae or juveniles and remain until they reach a juvenile stage, whereupon they return to the marine environment to replenish adult stocks.

The large expanse of natural habitat means the natural environment in the port has a regional and national, and if migratory birds are considered also international significance.

The area in the port where Berth 605 will be developed comprises a mix of low to high sensitivity and ecological value (in terms of productivity) habitat. The highest sensitivity habitat is a relatively small tidally influenced pool that is connected to the main port waterbody in the 600 Berth Basin by a pipe. The pool was paradoxically created during a port infrastructure development project, but has since been colonised by mangroves and numerous fish and shellfish species. The pool habitat will be lost because of the development of Berth 605, although it and all other existing estuarine habitat will be replaced by new estuarine habitat. The new habitat will generally have a lower ecological value than the pool habitat, but will cover a larger surface area.

Sediment that is dredged and soil that is excavated to facilitate the development of Berth 605 will be disposed at an authorised dredged spoil disposal site situated fairly near the entrance to the port. The dredged spoil disposal site is currently used to dispose of sediment that is maintenance dredged in the Port of Richards Bay. The natural environment on and surrounding the disposal site will be directly and indirectly adversely affected in the process.

Significance of Impacts Identified

The development of Berth 605 will have unavoidable impacts on the biophysical environment within the Port of Richards Bay and in the adjacent marine environment through the disposal of dredged material. The capital dredging campaign required for berth development will result in the temporary removal and remodification of sediment and other habitat in the project footprint, including ecologically important intertidal and shallow subtidal sediment habitat. It will also result in the direct and indirect disturbance of biological resources at the dredged spoil disposal site. The project will, however, result in a net gain in estuarine habitat since it involves the excavation of land near the existing 600 Berth Basin to allow development of the berth.

A total of 37 environmental impacts that might or will arise if the development of Berth 605 proceeds were identified, as outlined in the table below. Thirteen of the impacts were scoped out from detailed significance assessment since they are easy to manage or because they are difficult to assess with the information available. Of the remaining 24 impacts, five are anticipated to be of a **LOW** and nine of a **VERY LOW** environmental significance after mitigation. Nine are anticipated to be of a **MEDIUM** environmental significance and one of a **HIGH** environmental significance after mitigation.

There are no identified environmental fatal flaws associated with the proposed development of Berth 605 in the context of estuarine and marine ecology.

Although most of the identified impacts will have negative consequences for the biophysical environment, three will have positive (beneficial) consequences. The negative consequences can be mitigated to an acceptable degree if proposed or other effective mitigation measures are implemented. In the case of the three positive impacts, appropriate measures could enhance their ecological benefit.

Summary of environmental impacts that might arise if the Berth 605 Project proceeds and their significance assessment with and without mitigation.

Impact	Impact description	Without mitigation	With mitigation
1	Entry of non-hazardous solid waste from dredging, construction and support vessels	Screened out	
2	Entry of non-hazardous solid waste from construction sites on land	Screened out	
3	Entry of hazardous substances into the port due to spills, leaks and discharges from dredging, construction and support vessels	Screened out	
4	Entry of hazardous substances into the port due to spills and leaks at construction sites on land	Screened out	
5	Entry of construction material and demolition debris into the port	Screened out	
6	Navigation hazard posed by dredging, construction and support vessels	Screened out	
7	Marine megafauna strikes by dredging, construction and support vessels	Screened out	
8	Introduction of non-native aquatic biological resources	Screened out	
9	Increased vessel traffic	Screened out	
10	Noise from dredging, construction and support vessels	Screened out	
11	Underwater construction noise	Screened out	
12	Increased operational noise	Screened out	
13	Loss of recreation and tourism opportunities	Screened out	
14	Decrease in aquatic ecological function and productivity due to the physical disturbance, injury and displacement of benthic biological resources by dredging	N3 - Moderate	N3 - Moderate
15	Decrease in aquatic ecological function and productivity due to a deterioration in water quality related to increased suspended sediment concentrations and related turbidity during dredging	N3 - Moderate	N3 - Moderate
16	Decrease in aquatic ecological function and productivity in subtidal habitats due to the deposition of sediment resuspended by dredging	N3 - Moderate	N3 - Moderate
17	Decrease in aquatic ecological function and productivity in intertidal habitats due to the deposition of sediment resuspended by dredging	N3 - Moderate	N3 - Moderate
18	Remobilisation of oxygen depleting substances from sediment during	N2 - Low	N2 - Low

Impact	Impact description	Without mitigation	With mitigation
	dredging		
19	Nutrient remobilisation from sediment/soil during dredging	N1 - Very Low	N1 - Very Low
20	Remobilisation of noxious substances from sediment/soil during dredging	N1 - Very Low	N1 - Very Low
21	Bioaccumulation and biomagnification of noxious chemicals remobilised from sediment by biological resources	N1 - Very Low	N1 - Very Low
22	Deterioration in water quality related to increased suspended sediment concentrations during dredged spoil disposal	N3 - Moderate	N3 - Moderate
23	Remobilisation of oxygen depleting substances from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
24	Remobilisation of nutrients from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
25	Remobilisation of noxious substances from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
26	Deterioration in sediment quality on dredged spoil disposal site due to the disposal of contaminated dredged material	N1 - Very Low	N1 - Very Low
27	Physical disturbance of benthic biological resources by disposed dredged material	N3 - Moderate	N3 - Moderate
28	Change in hydrodynamic conditions due to accumulation of dredged material at dredged spoil disposal site	N3 - Moderate	N3 - Moderate
29	Bioaccumulation and biomagnification of noxious chemicals in disposed dredged material by biological resources	N1 - Very Low	N1 - Very Low
30	Loss of tidally influenced pool and related ecological value and productivity	N4 - High	N4 - High
31	Ecological effects of a change in hydrodynamic functioning in the port	N1 - Very Low	N1 - Very Low
32	Ecological effects of increased need for maintenance dredging and dredged sediment disposal	N3 - Moderate	N3 - Moderate
33	Gain in intertidal and subtidal sediment habitat	P2 - Low	P2 - Low
34	Gain in hard substrate habitat	P2 - Low	P2 - Low
35	Gain in open water habitat	P2 - Low	P2 - Low
36	Increased load of contaminants introduced into the port by surface runoff	N3 - Moderate	N3 - Moderate
37	Introduction of artificial light into port aquatic environment	N3 - Moderate	N2 - Low

Environmental Impact Mitigation

Mitigation of the impacts that were assessed as being of a medium, and high environmental significance will be necessary to minimise disturbance to ecological, commercial, and social receptors, or in the case of beneficial impacts to enhance their outcomes to the degree possible. An important mitigation measure, if feasible, is the compensation of ecologically valuable and productive habitat in the small tidally influenced pool connected indirectly to the 600 Berth Basin. Equivalent, or similar habitat could potentially be created along the south-southwestern part of the lengthened 600 Berth Basin by excavating into the surrounding land during the development of Berth 605. However, there are other potential areas where compensatory habitat could be created—the feasibility of habitat compensation is currently being investigated by TNPA. Ideally, the compensatory habitat should cover a larger area than the existing tidally influenced pool. Provided the excavated area is of a depth that it does not drain dry at low tide and there is a permanent tidal connection to the 600 Berth Basin, there is every reason to believe the compensatory habitat would be similarly colonised by mangroves and other biological resources over time and would make as important an ecological contribution per unit area to the port as the existing tidally influenced pool. If habitat compensation is feasible, the impact identified as being of a high significance will be reduced to low.

Environmental Monitoring

The monitoring of environmental impacts during and after dredging and dredged material disposal for the development of Berth 605 is recommended. The monitoring should focus on key physical, chemical, and/or

biological indicators that will provide clear evidence for impacts rather than monitoring for a wide range of indicators in the hope some will reveal an impact. For the purposes of operational management, the focus should be on indicators that can be measured in real time to the extent possible, notably total suspended solids via turbidity measurements. Thresholds for sensitive environmental areas need to be established to manage dredging and dredged spoil disposal impacts. Although recommendations for environmental monitoring are provided for most of the identified environmental impacts these do not constitute an environmental monitoring programme and should not be seen as such. An environmental monitoring programme will be submitted with the Environmental Impact Report for approval by the DFFE before the Environmental Authorisation is granted.

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Abbreviations and Units of Measurement

CSIR	Council for Scientific and Industrial Research
TNPA	Transnet National Ports Authority
WSP	WSP Group Africa (Pty) Ltd
km	kilometre
m	metre
mm	millimetre
µm	micrometre
ha	hectare
m ²	square meter
m ³	cubic meter
m.s ⁻¹	meters per second
°C	degrees Celsius
mg.L ⁻¹	milligrams per Liter
µg.L ⁻¹	micrograms per Liter
mg.g ⁻¹	milligrams per gram
µg.g ⁻¹	micrograms per gram
%	percent
<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
~	about/approximately
±	plus or minus

1. Introduction

Transnet National Ports Authority (hereafter TNPA) has identified the need to develop a new berth (Berth 605) in the Port of Richards Bay, in Richards Bay, by extending the existing 600 Berth Basin (Figure 1). The back of berth area will serve as a Container Handling Facility. Infrastructure that will be developed to support operations at the Container Handling Facility includes a new rail siding, new access road, container storage apron, and the provisioning of electricity, water, sewerage and stormwater networks. The quay wall for the berth will be ~340 m long and ~33 m wide. The new quay wall will interface with the western end of the existing Berth 606 quay wall. The extension to the basin will be dredged to a depth of -14.5 m Chart Datum, which is aligned to the depth of the existing 600 Berth Basin. Developing Berth 605 will require the excavation and dredging of a large volume of soil, sediment and rock from the area to west-northwest of the existing 600 Berth Basin. The intent is to construct part of the quay wall 'in the dry' and to temporarily stockpile the excavated soil and rock onsite. Although some of the soil might be beneficially reused on land, the most practical option is to dispose of the sediment and soil at an authorised open water dredged spoil disposal site situated off the coast of Richards Bay. The dredged spoil disposal site will probably be the existing disposal site, but a new that is site under investigation could also be used.

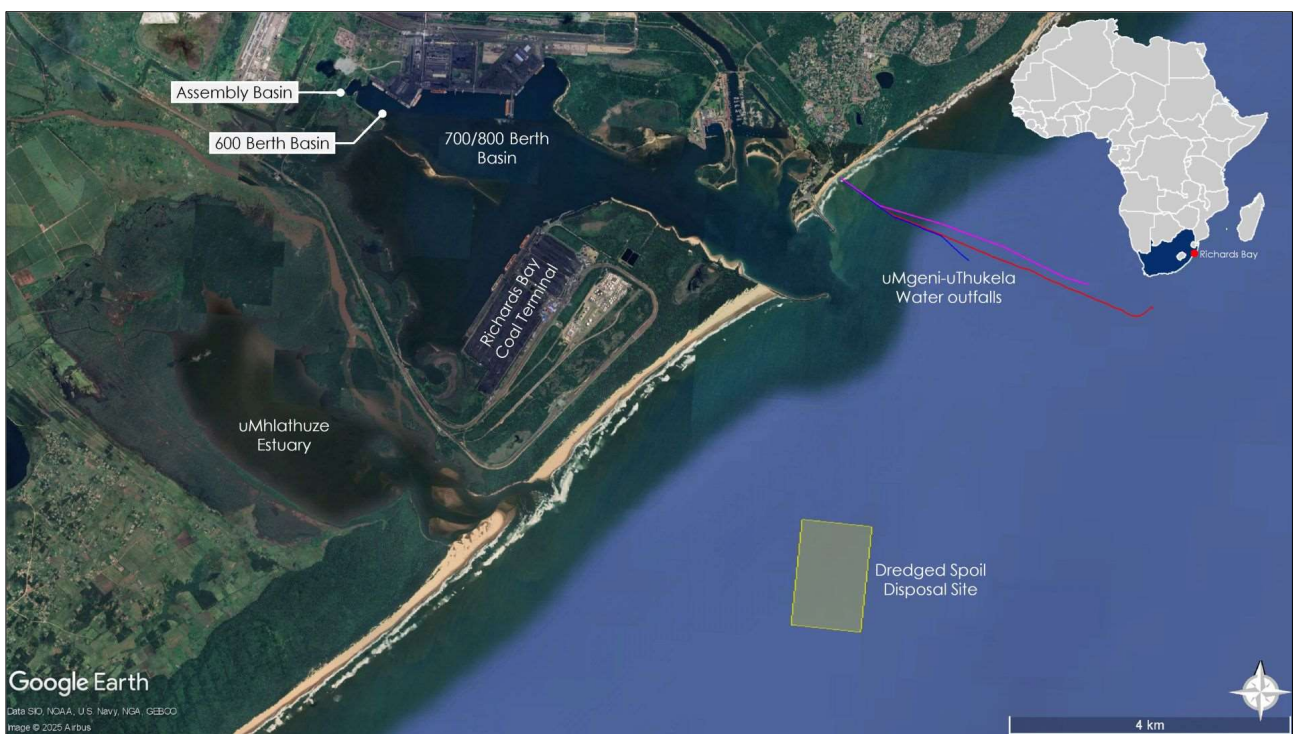


Figure 1. Aerial view of the Richards Bay area, showing the position of the 600 Berth Basin in the Port of Richards Bay and some places and physical features mentioned in the text.

The nature, scale and location of activities that will be required for the development of Berth 605 trigger numerous listed activities in terms of the National Environmental Management Act: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008). The development thus requires Environmental Authorisation from the Department of Forestry, Fisheries and the Environment. To this end, TNPA appointed WSP Group Africa (Pty) Ltd (hereafter WSP) to coordinate an Environmental Impact Assessment process in pursuance of Environmental Authorisation for the development of Berth 605. WSP appointed the Council for Scientific and Industrial Research (CSIR) to perform an Estuarine and Marine Ecology Specialist Study for the development of Berth 605.

2. Terms of Reference

The Terms of Reference for the CSIR were to:

- Briefly describe the proposed Berth 605 Project.
- Describe the baseline biophysical environment in the Port of Richards Bay and in the adjacent marine environment that might be directly or indirectly impacted by the development of Berth 605, using available information in scientific publications and technical reports and supplemented by an assessment of sediment and soil quality in the development footprint.
- Identify, describe and assess the significance of environmental impacts that might or will arise in the Port of Richards Bay and in the adjacent marine because of the development of Berth 605.
- Identify and describe mitigation to reduce the significance of negative environmental impacts and enhance the benefits of positive environmental impacts that might or will arise in the Port of Richards Bay and in the adjacent marine because of the development of Berth 605.
- Recommend environmental monitoring during the dredging, construction and operational phases should the development of Berth 605 proceed. However, this specialist study does not provide a detailed environmental monitoring programme. This will be formulated in due course.

3. Approach to the Specialist Study

The first part of this Estuarine and Marine Ecology Specialist Study provides a description of the baseline biophysical environment within the Port of Richards Bay and in the adjacent marine environment. The purpose is to compile information as a frame of reference for assessing the significance of environmental impacts that may arise if the Berth 605 Project proceeds. The second part of the study assesses the significance of identified environmental impacts. The environmental impact assessment was conducted in two stages. In the first stage, the nature of environmental impacts (positive or negative) that may arise were identified. In the second stage, the significance of these identified impacts was assessed.

Impacts result from the consequences of a change acting on a resource or receptor. A resource is any environmental component affected by an impact (*e.g.* items of environmental value, such as habitats). A receptor is any environmental or other defined feature (*e.g.* fauna, flora, humans) that is sensitive to, or has the potential to be affected by an environmental impact. The nature of the environmental impacts depends on the degree of impact (*e.g.* its spatial extent, duration, magnitude and whether it is reversible/recoverable), the sensitivity of the resources or receptors and the probability of the environmental impact occurring. For each significant environmental impact identified, appropriate secondary mitigation measures are recommended, and the residual environmental impact was then assessed in the light of this mitigation.

4. Description of the Proposed Project

4.1 Need and Desirability

The need and desirability of the Berth 605 Project can be appreciated through an overview of the Port of Richards Bay Masterplan. The masterplan outlines TNPA's ideas on future infrastructure developments and operations in the port, based on projected demand forecasts for the import and export of products. Three time-horizons for the masterplan are identified—short-, medium- and long-term (Figures 2-4).

The Berth 605 Project falls within the short-term horizon—present to 2032—for the Port of Richards Bay Masterplan (Figure 2). The overarching objective for the development of Berth 605 is to provide a dedicated berth for a Container Handling Facility in the port. Berth 605 will ensure that Berths 606-609 are used for Multi-Purpose Terminal operations and not container operations (TNPA PDFP, 2022). The proposed development footprint for the Berth 605 Project is provided in Figure 5.

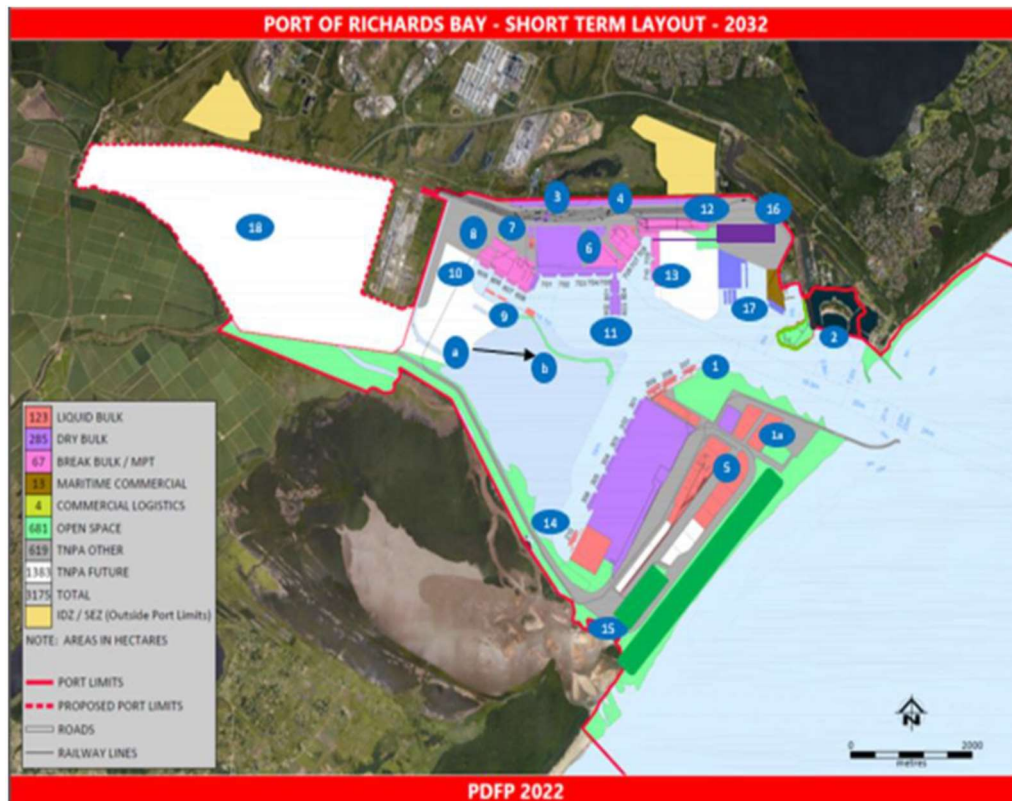


Figure 2. Port of Richards Bay Masterplan short-term layout (present to 2032).

Legend

1. Development of new liquid natural gas Berth 207
2. Naval Island and Pelican Island - relocation of navy from Durban Port
3. Relocation site for Bulk Commodities from Port of Durban
4. Bayvue railyard infrastructure upgrade and railyard expansion for 100 wagon trains
5. South Dunes liquid bulk development - land area increases from 74 ha to 162 ha.
6. Development of Mega Chrome Terminal
7. Relocation of South32 aluminium storage
8. Development of a new container handling facility
9. Liquid Natural Gas Powership becomes available
10. Development of new Berth 605 for containers
11. Extension of the finger jetty to develop new Berth 802 and 803 for Mega Chrome
12. Extension of ferro slab for additional storage capacity
13. Development of new Berths 709 and 710 for dry bulk
14. Development of a new liquid bulk Berth 210
15. Reserved sites for environmental offsets
16. Development of new dry bulk terminal
17. Development of a new Passenger facility at the existing Repair Quay
18. Bayvue Precinct – TNPA land acquisition, areas increase from 2215 ha to 3180 ha.

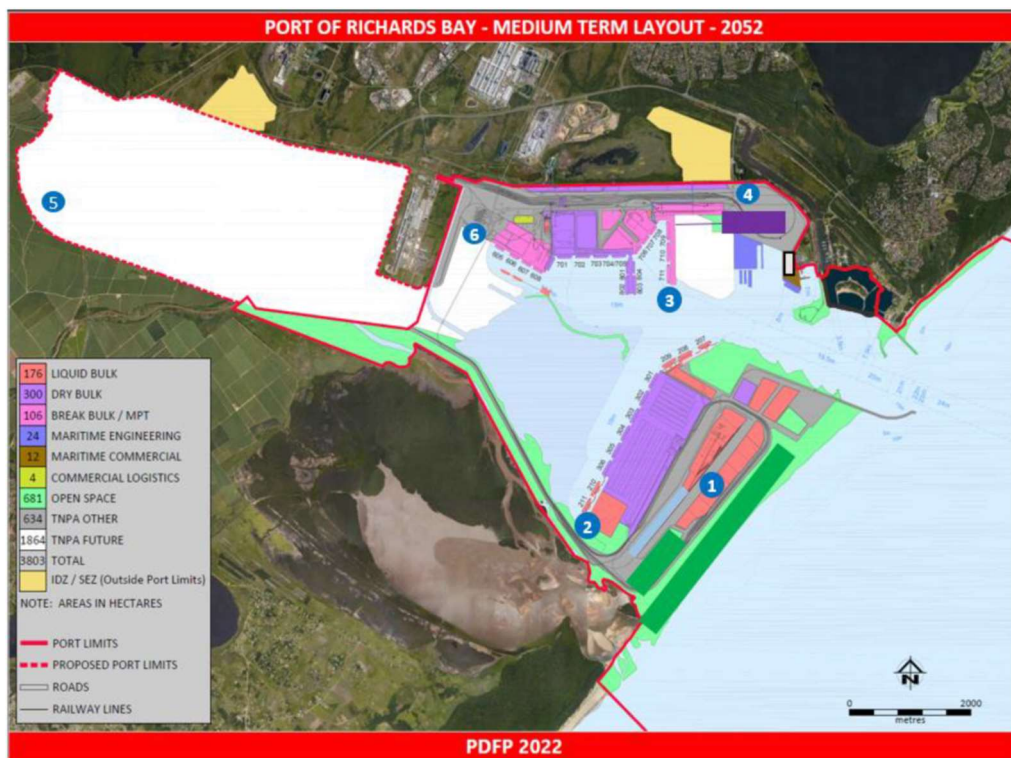


Figure 3. Port of Richards Bay Masterplan medium-term layout (2032 to 2052).

Legend

1. Development of more liquid bulk terminals at South Dunes area, part of South Dunes land will be used for bas to power and liquid petroleum gas
2. New liquid Berth 211 to support the South Dunes Liquid Terminals
3. 700 Series: Provision of additional berthing capacity for MPT – 711 (700 m quay wall)
4. Bayvue rail yard expansion – rail balloon for 150 wagon trains
5. Land acquisition for future port development Phase 2, area increased from 3 180 ha to 3 803 ha
6. uMhlathuze Rail Yard expansion to service 600 series berths.

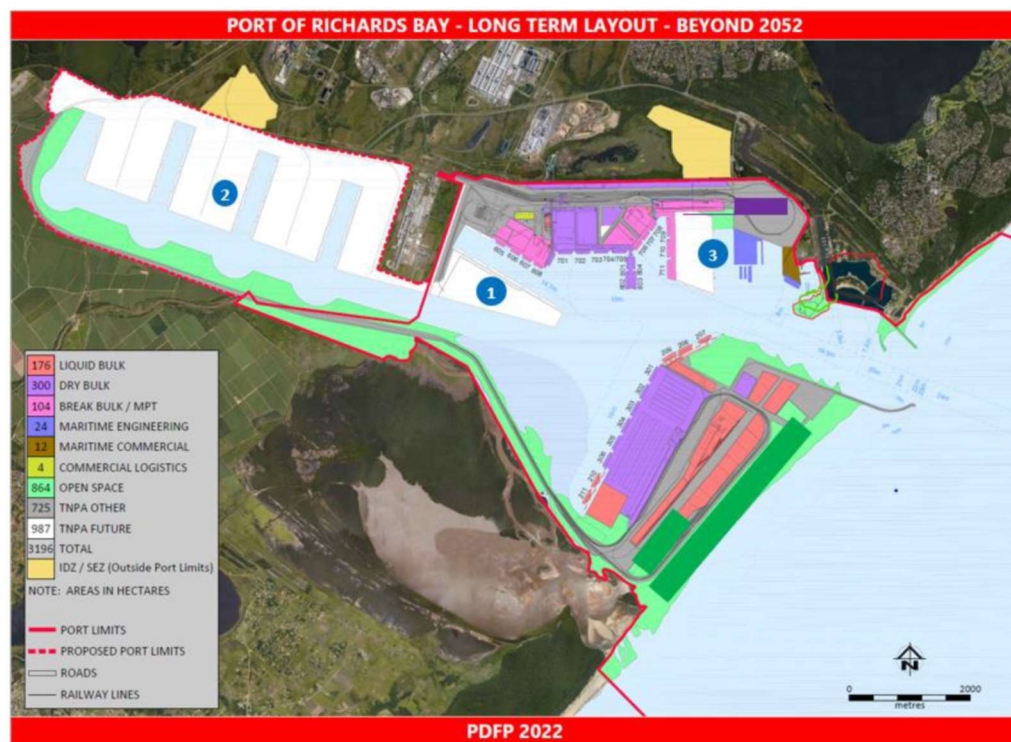


Figure 4. Port of Richards Bay Masterplan long-term layout (2052 onward).

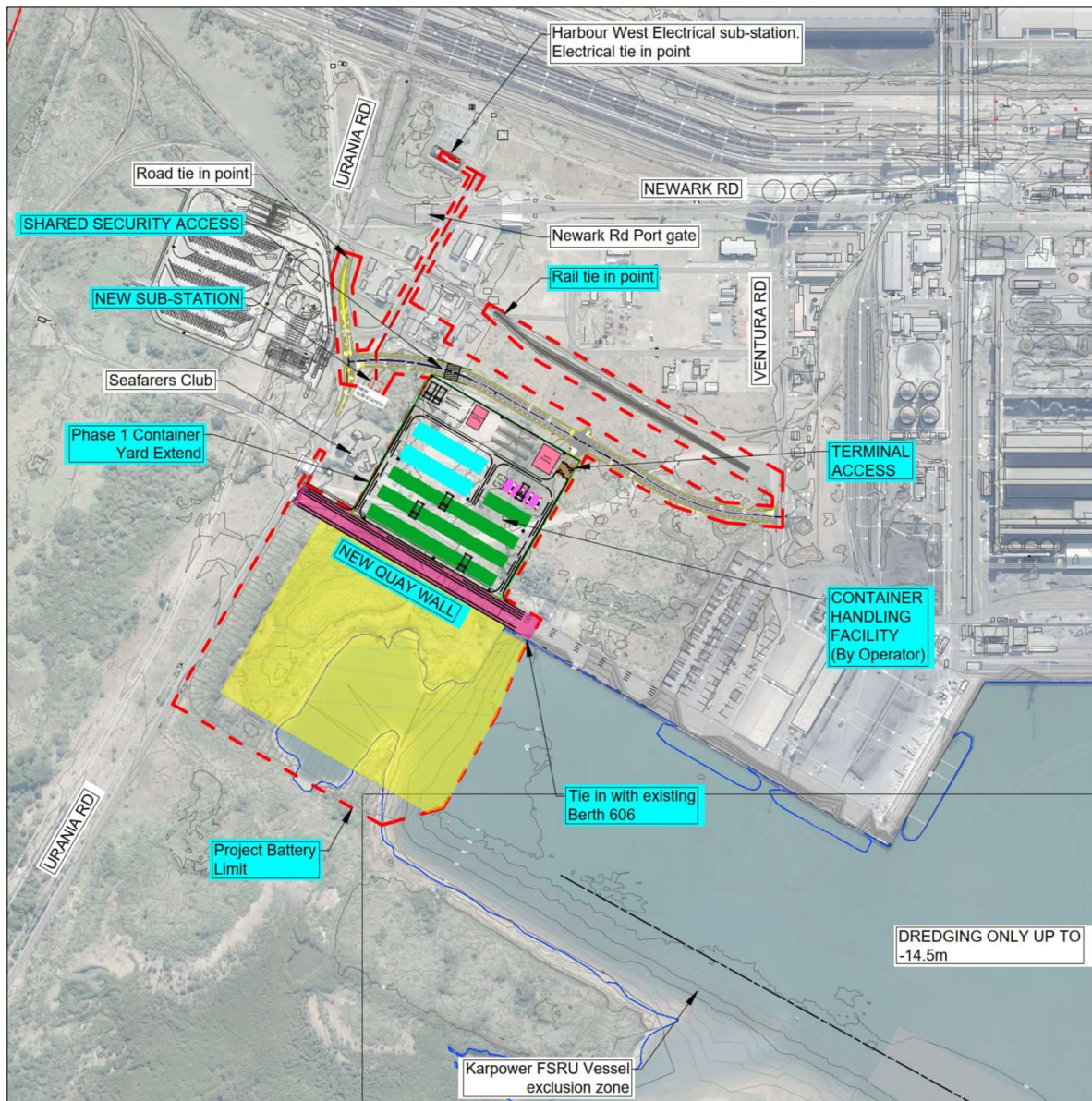


Figure 5. Proposed layout of Berth 605 and associated infrastructure.

4.2 Alternatives Considered

The South African Environmental Impact Assessment Regulations (2014) (GN R982) (as amended in 2017) requires that project proponents consider alternatives to the proposed activity. Alternatives are a different way/s of achieving the general purpose and requirements of the proposed activity and may include alternatives to the:

- property on which, or location where the activity is proposed,
- type of activity to be undertaken,
- design or layout of the activity,
- technology to be used in the activity, or
- operational aspects of the activity.

The alternative assessment also includes the so-called ‘Do Nothing’ or ‘No Action’ option. The ‘Do Nothing’ option refers to a continuation of existing conditions without implementation of the proposed activity. The purpose of considering alternatives is to broaden the scope of options that might be available to minimise or avoid impacts identified as likely to arise because of the activity.

4.2.1 Do Nothing

In this option, Berth 605 is not developed and no environmental impacts that might arise during the development and operation of the berth and Container Handling Facility will not manifest. Existing operations in the 600 Berth Basin will continue as they currently do.

4.2.2 Location alternative

No alternatives to the preferred (proposed) location (property) for the Berth 605 Project were considered other than the 'Do Nothing' option. The preferred location is based on:

- An agreement between TNPA and the intended operator regarding a preferred Container Handling Facility of 270 m × 250 m landward of Berth 605 (Figure 5). The total area considered is 6.75 ha for the Container Handling Facility, excluding the quay apron.
- The Container Handling Facility is located 33 m from the quay cope line to allow for a quay apron for mobile cranes (Figure 5).
- The Container Handling Facility is envisaged to have a storage capacity for 275 000 Twenty-Foot Equivalent Units (containers).

4.2.3 Quay wall design option alternatives

The existing 600 Berth quay walls are gravity type structures. Geotechnical and borehole information generated before the development of Berths 606, 607 and 608 showed there is cretaceous rock at the quay wall foundation level. The rock layer is deemed to have sufficient load bearing capacity for the foundations of a gravity type quay wall structure for Berth 605. The Berth 605 quay wall will interface with the existing Berth 606 quay wall, but the wall will be constructed with foundations that are 5 m deeper than the existing 600 Berth series quay walls to allow for future dredging to -19 m Chart Datum. This will allow for the expansion in container handling volumes, which will require larger vessels and consequently a deeper berth. Notwithstanding this provision, the current Environmental Impact Assessment evaluates dredging to -14.5 m Chart Datum.

Two types of quay wall design were considered.

4.2.3.1 Gravity type quay wall

A gravity type quay wall consists of a solid *in situ* mass concrete structure. It has a smaller footprint than other quay wall design options due to it having a denser construction, but this increases the bearing pressure under the structure. It also uses more concrete than other quay wall design options. The construction requires the excavation of a trench to the foundation level, the placement of formwork, and the casting of the *in situ* mass concrete in layers to form the final structural shape. The quay wall will thus be constructed in the dry—that is, in an excavated trench—rather than in the water. This is a more efficient and less environmentally harmful construction approach. The volume of concrete required for constructing the quay wall is ~82 000 m³. The volume of soil and rock that will need to be excavated for construction in the dry for the length of quay wall is estimated at ~350 000 m³.

4.2.3.2 Secant pile quay wall

A secant pile quay wall consists of a series of hard and soft piles that interlink to form a solid concrete wall. The soft piles have no reinforcement and have a weaker concrete—they are installed first before hard piles are drilled to join two neighbouring piles and to remove a secant for each. The hard pile is larger and has reinforcement. A second line of piles supports the back of the cope beam and then a third row of piles supports a deadman anchor that can be used in the future to support a landside crane rail beam. A 'deadman' anchor is a type of retaining wall tieback that consists of a substantial concrete block and one or more tie rods. Typically, the concrete block sits far below the ground and at least 3 m behind the retaining wall. This form of construction will limit the requirement for a large, deep, dewatered excavation trench

that is required for a gravity type quay wall. The volume of concrete for this quay wall is ~27 900 m³. The volume of soil and rock that will need to be excavated, including the cope beam, is ~50 000 m³.

4.2.3.3 Preferred quay wall alternative

A detailed engineering investigation between the above-mentioned quay wall design alternatives identified a gravity type quay wall with a concrete foundation and walls with soil and rock backfilling internally—which replicates the existing 600 Berth series quay wall design—as the preferred alternative. The reasons include:

- It is the least expensive option.
- The construction is possible with South African contractors and locally available equipment.
- The construction requires manual labour, which will provide local employment opportunities.
- The construction requires less concrete than many other quay wall options.
- The environmental considerations for alternative quay wall options are expected to be similar.

Only the preferred alternative is investigated in this Environmental Impact Assessment.

4.2.3.4 Quay wall construction sequence

The proposed sequence for the construction of the Berth 605 quay wall is outlined below. A typical section through the proposed quay wall temporary works is provided in Figure 6.

- Clean and clear site to facilitate trench excavation and dewatering for construction of the quay wall.
- Excavation to proceed at the end adjacent to the existing Berth 606.
- Excavate and shore excavation sides. Dewatering will be required. It is recommended that the excavation be done based on the completion of a 20 m long section of quay wall before progressing to the next 20 m long section. This will reduce the dewatering effort and maintain a manageable site.
- As excavation progresses to the foundation of Berth 606, the contractor should proceed with underpinning the exposed edge of Berth 606 in a preplanned and agreed construction sequence. A block that is no wider than 2 m should be excavated from beneath the existing Berth 606 foundation and then backfilled with mass concrete. The next section should be excavated (not adjacent to the previous section) and the process repeated until the Berth 606 quay wall is supported on the exposed edge by the underpinning.
- Clean and prepare rock for the foundation and place binding concrete.
- Cast the reinforced concrete base for the new Berth 605 quay wall.
- Cast the first 2 m high wall sections of the quay wall and backfill with a suitable graded fill material to achieve the specified bulk density.
- Repeat the process of casting 2 m high wall sections and then backfilling until top of the gravity structure is reached.
- Prepare shutters for cope beam and fix reinforcement and formwork for service tunnels and access ducts.
- Cast the cope beam.
- Repeat the process for the next 20 m long quay wall section.
- After the next quay wall section is complete, install filter sock (A6 BIDIM tube filled with gravel) to seal between adjacent quay walls, to prevent fine material passing through quay wall.
- Backfill behind the quay wall (landside) with graded core rock backfill to specification.
- Backfill in front of quay wall (seaside) with selected rock to the underside of the future scour rock protection.
- Complete quay wall.
- Install bollards, water pipes to landing, valves and other service ducts etc.
- Install fenders after dredging.

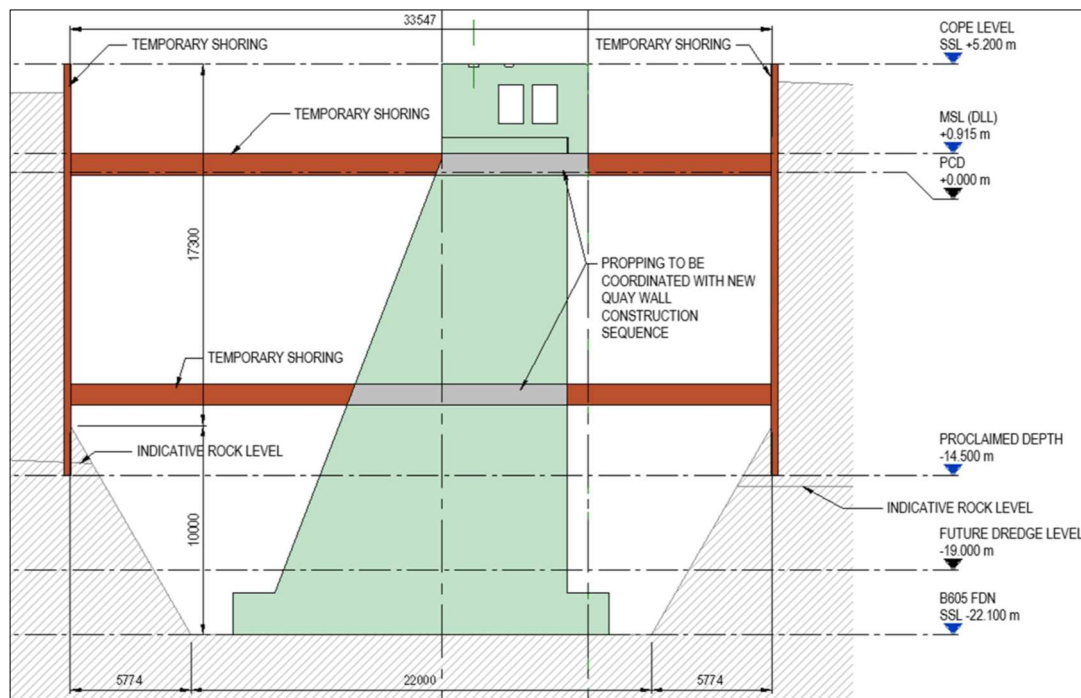


Figure 6. Section through proposed temporary construction works for the development of Berth 605.

4.2.4 Dredging/excavation alternatives

4.2.4.1 Smaller dredging depth

Berth 605 will be maintained at a depth of -14.5 m Chart Datum to accommodate the largest vessel that is envisaged to call at the berth—Post Panamax I Max, with a length of 315 m, beam of 42.8 m and maximum draft of 13 m. Accordingly, the amount of material that will need to be dredged/excavated is ~2.3–2.4 million m³, with most of the material being in the area directly opposite the new Berth 605. An estimated 15% of the material is rock and the remainder mud and sand of various grain sizes. After bulking (change in density), ~4.3 million m³ of material will need to be disposed.

‘Soft’ rock and compacted material dredging is typically done with a cutter-suction dredger, which uses a rotating cutter head with teeth to fracture the rock and compacted material and pump it away from the dredging area through pipes to a barge using a centrifugal pump. Rock of 15 MPa, which is typical of the siltstone that is reported to occur in the project footprint, is within the capabilities of a cutter-suction dredger. Alternatively, a backhoe dredger equipped with a hydraulic hammer could be used. This would require first breaking the rock with the hammer and then dredging it with the same backhoe dredger, employing a regular bucket. However, the production rate with the backhoe dredger will likely be extremely slow for the quantity of rock that needs to be removed. The mobilisation of this equipment is generally also more expensive than for other dredger types.

4.2.4.2 Dredging for future expansion

As stated above, the Berth 605 quay wall will interface with the existing Berth 606 quay wall. The Berth 605 quay wall will, however, be 5 m deeper to allow for future dredging of the basin to -19 m Chart Datum. The deeper foundation will allow the quay wall to be used if the basin is deepened to -19 m Chart Datum in future to accommodate larger vessels. Dredging to -19 m Chart Datum—and ensuring adequate basin and berth pocket area—provides a future-ready port since it would accommodate a Triple E (18 000 Twenty-Foot Equivalent Units) vessel. However, it will be expensive, requiring the dredging and excavation of an estimated 6 million m³ of material, most of which is rock (reported to be silt stone). Indications are that the dredging would take around 1-year to complete.

4.2.4.3 Preferred dredging alternative

Dredging to -14.5 m Chart Datum using a cutter-suction dredger is the preferred alternative since it:

- Provides sufficient capacity for the current design vessel.
- Is the least expensive option since it entails the least amount of material to be dredged and disposed.
- Is the least environmentally damaging option since it entails the least amount of material to be dredged and disposed.

Based on the above, dredging to a depth of -19 m Chart Datum was eliminated as an alternative and was not investigated as part of this Environmental Impact Assessment. However, this Environmental Impact Assessment assesses a quay wall development to a depth of -19 m Chart Datum, but Environmental Authorisation is only being sought to dredge to a depth of -14.5 m Chart Datum consistent with the current 600 Berth Basin depth.

4.2.5 Dredged/excavated material disposal alternatives

4.2.5.1 Preferred alternative for disposal of dredged and excavated material

The preferred alternative for the disposal of dredged/excavated material is an existing authorised dredged spoil disposal site off the Richards Bay coast (Figure 1). Land disposal or beneficial use of the dredged/excavated material is not investigated in this Environmental Impact Assessment since:

- The onshore disposal of material dredged in saline aquatic environments has a high salt content that makes it problematic for construction related purposes.
- The volume of dredged and excavated material will make the logistics of transporting the material to a land-based facility challenging.
- The land transportation of dredged and excavated material will be expensive.
- TNPA has several planned projects for the Port of Richards Bay that will also require disposal of dredged and excavated material and there is not a suitable land-based facility capable of handling all the material.

4.2.5.2 Temporary stockpile area for excavated material

As stated above, the Berth 605 quay wall will be constructed in the dry. This will require the excavation of rock and soil to form a trench. The rock and soil will not be immediately disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. The topsoil (surface 300 mm) and associated vegetation will be removed and carted away separately. In addition to the rock and soil excavated for quay wall construction, material will be excavated for road construction.

The intent is to place the excavated material in the so-called Assembly Basin at the end of the 600 Berth Basin (Figure 1), so named since it was historically used for the construction of caissons for the development of Berth 306 at the Richards Bay Coal Terminal. Alternately, and more likely, the excavated material will be placed at two stockpile sites either side of Urania Road. The volume of excavated material to be placed in the basin or stockpiled is ~350 000 m³ for the quay wall construction trench, and ~36 500 m³ of *in situ* material from road excavations. Assuming a bulking factor of 1.3, once excavated these volumes will increase to ~502 500 m³.

The rock and soil will be dredged along with other soil, sediment and rock, and then loaded onto barges for disposal at the dredged spoil disposal site off the Richards Bay coast. Construction rubble (concrete, rebar, etc.) will not be placed in the Assembly Basin.

Considering the current understanding of the quantity and nature of the material to be dredged (siltstone and sedimentary material indicated to be primarily sandy in nature), as stated above a cutter-suction dredger will probably be used to undertake the dredging. The concept design allows for a single cutter-

suction dredger operating with a small fleet of barges (minimum of two) transporting material to the dredged spoil disposal site.

4.2.5.3 Basin edges and scour protection

The extended 600 Berth Basin will be 305 m wide at the bottom, where a proclaimed depth of -14.5 m Port Chart Datum is to be maintained—these dimensions are the same as the existing 600 Berth Basin. At the south-western edge of this 305 m width, a 1V:3H slope will be employed (Figure 7).

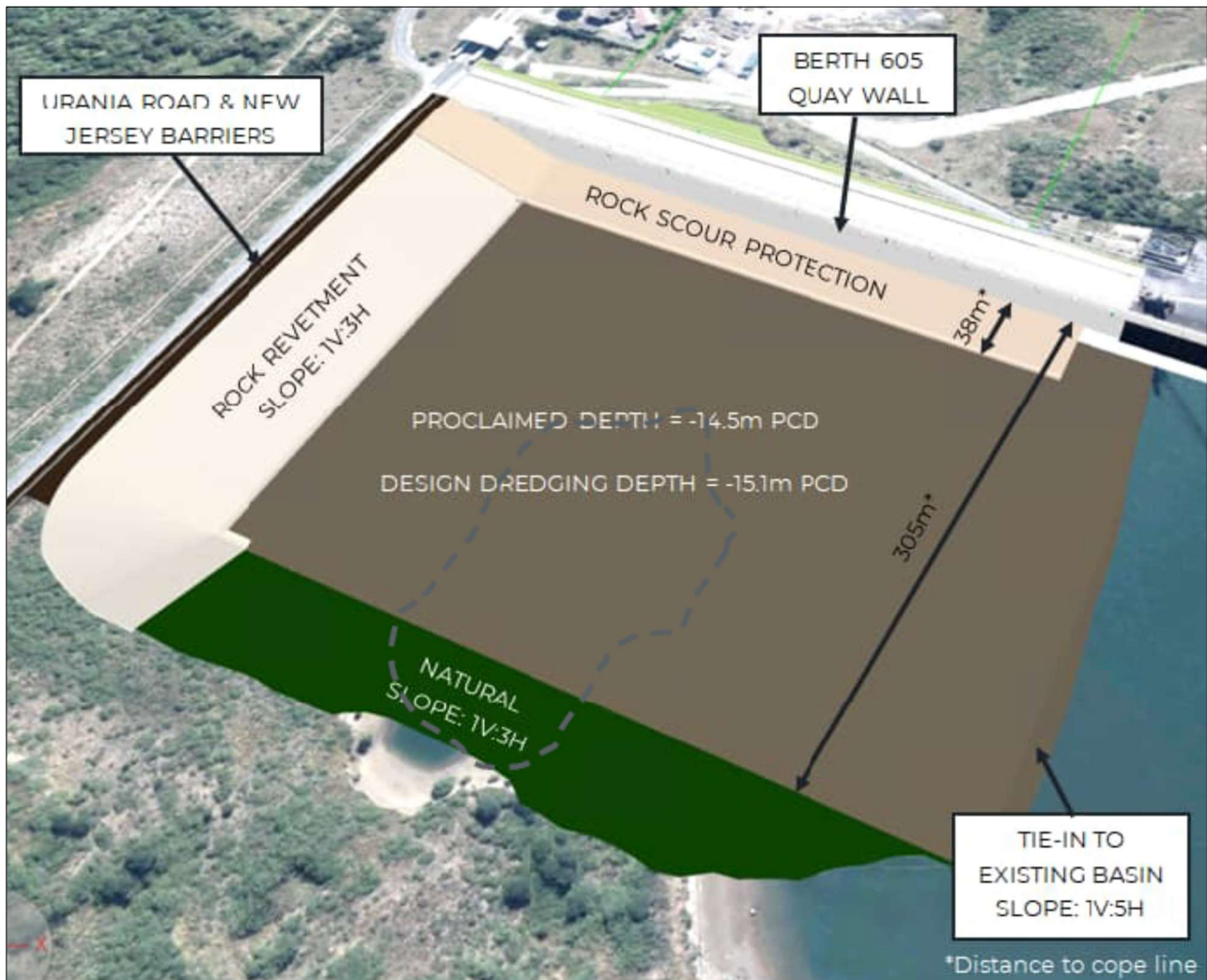


Figure 7. Basin area to be excavated plus outline of the existing Assembly Basin where caissons were formerly cast for the development of Berth 306 at the Richards Bay Coal Terminal.

The existing 600 Berth Basin will be extended westward by 338 m. At the western edge of the extension, a 1V:3H slope will be employed. The top of the slope will run alongside Urania Road—a minimum 10 m space for the safety of road users and stability of the slope will be provided. The slope will intersect with the new proposed slope opposite Berth 605 at the southwestern corner of the lengthened basin. A revetment (sloped embankment) will be constructed on the seaward side of Urania Road. This slope must be protected against wave and propeller wash to maintain the structural integrity of Urania Road—a rip-rap scour protection system will be considered (Figure 7).

Rip-rap consists of at least two rock layers that are placed onto a filter layer of gravel or filter fabric. The rock layers consist of an upper layer of larger rock and a secondary layer of smaller rock. Rip-rap scour protection will also be placed at the toe of the quay and extend 38 m into the basin, to protect against vessel propeller wash erosion (Figure 7).

5. Description of the Baseline Biophysical Environment in the Port of Richards Bay

5.1 Abiotic Environment

5.1.1 Physical description of the port

The Port of Richards Bay is situated in a large estuarine bay on the subtropical northeast coast of South Africa, in the province of KwaZulu-Natal (entrance at 28°48'36.55"S, 32°05'30.40"E). The original Richards Bay Estuary was extensively modified during the development of the Port of Richards Bay. The changes are extensively documented elsewhere—Weerts (2002) provides a useful discussion. It is beyond the scope of this specialist study to document and discuss the changes in detail. Briefly, prior to port development in the early to mid-1970's—the port was officially opened in 1976—the Richards Bay Estuary was a large (~3100 ha surface area; ~4.8 km width, ~12 km length, ~37 km shoreline), shallow (generally <1 m deep) bay with a narrow (~100 m wide) connection to the sea (Figures 8 and 9) (Millard and Harrison, 1954; Grindley and Wooldridge, 1971; Begg, 1978; Begg, 1984). The estuary was regarded as one of the most productive ecosystems on the KwaZulu-Natal coast at the time, attributed to its large size and diversity of habitats that included extensive seagrass *Zostera capensis* beds that served as nursery habitat for many invertebrate and fish species (Millard and Harrison, 1954).

Five rivers flowed into the estuary (Mhlathuze, Bhizolo, Mzingazi, Mtantatweni, Manzimnyama—the spelling of the river names has changed over time) (Figure 8). The freshwater input from the rivers combined with the narrow tidal inlet that limited the tidal influence in the system to ~0.4 m—far less of a range than in the adjacent marine environment—meant the estuary was characterised by a strong salinity gradient. Under conditions of high rainfall, the salinity was low across the estuary (Millard and Harrison, 1954; Grindley and Wooldridge, 1971).

The sediment was predominantly muddy and had a high particulate organic matter content, although small areas of sandy sediment were found near the mouth. The fine-grained sediment was largely contributed by the Mhlathuze River (CSIR, 2005). The water column was generally turbid, reflecting the resuspension of the muddy bottom by driven waves generated by wind flowing across the large, shallow expanse of open water (Hemens *et al.*, 1971). Extensive reed and papyrus swamps and freshwater swamp forests surrounded the estuary and played an important role in filtering and reducing the suspended sediment concentration in water before it reached the estuary (Vivier and Cyrus, 2009a,b). Mangrove swamps were located at the northern and south-eastern edges and at the western fringe of the original estuary (Begg, 1978; Begg, 1984).

The impetus for the development of the Port of Richards Bay was the lack of capacity in the Port of Durban to handle the increasing demand for (especially) coal and other mineral exports (Hemens *et al.*, 1971). The immediate impetus for the port was thus to provide a dedicated coal export facility, but the importance of the port as a route for the import and export of other bulk products and as a stimulus for industrial development on the northeast coast of South Africa was also recognised. To enable development of the port, while recognising the ecological significance of the Richards Bay Estuary at the time, the estuary was divided by an approximately 4 km long berm (causeway) into northern and southern parts (Figure 10). The northern two thirds of the bay was dredged to enable development of the port. In the port area, provision was made for the separation of bulk commodities, such as coal, from other commodities, such as general cargo, and (potential future) container cargo—which is now coming to fruition through the proposed Berth 605 Project. The lower part of the Mhlathuze River was canalised and diverted into the southern waterbody to negate the effects of floods and sediment deposition on operations in the port (Figure 10).

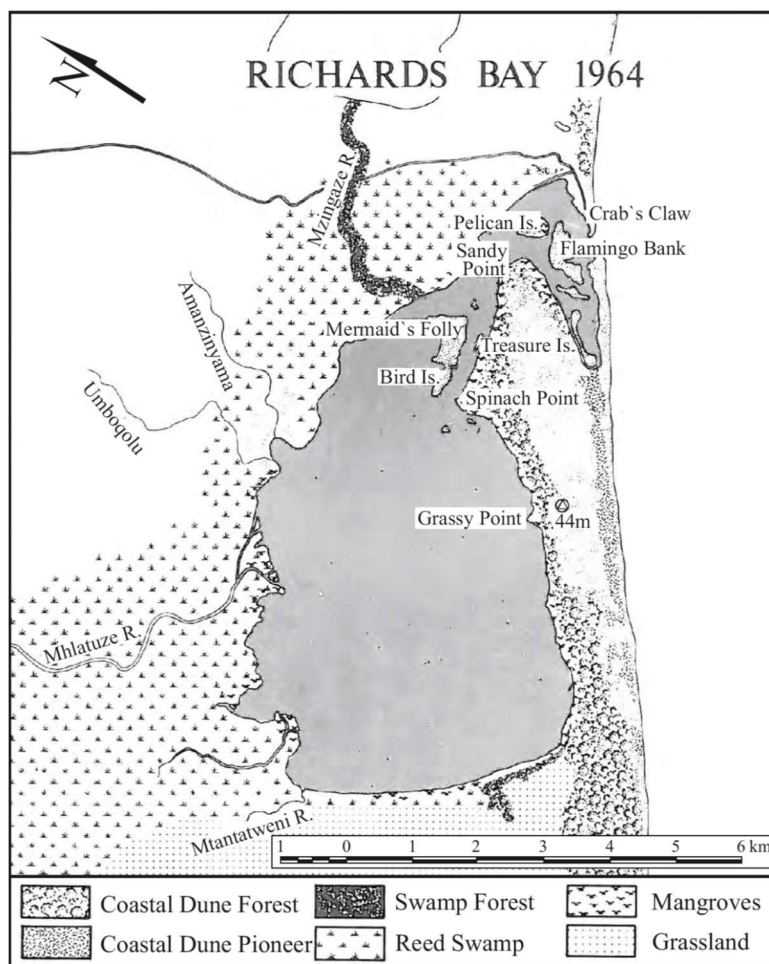


Figure 8. Map showing the layout of the Richards Bay Estuary in 1964 (modified from Begg, 1978).



Figure 9. Aerial photograph (date uncertain) showing the layout of the Richards Bay Estuary before development of the Port of Richards Bay (source unknown – downloaded from Digital Rail Images South Africa).

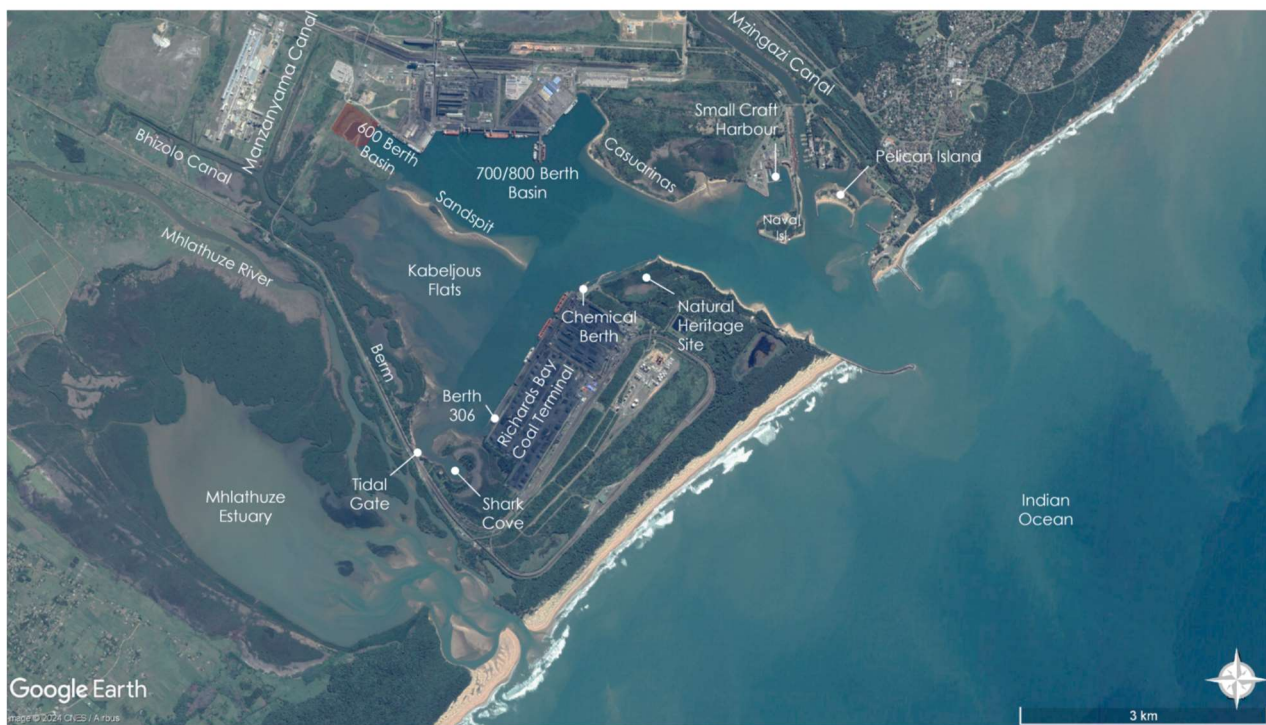


Figure 10. Aerial view of the current layout of the Port of Richards Bay and Mhlathuze Estuary.

The berm was intended to serve several purposes, including:

- restricting the transport into and deposition of sediment in the port, which would have implications for dredging frequency and volume,
- providing road and rail access to the Richards Bay Coal Terminal, rather than a longer and more complex road and rail route in terms of engineering and construction requirements around the south of the estuary,
- reducing the fetch, and hence size, of wind driven waves, which would present a navigation hazard for large slow-moving vessels in the port,
- preventing the draining of the southern waterbody at each low tide due to the larger tidal range in the port because of its wider and deeper entrance.

The port would have looked very different and would have functioned in a different ecological manner were the road and rail access to the Richards Bay Coal Terminal positioned around the south of the estuary. It was recognised that the berm would isolate the southern waterbody from the sea, and although it could have developed into an inland aquatic system (lake) its estuarine value to the ecology of the KwaZulu-Natal coast would have been lost. The need to connect the southern waterbody to the sea was thus recognised, but the idea was not pursued due to the high cost implications of dredging a new mouth and uncertainties on whether the mouth would remain open under tidal action. However, because of the abundance of silty material in the port area, several million cubic metres of sand would have to be borrowed from the eastern part of the southern waterbody for the construction of the levee. It then became apparent that the construction of a new mouth for the southern waterbody would be a viable proposition if studies showed that the mouth would remain open, which they did. A new mouth was thus dredged to connect the southern waterbody to the sea, creating the Mhlathuze Estuary.

As a safeguard against the possible closure of the new estuary mouth, the two parts of the system were connected by a tidal gate on the berm that could be closed to control the flow of water between the systems. In the event the new mouth showed signs of closing because of excessive siltation, water could be directed from the port into the estuary at high tide to aid in scouring the mouth. The tidal berm had other potential benefits, including:

- maintaining an ecological connection between the systems in the event the new mouth closed,
- providing a mechanism for releasing flood water from the estuary into the port to prevent back flooding of the Mhlathuze River floodplain, which was largely a problem for agriculture on the floodplain—other flood control measures were originally planned,
- avoiding the transfer of contaminants into the estuary in the event of heavy pollution in the port.

A reverse flow could also be followed into the port if it was found that flows were excessively scouring the new estuary mouth. In practice, however, the tidal gate proved ineffective—the two systems are now essentially isolated from one another. The Mhlathuze Estuary mouth is fortunately permanently open.

The Mhlathuze Estuary is often referred to as a proclaimed protected area, but when the Richards Bay Game Reserve (sometimes referred to as Richards Bay Nature Reserve, or Sanctuary) was proclaimed in 1935—there have been amendments to the proclamation—the reserves boundaries followed the shoreline at the time. Due to increased siltation because of the diversion of the Mhlathuze River into this part of the original Richards Bay Estuary and tidal action, the existing extent of the estuary, as defined by its shoreline, is larger than the proclaimed area. Despite the protected status of most of the Mhlathuze Estuary, its natural resources (fish, shellfish, mangrove trees *etc.*) are heavily exploited by local communities and there is virtually no enforcement presence.

Although large parts of the Port of Richards Bay are given over to port developments and operations, substantial areas have retained a natural function and support a high diversity of ecological habitats and biological resources (Figure 10). These natural areas lie near, or alongside traditional port infrastructure, urban infrastructure, and urban developments. The value of these natural habitats in providing ecosystem goods and services is widely acknowledged (see references in this specialist study). The most obvious feature of the port is the large expanse of open water (~870 ha). Most of the open water area is deepwater habitat, created to allow the movement of vessels in the port. The bottom in these deepwater areas is comprised of sediment.

Two canal systems connect to the larger port waterbody, namely the Bhizolo-Manzanyama Canal complex in the southwest and the Mzingazi Canal in the north nearer the mouth (Figure 10). The Mzingazi Canal represents the old river flow from Lake Mzingazi, but it was excavated and reoriented to its current dimensions. The upper part of Mzingazi Canal connects to the Ngodweni River, which drains the Thulazihleka Pan. The Bhizolo/Manzanyama Canal complex represents the historical flows of two rivers that were also excavated and reoriented to drain wetlands and swamps to allow the development of an aluminium smelter (Begg, 1984), although the Bhizolo River now no longer connects to the canal since it was diverted into the Mhlathuze River. The Bhizolo-Manzanyama Canal complex is shallow sediment habitat flanked by large mangrove forests in some parts and narrow, fringing mangrove forests in other parts, and saltmarshes and wetlands. The upper most part of the Manzanyama Canal will be ~560-620 m from the proposed edge of the lengthened 600 Berth Basin if the Berth 605 Project proceeds.

The Bhizolo-Manzanyama Canal complex opens onto a large (~440 ha; Cyrus and Vivier, 2021a,b) area that is variously referred to as the Mudflats or Kabeljous Flats—the latter is used forthwith in this report (Figure 10). The Kabeljous Flats comprises a mosaic of habitats that include intertidal (~208 ha) and shallow subtidal (~104 ha) sand and mud habitat, respectively, and mangroves (~114 ha) (surface areas from Cyrus and Vivier, 2014). The Kabeljous Flats is separated from the deepwater 600 and 700/800 Berth Basins to the north by an approximately 2 km long sinuous Sandspit that is largely covered by water at spring high tide and almost entirely covered at the highest equinox tides, but presents a fairly large, exposed area at spring low tide (Figure 10). There is a small (~0.4 ha) mangrove stand on the Sandspit. The Sandspit is separated from the adjacent land on its westernmost end by a narrow channel that is ~40 m wide at spring low tide. The channel allows the flow of water between the neighbouring part of the Kabeljous Flats and

the 600 and 700/800 Berth Basins (Figure 11). Prior to the development of the 600 Berth Basin the Sandspit was connected to a sandy shoreline that extended across the eastern part of the existing basin to Berth 609. Mangroves fringing the Kabeljous Flats thus extended to ~400 m from Berth 609 (Figure 12). The mangroves were removed and land was excavated during the development of the 600 Berth Basin—the Sandspit’s connection to the land was lost at the time. The south-southwestern extremity of the Kabeljous Flats is the berm separating the port from the neighbouring Mhlathuze Estuary, extending through to a small pool-like area fringed by mangroves to the south of the Richards Bay Coal Terminal that is sometimes referred to as Shark Pool or Shark Cove (Figure 10). The origin of the name is that this is where the erstwhile Natal Sharks Board tested shark bather protection mechanisms.



Figure 11. Aerial view of the 600 Berth Basin and its surrounds in the Port of Richards Bay.

Narrow sandflats/beaches are prevalent in the undeveloped part of the 700/800 Berth Basin and in an adjacent area known locally as Casuarinas on account of the Casuarina trees planted here for shoreline stabilisation (Figure 10). There is a large mangrove forest in the Casuarinas area and intertidal and shallow subtidal habitat in front of the forest to the southwest of the Small Craft Harbour. There is a smaller area of mangrove forest along the eastern shore of the 700/800 Berth Basin. There are beaches along the southern shore of the main navigation channel, punctuated by groynes constructed to limit shoreline erosion and protect port infrastructure. The eChwebeni Natural Heritage Site, comprising mud flats and mangroves that are apparently a remnant of the original mangroves in the Richards Bay Estuary, is situated on this shore and extends through to the Chemical Berth (Figure 10). A large part of the northeastern part of the port near Pelican Island comprises shallow water basins and intertidal sandflats (Figure 10). This area, and Mzingazi Canal are important recreational areas in the port.



Figure 12. Aerial views of the Port of Richards Bay before and during construction of the 600 Berth Basin (position shown by arrows).

The Berth 605 Project footprint encompasses part of the 600 Berth Basin and land to the west-northwest of the basin. The 600 Berth Basin is a dead-end basin ~700 m in length and ~300 m in width (Figures 10 and 11). The water depth in the basin increases sharply along the western and southern shoreline and is ~14.5 m Chart Datum across most of the basin, becoming deeper into the 700 Berth Basin. The northern part of the basin is given over to a break bulk/multipurpose terminal (Berths 606-608) and is consequently characterised by concrete quay walls (Figures 10 and 11). The southern side and part of the dead-end area on the western side is comprised of a narrow, largely rock, stone and rubble strewn shoreline interspersed with patches of sandy sediment and backed by a steeply cut terrace that was formed by soil and rock disposal during the development of the 600 Berth Basin. Part of the northwestern shore is a concrete wall. At its western end the 600 Berth Basin connects to a small pool-like basin that is often referred to as the 'Assembly Basin' on account of it being the area where caissons were assembled for the

construction of Berth 306 at the Richards Bay Coal Terminal (Figures 10 and 11). A small, sheltered basin existed here prior to the construction of Berth 306 (Figure 13)—having been used as a pit for caisson assembly during the development of the 600 Berth Basin—but it was extended for caisson assembly for the Berth 306 Project (Figures 14 and 15). The Assembly Basin, which is ~170 m in length, ~130 m in width, and ~11 m Chart Datum at its deepest, is fringed by a narrow sandy shore (Figures 10 and 11). There is a fairly large amount of construction waste on parts of the shoreline. Inland of the Assembly Basin is a small (~250 m in length, ~50 m at its widest), shallow, pool like area that is under tidal influence owing to its connection to the Assembly Basin by a pipe (Figure 11). A tidally influenced pool like area existed here prior to the construction of Berth 306 (Figures 13-15), but material excavated to enlarge the Assembly Basin was disposed in the pool like area and reduced it to its current dimensions.



Figure 13. View of the narrow channel between the 600 Berth Basin and Kabeljous Flats (in background) in the Port of Richards Bay.



Figure 14. Aerial view of caisson construction in the Assembly Basin in the 600 Berth Basin in the Port of Richards Bay. Part of the existing tidally influenced pool referred to in the text is visible in the background. Photo from Albert van Jaarsveld.



Figure 15. Aerial view of caissons in the Assembly Basin in the 600 Berth Basin in the Port of Richards Bay. The berm that sealed the basin has been breached in preparation of caisson floating to Berth 306. The existing dimensions of the tidally influenced pool referred to in the text is highlighted.

5.1.2 Estuary type and delineation

As stated above, the Port of Richards Bay is classified as an estuarine bay, but in its original state it was classified as an estuarine lake. Estuarine bays, which are the second rarest estuarine type in South Africa, are large systems (>1200 ha) characterised by a strong marine influence due to their permanent connection to the sea through a deep mouth. They are dominated by tidal processes and have a tidal amplitude close to that of the adjacent sea (van Niekerk *et al.*, 2020). The only other estuarine bays in South Africa are Durban Bay (Port of Durban) in KwaZulu-Natal and Knysna Estuary in the southern Cape. The Port of Richards Bay is an artificially created estuarine bay—the other two are natural. Nevertheless, based on its rarity alone, the Port of Richards Bay has local, regional and national ecological and conservation importance (MER, 2013). The diversity of estuarine habitats represented, and the relatively unpolluted state of the port further reinforce its ecological and conservation importance considering many estuaries in the KwaZulu-Natal area are currently highly degraded in some way (van Niekerk *et al.*, 2019). Wastewater discharges and chemical contamination has substantially diminished the ecological value and ecological functioning of many estuaries in KwaZulu-Natal. If migrating birds are considered, the port has international (global) ecological and conservation importance.

The Estuarine Functional Zone, as defined in terms of the National Environmental Management Act (NEMA), Environmental Impact Assessment (EIA) Regulations (as amended in 2017) (GN 324), is an important concept in the management of estuaries in South Africa. It includes the area encapsulated by an estuary waterbody and supporting physical and biological processes necessary for estuarine functioning and health. The Estuarine Functional Zone encompasses the area around an estuary below the 5 m topographical contour relative to mean sea level. However, a definition based on this areal extent has several shortcomings in the context of some estuaries in South Africa and the most recent (2018) National Biodiversity Assessment: Estuarine Realm (van Niekerk *et al.*, 2019) thus modified the Estuarine Functional Zone boundary for these systems to include the area below the 10 m topographical contour relative to mean sea level. The 2018 National Biodiversity Assessment also included the adjacent surf zone at the mouth of estuaries in the Estuarine Functional Zone, to emphasize estuarine-marine connectivity (van Niekerk *et al.*, 2019). The 5 m topographical contour remains the default Estuarine Functional Zone boundary in respect of Environmental Impact Assessments (2014 Environmental Impact Assessment (EIA) Regulations (as amended in 2017) (GN 324)), until (or if) the 10 m contour is formally adopted. Under this legislation, Environmental Authorisation is required before a development may proceed within an Estuarine Functional Zone. In other words, a Basic Assessment of Environmental Impact Assessment is required. The Berth 605 Project footprint falls within the Richards Bay Estuarine Functional Zone, as defined in the uMhlathuze and Richards Bay Estuarine Management Plan (DEA, 2018) (Figure 16).

The Richards Bay Estuarine Functional Zone is ~5509 ha in spatial extent, comprising ~3543 ha (or 64%) developed and/or transformed area and ~1966 ha (or 36%) natural habitat, of which ~869 ha is open water (van Niekerk *et al.*, 2019). The habitat breakdown for the estuarine area, excluding open water, is 69.9 ha for saltmarshes, 309.0 ha of reeds and sedges, 171.0 ha of mangroves, 531.0 ha of sand/mudbanks, and 15 ha of swamp forest. The Estuarine Functional Zone includes Lake Cubhu to the south-southwest and Lake Mzingazi to the north-northeast of the Port of Richards Bay. The lakes were historically connected to the Richards Bay Estuary waterbody but are now disconnected by the construction of weirs or other water control measures and function as freshwater lakes (DEA, 2019). The lakes were consequently not included in the estuarine management unit for the uMhlathuze and Richards Bay Estuarine Management Plan (DEA, 2019) (Figure 16).



Figure 16. Aerial view of the greater Richards Bay area showing the Estuarine Functional Zone for the Port of Richards Bay (Richards Bay Estuary) and Mhlathuze Estuary. The peach shaded area denotes the management unit for the uMhlathuze/Richards Bay Estuarine Management Plan (up to the weirs separating Lakes Mzingazi and Cubhu).

5.1.3 Climate

Richards Bay has a sub-tropical maritime climate that is characterised by generally hot, and at times uncomfortably humid and wet summers, and cooler, yet mild, dry winters. Most of the rain falls between October and March—highest rainfall is in January and February—but significant rainfall may occur at any time of the year (CSIR, 2005). The reported annual average rainfall is ~1230 mm (CSIR, 2005). Periods of heavy rainfall leading to localised flooding are fairly common. Wind data derived from the CSIR Integrated Port Operations Safety System weather stations at Port Control Tower and on Southern Breakwater shows that the prevailing winds are largely south to southwest and north-northeast to northeast, with the strongest winds in spring and summer. Strong winds have a significant influence on the wave climate in the port, which in turn affects the water and sediment environment and biological resources.

5.1.4 Bathymetry

As mentioned earlier, the Richards Bay Estuary was fundamentally transformed to allow the passage of large ocean-going vessels to berths in the Port of Richards Bay, for the loading and offloading of cargo. The water column depth over large parts of the port reflects this requirement (Figure 17). The Entrance Channel is maintained to a depth of -23.9 m Chart Datum offshore of the breakwaters, -21.9 m Chart Datum just inshore of the breakwaters, and -19.4 m Chart Datum along most of the main navigation channel. The 700/800 Berth Basin and Richards Bay Coal Terminal Basin are generally maintained at -18.9 m Chart Datum. The 600 Berth Basin and parts of the 700/800 Berth Basin are maintained at -14.4 m Chart Datum and -14.6 m Chart Datum, respectively. The Small Craft Harbour and the approach channel to this harbour are maintained at -7.9 m Chart Datum. As mentioned earlier, the Kabeljous Flats and Bhizolo/Manzanyama Canal complex are shallow water areas, as is the Mzingazi Canal and related areas (Figure 17).

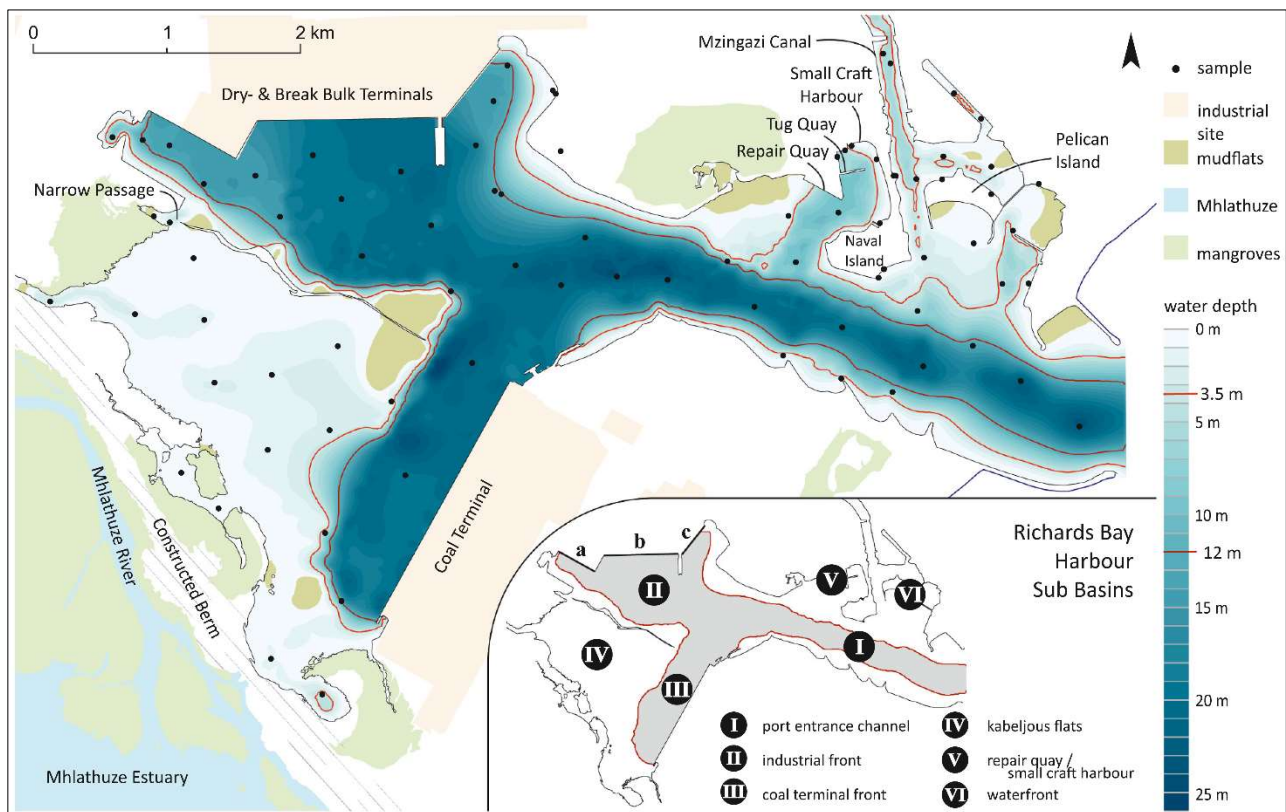


Figure 17. Bathymetry of the Port of Richards Bay (from Mehlhorn *et al.*, 2021).

5.1.5 Tides

Tidal water level variation in the Port of Richards Bay comprises predominantly a semi-diurnal tide with a period of ~12.4 h and a range of 0.51 m at neap tide, increasing to 1.84 m at maximum spring tide (Table 1). The mean high-water spring tide level is approximately +2.11 m to Chart Datum of the port or +0.91 m to mean sea level (Chart Datum for the port is 0.90 m below Mean Sea Level).

Table 1. Tidal characteristics for the Port of Richards Bay (from van Ballegooyen *et al.*, 2015).

Description	Tidal levels (m above Chart Datum)
Highest Astronomical Tide (HAT)	2.47
Mean High Water Springs (MHWS)	2.11
Mean High Water Neaps (MHWN)	1.48
Mean Level (ML)	1.20
Mean Low Water Neaps (MLWN)	0.97
Mean Low Water Springs (MLWS)	0.27
Lowest Astronomical Tide (LAT)	0.00

5.1.6 Hydrodynamic functioning

A schematic of the major hydrodynamic processes in the Port of Richards Bay is provided in Figure 18. Although the tidal flow in the Entrance Channel to the Port of Richards Bay is considerable, the cross-sectional area of the channel is large. Tidal currents are, therefore, weak, ranging from a peak, depth-averaged current of 0.03 m.s^{-1} at neap tide to 0.17 m.s^{-1} at spring tide along the centre of the Entrance Channel, as found by means of hydrodynamic modelling (CSIR, 2000). The profile of the Entrance Channel is such that the tidal flow is concentrated in the deeper part of the channel, with a smaller tidal flow on the upper slope close to the shoreline. Wind-driven surface currents normally flow at ~2-3% of the wind velocity. This means that by taking typical wind velocities into account (CSIR, 1997), wind-driven surface currents will normally be of the order of 0.10 m.s^{-1} to 0.15 m.s^{-1} during these conditions (CSIR, 2000). The

tidal flows diminish towards the inner recesses of the port. Tidal currents are nevertheless also significant in shallow parts of the port, including on the Kabeljous Flats and in the mangrove area near Shark Cove in the southern part of the Richards Bay Coal Terminal Basin. Under strong southwest winds and spring ebb flow conditions, currents of up to 0.5 m.s^{-1} may be generated on the northern side of Kabeljous Flats, while under strong northeast winds the flows are somewhat reduced and concentrated on the southern side of the flats. Under strong southwest winds a clockwise residual circulation is generated over the Kabeljous Flats during spring flood and ebb tides. Conversely, under strong northeast winds an anticlockwise residual circulation develops over the flats during both spring flood and ebb conditions. The magnitude of these residual circulations increases with increasing wind speed.

Accretion and erosion problems occur in the port due to (largely wind-driven) wave action, mainly along the southern shore of the main navigation channel (Figure 18). A series of groynes and floating pontoons were installed along this shore to control the erosion and protect port infrastructure (Figure 10).



Figure 18. Schematic of the major hydrodynamic processes in the Port of Richards Bay, Mhlathuze Estuary, and shoreline at Richards Bay (from CSIR, 2005).

5.1.7 Substrate

The Port of Richards Bay area is underlain by unconsolidated Cenozoic Era sediments of the Maputaland Lithological Group that stretch along the Maputaland coastal plain into Mozambique (SE Solutions, 2023) (Figure 19).



Figure 19. Photograph of the Assembly Basin in the 600 Berth Basin in the Port of Richards Bay, showing geological formations in the area. Photo from Albert van Jaarsveld.

There is a good amount of information on the grain size of sediment in the Port of Richards Bay, generated through surveys commissioned by TNPA and through independent or collaborative surveys and research by various other organisations. Spatially comprehensive surveys on the grain size of sediment in the port were made by the CSIR in 2011 and 2012 (CSIR, unpublished data; CSIR, 2013) (Figures 20 and 21). Although the surveys were made over a decade ago, a spatially extensive survey of sediment grain size made in the port in 2018 by Mehlhorn *et al.* (2021) (Figure 22) and across a large part of the Kabeljous Flats in 2020 by Cyrus and Vivier (2021a) (Figure 23) show that the broad trends evident in the earlier CSIR surveys were still relevant in the latter surveys. The common patterns evident in sediment grain size amongst the surveys is unsurprising considering there were no major changes to the bathymetry and layout of physical infrastructure in the port that might have influenced current flows and patterns, nor major changes in sediment sources to the port in the period since the earlier CSIR surveys.

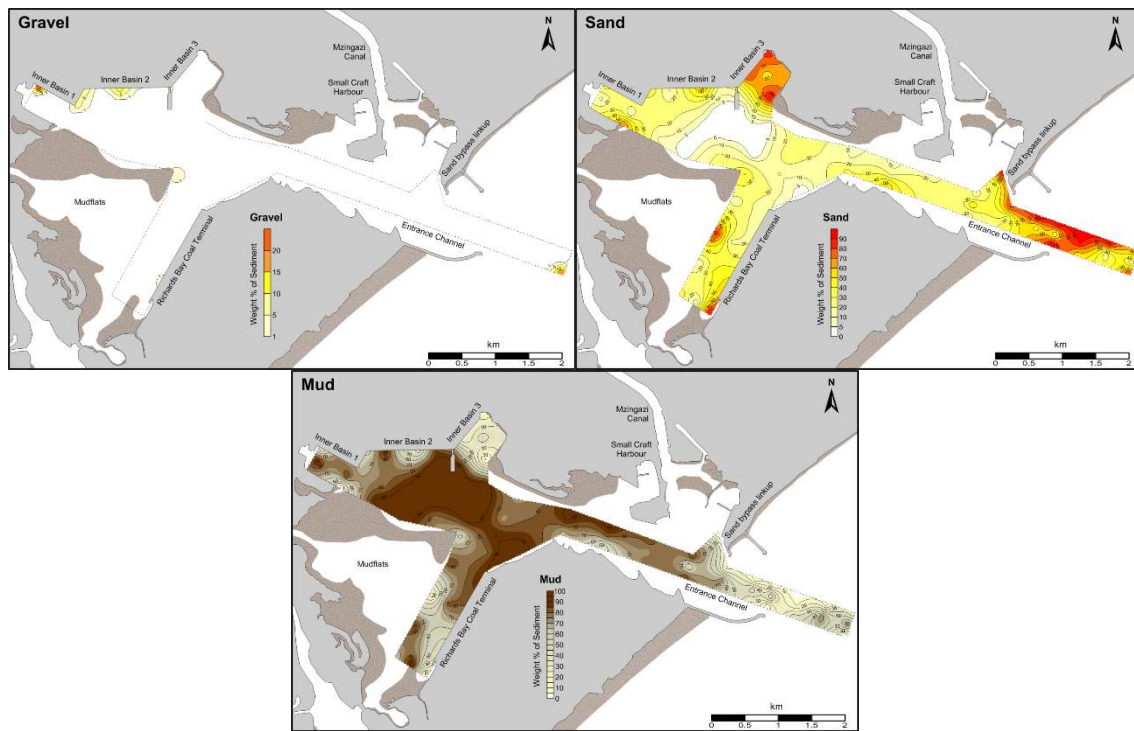


Figure 20. Interpolated spatial trend for the contribution of gravel, sand, and mud to the bulk weight of sediment sampled in the Port of Richards Bay in November 2011 (CSIR unpublished data).

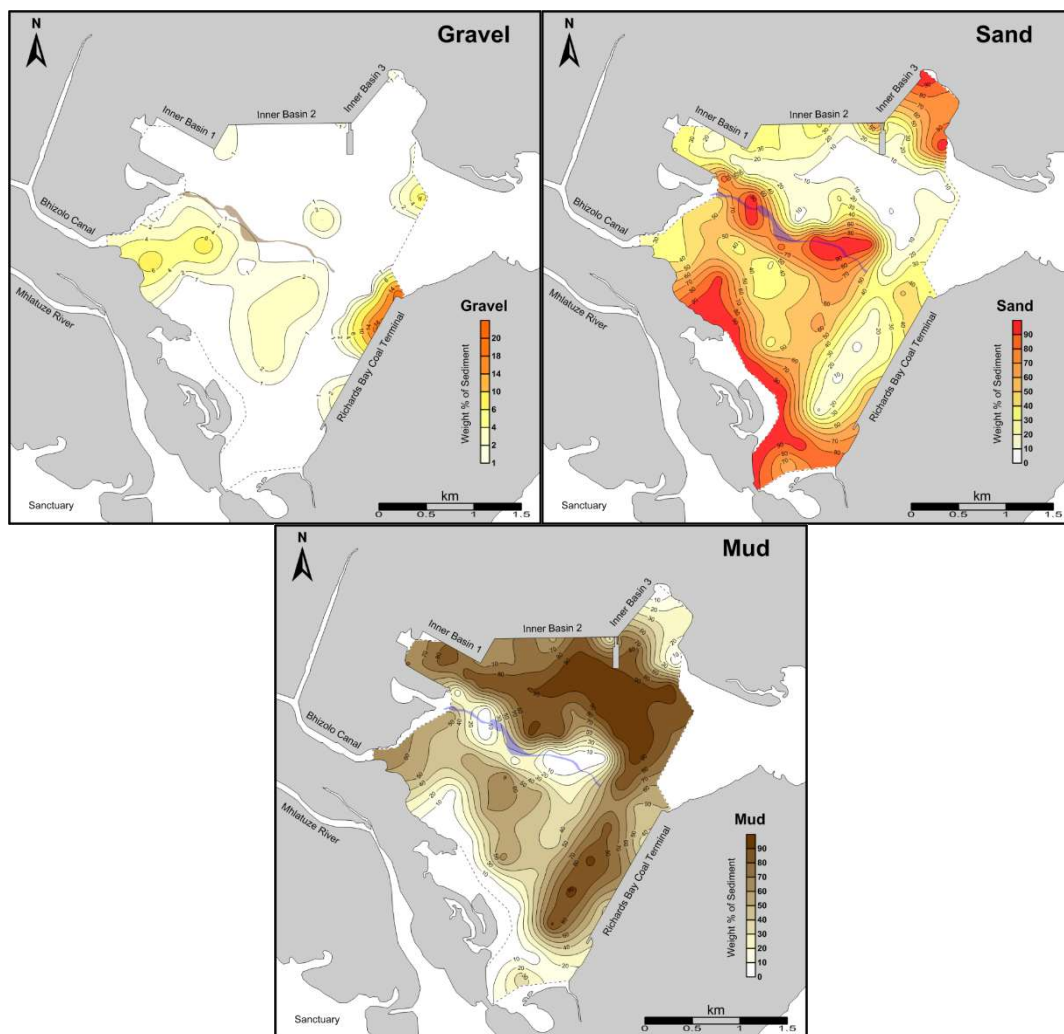


Figure 21. Interpolated spatial trend for the contribution of gravel, sand, and mud to the bulk weight of sediment sampled in the Port of Richards Bay in November 2012 (CSIR, 2013).

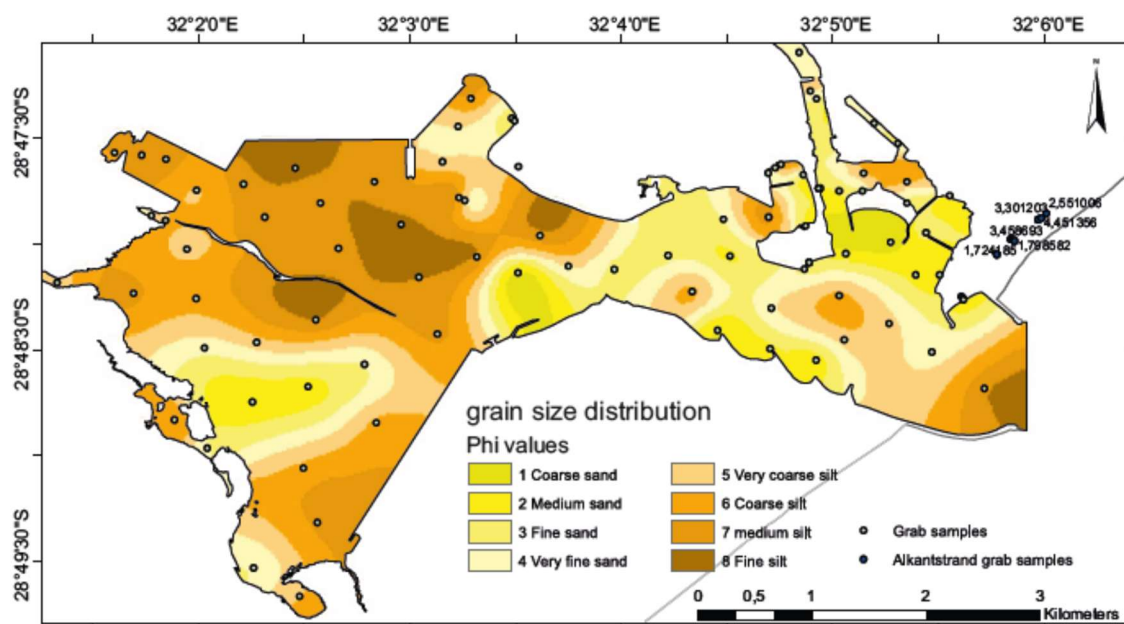


Figure 22. Interpolated spatial trend for the contribution of various grain size classes to the bulk weight of sediment sampled in the Port of Richards Bay in 2018 (from Mehlhorn *et al.*, 2021).

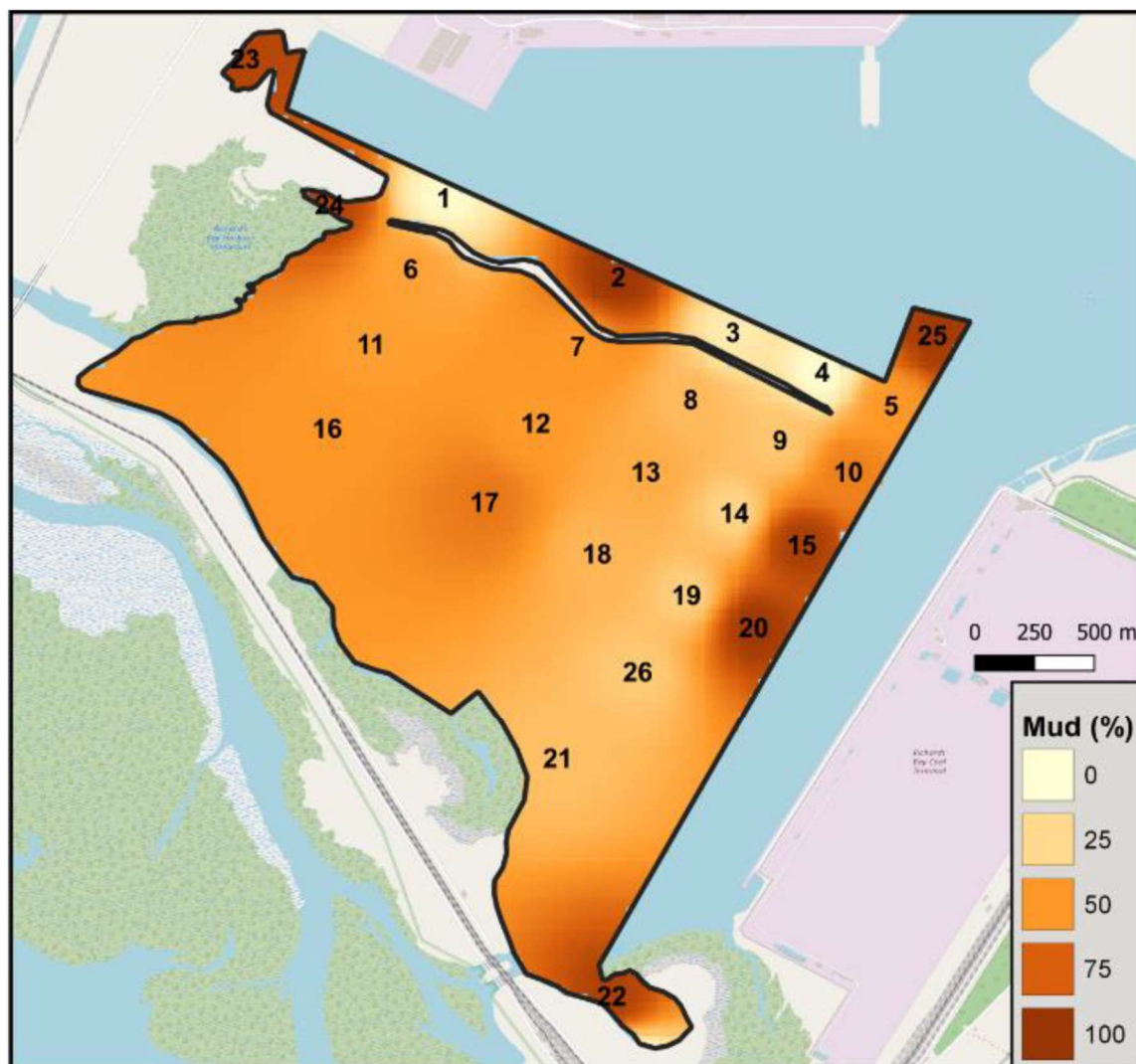


Figure 23. Interpolated spatial trend for the contribution of mud sized material to the bulk weight of sediment sampled in the Port of Richards Bay in 2020 by Cyrus and Vivier (2021).

The sediment in the deepwater channels and basins in the Port of Richards Bay is dominated by mud sized material (Figures 20-22), but the contribution of this material to the bulk weight of the sediment is variable. Notable exceptions are in part of the 700 Berth Basin, near the Sandspit, and in the southernmost part of the Richards Bay Coal Terminal Basin, where the sediment is largely dominated by sand. Sediment in the intertidal and shallow subtidal is usually sandier than in the adjacent deeper channels and basins, which in many areas reflects exposure to waves and related currents that erode and prevent the accumulation of finer-grained material (Figures 20-22). These areas are generally the lighter coloured areas along shorelines in Figure 10. The dominant sand grain size class varies quite widely amongst these areas, but the average grain size is generally coarser along the southern shoreline of the main navigation channel where groynes were inserted to control wave erosion. Areas where mud contributes appreciably or dominantly to the bulk weight of sediment in the intertidal and shallow subtidal include the Kabeljous Flats (Figures 21-23), in mangrove forests and in parts of the Bhizolo-Manzanyama Canal complex and Mzingazi Canal. However, the sediment grain size composition in these areas is also often quite variable and may change from mud to sand dominated sediment over small spatial scales. Although such changes occur along the gradient from the deeper to intertidal parts the sediment granulometry also often also occur between areas in the deeper parts in patterns that are not easily explained.

Surficial sediment in the deeper parts of the 600 Berth Basin, including the Assembly Basin, was dominated by mud in historical and recent surveys (CSIR, unpublished data; CSIR, 2013; Izegaegbe *et al.*, 2020; Cyrus and Vivier, 2021a; Mehlhorn *et al.*, 2021; Malan *et al.*, 2023) (Figures 20-23) apart from one of the five stations sampled in the basin by Malan *et al.* (2023) in 2022, where sand contributed ~95% of the bulk sediment weight. In intertidal and shallow subtidal areas in the basin, the sediment is dominated by sand. The most recent information on sediment grain size in basin was generated in November 2024 by the CSIR for the purpose of a capital dredging permit application for the Berth 605 Project. Detailed information on the survey is provided in a companion specialist study prepared by the CSIR (CSIR, 2024). The positions where the sediment was sampled are provided in Figure 24. The survey confirmed that the surficial sediment in the deeper parts of the basin is dominated by mud, giving way to sandier sediment along the south-southeastern shore (Figure 25). The most significant change that has occurred in the 600 Berth Basin in recent times is the accumulation of coal fragments and coal particles in the sediment, reflecting losses into the port aquatic environment during the loading of coal onto vessels and via wind and surface runoff erosion from coal stockpiles near the basin. The export of coal through the 600 Berth Basin is a relatively recent development. The dark colour of the sediment at some stations near the quay wall is assumed to reflect the accumulation of coal particles in the sediment (Figures 26 and 27). The sediment in parts of the basin is also characterised by sulphur balls, also reflecting losses into the port aquatic environment during the unloading from vessels (Figure 26). Sulphur balls were also evident along the road verge near Stations 15 and 17 in Figure 25.

As stated above, the Berth 605 Project footprint extends into land at the western end of the basin (Figure 5). There is some information on the grain size of soil in this area from surveys made by the CSIR in January 2009 and in November 2024. The survey in 2009 was made after the completion of caisson construction in the Assembly Basin for the development of Berth 306. The area was largely devoid of vegetation at the time (Figures 14 and 15), but is now vegetated—densely in parts. The positions where soil was sampled by the CSIR in 2009 and 2024 are provided in Figure 24. The soil sampled in 2009 had a variable grain size, comprised nearly equally of mud and sand sized material, but largely of medium-grained sand with an appreciable contribution of fine-grained sand at Stations 6 and 7 (Figure 28). The soil sampled in 2024 generally had a higher contribution of mud sized material apart from Station 12 and, to a lesser degree, Station 17 (Figure 25). The regrowth of vegetation appears to have trapped fine-grained material at the soil surface in parts of the Berth 605 Project footprint since 2008, noting there was little overlap in positions where soil was sampled in the surveys. The degree to which the soil sampled in 2024 is representative of deeper soil is unknown but will be revealed through geotechnical surveys for the Berth 605 Project.



Figure 24. Aerial view of the 600 Berth Basin in the Port of Richards Bay, showing the positions where sediment and soil samples were collected by the CSIR in November 2024, and where soil was sampled in 2009 by the CSIR.

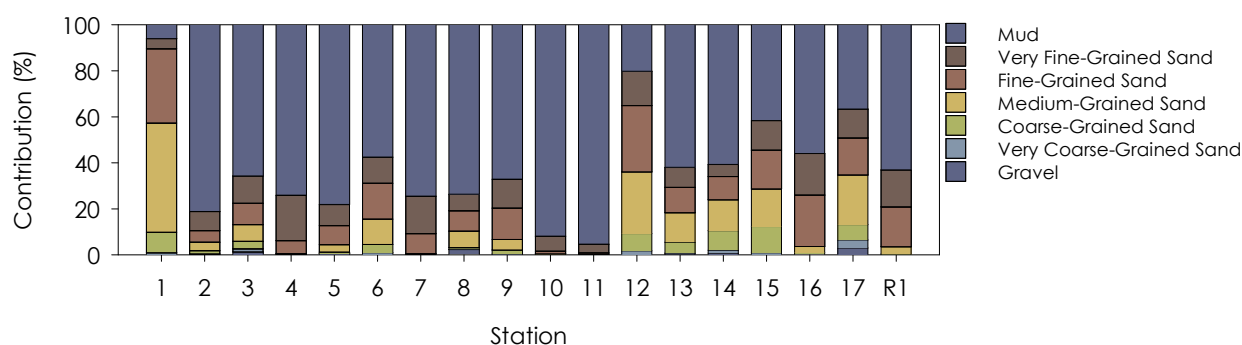


Figure 25. Contribution of various grain size classes to the bulk weight of sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay by the CSIR in November 2024 (see Figure 24 for station positions).



Figure 26. Coal fragments, sulphur balls (yellow-coloured objects), and other debris in sediment sampled near the quay wall in the 600 Berth Basin in the Port of Richards Bay by the CSIR in November 2024.



Figure 27 Sediment sampled at Station 6 (left) and Station 9 (right) in the 600 Berth Basin in the Port of Richards Bay by the CSIR in November 2024. Note the dark colour of the sediment, presumably imparted by coal particles.

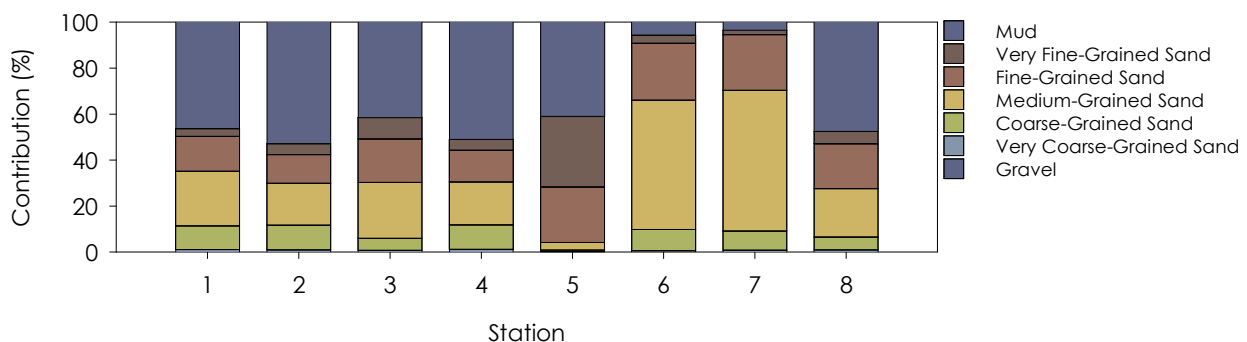


Figure 28. Contribution of various grain size classes to the bulk weight of soil sampled near the 600 Berth Basin in the Port of Richards Bay by the CSIR in January 2009.

5.1.8 Water quality

There is a good amount of information on water quality in the Port of Richards Bay, generated through surveys commissioned by TNPA and through independent or collaborative surveys and research by various other organisations. The combined findings of these studies provide a good understanding on spatial trends for numerous water quality indicators in parts of the port, but water quality in some areas, and temporal trends, are less well understood, while the amount of information available for some water quality indicators is limited. There is a good amount of information on water quality in and near the Berth 605 Project footprint, albeit at a coarse spatial scale. A dedicated water quality survey was not considered necessary to generate information to describe the baseline water quality environment in the basin and for assessing the significance of environmental impacts that may arise during and after the development of Berth 605. The baseline description below of water quality in the Port of Richards Bay and in the Berth 605 Project footprint is taken largely from water quality surveys made by the CSIR between 2015 and 2024, supplemented by the findings of other studies where necessary. The water quality surveys were made consistently at the stations provided in Figure 29, in summer and winter. Water quality measurements were made *in situ* using an automated water quality monitoring instrument at all the stations shown in Figure 29, while water samples were also collected at 11 of the stations for later analysis in the laboratory.

The temperature of the water column in the Port of Richards Bay has an obvious seasonal link, being warmer in summer than in winter. The water temperature was rarely below ~18°C or above ~28°C in the deeper channels and basins (Figure 30), but in very shallow parts on cloudless summer days the temperature can reach as high as ~35°C (CSIR, unpublished data).

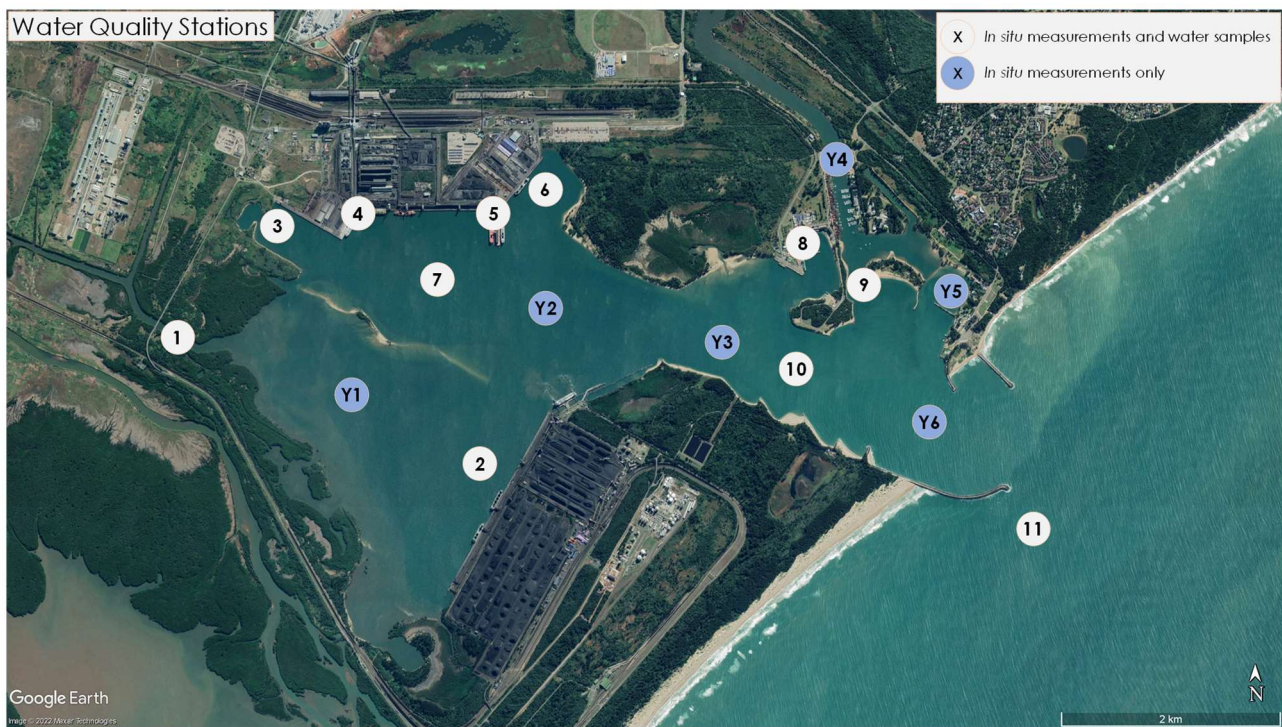


Figure 29. Aerial view of the Port of Richards Bay showing the stations where water quality was monitored *in situ* and surface water samples were collected by the CSIR for physical, chemical, and biological analysis and toxicity testing in 15 surveys between 2015 and 2024.

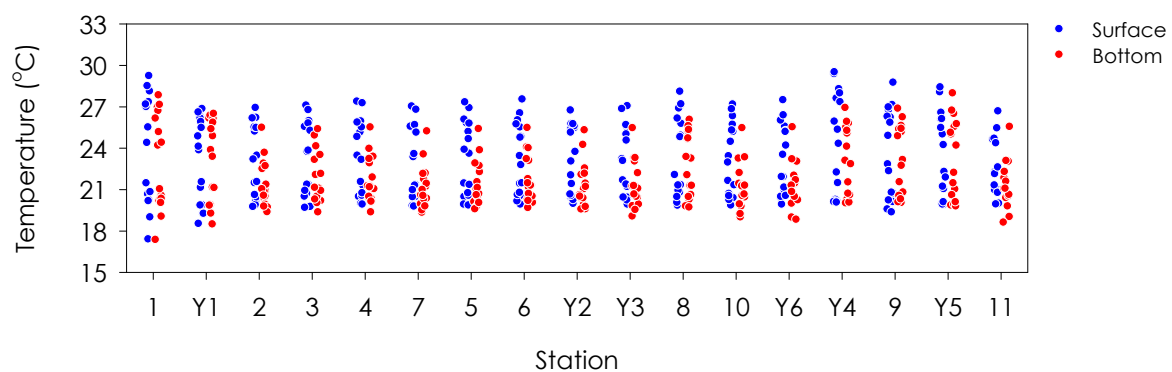


Figure 30. The temperature of surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

Salinity is a primary driver of estuarine biophysical variability and is commonly used to define the zonation pattern of biological resources since species establish within an estuary according to their preference or tolerance to average salinity conditions and extreme events. In estuaries with marked salinity gradients, truly marine species are usually excluded apart from near the mouth or the lower estuarine reaches due to their inability to tolerate salinities much below those for seawater. The salinity (Figures 31 and 32) of the water column across most of the Port of Richards Bay is broadly comparable to that for seawater in the nearshore marine environment off the Richards Bay coast and is generally stable, if often slightly lower and more variable in surface water. The stable salinity regime reflects the strong marine influence in the port and minimal freshwater inflow. Areas in the port where the salinity is often lower than that for seawater are the Bhizolo-Manzanyama Canal complex (Station 1 in Figures 29 and 31) and Mzingazi Canal (Stations Y4 and 9 in Figures 29 and 31). The salinity of water over the Kabeljous Flats is obviously by flows from the Bhizolo-Manzanyama Canal complex, but the salinity depression relative to seawater at the position where water quality was measured is not pronounced (see also Cyrus and Vivier, 2021a,b).

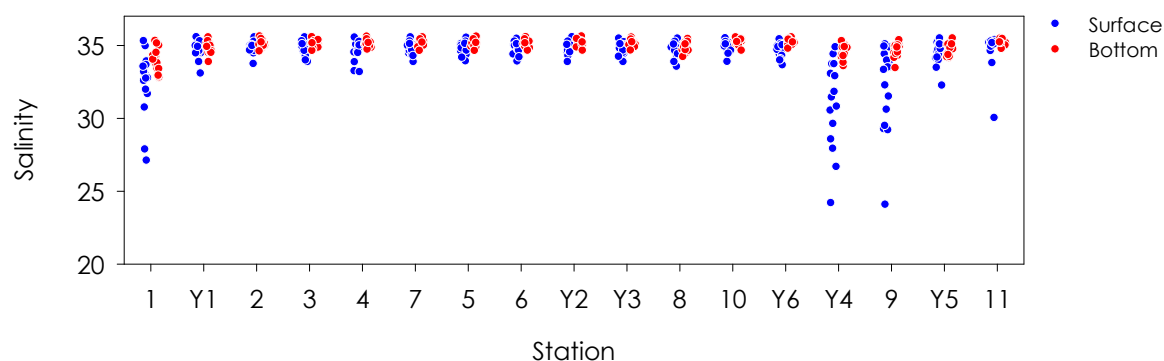


Figure 31. The salinity of surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

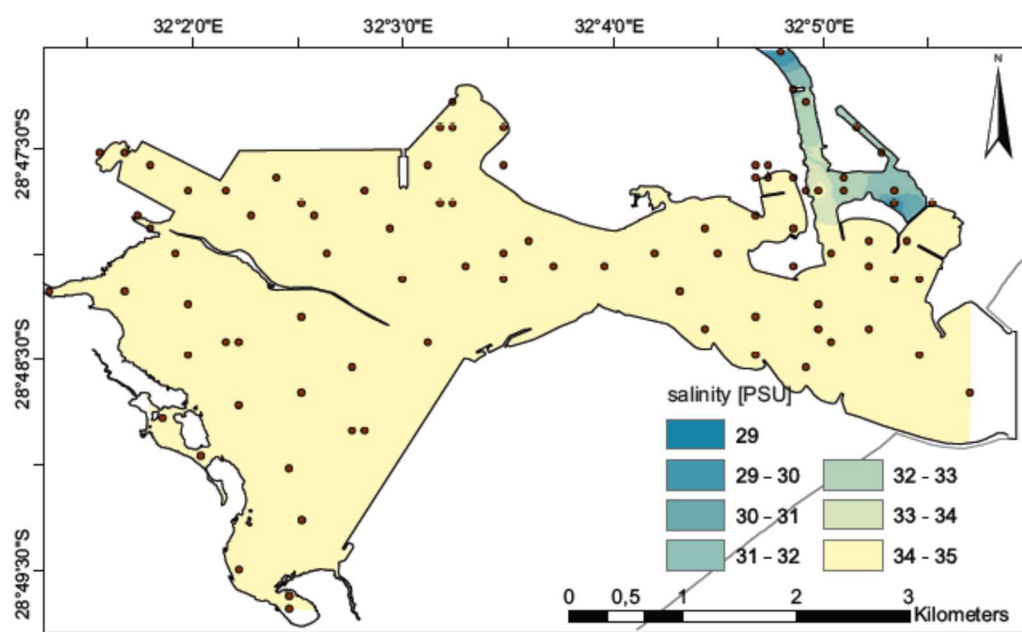


Figure 32. The salinity of surface water in the Port of Richards Bay in during a survey in 2018 (provided by Paul Mehlhorn).

The pH of surface water in the Port of Richards Bay is more variable than that for seawater in the adjacent marine environment off the Richards Bay coast, but it nevertheless reflects the strong marine influence and low volume of freshwater inflow in the port (Figure 33). The pH of bottom water is more variable than that for surface water at some deeper water stations in the 600 and 700/800 Berth Basins, but the variation between surface and bottom waters is generally small. Areas in the port where the pH is often (if usually only slightly) lower than that for seawater are the Bhizolo-Manzanyama Canal complex (Station 1 in Figures 29 and 33) and occasionally the Mzingazi Canal (Stations Y4 and 9 in Figures 29 and 33). The pH of water over the Kabeljous Flats is influenced by flows from the Bhizolo-Manzanyama Canal complex (CSIR, unpublished data; see also Cyrus and Vivier, 2021a,b), but at the position where water quality was measured the pH depression relative to seawater was not pronounced. The lower pH in the canals is linked in part to the inflow of freshwater—which naturally has a lower pH than seawater—but in the Bhizolo-Manzanyama Canal complex there is strong evidence the low pH may also reflect an anthropogenic impact related to groundwater flow and surface runoff from a phosphogypsum stockpile in the canal catchment. Waste phosphogypsum from a phosphoric acid and fertilizer industry—known as Triomf at the time, but now as Foskor—was stockpiled at this site before a deepwater outfall was constructed for its discharge into the sea off the Richards Bay coast. The stockpile is currently being removed.

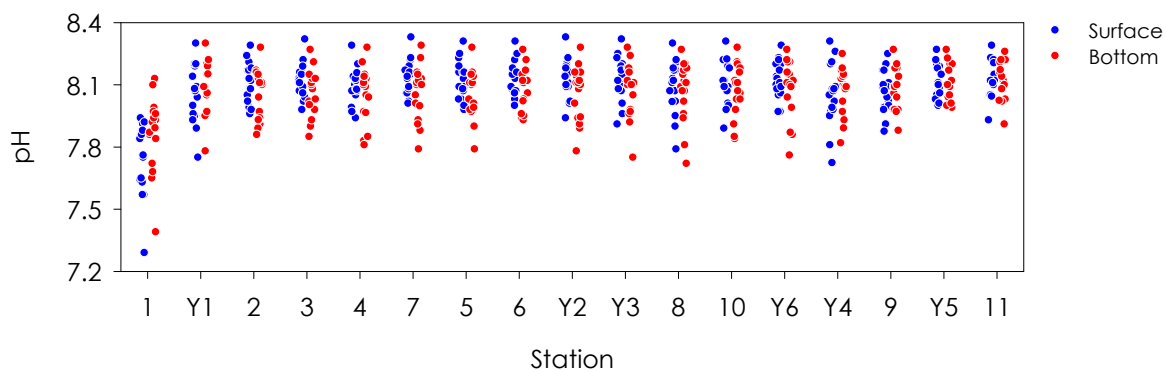


Figure 33. The pH of surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

The dissolved oxygen concentration is relevant to the Berth 605 Project since dredging invariably remobilises inorganic and organic oxygen depleting compounds from sediment into the water column. The water column in the Port of Richards Bay is generally well oxygenated (Figure 34). Although ‘low’ dissolved oxygen concentrations were periodically recorded near the bottom in the deeper water parts of some basins and channels, these conditions were rare (see also Cyrus and Vivier, 2021a,b). Even in late autumn and early winter, when winds are at their weakest and some stratification of the water column may occur, the dissolved oxygen concentration was rarely $<5 \text{ mg.L}^{-1}$ (CSIR, unpublished data)—this is a concentration that is widely regarded as protective of most aerobic biological resources in estuarine and marine systems. Izegaegbe *et al.* (2020) reported a dissolved oxygen concentration of 0.5 mg.L^{-1} at a station in the innermost part of the 600 Berth Basin, but they did not state if this was in bottom water. This appears to be the lowest dissolved oxygen concentration recorded in the port based on available information and is highly anomalous in terms of available information—compare to lowest concentration in Figure 34).

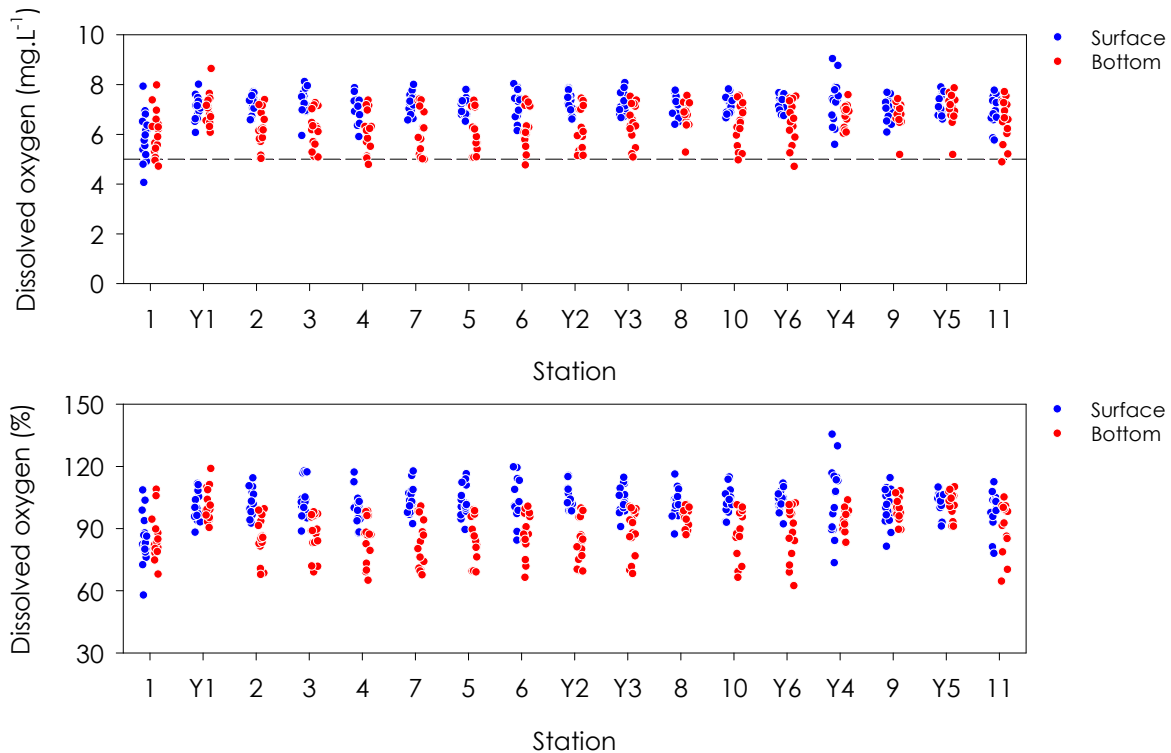


Figure 34. The dissolved oxygen concentration and saturation of surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024. The horizontal dashed line in the top graph represents a dissolved oxygen concentration of 5 mg.L^{-1} .

Turbidity is a measure of the cloudiness or haziness of water and is usually related to the mass of fine-grained particles (sediment, plankton) suspended in the water column. Turbidity is measured in Nephelometric Turbidity Units (NTU), which is a measure of the amount of light that is scattered by particles suspended in the water column rather than being transmitted in a straight line. Turbidity is caused by the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids and dyes. Suspended sediment is a measure of the dry-weight mass of non-dissolved solids/particles per unit of water. In general, higher suspended particles concentrations result in more turbid water. Turbidity is far more easily measured than suspended sediment and is often used as a proxy for the mass of particles in the water column by establishing a site-specific relationship between the turbidity and the mass of suspended particles in the water column.

Suspended sediment and related turbidity are relevant to the Berth 605 Project since the resuspension of sediment into the water column is an unavoidable and ecologically important consequence of dredging. The turbidity in the Port of Richards Bay is typically low (<10 NTU), particularly in deeper water channels and basins, but is often higher in shallower parts of the port such as on the Kabeljous Flats, in the Bhizolo-Manzanyama Canal complex, and in Mzingazi Canal (Figure 35) (see also Cyrus and Vivier, 2021a,b). Wind driven waves and currents combined with a relatively muddy substrate and shallow water column are an important driver of the higher suspended sediment concentrations and related turbidity of the water column on the Kabeljous Flats. Freshwater inflows also account for elevated suspended sediment concentrations and related turbidity in the Bhizolo-Manzanyama Canal complex and in Mzingazi Canal, but these flows have little effect on the larger port waterbody. However, even in the Bhizolo-Manzanyama Canal complex and in Mzingazi Canal the turbidity is usually not especially high.

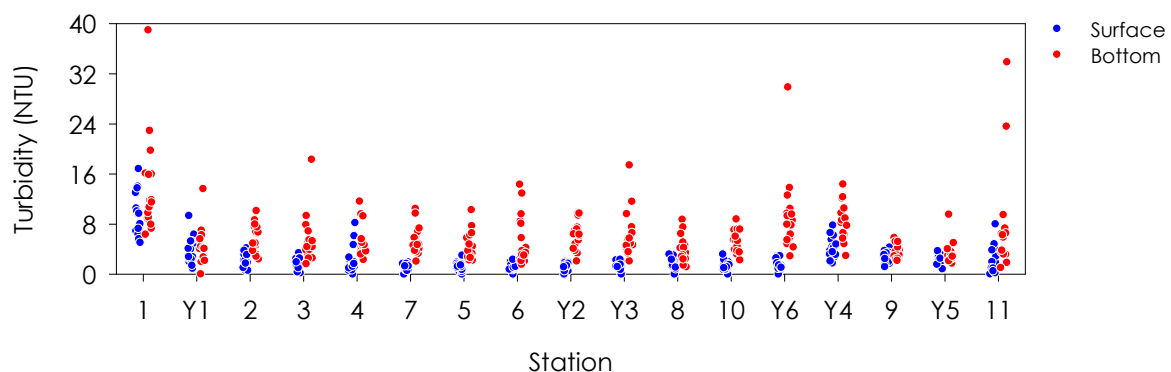


Figure 35. The turbidity measured in surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

Since deeper water channels and basins constitute the largest water expanse in the Port of Richards Bay and the turbidity of the water column in these parts is generally low, the port can be regarded as a low turbidity, although not necessarily clear water system. The suspended sediment concentration and related turbidity in the water column increases sharply when large vessels are manoeuvred by tugs due to vessel propeller wash disturbance of bottom sediment (Figure 36). As an example, scientists from the CSIR (unpublished data) measured a near-bottom turbidities of 86.5 and 77.8 NTU at positions near vessel berthing operations in the Richards Bay Coal Terminal Basin. Maintenance dredging also contributes to an increase in the suspended sediment concentration and related turbidity in the water column in the port (Figure 37). However, the increase in the suspended solids concentration and related turbidity associated with vessel propeller wash and maintenance dredging operations is usually short-lived, returning to the baseline within tens of minutes (CSIR, unpublished data; S Weerts (CSIR), B Newman (CSIR), personal observation).



Figure 36. Aerial views of the Port of Richards Bay showing the influence of vessel propeller wash on the turbidity of the water column.

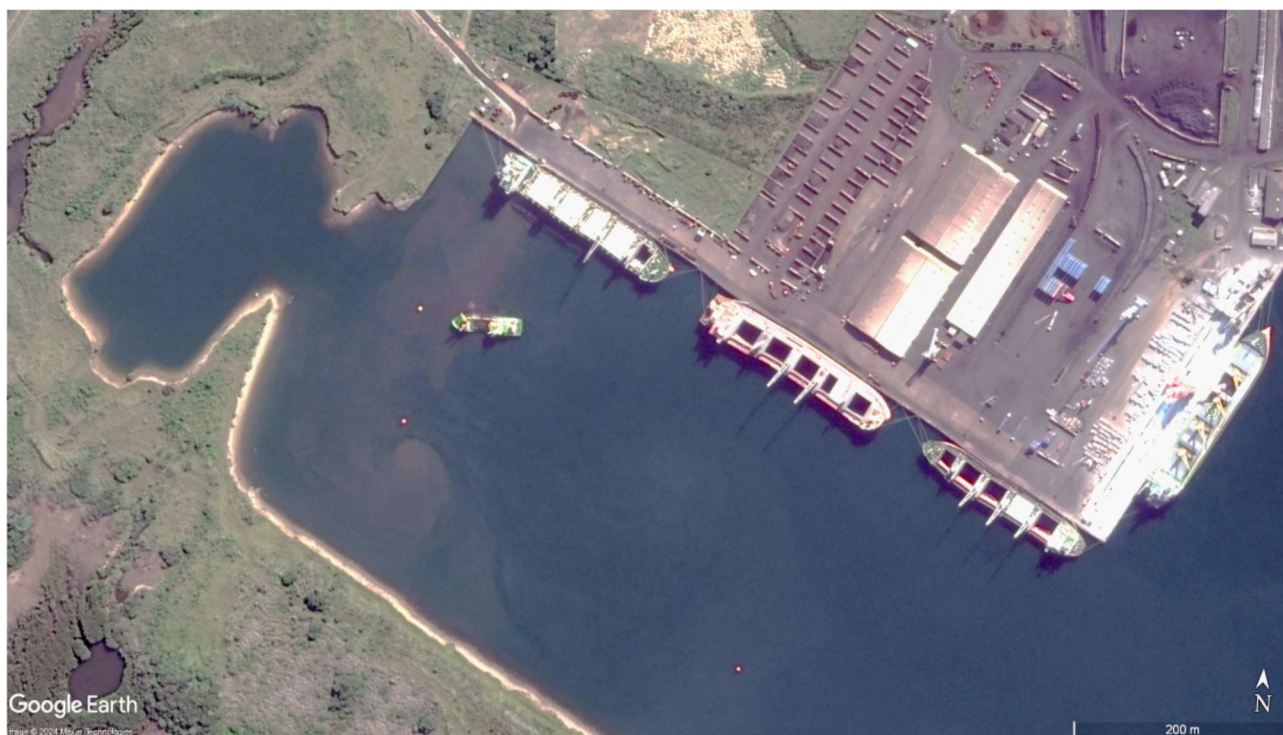


Figure 37. Aerial view of the 600 Berth Basin in the Port of Richards Bay showing the influence of maintenance dredging on the turbidity of the water column.

The last capital dredging programme that took place in the Port of Richards Bay was for the development of Berth 306 at the Richards Bay Coal Terminal, in the latter part of 2005. Dredging had on obvious and anticipated impact on the water column turbidity, which increased from an average of 8.3 NTU across 18 stations in the Richards Bay Coal Terminal Basin before dredging to 42.0 NTU during dredging. The highest turbidity was measured near the dredging operation—near Shark Cove—and decreased markedly with distance from the operation. However, even at a station situated ~3.6 km from dredging operation in the Bhizolo-Manzanyama Canal complex the turbidity during dredging was on average 60% higher than pre- and post-dredging measurements. Although this was influenced by the very high turbidity measured in one month, even discounting these data the turbidity was on average higher during dredging. Turbidities >100 NTU in the water column near the dredging operation were not uncommon and were on occasion >300 NTU (the highest measured turbidity was 381.7 NTU; Figures 38 and 39). However, within a week of the last dredging operation the turbidity had returned to the baseline established before dredging.

Faecal indicator bacteria are measured in water quality monitoring programmes to reveal the presence of sewage and wastewater because these bacteria are abundant in the digestive tracts and faeces of humans, and hence also in sewage and wastewater. Faecal indicator bacteria are also found in the digestive tracts and faeces of birds and mammals, but high concentrations of these bacteria in urban aquatic ecosystems (including ports) usually points to the influx of sewage and wastewater. In surveys made in the Port of Richards Bay between 2015 and 2024 by the CSIR, *E. coli* and faecal streptococci bacteria counts were almost always low and, apart from a few instances for *E. coli*, were below South African recreational water use guidelines (Figure 40). The low faecal indicator bacteria counts infer there are no significant or consistent inputs of sewage and wastewater into the port. The area that is most affected by sewage inputs is Mzingazi Canal, where the failure of infrastructure at a sewage macerator on the canals bank leads to the flow of sewage into the canal. There is no publicly available monitoring data for such events, but they are evidently infrequent.

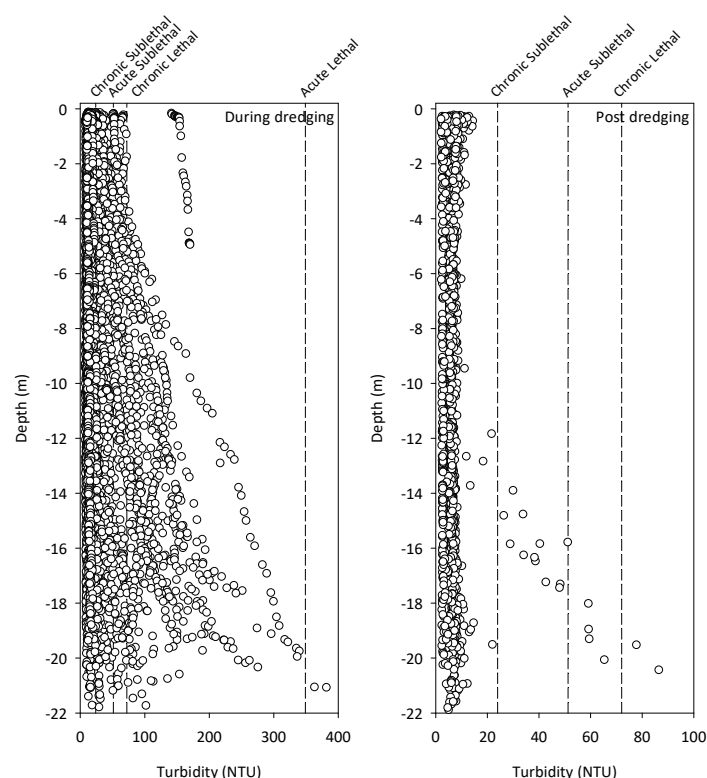


Figure 38. Turbidity profiles measured during (left) and after (right) dredging for the Richards Bay Coal Terminal expansion programme. Superimposed on the plots are turbidities that correspond to the suspended particulate matter 10th percentile effects levels derived by Anchor QEA (2003), as inferred using a predictive model derived by the CSIR.

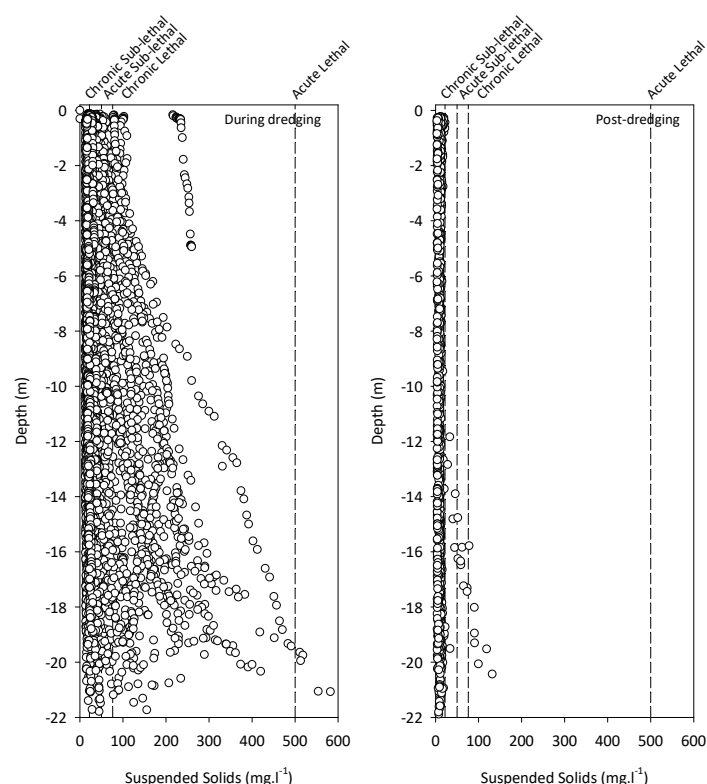


Figure 39. Suspended solids concentration profiles for the water column in the Richards Bay Coal Terminal calculated from turbidity profiles made during and after dredging for the Richards Bay Coal Terminal expansion programme, using a predictive model derived by the CSIR. The 10th percentile of suspended solids concentration endpoints defined by Anchor QEA (2003) are indicated.

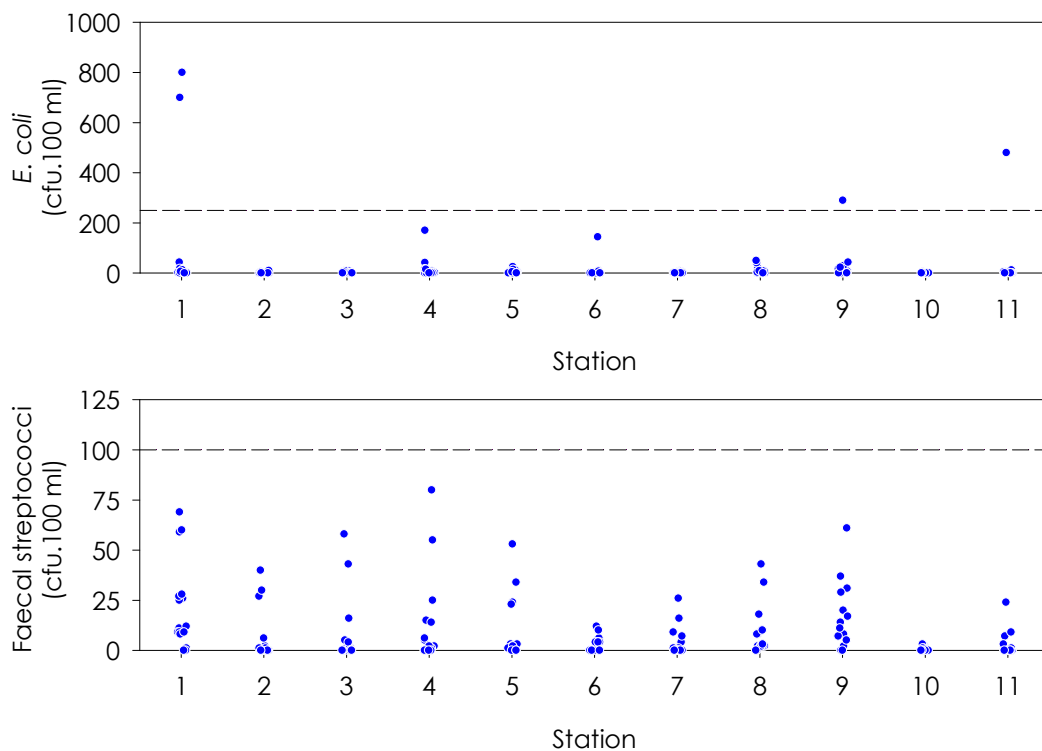


Figure 40. Faecal indicator bacteria colony forming unit counts measured in surface water in the Port of Richards Bay in 15 surveys between 2015 and 2024. The horizontal dashed lines represent the South African Water Quality Guidelines for Coastal Marine Waters: Recreational Use target for excellent bathing water quality.

Nutrients, such as ammonia, nitrate, orthophosphate and silica, are essential for the growth of aquatic plants. However, persistently high nutrient concentrations can stimulate the excessive growth of aquatic plants through a process known as eutrophication. Persistent and pronounced eutrophication may lead to a host of detrimental ecological effects—these include a reduction in the dissolved oxygen concentration in the water column and the development of anoxic conditions in sediment. These effects can stress biological resources and, in extreme cases, can cause their death. Fish kills linked to eutrophication are a common occurrence in many KwaZulu-Natal estuaries and are often linked to excessive nutrient contributions into the catchment from wastewater treatment works fuelling the eutrophication. In surveys made in the Port of Richards Bay between 2015 and 2024 by the CSIR, nitrogenous nutrient concentrations in surface water in the port were usually low and showed no trends that allude to a significant nor persistent anthropogenic source of the nutrients to the port (Figure 41). The orthophosphate concentration was, however, often elevated in parts of the port—and occasionally across most of the port. The highest orthophosphate concentrations were often recorded at Station 1 in the Bhizolo-Manzanyama Canal complex. A possible source of the orthophosphate might be groundwater and surface runoff from the waste phosphogypsum stockpile in the Bhizolo Canal catchment mentioned earlier.

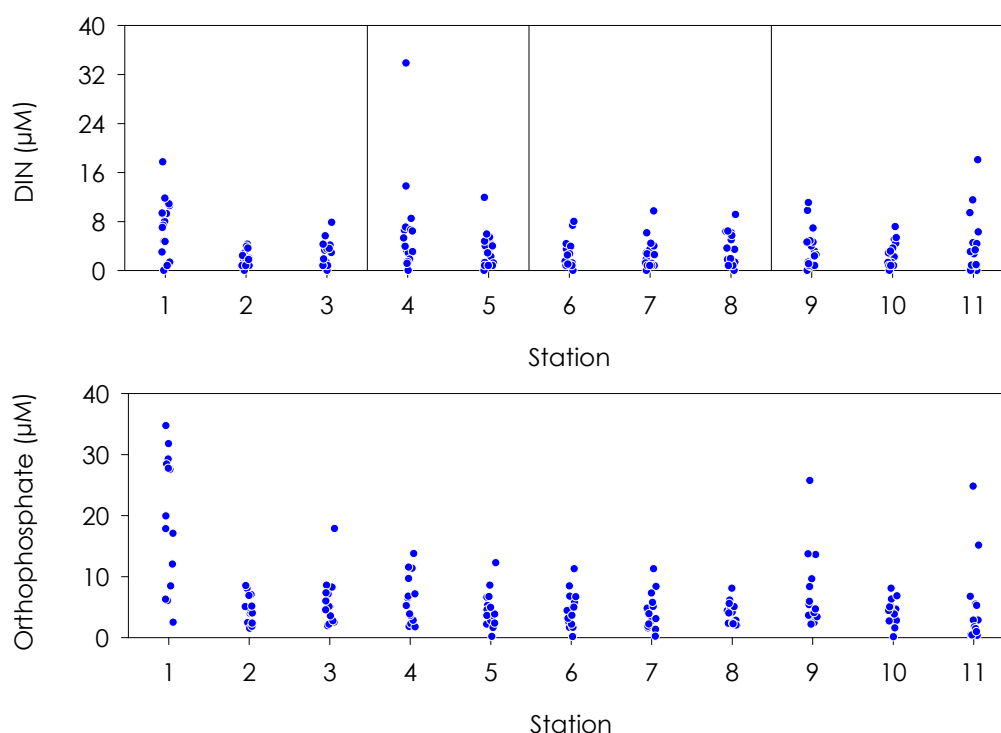


Figure 41. The dissolved inorganic nitrogen and orthophosphate concentration measured in surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

Metals are found naturally in aquatic ecosystems. Some, such as copper and zinc, are essential for the normal physiological functioning of biological tissue, but only in trace amounts. At elevated concentrations they become toxic to biological resources. Other (non-essential) metals, such as lead and mercury, have no known physiological function and may be toxic to biological resources at low concentrations.

Wepener (1997) and Mills (2005) recorded high (total) concentrations of several metals in the Port of Richards Bay water column. As examples, Wepener (1997) reported concentrations of $66 \mu\text{g.L}^{-1}$, $49 \mu\text{g.L}^{-1}$ and $94 \mu\text{g.L}^{-1}$ for copper, chromium and zinc, respectively, while Mills (2005) reported concentrations of $22.6 \mu\text{g.L}^{-1}$, $15 \mu\text{g.L}^{-1}$, and $738 \mu\text{g.L}^{-1}$ for the same metals, respectively. These concentrations are well above the $0.6 \mu\text{g.L}^{-1}$ and $1.8 \mu\text{g.L}^{-1}$ reported for copper and zinc (chromium was not analysed) for samples collected in the port by Hennig (1985) in the early stages of the ports operation. In surveys made in the Port of Richards Bay between 2015 and 2023 by the CSIR, the (dissolved) concentrations of most of the targeted metals in the port water column were low. The concentrations of numerous of the metals were in fact usually below the method detection limit across the port (Figure 42). The concentrations of some metals (e.g. zinc) were occasionally elevated across a large part of the port, but more often at a Station 1 in the Bhizolo-Manzanyama Canal complex and at Station 4 in the 700/800 Berth Basin. The high concentrations of some metals at Station 1 in the Bhizolo-Manzanyama Canal complex suggests there is an anthropogenic source of these metals into the canal, but might also reflect the naturally higher concentrations of some metals in freshwater compared to seawater. Indeed, a natural freshwater related source probably accounts for the often considerably higher manganese concentrations at Station 1 than elsewhere in the port. The source of the metals at Station 4 is probably a stormwater (surface runoff) discharge point very near the station. Cyrus and Vivier (2021a,b) recorded occasionally high, but variable zinc concentrations in 26 water samples collected near or (usually) over the Kabeljous Flats in 2020. The concentrations of most other metals targeted by Cyrus and Vivier (2021a,b) were below the method detection limit in the water at each station. Metals are thus clearly not significant contaminants of the water column in the port based on the findings of recent studies.

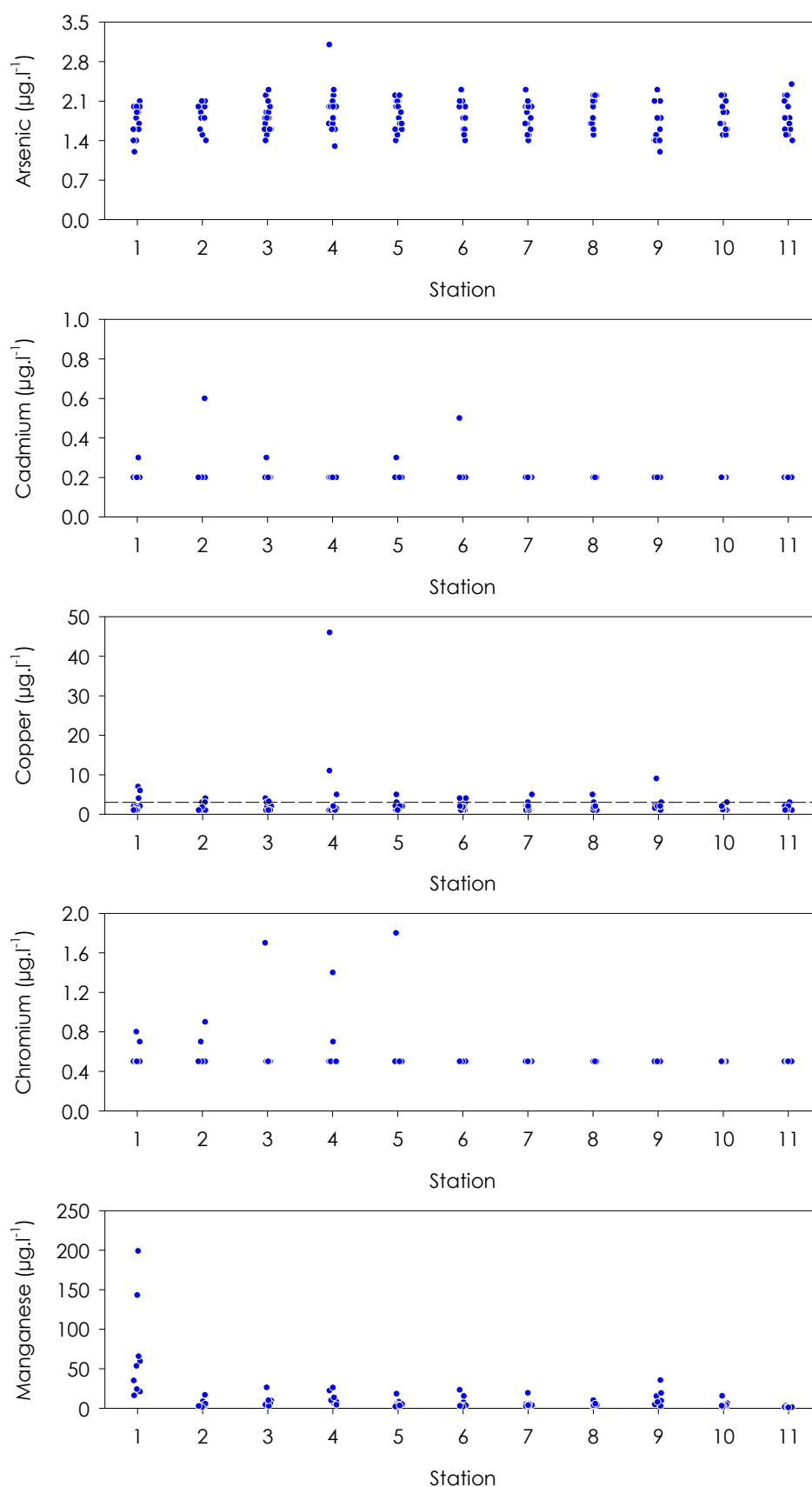


Figure 42. Metal concentrations measured in surface water in surface and bottom water in the Port of Richards Bay in 14 surveys between 2015 and 2024. Metal concentrations reported as below the method detection limit were replaced with a surrogate concentration equal to the detection limit for display purposes.

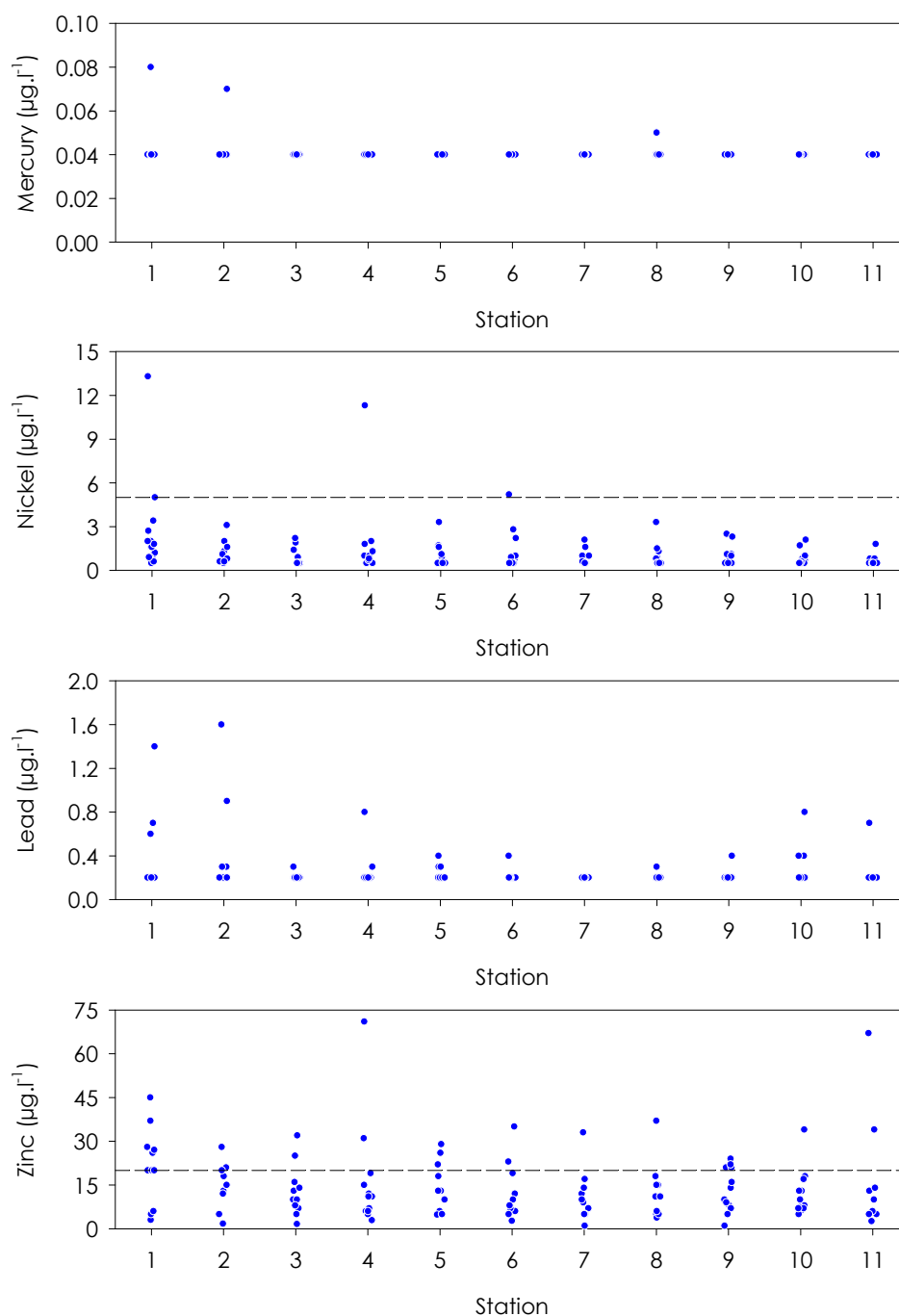


Figure 42 continued. Metal concentrations measured in surface water in surface and bottom water in the Port of Richards Bay in 14 surveys between 2015 and 2024. Metal concentrations reported as below the method detection limit were replaced with a surrogate concentration equal to the detection limit for graphing purposes.

In surveys made in the Port of Richards Bay between 2022 and 2024 by the CSIR, the total recoverable hydrocarbon, benzene, toluene, ethylbenzene, xylene (BTEX), and total polycyclic aromatic hydrocarbon concentration in surface water samples were always below the method detection limit. Cyrus and Vivier (2021a,b) also reported polycyclic aromatic hydrocarbon concentrations below the method detection limit in 11 water samples collected near or (usually) over the Kabeljous Flats in 2020. Hydrocarbons are thus clearly not significant contaminants of the water column in the port, although hydrocarbon spills and leaks from small boats are probably a common occurrence at small boat launching and mooring areas. The last major oil spill in the port was from an apparently disused pipeline at the Chemical Berth in 2014, when an estimated 1000 L of oil spilled into the port. There appear to be no long-lasting effects of the spill (see also hydrocarbons in sediment below).

The CSIR used an index to rate surface water quality in the Port of Richards Bay into five categories ranging from excellent to poor. The index considers the values and concentrations for most of the water quality indicators measured in water quality surveys relative to water quality targets. In 2024, water quality in the summer and winter surveys was rated good apart from a station in the 700/800 Berth Basin in the summer survey, where it was rated fair, and at Station 1 in the Bhizolo-Manzanyama Canal complex, where it was rated marginal (Figure 43). Water quality at Station 1 was regularly rated fair or marginal in earlier surveys, but at other stations it was usually rated good or excellent.

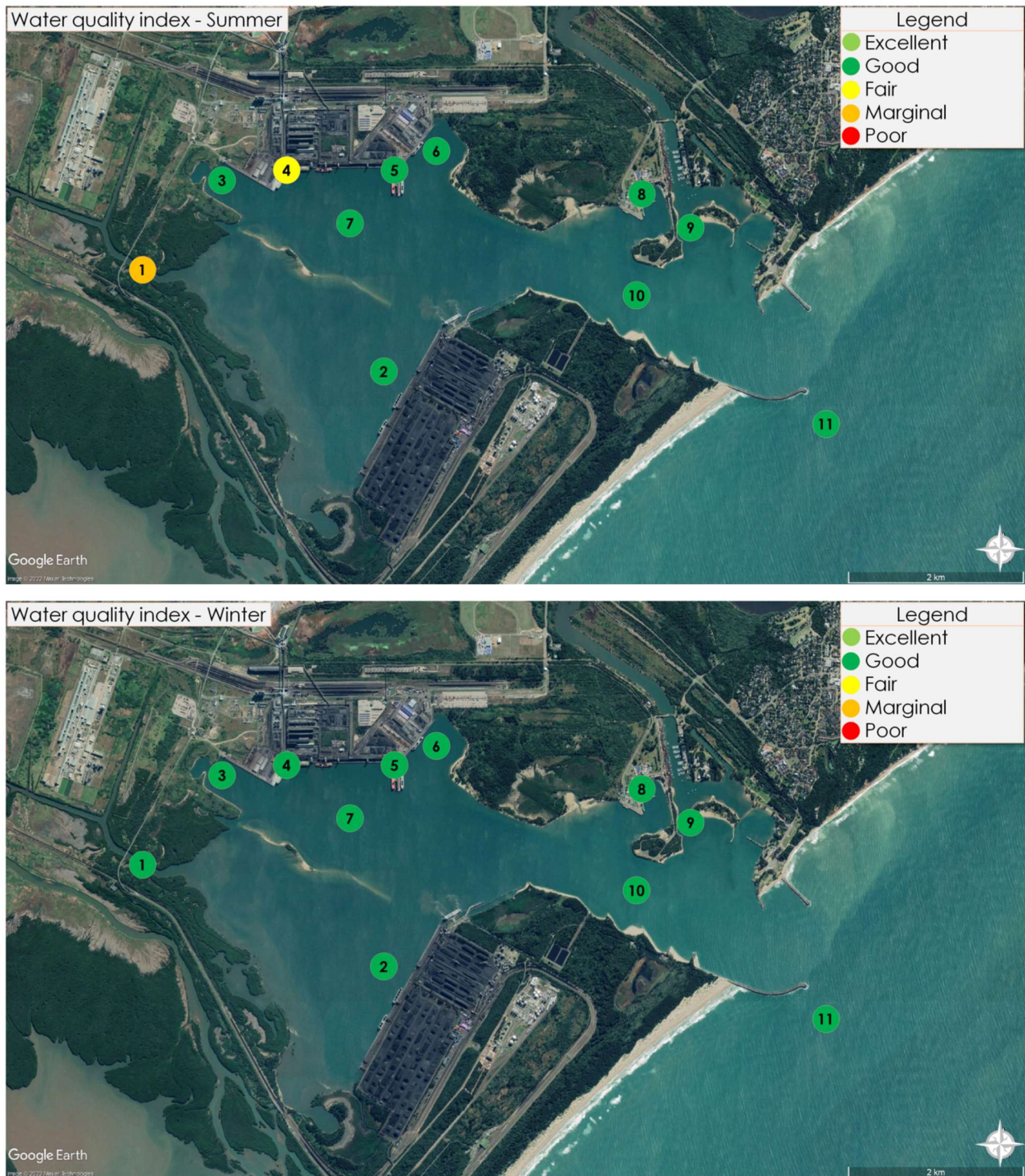


Figure 43. Water quality ratings for surface waters in the Port of Richards Bay in summer (top) and winter (bottom) in 2024.

The concentrations of chemicals in water are not necessarily a good predictor of toxic effects since the chemicals can be bound to suspended particulate matter to a degree that this limits their bioavailability. The chemicals may also interact in ways that enhance or diminish the toxic effects for each chemical on its own. Furthermore, there may be unmeasured chemicals in the water that could result in toxicity, but this will be unknown based only on the chemicals measured. A hazard assessment that is based on the comparison of chemical concentrations to water quality guidelines or similar targets thus provides at best only an estimate of the toxic hazard. Some form of biological assessment is required to understand the ecological hazard. The approach followed by the CSIR was thus to test the toxicity of water sampled at 23 stations in the Port of Richards Bay between 2022 and 2024 to sea urchin embryo-larvae. This test exposes sea urchin embryos to water samples under controlled temperature conditions in the laboratory for 3-4 days and then investigates if they were able to develop normally to a developmental stage that is known as a 4-arm pluteus. The water is identified as toxic if the number of 4-arm plutei found in water samples is less than the number found in a control (clean seawater) treatment. The water sampled in the port between 2022 and 2024 was never identified as toxic (results for 2024 in Figure 44). Cyrus and Vivier (2021a,b) collected seven surface water samples at stations over and near the Kabeljous Flats in 2020 and submitted these for toxicity testing to the CSIR. The samples were found to be not toxic when tested using the sea urchin fertilisation test. In this test, sea urchin eggs are exposed to water samples under controlled conditions in the laboratory for 10 minutes. Sperm is then added to the samples for a further 10 minutes. The number of eggs that fertilised is then counted. The water is identified as toxic if the number of fertilised eggs in the water samples is less than the number found in a control (clean seawater) treatment.

5.1.9 Sediment quality

Sediment is the particulate matter that accumulates on the bottom in rivers, estuaries and the sea. It provides essential habitat for many benthic and epibenthic biological resources. In other words, these biological resources are only able to live in or on sediment. Sediment is also a major sink for many contaminants introduced into aquatic ecosystems by man. If there is little sediment redistribution and continuous contaminant input, then the contaminants may accumulate in sediment to such high concentrations they become toxic to biological resources that live in or on sediment.

A significant amount of information on the geochemistry of sediment in the Port of Richards Bay has been generated through surveys commissioned by TNPA and through independent or collaborative surveys and research by various other organisations. The combined findings of the surveys are too voluminous to discuss in this specialist study. The baseline description of sediment environment in the Port of Richards Bay and Berth 605 Project footprint below is thus based largely on surveys made by the CSIR over an extended period, with additional findings from other surveys included where necessary.

The total organic content—which can also be measured as total organic carbon (there are various techniques to make these measurements)—is a measure of the amount of particulate organic matter in sediment. The particulate organic matter may come from natural sources, such as the decomposing remains of dead (mostly) plants and animals, or it may come from anthropogenic sources, such as wastewater. Particulate organic matter is a natural component of the sediment in healthy aquatic systems and is an important food source for many biological resources, such as worms and small crustaceans. However, if the mass-loading of particulate organic matter from anthropogenic sources is above the rate at which it can be consumed by benthic biological resources—as might occur when wastewater is discharged into a poorly flushed waterbody—this can lead to the development of very low dissolved oxygen concentrations (hypoxia), or in extreme cases the lack of oxygen (anoxia) in sediment porewater (water between the grains of sediment) and at the sediment-water interface. The dissolved oxygen depletion usually occurs when aerobic bacteria that decompose particulate organic matter proliferate to such a degree that they consume oxygen in sediment porewater and at the sediment-water interface at a rate faster than it can be replenished.

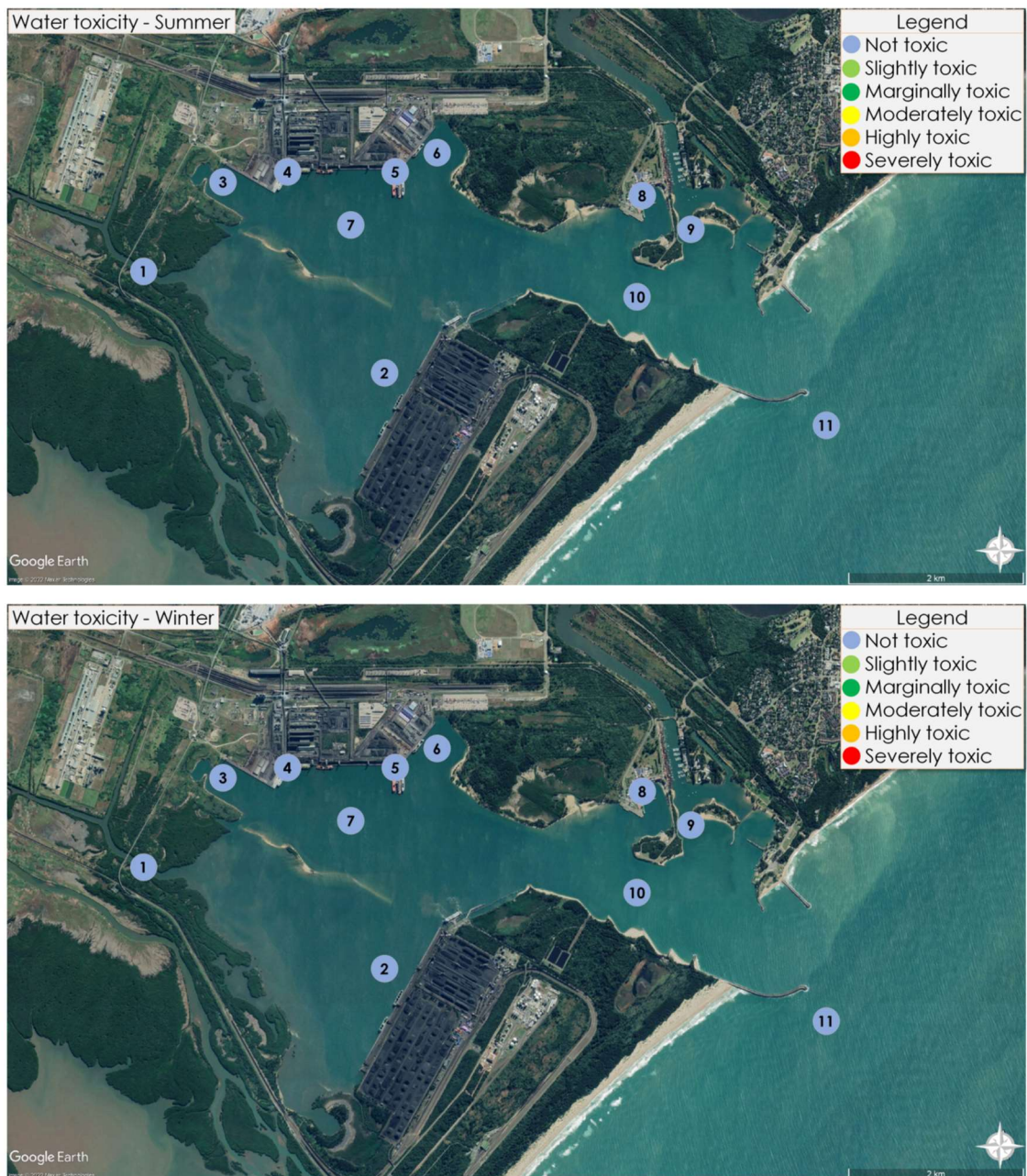


Figure 44. Results of the toxicity testing of surface waters in the Port of Richards Bay in summer (top) and winter (bottom) in 2024.

As the dissolved oxygen concentration falls, anaerobic sulphate-reducing bacteria begin to proliferate. These bacteria can tolerate low dissolved oxygen conditions because of their unique physiology. In low dissolved oxygen conditions, the bacteria reduce sulphate from the water column to fuel their respiration and produce hydrogen sulphide as a by-product. Hydrogen sulphide is toxic to many forms of aquatic life at low (micromolar) concentrations. As the loading of particulate organic matter increases and the dissolved oxygen concentration continues to fall, benthic invertebrates progressively die or are displaced. Knowledge on the quantity of particulate organic matter in sediment is important in the context of the Berth 605 Project since dredging may resuspend and expose particulate organic matter from sediment at quantities above the baseline. The dissolved oxygen consumption of aerobic bacteria that play an important role in decomposing the particulate organic matter can depress the dissolved oxygen concentration in the water column near a dredging operation, with potential adverse consequences for biological resources.

The most comprehensive surveys on the total organic content of sediment in the Port of Richards Bay were made in 2011 and 2012 by the CSIR (CSIR, unpublished data; CSIR, 2013) and in 2018 by Mehlhorn *et al.*

(unpublished data). The positions where the sediment was sampled in these surveys is provided in Figures 45 and 46. In the CSIR surveys, the number of times the measured total organic content was above or below a baseline established for the port was computed for each sediment sample. This is known as an Enrichment Factor. If the Enrichment Factor is >1 this means the total organic content is above the baseline. An Enrichment Factor = 2, for example, means the total organic content is twice as high as the baseline. The areas where the Enrichment Factor was >1 in the surveys made in 2011 and 2012 by the CSIR is provided in Figure 47. Where the sediment was enriched, the magnitude of the enrichment was usually low. There was low magnitude enrichment of sediment in part of the 600 Berth Basin in the 2012 survey, but not in the 2011 survey. The findings of recent, less spatially extensive surveys by the CSIR have also revealed the particulate organic matter enrichment of sediment in the port to be infrequent, but when so to usually be of a low magnitude. The total organic content measured by Mehlhorn *et al.* (unpublished data) showed minor enrichment of sediment at a station near the Finger Jetty in the 700/800 Berth Basin and at a station in the Small Craft Harbour. The sediment in the 600 Berth Basin was not enriched with particulate organic matter.

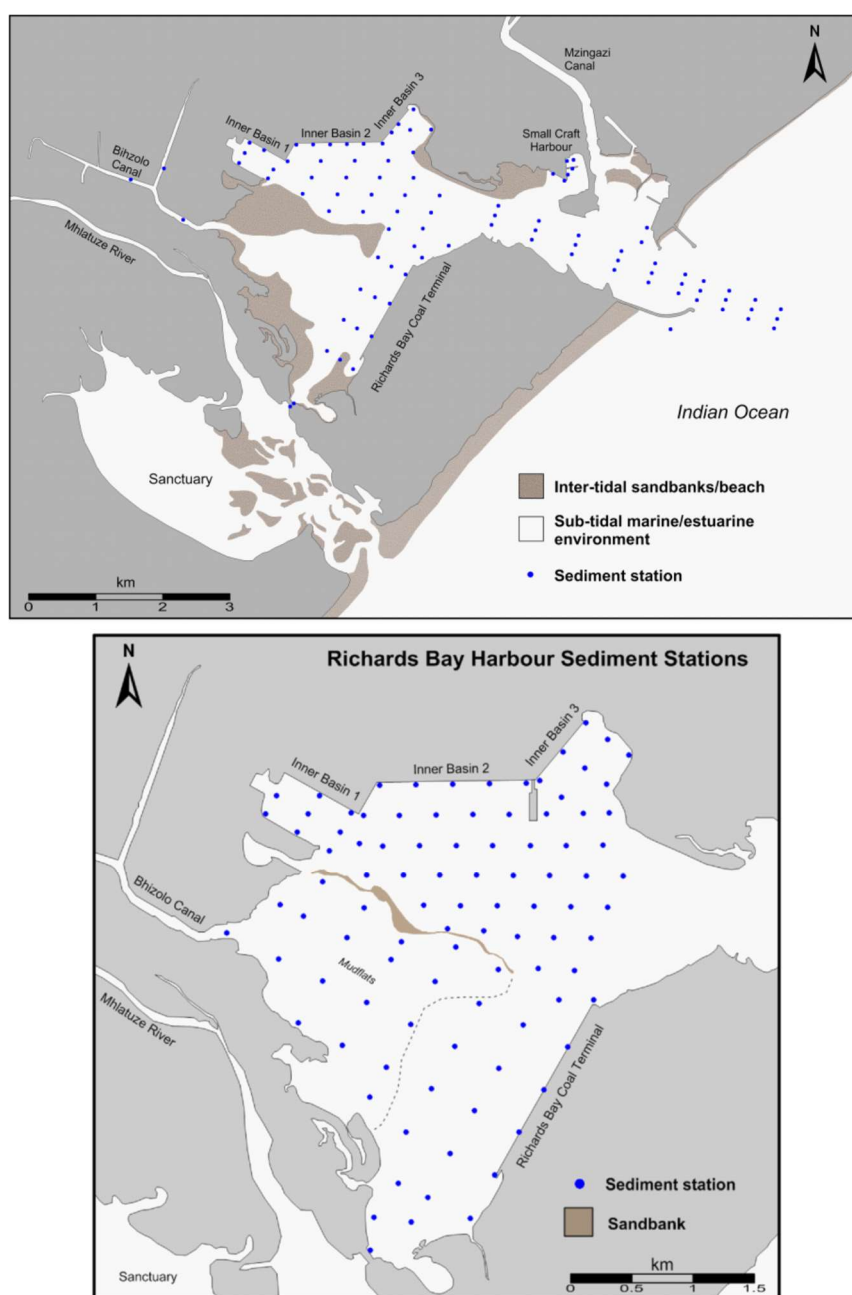


Figure 45. Positions where sediment was sampled in the Port of Richards Bay by the CSIR in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

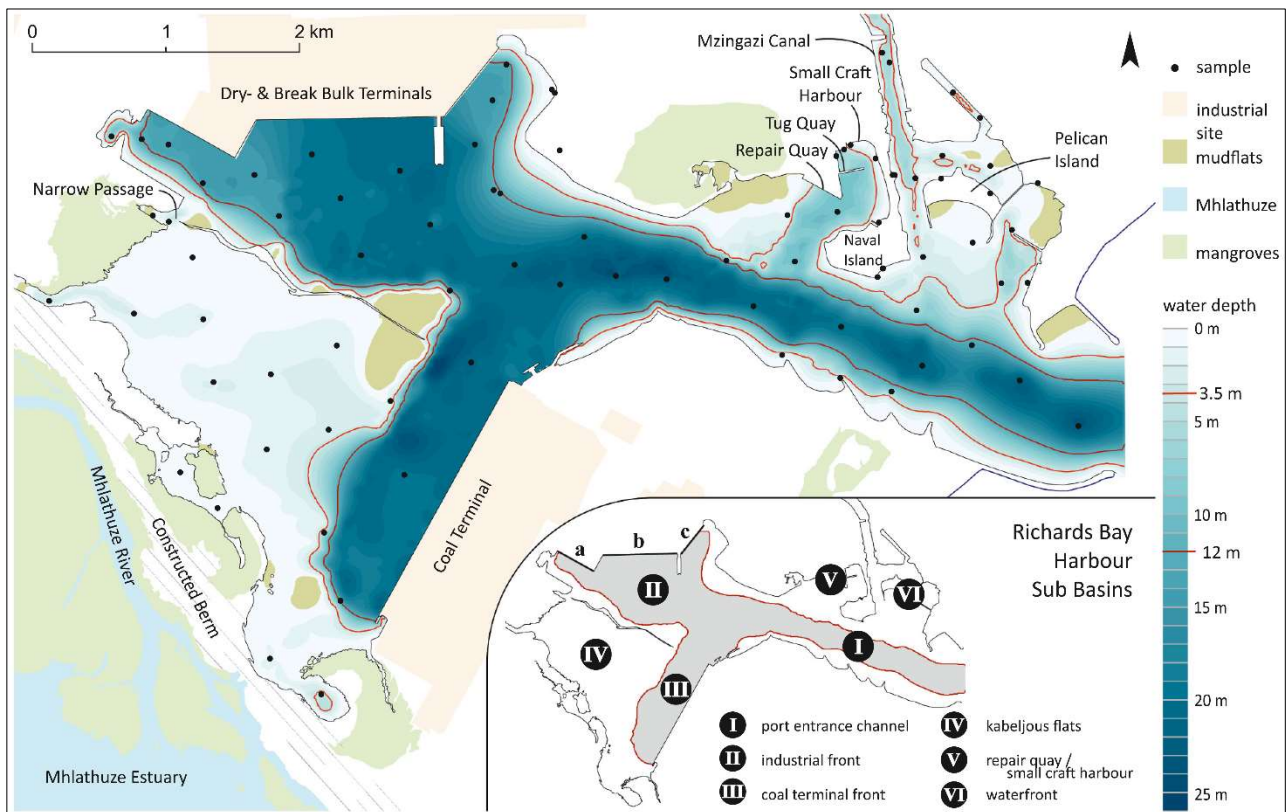


Figure 46. Positions where sediment was sampled in the Port of Richards Bay in 2018 by Melhorn *et al.* (2021).

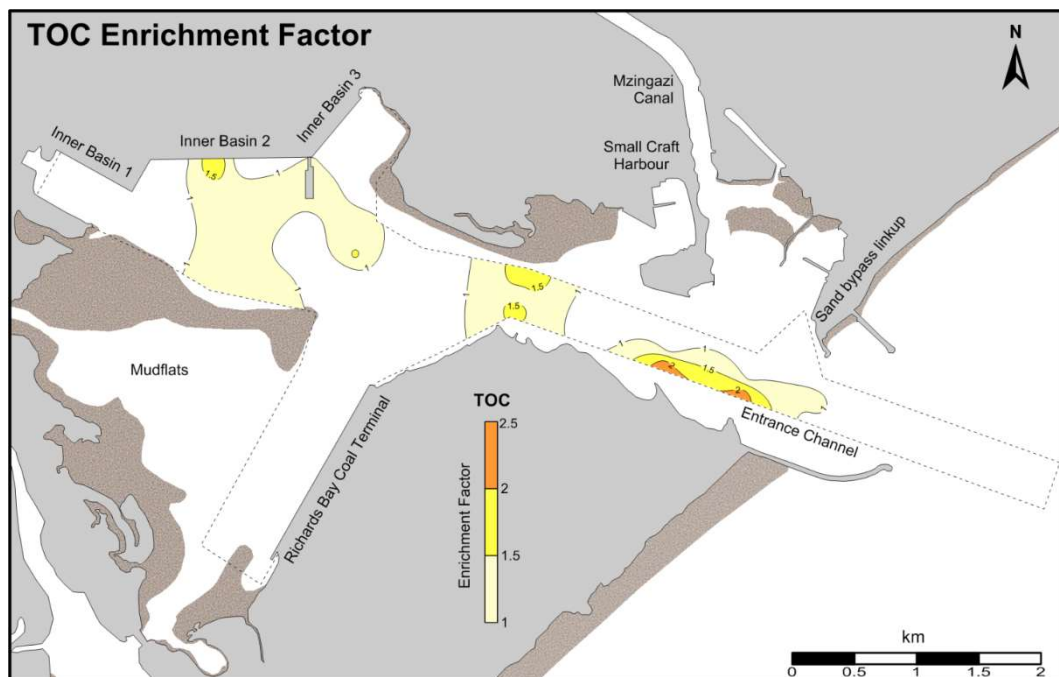


Figure 47. Spatial trend for particulate organic matter (total organic content, TOC) enrichment of sediment sampled in the Port of Richards in November 2011 (CSIR, unpublished data). Only Enrichment Factors >1 are shown, that is, areas where the total organic content is above the baseline.

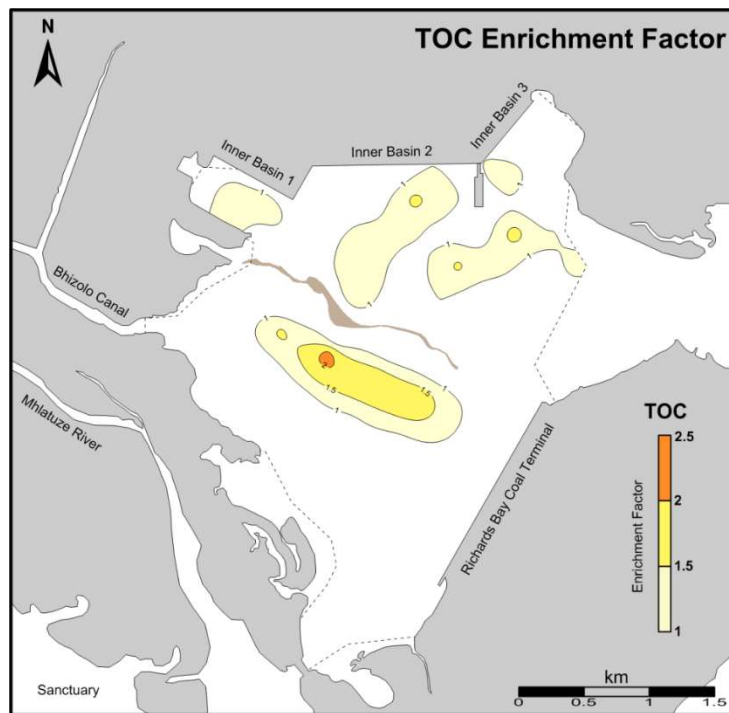


Figure 47 continued. Spatial trend for particulate organic matter (total organic content, TOC) enrichment of sediment sampled in the Port of Richards Bay in November 2012 (bottom) (CSIR, 2013). Only Enrichment Factors >1 are shown, that is, areas where the total organic content is above the baseline.

The most recent information on the total organic content of sediment in the 600 Berth Basin was generated in a survey by the CSIR in November 2024 for the purpose of a capital dredging permit application for the Berth 605 Project. Detailed information on the survey is provided in a companion specialist study prepared by the CSIR (CSIR, 2024). The positions where the sediment was sampled are provided in Figure 48. The sediment at none of the stations was enriched with particulate organic matter.

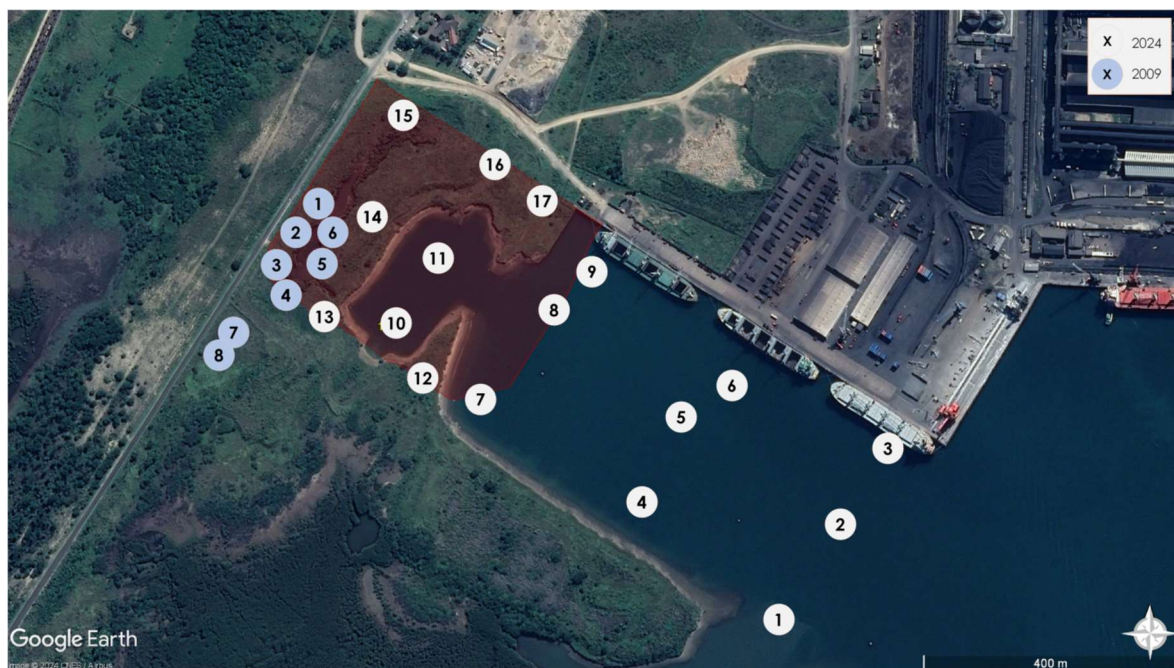


Figure 48. Aerial view of the Port of Richards Bay, showing the positions where sediment and soil was sampled in and near the 600 Berth Basin in November 2024 and where soil was sampled in 2009 (CSIR, unpublished data). The red shaded area denotes the proposed Berth 605 dredging and excavation footprint.

It is beyond the scope of this specialist study to discuss the findings of the numerous studies that have investigated metal concentrations in sediment in the Port of Richards Bay apart from stating that the impression gained from the study findings is that sediment in large parts of the 600 and 700/800 Berth Basins was consistently metal contaminated, and considerably more metal contaminated than sediment elsewhere in the port. In fact, sediment across most of the port was infrequently metal contaminated, but when it was the contamination was usually not nearly as significant as it was in the 600 and 700/800 Berth Basins. Spatially comprehensive surveys of metal concentrations in sediment in the port by the CSIR in 2011 and 2012 (CSIR, unpublished data) and by Mehlhorn *et al.* (2021) in 2018 emphasise these points. In these studies, baselines were established for metals in sediment in the port and these were used to calculate an Enrichment Factor for 14 metals in each sediment sample in the same way as that described above for the total organic content of the sediment. The areas where metal concentrations were above the baseline in the CSIR and Mehlhorn *et al.* (2021) studies are shown in Figures 49 and 50. Enrichment Factors >2 can be considered to indicate contamination. Copper and chromium were identified as the most widespread and significant metal contaminants of sediment in the port in each study. Several other metals were identified as contaminants of sediment across all, or most of the 600 Berth Basin. The studies also identified widespread and significant contamination of sediment in the 700/800 Berth Basin by copper and zinc, but usually less significant and widespread contamination by other metals. Some metals (*e.g.* iron, arsenic, manganese) in these studies were enriched in sediment on the Kabeljous Flats, but this was not attributed to contamination. A more likely explanation is that redox processes in the sediment on the Kabeljous Flats resulted in the natural enrichment of redox sensitive metals in the sediment. Iron and manganese, which are amongst the most redox sensitive metals, were enriched over the largest areas in the port on the Kabeljous Flats, but were rarely enriched in sediment elsewhere in the port. It is possible some of the metal enrichment of sediment elsewhere in the port might also reflect natural enrichment, but a more likely explanation is contamination.

Izegaegbe *et al.* (2023) measured metal concentrations in sediment sampled at seven stations in the Port of Richards Bay on a quarterly basis in 2016 and 2017. One station was in the innermost part of the 600 Berth Basin, alongside Berth 606. Izegaegbe *et al.* (2023) concluded that the sediment at this station was the most metal contaminated and that copper and chromium were the most significant metal contaminants in the sediment. Further evaluation of the average metal concentrations provided by Izegaegbe *et al.* (2023) supports their conclusion, but also suggests nickel and zinc were contaminants of sediment at the station. Izegaegbe *et al.* (2023) also identified concerns regarding metal concentrations in sediment at a station in the lower part of the Bhizolo-Manzanyama Canal complex, but the average metal concentrations provide no clear evidence the sediment was metal contaminated (at least not on average).

Malan and Clarke (2023) measured metal concentrations in sediment sampled at 26 stations across several areas of the Port of Richards Bay earmarked by the TNPA for port infrastructure development. Six of the stations were in the 600 Berth Basin, although sediment could only be sampled at five of the stations—the bottom was ‘gravelly’ at the other station. There was little evidence for metal contamination of sediment in most of the areas surveyed. Sediment at most stations in the 600 Berth Basin was enriched by copper and zinc, at one station by cadmium, and at several stations by nickel. Copper was also enriched in sediment in part of the 700/800 Berth Basin near the Casuarinas, but there was little evidence for metal contamination of sediment elsewhere. Chromium was not identified as a contaminant of sediment in the 600 Berth Basin, nor in the 700/800 Berth Basin, which is interesting considering other studies have consistently identified chromium as a common and often significant contaminant of sediment in these basins (as discussed above). In fact, records as far back as 1983 (CSIR, unpublished data) identified significant chromium contamination of sediment in the 700/800 Berth Basin (the 600 Berth Basin was not developed at that time). The chromium concentration measured in the sediment sampled at two stations in the 700/800 Berth Basin in 1983 was 514 $\mu\text{g.g}^{-1}$ and 8340 $\mu\text{g.g}^{-1}$. The sediment at these stations was also significantly contaminated by copper, chromium, manganese, nickel, lead and zinc.

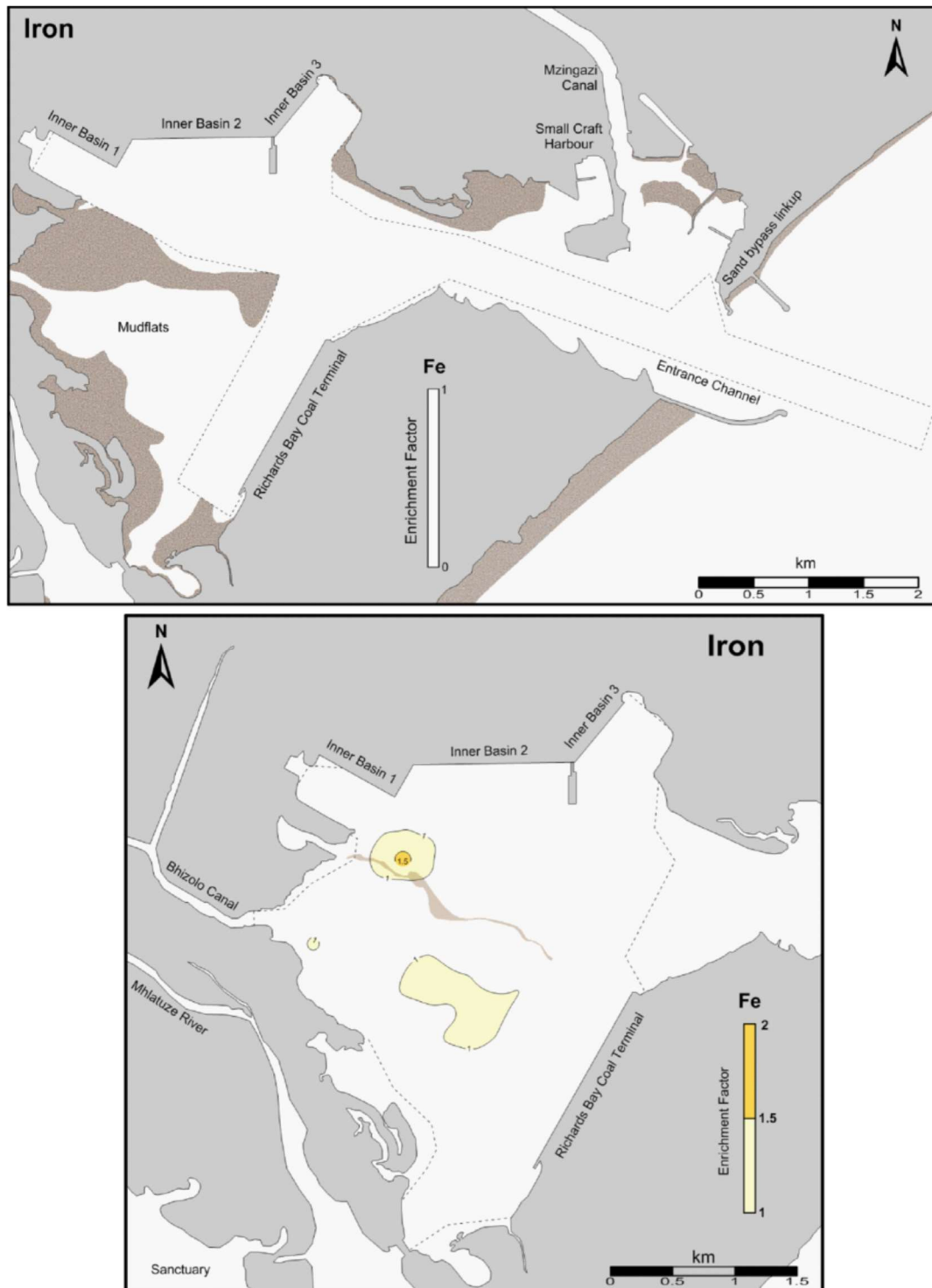


Figure 49. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

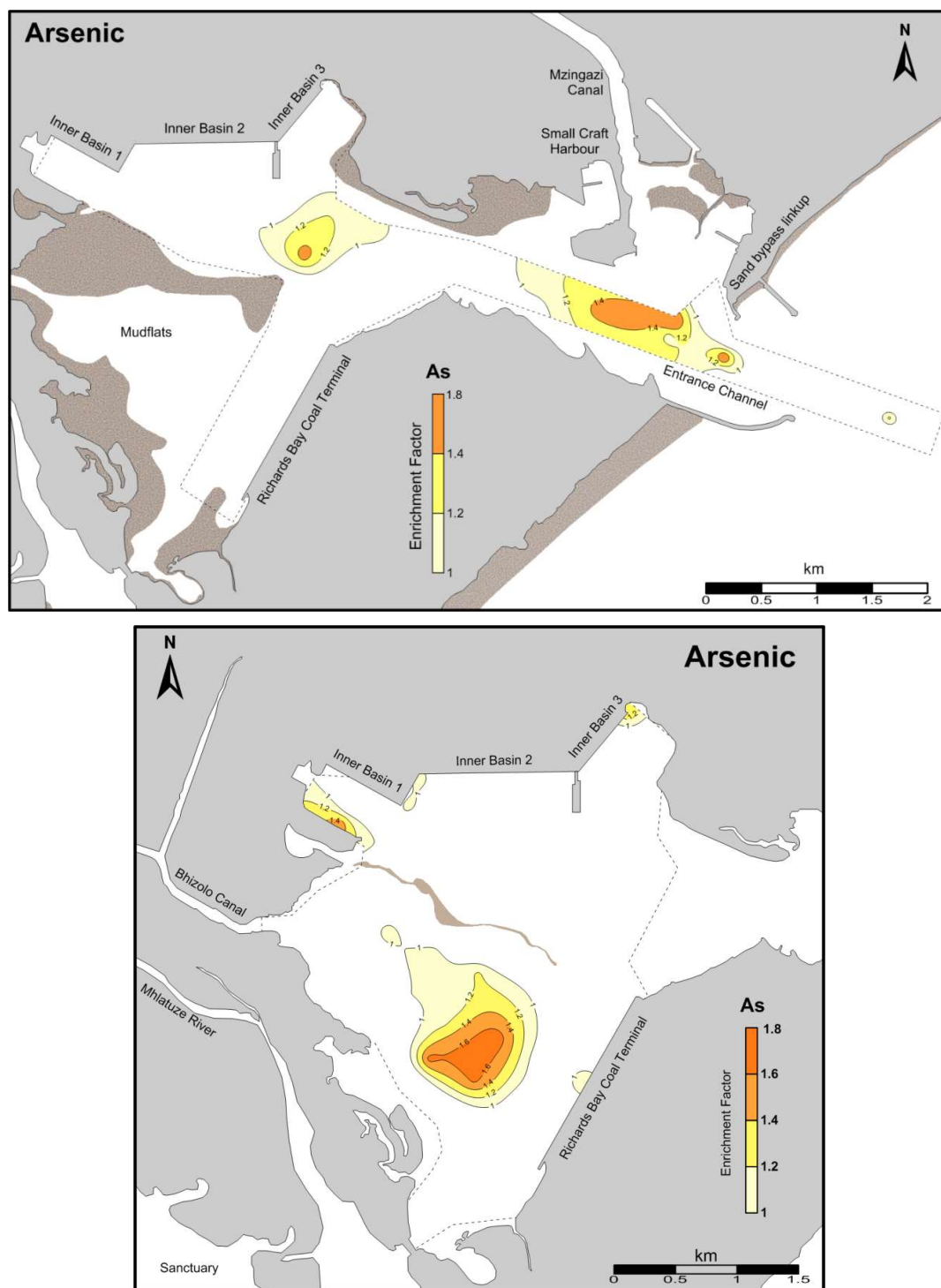


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

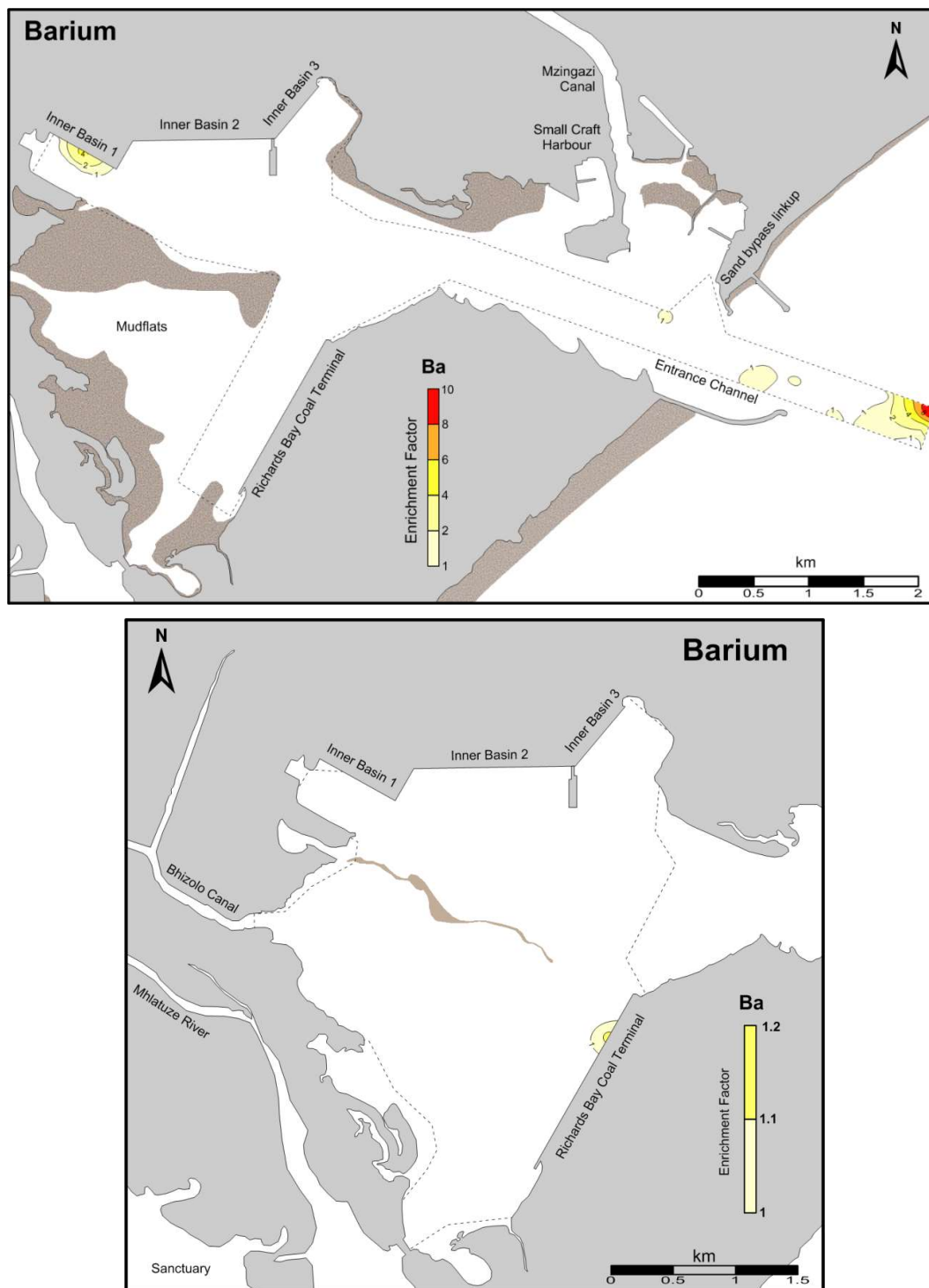


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

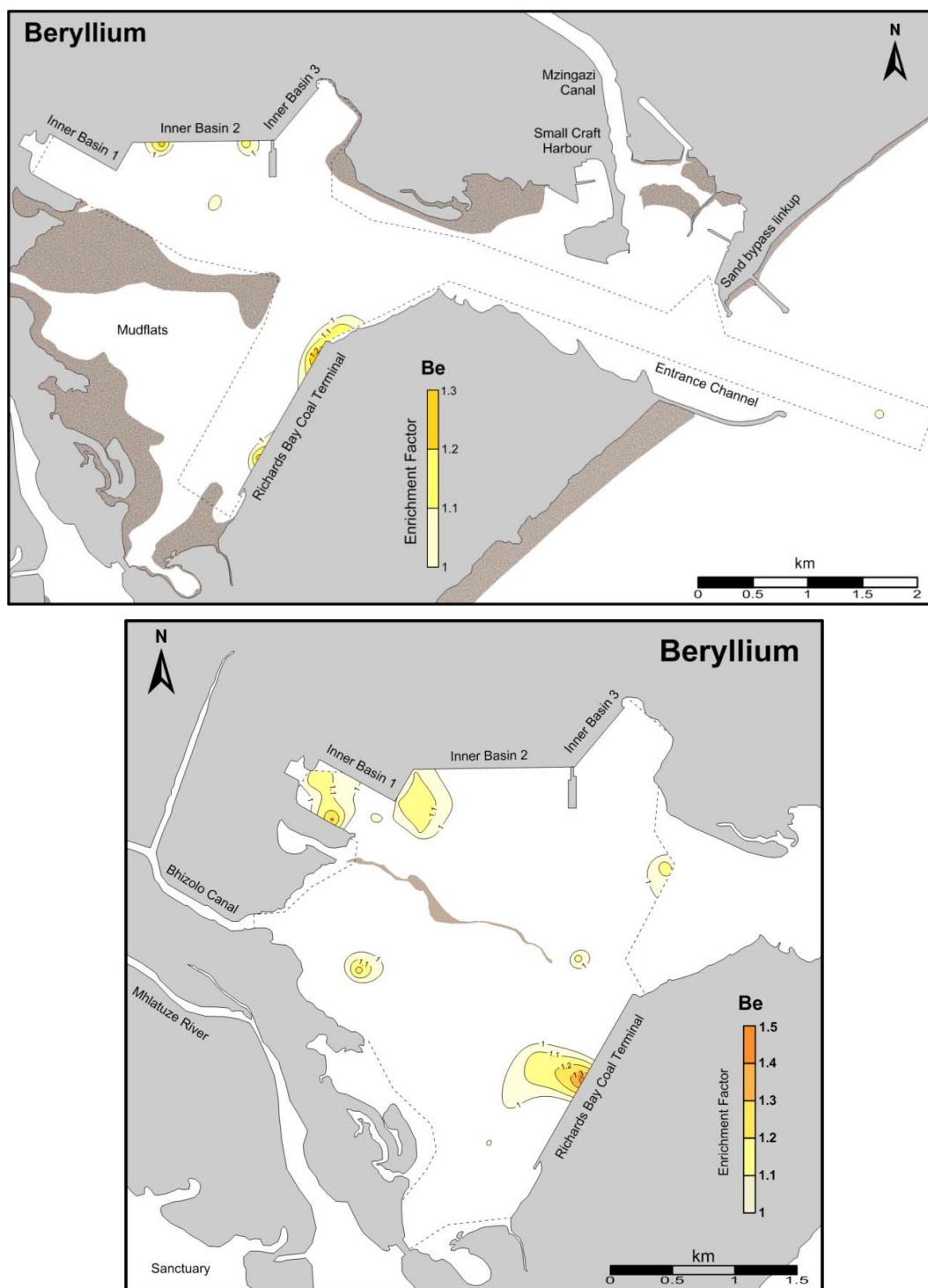


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

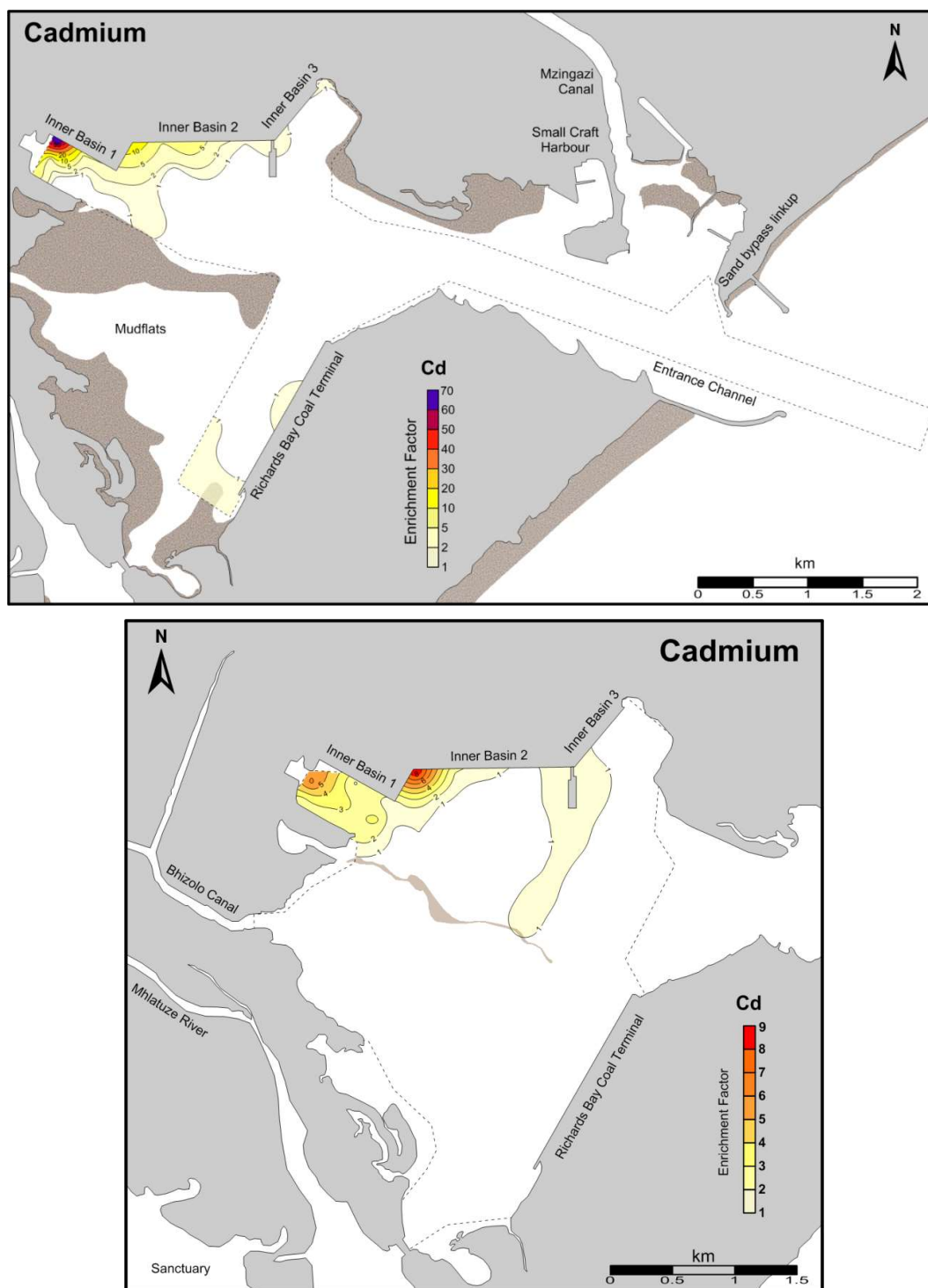


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

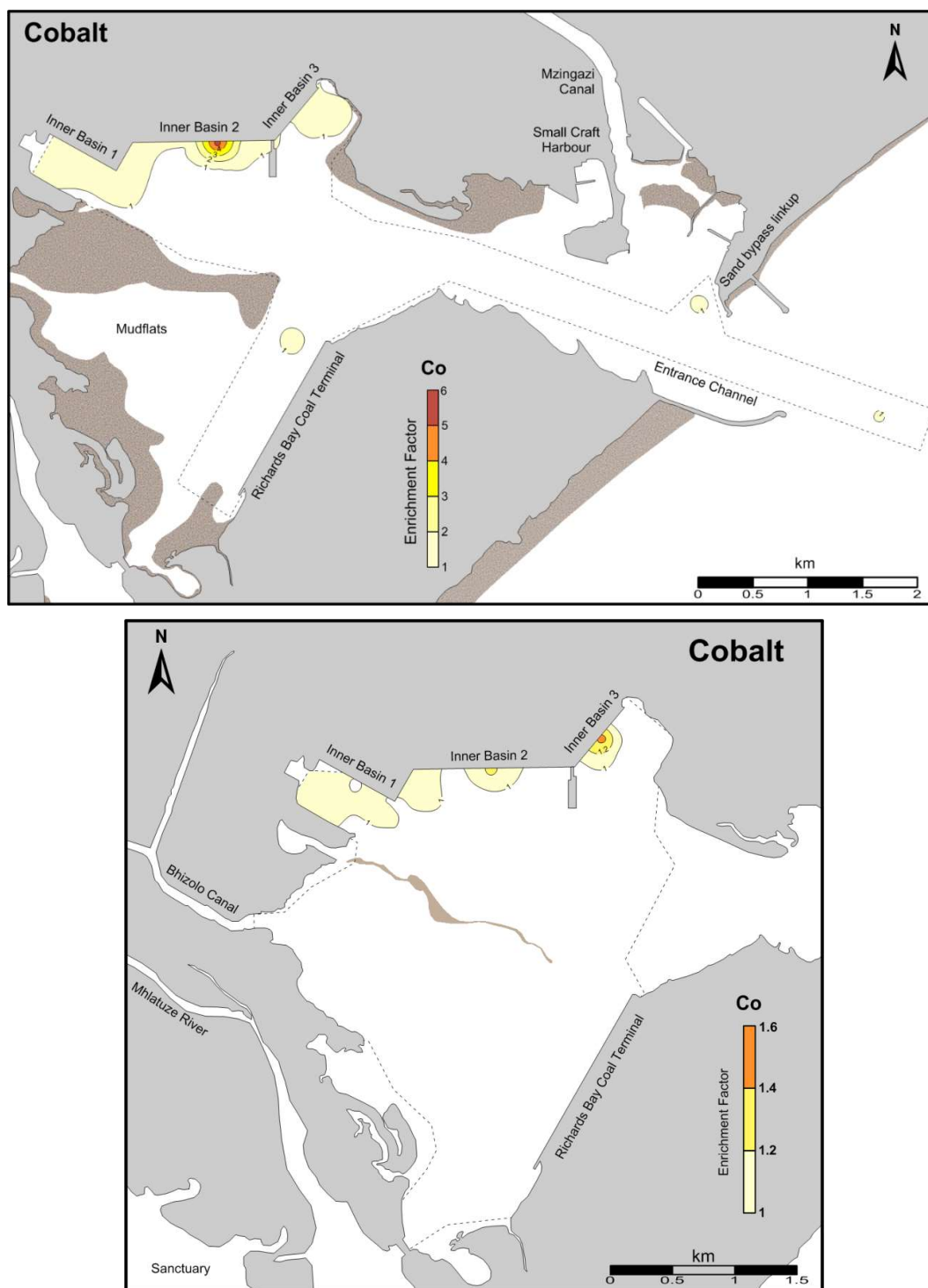


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

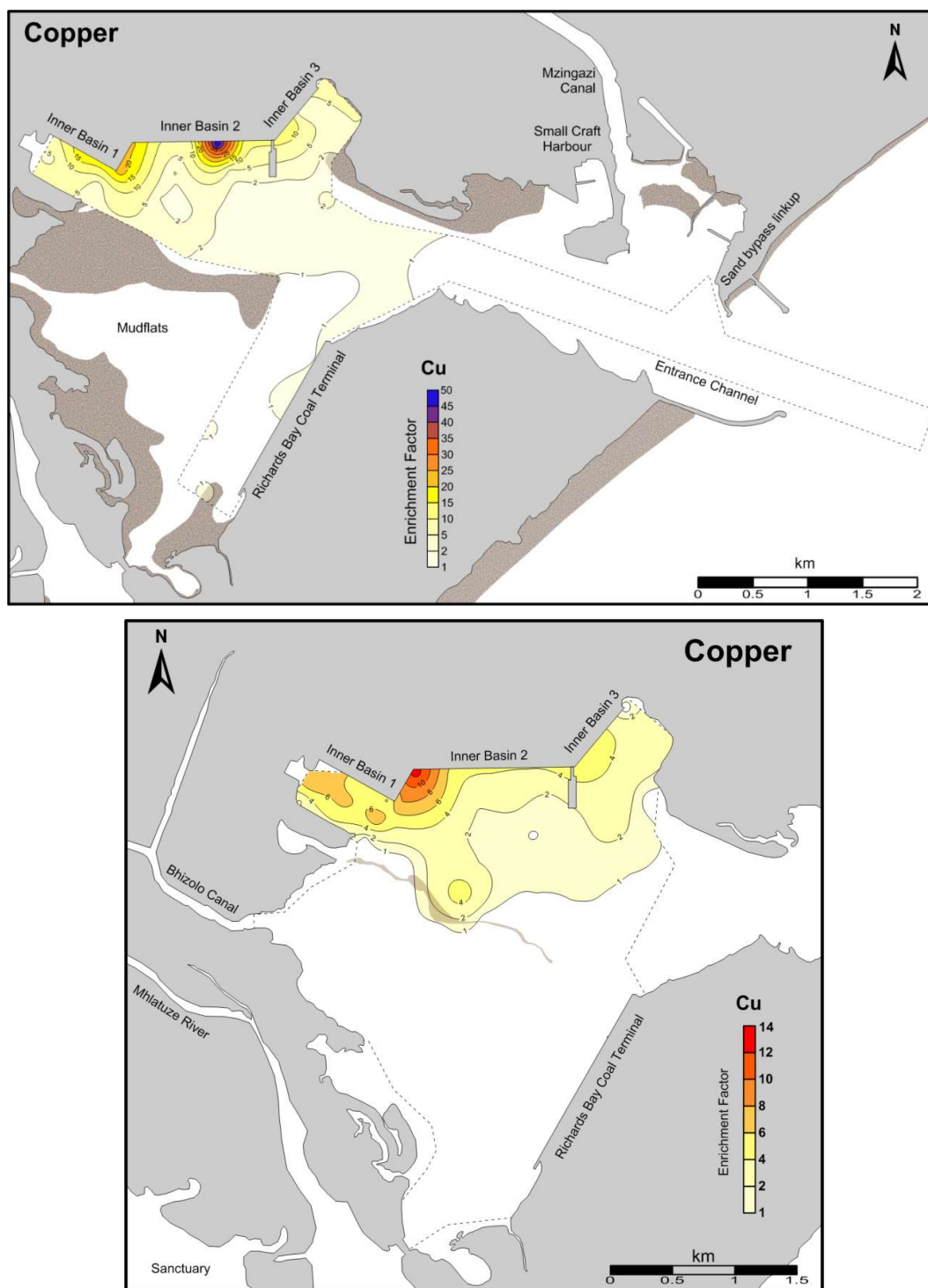


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

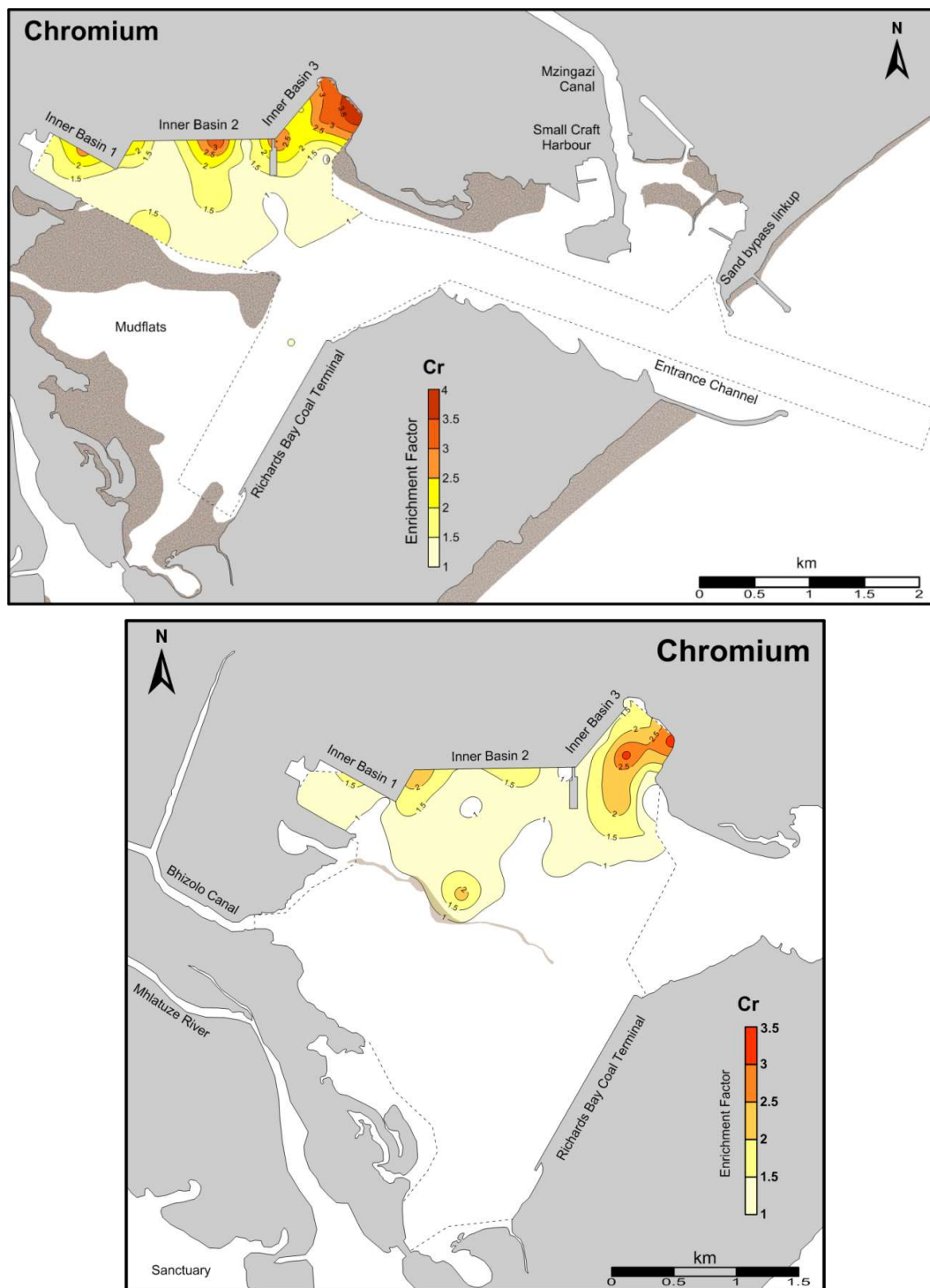


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

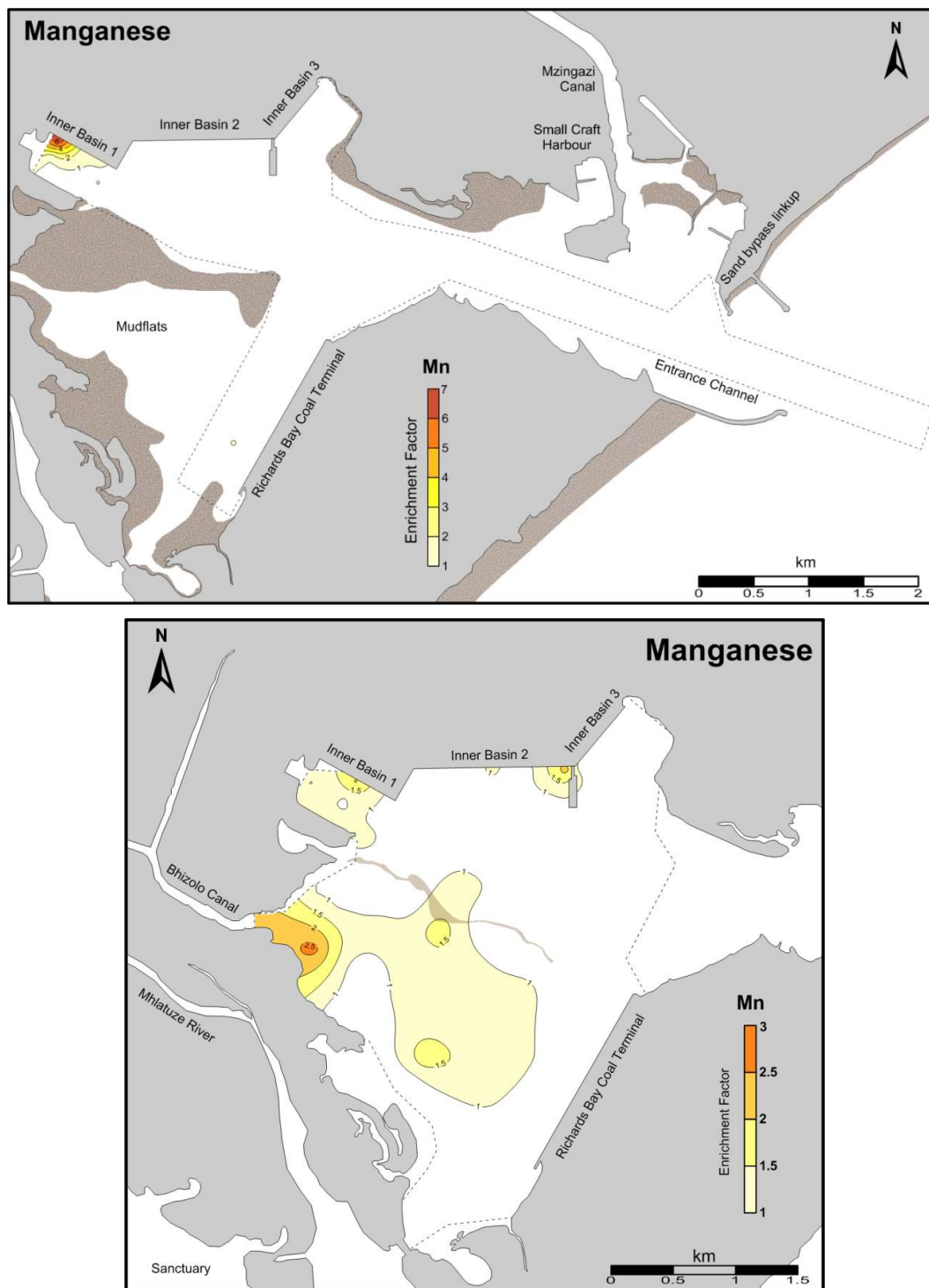


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

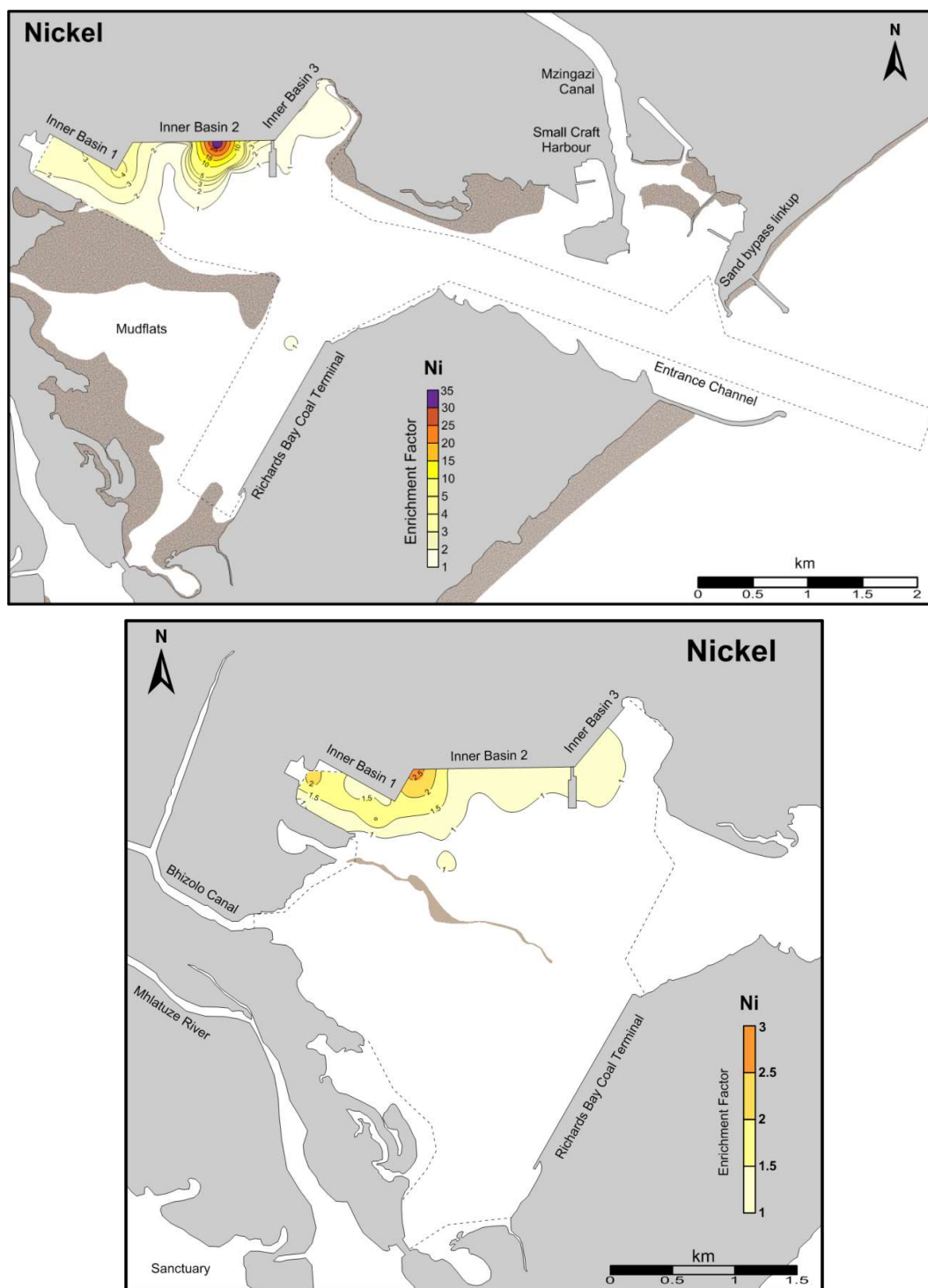


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

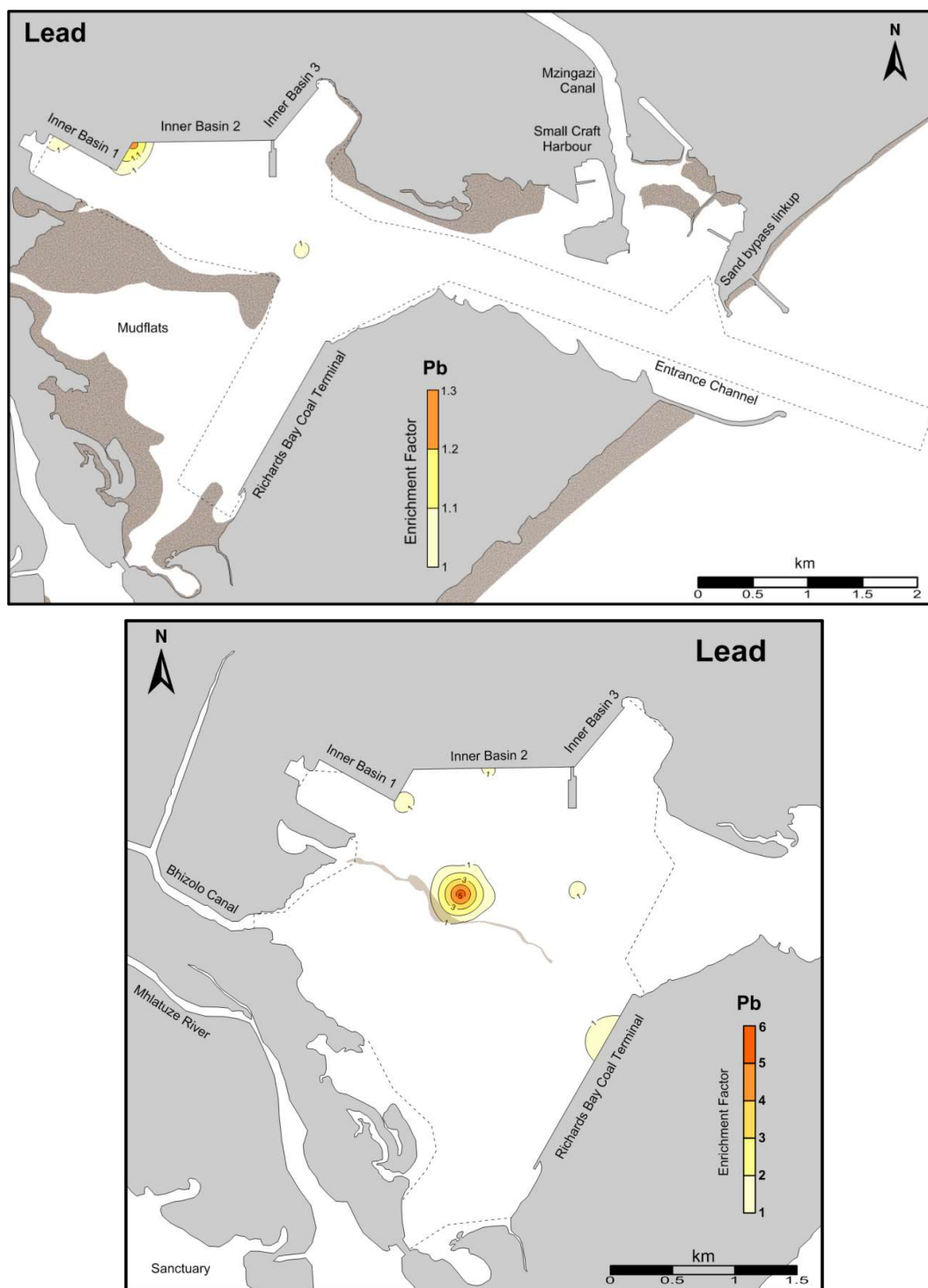


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

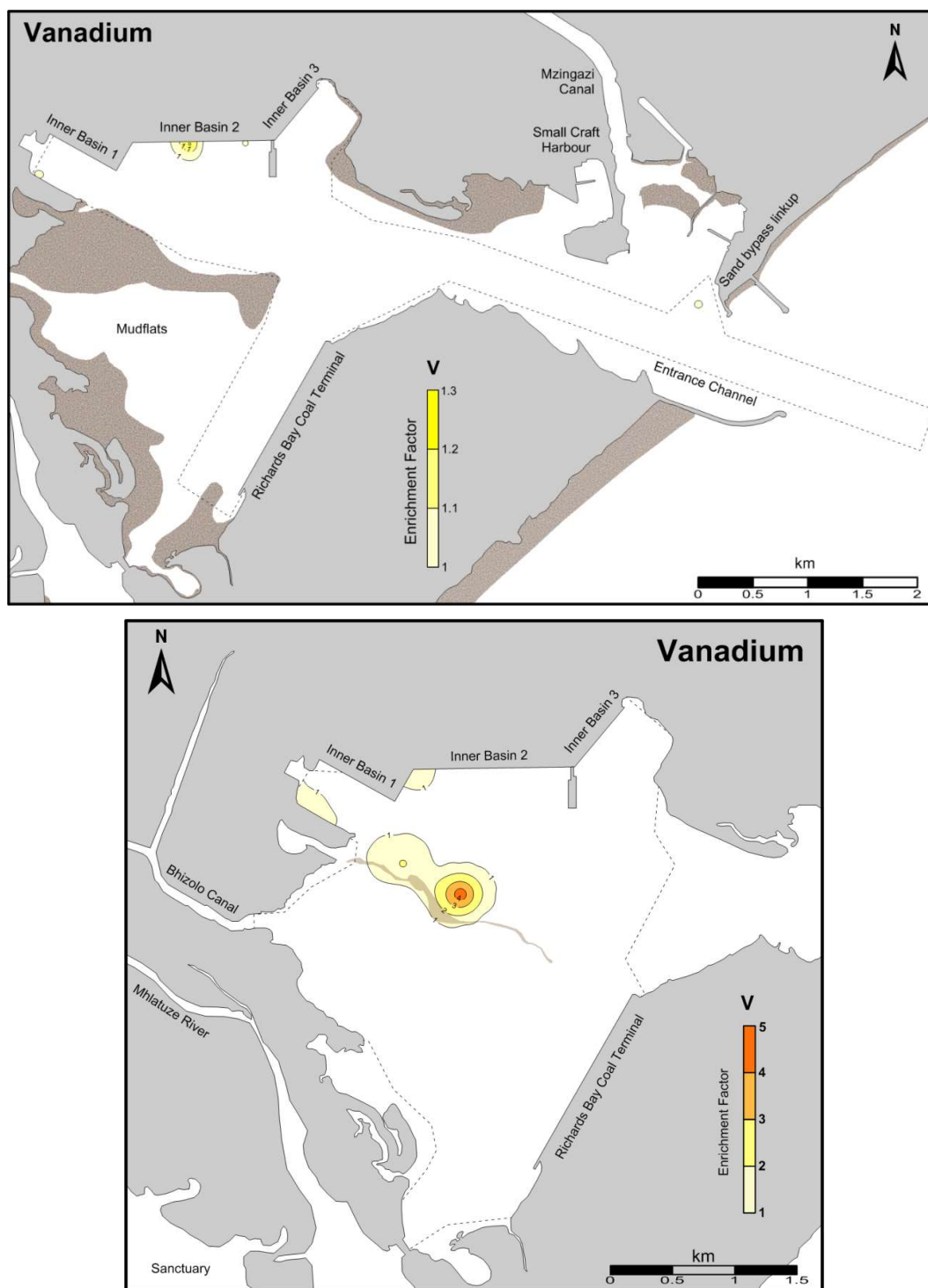


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

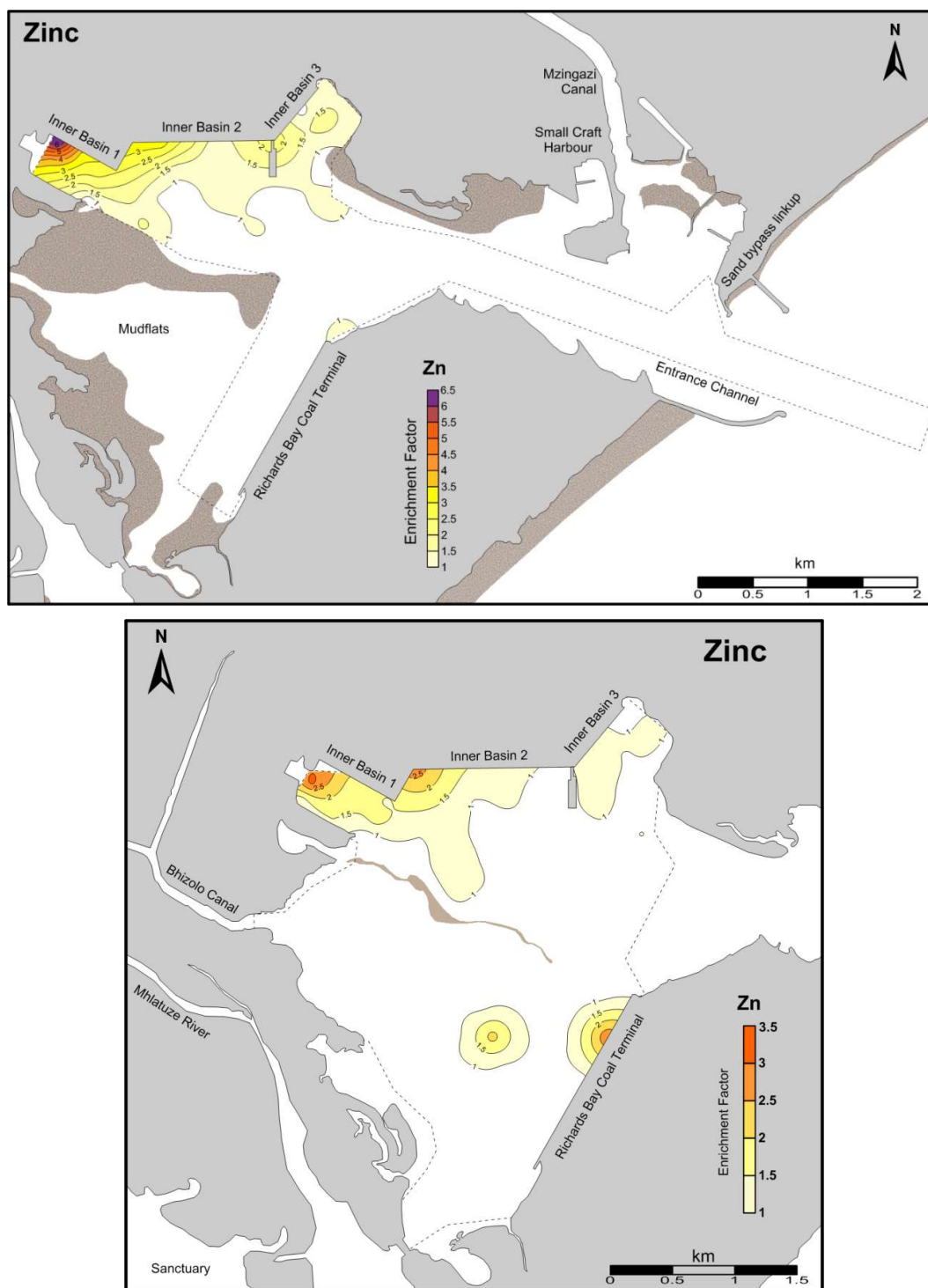


Figure 49 continued. Spatial trends for metal enrichment of sediment sampled in the Port of Richards in November 2011 (top) (CSIR, unpublished data) and November 2012 (bottom) (CSIR, 2013).

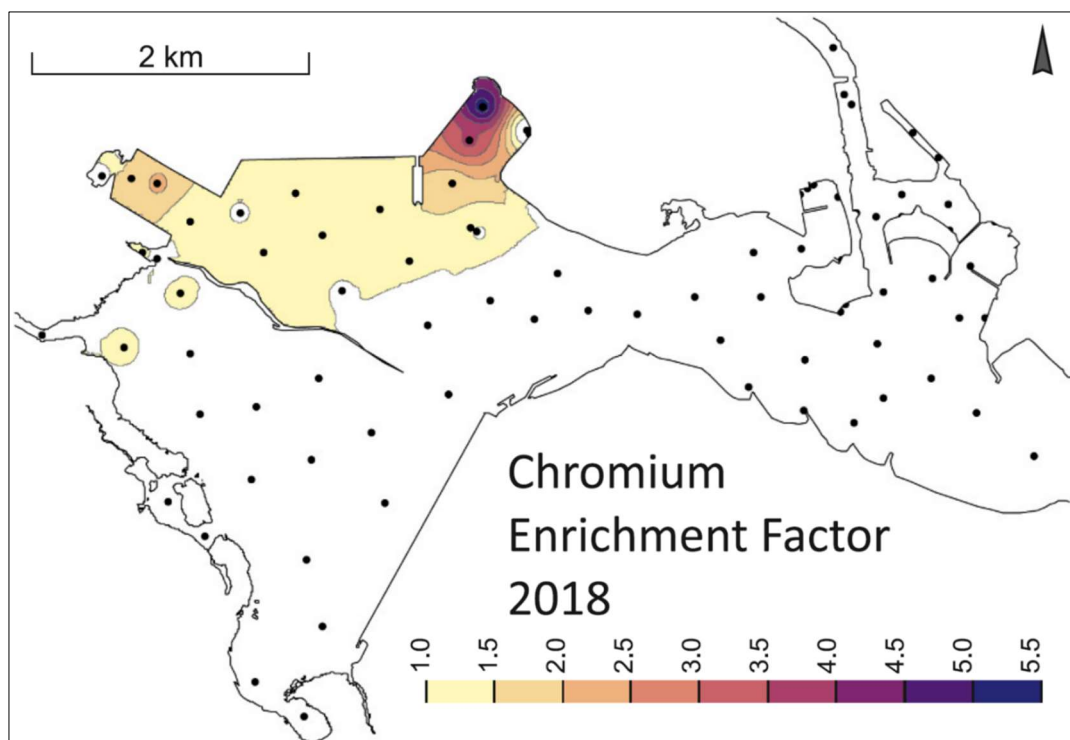


Figure 50. Enrichment Factor spatial trend for chromium in sediment sampled in the Port of Richards in 2018 (Melhorn *et al.*, 2021).

Metal concentrations were measured in sediment sampled in the 600 Berth Basin in November 2024 by the CSIR in support of a capital dredging permit application for the Berth 605 Project. Detailed information on the survey is provided in a companion specialist study (CSIR, 2024). The positions where the sediment was sampled are provided in Figure 48. Nine metals were found at a concentration above the baseline in the sediment at Station 6 (Figure 51). Three to six metals were found at a concentration above the baseline in the sediment at most other stations. Cadmium and copper were the most often and significantly enriched metals—they were found at a concentration above the baseline in the sediment at all but Station 1 (Figure 52). Copper was found at a concentration above the baseline in the sediment at 10 of the 11 stations.

Apart from chromium, the anthropogenic sources of the metals that were identified as frequent and/or significant contaminants of sediment in the Port of Richards Bay are difficult to identify. Chromite sand and ferrochrome are exported through the Port of Richards Bay. The entry of chromite sand and ferrochrome particles during vessel loading and erosion from stockpiles on land by wind and surface runoff (stormwater) provides

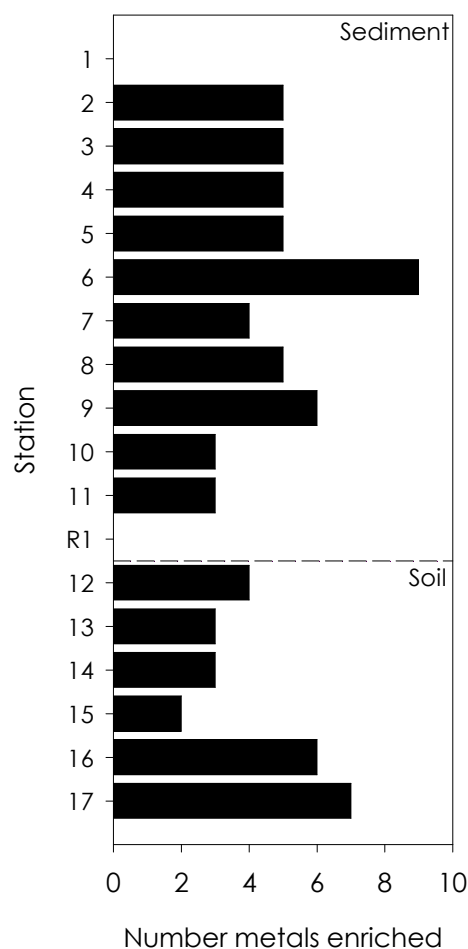


Figure 51. The number of metals enriched in sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay in November 2024.

a plausible explanation for the excess chromium in the sediment. The CSIR scientists that prepared this specialist study have isolated ferrochrome particles (Figure 53) and what is assumed to be chromite sand from sediment sampled in the 600 and 700/800 Berth Basins. Chromite sand resembles sediment and is thus not as easy to distinguish from sediment as chromite sand, nor are other potential metal bearing minerals (*e.g.* magnetite) without additional mineralogical analysis.

Copper concentrate was historically exported through the port, but the exports ceased in 2011 or 2012. The loss of copper concentrate particles into the port in the same ways for chromite sand and ferrochrome particles probably accounted for the copper contamination of sediment evident in the 600 and 700/800 Berth Basins at the time.

However, copper remains a significant and widespread contaminant of sediment in the 600 and 700/800 Berth Basins. Whether this reflects a residual impact of the historical export of copper concentrate through the port is uncertain but is difficult to explain in the light of ongoing maintenance dredging, which theoretically will have removed contaminated sediment over time once the metal source was removed. Other anthropogenic sources of metals in and to the port undoubtedly include antifouling coatings on the hulls of vessels, in which copper and zinc are used as biocides, zinc anodes used for corrosion protection of submerged manmade metal structures, spillage of scrap metal flakes during vessel loading (which has ceased in recent times), and metals washed from road and quay surfaces by surface (stormwater) runoff. However, these sources cannot account for the often-severe copper contamination of sediment evident in the 600 and 700/800 Berth Basins, yet infrequent, low magnitude contamination, or (largely) absence of copper contamination of sediment in other parts of the port where similar activities and sources are prevalent. Copper is such an insignificant impurity of chromite sand and ferrochrome particles that it is improbable these are a source of copper in the sediment.

The Department of Forestry, Fisheries and the Environment uses an Action List (sediment quality guidelines) to decide if sediment that is identified for dredging in South African ports is suitable for open water disposal. However, there are only guidelines for metals. There are three Action Levels, known as the Warning Level, Level I and Level II. The Warning Level provides a warning of incipient metal contamination of sediment, but it is not used for decision-making. Sediment with metals at a concentration below the Level I is not considered to pose a hazard to biological resources and is suitable for open water disposal. Sediment with metals at a concentration between the Level I and Level II is cause for concern to biological resources, the degree of concern increasing as metal concentrations approach the Level II. Decisions on the suitability of the sediment for open water disposal are made after considering the number of metals at a concentration above the Level I, and how much the concentration of each metal is above (or below) the level. The Department may request further testing to identify if metals in the sediment pose a toxic hazard to biological resources. Sediment with metals at a concentration above the Level II is considered to pose a high hazard to biological resources. The sediment is unsuitable for open water disposal unless other evidence (*e.g.* toxicity testing) shows the metals are not posing a toxic hazard due, for example, to their not being in a bioavailable form.

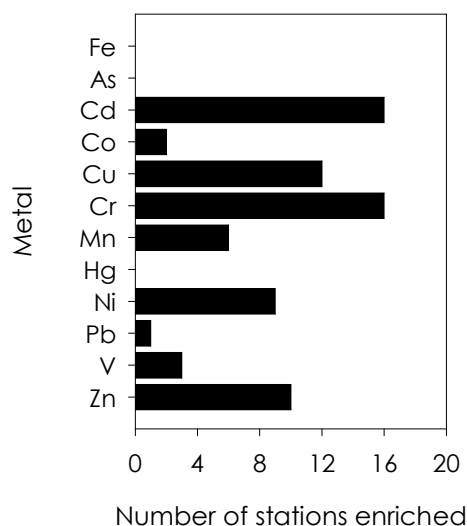


Figure 52. The number of stations where the sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay was enriched by various metals in November 2024.

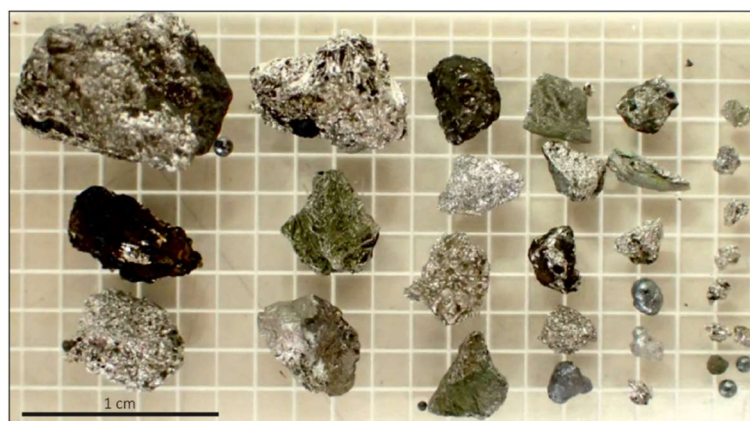


Figure 53. Photo of ferrochrome particles retrieved from sediment sampled in the Port of Richards Bay by the CSIR. Not all of the particles are ferrochrome.

The concentration of chromium in the sediment sampled at most stations in the 600 Berth Basin in 2024 by the CSIR was above the Level I and Level II (CSIR, 2024). The copper concentration in the sediment at three stations was above the Level I, and at one of these stations the concentration was also above the Level II (Figures 54 and 55). The finding of chromium and copper concentrations in sediment in the 600 Berth Basin above Action Levels in 2024 is consistent with the findings of numerous earlier surveys—as stated above there is evidence from as far back as 1983 that sediment in the 700/800 Berth Basin was significantly contaminated by chromium (CSIR, unpublished data). The CSIR has regularly measured copper and chromium concentrations above the Level I or Level II in sediment sampled in the 600 and 700/800 Berth Basins over the last 25 years. The copper concentration in the sediment at two of the four stations sampled in the 600 Berth Basin by Mehlhorn *et al.* (2021) in 2018 was above the Level I while the chromium concentration in the sediment at one of the stations was above the Level I and at two other stations was above the Level II. Mehlhorn *et al.* (2021) also recorded metal concentrations above the Level I or Level II in the neighbouring 700/800 Berth Basin (Figure 56). Izegaegbe *et al.* (2023) provide average metal concentrations in sediment sampled at a station in the 600 Berth Basin in eight surveys over 24 months (2016-2017). The average ($\pm$ standard deviation) chromium concentration ($308 \pm 152 \mu\text{g.g}^{-1}$) was above the Level I ($260 \mu\text{g.g}^{-1}$). The wide standard deviation suggests at least some of the chromium concentrations were above the Level II ($370 \mu\text{g.g}^{-1}$). The copper concentration in the sediment at two of five stations sampled in the 600 Berth Basin by Malan and Clarke (2023) in 2022 was above the Level I.

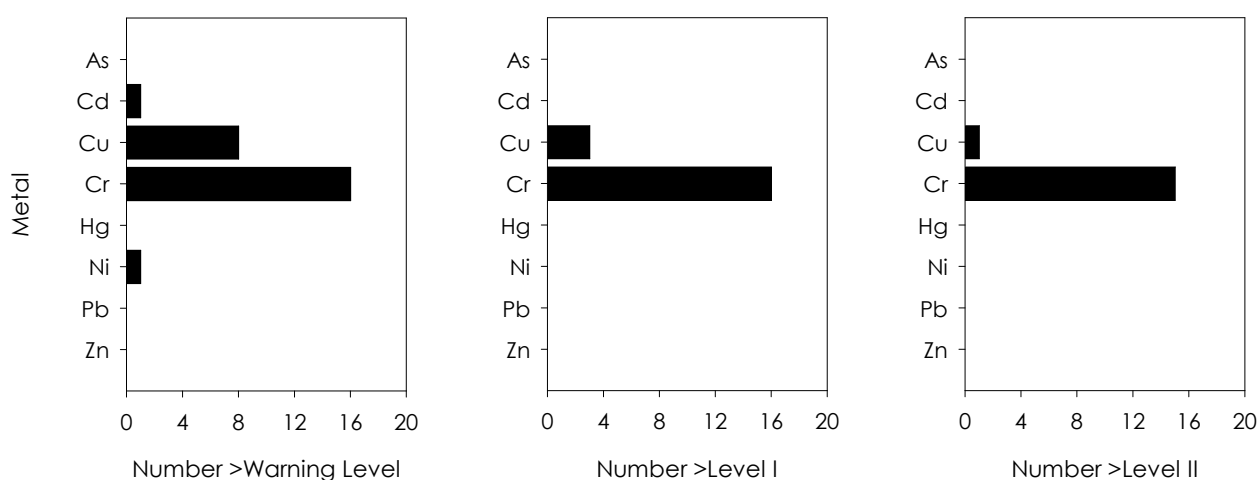


Figure 54. The number of stations at which concentrations of metals in sediment and soil sampled in and near the 600 Berth Basin in Richards Bay in November 2024 that exceed the Warning Level, Level I, and Level II of the sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal.

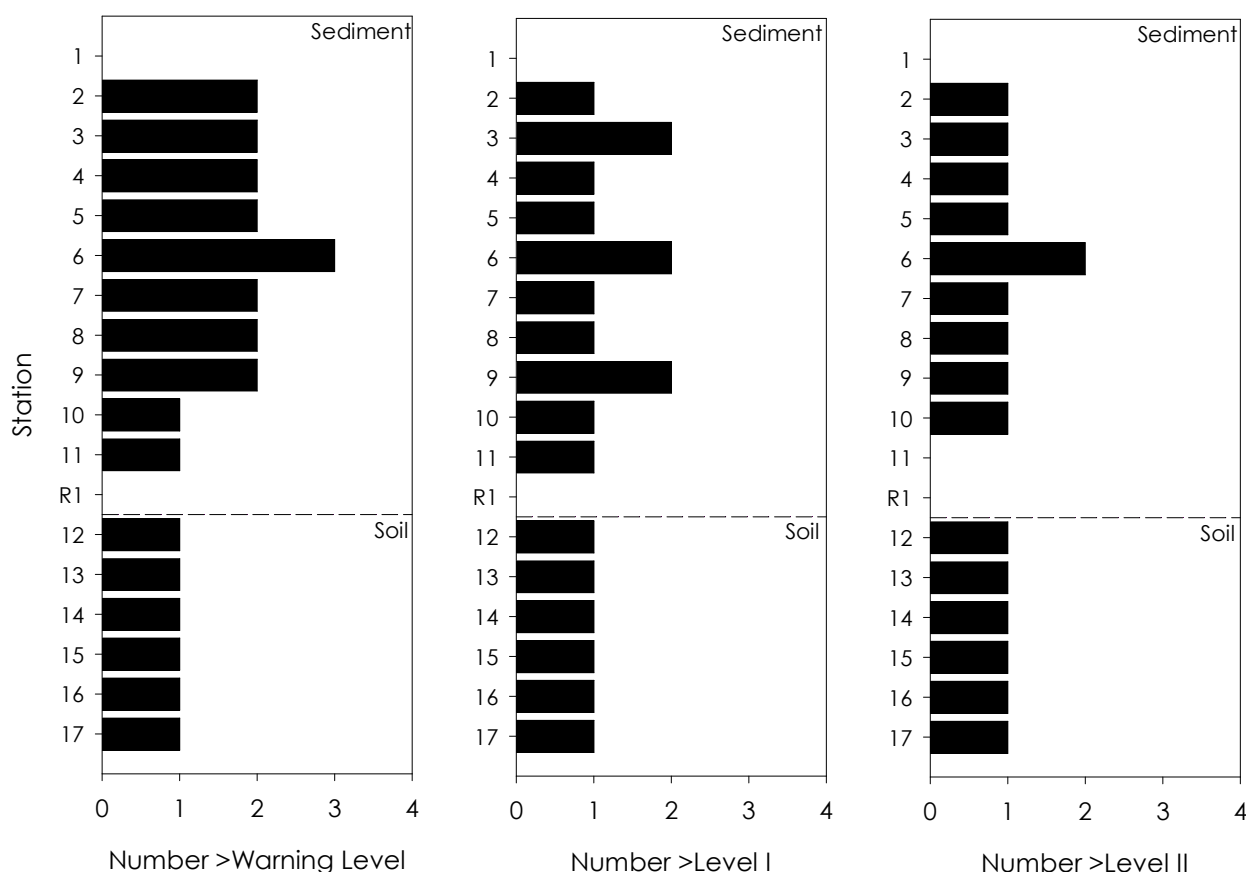


Figure 55. The number of metal concentrations in sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay in November 2024 that were above the Warning Level, Level I, and Level II of the Action List used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal.

In the absence of other information, the chromium and copper concentrations above the Level I or Level II in sediment sampled in the 600 Berth Basin are interpreted as posing a possible to probable toxic hazard to biological resources, and the sediment is thus unsuitable for open water disposal. A limitation of Action Levels, however, is they assume the entire concentration of a chemical in sediment is in a bioavailable form, but this is not necessarily the case (and is invariably not the case). Research by the CSIR (unpublished data) has shown that virtually the entire chromium concentration in sediment in parts of the Port of Richards Bay where the sediment is characterised by high concentrations of this metal is not in a bioavailable form.

The CSIR scientists concluded that the high chromium concentrations measured in sediment sampled in the 600 and 700/800 Berth Basins are largely a consequence of the loss of chromite sand and ferrochrome particles into the port during vessel loading and through wind and surface runoff erosion from stockpiles in port, as discussed above. This conclusion was supported by the extraction of ferrochrome particles from the sediment. Chromite sand resembles sand in texture, but since it is black in colour it is not easily discernible for sediment. Further studies in the laboratory by the CSIR (unpublished data) showed that the chromite sand and ferrochrome particles are insoluble in seawater and do not leach chromium into the water column. Seawater leachates of chromite sand and ferrochrome particles were also not toxic to sea urchin embryo-larvae.

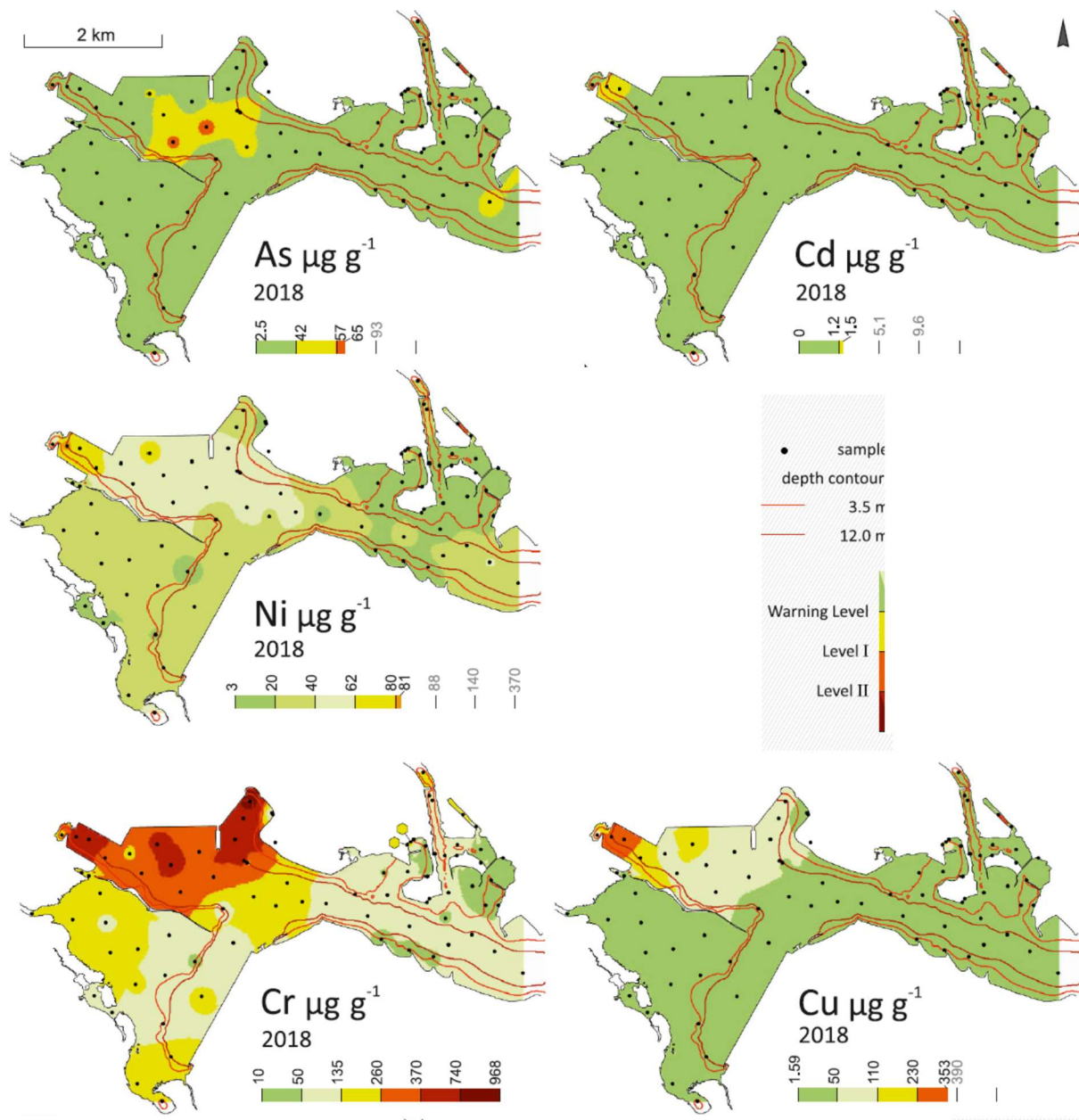


Figure 56. Spatial trends for the concentrations of some metals in sediment sampled in the Port of Richards in 2018 by Mehlhorn *et al.* (2021) and areas where the metal concentrations were above the Warning Level, Level I, Level II of the Action List used to by the Department of Forestry, Fisheries and the Environment to decide of sediment identified for dredging in South African ports is suitable to open water disposal.

There is less information on the concentrations of organic chemicals in sediment in the Port of Richards Bay than there is for metals. Polycyclic aromatic hydrocarbons have received the most attention. Polycyclic aromatic hydrocarbons are amongst—if not the most ubiquitous—contaminants of sediment in aquatic systems in urban areas and ports. These are chemicals that are derived largely from fossil fuels (*e.g.* oil, coal), but they may also be generated by natural processes such as bushfires.

In urban areas and in ports, polycyclic aromatic hydrocarbons have a predominantly anthropogenic origin that includes the incomplete combustion of fossil fuels (*e.g.* oil) in vehicles, vessels and industry, oil/fuel leaks from vehicles and vessels, and the illegal discharge and disposal of used oil in waterways. These chemicals are of concern since some are known to be carcinogenic and mutagenic while others cause cell damage and tumours (IARC, 1991; ATSDR, 1995; Luch, 2005; Xue and Washarsky, 2005; Kannan and Perrotta, 2008).

Polycyclic aromatic hydrocarbons were measured in sediment sampled across a large part of the Port of Richards Bay between 2015 and 2024 by the CSIR, including at stations in the 600 Berth Basin. Polycyclic aromatic hydrocarbons were nearly ubiquitous in the sediment but were usually present at a low to moderate concentration—the 85th percentile of the total polycyclic aromatic hydrocarbon concentrations (sum of 20 individual chemicals) between 2015 and 2024 was $4773 \mu\text{g.kg}^{-1}$, but the highest concentration was $70\,065 \mu\text{g.kg}^{-1}$ recorded at a station alongside the Repair Quay in 2023. The concentrations recorded in sediment sampled in the 600 Berth Basin between 2015 and 2024 were between $2465\text{--}5231 \mu\text{g.kg}^{-1}$. The concentrations recorded in sediment sampled in the port in 2024 are provided in Figure 57. The concentrations recorded at Stations 8 and 9 in the 600 Berth Basin were amongst the highest recorded in the port.

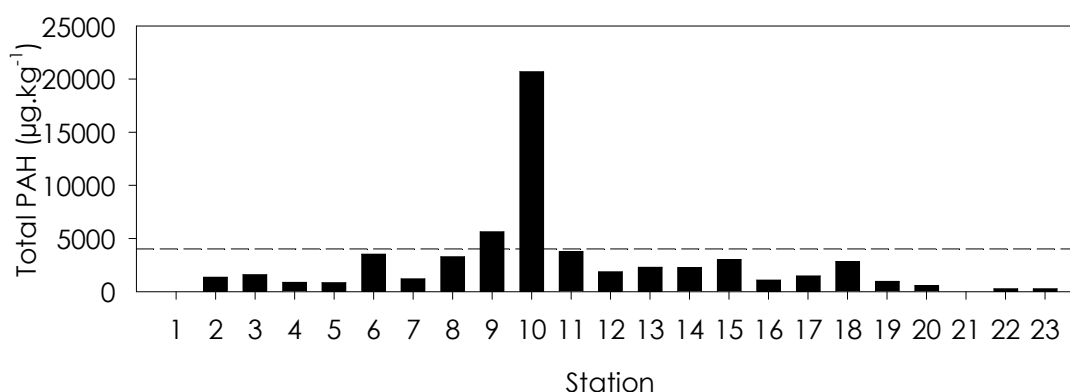
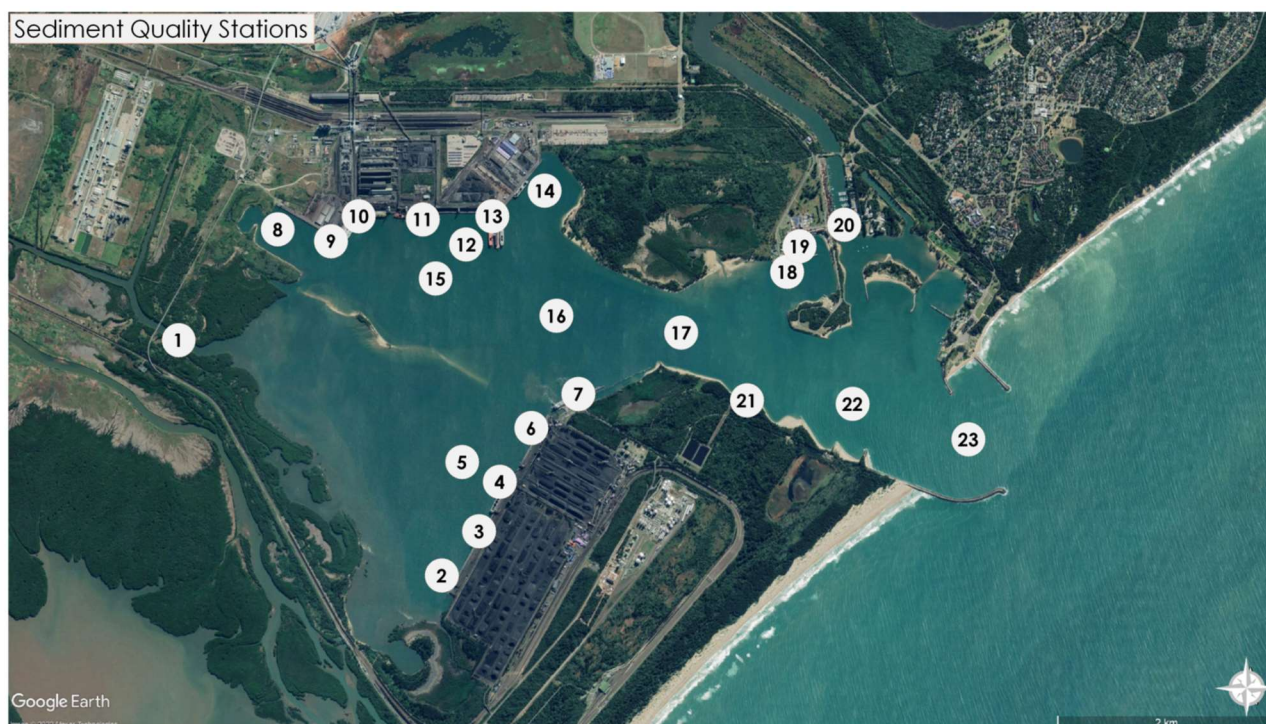


Figure 57. Polycyclic aromatic hydrocarbon (PAH) concentrations in sediment sampled in the Port of Richards Bay in June 2024 (top) and the positions where the sediment was sampled.

Roos (2010) recorded a low total polycyclic aromatic hydrocarbon concentration (sum of 16 individual chemicals) in two sediment samples collected in the Bhizolo-Manzanyama Canal complex, at $686 \mu\text{g.kg}^{-1}$ in the Manzanyama Canal and $1715 \mu\text{g.kg}^{-1}$ at a position downstream of the confluence of this canal and the Bhizolo Canal. Vivier and Cyrus (2020; referenced in Cyrus and Vivier, 2021a,b) also recorded polycyclic aromatic hydrocarbons in sediment sampled in the Bhizolo Canal. In contrast, Cyrus and Vivier (2021a,b) did not record polycyclic aromatic hydrocarbons in sediment sampled at seven stations on the Kabeljous Flats, at two stations to the immediate north of the Sandspit, and at single stations in the Assembly Basin

and Shark Cove. The reason for the absence of polycyclic aromatic hydrocarbons in these samples is uncertain considering the consistent detection of these chemicals in sediment sampled by the CSIR in some of the same areas where sediment was sampled by Cyrus and Vivier (2021a,b).

The South African Action List does not include guidelines (Action Levels) for organic chemicals. The CSIR– and other investigators–has historically screened the ecological significance of polycyclic aromatic hydrocarbon concentrations in sediment in the Port of Richards Bay using sediment quality guidelines derived for North American coastal systems by Long *et al.* (1995). Long *et al.* (1995) derived two guidelines, namely the Effects Range Low and Effects Range Median. The guidelines essentially have the same narrative intent as the Level I and Level II of the South African Action List.

The total polycyclic aromatic hydrocarbon concentration measured in 21 of the 116 sediment samples collected by the CSIR in the port between 2015 and 2024 was above the Effects Range Low ($4022 \mu\text{g.kg}^{-1}$), while one concentration was above the Effects Range Median ($44\,792 \mu\text{g.kg}^{-1}$). One of the concentrations ($5231 \mu\text{g.kg}^{-1}$) measured in eight sediment samples collected in the 600 Berth Basin in this period was above the Effects Range Low. The polycyclic aromatic hydrocarbon concentrations measured in sediment collected in the Bhizolo-Manzanyama Canal complex by Roos (2010) were below the Effects Range Low. The impression gained from these studies is that polycyclic aromatic hydrocarbons in sediment in the Port of Richards Bay, albeit widespread, are unlikely to pose a toxic hazard to benthic biological resources.

Polychlorinated biphenyls are common contaminants of sediment in urban areas in many parts of the world. They are classified as persistent organic pollutants. Their use has been banned in South Africa and in most other parts of the world due to toxicological concerns. Polychlorinated biphenyls tend to accumulate in biological tissue, giving them the potential to pose a hazard to the biological resources themselves and to their predators and humans that consume them. Polychlorinated biphenyl concentrations were measured in sediment sampled at 14 sites across a large part of the Port of Richards Bay between 2015 and 2019 by the CSIR but were never detected. In contrast, Roos (2010) recorded moderate total polychlorinated biphenyl concentrations (sum of seven individual chemicals) in two sediment samples collected in the Bhizolo-Manzanyama Canal complex, at $39.8 \mu\text{g.kg}^{-1}$ in the Manzanyama Canal and $20.1 \mu\text{g.kg}^{-1}$ at a position downstream of the confluence of this canal and the Bhizolo Canal. The reason why the sediment samples analysed by the CSIR yielded no polychlorinated biphenyls yet they were found in both sediment samples analysed by Roos (2010) is uncertain. The former concentration measured by Roos (2010) is above the Effects Range Low ($22.7 \mu\text{g.kg}^{-1}$) of the sediment quality guidelines derived by Long *et al.* (1995) for North American coastal systems, while the latter concentration is only slightly lower than this guideline. The concentrations are well below the Effects Range Median ($180 \mu\text{g.kg}^{-1}$). The impression gained from these studies is that polychlorinated biphenyls are not widespread contaminants of sediment in the Port of Richards Bay, but where present they may be posing a low toxic hazard to benthic biological resources.

Organochlorine pesticides are banned for use in South Africa and in most other parts of the world due to toxicological concerns. However, the use of DDT for the control of malaria transmitting mosquitoes is allowed under certain circumstances, including in South Africa. Organochlorine pesticides or their metabolites were analysed in sediment sampled at 14 stations across a large part of the Port of Richards Bay between 2015-2019 by the CSIR, but were found in only three samples. In contrast, Roos (2010) recorded 8 of 12 targeted organochlorine pesticides and their metabolites in two sediment samples collected in the Bhizolo-Manzanyama Canal complex. Mehlhorn *et al.* (2021) recorded 18 organochlorine pesticides and their metabolites in sediment sampled at 13 stations in the Port of Richards Bay in 2018 (Figure 58). One of these stations was in the 600 Berth Basin. The reason why sediment analysed by the CSIR yielded no organochlorine pesticides while samples analysed in other studies revealed the presence of numerous organochlorine pesticides is uncertain. Ratios amongst the concentrations of parent compounds and their metabolites in sediment samples analysed by Mehlhorn *et al.* (2021) suggests recent inputs of

some pesticides. The ecological significance of DDT concentrations was estimated by their comparison to sediment quality guidelines derived by Long *et al.* (1995) for North American coastal systems. The DDT concentration at each station (range 15-210 $\mu\text{g.kg}^{-1}$) was above the Effects Range Low (1.58 $\mu\text{g.kg}^{-1}$), and at many stations was also above the Effects Range Median (46.1 $\mu\text{g.kg}^{-1}$). The DDT concentrations recorded by Roos (2010) were, in contrast, below the Effects Range Low and Effects Range Median. The DDT concentration, and the concentrations of many other pesticides, was also above similar two-threshold guidelines derived by MacDonald *et al.* (2000), also for North American coastal systems. The impression gained from these studies is that organochlorine pesticide concentrations in sediment in the Port of Richards Bay may be posing a high toxic hazard to benthic biological resources.

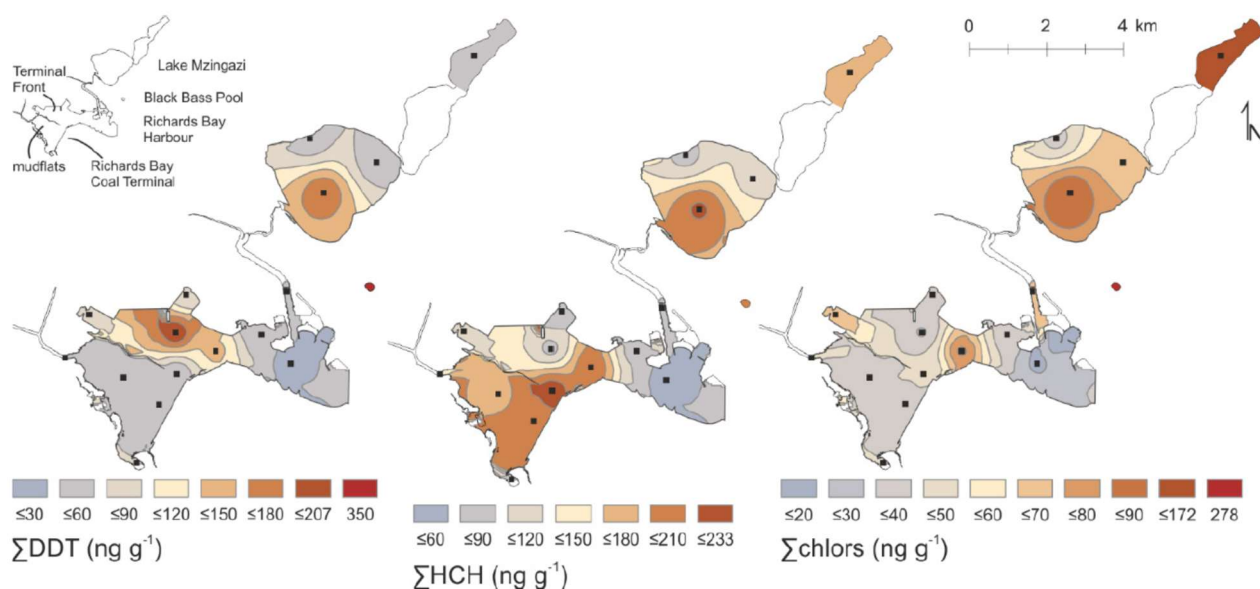


Figure 58. Organochlorine pesticide concentrations measured in sediment sampled in the Port of Richards Bay and neighbouring Lake Mzingazi in 2018 by Mehlhorn *et al.* (2023).

Tributyltin is one of the most prevalent contaminants of sediment in ports and other waterbodies that are characterised by maritime activities. The contamination reflects the historical use of tributyltin as a biocide in antifouling coatings on vessel hulls. Its use for this purpose has been banned in many countries due to its broad-spectrum toxicity and unintended consequences for non-target organisms. One consequence of tributyltin exposure is imposex—the development of male sexual characteristics in female gastropods that are exposed to sub-lethal concentrations, leading to their sterility. The concentration of tributyltin was measured in sediment sampled across a large part of the Port of Richards Bay between 2015-2019 by the CSIR (Figure 59). Tributyltin was essentially ubiquitous in sediment in the port, recorded in 88% of the samples. The concentrations were not particularly high, ranging between <0.5-2800 $\mu\text{g.kg}^{-1}$ but <30 $\mu\text{g.kg}^{-1}$ in 77% of the samples.

There are currently no reliable guidelines to estimate the potential ecological significance of tributyltin in sediment, making it difficult to estimate the toxic hazard posed by this chemical. Marshall and Rajkumar (2003) reported imposex in all females of the gastropod *Nassarius kraussianus* sampled at two sites in the Port of Richards Bay, indicating that tributyltin had affected the endocrinology of at least some gastropods in the port at the time of the survey.

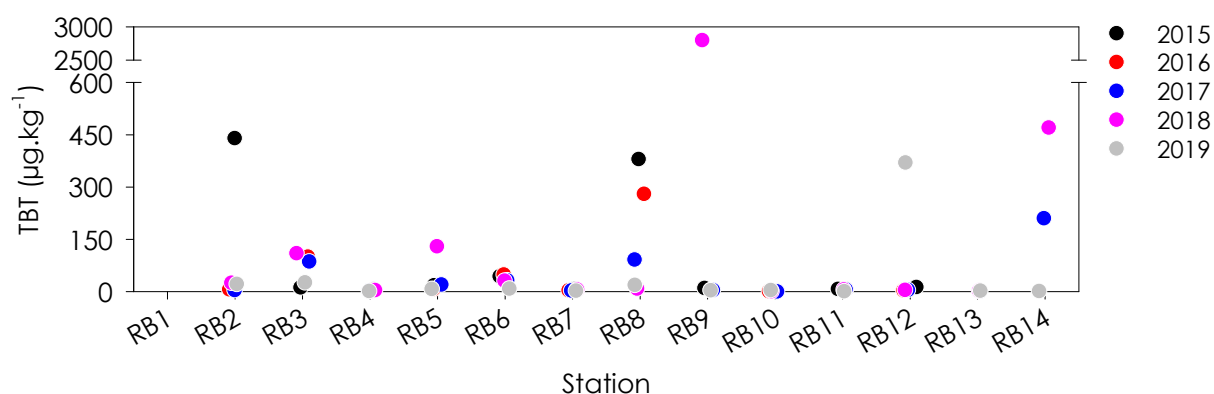


Figure 59. Tributyltin concentrations measured in sediment sampled in the Port of Richards Bay between 2015-2019 by the CSIR (unpublished data).

The CSIR used an index to classify sediment quality in the Port of Richards Bay in 2024. The index ratings can fall in a range from excellent to poor. The index ratings are provided in Figure 60. The sediment quality was rated good or excellent apart from in the 600 and 700/800 Berth Basins, where it was rated fair, marginal, or poor apart from one station. The sediment quality at the two stations sampled in the 600 Berth Basin was rated marginal.

The use of sediment quality guidelines (*e.g.* Action List) provides, at best, only an estimate of the toxic hazard posed by chemicals in sediment to benthic biological resources. A major limitation of sediment quality guidelines is they do not account for bioavailability, but rather assume the entire concentration is in a bioavailable form. However, various processes in sediment can immobilise chemicals in sediment, limiting their bioavailability. Chemicals can also interact in ways that magnify the toxic effect of the chemicals on their own, while unmeasured chemicals may be present in sediment at concentrations that pose a hazard. The magnitude of toxicity is thus not necessarily related to the concentrations of noxious chemicals measured in sediment. Sediment quality guidelines are thus most effectively used as a screening tool to identify areas where chemicals in the sediment are unlikely to present an ecological problem, and to identify chemicals that require more detailed evaluation through further lines of investigation. An effective strategy to identify if chemicals in sediment are posing a toxic hazard to biological resources is to test the toxicity of the sediment in the laboratory. A toxicity test is a procedure that involves the exposure of organisms to complex environmental samples (water, sediment, or sediment extract) under controlled conditions to determine if adverse effects occur. The advantage is that toxicity tests measure the combined effects and bioavailability of chemicals in sediment.

The CSIR tested the toxicity of sediment sampled at 23 stations across the Port of Richards Bay between 2022-2024, using the sea urchin embryo-larval test under a sediment-water interface toxicity testing regime. The sea urchin embryo-larval test measures how many sea urchin embryos that are exposed to a test medium go on to develop normally (*i.e.* do not show delayed development or morphological abnormalities) to a stage in the larval development known as the 4-arm pluteus. The sediment sampled in the Port of Richards Bay between 2022-2024 was usually not toxic to sea urchin embryo-larvae. The sediment sampled at a station in the 600 Berth Basin in 2022 was identified as slightly toxic, and at a station in the 700 Berth Basin as marginally toxic, but the sediment sampled at these stations in 2023 and 2024 was identified as not toxic. The sediment sampled in 2024 at a station in the Bhizolo-Manzanyama Canal complex and at a station in the Mzingazi Canal was identified as marginally toxic (Figure 61). Slight and marginal toxicity refer to a low level of toxicity. Other toxicity testing of sediment sampled in smaller areas of the port by the CSIR has revealed some incidences of toxicity in the 700/800 Berth Basin, but the sediment was usually not toxic.

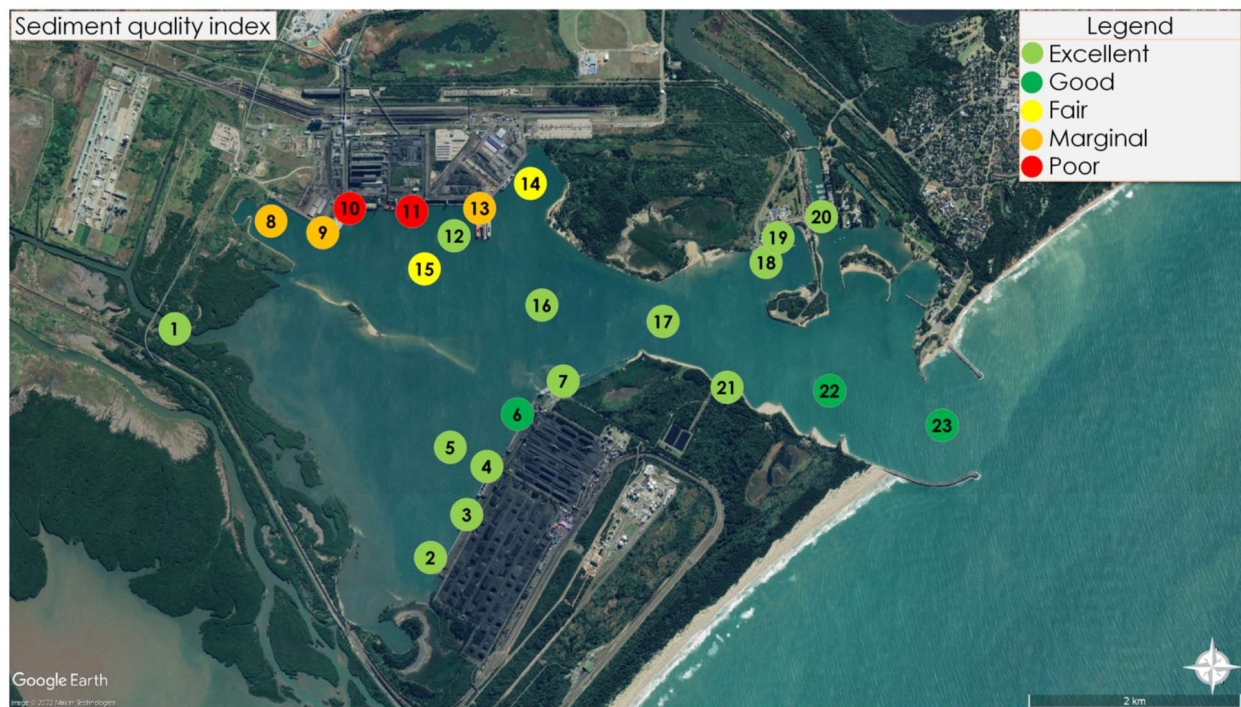


Figure 60. Sediment quality index classification of sediment sampled in the Port of Richards Bay in June 2024.

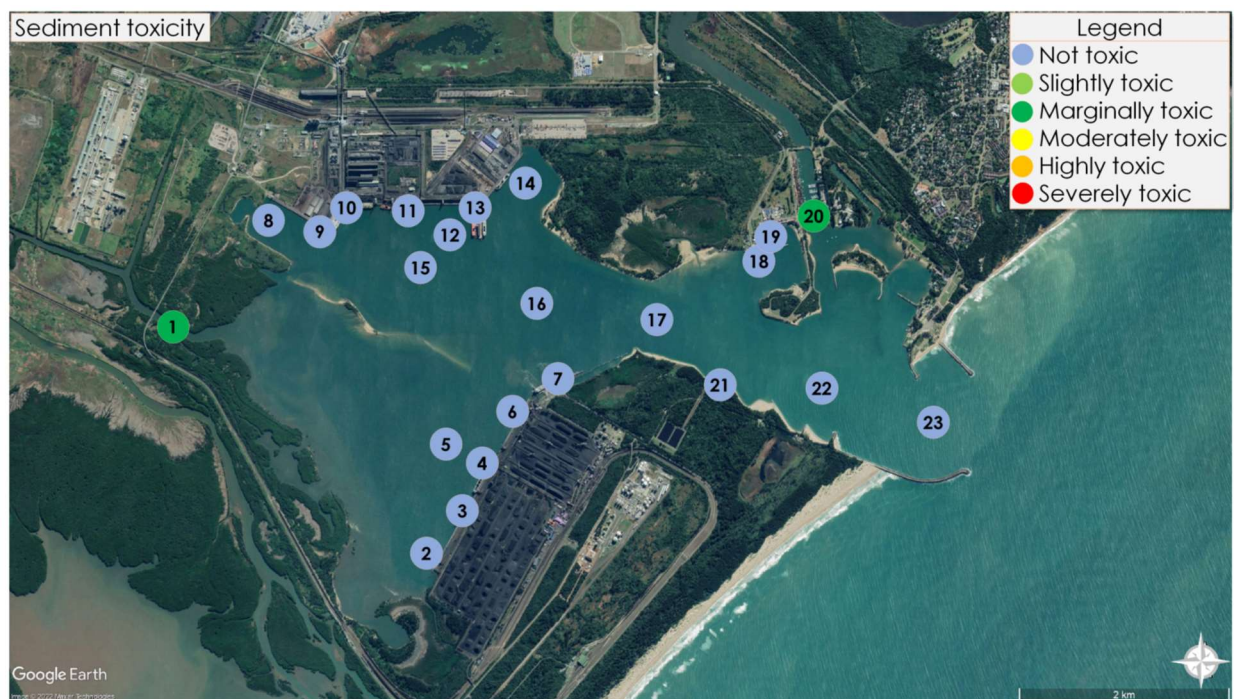


Figure 61. Classification of sediment based on the results of a sediment-water interface toxicity testing of sediment sampled in the Port of Richards Bay in June 2024.

The toxicity of sediment sampled in the Berth 605 Project footprint in 2024 was tested by the CSIR. Detailed information on the toxicity testing is provided in a companion specialist study prepared by the CSIR (CSIR, 2024). Two tests were used. The first test is the same as that described above, namely a sea urchin embryo-larval test under a sediment-water interface toxicity testing regime. The second test is known as an elutriate test, which investigates if chemicals are remobilised from sediment under strong agitation that imitates dredging at concentrations and in forms that are toxic to sea urchin embryo-larvae. The toxicity testing showed that none of the elutriates prepared using sediment sampled in the 600 Berth Basin were toxic to sea urchin embryo-larvae (Figures 62-64).

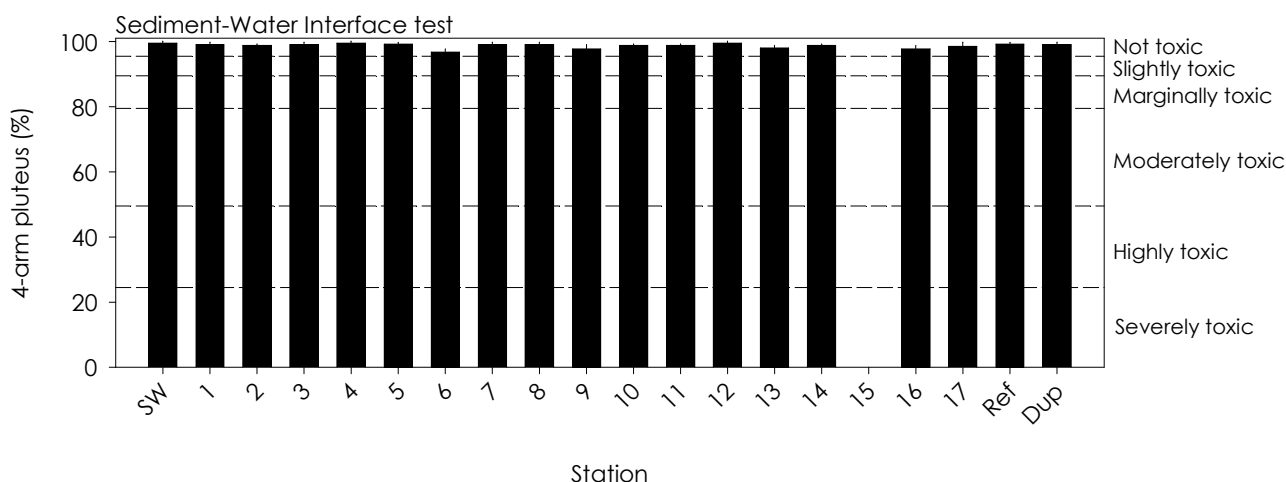


Figure 62. Proportion (mean $\pm$ standard deviation) of sea urchin (*Tripneustes gratilla*) embryos that developed to a normal 4-arm pluteus after exposure to sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay in November 2024 under a sediment/soil-water interface toxicity testing regime. SW = seawater control, Ref = reference sediment, Dup = duplicate.

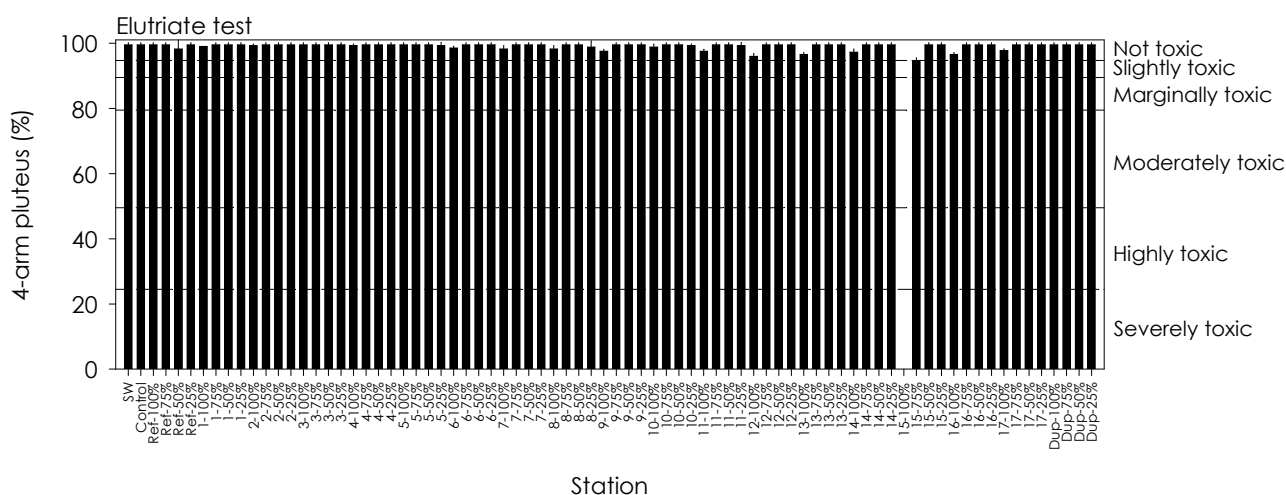


Figure 63. Proportion (mean $\pm$ standard deviation) of sea urchin (*Tripneustes gratilla*) embryos that developed to a normal 4-arm pluteus following exposure to elutriates prepared using sediment and soil sampled in and near the 600 Berth Basin in the Port of Richards Bay in November 2024. SW = seawater control, Ref = reference sediment, Dup = duplicate.



Figure 64. Development stages reached by sea urchin embryos exposed to soil elutriates for Station 15 (left) compared to development to a normal 4-arm pluteus for embryos exposed to sediment/soil elutriates for other stations (right).

Thus, despite the confirmed metal and polycyclic aromatic hydrocarbon contamination of sediment sampled in parts of the Berth 605 Project footprint in 2024 and the likely contamination of the sediment by other chemicals based on the findings of earlier surveys, as discussed above, the sediment was not toxic to sea urchin embryo-larvae when tested using the sediment-water interface and elutriate toxicity tests. The significance of these findings is that noxious chemicals are unlikely to be released in the hopper overflow from dredging vessels and barges or when dredged sediment is disposed at the open water dredged spoil disposal site off the Richards Bay coast at concentrations and in forms that will cause toxicity.

The absence of sediment toxicity in the Port of Richards Bay, despite the very high concentrations of certain metals in sediment in parts of the port, implies the metals, and indeed other unmeasured chemicals that might be present in the sediment, were not in a bioavailable form, or were remobilised at too low a concentration to be toxic to sea urchin embryo-larvae. In the case of chromium, the absence of toxicity probably reflects the presence of chromite sand and ferrochrome particles in the sediment. The CSIR (scientific publication to be submitted) soaked various masses of chromite sand and ferrochrome particles in seawater. The water was then tested for toxicity using the sea urchin embryo-larval test. The testing showed that the chromite sand treatments were not toxic to sea urchin embryo-larvae. All ferrochrome particle treatments were, in contrast, toxic—no embryo-larvae in these treatments developed to a normal 4-arm pluteus. The chromium concentration in the leachates was below the method detection limit. Chromium obviously did not thus leach from the chromite sand and ferrochrome particles and was not responsible for the toxicity. Further toxicity testing of ferrochrome particles showed that the toxicity depended on the mass and size of the particles—smaller particles leached a higher concentration of toxic compounds than did larger particles of an equivalent mass, and within a particle size the toxic compound concentrations increase with the mass of particles based on a gradient in the severity of toxicity with increasing particle masses. In a further test, ferrochrome particles that were previously leached in seawater were leached for a second time. The seawater was found to not be toxic. The compounds that caused the toxicity in the first soaking treatment were thus not leached continuously, at least not at a toxic concentration. Spilled ferrochrome particles might thus release toxic compounds into the water column for a very short period, but are unlikely to present a long-term toxic risk in the port. Chromium and copper concentrations in sediment in parts of the Port of Richards Bay that exceed Action Levels do not thus infer a toxic risk.

5.1.10 Aquatic impacts of coal dust

As discussed above, the most significant change that has occurred in the 600 Berth Basin in recent times is the accumulation of coal fragments and coal particles in the sediment, reflecting losses into the port during the transfer of coal onto vessels and via wind and surface runoff erosion from coal stockpiles on the quayside near the water's edge. The export of coal through the basin is a relatively recent development. The dark colour of the sediment sampled at some stations near the quay wall is assumed to reflect the accumulation of coal particles (Figure 27). The coal fragments and coal particles will be transferred to the open water dredged spoil disposal site off the Richards Bay coast when the dredged sediment is disposed. It is thus worth reviewing information on the ecological effects of coal particles and coal dust on aquatic biological resources.

The impression gained from a review of studies in this context is that coal particles and coal dust are unlikely to leach noxious chemicals into the water column at concentrations that are toxic to aquatic biological resources. Coal particles and coal dust do not readily dissolve in water but form a suspension. Suspended coal particles and coal dust have a physical effect on aquatic biological resources depending on the concentration.

Bender *et al.* (1987) investigated the absorption of polycyclic aromatic hydrocarbons from ingested coal in the oyster *Crassostrea virginica*. Oysters exposed to a 10 mg.L⁻¹ coal suspension and then depurated

showed no increase in the polycyclic aromatic hydrocarbon tissue burden. Higher concentrations were found in non-depurated oysters, but this was associated with coal particles in the gut rather than these chemicals being absorbed into the tissue. A study on three types of South African coal showed that the leaching of metals such as copper, chromium, iron and lead in seawater at a pH of 8 was insignificant due to the presence of humic substances in the coal or seawater, which prevented the metals moving from coal to seawater. However, a higher solubility of nickel and manganese was noted (Cabon *et al.*, 2007). Jaffrennou *et al.* (2007) found that South African coal introduced into seawater reduced light penetration up to 100% at certain suspensions. However, polycyclic aromatic hydrocarbons and metals were not leached from the coal apart from manganese at a low concentration ($\sim 1 \mu\text{g.L}^{-1}$), although the concentration was nevertheless higher than the baseline for the seawater used in the study (Brest Harbour, France; $0.35 \mu\text{g.L}^{-1}$). Berry *et al.* (2016) also found no evidence for metals being leached from coal particles in water.

The crab *Cancer magister* accumulated coal in its gills when exposed to a mixture of coal dust and sand (Pearce and McBride, 1977). Bender *et al.* (1987) found that the filtration rate, shell gape and growth of the oyster *Crassostrea virginica* was unaffected by exposure to coal suspensions of 10 mg.L^{-1} . The abundance of the lugworm *Arenicola marina* was lower in sediment with coal particles at 11% weight compared to uncontaminated areas (Hyslop and Davies, 1999). Berry *et al.* (2016) exposed the tropical seagrass *Halodule uninervis*, coral *Acropora tenuis*, and tropical reef fish *Acanthochromis polyacanthus* to coal particles $< 63 \mu\text{m}$ at concentrations of 0, 38, 73, 202, and 275 mg.L^{-1} for 28 days. Coal exposure affected the growth and shoot density of the seagrass at some concentrations, presumably due to the coal particles attaching to and coating the leaves. Corals experienced significantly higher tissue mortality at all exposure concentrations than in control treatments. The growth of fish at all exposure concentrations was lower than in control treatments. However, despite the considerable effects on fish growth, all coal-exposed fish survived apart from two individuals exposed to the highest coal concentration. A preliminary postmortem revealed coal in the fish alimentary tracts, which was presumably mistakenly ingested and could have physically blocked normal feeding and digestion contributing to starvation and debilitation.

Benitez-Polo and Velsco (2020) exposed the Caribbean scallop *Argopecten nucleus* to coal suspensions of 0, 2, 9 and 40 mg.L^{-1} . The concentration range is representative of areas proximate to coal loading and shipping ports. At increasing concentrations, the rate of filtration and pseudofaeces production increased while the rate of ingestion and absorption remained constant. The rate of oxygen consumption and ammonium excretion decreased, as did the absorption efficiency and scope for growth. Suspended coal dust particles at concentrations $\geq 2 \text{ mg.L}^{-1}$ were ingested preferentially over microalgae, leading to a reduction in absorption capability, metabolism, and the amount of energy available for growth and reproduction, thus generating physiological stress.

There is some information available on the effects of coal particles for the Port of Richards Bay. The CSIR found no toxic effect of coal washings or coal particle suspensions from the Richards Bay Coal Terminal on the fertilisation success of sea urchins (CSIR, 1993). The CSIR (1995) concluded that the fallout of coal dust in the Port of Richards Bay was unlikely to adversely affect pelagic biological resources at the fallout rates assumed to occur. However, other studies by the CSIR (unpublished) have shown that water samples with high concentrations of particles evinced a 'toxic' effect. However, the effect was a response to the physical effect of the coal particles inhibiting fertilisation since the testing of the same samples after centrifugation did not evince a toxic response. In other words, there was no leaching of contaminants from the coal particles into the water, in agreement with other studies.

The deposition of coal dust on leaf surfaces reduced photosynthetic performance in the mangrove *Avicennia marina* and mangrove associate *Hibiscus tiliaceus* in the Port of Richards Bay, but not the performance of the mangroves *Bruguiera gymnorrhiza* and *Rhizophora mucronata* (Naidoo and Chirkoot, 2004; Naidoo and Naidoo, 2005). Field observations showed that leaves of *A. marina* and *H. tiliaceus* were

more prone to coal dust accumulation than the other species, especially on the abaxial surfaces, which appeared completely black at exposed sites. The reduction in photosynthetic performance was attributed to a reduction in light energy incident on the photosynthetic tissues due to coal dust accumulation.

5.1.11 Soil quality

The Berth 605 Project footprint includes land to the west of the 600 Berth Basin that will be excavated to allow development of the berth (Figure 5). The excavated soil and rock will be disposed along with sediment dredged in the basin at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. The CSIR analysed the grain size, total organic content and metal concentrations in surface soil samples collected at six stations (composite of five smaller samples per station) in 2008 near the small tidally influenced pool inland of the Assembly Basin, and in two further samples collected ~100 m south of the pool (Figure 48). When the soil samples were collected in 2008, the small tidally influenced pool and surrounding land was heavily disturbed following the construction of caissons in the Assembly Basin for the development of Berth 306 at the Richards Bay Coal Terminal, to the extent there was no vegetation in the immediate surroundings of the pool (see Figure 15). Surface soil from each station comprised relatively unconsolidated sediment that was easily penetrated by the scoop used to collect soil for analysis. The total organic content of the soil was between 0.62-1.76%. The total organic content and metal concentrations in the soil were, where possible, compared to baselines established by the CSIR for sediment in the Port of Richards Bay. The total organic content and metal concentrations were within the baseline for the port apart from arsenic and cadmium, which revealed enrichment at numerous stations.

The total organic content and metal concentrations were measured in soil sampled in the Berth 605 Project footprint in November 2024 by the CSIR (Figure 48) for the purpose of a capital dredging permit application. Detailed information on the survey is provided in a companion specialist study (CSIR, 2024). The concentrations of most metals in the soil sampled at most stations fall within the baseline for sediment in the Port of Richards Bay. The concentrations of one or more metals in the soil at all stations were nonetheless above the baseline. Seven metals were at a concentration above the baseline in the soil at one station. Six metals were at a concentration above the baseline in soil at another station, while two or three metals were at a concentration above the baseline in the soil at other stations. Chromium was the most often and significantly enriched metal, at a concentration above the baseline at all stations. Copper was at a concentration above the baseline at two of the six stations. The soil at all stations was thus contaminated by metals. The difference between the 2008 and 2024 surveys was thus pronounced for several metals, most notably chromium and to a lesser degree manganese.

The metal contamination of sediment in the Berth 605 Project, as discussed above, was anticipated based on the findings of earlier surveys. However, the metal contamination of soil near the basin was not anticipated, at least not to the magnitude evident for some metals (*e.g.* chromium). The source of the chromium and other contaminant metals is uncertain. Magnetic particles and metal fragments were found in the soil at some stations, which might account for some of the elevated metal concentrations. However, the high metal concentrations could also reflect the presence of magnetite in the soil, which occurs naturally in the Richards Bay area and is additionally exported through the port. A more detailed study will be required to identify the composition of the material (*e.g.* by X-ray diffraction), but this was beyond the scope of the study and has no bearing on deciding if the soil is suitable for open water disposal.

In the absence of other information, the chromium concentrations above the Level II in soil near the 600 Berth Basin are interpreted as posing a high toxic hazard to biological resources if the Level II is considered to also be relevant to soil placed in water. The soil was tested for toxicity in the same way as was sediment (see Section 5.1.9 of this specialist study). Apart from Station 15, the soil was not toxic to sea urchin gametes when tested using soil-water interface and elutriate toxicity tests. The chromium concentrations, other metals, and unmeasured chemicals in the soil were thus clearly in a non-bioavailable

form, or if so they were at too low a concentration to be toxic to sea urchin embryo-larvae. Metals and other possibly noxious chemicals are thus unlikely to be remobilised into the water column to a degree this will pose a toxic hazard to biological resources when the soil excavated across most of the Berth 605 Project footprint deposits on the seabed at the dredged spoil disposal site off the Richards Bay coast. There is a possibility this might be the case when soil excavated at and near Station 15 is disposed at the dredged spoil disposal site. However, only two dilutions with clean site water were required to render the raw elutriate for this station not toxic. A far higher number of dilutions can be expected at the dredged spoil disposal site in the marine environment, even at very low current velocities. Any toxic effect that might occur will thus be restricted to an inconsequentially small area at the point of disposal. It is worth reiterating that while the soil at Station 15 was identified as severely toxic in both toxicity tests, this terminology is somewhat misleading since embryos managed to develop to a mix of blastula, gastrula and early prism stages. The chemicals causing the delayed development (toxicity) were thus not at a high enough concentration to cause the mortality of (all) embryos.

5.2 Biotic Environment

5.2.1 Microalgae

Microalgae are single celled plants that live independently or in colonies. Microalgae that remain suspended in the water column are referred to as phytoplankton, while those that live on the bottom substrate are referred to as microphytobenthos. As their name implies, microalgae are small, usually invisible to the naked eye, but they may become indirectly visible when they form colonies or when they are present at such high densities in water column (called a bloom) that they discolour the water. They may also reach high densities on sediment in the intertidal, discolouring the sediment (usually a green colour). Microalgae are important to the ecological functioning of estuaries as they contribute to the primary productivity of these systems (*i.e.* they form the base of food webs). The productivity of many other biological resources, such as zooplankton, bivalves, worms, mussels and fish, depends on the productivity of microalgae.

There appears to be no information on the species composition of microalgae and microphytobenthos in the Port of Richards Bay, at least not in the peer reviewed scientific literature. Chlorophyll-*a*, which is the main green pigment in plants that is responsible for photosynthesis, is used in water quality monitoring programmes as a surrogate indicator for phytoplankton and microphytobenthic biomass. The CSIR (unpublished data) has measured the chlorophyll-*a* concentration in the water column in the Port of Richards Bay for various studies and research. The chlorophyll-*a* concentration was usually low to moderate, but was periodically elevated in the Bhizolo-Manzanyama Canal complex, Mzingazi Canal and 600 Berth Basin areas of the port (Figure 65). The conclusion that can be reached from the surveys is that the concentrations of nutrients and other environmental conditions are such that they periodically promote the growth of microalgae to bloom status, that is, growth above the normal situation. As discussed above, nutrient concentrations (notably orthophosphate) in the Bhizolo-Manzanyama Canal complex and in the 600 Berth Basin are periodically elevated because of anthropogenic inputs.

Microphytobenthos live in the surface few millimetres of bedded sediment where there is adequate light to sustain their photosynthetic requirements. Apart from their role in primary productivity and forming the base of food webs, they perform an important (bio)stabilising effect on sediment. Benthic diatoms, for example, produce extracellular polymeric substances that create a biofilm on the sediment surface that increases the critical threshold for erosion, thereby reducing bed erosion and sediment resuspension (Malarkey *et al.*, 2015; Parsons *et al.*, 2016). No measurements on microphytobenthic chlorophyll-*a* concentrations appear to have been made in the Port of Richards Bay, or at least this information has not been published in the peer reviewed scientific literature. However, small areas of muddier sediment in the intertidal in the 600 Berth Basin presented a green tinge during a field survey in 2024, reflecting a high

microphytobenthic biomass that will contribute to the primary productivity in the basin. Similar discolouration was not evident in the Assembly Basin, but the sediment here is less stable and coarser (in part due to wind driven waves) and this may prohibit the formation of dense accumulations.

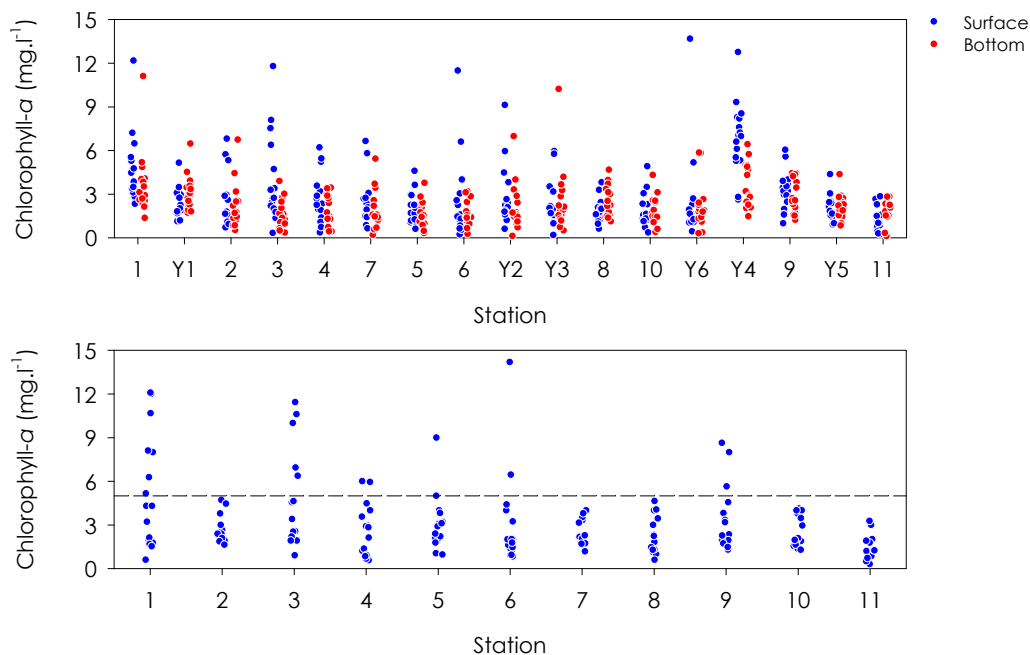


Figure 65. The chlorophyll-a concentration of surface and bottom water in surface and bottom water in the Port of Richards Bay in 15 surveys between 2015 and 2024.

5.2.2 Macroalgae

Macroalgae (seaweeds) are an insignificant component of the primary producer community in the Port of Richards Bay since the substrate across most of the port is characterised by sediment, making it difficult for many macroalgal species to establish as they require a hard substrate. Macroalgae are largely restricted to floating structures (*e.g.* navigation markers, walk on moorings in yacht mole in Mzingazi Canal) and on dolosse forming breakwaters in and near the Entrance Channel to the port (B Newman, CSIR, personal observation). In the Berth 605 Project footprint, the only macroalga that is present to any degree worth mentioning is the chlorophyte *Ulva* sp. (sometimes known as sea lettuce) that fouls navigation markers. It is, however, not found on quay walls, nor on rocks in the intertidal in the basin (a common habitat on the coast). The growth of this macroalga on navigation markers in the 600 Berth Basin is often luxurious, with fronds on some markers reaching ~1 m in length. Fronds of this length are highly anomalous—on rocky shores in KwaZulu-Natal the fronds of this macroalga are usually <15 cm in length (and often shorter) (B Newman, CSIR, personal observation). Although *Ulva* sp. fouls navigation markers and floating structures elsewhere in the Port of Richards Bay, the growth is not nearly as luxurious as it is on markers in the 600 Berth Basin. The luxurious growth of *Ulva* sp. on navigation markers in the 600 Berth Basin must reflect favourable nutrient concentrations and other environmental conditions, but as discussed above nutrient concentrations in the basin are usually not particularly high nor are they markedly different on average to other parts of the port. There is evidence to suggest that orthophosphate concentrations in the Port of Richards Bay are elevated and it might be the nutrient responsible for the luxurious growth even though nitrogen is typically the limiting nutrient in marine ecosystems and phosphorous is typically the limiting nutrient in low salinity waters. This still, however, does not account for the luxurious growth being restricted to this basin. Furthermore, *Ulva* sp. also fouls navigation markers in the Port of Durban, in which orthophosphate concentrations are also often high, yet the growth is far less luxurious—fronds are rarely longer than ~10 cm. Further research is needed to understand factors that favour and promote the luxurious growth of *Ulva* sp. on navigation markers in the 600 Berth Basin, but this is not necessary for the Berth 605 Project.

5.2.3 Saltmarshes

Saltmarshes cover a comparatively small area (~70 ha) compared to other typical estuarine vegetation in the Port of Richards Bay, being restricted to the upper intertidal largely in the Kabeljous Flats area (inland of mangroves) and the Bhizolo-Manzanyama Canal complex where salt water from spring tides is left behind on evaporation pans (van Niekerk *et al.*, 2019; S Weerts (CSIR), B Newman (CSIR), personal observation). Over time, the hyper accumulation of sea salts has left the sediment saline. Only a small number of plants can tolerate such high salinities. Less than 5% of the saltmarsh area is covered with plants, meaning >95% of the sediment is bare and salt encrusted. The dominant salt marsh plants include *Sarcocornia natalensis*, *Juncus kraussii*, *Sporobolus virginicus* and *Paspalum vaginatum*, herbs, such as *Apium graveolens* and *Salicornia pachystachya* (Adams *et al.*, 2016; cited in DEA, 2017).

5.2.4 Seagrass

The seagrass *Zostera capensis* was an important botanic element in the Richards Bay Estuary prior to the development of the Port of Richards Bay, reportedly covering an area of ~62 ha near the mouth (EAS, 1996). Numerous species of juvenile fish and prawns were particularly abundant in the seagrass beds, which constituted an important nursery habitat (Millard and Harrison, 1954). The seagrass beds disappeared during port development, due to a combination of habitat loss and excessive turbidity and siltation. Seagrass was transplanted to the Mhlathuze Estuary from the St Lucia Estuary in 1991, and by 1999 beds covered an area of ~29 ha (Cyrus *et al.*, 2000). Attempts to transplant seagrass to the Port of Richards Bay at about the same time failed (Weerts, 2002). The presence of seagrass in the Mhlathuze Estuary has a significant influence on that estuary's macrocrustacean and fish diversity through its role as nursery habitat, as it did in the Richards Bay Estuary prior to port development (Forbes and Cilliers, 1999; Weerts, 2002; Weerts and Cyrus, 2002; Vivier and Manukuza, 2020—cited in Cyrus and Vivier, 2021a). Of particular interest is the marked preference shown for seagrass habitat by the juveniles of fish families that are highly targeted by the recreational angling community—this is illustrated by the fact that >80% of Sea Breems (Sparidae), Emperors (Lethrinidae), Snappers (Lutjanidae), Rockcods (Serranidae) and Barracudas (Sphyraenidae) sampled Weerts (2002) were recorded in seagrass beds.

In 2014, a bed of seagrass was discovered in the small tidally influenced pool inland of the Assembly Basin in the Berth 605 Project footprint (Mostert, 2014). Cyrus and Vivier (2014a,b) estimated that seagrass covered about 40% of the shallow water habitat in the pool. However, a field survey by CSIR scientists in November 2024 showed that the seagrass was no longer present. The reasons for the loss of the seagrass are unknown since conditions in the pool, such as the sheltered habitat and clear water, appear outwardly well suited to supporting seagrass. A possible explanation is shading by mangrove trees. At the time that Cyrus and Vivier (2014a,b) surveyed the pool in 2014, mangrove trees fringing the pool were not particularly dense nor particularly tall (concluded from photos provided). However, mangrove trees were both dense and tall in 2024, and because of the small size of the pool cast shade over a large part of the shallow water habitat in the pool.

An important issue that emerges from the reestablishment of seagrass beds in the small tidally influenced pool, but its absence elsewhere in the port, is the specific conditions that seagrass requires to establish. If biodiversity compensation in the Port of Richards Bay is planned with seagrass reestablishment in mind, there is every reason to suspect seagrass could be returned to the port if the compensation is properly planned. The return of seagrass beds could potentially allow compensation for habitat loss due to infrastructure development in the port to be of a smaller size than a like-for-like compensation area, due to the high ecological value of seagrass habitat.

5.2.5 Mangroves

Mangroves are the most conspicuous botanic element in the Port of Richards Bay and neighbouring Mhlathuze Estuary. Mangroves were an important botanic element of the Richards Bay Estuary prior to port construction, but the conditions created by port construction, and in the Mhlathuze Estuary by river diversion and associated siltation and larger tidal range due to the new mouth, promoted the establishment of mangroves in these systems to a degree the Port of Richards Bay (~333.3 ha) and Mhlathuze Estuary (~1439.1 ha) now support ~77% of the total mangrove habitat in South Africa (~2301.7 ha; Riddin *et al.*, 2024). The significant contribution that the Port of Richards Bay and Mhlathuze Estuary make to the spatial extent of mangroves highlights the rarity of these forests in South Africa. Mangroves are under increasing threat in most estuaries in South Africa. Apart from the Mhlathuze Estuary and the Port of Richards Bay, there has been a loss of 40% of mangrove area in other estuaries over the last 50 years (Riddin *et al.*, 2024). Mangrove forests in South Africa are classified as Endangered (Riddin *et al.*, 2024), further emphasising the importance of the enabling environment provided for mangroves in the Port of Richards Bay and Mhlathuze Estuary.

There are three major mangrove forest areas in the Port of Richards Bay—at the eChwebeni Natural Heritage Site, fringing the Kabeljous Flats and extending from there into the Bhizolo-Manzanyama Canal complex and along the berm to the southern part of the Richards Bay Coal Terminal Basin, and in the so-called Casuarinas area (Figures 10 and 11). Mangroves also fringe the uppermost part of Mzingazi Canal, while there is a small mangrove stand alongside the eastern most part of the 700 Berth Basin. Three species of mangrove are found in the port, namely White (*Avicennia marina*), Black (*Bruguiera gymnorhiza*) and Red (*Rhizophora mucronata*), but White Mangroves are by far the most abundant (Mostert, 2014). In fact, the other species are relatively rare and the mangrove forests in some parts of the port are essentially monospecific. Despite their transformation, low species diversity and evidence for being anthropogenically impacted, the functionality of mangrove forests in the port is high (Mostert, 2014).

In the Berth 605 Project footprint, a narrow band of white and black mangroves fringe the small tidally influenced pool inland of the Assembly Basin, while a few scattered mangrove trees have established in the Assembly Basin (see further below). Mostert (2014) considered the ecosystem functionality of the mangroves fringing the small tidally influenced pool to be very high. These mangroves will be lost through the development of Berth 605. As mentioned earlier, there is an extensive mangrove forest fringing the Kabeljous Flats to the south of the Sandspit near the project footprint, but this forest, nor other forests in the port will not be directly affected by the development of Berth 605.

The National Forests Act, 1998 (Act 84 of 1998), Section 3 states that “...natural forests may not be destroyed unless in exceptional circumstances where, in the opinion of the Minister, a proposed new land use is preferable in terms of its economic, social or environmental benefits”. Section 7 of the Act prohibits the cutting, damaging, disturbance, destruction and removal of any indigenous living or dead protected tree in a forest without a licence. Mangroves are protected according to the Act. The removal of mangroves that fringe the tidally influenced pool inland of the Assembly Basin, and in the Assembly Basin itself will thus need to be motivated to the Minister, and a licence secured. A case of “exceptional circumstances” for their removal would be the construction of Berth 605 to enhance the economy in northern KwaZulu-Natal and South Africa.

5.2.6 Zooplankton

Zooplankton are microscopic and macroscopic invertebrate animals that either float or swim in open water. There are two groups of zooplankton. The holoplankton spend their entire life in the plankton. Common holoplankton include copepods, mysids and chaetognaths. The meroplankton, in contrast, spend only a part of their life in the plankton and include the larval forms of gastropods, bivalves, barnacles, polychaetes

and crabs. The distribution of many zooplankton species is largely controlled by tides and currents, but many have a surprising ability to regulate their position in the water column in such a way they can move in a direction that allows them to remain in an area or to move between areas in a semi-controlled manner. The productivity of many biological resources, including bivalves, worms, mussels and fish, depend on zooplankton as a food source.

The zooplankton in the Port of Richards Bay has received little attention and important, if somewhat academic, questions remain on whether the larvae of estuarine invertebrates are exported to the marine environment to escape the variable salinity, as is the case in most estuaries, or can complete development in the port due to its stable salinity. Jerling (2008) surveyed zooplankton in the Port of Richards Bay and Mhlathuze Estuary at nearly monthly intervals from February 1996 to February 1997. The zooplankton community in the port was relatively diverse, but the density was quite low when compared to many South African estuaries. The zooplankton community that characterised the Richards Bay Estuary prior to port development was dominated by 'typical' estuarine zooplankton, but particularly by the copepods *Pseudodiaptomus stuhlmanni* and *Acartia natalensis* (Grindley and Wooldridge, 1974). However, by the time Jerling (2008) performed his study these had given way to a community dominated by marine taxa, notably the paracalanid copepod *Parvocalanus crassirostris* and cyclopoid copepod *Oithona* spp. The shift was attributed to the strong marine influence in the port. Copepods and their instars were by far the most abundant component of the zooplankton (94% of total density) in Jerling's (2008) study. The zooplankton community across the port was fairly uniform, probably reflecting the uniform salinity across most of the port. Estuarine copepod taxa that dominated the Richards Bay Estuary prior to port development were found in appreciable numbers only in the Bhizolo-Manzanyama Canal complex and Mzingazi Canal, where there is some freshwater inflow, but at much lower densities than in the past (Jerling, 2008). There appears to be no recent information on the zooplankton community in the Berth 605 Project footprint. However, the community is likely similar to that in the middle part of the 700/800 Berth Basin, where Jerling (2008) recorded 26 taxa.

The copepod, *Acartia spinicauda*, which is a non-native (alien) species is found in the Port of Richards Bay. The copepod likely reached the port in ballast water (Jerling, 2008).

5.2.7 Ichthyoplankton

Ichthyoplankton are the eggs and larval forms of fishes. The Port of Richards Bay provides important habitat for many fish that spend their entire life in estuaries, but also for fish that reside as adults in the marine environment and use estuaries as a nursery during their juvenile phase (Cyrus and Forbes, 1996; Weerts, 2002; MER, 2013). Several studies have recorded the occurrence of eggs and larvae of marine and estuarine fish in the port (Harris and Cyrus, 1997; Jerling, 2008). Harris and Cyrus (1997) recorded the larvae of 105 taxa from 53 fish families in 12 surveys made in the entrance to the port in 1991 and 1992. Species from the families Engraulidae (anchovies; 50.0%) and Gobiidae (gobies; 36.5%) dominated the total catch. The most abundant larvae were those of the Thorny Anchovy *Stolephorus holodon* and an unidentified goby. Other abundant species included Orangemouth Anchovy *Thryssa vitirostris*, Bulldog Eelgoby *Taenioides esquivel*, Indian Pellona *Pellona ditchela*, and Burrowing Goby *Croilia mossambica*. Marine spawners that do not depend on estuaries contributed 72.4% of all the taxa recorded, but they did not dominate in terms of total density. Rather, estuarine associated taxa were numerically dominant, with 11 of the 28 estuarine dependent taxa recorded being dependent on estuaries at some stage in their life. The larvae of several fish targeted by recreational anglers and commercial fishers were recorded, including Spotted Grunter *Pomadasys commersonnii* and various Kob *Argyrosomus* spp. The fish larval community composition in the Port of Richards Bay was intermediate between a 'typical' estuary, like the St Lucia Estuary (Harris and Cyrus, 1995), and a marine-dominated habitat, like the Port of Durban (Harris, 1996), since both estuarine- and marine-associated species dominated the catch. Turbidity and temperature were found to be significant variables accounting for the variation in the larval density of estuarine-dependent

species in the entrance to the port. Turbidity may, therefore, provide a recruiting cue for the larvae of estuarine-dependent fish species to the port (Harris and Cyrus, 1997).

5.2.8 Benthic macrofauna

Estuarine benthic macrofauna are typically defined as invertebrate animals >0.5 mm in size that live in and on sediment, including gastropods, bivalves, polychaetes, oligochaetes and several types of crustaceans (amphipods, isopods, crabs, shrimp). Benthic macrofauna are widely used as indicators of the health of the sediment environment in aquatic systems. They may be suspension feeders, predators, or decomposers. They form an important link in the marine food web by coupling pelagic and benthic environments and are an important food source for other biological resources, such as fish and water birds. The composition and structure of benthic macrofaunal communities varies in response to natural variations in water (*e.g.* salinity) and sediment (*e.g.* grain size), depending on species specific preferences and tolerances, hydrological conditions and biotic interactions (*e.g.* competition, predation). A change in environmental conditions usually results in a change in benthic macrofaunal community composition. Benthic macrofaunal community composition may also be affected by anthropogenic pressures. The species that make up the benthic macrofaunal community respond differently to anthropogenic pressures. Exposure to contaminants may thus cause a shift in the dominance of certain benthic macrofauna, and in extreme cases the loss of these animals.

The species composition, abundance and distribution of the benthic macrofauna in the Port of Richards Bay is well documented. The port has a diverse benthic macrofaunal community that comprises a mix of estuarine and marine taxa, although most have a marine origin. The CSIR (2008) recorded 113 benthic macrofaunal taxa in six surveys made at approximately two-month intervals in 2004-2006. The highest number of taxa sampled in any survey was 36 and 39 at two stations on the Kabeljous Flats. However, the number of taxa recorded at each station was variable amongst surveys. The benthic macrofaunal community at a station in the Bhizolo-Manzanyama Canal complex (below the confluence of the canals) was dissimilar to the communities at other stations, probably reflecting this station being more affected by freshwater flows (and possibly pollution) than other stations due to its position in the canal complex. The benthic macrofaunal communities at other stations were variable and no distinct similarity could be distinguished—each station supported a unique array of taxa, probably reflecting species preferences and tolerances to the local conditions.

Izegaegbe *et al.* (2020) analysed the benthic macrofaunal community at seven stations in the Port of Richards Bay on a quarterly basis in 2016 and 2017. The stations represented a range of the habitats in the port, including the 600 Berth Basin, Kabeljous Flats, Bhizolo-Manzanyama Canal complex, and Mzingazi Canal. A total of 98 benthic macrofaunal taxa were recorded across the stations, dominated numerically by the crustaceans *Halmyrapseudes digitalis* (a small shrimp-like animal) and *Paratylodiplax blephariskios* (a small crab), and the polychaetes (worms) *Mediomastus capensis*, *Aphelochaeta marioni* and *Prionospio sexoculata*. The most impoverished community was found in the 600 Berth Basin. The variability in benthic macrofaunal communities amongst stations was largely influenced by environmental variables, notably sediment grain size and total organic content and water column depth, rather than by sediment metal concentrations. Sediment grain size appeared to be the single most important variable structuring the communities. The benthic macrofaunal community at a station in the 600 Berth Basin was strongly correlated with concentrations of cadmium, copper, chromium, nickel and zinc in the sediment, suggesting the community was potentially affected by metal exposure. Izegaegbe *et al.* (2020) used a biotic index to evaluate the status of the benthic macrofaunal communities and their habitat. The index has four ratings, namely poor, moderate, good and high. The highest benthic macrofaunal habitat quality (good) was at stations on the Kabeljous Flats, in the Shark Basin, on a sandflat near the Small Craft Harbour, and on an intertidal mudflat in a shallow water basin near the port entrance. The habitat quality at a station in the lower part of the Bhizolo-Manzanyama Canal complex, at a station in the 600 Berth Basin, and at a station

in the upper part of Mzingazi Canal was rated moderate.

Cyrus and Vivier (2021) also found that benthic macrofaunal communities on the Kabeljous Flats were dominated by polychaetes, followed by molluscs and crustaceans. They recorded 98 taxa at 26 stations that were largely positioned on or near the Kabeljous Flats. The benthic macrofaunal community on the Kabeljous Flats was distinct from, and more species diverse than communities in deeper water sediment habitat in the Richards Bay Coal Terminal Basin and in shallower water sediment habitat to the north of the Sandspit. The highest species richness and species diversity was at site in the shallow intertidal zone to the immediate south of the Sandspit, suggesting this area is of particular ecological importance to benthic macrofauna. Cyrus and Vivier (2021) used a biotic index to evaluate the status of the benthic macrofaunal communities and their habitat. The index has four ratings, namely poor, moderate, good and high. The benthic macrofaunal habitat quality at stations on the Kabeljous Flats was consistently rated high, compared to good to high in areas to the north and moderate to good in areas to the east of the Sandspit. The high species diversity of benthic macrofaunal communities recorded on the Kabeljous Flats by Vivier and Cyrus (2021) is consistent with studies by the CSIR (2008), MER (2013) and Izegaegbe *et al.* (2020).

Benthic macrofaunal communities in some intertidal and shallow subtidal sediment habitats in the Port of Richards Bay are not as species diverse as on the Kabeljous Flats. Vivier and Cyrus (2014) recorded only 13 taxa in intertidal mangrove channels near the Small Craft Harbour, compared to 24 taxa on a nearby sandflat habitat. The species composition was different amongst these habitats. The community in the intertidal mangrove channels was dominated numerically by a few bivalve species, while the community on the sandflat was dominated by amphipods (one species was particularly dominant), a bivalve, and various polychaete species. Mean densities were lower in the intertidal mangrove channels than on the sandflat. Vivier and Cyrus (2014) concluded that the low species diversity in the intertidal mangrove channels was related to the unusually sandy (medium-grained sand) nature and very low particulate organic matter content of the sediment. Sediment on the intertidal sandflat was dominated by fine-grained sand with an even lower particulate organic matter content than in the intertidal mangrove channels.

Vivier and Cyrus (2014) and Cyrus and Vivier (2021) found that polychaetes dominated benthic macrofaunal communities in deepwater sediment habitat at two sites near the Finger Jetty in the 700/800 Berth Basin.

In 2024, the CSIR surveyed the benthic macrofaunal community at 23 stations in the Port of Richards Bay. Most of the stations were in deeper water channels and basins. A total of 103 taxa were identified across the stations. At the station level, the number of taxa ranged from lows of three taxa at a site in the Entrance Channel and nine taxa at a site at the base of the Finger Jetty in the 700/800 Berth Basin to highs of 28 taxa at a station alongside the Repair Quay and 30 taxa at a station in the innermost part of the Small Craft Harbour. Polychaete worms (particularly capitellids, cirratulids and sigambrids) were the most abundant taxa, contributing $\geq 50\%$ of the total abundance at all but three of the stations (Figures 66 and 67). Bivalves, gastropods, sipunculids and scaphopods were important at many stations. The status of the benthic macrofaunal communities surveyed by the CSIR in 2024 was evaluated using a biotic index that describes the ecological integrity of the habitat based on the sensitivity of different taxa to pollution and habitat disturbance. The benthic macrofaunal communities spanned the range from undisturbed through to heavily disturbed. Although the disturbance ratings at some stations seem logical, at other stations the ratings appear to hold little relevance.

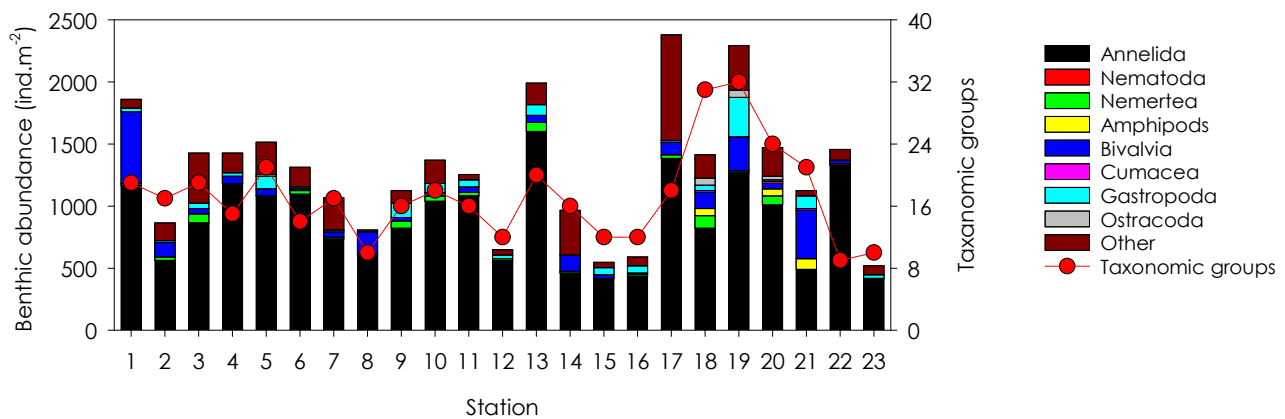


Figure 66. Abundance and number of taxonomic groups comprising the benthic macrofaunal community in sediment sampled in the Port of Richards Bay in June 2024.

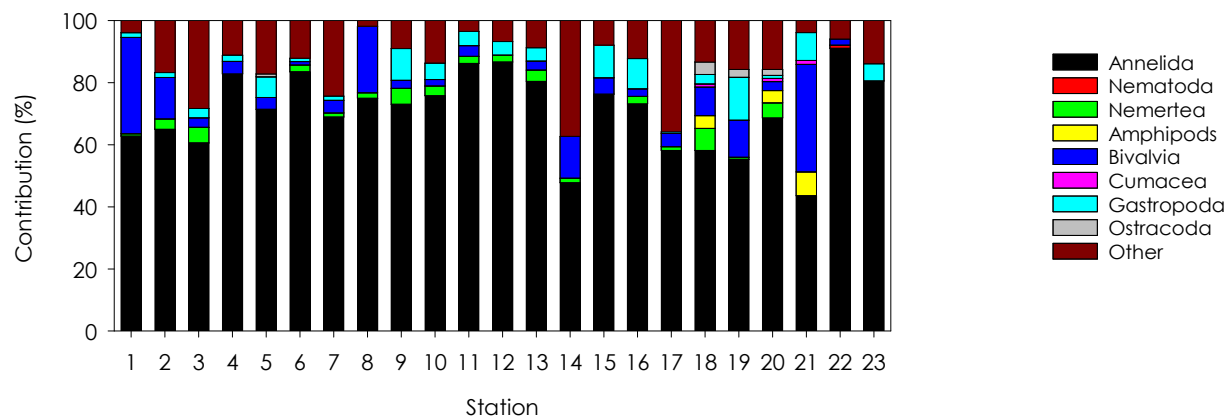


Figure 67. Contribution of various taxonomic groups to benthic macrofaunal abundance in sediment sampled in the Port of Richards Bay in June 2024.

Benthic macrofauna in and near the Berth 605 Project footprint were surveyed in certain of the above studies. In 2024, the CSIR recorded 17 and 18 benthic macrofauna taxa at two stations in the 600 Berth Basin. Polychaete worms contributed by far the largest number of animals to the total abundance at one station ($\sim 90\%$ of the 1659 animals.m²), while polychaete worms and bivalves contributed about equally to the total abundance at the other station ($\sim 48\%$ of the 2453 animals.m²). The findings on the benthic macrofaunal community sampled at a station in the 600 Berth Basin by Izegaegbe *et al.* (2020) were discussed above. As a brief repeat, the community at this station was more impoverished in terms of number of taxa and usually also abundance compared to other stations sampled in the port. The benthic macrofaunal communities sampled at five stations in the 600 Berth Basin in 2022 by Malan *et al.* (2023) were generally less species diverse and abundant than communities sampled in four areas elsewhere in the port, namely the 700/800 Berth Basin, the Richards Bay Coal Terminal Basin, Small Craft Harbour and lower part of Mzingazi Canal. A total of 58 taxa were recorded across all stations.

The overall impression from the above (and other unmentioned) studies is that benthic macrofaunal communities in deeper water sediment habitat in some parts of the 600 Berth Basin show evidence for anthropogenic disturbance, which probably reflects a combination of vessel propeller wash, maintenance dredging, and the accumulation of coal fragments, coal particles and other debris in the sediment. Izegaegbe *et al.* (2020) were of the opinion that the structure and composition of the benthic macrofaunal community they sampled repeatedly at a station in the 600 Berth Basin was reflective of metal exposure. Although this cannot be disproved, metal exposure (toxicity) seems an unlikely factor contributing to the composition and structure of the benthic macrofaunal community in the light of the toxicity testing of sediment sampled in the basin in 2024, which, as discussed earlier, provided no evidence the sediment was toxic to sea urchin embryo-larvae despite the presence of high metals concentrations in the sediment.

A further impression from studies on benthic macrofauna in the Port of Richards Bay is that the species diversity of these fauna is higher and unique on the Kabeljous Flats compared to other sediment habitat in the port, further emphasizing the ecological importance of the flats.

Despite being a large and busy port, the benthic macrofaunal community in the Port of Richards Bay compares favourably with the neighbouring essentially unpolluted Mhlathuze Estuary (Izegaegbe *et al.*, 2020). The benthic macrofaunal community across the port was in fact more species diverse than in the Mhlathuze Estuary during 2016-2017 (Izegaegbe *et al.*, 2020).

5.2.9 Macrocrustacea

The term macrocrustacea is a loose term, but it is usually used to refer to decapod crustaceans (*e.g.* swimming and burrowing prawns, shrimps and crabs) that are larger than ~1-1.5 cm in size. The term is also often used to refer to decapod crustaceans that are conspicuous because of their size, or that are captured by trawling or seining with nets rather than through grab sampling of sediment, but in this study the term is used to refer to all 'large' forms of prawns, shrimps and crabs, even though some are more often considered to be part of the benthic macrofauna.

Weerts and Newman (2007) recorded 30 macrocrustacean taxa in the Port of Richards Bay, including 15 swimming and burrowing prawn species, 12 true crab species, two hermit crab species, and a species of snapper shrimp. A study in the Bhizolo-Manzanyama Canal complex and on the Kabeljous Flats yielded 34 macrocrustacean species, including five swimming prawn species, a burrowing sandprawn and 20 true crab species. The species recorded in these studies do not represent the entire macrocrustacean community in the port. Macrocrustacea that associate with hard substrata, such as quay walls, breakwaters and floating structures (walk-on moorings and navigation markers) are poorly studied, yet host at least 11 crab species (B Newman (CSIR), unpublished records). The macrocrustacea that associate with hard substrates in the port are generally stenohaline marine rocky shore and reef species that have managed to colonise hard substrates in the port due to the uniform and high salinity of the water column. These species are not recorded in most estuaries in KwaZulu-Natal due to a combination of the lack of the hard substrate they rely on and variable and often low salinities in the water column that they are unable to tolerate.

Most swimming prawns have a marine adult phase. Spawning and larval development occur at sea. The post-larvae recruit to and use estuaries and sheltered coastal waters as a nursery. Juveniles return to the sea to complete their life cycle (Forbes *et al.*, 1994). The Richards Bay Estuary provided rich feeding and nursery habitat for swimming prawns prior to port development, particularly the extensive seagrass beds (Millard and Harrison, 1954). The Port of Richards Bay continues to provide nursery habitat for swimming prawns, albeit much diminished when compared to the original estuary due to habitat loss (primarily seagrass beds) and modification.

Weerts *et al.* (2003) recorded 15 species of freshwater, estuarine and marine swimming prawns in the Port of Richards Bay during eight surveys between 1996 and 1997. However, the catch was predominantly composed of four species: *Acetes erythraeus*, *Palaemon peringueyi*, *Metapenaeus monoceros* and *Penaeus japonicus*. The mangroves around the Kabeljous Flats and in the Bhizolo-Manzanyama Canal complex were identified as the most important habitats for swimming prawns in the port. These areas accounted for 13 of the 15 recorded species and more than 90% of the total catch. Weerts *et al.* (2003) attributed the high abundance and diversity of swimming prawns in these areas to the turbid waters that provide protection from predators and the muddy sediment in which many swimming prawns apparently prefer to feed.

Cyrus and Vivier (2021) surveyed the swimming prawn community at several locations in the Port of Richards Bay, including sites on the Kabeljous Flats, two sites north of the Sandspit, a single site in the Assembly Basin within the Berth 605 Project footprint, and another site in Shark Cove at the southernmost

part of the Richards Bay Coal Terminal Basin. The abundance and number of swimming prawn taxa recorded were significantly lower than those reported by Weerts *et al.* (2003). Six swimming prawn species were identified: three penaeid, two caridean and one sergestid. Very few prawns were found at sandy-bottom sites south of the Sandspit (one individual) and in the unvegetated shallows on the Kabeljous Flats (six individuals at one site). No prawns were recorded at sandy-bottom sites on the northern side of the Sandspit. Cyrus and Vivier (2021) suggested this absence might reflect the prawns preference for turbid waters and muddy, organically rich sediment (de Freitas, 1986; de Villiers *et al.*, 1999). The highest abundance and diversity of taxa (five species) were recorded in the Assembly Basin within the Berth 605 Project footprint. A notable abundance of prawns was also observed near mangroves in the area where the narrow channel connects the 600 Berth Basin to the Kabeljous Flats—however, only two species were represented. In Shark Cove, a low abundance of prawns comprising two species was recorded. These findings indicate a significant decline in the abundance and diversity of swimming prawns on the Kabeljous Flats. Cyrus and Vivier (2021) cautioned that their results reflect a once-off study during daylight when swimming prawns are less active and often shelter to avoid predation. However, the time of day does not fully explain the observed decline since the surveys by Weerts *et al.* (2003) were also made during daylight.

Encouragingly, a survey in 2020 by Vivier and Manukuza (cited in Cyrus and Vivier, 2021) revealed an order of magnitude higher abundance of swimming prawns in the Bhizolo-Manzanyama Canal complex. However, consistent with the findings of Cyrus and Vivier (2021), only three of the seven penaeid prawn species known to occur along the KwaZulu-Natal coastline (Forbes and Forbes, 2013) were recorded (*Penaeus indicus*, *Penaeus monodon* and *Metapenaeus monoceros*).

In a 2014 survey, Vivier and Cyrus (2014a,b) recorded no swimming prawns in sand-dominated intertidal mangrove channels and on an intertidal sandflat near the Small Craft Harbour. This absence of swimming prawns might be attributable to the same factors limiting prawn presence in sandy, clearwater habitats north of the Sandspit. The absence or low abundance of swimming prawns in these habitats underscores the importance of the Kabeljous Flats and Bhizolo-Manzanyama Canal complex as prawn habitat. Also important is the small tidally influenced pool-like area inland of the Assembly Basin. Although the swimming prawn community was not sampled quantitatively, each of several hauls made in the basin with a fine-mesh size net by CSIR scientists in November 2024 revealed an abundance of swimming prawns.

The nursery habitat provided by Port of Richards Bay, Mhlathuze Estuary and St Lucia Estuary for penaeid swimming prawns historically supported a small, yet important commercial fishery on the Thukela Banks on the northeast coast of South Africa (Demetriades, 1990; Cyrus and Forbes, 1996; Weerts, 2002; Weerts *et al.*, 2003, CSIR, 2005; Forbes and Demetriades, 2005; Vivier and Cyrus, 2009). Forbes and Demetriades (2005) argued that the Port of Richards Bay contributed as much as 30-40% to the offshore commercial catch. The essentially permanent closure of the St Lucia Estuary mouth since 2008 and concomitant loss of this nursery habitat means the nursery habitat in the Port of Richards Bay is critical for the recovery of breeding populations of penaeid swimming prawns (Cyrus and Vivier, 2021). However, there appears to have been a decline in the nursery value, or at least functioning, of the Port of Richards Bay for penaeid swimming prawns (MER, 2013; Cyrus and Forbes, 2021), evident in declines in the Thukela Banks fishery to the extent it is no longer commercially viable (but compounded by environmental conditions in the St Lucia Estuary). The dependence on estuaries in the lifestyle of penaeid swimming prawns not only emphasises the ecological link between estuaries and the marine environment (MER, 2013) but also how infrastructure development in the Port of Richards Bay (nursery habitat loss) has ramifications beyond the port.

Although intertidal crabs are obviously the most conspicuous macrocrustaceans in the Port of Richards Bay, often occurring at high to very abundances in the intertidal, crabs also inhabit the subtidal and in some areas also extend into or very near the supratidal. However, the crab community in the port has received surprisingly little attention. There is little doubt that shallow subtidal and intertidal sediment habitat,

including that in mangroves, supports a far larger crab abundance and biomass, and probably also species diversity, than does (largely artificial) hard substrata. Five species of sesarmid crabs (*Neosarmatium africanum*, *Neosarmatium smithi*, *Parasesarma catenatum*, *Chiromantes eulimene*, *Perisesarma guttatum*) and four of the five fiddler crabs (*Austruca occidentalis*, *Paraleptuca chlorophthalmus*, *Tubuca urvillei*, *Gelasimus vocans*) found in South Africa preferentially inhabit mangroves or areas near mangroves in the port, although one of the fiddler crabs and one of the sesarmid crabs are hardy and are found in a range of intertidal sediment habitats away from mangroves. These crabs are found only in estuaries in South Africa. Several other crabs that do not show such a strong association to mangroves, many of which are also restricted to estuaries for various reasons, are also found in the port. The Soldier Crab *Dotilla fenestrata* swarms on intertidal sandflats, Crown Crabs from the family Hymenosomatidae are found in muddy and sandy subtidal sediment in sheltered waters. Several species of ghost crabs *Ocypode* spp are common on exposed sandy shores. The Lunar Box Crab *Ashtoret lunaris* is found on sandy shores, where it hides beneath the sediment surface and its presence is usually only revealed opportunistically (e.g. in seine nets hauled for fish surveys). The Eastern Oval Crab *Paratyloidiplax blephariskios* is abundant in muddy subtidal sediment in parts of the port, including the Kabeljous Flats (Vivier and Cyrus, 2014; CSIR personal observation), Mzingazi Canal, and deeper water channels and basins (CSIR, unpublished data; Izegaegbe *et al.*, 2020). As alluded to above, many of the crabs are quite specific in the habitat they occupy, meaning the loss or disturbance of the habitat through infrastructure development will have population level impacts. As an example, the Soldier Crab is restricted to the intertidal where the sediment is sandy, largely because of its mode of feeding. It is never found on muddy intertidal sediment, including in mangroves, which tends to be occupied by sesarmid and fiddler crabs. The habitat dependence of the Soldier Crab is also driven by its burrowing lifestyle—it cannot burrow in coarse sandy sediment and is thus excluded from shores where the sediment is too coarse. The Eastern Oval Crab is found only in very muddy subtidal sediment, also due to its mode of feeding habit and burrowing lifestyle, it being a feeble crab that is unable to burrow in coarse sediment.

An important, if outwardly inconspicuous component of the macrocrustacea in the Port of Richards Bay due to its burrowing lifestyle is the Sandprawn *Kraussillichirus kraussi*, which very abundant on intertidal and shallow subtidal sandbank habitat in parts of the port. The high biomass of Sandprawns undoubtedly contributes importantly to the ecological functioning of the port.

There are numerous species of macrocrustacea in the Berth 605 Project footprint, but the full inventory is unknown. Where the substrate is sandy in the intertidal of the 600 Berth Basin and in the Assembly Basin, macrocrustacea include the Sandprawn *Kraussillichirus kraussi*, fiddler crab *Austruca occidentalis*, Soldier Crab *Dotilla fenestrata* and ghost crabs *Ocypode* spp. The abundance of these macrocrustacea is considerably lower than in similar habitat in many parts of the port (CSIR scientists, personal observation). Where the substrate in the intertidal comprises rocks, stones and rubble, a cursory survey showed the presence of two species of unidentified Xanthid Crab and a species of Porcelain Crab *Petrolisthes* sp, all of which were relatively common. The Eastern Oval Crab *Paratyloidiplax blephariskios* is fairly abundant in deeper water muddy sediment in parts of the 600 Berth Basin. As discussed above, Cyrus and Vivier (2021) recorded several species of swimming prawns (penaeids and carids) in the Assembly Basin.

The species diversity of macrocrustacea in the tidally influenced pool like area inland of the Assembly Basin is higher than elsewhere in the 600 Berth Basin. A non-quantitative survey by CSIR scientists in November 2024 revealed the presence of five species of sesarmid crabs, all four species of fiddler crabs recorded in the port, Mud Crab *Scylla serrata* and Sandprawn *Kraussillichirus kraussi*. All were present at a high abundance. Several species of swimming prawn (penaeids and carids) were recorded by netting. An interesting note here is Sandprawns occupying far muddier sediment than the sandy sediment with which it is normally associated in the port and other estuaries (and is the origin of its common name). It is clear the tidally influenced pool like area provides more ecologically valuable and productive habitat for

macrocrustacea than the 600 Berth Basin and Assembly Basin.

The macrocrustacea in the Port of Richards Bay constitute an important food source and are thus important in sustaining populations of fish and water birds. Included here are fish that use estuaries as a nursery but as adults reside in the sea, including fish targeted by recreational and commercial anglers and birds that migrate from the northern hemisphere. The loss of macrocrustacea supporting habitat in the port through infrastructure development will have implications for fish populations in the port and marine environment, and for bird populations in the port and internationally.

5.2.10 Fish

The importance of the Richards Bay Estuary as a nursery for fish (and macrocrustaceans, see above) was recognised before the development of the port based on the virtual absence of adult fish target by anglers, yet abundance of juveniles of these fish in research catches (Hemens *et al.*, 1970; Wallace, 1970). Seagrass *Zostera capensis* beds in the lower part of the estuary were recognised as important fish nursery habitat (Millard and Harrison, 1954). Although the Port of Richards Bay, in its modified state, is more marine than it was in its reference condition and no longer supports seagrass beds, one of its primary ecological values remains that of serving as a nursery for fish. The nursery value is underpinned by recruitment from the sea of marine spawned estuarine dependent species and the natural habitat within the port. The port is ranked as the third most important of 247 South African estuaries in terms of its importance to fish populations (Turpie *et al.*, 2002).

Fish surveys have invariably been restricted to shallow water areas in the port due to the gear used for the surveys (seine nets). Any consideration of the fish community must take this sampling limitation into account, but available evidence suggests it is the shallower water areas that offer the most valuable fish habitat. Reference is nevertheless made below to fish sampled using other gear.

Whitfield (1994) assessed the species composition of fish in southern African estuaries and allocated them to five categories based on their origins and the degree to which they depend on estuaries to complete their life cycle (Table 2). This scheme has since been widely adopted in studies on fish in South African estuaries, and reference is made to it below for fishes in the Port of Richards Bay.

Table 2. Life cycle categories for fish utilising estuaries in southern Africa (after Whitfield, 1994).

Category	Description
I	Estuarine species that breed in southern African estuaries. This category includes resident species that spawn only in estuaries, and species that also have marine or freshwater breeding populations.
II	Euryhaline marine species that usually breed at sea, with the juveniles showing varying degrees of association with southern African estuaries:
Ila	Juveniles dependent on estuaries as nursery areas.
Ilb	Juveniles occur mainly in estuaries but are also common at sea.
Ilc	Juveniles sometimes occur in estuaries but are more abundant at sea.
III	Marine stragglers that occur in estuaries in very small numbers and are not dependent on these systems.
IV	Freshwater species whose penetration into estuaries is determined primarily by salinity tolerance. This category includes a few species that may breed in both freshwater and estuarine systems. It also includes some freshwater stragglers seldom recorded in estuaries.
V	Obligate catadromous species that use estuaries as transit routes between the marine and freshwater environments.

Studies have reported variable numbers of fish species and abundances in the Port of Richards Bay, but species richness was generally high. Cyrus and Forbes (1996) sampled the sheltered mangrove areas on the south-western edge of the Kabeljous Flats, and while detailed information on the species composition was not provided, they recorded 53 species of which 63% were estuarine dependent marine species that utilise the mangrove habitat as a nursery area. Most of the fish caught were the juveniles of benthic feeders. Abundances were relatively low. Weerts (2002) recorded 64 fish species in the port, with 41 of these occurring on subtidal mudflats, 32 on subtidal sandflats, 24 in mangroves, and 26 in the Bhizolo-Manzanyama Canal complex. The fish community was dominated by various species of mullet, Glassies *Ambassis* spp (predominantly *Ambassis gymnocephalus*), Silver Sillago *Sillago sihama* and Anchovies *Stolephorus* spp, which accounted for 51.2%, 29.9%, 5.4% and 3.6% of the total catch respectively. Mullet and Glassies were mostly sampled over muddy areas along mangrove fringes, while Anchovies and Silver Sillago were mainly sampled over mudflats and sandbanks, respectively. Distinct fish communities were found in the different habitat types, showing the importance of each habitat type in supporting a unique fish assemblage. Estuarine-dependent marine species dominated in terms of abundance, comprising 83.7% of the total catch, with marine fishes contributing 14.4%. There were strong habitat and seasonal influences on the proportions of fishes with different estuarine affinities (Figure 68). Marine species were important components of fish assemblages at sandbanks on the Sandspit and in Mzingazi Canal and the Kabeljous Flats, but they did not contribute >7% to average abundances at three sites fringed with mangroves (Bhizolo-Manzanyama Canal complex, eChwebeni Heritage site, mangrove embayment on Kabeljous Flats). More than 90% of the fish caught on the Kabeljous Flats were euryhaline marine species that depend on estuaries, highlighting the importance of this habitat as a nursery area for juvenile marine fish (a role identified by Cyrus and Forbes (1996) and Forbes *et al.* (1996)). Conversely, estuarine-dependent marine species were relatively more abundant at mangrove sites than at unvegetated habitats. Estuarine spawning species only accounted for >10% of fish abundance on the Kabeljous Flats and at a mangrove embayment on the Kabeljous Flats. The relative lack of marine stragglers reflects the estuarine character of the habitats studied—if not in the physical and chemical properties of the water then in the nature of the habitats.

Nhleko and Cyrus (2008—cited in Cyrus and Vivier, 2021), in a comparative study on the species richness of fish in KwaZulu-Natal estuaries, reported a total of 80 species in the Port of Richards Bay, the 5th highest among the 72 estuaries in the province, after St Lucia, Kosi Bay, Mlalazi Estuary and Mhlathuze Estuary.

Vivier and Cyrus (2014) recorded 20 fish species in the 600 Berth Basin. Cyrus and Vivier (2021) recorded 41 species at sites on unvegetated parts of the Kabeljous Flats, near mangroves fringing the flats, near the Sandspit and in the Assembly Basin and Shark Cove. Malan *et al.* (2023) recorded 43 fish species at numerous sites across the port. In most studies, most fish sampled were juveniles occurring within the intertidal and shallow subtidal zones, demonstrating the importance of this habitat (MER 2013).

Based on the classification proposed by Whitfield (2019), most fish species encountered in the Port of Richards Bay are partially (Category II, euryhaline marine species that breed at sea, with their juveniles showing varying degrees of dependence on estuaries as part of their life cycle) or wholly (Category I, estuarine species that breed in the system) dependent on the port (estuary).

The fish community in the Berth 605 Project footprint has not received as much attention as fish communities elsewhere in the Port of Richards Bay. Cyrus and Vivier (2014) investigated the fish community in the small tidally influenced pool inland of the Assembly Basin. A total of 269 fish belonging to nine species were caught in two seine net hauls—the small size of the pool made it difficult to haul the net. The catch per unit effort was considered to be above average when compared to catches made in the Mfolozi and St Lucia Estuaries at broadly the same time. Of the nine fish species recorded, 11% were marine species that do not depend on estuaries for any part of their life cycle (Category III), while 33% were euryhaline marine species that breed in the marine environment but have juveniles that show varying degrees of dependence on estuaries in part of their life cycle (Category II).

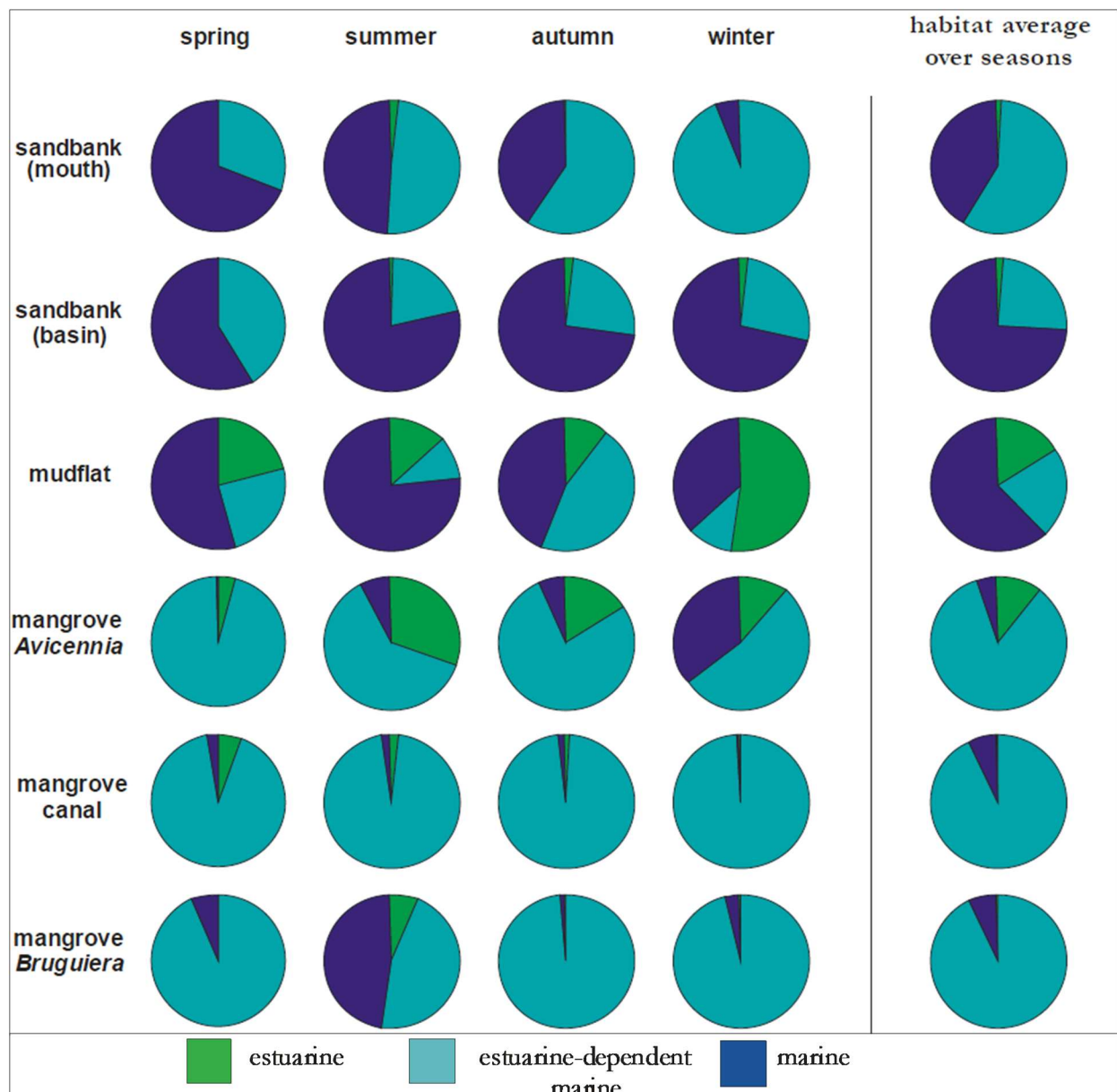


Figure 68. Relative contribution of different categories of fishes sampled in different habitats in different seasons in the Port of Richards Bay in 1997 and 1998 (Weerts, 2002).

Most of the fish (56%) were species that breed in estuaries (Category I). No euryhaline freshwater species, some of which may breed in estuaries and in freshwater (Category IV), or obligate catadromous species that migrate through estuaries to reach the marine or freshwater environment (Category V) were recorded. The bulk of the fish were juveniles within the size range of 10-30 mm standard length. One specimen, tentatively identified as *Redigobius batteatops*, appears to be a new record for South Africa, which as far as is known has only previously been recorded as far south as Maputo Bay in Mozambique.

Cyrus and Vivier (2021) investigated the fish community in the Assembly Basin using three types of fishing gear. They recorded 18 fish species in the basin, almost all of which in some way or other depend on estuaries to complete their life cycle. Three of the species (two glassies, one goby) recorded spend their life in estuaries (Category I), while six depend totally on estuaries as a nursery (Category IIa). The vast majority of individuals of the 41 species caught in the port were juveniles, further emphasizing the role of the port as a nursery.

The surveys on fish reported above were made using beam trawls and (more often) seine nets in shallow waters. The catches do not properly reflect the fish that reside in deeper waters in the port, or in habitats

where these sampling methods are inefficient or ineffective (e.g. near quays, breakwaters, floating structures). Everett and Fennessy (2007) surveyed the recreational boat-angling community in the Port of Richards Bay from June 2002 to May 2003. The findings provide perspective on fish that are not sampled by the survey methods in the above shallow water studies. Everett and Fennessy (2007) recorded a total of 76 fish species that anglers reported as having been caught—37 species retained by the anglers could be verified. The fish included several species of sharks, rays, rockcod, grunter and kob. Marine species were more prevalent than estuarine species, reflecting the strong marine influence and wide, deep mouth of the port. Many of the fish are not normally associated with estuaries but make use of artificial structures that act as reefs in the port. The wide range of fish species caught further demonstrates the value of the Port of Richards Bay as fish habitat.

Beckley *et al.* (2008) surveyed the shore angling community in the Port of Richards Bay. In total, 46 fish species representing 28 families were positively identified by the researchers in angler catches in the port, with another 25 species (from a further 13 families) reported by the respondents as fish they had caught and released. Most fish caught by anglers were marine species that are estuarine-associated or estuarine-dependent to various degrees and were similar to catches made in other KwaZulu-Natal estuaries. The overall diversity was higher than that recorded for the Port of Durban, possibly reflecting the more subtropical conditions and the opportunity to catch marine species from the dolosse near the deep entrance channel.

Both above studies highlighted the important contribution that angling makes to the local economy.

The ecological importance of the estuarine habitat in the Port of Richards Bay to fish can be appreciated by considering the available estuarine habitat for regional fish populations in view of the continued failure of St Lucia to act as refuge for estuarine dependent marine fish during the past 8-10 years (Cyrus *et al.* 2020). With St Lucia being closed more often than it is open, the Port of Richards Bay comprises ~22% of the available estuarine area in KwaZulu-Natal north of the Tugela mouth, and together with the Mhlathuze Estuary comprises ~41% of the estuarine area (Nhleko and Cyrus, 2008). Kosi Bay, the only other large estuarine system north of the Tugela when the St Lucia Estuary is closed, comprises ~51% of the available estuarine area, but this system is ~175 km north of St Lucia. In contrast, the Port of Richards Bay is located only a third of that distance from St Lucia. Although the present understanding of the distances that the post-larvae of marine fish species spawning at sea can migrate is still limited and there is incomplete information on where spawning occurs and the mechanism whereby the post-larvae locate and recruit into estuaries, it is well-known that the larvae of these species must recruit into an estuary to survive (Mann and Pradervand, 2007). These data, therefore, indicate that the Port of Richards Bay, in terms of estuarine size and relative proximity to St Lucia, is playing a key role as alternative nursery habitat along the northern KwaZulu-Natal coastline during prolonged closure of the St Lucia Estuary. The underlines the regional ecological importance of the Kabeljous Flats, being the last intertidal mud- and sandflat and mangrove area of any size within the port and comprises most of the nursery area within the system.

Of the species that use the Port of Richards Bay as a nursery area, Perch *Acanthopagrus vagus* and Elf/Shad *Pomatomus saltatrix* are listed as Vulnerable in the IUCN Red List, and Dusky Kob *Argyrosomus japonicus* is listed as Endangered (Mann *et al.*, 2014; Carpenter *et al.*, 2015; Fennessy, 2020). Also found in the port are Bonefish *Albula vulpes*, Catface Rockcod *Epinephelus andersoni* and Bronze Bream *Pachymetopon grande*, all listed as Near Threatened in the IUCN Red List (Adams *et al.*, 2012; Mann *et al.*, 2014; Fennessy, 2018). Additionally, the Vulnerable Yellowbelly Rockcod *Epinephelus marginatus* is also found in the port (Pollard *et al.*, 2018; Bills, 2019).

5.2.11 Marine reptiles

No surveys on marine reptiles (e.g. turtles) in the Port of Richards Bay could be found in peer reviewed scientific journals or other information sources. Five species of sea turtles are found along the east coast of South Africa—Leatherback Turtle *Dermochelys coriacea* (Critically Endangered), Green Turtle *Chelonia mydas* (Endangered), Hawksbill Turtle *Eretmochelys imbricate* (Critically Endangered), Olive Ridley Turtle *Lepidochelys olivacea* (Vulnerable), Loggerhead Turtle *Caretta caretta* (Endangered). Leatherback and Loggerhead Turtles nest along sandy beaches in the iSimangaliso Wetland Park to the north of Richards Bay in summer (Nel *et al.*, 2013), but no information could be found on whether they nest in the greater Richards Bay area. Reports in various forms of communication media provide evidence that turtles do periodically enter the Port of Richards Bay, but how often is unknown. A large Loggerhead Turtle in poor condition found at Naval Island in October 2024 was taken to uShaka Marine World for rehabilitation (<https://www.citizen.co.za/zululand-observer/news-headlines/local-news/2024/10/19/watch-loggerhead-turtle-safely-removed-from-richards-bay-beach/>). Turtles observed in the port at other times were by all accounts healthy (<https://www.facebook.com/Edutourism95/photos>). Dead turtles have been found in the port. One showed injuries that could have been caused by the propeller of a boat or by a shark, but was too decomposed to reach a confident conclusion on the cause of death (<https://www.coastkzn.co.za/wacky-wildlife-week-in-richards-bay/>).

Crocodiles that live in Lake Mzingazi periodically enter the Port of Richards Bay (see <https://www.youtube.com/watch?v=Ok-6XvGer8s> and <https://www.facebook.com/Edutourism95/photos>) but do not remain for any significant length of time (and are removed by authorities if necessary).

5.2.12 Birds

Bird communities in the Port of Richards Bay and how these might or will be impacted by the Berth 605 Project is the focus of a companion specialist study.

5.2.13 Marine mammals

Two related groups of marine mammals found in the nearshore marine environment off the Richards Bay coast that could be affected by the Berth 605 Project are dolphins and whales. These include the Humpback Dolphin *Sousa plumbea*, a Protected Species in terms of the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) Threatened or Protected Marine Species Regulations of 2017, and rated as Endangered by the International Union for Conservation of Nature (Braulik *et al.*, 2017). Humpback Dolphins reside permanently along the east coast of South Africa and are sighted with regularity in the marine nearshore off the Richards Bay coast, and to a lesser degree in the Port of Richards Bay (Atkins *et al.*, 2004; Keith *et al.*, 2013; Atkins *et al.*, 2016).

The size of the Humpback Dolphin population off the Richards Bay coast is unknown, but Johnson (2012) estimated it at 203 individuals. Earlier studies provide lower or higher estimates, but Johnson (2012) used a stricter approach to estimate the population size. Keith *et al.* (2013) analysed 249 sightings and the behaviour—foraging/feeding, resting, socialising, travelling—of Humpback Dolphins in the Richards Bay area between 1998 and 2006 to generate area use maps (Figure 69). Dolphins used most of the port area for foraging/feeding, but avoided the Kabeljous Flats and southernmost part of the Richards Bay Coal Terminal Basin. The core foraging/feeding area was in and near the entrance to the port and in the dredged navigation channel leading to the port. Dolphins never used the port for resting and rarely for socialising. Humpback Dolphins feed predominantly on reef-associated, estuarine and demersal fish. Keith *et al.* (2013) postulated that the dolphins are using the port entrance for feeding since the breakwaters armouring the entrance act as artificial reefs, attracting fish. Dolphins used large areas outside the port for all activities, including near the existing dredged spoil disposal site. The core use area was situated relatively close inshore, within ~10 m depth contour, and decreased sharply with distance offshore. Dolphins were rarely observed more than ~3 km offshore.

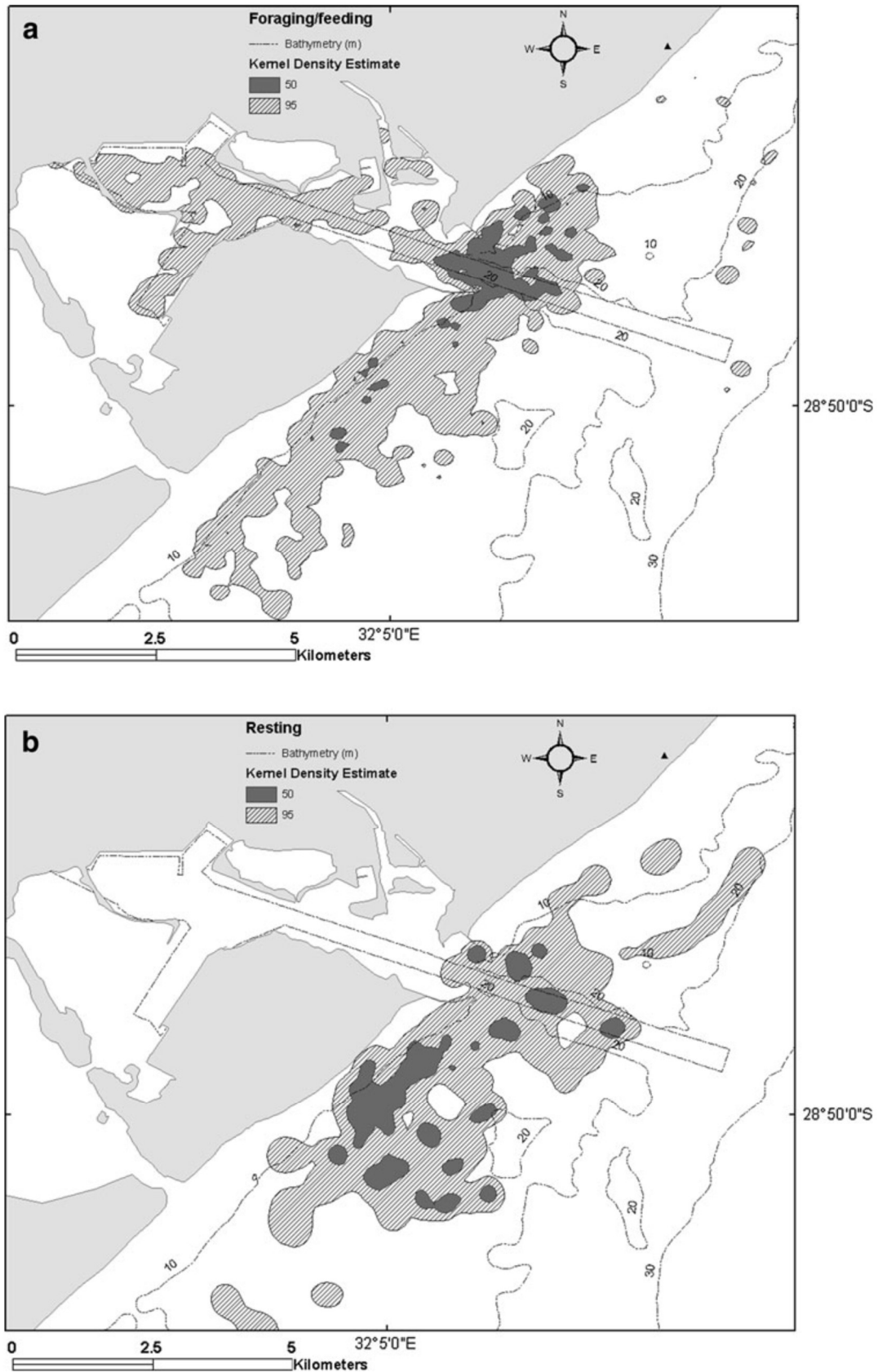


Figure 69. Kernel density estimates for each of four behaviours of humpback dolphins in the Richards Bay area for the period of 1998-2006. Dark grey shading 50% kernel density estimate, hatched area 95% kernel density estimate.

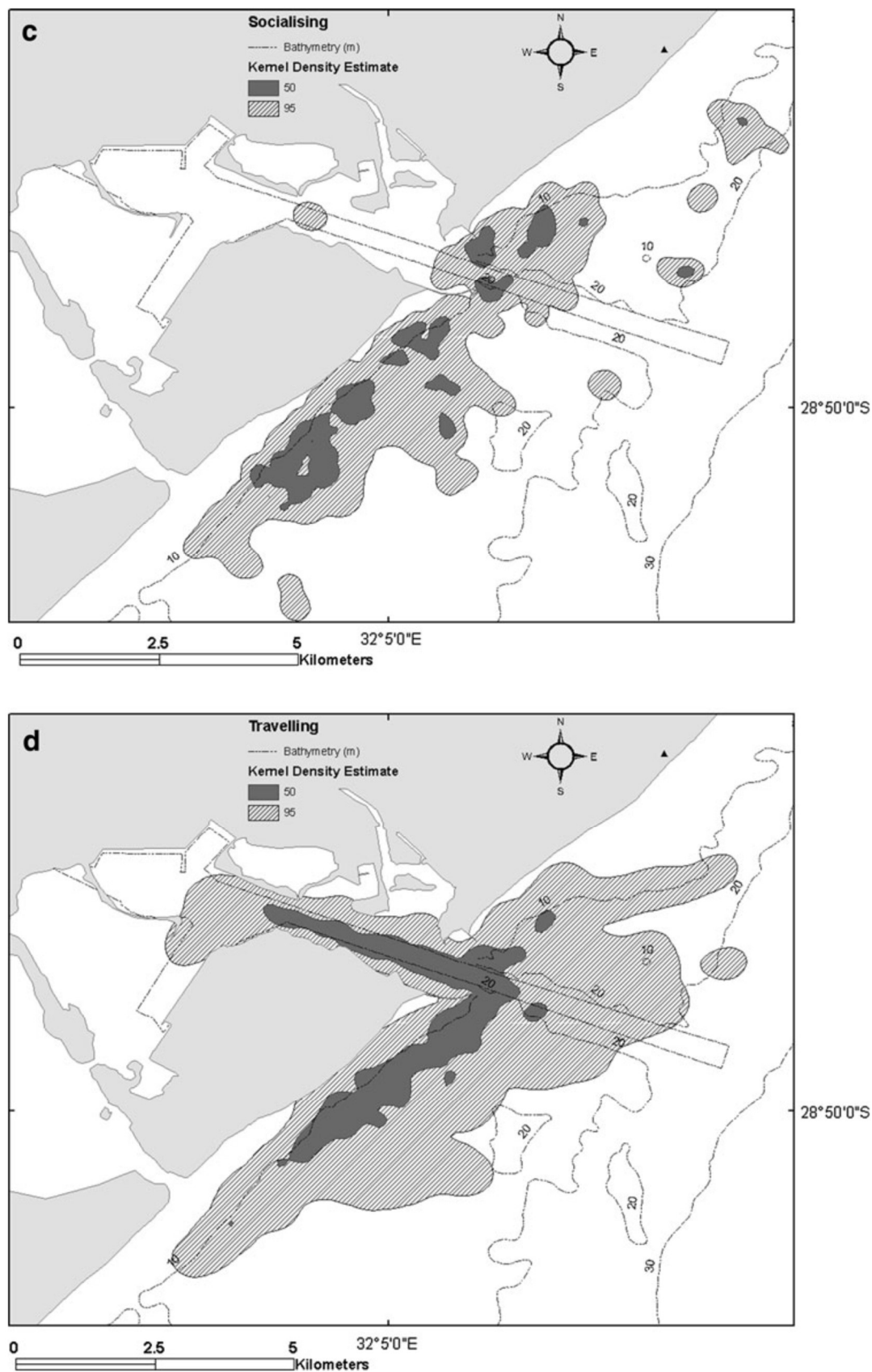


Figure 69 continued. Kernel density estimates for each of four behaviours of humpback dolphins in the Richards Bay area for the period of 1998-2006. Dark grey shading 50% kernel density estimate, hatched area 95% kernel density estimate.

Several whale species (e.g. Humpback Whales *Megaptera novaeangliae*) frequent the nearshore coastal waters off the Richards Bay coast between about June to November (species dependent) (Findlay and Best, 2016), on their migration to more northerly breeding and calving waters. There is, however, little information on their movements in nearshore coastal waters off the Richards Bay coast. There appear to be no records of whales entering the port.

5.3 Fisheries

Angling from kayaks, small, motorised boats and the shoreline is a popular recreational pastime in the Port of Richards Bay (Everett and Fennessy, 2007; Beckley *et al.*, 2008). There are two fishing clubs in the port, which have launching sites for small, motorised boats. Recreational angling from boats is only allowed alongside the main navigation channel east of the 700 Berth Basin. Parts of the shoreline in the port (e.g. Casuarinas) are inaccessible to anglers due to access control by TNPA. Recreational angling from the shoreline is largely centred on the Mzingazi Canal, small bays around and near Pelican Island, along the northern breakwater and associated shoreline, and from the Dolphin Viewing Pier.

Some subsistence fishing probably occurs in the port, and there is known illegal harvesting (poaching) of fish and shellfish using gill nets and other fishing means, primarily in the Bhizolo/Manzanyama Canal complex and on the Kabeljous Flats (S Weerts (CSIR), B Newman (CSIR), personal observation).

There are currently no commercial fisheries in the port, but the port historically supported a penaeid prawn bait fishery (Forbes and Demetriades, 2005).

5.4 Aquaculture

The Department of Forestry, Fisheries and the Environment has earmarked an aquaculture development zone for the Port of Richards Bay. The uMhlathuze and Richards Bay Estuarine Management Plan (DEA, 2018) provides a proposed zonation plan for agricultural and fisheries activities that reflects a zone for aquaculture in the port. However, the Port of Richards Bay Masterplan does not appear to make allowance for a dedicated aquaculture zone. A Dusky Kob *Argyrosomus japonicus* cage-based aquaculture project, comprising three circular cages anchored to the bottom to the north of the Sandspit, was trialled by the University of Stellenbosch and partners (Viljoen, 2019) (Figure 70). The project showed that Dusky Kob could be successfully reared in cages in the port. However, various challenges, including the presence of port operations nearby, apparently led to the mothballing of the project. There appear to be no (at least immediate) plans to reestablish an aquaculture operation in the port.



Figure 70. Dusky Kob aquaculture trial in the Port of Richards Bay (from Viljoen, 2019).

5.5 Ecological importance of the Port of Richards Bay and ecologically important habitats in the port

As described elsewhere in this specialist study, the original Richards Bay Estuary was extensively transformed during the development of the Port of Richards Bay. However, the port is still characterised by a wide range of natural habitat types, to a degree exceeding that for any other port in South Africa. The CSIR (2005) classified the ecological (conservation) importance of different habitats in the port using the approach outlined in Box 1. Although the classifications were made almost 20 years ago, various investigators have since confirmed and reinforced the relevance of the CSIR ratings.

Box 1

Habitat Assessment Criteria

Key	Criteria
A	Size of habitat
B	Biodiversity
C	Naturalness of habitat
D	Species rarity
E	Fragility of habitat
F	'Typicalness' or degree of 'representativeness' of habitat type
G	Recorded site history
H	Position in the ecological/geographical unit
I	Potential value
J	Intrinsic appeal

A significance importance category was assigned to each of the assessment criteria, as:

- 3 = high
- 2 = moderate
- 1 = low

The sum of the scores provides a ecological (conservation) significance value. The value was interpreted as.

Value assigned	Significance rating
20 – 30	High
15 – 19	Moderate
< 15	Low

Conservation/Ecological Significance of the Identified Habitats

Habitat	Total Score (max 30)	Importance
Sandbanks	27	High
Mudflats	26	High
Papyrus Swamp	26	High
Hygrophilous Trees (Swamp Forest)	25	High
Mangrove Swamps	25	High
Freshwater Pans/Channels	24	High
Hygrophilous Grass/Sedge Lands	24	High
Tidal Artificial Channel	23	High
Reed Swamp	23	High
Rivers	21	High
Harbour (Marine Embayment)	20	High
Intertidal Beaches	17	Moderate
Saltmarsh	17	Moderate
Deepwater Sediment	13	Low

Although the CSIR rating evaluated distinct habitats in the port, and the habitats support unique biological communities, the habitats do not function ecologically in isolation. Various biological resources will use more than one habitat on various time scales. Prawns (e.g. Indian Prawn *Fenneropenaeus indicus*) and fishes (e.g. Bream *Acanthopagrus berda*) leave shallow water mudflats on a tidal basis and move into mangroves to feed or take refuge from predators on the rising waters (Weerts *et al.*, 2003). In the neighbouring Mhlathuze Estuary, Stumpnose *Rhabdosargus holubi* and *Rhabdosargus sarba* use eelgrass during their early life stages before moving to sandflat habitat (S Weerts (CSIR), unpublished data). Similar ontogenetic habitat shifts are likely to occur in other fishes and macrocrustaceans in the port. Connectivity between spawning and settlement habitats in the port and the dispersal and spawning grounds in coastal marine waters, is also important. The free flow of eggs and larvae between port habitats and the adjacent marine environment is critical to fish and shellfish populations within the port and the continued contribution of the port to regional stocks and populations. The export of larvae from intertidal crab populations in the port probably runs into the multi-millions of larvae each year (B Newman (CSIR), personal understanding of crab reproduction).

The entire Port of Richards Bay can thus be considered ecologically important habitat. Indeed, by virtue of the port being an estuarine embayment, of which it is one of only three in South Africa, gives it conservation (ecological) significance. Estuaries in South Africa are generally small, meaning large estuarine bays like the Port of Richards Bay assume an even greater ecological significance by virtue of the number and area of the habitats represented. The extensive mudflats in the Port of Richards Bay (and those in the adjacent Mhlathuze Estuary) are important by virtue of their extent, as there are few large, open mudflats along the KwaZulu-Natal coast (EAS, 1996; Weerts, 2002). Turpie *et al.* (2002) ranked the ecological importance of South African estuaries, based on their size, link with freshwater and marine environments, rarity of estuary type, habitat diversity and biodiversity in terms of species richness, species rarity, or endemism and abundance. The Port of Richards Bay was ranked 26th out of 250 estuaries in the country. The ranking strongly emphasized the ecological and conservation importance of estuarine habitat in the port, ranking it 3rd in the country for the ecological significance of its fish and bird communities, 5th for zonal type rarity (how 'rare' or 'unique' the estuary is for the zone under consideration), a score of 100% for estuarine size (relative to all estuarine habitat in the country), and a score of 85% for biological diversity. MER (2013) ranked the Richards Bay estuary as 6th for overall conservation importance of the 22 Zululand estuaries in KwaZulu-Natal north of Durban, 2nd for zonal rarity, 8th for biodiversity, and one of only four estuaries with a score of 100% for estuarine size. On this basis, the Port of Richards Bay aquatic system has local, national, and in the case of certain seabirds also international importance.

It is not surprising, then that the intertidal and associated terrestrial habitat across most of the Port of Richards Bay is considered an irreplaceable Critical Biodiversity Area according to Ezemvelo KwaZulu-Natal Wildlife's Systematic Conservation Assessment (EKZNW, 2016), meaning its protection is critical for meeting biodiversity targets and thresholds and to ensure the persistence of viable populations of species and the functionality of ecosystems in KwaZulu-Natal. Interestingly, the eChwebeni Natural Heritage Site is not included in the Critical Biodiversity Area. Whether this was due to an oversight or because the area already has some level of protection through its heritage status is uncertain, although Ezemvelo KwaZulu-Natal Wildlife's Systematic Conservation Assessment incorporates formally protected areas. The estuary can also be considered an irreplaceable Critical Biodiversity Area at the National level (MER, 2013).

5.6 Ecologically important habitats and species in and near the Berth 605 Project footprint

Four habitats the CSIR (2005) classified in terms of their ecological importance in the Port of Richards Bay are represented in the 600 Berth Basin, namely Sandbanks (beaches), Mangrove Swamps, Harbour (Marine Embayment) and Deepwater Sediment. Parts of the small tidally influenced pool inland of the Assembly Basin could possibly be regarded as representing Mudflat habitat in addition to Mangrove Swamp habitat.

The most ecologically sensitive and important habitat in the Berth 605 Project footprint is the small tidally influenced pool inland of the Assembly Basin. The pool is fringed by mangrove trees, including Black Mangroves, a protected tree in terms of the National Forestry Act (Figures 71-73). As discussed above, there is a high diversity and abundance of fish and pelagic and benthic invertebrates in the pool. Cyrus and Vivier (2014a,b) recorded nine fish species in the pool by netting. The Catch Per Unit Effort was above average when compared to catches made at about the same time in the Mfolozi and St Lucia Estuaries. The bulk of fish caught were small juveniles. The catch included marine species that do not depend on estuaries at any stage in their life cycle (Category III, 11% of total catch; see Table 2). Thirty-three percent of the fish were euryhaline marine species that breed at sea, with their juveniles showing varying degrees of dependence on estuaries as part of their life cycle (Category II), while 56% were estuarine species that breed in estuaries (Category I). Despite Category II species only comprising 33% of the total catch, Cyrus and Vivier (2014a,b) were of the opinion the pool is of greater importance to this group of fish based on the observation of many larger sized fish that had congregated in a small area of deeper water at the point where a pipeline connects the pool to the Assembly Basin, most of which were Category II fish.

A field survey of the small tidally influenced pool by CSIR scientists in November 2024 using a fine-mesh seine net also revealed the presence of numerous fish and swimming prawn species. Three species of fiddler crabs and three species of sesamid crabs and the burrowing Sandprawn *Kraussillichirus kraussi* are abundant in the pool, while the large Mud Crab *Scylla serrata* is also present. The Giant Mangrove Whelk *Terbralia palustris* is abundant in the pool. None of these species is not restricted to the small tidally influenced pool—they were abundant in 2024 in mangrove forests fringing the Kabeljous Flats and in intertidal sandflats in 2024. The significance of the Giant Mangrove Whelk is that there has been a marked decline in its distribution in South Africa. Raw *et al.* (2014) recorded the Giant Mangrove Whelk only in Kosi Bay and Durban Bay, but it was absent at the time in the Port of Richards Bay. It has since disappeared from Durban Bay. Its presence in the Port of Richards Bay thus attests to the value of the port for this species, although based on the survey by Raw *et al.* (2014) it is not permanently present.

The small tidally influenced pool undoubtedly provides important nursery habitat for a variety of fish and invertebrates, but is also undoubtedly an important feeding habitat for larger fishes that access the pool at high tide. These fishes leave the pool at low tide or, as stated above, congregate in a small area of deeper water at the point where a pipeline connects the pool to the Assembly Basin because large parts of the pools bottom are exposed or are covered by only a shallow layer of water at low tide. The importance of the pool to large fishes was evident in a large ray entering the pool on the incoming tide during the field survey in 2024. As stated elsewhere in this specialist study, a seagrass bed had established in the pool in 2014, but it was no longer evident in the field survey in 2024.

Although no empirical measurements were made during the field survey of the small tidally influenced pool in November 2024, based on a professional understanding of ecological productivity in relation to habitat types in KwaZulu-Natal estuaries the scientists that prepared this specialist study are of the opinion the pool ‘punches above its weight’ in terms of ecological productivity relative to its size. It certainly will be the most productive habitat—on an area normalised basis—compared to other habitats in the 600 Berth Basin. The pool will be destroyed during the construction of Berth 605. Based on its undoubted ecological importance and the loss of ecologically important habitat that will accompany other planned infrastructure developments in the Port of Richards Bay in the future, if feasible TNPA should consider creating similar habitat alongside the lengthened 600 Berth Basin—and if the opportunity arises elsewhere in the port. The habitat could be created along the south-southwestern part of the lengthened 600 Berth Basin, by excavating a pit into the surrounding land and connecting to the basin while excavations for the Berth 605 development are underway. Ideally, the habitat should cover a larger area than the existing tidally influenced pool.



Figure 71. Comparison of the small tidally influenced pool inland of the Assembly Basin in the Port of Richards Bay in 2014 (left side; from Cyrus and Vivier, 2014) and in November 2024 (CSIR survey). Although the photos were not taken in the same positions, differences in mangrove growth are clear, as is the mangrove shading of the water surface in the photos on the right. Note that a fire affected the area near the pool before the 2014 survey (burned plants in the foreground) and this partly accounts for the lower amount of vegetation in the middle left side photo, looking down the channel leading from the point where a pipe connects the pool to the Assembly Basin. The corresponding photo in the middle right is looking toward the position of the pipe which is just beyond the mangrove tree in the distance.



Figure 72. Photographs of the tidally influenced pool inland of the Assembly Basin in the Berth 605 development footprint.



Figure 73. Photographs of fauna in the dally influenced pool inland of the Assembly Basin in the Berth 605 development footprint. (a) fiddler crab, (b) fiddler crab and grapsid crab, (c) fiddler crab, (d) gastropods, (e) goby, (f) swimming prawn.

Provided the excavated area is of sufficiently deep to retain water at low tide and it has a permanent tidal connection to the 600 Berth Basin, it is reasonable to expect that it would, over time, be similarly colonised by mangroves and other biological resources and make as important an ecological contribution per unit area to the port as the existing tidally influenced pool. Another obvious benefit is that the habitat would provide some measure of compensation for other planned infrastructure developments in the port that will have more significant ecological implications than the development of Berth 605, including the loss of mangrove and shallow subtidal sediment habitat.

The Kabeljous Flats—including the mangroves that fringe the flats, the Bhizolo/Manzanyama Canal complex and Sandspit—are widely recognised as the most ecologically sensitive and important habitats in the port (e.g. Weerts, 2002; Weerts *et al.*, 2003; CSIR, 2005; CSIR, 2008; Allan, 2009; Cyrus and Vivier, 2009; Vivier and Cyrus, 2009; MER, 2013; DEA, 2018; Cyrus and Vivier, 2021; Cyrus and Vivier, 2023). The loss and disturbance of these habitats, or any part thereof, would have significant adverse consequences for the ecological functioning of the port, and both indirectly and directly for the neighbouring marine ecosystem. Although large portions of the Sandspit are inundated by tides and there is water flow via a narrow channel between the deepwater 600 and 700/800 Berth Basins and the Kabeljous Flats at the northwestern most part of the Sandspit, the Sandspit nevertheless provides an effective barrier between the flats and the deepwater basins, limiting erosion of the flats and the movement of some contaminants between the 600 and 700/800 Berth Basins and the flats. The clearest evidence for this barrier effect is in the water column, which is usually more turbid over the Kabeljous Flats than in the 600 and 700/800 Berth Basins. That said, the difference in turbidity is not always pronounced. The disturbance of the Kabeljous Flats and Sandspit can thus be considered as constituting a fatal flaw, even if habitat compensation is implemented as fragmented habitat will be of a lesser ecological value. It is, therefore, noteworthy that the Berth 605 Project footprint does not encroach upon either the Kabeljous Flats or the Sandspit.

5.7 Trends in ecological state

Although the Port of Richards Bay retains an important ecological function, as stated elsewhere in this specialist study it is in a markedly different condition from its state prior to port development. The altered ecological function is unsurprising given the extensive physical changes that were required to enable port development. These changes included the widening and deepening of the mouth to form the entrance channel, the deepening of much of the water body for vessel navigation, the hardening of large parts of the shoreline to form quay walls or to provide protection from waves and erosion, and the infilling of intertidal and shallow subtidal sandbanks and mudbanks and mangroves for port infrastructure.

The most recent National Biodiversity Assessment evaluated the health of South African estuaries (van Niekerk *et al.*, 2019). The state of various abiotic and biotic components of estuaries (hydrology, hydrodynamics and mouth condition, water chemistry, sediment processes, microalgae, macrophytes, invertebrates, fishes and birds) were used to compute an Estuarine Health Index score, also known as the Present Ecological State. Estuaries were assigned a score based on the similarity to an assumed natural (pristine) condition for the abiotic and biotic components. For each component, the change was estimated as a percentage (0-100%) of the natural state. Scores were weighted (25% abiotic, 20% biotic components) and aggregated (50:50) to provide an overall Estuarine Health Index score that reflects the present health of the estuary as a percentage of that under natural conditions. The degree of similarity in the scoring system is reflected in six broad categories relate to decreasing levels of ecosystem condition (A-F scale), ranging from natural to critically degraded. The change in condition occurs on a continuum. Estuaries >90% similar to their natural state are rated as 'Natural' and those degraded to <40% of natural condition are rated as 'Severely or Critically Modified'. The A-F scale represents a continuum and boundaries between categories are conceptual points along a continuum. There may, therefore, be cases where there is uncertainty on the category to which an estuary belongs, potentially having components that have

membership in two categories (van Niekerk *et al.*, 2019).

The Present Ecological State for ~30% of the estuaries in KwaZulu-Natal was rated poor (Present Ecological State of D-heavily modified, E-severely modified, or F-critically modified), with pollution playing an important role in this regard in many systems. A single estuary (Kosi Bay) was rated to be in good health (Present Ecological State of A/B—unmodified approximate natural condition/near natural with few modifications). Estuaries in urban areas and those with closely linked urban developments were identified as particularly poor. The Present Ecological State for the Port of Richards Bay was rated ‘D-HIGHLY MODIFIED’ (41-60% condition of pristine) (Table 3). The Mhlathuze Estuary was also rated ‘D-HIGHLY MODIFIED’. The Present Ecological State for the Port of Richards Bay reflects the loss of a large amount of natural habitat, biological resources and basic ecosystem functions and processes in the port. However, despite the score, as emphasised elsewhere in this specialist study the port retains an important ecological function, if different to that which existed prior to port development. The importance of the port is reflected in it being identified as a priority estuary for biodiversity protection (van Niekerk *et al.*, 2019).

Table 3. Desktop Present Ecological Status for the Port of Richards Bay and Mhlathuze Estuary.

Component	Category	
	Mhlathuze	Richards Bay
Hydrology	B	D
Hydrodynamics and mouth condition	D	D
Water quality	E	D
Physical habitat alteration	E	E
Habitat health score	D	D
Microalgae	C	D
Macrophytes	E	F
Invertebrates	D	E
Fish	F	E
Birds	E	D
Biotic health score	D	E
Present Ecological State	D	D
2018 Condition Status	Heavily Modified	Heavily Modified

5.8 Estuarine Management Plan

The CSIR formulated an Estuarine Management Plan for the uMhlathuze/Richards Bay Estuary on behalf of the Department of Forestry, Fisheries and the Environment (DFFE, 2019). The plan identifies a vision for the estuary, management objectives and actions that should be followed to meet the vision and roles and responsibilities of role players and stakeholders to cooperatively execute the plan. The vision identified for the uMhlathuze/Richards Bay Estuary is:

The uniqueness and socioeconomic values of our beautiful estuaries are sustainably protected for future generations through responsible, holistic, and inclusive management approaches

The Estuarine Management Plan makes provision for port expansion, but is also clear that future infrastructure development must:

- Be sustainable and operated in environmentally responsible manner
- Protect and improve existing functional estuarine habitat
- Provide opportunities for the rehabilitation, restoration and/or creation of estuarine habitat
- Provide recreation and tourism related opportunities
- Provide educational opportunities.

5.9 Existing impacts to the biophysical environment in the Berth 605 Project footprint

Several port related activities and operations currently directly or indirectly impact on the aquatic environment in the Berth 605 Project footprint. The most obvious are the movement of large vessels into and from the 600 Berth Basin and the transfer of bulk cargo to and from the vessels. The movement and presence of large vessels creates several environmental impacts, including:

- propeller wash disturbance of the bottom that degrades water quality by resuspending sediment into the water column (Figure 36),
- propeller wash disturbance of benthic biological resources,
- generation of waves by tugs that erode intertidal habitat and affect intertidal biological resources,
- the discharge of ballast water that potentially contains contaminants and non-native biological resources,
- potential introduction of non-native biological resources by their translocation from vessel hulls or the release of gametes, larvae and spores by adults on vessel hulls,
- leaching of antifouling biocides from vessel hulls and affecting water quality, sediment quality and biological resources,
- shading of water due to the physical presence of vessels affecting microalgal photosynthesis (also relevant to quay walls and quayside infrastructure),
- casting of artificial light on the water surface at night from vessels that suppresses the diel migration of zooplankton and attracts small fish that become susceptible to intensified predation (also relevant to quay artificial light cast from quayside),
- vessel (and quayside) noise disturbance of biological resources, including birds.

The 600 Berth Basin has had a varied history in terms of the bulk products handled, but this has included granite, coal and scrap metal. The export of coal, which is a relatively recent development, currently contributes the largest volume of product moved through the basin. The coal is loaded onto vessels using skips. Coal particles and dust lost from skips settles on nearby land, water and hardstand areas. Coal particles and dust also enter the port via surface runoff and wind erosion of stockpiles near the water's edge. Although the most significant deposition and settlement of coal particles undoubtedly occurs in and near the 600 Berth Basin, the scientists that prepared this specialist study have observed slicks of coal dust on the water surface near the Small Craft Harbour. Such long-distance dispersion of coal dust on the water surface likely only occurs in calm weather since wind generated surface waves disrupt the surface tension and cause the dust to sink. The coal dust is unlikely to have originated at the Richards Bay Coal Terminal since there is little evidence for the similar slicks on the water surface in the Richards Bay Coal Terminal Basin. This said, coal dust is dispersed by wind over large distances from the Richards Bay Coal Terminal. As discussed in Section 5.1.9 of this specialist study, the most significant recent change in the 600 Berth Basin is the accumulation of coal fragments, particles and dust on the bottom—the dark colour of the sediment at some stations near the quay wall reflects the accumulation of coal particles in the sediment (Figure 27).

The 600 Berth Basin is periodically maintenance dredged to maintain a water depth that is safe for vessel movement. The dredging removes, destroys, or otherwise disturbs benthic biological resources in the dredging footprint and indirectly affects pelagic and benthic biological resources outside the dredging footprint by degrading water quality and suspended sediment depositing on the bottom. The influence of dredging on the benthic habitat and related biological resources can be seen in furrows left by a trailer suction hopper dredger on the bottom in Figure 37.

The 600 Berth Basin is periodically used for the storage of floating pipes near the southern and western shores. Although the pipes float on the water surface, they are anchored to the bottom to ensure they remain in place for the duration of the storage period. The anchor system will affect benthic biological

resources, albeit in a small area.

There are several navigation buoys in the 600 Berth Basin. The buoys are on swing moorings that consist of a large-link metal chain on a concrete anchor block on the bottom. The chains are of a length that allows the buoys to rise and fall with the tide. A part of the anchor chain thus drags on the bottom in an arc around the concrete block depending on the wind and current direction, and in this way disturbs (scours) the bottom sediment and associated benthic biological resources. The area of sediment affected in this way is small for each buoy and all buoys combined, but nevertheless adds to the cumulative area of sediment affected by anthropogenic disturbances. The rusting and scouring of chains dragging over the sediment will also contribute metals as contaminants to the water column and sediment. However, the buoys provide habitat for various fouling biological resources, including macroalgae, barnacles, mussels and sponges amongst others, and thus have some ecological value.

6. Description of the Baseline Biophysical Marine Environment off the Richards Bay Coast

6.1 General

The sediment dredged and soil and rock excavated in the Berth 605 Project footprint will probably be disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. However, the dredged material could potentially be disposed at a proposed new disposal site that is currently under consideration. The rationale for considering a new dredged spoil disposal site is that the existing disposal site may be too small to handle the anticipated ~10 million m³ of material that will need to be dredged and disposed as part of planned infrastructure developments under consideration by TNPA in the Port of Richards Bay Masterplan in the short-term (see Section 4.1 of this specialist study). However, the assumption for this Environmental Impact Assessment is that the dredged material will be disposed at the existing dredged spoil disposal site.

The existing dredged spoil disposal site is situated ~3.5 km to the south-southeast of the entrance to the Port of Richards Bay, in water of ~15-20 m depth. The site has a surface area of ~1.82 km². Additional disposal sites under consideration by TNPA are provided in Figure 74. Alternative Site 1 is situated ~7.1 km from the entrance channel to the port. There are several constraints in this area—the site is near the main navigation routes, anchorage area and a wreck. Alternative Site 1 is 1350 m by 3150 m, with a total surface area of ~4 250 000 m² and an average water depth of -32.9 m Chart Datum. The site is inside the promulgated Port of Richards Bay limits. Alternative Site 2 is ~8.4 km from the entrance channel to the port, at least 3 km from the uMgeni-uThukela Water outfalls, and is outside of the promulgated Port of Richards Bay limits. Alternative Site 2 is 1400 m by 2800 m, with a total surface area of ~3 920 000 m² and an average water depth of -34.6 m Chart Datum (PRDW, 2024). There are less constraints near Alternative Site 2 than Alternative Site 1. However, Alternative Site 2 was discounted because of the presence of the uMgeni-uThukela Water outfalls near the site and a potential offshore floating wind farm development in the area—the wind farm would be situated further offshore than the site, but power cables will need to be run to the shoreline.

uMgeni-uThukela Water discharges domestic and industrial wastewater into the marine environment off the Richards Bay coast through three outfalls known as the A-, B- and C-lines. The outfalls lie to the immediate north of the entrance channel to the Port of Richards Bay (Figure 74).

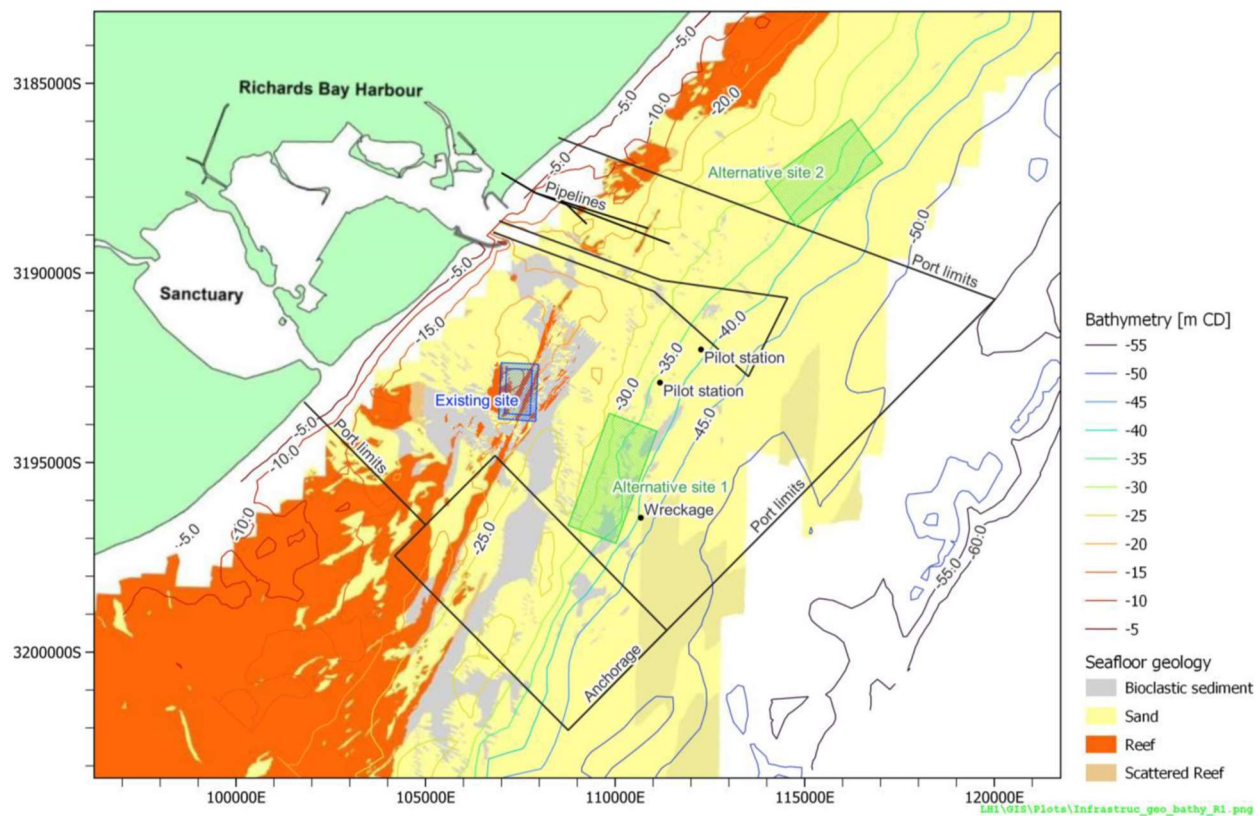


Figure 74. Proposed alternative dredged spoil disposal sites and existing infrastructure, geology and bathymetry off the Richards Bay coast (PRDW, 2022).

6.2 Abiotic Environment

6.2.1 Physical description of the coast

The KwaZulu-Natal coast, which is generally uniformly oriented northeast to southwest, is often described as featureless since it lacks prominent headlands and bays. The most significant topographical feature is the KwaZulu-Natal Bight, an indentation of the coast between Cape Vidal in the north and Durban in the south. The continental shelf is narrow and steep north of Cape Vidal and south of Durban but extends ~45-50 km from the shoreline at the widest point of the bight (Martin and Fleming, 1988). The coastal topography of the bight interacts with the prevailing Agulhas Current to affect the regional oceanography, generating Natal Pulses and local current regimes (Lutjeharms and van Ballegooyen, 1988; Lutjeharms *et al.*, 2000a, Lutjeharms, 2006; Guastella and Roberts, 2016). The oceanography and physical conditions of substrate in the so-called Thukela Depocenter or Thukela Banks, where the delivery of large volumes of fine-grained sediment by the Thukela River results in muddier sediment compared to elsewhere along the coast (Green and Mackay, 2016), exert an important role on the biology and ecology of marine biological resources (Fennessey, 2016).

At Richards Bay, the most pronounced physical feature on the coast is the breakwaters for the Port of Richards Bay. Other than these man-made structures, the coast is essentially featureless and uniform in its orientation and topography.

6.2.2 Oceanography

The oceanography along the northeast and east coast of South Africa is dominated by the Agulhas Current, a warm, strong ($>2 \text{ m.s}^{-1}$; Pearce *et al.*, 1978), poleward flowing current (Schumann, 1988). Although the core of the current generally follows the continental shelf edge, meanderings of the current have a strong influence on the continental shelf oceanography (Schumann, 1988). Shelf current directions alternate between southward (predominantly) and northward, influenced by prevailing north-easterly and south-

westerly winds and the proximity of the Agulhas Current to the coast; a semi-permanent cyclonic eddy south of Durban is responsible for an inshore north-flowing current 'swirl' north of Durban (Guastella, 2014).

6.2.3 Bathymetry and substrate

The following information on the bathymetry and substrate off the Richards Bay coast is largely taken from Leuci *et al.* (2004), supplemented by the findings of other studies where necessary. The Richards Bay continental shelf shows a gradation, from extensive reef in the south off the Mlalazi River mouth to a sand cover to submarine dune field in the north (Ramsay *et al.*, 1996; Leuci *et al.*, 2004) (Figure 75). The reef in the south is a combination of high- and low-relief exposed rock present at depths of -10 m down to -70 m, but wedges northward to -25 m off the Richards Bay coast where it becomes discontinuous. North of Richards Bay, the reef continues as a thin strip of coastal reef, with a base at -25 m.

The absence of reef directly off the Port of Richards Bay (and northward deeper than -25 m) is probably due to sediment mantling. The wedge of reef to the south coincides with the structural change in the coastline and sudden narrowing of the Thukela Shelf at the north end. This constriction of the continental shelf causes acceleration of currents on the continental shelf and inhibits sediment deposition. The exposed reef is probably the result of this area being swept by both the northward flowing counter-current and the southward flowing Agulhas Current.

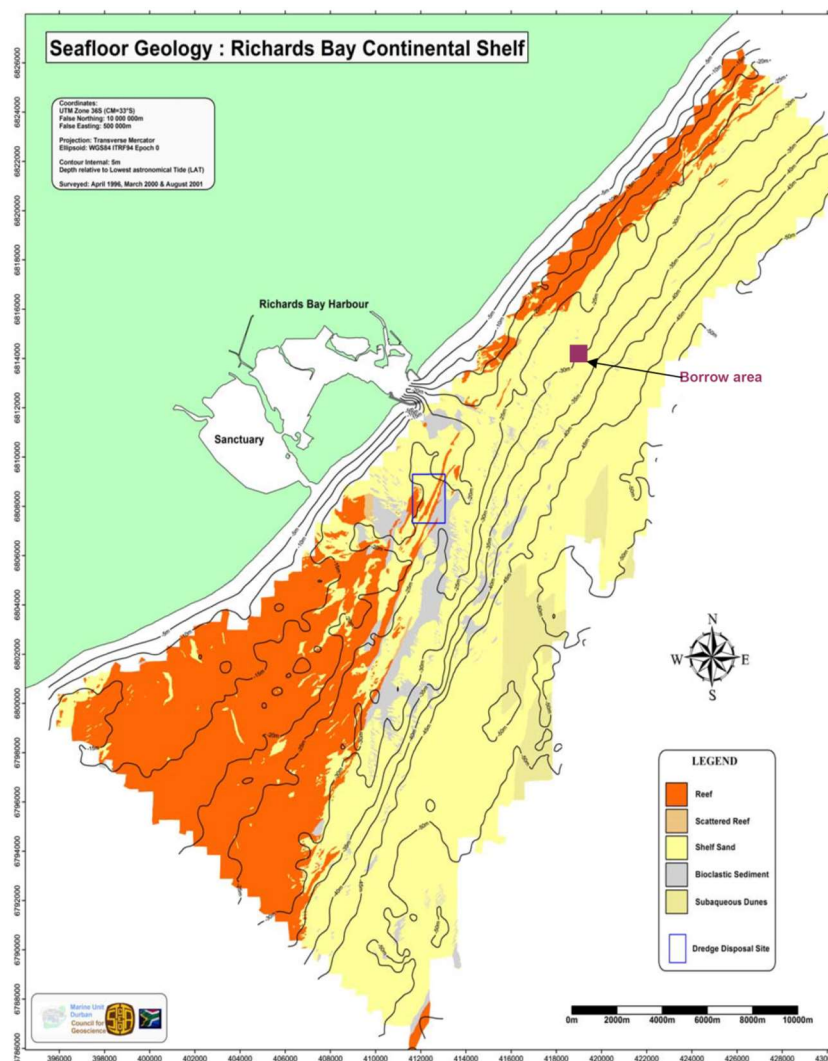


Figure 75. Seabed bathymetry and geology of the continental shelf off the Richards Bay coast (Leuci *et al.*, 2004).

Sediment on the Richards Bay continental shelf is derived from coastal erosion, river flows/floods and continental shelf and shoreline erosion. For the most part, the substrate is comprised of sand, but ~25% of the area is reef. Minor amounts of gravel—mostly bioclastic—are also present. The second most common sediment type off the Richards Bay coast (although very much a minor component) is muddy sand—mud patches are interspersed amongst sand to the north of the entrance channel to the Port of Richards Bay (CSIR, 2023, 2024; B Newman (CSIR), personal observation).

Bathymetric survey outputs of the existing dredged spoil disposal site made in July 2007 and June 2022 are presented in Figure 76, while the seabed level change from 2007 to 2022 is shown in Figure 77 (PRDW, 2024). The most important feature is the uneven seabed on the dredged spoil disposal site, reflecting the disposal of dredged material only in parts of the site. These undulations will need to be considered when disposing of dredged material for the Berth 605 Project, to avoid undue changes to the local wave climate and impacts to the receiving ecological environment.

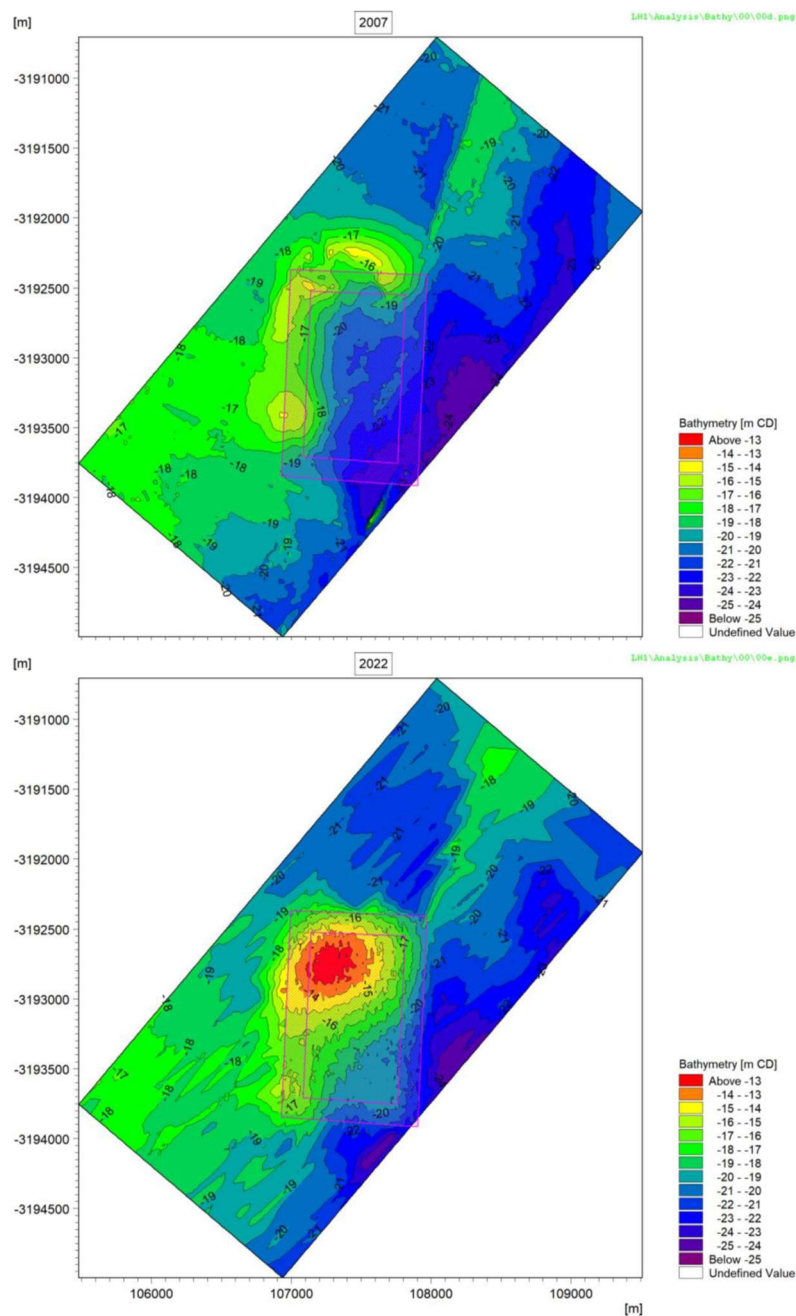


Figure 76. Bathymetry of the area around the existing dredged spoil disposal site in 2007 and 2022 (PRDW, 2022).

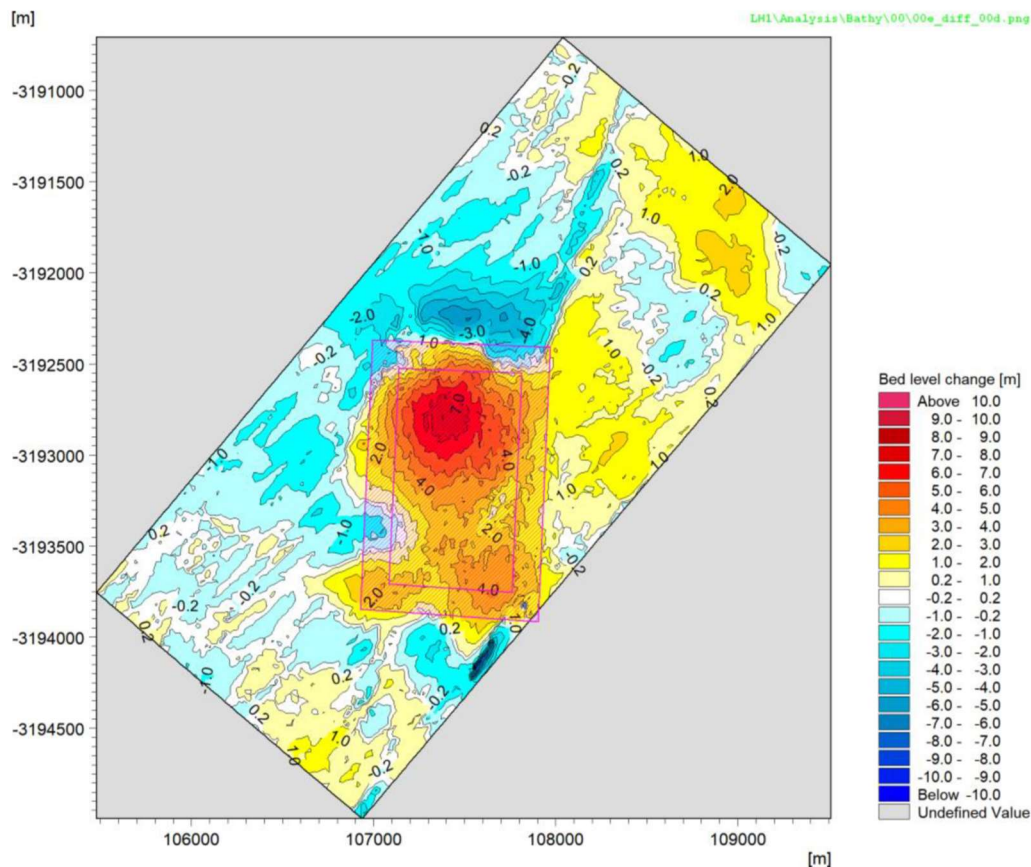


Figure 77. Bed level change plot from the 2022 bathymetric survey of the area near the existing dredged spoil disposal site relative to the 2007 bathymetric survey (PRDW, 2022).

6.2.4 Water quality

There appears to be no recent information on water quality at or very near the existing dredged spoil disposal site off the Richards Bay coast –the last water quality surveys appear to be those made by the CSIR (2008) in 2005-2007, before, during and shortly after the disposal of sediment dredged for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay (Figure 78). There is more recent information on water quality in the greater nearshore marine environment off the Richards Bay coast, generated through surveys to evaluate the impact of wastewater discharged by uMgeni-uThukela Water through deepwater outfalls to the north of the port entrance (*e.g.* CSIR, 2023, 2024). The nearest water quality monitoring positions for the uMgeni-uThukela Water outfalls monitoring programme are ~1.6 km to the north-northeast of the dredged spoil disposal site. There is evidence for water quality impairment in the nearshore marine environment off the Richards Bay coast related to wastewater is discharged through the uMgeni-uThukela Water outfalls. Periodic upset conditions that affect the outfalls (*e.g.* leaks that require discharge through bypass valves) result in water quality impairment over a wide area–wastewater plumes can be seen in satellite imagery extending past the dredged spoil disposal site under certain conditions.

The water in the nearshore marine environment off the Richards Bay coast is warm, the temperature rarely falling below ~20°C in winter and usually rising to ~24-25°C in summer (but may be higher at times; Lamont *et al.*, 2016; CSIR, 2023, 2024). Temperature measurements made off the Richards Bay coast by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figure 79.

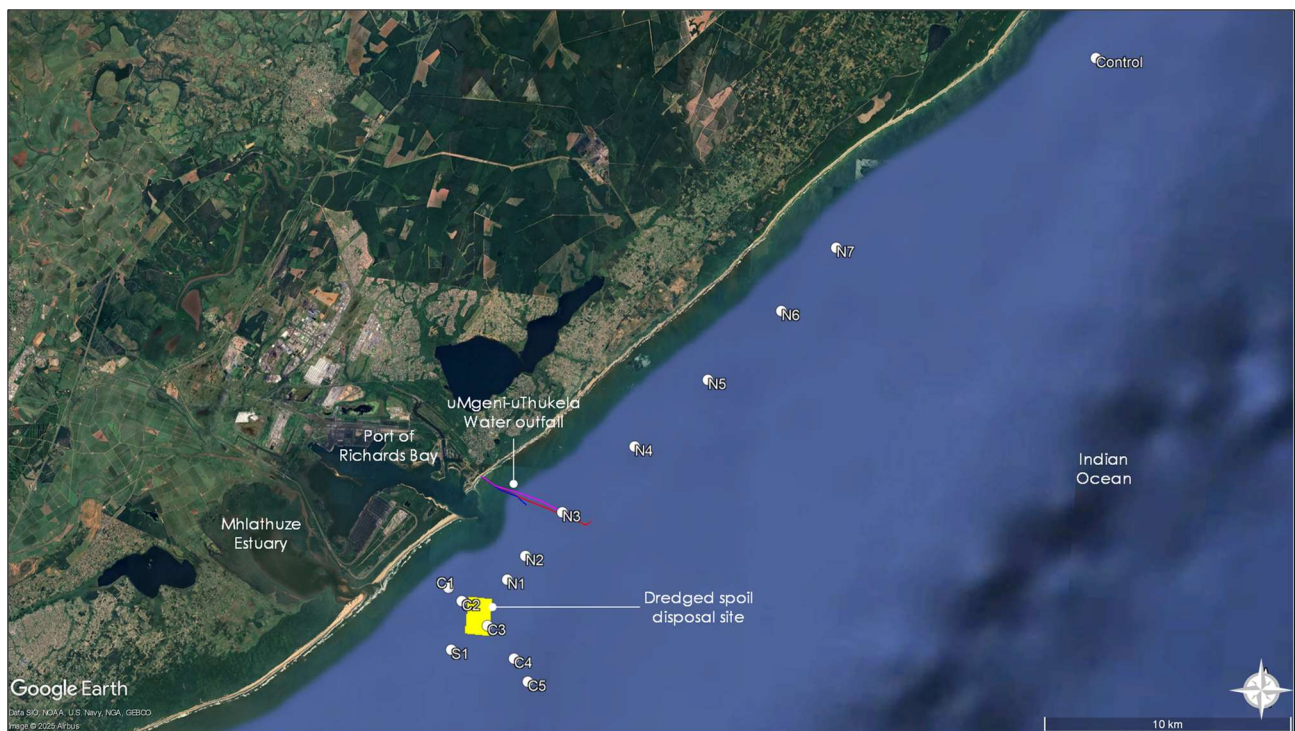


Figure 78. Positions where the CSIR (2008) surveyed water quality, sediment quality and benthic macrofaunal communities in 2005 and 2006 for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay.

The salinity of the water column along and off the Richards Bay coast usually approximates that for seawater (~35-35.5; Pearce, 1978; Lamont *et al.*, 2016; CSIR, 2023, 2024). However, the salinity of surface water may be lower during times of high flow from the Mhlathuze River (Lamont *et al.*, 2016; CSIR, unpublished data). Salinity measurements by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figure 80.

The pH of seawater off the Richards Bay coast is usually in the range 8.1-8.3, but may fall <7 near two of the uMgeni-uThukela Water outfalls that discharge an acidic (pH of ~2.5-3.5) phosphogypsum based wastewater (CSIR, 2023, 2024). pH measurements made off the Richards Bay coast by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figure 81.

Suspended sediment concentrations and related turbidity in the water column off the Richards Bay coast are highly variable (Figure 82), influenced by flows from the Mhlathuze River, maintenance dredging (including the sand trap just south of the port entrance), dredged material disposal at the dredged spoil disposal site, the pumping of sediment onto beaches to the north of the port entrance as part of a beach nourishment programme, erosion of the shoreline where it is characterised by clay outcrops, and wastewater discharge through the uMgeni-uThukela Water outfalls.

Turbidity and suspended sediment measurements made off the Richards Bay coast by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figures 83 and 84. Suspended solids concentrations as high as 43.5 mg.L^{-1} were recorded in non-dredged spoil disposal periods (CSIR, 2008). The lowest concentration recorded was $\geq 3.78 \text{ mg.L}^{-1}$ (a measurement made at the surface at Station N2)

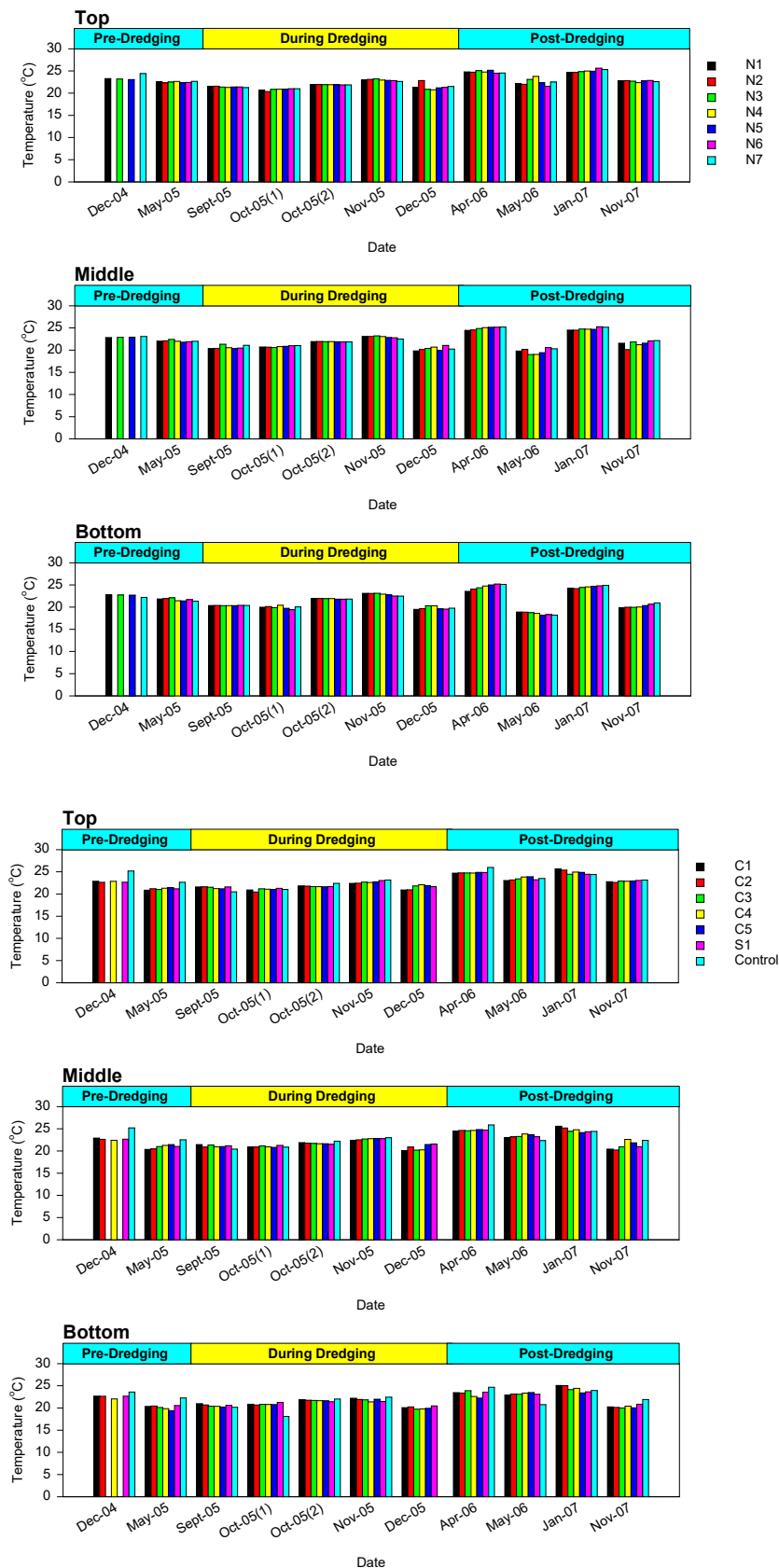


Figure 79. Temperature measurements in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

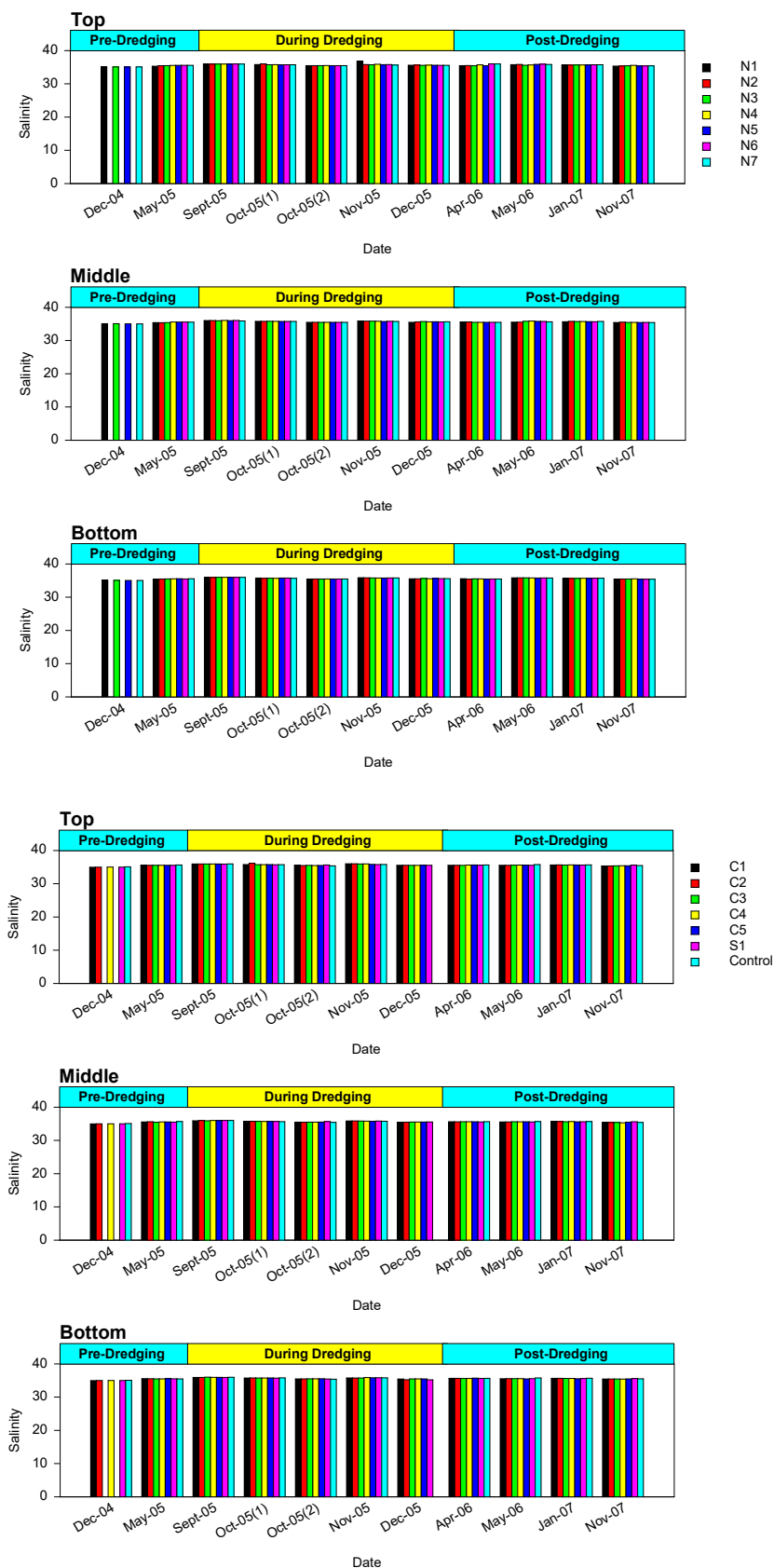


Figure 80. Salinity measurements in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

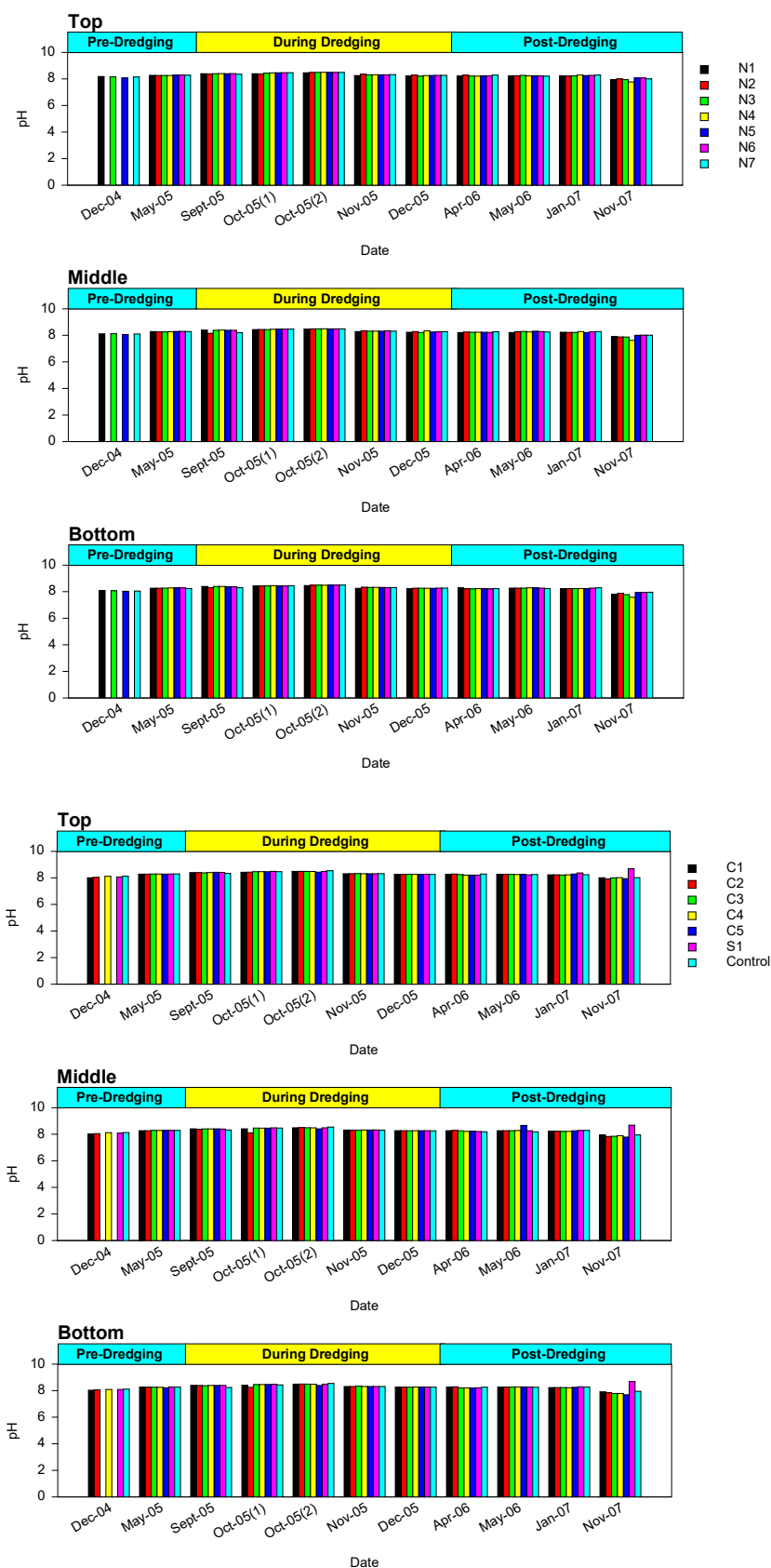


Figure 81. pH measurements in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

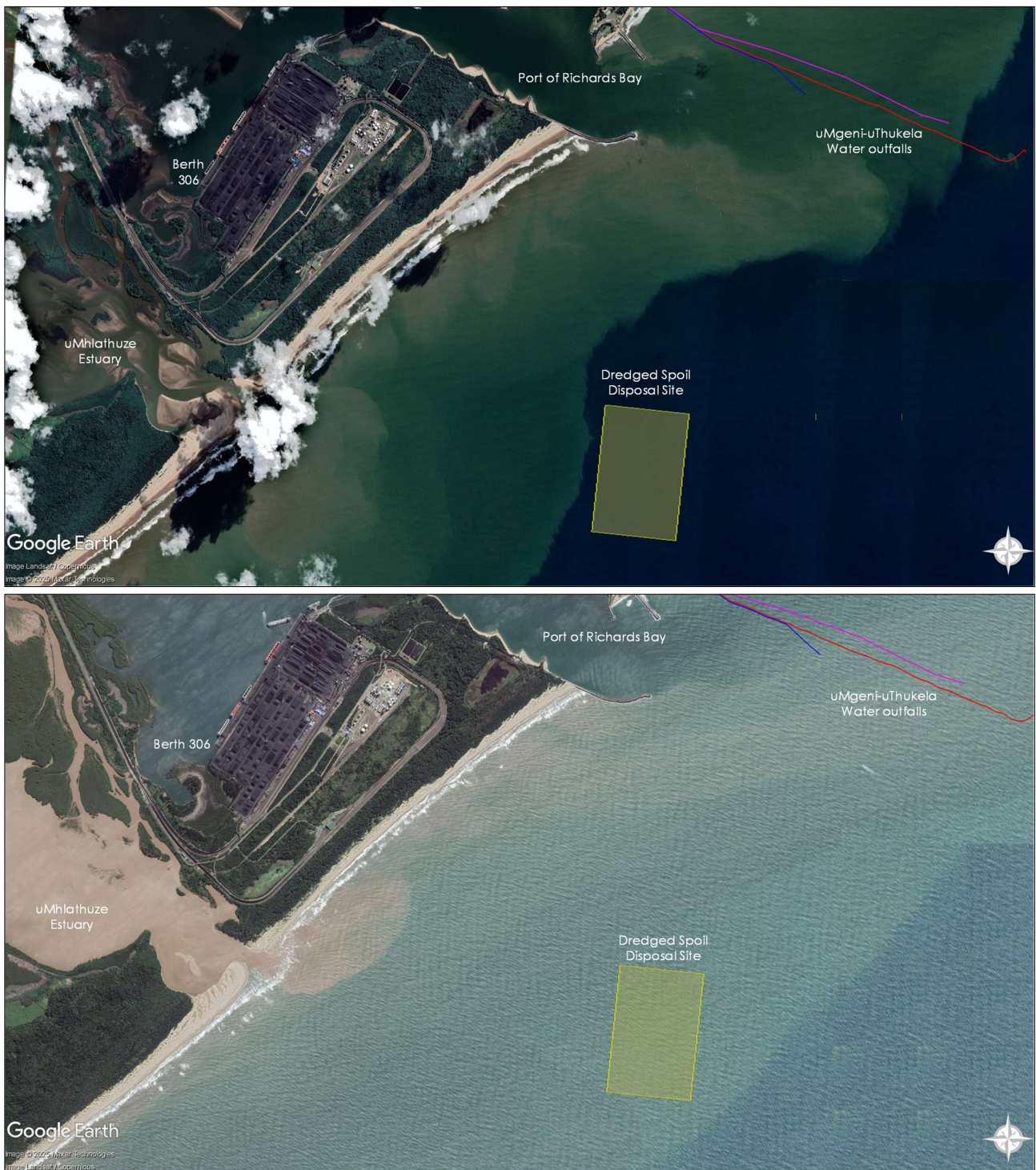


Figure 82. Suspended sediment plumes in the nearshore marine environment off the Richards Bay coast.

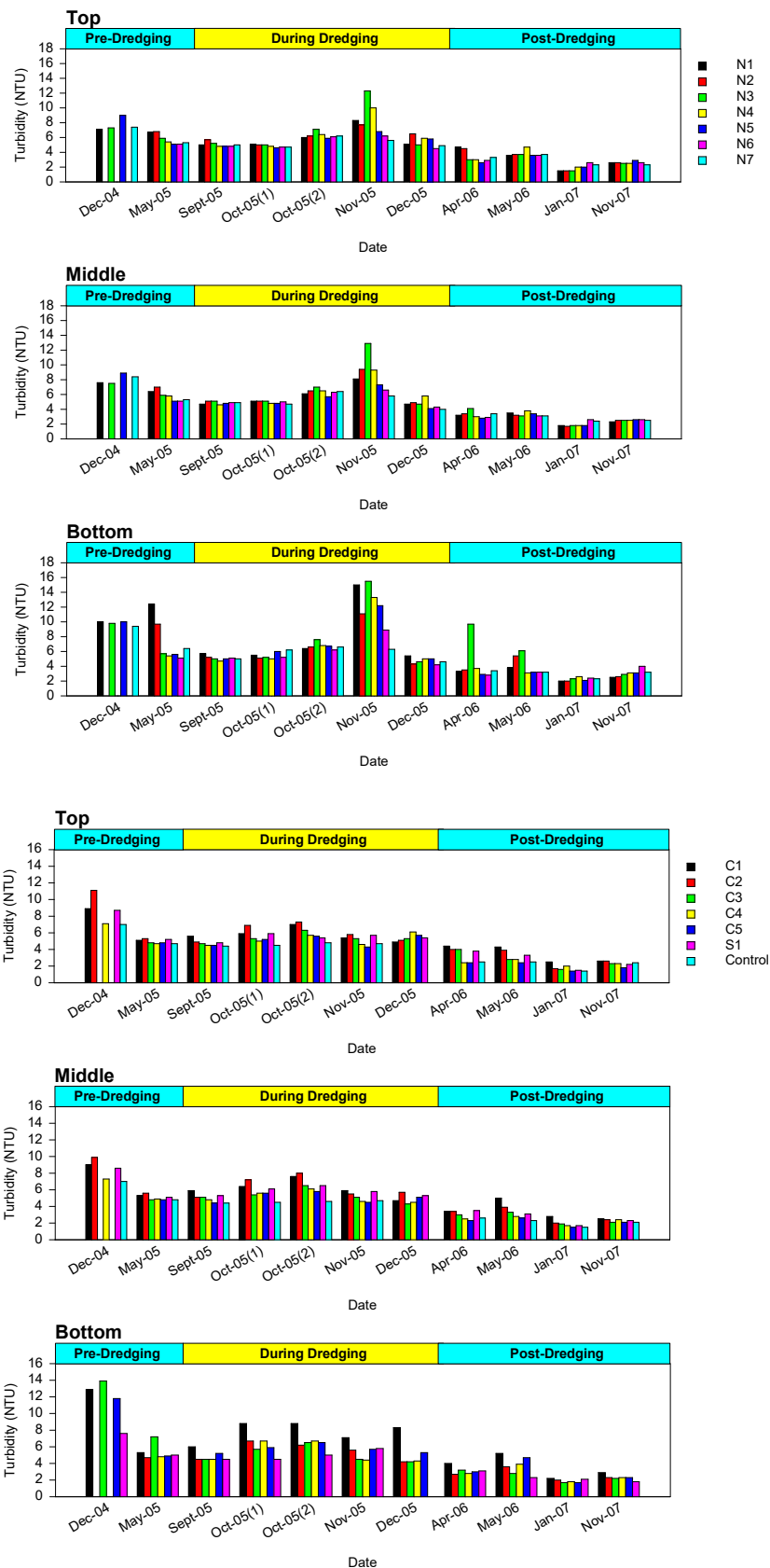


Figure 83. Turbidity measurements in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

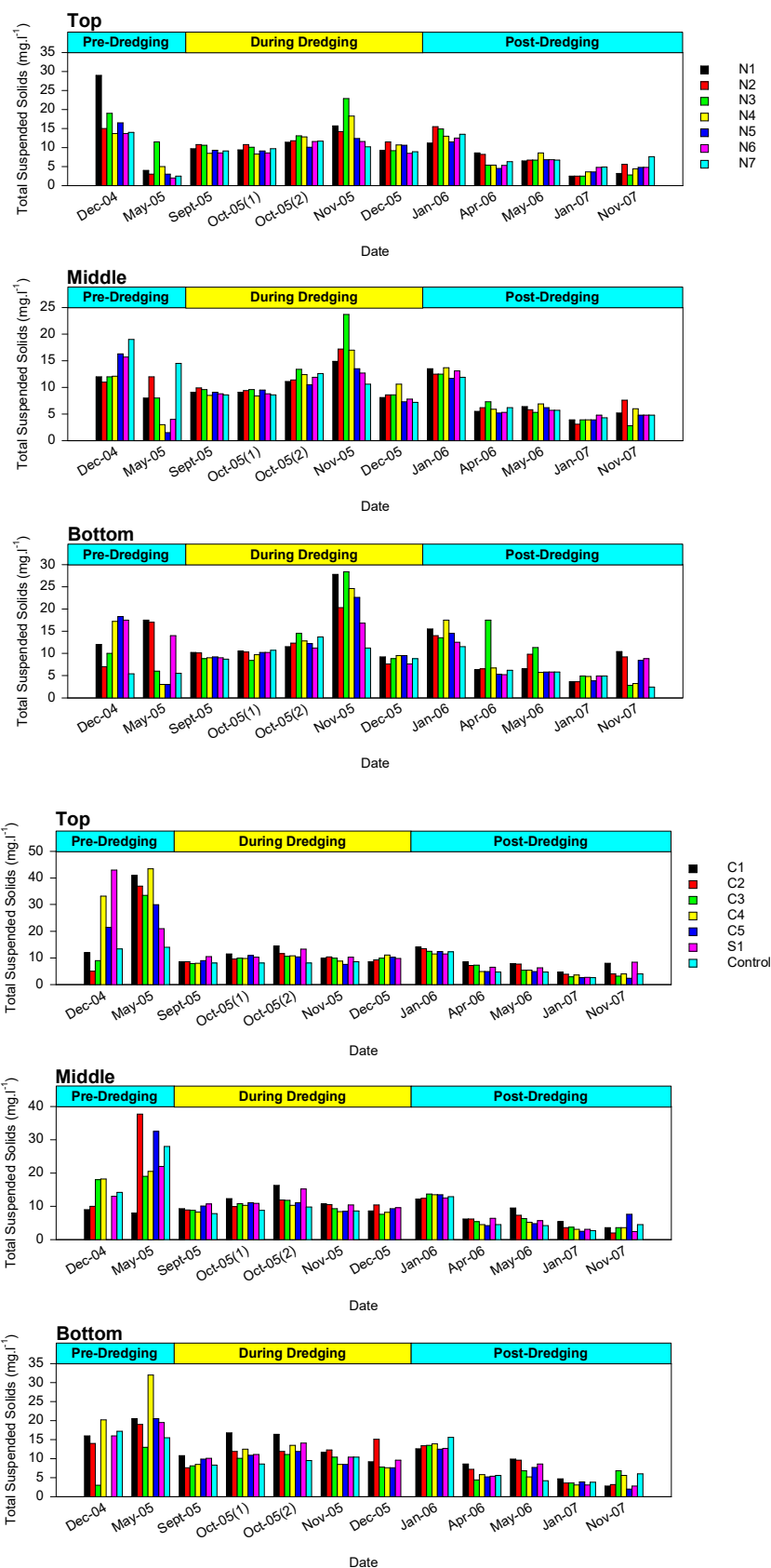


Figure 84. Suspended solids concentrations in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

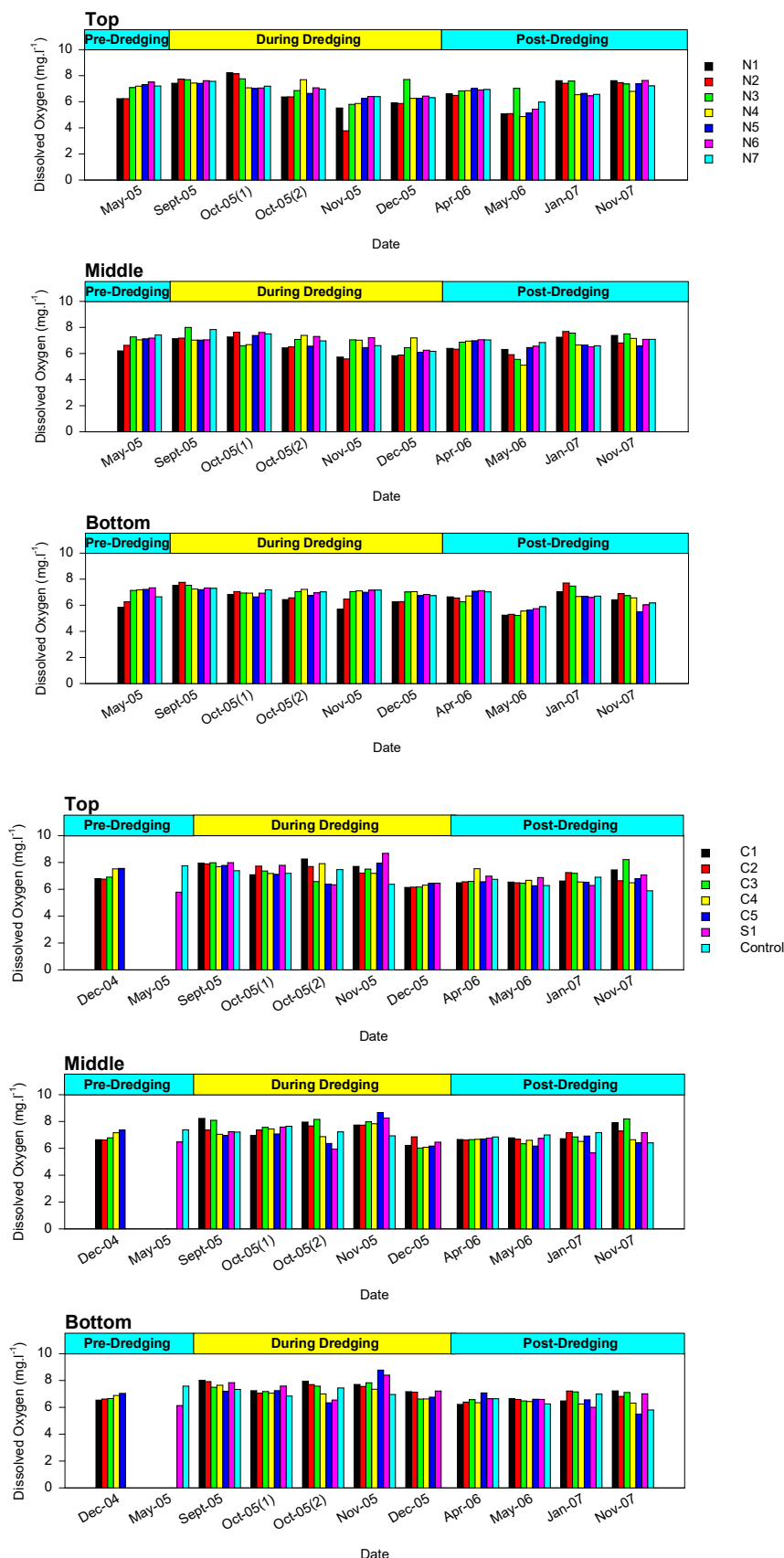


Figure 85. Dissolved oxygen concentrations in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

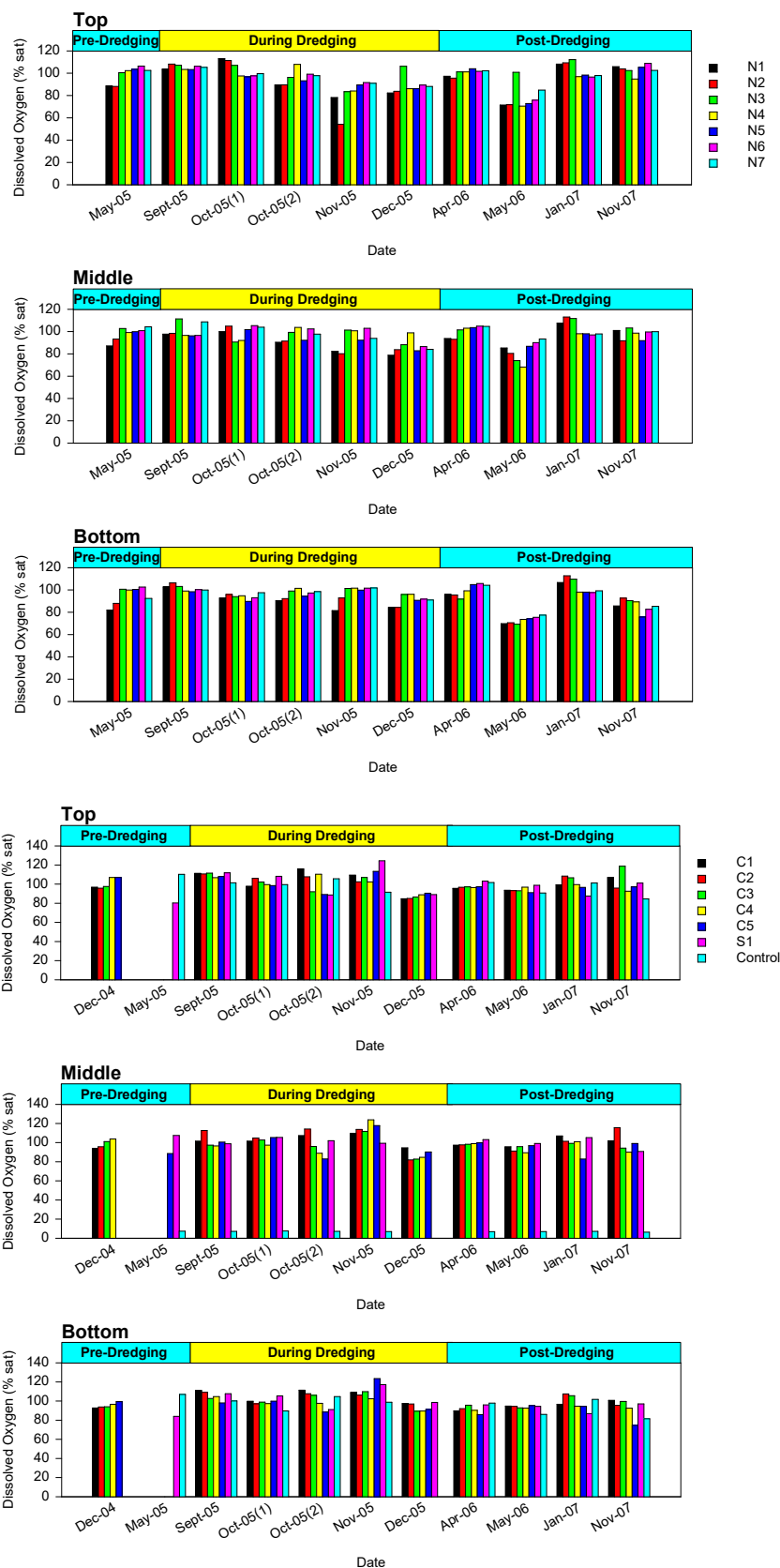


Figure 86. Dissolved oxygen saturation measurements in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data.

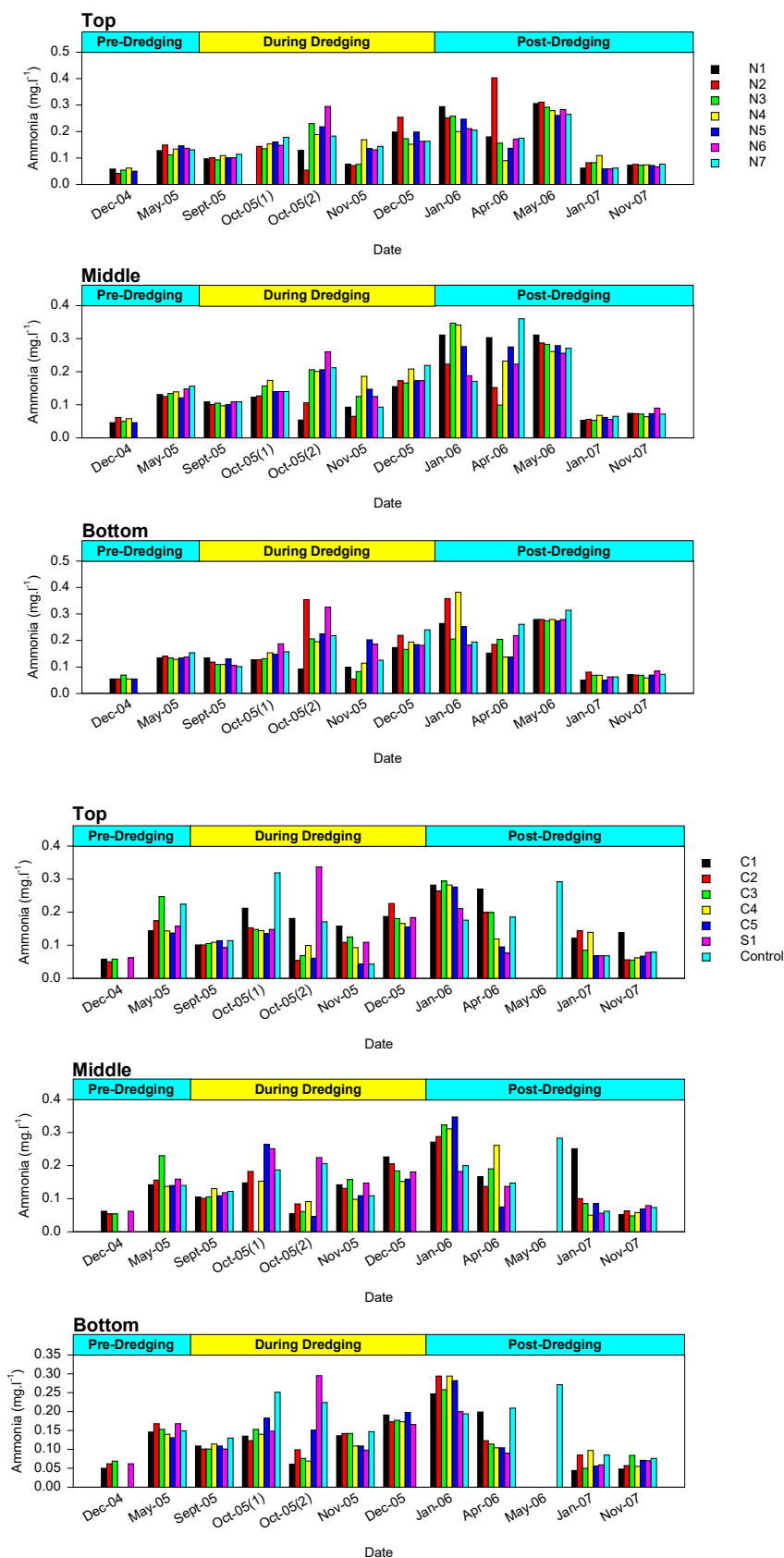


Figure 87. Ammonia concentrations in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data or the concentration was below the method detection limit.

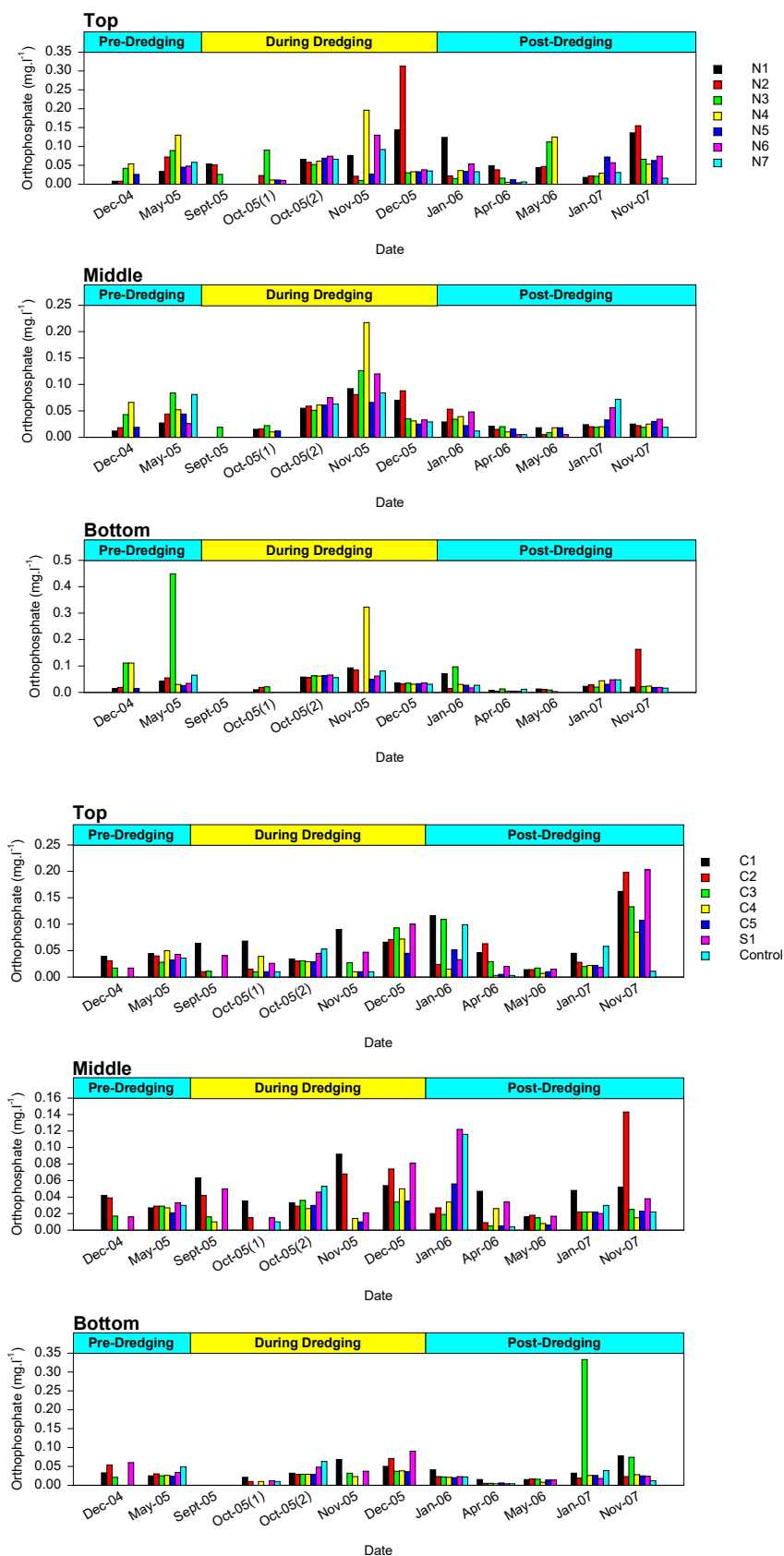


Figure 88. Orthophosphate concentrations in surveys made by the CSIR in the marine environment off the Richards Bay coast before, during and after dredged material disposal for the Berth 306 development in the Port of Richards Bay: C, S and Control sites. Data gaps reflect no data or the concentration was below the method detection limit.

The water column off the Richards Bay coast is usually well oxygenated, with dissolved oxygen concentrations rarely falling to $<6 \text{ mg.L}^{-1}$ and very rarely to $<5 \text{ mg.L}^{-1}$ (CSIR, 2008). Dissolved oxygen concentration and saturation measurements made off the Richards Bay coast by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figures 85 and 86. The dissolved oxygen concentration was generally lowest in the bottom part of the water column, but the average concentration was indistinguishable from that in the middle and surface of the water column. The water column was usually well oxygenated—of the 416 measurements made, two were $<5 \text{ mg.L}^{-1}$ and 34 were $<6 \text{ mg.L}^{-1}$. As mentioned elsewhere, a dissolved oxygen concentration of $\geq 5 \text{ mg.L}^{-1}$ is considered adequate to sustain aerobic aquatic life.

Nutrient concentrations in the nearshore and continental shelf environment along the KwaZulu-Natal coast are usually low, reflecting the nutrient-poor characteristics of Agulhas Current water (Carter and d'Aubrey, 1988; 2000b; Meyer *et al.*, 2002; van der Molen *et al.*, 2016). Topographically induced upwelling brings nutrient 'rich' water (relative to elsewhere along the coast) onto the continental shelf, especially between Richards Bay and Cape St. Lucia (Lutjeharms *et al.*, 2000). Nutrient concentrations decrease with distance offshore of Richards Bay (Oliff, 1973; Pearce, 1977; Gill and Schumann, 1979). However, nutrient concentrations in the area exhibit large vertical and horizontal gradients (Carter and d'Aubrey, 1988; CSIR, 2008) that might be attributed to the movement of nutrient poor Agulhas Current water onto the continental shelf water due to the meandering of the current and upwelling of nutrient rich water at a topographically induced upwelling cell situated just south of Richards Bay.

The discharge of wastewater into the nearshore marine environment through the uMgeni-uThukela Water outfalls at Richards Bay is a localised anthropogenic source of nutrients, particularly phosphate from a phosphogypsum based wastewater. However, the wastewater discharge only elevates nutrient concentrations above the baseline near the discharge points (several hundred meters at the very most), because of rapid dilution in the naturally nutrient poor receiving water (CSIR, 2023, 2024).

Ammonia and orthophosphate concentration measurements made off the Richards Bay coast by the CSIR (2008) in surveys before, during and after dredged material disposal for the Berth 306 Project in the Port of Richards Bay are provided in Figures 87 and 88.

Metal concentrations in the water column in the nearshore marine environment off the Richards Bay coast appear to invariably fall within the baseline range apart from very near the uMgeni-uThukela Water outfalls, which are a source of anthropogenic metals. However, the metal concentrations are usually not particularly high and seldom are above South African Water Quality Guidelines for Coastal Marine Waters (CSIR, 2023, 2024).

Toxicity testing of water collected off the Richards Bay coast for the uMgeni-uThukela Water outfalls monitoring programme has shown that wastewater discharges cause toxicity in the marine receiving environment. The most frequent incidences of toxicity are usually near the outfalls that discharge a phosphogypsum based wastewater, but incidences of toxicity have been recorded over a wider area at times by both discharges (CSIR, 2023, 2024).

6.2.5 Sediment quality

There appears to be no recent information on chemical contaminants in sediment at or very near the existing dredged spoil disposal site off the Richards Bay coast. The most recent sediment quality surveys appear to be those that were made by the CSIR in 2005-2007, before, during and after the disposal of sediment dredged for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay. The CSIR measured metal concentrations in sediment sampled at the positions shown in Figure 78. Baseline metal concentrations defined by the CSIR for the Richards Bay area were used to interpret the metal concentrations measured in the sediment, that is, to determine if the concentrations were within or

above the baseline. The CSIR found little evidence for metal contamination of sediment at and near the dredged spoil disposal site at the time—a single copper concentration in sediment sampled at Site C3 near the disposal site before dredging was above the baseline, but to such a low magnitude it was not considered to reflect contamination. Five metal concentrations in sediment sampled at and near the dredged spoil disposal site after dredged material disposal had ceased were above the baseline. A mercury concentration in sediment at Site C3 near the dredged spoil disposal site and the copper and lead concentrations in sediment at Site N3 near the uMgeni-uThukela Water outfalls were high enough to be considered as having a probable anthropogenic source. It is doubtful that the elevated copper and lead concentrations at Site N3 were a consequence of the dispersal of contaminants in sediment from the dredged spoil disposal site—either in particulate or dissolved form—but rather to wastewater discharge through the uMgeni-uThukela Water outfalls. If dredged material dispersal and wastewater were the source of the metals, then metal enrichment of sediment at sampling sites nearer the dredged spoil disposal site would have been expected—this was not the case. The absence of metal contamination of sediment at and near the dredged spoil disposal site probably reflects the fact that sediment dredged for the Berth 306 development itself was not metal contaminated (CSIR, 2008), although the disposal of maintenance dredged sediment could have been expected to lead to some metal contamination. There was, therefore, little evidence that surface sediment from sites sampled in the marine nearshore environment off the Richards Bay coast was metal contaminated because of dredged material disposal for the development of Berth 306.

Sediment quality surveys performed to assess the impact of wastewater discharge through the uMgeni-uThukela Water outfalls have provided evidence that metals in the wastewaters are accumulating on the seabed near the outfalls. The highest metal concentrations are found in sediment very near (<75 m) to the points where a phosphogypsum based wastewater is discharged through two of the outfalls, but there is evidence for lower magnitude metal contamination—primarily by barium—of sediment over an area that extends several kilometres from these discharge points where. The contamination extends further to the north-northeast of the outfalls than it does to the south-southwest, presumably reflecting the predominant dispersion of the wastewater in a north-northeast direction.

6.3 Biotic Environment

6.3.1 Biogeography

Biogeographically, the Richards Bay area is situated within the Natal Ecoregion—a subtropical marine zone that extends from the Mbashe River mouth in the Eastern Cape to Cape Vidal in northern KwaZulu-Natal and is bounded offshore by the continental shelf edge (Sink *et al.*, 2012). The marine environment off the Richards Bay coast also lies within the KwaZulu-Natal Bight and uThukela River Ecologically and Biologically Significant Area, which spans a broad region from Durban to Maphelane, just south of St Lucia, and extends >50 km offshore.

6.3.2 Microalgae

The nutrient-poor waters of the Agulhas Current are reflected in a relatively low primary productivity in nearshore and continental shelf waters along the KwaZulu-Natal coast (Carter and Schleyer, 1988; Meyer *et al.*, 2002; CSIR, 2008; Barlow *et al.*, 2008, 2010; Coetzee *et al.*, 2010). Chlorophyll-a concentrations are typically <3 µg.L⁻¹—and often considerably lower. Variable, short-term increases in phytoplankton productivity are associated with topographically induced upwelling at Cape St Lucia and to the south of Richards Bay. Upwelled nutrients may be advected by currents further south and influence phytoplankton productivity on the Thukela Banks in the KwaZulu-Natal Bight (Oliff, 1973; Barlow *et al.*, 2008, 2010; Coetzee *et al.*, 2010). The phytoplankton community composition in two seasonal surveys made in 2010 at four sampling positions in the south, middle and north of the KwaZulu-Natal Bight was fairly uniform, dominated in general by *Chaetoceros* species and on occasion co-dominated by *Thalassionema*

nitzschioides and *Dactyliosolen fragilissimus* (van der Molen *et al.*, 2016).

In the nearshore marine environment off the Richards Bay coast, the chlorophyll-*a* concentration (measured *in situ*) is usually as low as elsewhere along the KwaZulu-Natal coast (CSIR, 2008, 2023, 2024), but extreme concentrations of up to 20 µg.L⁻¹ were recorded in one survey for the uMgeni-uThukela Water outfalls monitoring programme (CSIR, 2023). The reason for these extreme concentrations is uncertain, but is highly anomalous.

6.3.3 Macroalgae

A high diversity (~225 species) of macroalgae (seaweeds) have been reported for the area of coast that incorporates Richards Bay (Bolton and Stegenga, 2002). However, no information could be found in the peer reviewed scientific literature on macroalgal surveys in the immediate Richards Bay area apart from that mentioned in a section below, which recorded a turf alga on subtidal reefs. As stated above, intertidal rocky shores are sparse in the Richards Bay area and the only areas where macroalgae are found in the intertidal to any significant abundance is on dolosse and other man-made structures that constitute the breakwaters to the Port of Richards Bay. Macroalgae on nearshore subtidal reefs to the immediate south, and probably also north, of the Port of Richards Bay are probably sparse and of a low biomass due to the high suspended sediment concentrations and related turbidity that characterise these waters, but this conclusion is speculative in the absence of surveys.

6.3.4 Zooplankton and ichthyoplankton

Continental shelf waters along the KwaZulu-Natal coast support a higher and more variable zooplankton biomass than offshore waters (Carter, 1977; Carter and Schleyer, 1988; Beckley and van Ballegooyen, 1992; Pretorius *et al.*, 2016). However, findings on seasonal species composition and biomass are inconsistent, with some studies showing no seasonal difference (Carter and Schleyer, 1988) and others a marked difference (Pretorius *et al.*, 2016). The zooplankton biomass along the KwaZulu-Natal coast is considerably lower than that recorded along the south and west coasts of South Africa (Coetzee *et al.*, 2010; Pretorius *et al.*, 2016). Ichthyoplankton are likewise confined primarily to inshore waters, with abundance decreasing rapidly with distance offshore (Beckley and van Ballegooyen, 1992). Oliff (1973). Barlow *et al.* (2008) recorded a positive response of phytoplankton to a quasi-permanent upwelling cell in the Richards Bay area –but possibly arising further north of Cape St Lucia–the high zooplankton biomass recorded in this area and to the north of Richards Bay by Pretorius *et al.* (2016) may be a response to phytoplankton blooms stimulated by the upwelling. Pretorius *et al.* (2016) found no evidence for an elevated zooplankton biomass associated with riverine input from the Thukela River–however, river flow has been shown to be a driver of ecological productivity in the nearshore marine environment along parts of the KwaZulu-Natal coast (de Lecea *et al.*, 2015; Scharler *et al.*, 2016).

Collocott (2016) reported a generally lower abundance of ichthyoplankton on the continental shelf off the Richards Bay coast compared to that on the continental shelf off the Thukela River and Durban. The most abundant ichthyoplankton off the Richards Bay coast –accounting for 30% of total abundance–were from the families Myctophidae (Lanternfish), Bregmacerotidae (Codlets), Tripterygiidae (Threefin Blennies), Priacanthidae (Bigeyes), Scombridae (Mackerel, Tuna, Bonito), Mullidae (Goat Fishes/Red Mulletts) and Pseudochromidae (Dottybacks). Overall, season, depth and the dynamic oceanographic environment accounted for most of the observed spatial and temporal patterns.

6.3.5 Benthic biological resources

The sediment on many beaches along the KwaZulu-Natal coast comprises coarse- to medium-grained sand, reflecting the exposure to high wave energy (Jackson and Lipschitz, 1984; Harris, 2008, 2012). The beaches generally reflective and morphologically unstable, often changing in volume (width and height) between

seasons and after heavy seas. As a result, the benthic macrofaunal assemblages are depauperate when compared to the neighbouring deeper subtidal environment (CSIR, 1998). Benthic macrofauna may be entirely absent from beaches that are highly exposed to waves and are thus unstable in their morphology. On less exposed beaches the benthic macrofaunal communities are usually dominated—both in terms of biomass and/or abundance—by the ‘sea lice’ or Mole Crab *Emerita austroafricana* and Plough Whelk *Bullia natalensis*. Isopods, polychaete worms and other fauna are comparatively poorly represented (Dye *et al.*, 1981; Wooldridge *et al.*, 1981; Harris, 2008, 2012). Several species of Ghost Crabs *Ocypode* spp are common from the high-water mark into vegetated dunes at the back of sandy beaches.

Benthic macrofaunal communities in sediment off the Richards Bay coast comprise a typical taxonomic array of polychaetes, crustaceans and molluscs. However, species diversity and abundance off the Richards Bay coast is lower compared to off Durban, where it is more than double. The reason for this difference is not well understood but appears to be a natural phenomenon—the difference was apparent even before the construction of the Port of Richards Bay and discharge of effluent through the uMgeni-uThukela Water wastewater outfalls (McClurg, 1988; T McClurg, personal communication). Sediment type appears to be a factor influencing the type of benthic macrofaunal communities off the Richards Bay coast, in common with these fauna elsewhere. In the Richards Bay area, sandy sediment appears to support a lower abundance and species diversity of benthic macrofauna than muddy sediment (Tim McClurg, personal communication).

There appears to be no recent information on benthic macrofaunal communities in sediment at or near the existing dredged spoil disposal site off the Richards Bay coast—the last surveys appear to have been those made in 2005 to 2007 by the CSIR before, during and after the disposal of sediment dredged for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay. There have, in contrast, been numerous surveys using benthic macrofauna to identify the impact of wastewater discharged through the uMgeni-uThukela Water outfalls. The surveys have identified clear and consistent impacts to benthic macrofaunal communities near the points where a phosphogypsum based wastewater is discharged, largely due to the smothering effect of phosphogypsum depositing on the seabed (CSIR, 2023, 2024).

The CSIR surveys on benthic macrofaunal communities for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay were made at the positions shown in Figure 78. The benthic macrofaunal assemblages separated into three main groups on locality when subjected to multivariate statistical analysis—either at or near of the dredged spoil disposal site (Sites S1, C1-C 5, N1), immediately off the Richards Bay coast (Sites N2 and N3), and north of Richards Bay (Sites N4-N7, Control). A total of 68 benthic macrofaunal taxa were identified, but this number would have been higher if a higher level of taxonomic resolution was possible (numerous taxa could not be identified to the species level because of an absence of morphological descriptions). Polychaete worms were the dominant taxon in terms of abundance, followed by crustaceans. Taxa that were recorded frequently included the polychaete families Nephtyidae, Glyceridae and Eunicidae, and nermertean worms. Abundances ranged from 13.3-661.3 (average 99.8) inds.m⁻². *Magelona* sp (polychaete worm) occurred in very high abundances (>50 inds.m⁻²) on three occasions, but *Urothoe* (amphipods) occurred most often at elevated abundances (>10 inds.m⁻², average abundance of taxon at a site was 1.5 inds.m⁻²). The number of taxa, abundance, species richness and species diversity were generally highest at the most northerly sites and lowest off the Richards Bay coast, supporting earlier findings of a low benthic macrofaunal species diversity off the Richards Bay coast.

Rocky intertidal habitats are relatively scarce along the KwaZulu-Natal coastline, comprising less than one-third of the total coastline length (Jackson and Lipschitz, 1984; Harris, 2008, 2012). Many intertidal rocky habitats are periodically inundated by sand, making them unsuitable habitat for long-term colonisation by benthic invertebrates and algae. The rocky intertidal fauna in KwaZulu-Natal is nevertheless comparatively diverse (Sink *et al.*, 2005). Dominant species that characterise rocky intertidal habitat between Leven Point

and Port Edward include the Brown Mussel *Perna perna*, Eightshell Barnacle *Octomeris angulosa*, Columnar Sandy Zoanthid *Palythoa nelliæ*, Eastern Granular Limpet *Scutellastra natalensis*, the algae *Ralfsia expansa*, *Jania verrucosa*, *Cheilosporum sagittatum* and *Hypnea spicifera*, and encrusting coralline algae. North of Leven Point, intertidal communities differ markedly in species composition, being dominated by the Redbait *Pyura stolonifera* and various Tubeworm species and showing greater tropical affinities compared to communities south of Leven Point, which show greater subtropical affinities. Several intertidal invertebrates are subject to high levels of subsistence harvesting in northern KwaZulu-Natal and this might also account for some of the geographical differences (Brown Mussels are, for example, heavily exploited) (Sink *et al.*, 2005).

Rocky intertidal habitat in the Richards Bay area is particularly limited—breakwaters protecting the entrance to the Port of Richards Bay, the Dolphin Viewing Pier, and other artificial hard substrate in the port constitute by far the largest extent of intertidal hard substrate in the area. The nearest natural intertidal rocky substrates are situated several kilometres to the north and south of Richards Bay. Although numerous of the species recorded by Sink *et al.* (2005) on intertidal rocky shores are represented on artificial hard substrates in the Port of Richards Bay (S Weerts (CSIR), B Newman (CSIR), personal observation), there appears to be no published studies detailing the species composition of hard substrates on the breakwaters and Dolphin Viewing Pier. As discussed earlier, a wedge-shaped reef extends from near the mouth of the Mlalazi River south of Richards Bay to just south of the entrance to the Port of Richards Bay (Figure 75). This reef continues north of the port entrance as a narrow strip of coastal reef. The only biological information on these subtidal reefs appears to be transect photographic surveys and fauna and flora sample collection performed for the Berth 306 Project at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008). Two transect photographic surveys were made on reefs on the dredged spoil disposal site and 11 transect photographic surveys on surrounding reefs to the north and south of the disposal site (Figure 89). The most abundant biota were sampled by SCUBA divers.

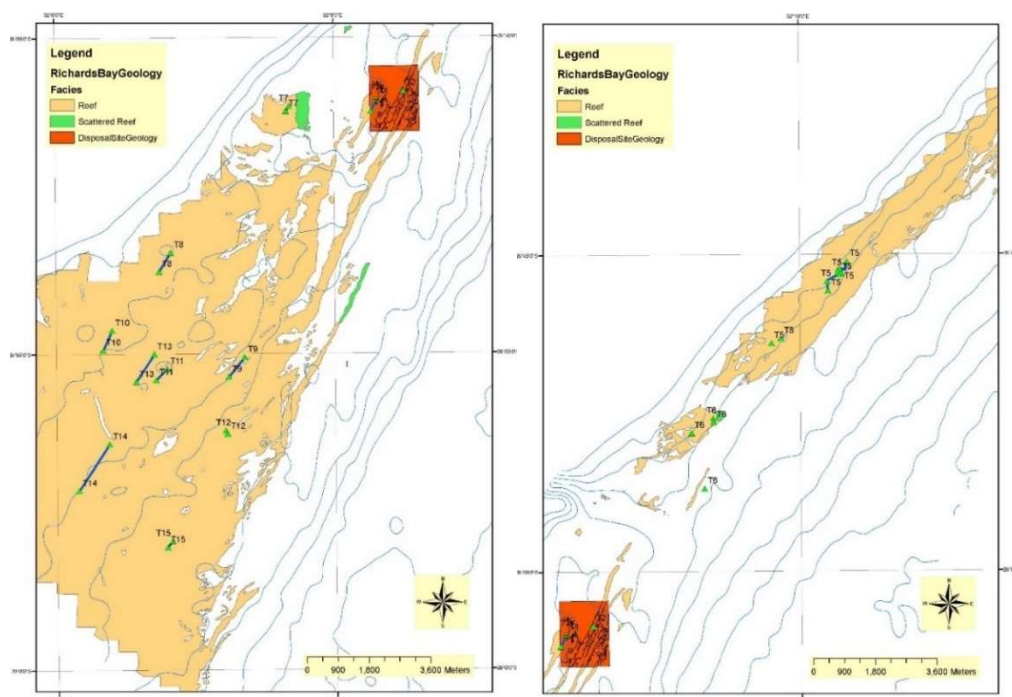


Figure 89. Locations of photographic transects on reefs at and to the south and north of the dredged spoil disposal site off the Richards Bay coast (CSIR, 2008).

The quality of the photographs was generally 'low' to 'average' and they were often 'dark' due to the low visibility caused by high suspended sediment concentrations and related low light conditions—including prior to dredged material disposal for Berth 306 (Figure 90). Gorgonians, sponges and ascidians were the

most commonly benthic macrofauna in the photographs, while an unidentified turf alga was abundant throughout the survey area. The benthic biotic community is indicative of an environment characterised by high suspended sediment concentrations and low light. Overall, the reef benthic biotic cover was sparse (CSIR, 2008).

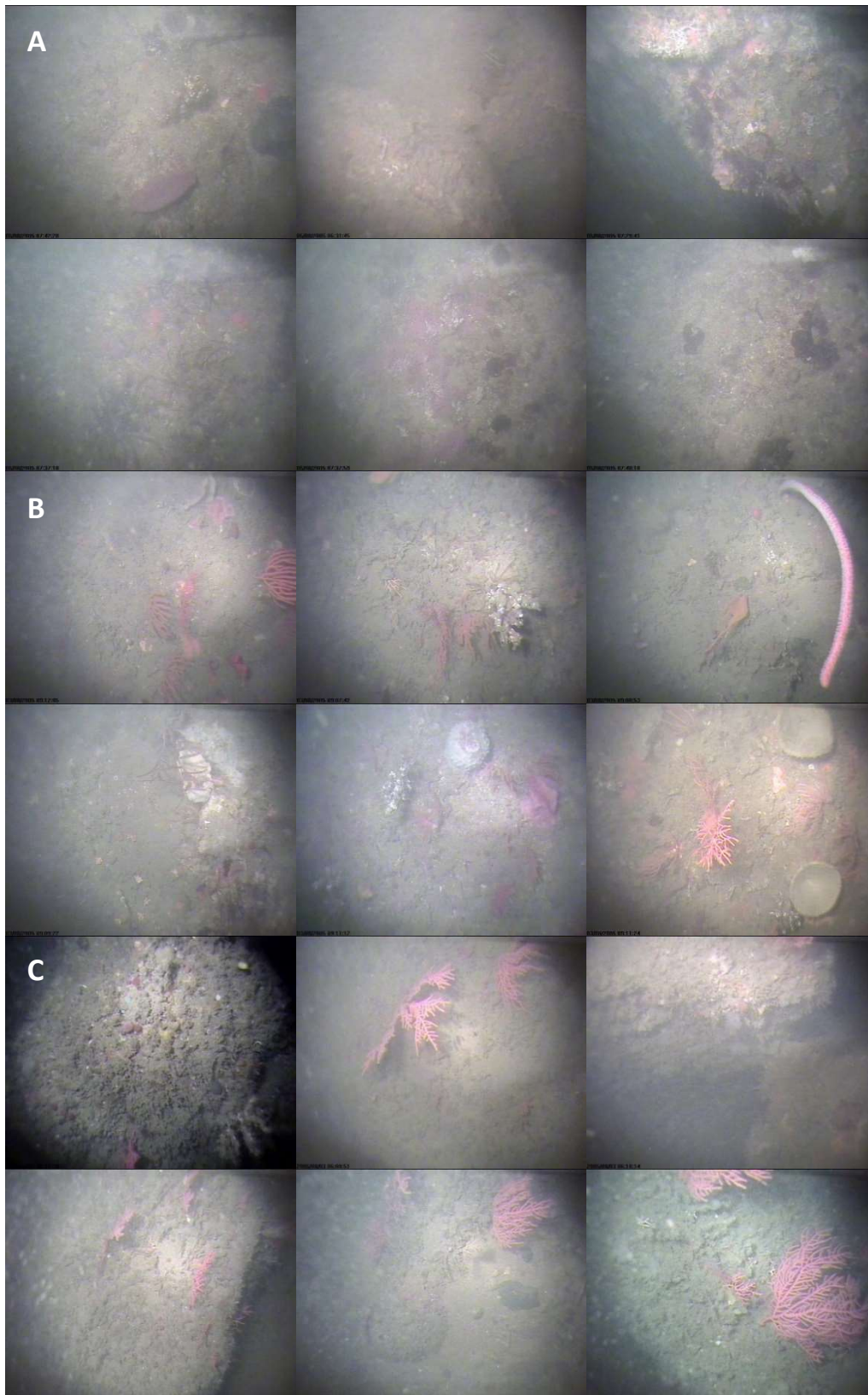


Figure 90. Photographic images of the reef benthic environment off the Richards Bay coast: a) deep reefs, b) shallow reefs, c) reefs on the dredged spoil disposal site.

Thirty-nine sponge taxa, ten ascidians, nine gorgonians, eight algae, eight bryozoans, three hydroids, two soft corals and two hard corals were sampled by SCUBA divers. A greater-than-expected variation in species composition and abundance between photographic transects and SCUBA diver sampling sites likely reflects highly heterogeneous environmental conditions over relatively small spatial scales. The reef biota are typical of deeper, flat reef found further north—such as deeper Seven-Mile Reef and Sponge Reef (-26-35 m)—but are more impoverished, likely due to higher turbidity and sedimentation. The impoverishment is typical of deeper reefs, but in the Richards Bay region the impoverishment extends to shallower reefs (-12-25 m) than at Sodwana Bay (-25-30 m).

In conclusion, the generally low biotic diversity and cover on the reefs off the Richards Bay coast are primarily attributable to naturally high turbidity and sedimentation, these conditions exacerbated by anthropogenic activities such as dredged material disposal and possibly also wastewater discharge.

6.3.6 Macrocrustacea

Several macrocrustacean species are targeted by commercial fisheries along the KwaZulu-Natal coast. The fishery is primarily concentrated on the Thukela Banks in the KwaZulu-Natal Bight, where the muddy substratum supports sufficient benthic productivity to sustain populations at densities viable for commercial exploitation (although the fishery is now commercially marginal due to 'collapsed' stocks). Targeted species include a range of penaeid prawns, most notably the White Prawn *Fenneropenaeus indicus*, Brown Prawn *Metapenaeus monoceros* and Tiger Prawn *Penaeus monodon*, but also Pink Prawns *Haliporoides triarthrus*, Red Prawns *Aristaeomorpha foliacea*, Langoustines *Metanephrops mozambicus* and *Nephropsis stewartia* and Red Crab *Chaceon macphersoni* (Fennessy and Groeneveld, 1997; Everett, 2014).

There is no active commercial macrocrustacean fishery in the nearshore marine environment off the Richards Bay coast. However, as noted earlier several penaeid swimming prawn species rely on estuarine environments as nurseries during their juvenile development, including the Port of Richards Bay and neighbouring Mhlathuze Estuary. Historically, the St Lucia estuary served as a critical nursery area for penaeid swimming prawns. However, prolonged closure of the St Lucia estuary mouth in recent years coupled with overfishing in the Port of Richards Bay and Mhlathuze Estuary has likely contributed to recruitment failure and the subsequent decline in the penaeid swimming prawn fishery productivity on the Thukela Banks (Everett, 2014).

6.3.7 Fish

The nutrient poor waters along the northeast coast of South Africa mean this area does not support large commercial finfish (and shellfish) fisheries compared to those along the southeastern and western Cape Province coast. There is fairly good understanding of commercial and recreational fisheries in the Richards Bay area, although the information below is from a historic study based on boat inspections and fishing locality information derived from TNPA Port Control records (Jairam, 2005; CSIR, 2008). A small commercial, and vibrant recreational offshore line fishery operates in the Richards Bay area, making a small yet important contribution to the local economy. The catches by the commercial and recreational sectors are dominated by demersal, reef-associated endemic species, many of which are resident and have restricted distributional ranges. Although their movement patterns are not very well known, most species probably do not undertake large-scale seasonal migration—this accounts for their consistent appearance in catches throughout the year. Species that exhibit seasonality in catches are either summer (Tunas, Mackerels, Dorado) or winter (Geelbek, Salmon) migrants. Commercial and recreational line fishery catches are dominated by Slinger *Chrysoblephus puniceus* (~83% of fish landed by commercial fishers) and Soldier *Cheimerius nufar* (~6% of fish landed by commercial fishers). Other important species include various Rockcod *Epinephelus* spp, various Kob/Salmon *Argyrosomus* spp, Dane Seabream *Porcostoma dentata*, Blue Emperor *Lethrinus nebulosus*, Cavebass *Dinoperca petersi*, Javelin Grunter *Pomadasys kaakan*, Queen Mackerel *Scomberomorus plurilineatus*, Geelbek *Atractoscion aequidens* and Dorado *Coryphaena hippurus*.

The fishing effort was markedly seasonal, with most launches occurring from December to July. The main determinants of fishing effort for both recreational and commercial sectors were the weather and sea conditions—strong winds, strong currents, rough seas and rain were deterrents to fishing, which accounts for the lower fishing effort from August to November (the windy season). Fishing effort in the recreational sector was more sensitive to these factors than the commercial sector and was also mainly concentrated on weekends and holiday periods—there were peaks in recreational fishing in April and December because of the holiday seasons. Apart from an intensively fished area immediately south of the Port of Richards Bay, most recreational and commercial fishing effort occurred to the north of Richards Bay. The continental shelf is narrow to the north, meaning the reefs are concentrated in a relatively narrow band and are easily accessed by commercial and recreational fishers in this region. Recreational fishers spent about half of their time fishing for pelagic gamefish, which favour the clear, warm water of the south-flowing Agulhas current. The current flows close to the shelf break, so fishing in the northern area facilitates access to the current. Intrusions of the current onto the shelf also permit commercial and recreational fishers to fish for demersal species while drifting along the reef contours. Lastly, commercial and recreational fishers prefer to return home with a following wind—prevailing north-easterly winds in the afternoon assist boats fishing in the north to return to port. The comparative distribution of commercial and recreational fishing effort was similar, except that commercial boats fished in more areas than recreational boats and operated further from the port. Anecdotal reports from fishers indicate that commercial operations now occur further offshore than in earlier years, suggesting depletion of fish on inshore reefs. The area near the existing dredged spoil disposal site off the Richards Bay coast was utilised fairly frequently, particularly by commercial operators, but not as often as areas to the north of Richards Bay (Jairam, 2005; CSIR, 2008).

The CSIR evaluated the impact of dredged spoil disposal during the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay on commercial and recreational fishing catches using inspections of catches by returning boats, fishing locality information from TNPA Port Control records and discussions with fishers in both sectors (CSIR, 2008). Recreational fishing localities were spatially more confined in the three six-month periods leading up to, including and immediately after dredging for the Berth 306 Project, in comparison to the earliest pre-dredging period and the later post-dredging periods, in which fishing occurred over a much wider area. There is no obvious explanation for this, and the phenomenon was probably not dredging-related since it commenced in the 6-month period before dredging. There were no changes in catch composition that could be attributed to dredging, and there were no changes in catch rates recorded. It can, therefore, be concluded that the dredged spoil disposal did not affect the recreational fisheries sector in ways detectable by the methods employed in the study. Some changes noted for the commercial fishery could be interpreted as being due to dredged spoil disposal. During the 6-month dredged spoil disposal period and in the 6-months thereafter, the numbers of reported outings to the dredged spoil disposal site area increased markedly compared to that in the pre- and later post-dredged spoil disposal periods. The distribution of fishing effort in the 6-months immediately post-dredging was also much more localised compared to the other periods. This suggests that dredged spoil disposal acted as an attractant to commercial fishing, despite the consequent substantial reef loss in the area of about 64% relative to that before disposal commenced because of smothering (Ramsay and MacHutchon, 2006). However, the records are for a 5 × 5 nautical mile fishing block and do not record if fishing occurred over the wider block or near the dredged spoil disposal site. Commercial fishers indicated that they seldom fish in the block and when they do it is on deeper reefs—particularly on the so-called ‘Ledge’ formed by the close-set parallel series of depth contours from 30-45 m, comprising an aeolianite/beach-rock paleo-coastline. Given the increased catch rates in this and surrounding 5 × 5 nautical mile blocks, it appears that the loss of reef by smothering on the dredged spoil disposal site did not impact directly on commercial fishing activities, but may have displaced resident fish to adjacent reefs. However, the observed increase in both fish effort and catch rates in the dredged spoil disposal site area does not explain the increased effort in an area far from the dredged spoil disposal site during the 6-month

post-dredged spoil disposal period. Furthermore, increased catch rates during and after dredged spoil disposal were also recorded in an area that was probably beyond the influence of the dredged spoil disposal activity (10 nautical miles to the north). These observations suggest it is likely that some other factor may have been responsible for the increased catch rates in the vicinity of the dredged spoil disposal site and in a block to the north. Significantly, there were no marked changes in catch composition near the dredged spoil disposal site. This was not entirely unexpected since dredged spoil has been disposed at the site for many years as part of the maintenance dredging programme in the Port of Richards Bay and the fish community would have acclimatised to this impact. It is, therefore, reasonable to assume that fishes in the area either moved out of the area if they were intolerant of disturbance associated with dredged spoil disposal, or they have acclimatised to episodic perturbations associated with dredged spoil disposal to some extent. The unchanged species composition during the Berth 306 survey period indicated that dredged spoil disposal did not obviously benefit nor compromise the fishes retained by the offshore line fishery.

6.3.8 Marine reptiles

No specific surveys on marine reptiles (*e.g.* turtles) in the marine environment off the Richards Bay coast could be found in peer reviewed literature or other information sources. Five species of sea turtles are known to occur along the east coast of South Africa—Leatherback Turtle *Dermochelys coriacea* (Critically Endangered), Green Turtle *Chelonia mydas* (Endangered), Hawksbill Turtle *Eretmochelys imbricate* (Critically Endangered), Olive Ridley Turtle *Lepidochelys olivacea* (Vulnerable), Loggerhead Turtle *Caretta caretta* (Endangered). Green turtles, Hawksbills and Olive Ridley's are typically found on inshore reefs as non-resident visitors (Mortimer, 1984; Lauret-Stepler *et al.*, 2007, Pereira *et al.*, 2008). Leatherback and Loggerhead Turtles nest on sandy beaches within the iSimangaliso Wetland Park to the north of Richards Bay in the summer months (Nel *et al.*, 2013). Richards Bay represents the southern extent of their known nesting range (Harris *et al.*, 2012), although there are no confirmed records of turtles nesting on beaches in Richards Bay could be found in the literature or other information sources. Satellite tracking studies of Leatherback Turtles has shown that their home range includes the waters off the Richards Bay coast (CSIR, 2016), but some species move offshore to use the Agulhas Current to migrate to the west coast of South Africa before returning to breed (Luschi *et al.*, 2006). It is, therefore, reasonable to assume that turtles will be encountered by dredging vessels and barges in the waters off the Richards Bay coast.

6.3.9 Marine mammals

There are two related groups of marine mammals in the nearshore marine environment off the Richards Bay coast that might be affected by the Berth 605 Project, namely dolphins and whales. These include the Humpback Dolphins *Sousa plumbea*, a Protected Species in terms of the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) Threatened or Protected Marine Species Regulations of 2017 and is rated as Endangered by the International Union for Conservation of Nature (Braulik *et al.*, 2015) and is in the Red List of Mammals of South Africa (Plön *et al.*, 2016). Humpback Dolphins reside permanently along the east coast of South Africa and are sighted with regularity in the marine nearshore off the Richards Bay coast, and to a lesser degree in the Port of Richards Bay (Atkins *et al.*, 2004; Keith *et al.*, 2013; Atkins *et al.*, 2016).

The size of the Humpback Dolphin population off the Richards Bay coast is unknown, but Johnson (2012) estimated it at 203 individuals. Earlier studies provide lower or higher estimates, but Johnson (2012) used a stricter approach to estimate the population size. Keith *et al.* (2013) analysed 249 sightings and the behaviour (foraging/feeding, resting, socialising, travelling) of Humpback Dolphins in the Richards Bay area between 1998 and 2006 to generate area use maps. Dolphins used most of the Port of Richards Bay area for foraging/feeding but avoided the Kabeljous Flats and southernmost part of the Richards Bay Coal Terminal Basin. The core foraging/feeding area was in and near the entrance to the port and in the dredged

navigation channel to the port. Dolphins never used the port for resting, and rarely for socialising. Humpback Dolphins feed predominantly on reef-associated, estuarine and demersal fish. Keith *et al.* (2013) postulated that the dolphins might be using the port entrance for feeding since breakwaters armouring the entrance are acting as artificial reefs, attracting fish. Dolphins used large areas outside the port for all activities, including near the existing dredged spoil disposal site. The core use area was situated relatively close inshore, within ~10 m depth contour and decreased sharply with distance offshore. Dolphins were rarely observed more than ~3 km offshore.

Although Humpback Dolphins can tolerate and indeed prefer turbid environments, there is a potential concern that their main food sources could be affected by levels of suspended sediment that are elevated above natural conditions, resulting in an indirect impact on the resident population. The likelihood of this impact is not well understood, as is the case with other potential effects on behaviour associated with increased noise levels and disturbance. However, dredging and dredged spoil disposal activities for the Berth 306 Project appeared to have no long-term negative consequences for the Humpback Dolphin population in the Richards Bay area, but this conclusion should be caveated with the fact that a dedicated monitoring programme was not undertaken at the time.

Several whale species (*e.g.* Humpback Whales *Megaptera novaeangliae*) frequent the nearshore coastal waters off the Richards Bay coast between about June to November (species dependent) (Findlay and Best, 2016), on their migration to more northerly breeding and calving waters. There is, however, little information on their movements in the nearshore off the Richards Bay coast, but discussions with local recreational anglers suggests they occur commonly in the marine nearshore environment off the Richards Bay coast in the 'whale season'. There appear to be no records of whales entering the port.

7. Assessment of Environmental Impacts

7.1 Impact assessment procedure

The approach followed to assess the significance of impacts for this Estuarine and Marine Ecology Environmental Impact Assessment is outlined below. Note that the impact assessment before mitigation considers embedded mitigation—measures that are reasonably expected to be implemented as part of standard operating procedures by construction and dredging contractors.

Status: Impacts/effects were rated in terms of their status – they can either be positive, negative, or neutral:

Definition
Positive: the change will improve the quality of the environment (<i>e.g.</i> an improvement in water quality or increase in species diversity of biological communities).
Negative: the change will reduce the quality of the environment (<i>e.g.</i> a deterioration in water quality or a reduction in species diversity).
Neutral: the change will neither improve nor reduce the quality of the environment (including because the effect of an impact might not be perceptible within the natural range of variability).

Nature of the impact: Environmental impacts were rated in terms of whether they are direct or indirect:

Direct impacts: these are impacts that are caused directly by an activity and generally occur at the same time and place as the activity. These impacts are usually associated with the construction, operation, or maintenance of an activity and are generally obvious and quantifiable. An example of a direct impact is the loss of a biological communities in sediment by dredging.
Indirect impacts: these are changes that may occur because of an activity, but with a degree of separation in time and/or space. These types of impacts thus include potential impacts that do not manifest immediately when an activity is undertaken, or which occur at a different place because of the activity. An example of an indirect impact is the displacement of fish from a breeding area due to noise disturbance, resulting in birds leaving the area due to their inability to find sufficient fish on which to feed.

Reversibility of impacts: Impacts/effects were rated in terms of their reversibility, which is the likelihood the affected parameters, resources, or processes will return to the baseline:

Definition	Score
Reversible: the impact/effect is reversible, with or without mitigation.	1
Recoverable	3
Irreversible: recovery from the impact/effect is not possible, or mitigation that could reverse the impact is unlikely to be implemented.	5

Extent: The extent is the spatial or geographical area that might or will be affected by an impact/effect:

Definition	Score
Site only: generally within ~250 m of proposed project footprint in the Port of Richards Bay or within ~500 m of the dredged spoil disposal site offshore of Richards Bay.	1
Local: within the confines of the Port of Richards Bay, or within 2 kilometres of the dredged spoil disposal site offshore of Richards Bay.	2
Regional: within the greater area offshore of Richards Bay and KwaZulu-Natal.	3
National: extending over a greater scale than regional, but within South Africa's territorial waters.	4
International: having a global impact.	5

Duration: Impacts/effects were rated in terms of the period during which the impact will be experienced or perceived or that it will take for impacted parameter, resources, or processes to return to the baseline, and considers ecological characteristics (such as the lifecycle of a plant or animal) and human timeframes:

Definition	Score
Immediate	1
Short-term: ~0-6 months, impact ceases after construction phase.	2
Medium-term: ~6 months to 5 years.	3
Long-term: ~5-10 years.	4
Permanent: >10 years, or leading to a permanent change.	5

Magnitude: The intensity is the anticipated severity of the impact/effect:

Negative Impacts

Definition	Score
Very low: The disturbance will cause a very slight change from the baseline condition. The change is barely distinguishable, approximating to the 'no change' situation; and/or having negligible effect on the known population or range of the element/feature.	1
Low: The disturbance will cause a small shift away from the baseline condition. The change arising from the loss/alteration will be discernible, but the underlying character, composition and/or attributes of the existing baseline condition will be like pre-development circumstances or patterns; and/or having a minor effect on the known population or range of the element/feature.	2
Medium (moderate): The disturbance will cause the loss or alteration of one or more key elements/features of the baseline condition, such that the post-development character, composition and/or attributes will be partially changed; and/or loss of a moderate proportion of the known population or range of the element/feature.	3
High: The disturbance will cause a major loss or major alteration to key elements/features of the baseline condition such that the post-development character, composition and/or attributes will be fundamentally changed; and/or loss of a high proportion of the known population or range of the element/feature.	4
Very high/unknown: The disturbance will cause a total loss of, or very major alteration to, key elements/features/ of the baseline condition, such that the post-development character, composition and/or attributes will be fundamentally changed and may be lost from the site altogether; and/or loss of a very high proportion of the known population or range of the element/feature.	5

Probability of occurrence: Impacts/effects were rated in terms of the probability of occurring:

Definition	Score
Improbable: highly unlikely to occur but theoretically possible (<5% chance).	1
Low probability: unlikely to occur, but a not negligible probability (5-40% chance).	2
Medium probability: less likely than not to occur, but still appreciable (40-60% chance).	3
Highly probable: likely to occur (60-90% chance).	4
Definite: unavoidable impact that will definitely occur (100% chance).	5

Impact significance assessment: The significance assessment for impacts/effects was determined by a combination of the above impact characteristics as:

$$\text{Significance} = (\text{Magnitude} + \text{extent} + \text{reversibility} + \text{duration}) \times \text{probability}$$

Negative	Positive
Very Low	Very Low
Low	Low
Moderate	Moderate
High	High
Very High	Very High

7.2 Mitigation of environmental impacts

- In the event the significance of an identified environmental impact was rated negative MODERATE or HIGH, mitigation measures to avoid, prevent, or minimise the impact are recommended. Similarly, in the event the significance of an identified environmental impact was rated positive MODERATE or HIGH, mitigation measures to enhance and promote the impact are recommended.
- Although not required, mitigation measures are also recommended for impacts that are assessed as being of a VERY LOW significance in the interests of good environmental management practice.
- If no mitigation measures are possible, or necessary, this is stated.
- The significance of impacts was rated before and after the implementation of mitigation. The scenario 'without mitigation' considers all management actions already included in the project description–embedded mitigation or upfront commitments. The scenario 'with mitigation' assesses the significance of an impact considering additional recommended mitigation measures, that is, residual impacts.
- The mitigation measures will invariably not be all encompassing since additional information may come to light on possible impacts as more detailed project planning is finalised. A comprehensive Environmental Management and Monitoring Programme must be formulated before the project proceeds, to guide the management of environmental impacts related to the proposed project.
- The dredging and construction contractor/s are expected to also prepare Environmental Management Plans to control and manage the environmental impacts related to their operations.

7.3 Recommended environmental monitoring

In the event the significance assessment for a potential environmental impact was negative MEDIUM or HIGH, recommendations for environmental monitoring to audit the impact are provided. The environmental monitoring recommendations are not of a detailed form for the reason an Environmental Monitoring Programme programme will be formulated before the project proceeds. The recommended monitoring programme will be submitted to relevant authorities for approval.

7.4 Cumulative environmental impacts/effects

Cumulative impacts/effects refer to impacts/effects of past, present, or reasonably foreseeable future projects or activities that could have an incremental impact/effect via the same pathway and could, therefore, result in a change of greater or lesser significance than the significance of impacts/effects assessed for the Berth 605 Project in isolation.

TNPA has outlined intended infrastructure developments in the Port of Richards Bay in the short- (present-2032), medium- (2032-2052) and long-term (beyond 2052). The planned infrastructure developments in the short- and medium-term in the most recent iteration of the Port of Richards Masterplan are outlined below, as are other developments contemplated by other project proponents. The way these developments will alter the physical layout of the port compared to the existing layout is shown in Figures 2-4. The numbering used below corresponds to the numbering in Figures 2 and 4. It is important to note that the final layout for the planned infrastructure developments is not yet finalised and may change depending on the findings of further detailed investigations, including an evaluation of the environmental

impacts related to the planned infrastructure developments.

Short-term planning (present-2032)

1. Development of LNG Berth 207.
2. Naval Island and Pelican Island for the relocation of Navy from Port of Durban.
3. Relocation site for bulk commodities from Port of Durban.
4. Bayvue railyard infrastructure upgrade and railyard expansion for 100 wagon trains.
5. South Dunes liquid bulk development, land area increases from 74 ha to 162 ha.
6. Development of mega chrome terminal.
7. Relocation of South32 aluminium storage.
8. Development of a new container handling facility.
9. LNG Powership becomes available.
10. Development of Berth 605 for container handling.
11. Extension of the Finger Jetty to develop Berths 802 and 803 for Mega Chrome.
12. Extension of ferro slab for additional storage capacity.
13. Development of Berths 709 and 710 for dry bulk.
14. Development of a Liquid Bulk Berth 210.
15. Reserved sites for environmental offsets.
16. Development of new dry bulk terminal.
17. Development of a new passenger facility at the existing Repair Quay.
18. Bayvue Precinct - TNPA land acquisition, areas increase from 2215 ha to 3180 ha.

Medium-term planning (2032-2052)

1. Development of more liquid bulk terminals at South Dunes area, part of South Dunes land will be used for gas to power and liquid petroleum gas.
2. Development of Liquid Bulk Berth 211 to support the South Dunes liquid terminals.
3. 700 Series: provision of additional berthing capacity for Multi-Purpose Terminal.
4. Bayvue rail yard expansion - rail balloon for 150 wagon trains.
5. Land acquisition for future port development Phase 2, area increased from 3 180 ha to 3 803 ha.
6. Mhlathuze rail yard expansion to service 600 series berths.

Long-term planning (beyond 2052)

1. Additional dig-out at the Bayvue Precinct for the provision of additional quay lengths and berths.
2. Dig-out inside the new proposed port limits for additional port activities.
3. TNPA land area between the break bulk terminal and proposed dry dock to be converted to additional berths.

7.5 Planned infrastructure developments considered in cumulative environmental impacts/effects assessment

The planned short-, medium- and long-term infrastructure developments will not necessarily interact directly with the development of Berth 605 because of spatial and/or temporal separation, but will interact cumulatively in some way at the port and nearshore coastal marine environment scale. The ongoing port operations and planned infrastructure developments outlined below were considered in the assessment of cumulative effects for the Berth 605 Project. The main focus is on ongoing port operations and short-term planned infrastructure developments, but projects that involve the development of landside infrastructure were not considered. However, it is important to note that the development of landside infrastructure, while not necessarily impacting directly on the port's aquatic environment, will have indirect impacts by facilitating the transfer and storage of bulk products in the port that may in turn lead to the contamination of water and sediment, including through the increased flow of surface runoff from larger hardstand and other impervious surface areas.

Longer-term (beyond 2052) planned infrastructure developments for the Port of Richards Bay will witness wholesale changes to the port. The long-term plan involves extending the port a considerable distance inland by reclaiming land, such that the port surface area will increase three-fold and the length of quays five-fold. The long-term infrastructure developments will result in the loss of existing ecologically sensitive and valuable habitat, including the Kabeljous Flats and associated mangroves and the Bhizolo-Manzanyama Canal complex. The longer-term plan does, however, present an opportunity for creating estuarine habitat that might compensate for the losses if properly planned. The longer-term infrastructure developments are conceptual at this stage and cannot be effectively evaluated from a cumulative effects perspective along with the Berth 605 Project.

- **Vessel manoeuvring**

Large ocean-going vessels will continue to access berths in the 600 Berth Basin to load and offload bulk cargo while dredging and construction operations for the development of Berth 605 are underway. The tugboat assisted manoeuvring of large vessels has several environmental consequences that have similar impact pathways to dredging operations, including the resuspension and remobilisation of sediment and noxious chemicals into the water column and the disturbance of benthic biological resources by propeller wash.

- **Maintenance dredging**

Parts of the Port of Richards Bay may need to be maintenance dredged while dredging and construction operations for the development of Berth 605 are underway. Maintenance dredging and capital dredging have several environmental consequences that have similar impact pathways to dredging operations, including the resuspension and remobilisation of sediment and noxious chemicals into the water column and the removal and disturbance of benthic biological resources.

- **Berth 207 Project**

TNPA is intending to develop Berth 207 at the Chemical Quay near the Richards Bay Coal Terminal Basin (Figure 2). The berth and associated landside infrastructure will enhance the capacity for chemical imports. The Berth 207 Project will present many of the same environmental impacts as the Berth 605 Project since it will involve the construction of a new quay and will require capital dredging.

- **Berth 210 Project**

TNPA is intending to develop Berth 210 at the Richards Bay Coal Terminal (Figure 2). The berth and associated landside infrastructure will enhance the capacity for chemical imports. The Berth 210 Project will present many of the same environmental impacts as the Berth 605 Project since it will involve the construction of a new quay and will require capital dredging, but will involve the reclamation of open water and sediment habitat.

- **Berths 709 and 710 Project**

TNPA is intending to develop Berths 709 and 710 in the 700/800 Berth Basin (Figure 2). The Berths 709 and 710 Project will present many of the same environmental impacts as the Berth 605 Project since it will involve the construction of a new quay and will require capital dredging, but will involve the reclamation of open water and sediment habitat.

- **Berths 802 and 803 Project**

TNPA is intending to develop Berths 802 and 803 at the so-called Finger Jetty in the 700/800 Berth Basin, relatively near the Berth 605 Project (Figure 2). The berths will be used primarily for the export of chromite sand and ferrochrome. The Berths 802 and 803 Project will present many of the same environmental impacts as the Berth 605 Project since it will involve the construction of a new quay and will require capital dredging.

- **Navy relocation Project**

Naval and Pelican Islands have been earmarked as a base for the South African Navy (Figure 2), which will relocate from Salisbury Island in the Port of Durban. TNPA will seek authorisation for the development of the islands. The project will present many of the same environmental impacts as the Berth 605 Project since it will involve the construction of a new quay and will require capital dredging, but will involve the reclamation of open water and sediment habitat.

- **Karpowership Project (project is no longer envisaged)**

Karpowership has applied for Environmental Authorisation to place infrastructure required for the generation of electricity in the Port of Richards Bay. Although Environmental Authorisation for the project was denied, this decision was appealed. A final decision on whether this project will proceed has not been made. The Karpowership project will involve capital dredging and limited reclamation of open water and sediment habitat but will include the presence of power generating vessels in the port on an essentially permanent basis.

- **Nseleni Power Project (non TNPA project)**

Nseleni Power Corporation (Pty) Ltd has proposed the establishment of a floating gas-powered power station (known as the Nseleni Independent Floating Power Plant) and associated infrastructure for the evacuation of power from the plant to the National Grid in the Port of Richards Bay. Anchor Energy (Pty) Ltd would construct the physical infrastructure for the floating power plant in the port, including infrastructure for receiving and storing gas, delivered as Liquid Natural Gas, and other infrastructure to support the plant. The project would consist of a series of jetties with concrete platforms on marine piles and would be made up of offloading berths, Liquid Natural Gas Floating Storage Units, Liquid Natural Gas storage tanks, regasification facilities and a series of berths occupied by floating Combined Cycle Gas Turbine power plants. A transmission line would connect the power plant to landside high voltage transmission infrastructure. All marine infrastructure required for Phase 1 (4 barges) is anticipated to be completed in 24 months after the start of construction, and the entire marine construction in 32 months. A final decision on whether this project will proceed has not been made.

- **Floating Storage and Regassification Unit Project**

TNPA is proposing to construct a 170 000 m³ Floating Storage and Regasification Unit, a 170 000 m³ Floating storage Unit with an Onshore Liquid Natural Gas Terminal, which will include an Onshore Regasification Facility, cryogenic pipeline and seawater pipelines, onshore storage of 440 000 m³ of Liquified Natural Gas, and Liquified Natural Gas truck loading facility for the Port of Richards Bay South Dunes Precinct (Figure 2).

- **Wastewater Discharge (non TNPA project)**

Domestic and industrial wastewater is discharged through deepwater marine outfalls situated to the immediate north of the entrance to the Port of Richards Bay. The wastewater discharge has degraded water and sediment quality, mainly near the point of wastewater discharge but at times over a larger area. Benthic biological resources over a relatively small area near the points of wastewater discharge have been adversely affected.

- **Gagasi Offshore Floating Wind Farm Project (non TNPA project)**

Hexicon AB and Genesis Eco-Energy Developments are seeking to develop the Gagasi Offshore Floating Wind Farm off the northeast coast of South Africa. If the project goes ahead, it could involve the installation of up to 54 floating turbines tethered to the seabed in a 140 km² rectangular block that will be ~5 km from the coast at its closest point in the north and ~17 km from the coast at its closest point in the south.

7.6 Assumptions and limitations

- It is impossible to identify, or it is unnecessary to assess in detail each environmental impact that may arise from a proposed project. The emphasis of the Environmental Impact Assessment process is on identifying and assessing environmental impacts that, because of their scale, magnitude and/or duration, may influence decision-making and thus warrant further consideration and mitigation. The environmental impacts identified in this specialist study are assumed to encompass those that are reasonably foreseeable based on the existing project description.
- The environmental impacts identified in this specialist study and the assessment of their significance is assumed to encompass and address more complex interactions in the environment that might arise because of an environmental impact, but which interactions are not specifically discussed or assessed.
- As noted above in the Description of Proposed Project (Section 4 of this specialist study), certain aspects of the Berth 605 Project have not yet been finalised. These details will only become available after Environmental Authorisation is issued and contractors are appointed. In the absence of this information, it is assumed that the construction-related and dredging-related impacts identified and assessed in this specialist study encompass the range of potential construction-related and dredging-related scenarios associated with the Berth 605 Project. If this assumption proves incorrect and the final construction and dredging plans indicate that the impacts may be more significant than anticipated, the CSIR scientists that prepared this specialist study assume they will be afforded the opportunity to reassess the environmental impacts if necessary.
- It is assumed the proposed mitigation to reduce the severity of negative environmental impacts or to enhance the benefits of positive impacts are both reasonable and feasible, or that alternative reasonable and feasible mitigation with equivalent outcomes will be identified by other parties. Furthermore, it is assumed that, when the mitigation is implemented, it will enhance the benefits of positive impacts and reduce the severity of negative impacts as intended and assumed in the assessment of the significance of impacts with mitigation.

7.7 Impact identification, description and assessment

7.7.1 Impacts excluded from detailed significance assessment

Several environmental impacts that may or will arise if the Berth 605 Project proceeds were excluded (scoped out) from a detailed significance assessment because:

- a) It is assumed the (potential) causes of the environmental impacts will be properly controlled and managed—and it is usually easy to do so,
- b) the environmental impact will not result in a major additional change compared to the existing environmental impact, and/or
- c) the likelihood of the environmental impacts occurring and their significance if they do occur is difficult to assess, due in part to limited information.

The excluded environmental impacts and justification for their exclusion are outlined below.

The environmental impact significance assessment thus focused primarily on impacts that have the greatest likelihood of occurring and for causing the most significant environmental harm if they are not properly controlled and managed.

Impact 1: Entry of non-hazardous solid waste from dredging, construction and support vessels

Non-hazardous solid wastes could enter the Port of Richards Bay from dredging, construction and support vessels during dredging and construction operations if waste control and management on the vessels is inadequate. Non-biodegradable plastic waste, including plastic bottles, plastic bags, plastic food wrappers, synthetic strapping tape and synthetic rope is most problematic. Many types of plastic items and other low

density solid wastes are buoyant and can be transported over large distances by ocean currents. The spatial extent of environmental impacts related to solid waste is thus potentially international. Ryan *et al.* (2021) found plastic bottles from 78 countries at 32 sites along the South African coast. Although some of the bottles may have been discarded overboard from passing vessels, it seems likely a proportion of the bottles will have entered the ocean in the country of origin and subsequently have been transported by ocean currents to South Africa's coast. It is thus not inconceivable that plastic waste discarded in South Africa reaches international shores.

Marine mammals, sea turtles and fish are known to mistake plastic as food and ingest it. Plastic ingestion can adversely affect animals in many ways, including the ulceration or laceration of the digestive tract leading to infection or internal bleeding and blockage or retention in the digestive tract that reduces nutrient uptake and the urge to feed, leading to starvation (NOAA Marine Debris Program, 2014a, 2016). Marine animals can also become entangled in solid waste, affecting their swimming and feeding ability, and/or resulting in injury or death (NOAA Marine Debris Program, 2014b). Plastic waste that sinks to the bottom can smother benthic habitat and displace or cause the death of benthic biological resources. Plastic leaches constituent chemicals, such as plasticisers, as it breaks down, which can pose a toxic risk to biological resources (Thompson *et al.*, 2009). Plastic degrades into smaller and smaller particles over time to form so-called microplastics. Microplastics have been found in zooplankton (Sun *et al.*, 2018), which are amongst the smallest animals in aquatic systems, and in many higher-level biological resources. Although the effects of microplastics on most biological resources is unknown, it is reasonable to assume many will experience at least some form of adverse effect if they ingest microplastics.

Floating solid waste provides a site for the attachment of encrusting (fouling) biological resources (*e.g.* barnacles, mussels) and microbes. The biological resources and microbes can be transported with floating solid waste by ocean currents to areas outside their natural range, where they may establish populations and potential become invasive and in this way degrade local ecosystems (Lewis *et al.*, 2005; Allsopp *et al.*, 2006; Gregory, 2009; NOAA Marine Debris Program, 2017; Mghili *et al.*, 2023; Barry *et al.*, 2024).

Plastic and other solid waste that washes up on estuarine and marine shorelines is unsightly and detrimental to tourism and recreation.

The International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL convention), as modified by the 1978 protocol thereto (MARPOL 73/78), governs the management of waste on vessels. The convention includes regulations that are aimed at preventing non-hazardous solid waste pollution from vessels arising through routine operations or accidents. All vessels that are flagged under signatory countries to the MARPOL convention are subject to the conventions regulations, irrespective of where they sail. In South Africa, the Marine Pollution (Prevention of Pollution from Ships) Act of 1986 (and amendments) is also relevant to non-hazardous solid waste management on vessels.

Dredging, construction, and support vessels are expected to have procedures in place for managing non-hazardous solid waste in accordance with the International Convention for the Prevention of Pollution from Ships (MARPOL convention), the Marine Pollution (Prevention of Pollution from Ships) Act of 1986 (and amendments), and any additional requirements the South African Maritime Safety Authority, TNPA, and/or other authority might prescribe to minimise the potential for this impact. The management of solid waste on vessels while in the Port of Richards Bay should furthermore be easy to implement since land-based disposal options are available.

Mitigation

Recommended mitigation for this potential environmental impact is outlined below.

- The construction and dredging contractor(s) must develop a method statement detailing procedures

for managing non-hazardous solid waste on all dredging, construction, and support vessels.

- Adherence to the method statement must be monitored by an Environmental Control Officer.
- The construction and dredging contractor/s must provide comprehensive and compulsory environmental awareness training to all personnel and sub-contractors. This training should emphasise the environmental impacts of non-hazardous solid waste—particularly plastics—and the importance of preventing such waste from entering the port's aquatic environment.
- A reduce, reuse, recycle waste philosophy should be followed in the context of non-hazardous solid waste.
- The intentional disposal of non-hazardous solid waste—or indeed any waste—into the port's aquatic environment must be strictly prohibited. Clear disciplinary procedures should be developed and enforced, including the potential removal of personnel from site if, despite receiving environmental training, they are found to have intentionally disposed of waste into the aquatic environment.

Impact 2: Entry of non-hazardous solid waste from construction sites on land

Non-hazardous solid waste could enter the Port of Richards Bay aquatic environment from construction operations on land if waste control and management practices are inadequate. The waste could pose the same environmental impacts as those outlined for the losses of such waste from dredging, construction and support vessels.

It is expected that the construction contractor/s will have procedures in place to manage non-hazardous waste. The control and management of non-hazardous solid waste is also easy to implement since land-based disposal options are available.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The construction contractor(s) should develop a method statement that outlines how non-hazardous solid waste will be managed at the construction site.
- Adherence to the method statement should be monitored by an Environmental Control Officer.
- The construction contractor(s) should provide comprehensive and compulsory environmental awareness training for their workforce and sub-contractors. The training should sensitise the workforce and sub-contractors to the consequences of non-hazardous solid waste (especially plastic) on the environment and the need to avoid the loss of such waste into the port's aquatic environment.
- A reduce, reuse, recycle waste philosophy should be followed in the context of non-hazardous solid waste.
- The intentional disposal of non-hazardous solid waste—or indeed any waste—into the port's aquatic environment must be strictly prohibited. Procedures should be developed, and, if necessary, implemented to remove personnel from the site if they have received environmental awareness training yet still intentionally dispose of non-hazardous solid waste into the port's aquatic environment.
- Construction personnel should be encouraged to collect plastic litter and other non-hazardous solid waste they see in the construction site, even if it does not originate from the construction site.
- If necessary, litter sweeps should be carried out across the construction site.
- If non-hazardous solid waste from the construction site enters the port's aquatic environment this should be recovered immediately where practicable. This might be difficult from the quayside, but pool cleaning nets can be used for this purpose if a construction support vessel is available.
- Onsite temporary storage areas for non-hazardous solid waste should be clearly demarcated, signposted and maintained. These should be situated as far as practicable from the port's aquatic environment.
- Bins, skips and/or other receptacles for the temporary storage of non-hazardous solid waste should be

sealed and secured to avoid them becoming a source of litter in the port's aquatic environment, noting the proposed project area is often characterised by gale force winds that can blow plastic and other light non-hazardous solid waste from unsealed waste receptacles and can overturn unsecured waste receptacles.

- Non-hazardous solid waste receptacles must be vermin proof.
- Non-hazardous solid waste should be regularly removed from the construction site and disposed at a registered waste disposal site in accordance with national and local waste legislation, using a licensed waste disposal contractor. The waste contractor should provide proof the waste was disposed at a registered waste disposal site. The contractor should keep such records onsite for auditing by an Environmental Control Officer.
- Non-hazardous solid waste receptacles should not be washed onsite unless the wash water is captured and disposed to sewer or a registered wastewater site. The washing water should not be allowed to enter surface runoff channels or stormwater drains as these will flow into the port's aquatic environment.

Impact 3: Entry of hazardous substances into the port due to spills, leaks and discharges from dredging, construction and support vessels

Hazardous substances, such as oil, grease, lubricants and hydraulic fluid, could be accidentally spilled, leaked or discharged into the Port of Richards Bay from dredging, construction and support vessels during dredging and construction operations for the development of Berth 605. Chemical substances are classified as hazardous if they pose a toxic risk to biological resources and humans in aquatic systems. The magnitude of the impacts that result from a spill, leak, or discharge of a hazardous substance depends on the nature of the substance and quantity involved. The impacts can be acute if a particularly hazardous substance enters a waterbody, leading to the death of biological resources (Hutchinson *et al.*, 2013; Wenger *et al.*, 2017). Alternately, a hazardous substance may cause chronic (sub-lethal) impacts if it accumulates in the bodies of biological resources over time and affects their health and fitness (Oleksiak, 2008; Hamilton *et al.*, 2017). The propagules, larvae and juveniles of aquatic biological resources are usually affected by a lower quantity of a hazardous substance (are more sensitive) than later life stages (Costa *et al.*, 2011; Limburg and Waldman, 2009; Wenger *et al.*, 2017). Hazardous substances can:

- affect primary production by microalgae and macroalgae and aquatic plants, affecting food webs and diminishing ecological productivity,
- decrease the availability of oxygen in water when they are degraded in an oxygen demanding process known as oxidation, adversely affecting biological resources,
- influence the diversity and health of microbial communities, affecting nutrient recycling,
- cause cancer-like tumours to develop in fish, affecting their health and fitness, or their death.

The International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL convention), as modified by the 1978 protocol thereto (MARPOL 73/78), governs the management of waste and hazardous substances on vessels. The convention includes regulations aimed at preventing oil and noxious liquid substance pollution from vessels arising from routine operations or accidents. All vessels flagged under signatory countries to the MARPOL convention are subject to the conventions regulations irrespective of where they sail. In South Africa, the Marine Pollution (Prevention of Pollution from Ships) Act of 1986 (and amendments) is also relevant to hazardous waste and substance management on vessels.

It is expected that dredging, construction and support vessels will have procedures in place to manage hazardous waste and noxious substances in accordance with the International Convention for the Prevention of Pollution from Ships (MARPOL convention), the Marine Pollution (Prevention of Pollution from Ships) Act of 1986 (and amendments), and any additional requirements the South African Maritime Safety Authority, TNPA, and/or other authority might prescribe to minimise the potential for this impact.

Furthermore, it is expected that dredging, construction and support vessels and the equipment on these vessels and boats will be well maintained and will be operated by appropriately qualified and trained personnel, and there will be standard pollution prevention procedures in place. These plans and procedures will not eliminate the potential for hazardous waste and noxious substance spills and leaks. In fact, hazardous substances are expected to be leaked into the port from the engines of small support vessels. Any small boat user is likely familiar with the small oil sheens that often develop on the water surface near outboard engines when they are started even if the engines are in good condition. However, it is anticipated that any spills or leaks that do occur will be of such a small volume that their impact on water and sediment quality and biological resources in the port will be minimal. The management of hazardous substances is reasonably easy to implement.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The construction and dredging contractor(s) must develop a method statement detailing procedures for managing hazardous waste on dredging, construction and support vessels.
- The method statement should include a Hazardous Substance Spill Response and Contingency Plan. The plan should identify appropriate response procedures in the event of a hazardous substance spill in water. The plan should also provide specific responses for spills of different types of hazardous substances that may potentially be spilled.
- Adherence to the method statement should be monitored by an Environmental Control Officer.
- Hazardous substance spills and leaks that occur should be reported immediately. The line of reporting must be outlined in the Hazardous Substance Spill Response and Contingency Plan. The plan should also outline subsequent lines of reporting as deemed necessary (*e.g.* Transnet National Ports Authority, SAMSA, other relevant authorities).
- Hazardous substances should be stored and handled in accordance with appropriate legislation and standards, including the Hazardous Substances Act (Act No. 15 of 1973) and Occupational Health and Safety Act (No. 85 of 1993).
- The construction contractor(s) should provide comprehensive and compulsory environmental awareness training for their workforce and sub-contractors. The training must sensitise the workforce and sub-contractors to the adverse consequences of hazardous substance spills and leaks on the environment and the need to avoid the entry of such substances into the port's aquatic environment.
- The intentional disposal of hazardous substances (including waste) into the port's aquatic environment must be strictly prohibited. Procedures should be developed and, if necessary, implemented to remove personnel from the site if they have received environmental awareness training yet still intentionally dispose of hazardous waste and substances into the port's aquatic environment.
- Spill containment and clean-up kits—including floating booms—should be readily available on vessels/boats and on land in areas where there is a risk of a hazardous substance spill or leak, and must be appropriate to the type of possible spill or leak.
- Trained personnel must be available to deal with hazardous substance spills and leaks. Training/drills should be implemented to enable personnel to respond appropriately to hazardous substance spills and leaks.
- Methods for the disposal of cleaned up hazardous substances and clean-up materials should be identified in the Hazardous Substance Spill Response and Contingency Plan—this material must not be disposed with 'normal' waste but rather at an appropriately licensed hazardous waste disposal site.
- Dredging, construction and support vessels—and related equipment and machinery—must be properly maintained and regularly checked for hazardous substance leaks.
- Fuel tanks on small support vessels should not be refilled onboard, but at a dedicated site on land or on a larger, more stable vessel.

Impact 4: Entry of hazardous substances into the port due to spills and leaks at construction sites on land

If hazardous substances, such as oil, grease, lubricants and hydraulic fluid, are accidentally spilled or leaked at construction sites on land for the development of Berth 605, they could find their way into the Port of Richards Bay aquatic environment via surface runoff. The hazardous substances would pose the same environmental impacts as those outlined above for the entry of hazardous substances into the port's aquatic environment from vessels (Impact 3).

It is expected that the construction contractor(s) will have procedures in place to manage hazardous waste according to the Hazardous Substances Act (Act No. 15 of 1973) and Occupational Health and Safety Act (No. 85 of 1993), including spill containment and cleanup procedures and related materials. Furthermore, it is expected that construction equipment will be well maintained and operated by qualified and trained personnel. Relatively little construction over and in water is anticipated since most of Berth 605 will be constructed in the dry. The plans and procedures implemented by the construction contractor(s) will not eliminate the potential for hazardous substance spills or leaks. In fact, hazardous substances spills or leaks are probable since the regular handling of hazardous substances and frequent operation of construction equipment, machinery and vehicles will statistically increase the chance of a spill or leak. However, the spills or leaks are expected to be of a small volume that can easily be contained and cleaned up.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The construction contractor(s) should develop a method statement that outlines how hazardous substances and waste will be managed at the construction site(s). The method statement must be approved and signed off by TNPA and/or an Environmental Control Officer.
- The method statement should include a Hazardous Substance Spill Response and Contingency Plan. The plan should identify appropriate response procedures in the event of a hazardous substance spill or leak. The plan should provide specific responses for spills or leaks of different types of hazardous substances that may be handled and used onsite.
- The method statement should include a site drainage plan that shows the positions of sewers, stormwater drains and surface drainage channels, including where the channels and drains flow into the port's aquatic environment. Hazardous substances must not be stored or handled in these areas.
- Adherence to the method statement must be monitored by an Environmental Control Officer.
- Hazardous substances must be stored and handled in accordance with appropriate legislation and standards, including the Hazardous Substances Act (Act No. 15 of 1973) and Occupational Health and Safety Act (No. 85 of 1993).
- The construction contractor(s) should provide comprehensive and compulsory environmental awareness training for the workforce and sub-contractors. The training must sensitise the workforce and sub-contractors to the adverse consequences of hazardous substances on the environment and the need to avoid spills and leaks of such substances into the port's aquatic environment.
- The intentional disposal of hazardous substances (including waste) into the port's aquatic environment must be strictly prohibited. Personnel that have received environmental awareness training, yet intentionally dispose of hazardous substances and waste into the port's aquatic environment should be removed from the construction site.
- Hazardous substance spills and leaks should be reported immediately. The line of reporting should be outlined in the Hazardous Substance Spill Response and Contingency Plan. The plan should also outline subsequent lines of reporting as deemed necessary (e.g. Transnet National Ports Authority, other relevant authorities).
- Spill containment and clean-up kits—including floating booms—should be readily available in areas where there is a risk of a hazardous substance spill or leak and should be appropriate to the type of

substance that might be spilled or leaked.

- Trained personnel should be available to respond and deal appropriately with hazardous substance spills and leaks.
- Cleaned up hazardous substances and clean-up materials should be disposed at an appropriately licensed hazardous waste disposal site—this material should not be disposed along with ‘normal’ waste.
- Construction related equipment, machinery and vehicles should be properly maintained and regularly checked for hazardous substances leaks.

Impact 5: Entry of construction material and demolition debris into the port

Various types of construction material and demolition debris could enter the aquatic environment in the Port of Richards Bay during the development of Berth 605, including soil, sand, stone fill material and concrete debris generated during the demolition of concrete structures when Berth 605 is tied into Berth 606. Potential pathways for soil and sand into the port water environment include erosion by surface runoff and wind. The Richards Bay area periodically experiences torrential rainfall, with a high erosive potential. Soil and sand entering the port’s aquatic environment from the construction site will degrade water quality by increasing the suspended sediment concentration, adversely affecting biological resources (the ecological consequences are dealt with in more detail in Impact 16). Small stones, gravel, concrete pieces and other solid debris that enter the port’s aquatic environment will alter the physical properties of the benthic habitat, potentially changing it from a sediment dominated one to a mixed sediment and gravel/stone type habitat depending on the quantity of material and debris that is introduced. These changes may impact on benthic biological resources that preferentially live in and on sediment rather than hard substrate, to the extent they are displaced. Small stones, gravel, concrete pieces, and other solid debris can be buffeted along the bottom by vessel propeller wash, physically damaging (epi)benthic biological resources.

Concrete will be poured *in situ* during the construction of Berth 605. Fresh concrete, cement and grout are highly alkaline and corrosive. The entry of cementitious material and grout into the port’s aquatic environment could adversely affect biological resources by impairing water quality, most notably by increasing the pH above the baseline. The concrete, cement and grout will harden over time and will alter the physical properties of the benthic habitat in the same way as discussed above for stones, gravel, concrete pieces and other solid debris entering the port’s aquatic environment.

The intent is to construct Berth 605 ‘in the dry’. It will thus be easy to control many of the losses of construction material into the port. The largest risk will occur during the demolition of concrete structures when Berth 605 is tied into Berth 606. It is inevitable that construction material will enter the port’s aquatic environment. As an example, sand used as fill in the quay will inevitably be blown by wind into the port’s aquatic environment. However, the quantity of material and debris lost is anticipated to be small.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The construction contractor(s) must develop a method statement that outlines how construction material and demolition debris will be managed.
- Adherence to the method statement should be monitored by an Environmental Control Officer.
- The construction contractor(s) must provide comprehensive and compulsory environmental awareness training for their workforce and sub-contractors. The training must sensitise the workforce and sub-contractors to the adverse environmental consequences of construction material and demolition debris entry into the port’s aquatic environment, and the need to avoid such entry.

Demolition and concrete and cement handling

- During demolition alongside and over water, structurally adequate debris shields should be used

where practicable to contain debris and prevent it from entering the port's aquatic environment.

- The intentional disposal of debris into the port's aquatic environment is strictly prohibited. Debris on the quay apron must not be swept into the port's aquatic environment but must be recovered and disposed at an appropriate waste disposal site by a licensed contractor.
- Fresh concrete and cement are highly alkaline and corrosive and can cause significant water and sediment quality impairment. The use of wet concrete and cement near, over and in the port's aquatic environment thus requires careful control to minimise the risk of spillage. Wherever possible, pre-cast concrete structural elements should be used.
- Concrete and cement batching should ideally not occur at the construction site but rather be delivered in ready-mix form. It is, however, acknowledged that some batching will probably be required at the construction site.
- If concrete is poured with a concrete pump, the hoses and couplings should be checked to ensure they are sealed and secured.
- Concrete should ideally not be poured when the weather is adverse.
- If concrete is placed under water, fast-setting concrete should be used to limit losses from shuttering and to minimise the period over which potential impacts can occur.
- Concrete forms must be properly sealed to prevent the loss of concrete into the port's aquatic environment.
- Concrete forms should not be filled to overflowing.
- Concrete mixing and pouring equipment should not be washed onsite unless this is unavoidable. In these instances, the wash water should be collected in a dedicated wastewater collection system and disposed appropriately.

Construction material stockpiles

- The project method statement should include a site drainage plan that shows the positions of sewers, surface drainage channels and stormwater drains, including where the channels and drains flow into the port, must be prepared. Construction materials should not be stockpiled in these areas.
- Appropriate controls to minimise wind and surface runoff erosion of construction materials stored onsite into the port's aquatic environment, including soil and other fine-grained materials. If erosion from construction material stockpiles becomes a problem, then these should be covered, and silt barriers or other suitable controls should be used to avoid sediment ingress into the port's aquatic environment.
- Where practical and possible, minimise the amount of construction materials that can be easily mobilised or eroded by wind and surface runoff stored onsite.
- Where practical, store stockpiles of construction materials that can be easily mobilised or eroded by wind and surface runoff as far from the port's aquatic environment and drainage channels that lead to this environment as possible.
- Where practical and possible, and without unduly delaying the project, the handling of construction materials that can be easily mobilised by wind—such as soil—should be avoided when the wind speed is excessive.
- If the dewatering of trenches during construction and/or the discharge of surface water from sumps is required, a treatment system prior to the discharge should be used (silt traps, settlement skips etc). This measure will allow additional settlement of any suspended sediment within surface runoff arising from the construction areas.

Impact 6: Navigation hazard posed by dredging, construction and support vessels

There is currently a relatively high volume of large vessel and small boat traffic in the Port of Richards Bay. Dredging, construction and support vessels could pose a navigation hazard for other vessels and small boats, and in the worst case could cause a collision that leads to environmental harm (*e.g.* a spill of oil). The

largest risk is when dredging and/or dredging support vessels transit to the dredged spoil disposal site off the Richards Bay coast, particularly at night. According to van Ballegooyen *et al.* (2025), dredging barges will need to make ~1700 trips to the dredged spoil disposal site. TNPA is proposing several other major infrastructure developments in the Port of Richards Bay that will involve capital dredging campaigns. If the infrastructure developments coincide with dredging operations for the development of Berth 605, then the number of dredging vessels transiting to the dredged spoil disposal site and the risk of collisions will be higher.

TNPA will stipulate procedures to which the dredging and construction contractor(s) must adhere to avoid dredging, construction and support vessels posing a navigation risk to other vessels and that the dredging and construction contractor(s) will adhere to the procedures. Marine dredging and construction contractors invariably have experience operating in busy waterways and have in place procedures to avoid accidents and undue influences on other vessel traffic. It is expected that TNPA will appoint a marine dredging and construction contractor(s) that has/have experience in the construction of infrastructure in ports.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- TNPA and the dredging contractor(s) must formulate a plan on how dredging and construction vessel movements will be coordinated and tracked to avoid collisions. The plan should be approved by the South African Maritime Safety Authority.
- A Notice to Mariners about the dredging activities should be issued, including the location, dates, types of vessels involved, designated dredging zones, safety measures to take, and any potential navigational hazards due to the operations.

Impact 7: Marine megafauna strikes by dredging, construction and support vessels

Vessel strikes are responsible for the death or injury of many types of marine megafauna (Schoeman *et al.*, 2020). There are documented cases of whale deaths caused by vessel strikes in South African coastal waters. A total of 152 Southern Right Whale deaths were recorded in South African waters between 1963 and 2019 (Best *et al.*, 2001; Vermeulen *et al.*, 2022). Fifteen (~10% of total deaths) could be confidently attributed to a vessel strike, one of which was a dredging vessel (~0.7% of total deaths). This involved the death of a juvenile whale struck by a dredging vessel in the entrance to the Buffalo River Estuary (Port of East London) in 1984 (Best *et al.*, 2001). A further four deaths may have been caused by a ship strike, but this could not be confirmed. There were 21 vessel strikes that did not result in mortality. Most of the strikes were in the Western Cape.

Winkler *et al.* (2020) evaluated a database of vessel strikes on whales maintained by the International Whaling Commission. There were 402 entries in the database that had information on the vessel responsible for the strike. Two (or ~0.5% of the) entries were for dredging vessels, including the death in the Buffalo River Estuary mouth mentioned above.

The above statistics suggest dredging vessels are responsible for a very low proportion of vessel strikes on whales. Vessel speed is an important factor in the probability of a marine mammal being struck by a vessel and of the strike being lethal (Vanderlaan and Taggart, 2007). Dredging vessels tend to travel slowly, especially when they are transporting dredged material, and this may account for the low proportion of strikes by these vessels. Other factors, such as vessel size and the behaviour of the animal, also play a role (Schoeman *et al.*, 2020).

Dredging and/or dredging support vessels will need to transit from the Berth 605 Project dredging footprint in the Port of Richards Bay to the dredged spoil disposal site off the Richards Bay coast. According to van

Ballegooyen *et al.* (2025), dredging vessels will operate for ~18 hours per day, 7 days per week, for an estimated 20 weeks, and will need to make an estimated 1700 trips from the 600 Berth Basin to the dredged spoil disposal site. However, a better estimate of the number of trips will only be known once the dredging methodology is finalised, which is likely to be only a short period before dredging proceeds. TNPA is proposing several other major infrastructure developments in the Port of Richards Bay that will also involve capital dredging campaigns. If the infrastructure developments coincide with dredging operations for the development of Berth 605, then the number of dredging vessels transiting to the dredged spoil disposal site and the risk of megafauna strikes will be increase—but only if the dredging coincides with the period when whales are prevalent in nearshore coastal waters (see below).

As discussed in Section 5.2.13 of this specialist study, Humpback Dolphins make extensive use of nearshore coastal marine waters off the Richards Bay coast throughout the year. The Port of Richards Bay entrance is an important feeding area for Humpback Dolphins. The dolphins also make feeding forays into most parts of the port, including the 600 Berth Basin. Several whale species frequent nearshore coastal marine waters off the Richards Bay coast between about June to November (species dependent), where they come to breed and calve or continue their migration to more northerly breeding and calving waters (Findlay and Best, 2016). However, there appears to be no evidence that whales remain for extended periods in the Richards Bay area. There is less information on the utilisation of nearshore coastal marine waters off the Richards Bay coast by other marine megafauna, such as turtles.

There is thus a possibility that dredging and/or dredging support vessels used for the development of Berth 605 could strike and injure, or in the worst case kill marine mammals and/or other marine megafauna while transiting to and from the dredged spoil disposal site off the Richards Bay coast. Marine mammals and other megafauna cannot be seen easily from the vessel bridge in high seas or at night and may surface to breath suddenly, providing vessels little time for evasive action. Dolphins, by virtue of their extensive use of areas where dredging vessels will transit to the dredged spoil disposal site off the Richards Bay coast, are outwardly the most at risk of a vessel strike. However, no information could be found in the scientific literature on dolphin deaths caused by vessel strikes in South Africa. There appear to be no records of dredging and dredging support vessels striking marine mammals during previous capital and ongoing maintenance dredging campaigns in the Port of Richards Bay, but records may admittedly have been poor or a strike could have gone unreported (although dead dolphins will have drawn attention from the public if they were noticed). Other megafauna, such as turtles, are slow swimming and have little ability to evade 'fast' moving vessels. However, as in the case for dolphins no information could be found in the scientific literature on turtle deaths caused by vessel strikes in South Africa, but it would be irresponsible to suggest this does not occur and for large vessels would probably go unnoticed.

It is expected that TNPA will stipulate the procedures the dredging contractor(s) must follow to reduce the risk of dredging vessels striking marine megafauna while in transit to the dredged spoil disposal site and that the contractor(s) will implement and follow these procedures. It would be beneficial if the dredging and dredging support vessel captains and crew maintain a record of where whales, dolphins and other marine megafauna are observed during transit to and from the dredged spoil disposal site, and their behaviour during dredged material disposal. The information will aid in assessing the potential risk of vessel strikes in Environmental Impact Assessments for future planned projects that have a dredging component.

The risk of vessel strikes on megafauna once Berth 605 becomes operational is not anticipated to increase significantly compared to the current situation, despite a slight increase in vessel traffic.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The dredging contractor(s) must develop a method statement that outlines the actions that will be

followed to minimise the risk of vessel strikes to marine megafauna.

- The method statement should be audited by an Environmental Control Officer.
- In the unlikely event a dredging, construction, or support vessel strikes a marine megafauna this should be reported to the relevant authorities. The method statement should outline the reporting line in the event a strike occurs.
- Small support boats must maintain a reasonable speed in the port so that evasive action—including dropping immediately to a low speed—can be taken in the event dolphins surface in the boat path.

Impact 8: Introduction of non-native aquatic biological resources

Vessel and boat traffic is widely acknowledged as the single most important vector for the introduction of non-native biological resources to the aquatic environment in ports and small craft harbours. These are plants, animals and other organisms that are not indigenous to an area but have their origin elsewhere in the world. They attach to the hulls of vessels and are transported to geographical areas beyond their natural range, where they may establish viable populations if local physicochemical environmental conditions are within their tolerances. No port and small craft harbour is immune from the introduction of non-native species. They can be introduced in ballast water discharges (*e.g.* plankton, microbes), the release of gametes and larvae, and migration of later life stages (*e.g.* adult crabs) from biofouled hulls. Non-native biological resources may establish in a habitat without having a detrimental effect on the integrity of the ecosystem. However, they can become invasive, and, in the process, may transform habitats and displace or compete with native biological resources, detrimentally affecting ecosystem integrity (Bax *et al.*, 2003). Invasive non-native biological resources may also have significant economic impacts. The zebra mussel *Dreissena polymorpha*, for example, has been reported to accumulate to such high densities on navigation buoys and in drinking water intake pipes in the Great Lakes of North America that the buoys sink and pipes become blocked. Non-native biological resources are virtually impossible to eradicate once they have established in estuarine and marine systems. Their impact is thus permanent, irreversible and highly significant from a biodiversity protection perspective even if they do not become invasive. Numerous non-native biological resources are known to have established in the Port of Richards Bay, including the copepod *Acartia spinicauda* (Jerling 2008), hydrozoan *Obelia dichotoma*, isopod *Paracerceis sculpta*, amphipod *Monocorophium ascherusicum* and bryozoan *Bugula flabellata* (Peters *et al.*, 2017). None of the non-native biological resources in the port appears to have established to the point of being considered ecologically ‘problematic’.

TNPA might contract an international dredging company to complete capital dredging for the Berth 605 Project. If so, the dredging and dredging support vessels will arrive in South African coastal waters from elsewhere in the world. The vessels could introduce non-native estuarine and marine biological resources to South African coastal waters. In a similar vein, the Berth 605 Project and other projects outlined in the Port of Richards Bay Masterplan will create additional space for the mooring of vessels and will increase the risk of non-native biological resource introduction since the risk is, in part, related to the frequency of vessel calls.

It is expected that dredging, construction and support vessels that do not originate from South Africa and have not been actively working in South African territorial waters for at least several months, and vessels calling at the Port of Richards Bay in future when Berth 605 is operational will abide with and implement regulations of the International Maritime Organisation Convention for the Control and Management of Ship's Ballast Water and Sediments, South Africa's (draft) Ballast Water Management Bill, and any additional protocols that TNPA and the South African Maritime Safety Authority might deem fit to identify to mitigate this impact.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The dredging contractor(s) must develop a method statement that outlines the actions that will be followed to minimise the introduction of non-native biological resources into the Port of Richards Bay.
- The method statement should be audited by TNPA, an Environmental Control Officer, and/or the South African Maritime Safety Authority.
- Dredging and dredging support vessels must, at a minimum, exchange ballast water in the open ocean (200 nautical miles from shore, at least 200 m water depth) before entering the Port of Richards Bay. The hoppers, suction pipes, hulls and so on of the vessels should be free of sediment and biological resources from the last dredging campaign. Records of the actions taken should be provided to TNPA and an Environmental Control Officer.

Impact 9: Increased vessel traffic

The purpose for the development of Berth 605 is to increase maritime trade. The new berth will result in an increase in vessel traffic in the port and in the marine environment off the Richards Bay coast. The movement of large vessels in the port has several environmental consequences. Disturbance of bottom sediment during tugboat assisted manoeuvring causes a temporary increase in the suspended sediment concentration and related turbidity in the water column, with several potential impacts to pelagic and benthic biological resources. The disturbance of bottom sediment by vessel propeller wash also disturbs benthic biological resources. Increased vessel traffic will also generate increased noise (dealt with below).

The change in propeller wash related disturbance of sediment on pelagic and benthic biological resources in the port is anticipated to be small compared to the existing situation.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The basin should be dredged to a depth that provides sufficient under keel clearance to minimise vessel propeller wash impacts.
- Tugboats should travel at low speeds to avoid the generation of large wake waves.

Impact 10: Noise from dredging, construction and support vessels

According to van Ballegooyen *et al.* (2025), dredging for the development of Berth 605 will proceed for ~18 hours per day, 7 days per week, for an estimated 20 weeks. A cutter suction dredger, which will probably be used for the development of Berth 605, is the loudest noise generated by dredging types. The major processes that contribute to dredging sounds include: 1) dredge material collection sounds originating from the rotating cutterhead in contact with the bed and intake of the sediment-water slurry, 2) sounds generated by pumps and impellers driving the suction of material through the pipes, 3) transport sounds involving the movement of sediment and stones through the pipes, and 4) ship and machinery sounds, including those associated with the lowering and lifting of spuds and moving of anchors by dredging support vessels (Reine *et al.*, 2012).

The noise generated by the cutter suction dredger, barges and other vessels in and near the Berth 605 Project footprint will thus be louder and more persistent than is currently the case. The cutter suction dredger and dredging support vessels will also operate near intertidal habitat. One benefit of dredging in the end portion of the 600 Berth Basin is that the sides and bottom—especially sediment—of the relatively shallow basin will absorb and dampen some of the noise, although noise propagation will be focussed in the direction of the basin mouth.

Reine *et al.* (2012) found that most underwater sounds produced by a cutter suction dredger during rock fragmentation were of relatively low frequency (<1000 Hz). The source level was estimated to be between

170-175 dB re 1 μ Pa@1-m. The level decreased with distance from the source—the area of influence was limited to <100 m. At 100 m, received levels were <150 dB re 1 μ Pa rms. According to NOAA (2013), thresholds for determining impacts to marine mammals are between 180 and 190 dB re 1 μ Pa for potential injury to cetaceans and pinnipeds, respectively, and 160 dB re 1 μ Pa for behavioural disturbance/harassment from an impulsive noise source, and 120 dB re 1 μ Pa from a continuous source. Based on reviews by Popper *et al.* (2006) and Southall *et al.* (2007), it is unlikely that underwater sound from conventional dredging operations causes physical injury to fish. Some temporary loss of hearing could occur if fish remain in the immediate vicinity of a dredger for an extended period, but the risk is low (CEDA, 2011). Fish will likely respond to dredging noise by avoiding the area near the noise source. The NOAA (2013) criteria for physical injury to fish is 206 dB peak, regardless of fish size. Dredging for the Berth 605 Project will thus probably cause avoidance of the area by fish but is unlikely to cause hearing damage. This will not likely influence fish populations since they will be able to use areas outside of the 600 Berth Basin for feeding.

The biological resources that are most sensitive to noise disturbance are birds and mammals. Potential impacts of the proposed Berth 605 Project on birds are dealt with in a separate specialist study due to the importance of the port to these fauna. There is comparatively little information on the influence of underwater noise on other biological resources, but there is an increasing body of evidence that fish and invertebrates are affected by various types of underwater noise. Underwater noise impacts from dredging operations are not anticipated to cause permanent auditory damage to biological resources in the area.

Humpback dolphins make extensive use of the nearshore coastal waters off the Richards Bay coast throughout the year. The Port of Richards Bay entrance is an important feeding area for the dolphins. The dolphins also use most parts of the main waterbody of the port for feeding, including the 600 Berth Basin. It is assumed the dolphins use these areas despite existing vessel and other anthropogenic noise and are thus habituated to the noise to the degree possible.

CEDA (2011) indicate that pipeline cutter suction dredgers have a noise source level at 1 m of 172 dB-185 dB re 1 μ Pa. Clarke *et al.* (2002) found that cutterhead sounds peaked at 100-110 dB and were inaudible at ~500 m from the source. According to Richardson *et al.* (1995), noise levels diminish by about 60 dB between the source and a radius of 1 km. For marine mammals to be exposed to a received level of 140 dB at 1 km radius, the source level would have to be about 200 dB re 1 μ Pa/m.

On the basis of (1) the predicted noise effect thresholds noted by Richardson *et al.* (1995), (2) the background noise that already exists in the marine environment (approximately 120 dB), and (3) the ability of marine mammals and fish to move away from the immediate noise source, noise generated by cutter suction dredger activities are not expected to affect mammals and fish outside the Berth 605 Basin to any significant degree.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The dredging contractor(s) must develop a method statement that outlines the actions that will be followed to limit the generation and propagation of noise from dredging, construction and support vessels. The method statement must be audited by an Environmental Control Officer.

Impact 11: Underwater construction noise

One of the most environmentally significant sources of underwater noise that is usually associated with quay development in ports is percussive piling—the ‘hammering’ of long pieces of steel that provide structural stability to quay walls into sediment—will not affect the underwater noise environment in the Port of Richards Bay since Berth 605 will be constructed ‘in the dry’ and the quay wall design does not

incorporate piles. If piling is required, such as for shoring the excavated trench for quay wall construction, the noise will need to propagate through soil/land and will be substantially dampened before it reaches the aquatic environment. There will of course be some underwater construction noise when Berth 605 is tied into Berth 606, but this is expected to be of a relatively short duration. The noise will nevertheless affect aquatic biological resources while it is ongoing.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The dredging contractor(s) must develop a method statement that outlines the actions that will be followed to minimise the generation of underwater noise on aquatic biological resources.
- The method statement should be audited by an Environmental Control Officer.

Impact 12: Increased operational noise

The purpose of the development of Berth 605 is to increase maritime trade. Operations at Berth 605 will increase the amount of under- and above water operational noise, including vessel related noise, in the Port of Richards Bay. The noise will have adverse effects on some aquatic biological resources.

There is already a considerable amount of operational noise in the Port of Richards Bay and aquatic biological resources in the 600 Berth Basin are assumed to be habituated to the noise to the degree possible. Aquatic biological resources that have not been displaced or disturbed by the existing operational noise are not thus anticipated to be significantly affected by the increased noise when Berth 605 is operational.

Mitigation measures

None.

Impact 13: Loss of recreation and tourism opportunities in the port

The Port of Richards Bay is a popular recreational destination for residents and tourists in the Mhlathuze Municipal area. Angling from kayaks, small boats and the shoreline is a popular pastime. Other recreational pursuits include canoeing, sailing and bird watching, while Mzingazi Canal and the greater Pelican Island area are popular relaxation areas. Small boat tours in the port are popular with tourists. As outlined below, numerous operations required for the development of Berth 605 will affect water and sediment quality that could in turn affect populations of fish and bait organisms (*e.g.* sandprawn), with concomitant impacts on recreational angling opportunities, other recreational pursuits, and general enjoyment (*e.g.* discolouration of water due to suspended sediment plumes). Suspended sediment plumes generated during the disposal of dredged material at the existing dredged spoil disposal site off the Richards Bay coast could be visible from high vantage areas on the coast. The degradation in water and sediment quality related to dredged material disposal could also affect fish populations, with concomitant impacts on recreational angling and commercial fisheries.

The Berth 605 Project footprint is far from recreational angling areas in the Port of Richards Bay, which are restricted to an area east of an imaginary line extending between the eastern part of the 700 Berth Basin and the Chemical Berth near the Richards Bay Coal Terminal Basin (see Figure 1). Bait organism collection areas are far from the 600 Berth Basin and are unlikely to be directly affected by dredging operations. More importantly, numerical modelling by van Ballegooyen *et al.* (2025) suggests that suspended sediment plumes are highly unlikely to extend much beyond the 600 Berth Basin and unsightly turbid plumes are unlikely to significantly detract from the visual experience in recreational areas in the port.

Mitigation measures

Recommended mitigation for this potential environmental impact is outlined below.

- The dredging contractor(s) must develop a method statement that outlines the actions that will be followed to minimise the generation of suspended sediment plumes in the Port of Richards Bay during dredging and in the nearshore marine environment off the Richards Bay coast during dredged material disposal.
- The method statement must aim to restrict suspended sediment plumes to the smallest area possible.
- The method statement must be audited by an Environmental Control Officer.
- It is recommended that TNPA communicate to the public when dredging operations will proceed through community notices in the traditional news and social media.

7.7.2 Impacts subjected to detailed significance assessment

Impact 14: Decrease in aquatic ecological function and productivity due to physical disturbance, injury and displacement of benthic biological resources by dredging

Impact description

The physical removal, disturbance, injury and/or displacement of benthic biological resources are unavoidable consequences of dredging—there is no dredging technology that can eliminate these impacts. Benthic macroalgae and microalgae, burrowing invertebrate fauna (*e.g.* burrowing prawns, worms), slow moving invertebrate epifauna (*e.g.* gastropods) and the eggs of fish and invertebrates that develop on sediment are the most vulnerable. A consequence of dredging is a decline in the species diversity, abundance and biomass of benthic biological resources in the dredging footprint (*e.g.* Newell *et al.*, 1998; Sousa *et al.*, 2023). The decline amounts to (temporary) habitat loss or displacement for other biological resources—such as fish and larger motile invertebrates—that depend on the biological resources in the dredging footprint for food or the physical habitat for breeding. This may directly affect their abundance and survivorship and indirectly affect ecosystem functioning and productivity.

Benthic biological resources will recolonise newly exposed sediment after dredging ceases. Some benthic biological resources are believed to recolonise, or at least exploit, newly dredged sediment within hours to days of dredging ceasing. However, recovery to a pre-dredging species composition, abundance and biomass takes longer provided no further disturbances occur and conditions in the benthic environment are broadly comparable to the pre-dredging state (Newell *et al.*, 1998). The recovery rate varies by substrate type. Benthic biological resources on muddy substrata—which characterises large parts of the Port of Richards Bay—recover faster than biological resources on sandy substrata. Recovery is slowest on gravelly substrata (Newell *et al.*, 1998). Short-lived species and/or species with a high reproduction rate, such as certain amphipods and small worms that can mature within a matter of weeks, recover faster than slower growing, longer-lived species, such as large gastropods, large crustaceans, bivalves and certain worm species. Initial recolonisation of dredged sediment occurs through active migration by more motile benthic biological resources (*e.g.* amphipods, crabs; Morton, 1977; van Moorsel, 1993, 1994; Hall, 1994) from less disturbed or undisturbed habitats nearby, and by larval/juvenile settlement from the plankton (Skilleter, 1998). In estuaries, dredging may result in the sediment becoming muddier—or at least finer-grained—than the pre-dredging state since mud is expelled from dredger hoppers and barges in the overflow while sand is retained. The change in grain size can present an impediment to the recovery of benthic biological resources. However, this is unlikely to be a major problem in the Berth 605 Project since subtidal sediment in the dredging footprint, and indeed further afield in the Port of Richards Bay is already characterised by a high mud content—in parts of the footprint the sediment is in fact classified texturally as mud. Benthic biological resources in the Berth 605 Project footprint and in the greater Port of Richards Bay are thus adapted to these conditions—this will be advantageous in terms of recovery.

Impact significance assessment without mitigation

Dredging will result in the direct physical removal, injury and disturbance of benthic biological resources in the Berth 605 Project dredging footprint. The impact will be restricted to the dredging footprint and will thus be **site only**. Benthic biological resources in estuaries are generally resilient to numerous forms of disturbance since they have evolved strategies to deal with the variable physical and chemical conditions that characterise these environments. Furthermore, most of the benthic macrofauna recorded in the 600 Berth Basin are small, short-lived species that are resilient to disturbance. It is anticipated that benthic biological resources will begin to colonise newly dredged sediment within days of the dredging ceasing. However, it will take longer (months) to recover to a species composition, abundance and biomass that broadly reflects the existing benthic biological resource community in the Berth 605 Project footprint. It is assumed that the sediment habitat created by the lengthening of the 600 Berth Basin will be similar in grain size but will have a lower particulate organic matter content compared to the sediment habitat that currently exists in the basin. If so, this habitat may take longer to colonise simply because it will be virgin sediment. The loss in benthic ecology is thus anticipated to be **medium-term**. Benthic biological resources in the Berth 605 Project dredging footprint will be highly impacted, to a degree there will be a near-complete loss of benthic ecology in the footprint. The loss will **definitely** affect the ecological productivity of the Port of Richards Bay. However, the absolute area that will be affected by dredging (~8 ha) is small (~1%) when compared to the larger port area (~870 ha). The benthic biological resources and related ecological function and productivity in a part of the dredging footprint is furthermore already disturbed. The magnitude of the loss in benthic biological resources and related ecological function and productivity on the ports ecological functioning and productivity is thus anticipated to be **low**. The impact is **recoverable** since benthic biological resources will recolonise the dredged sediment over time, as has been demonstrated for other capital dredging campaigns in the port and more specifically for the Berth 605 Project after the development of the 600 Berth Basin. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredging should be completed within the shortest timeframe possible to limit the period over which benthic ecology and related ecological functioning and productivity is impacted. However, the dredging rate should not be so high that this leads to other less manageable environmental impacts (e.g. generation of excessively high suspended sediment concentrations).
- Dredging should be restricted to the dredging footprint to limit the area over which benthic ecology is impacted.

Impact significance assessment with mitigation

The physical removal, injury and disturbance of benthic biological resources in the dredging footprint is an unavoidable consequence of dredging. Little can be done to mitigate this impact other than not dredging (the 'Do Nothing' option). A dredging method statement will only be prepared after Environmental Authorisation is issued and the dredging contractor(s) is/are appointed. A certainty is that the dredging contractor(s) will restrict dredging to the dredging footprint and to the shortest timeframe possible for financial reasons, since dredging contracts are structured around a total price rather than a daily rate. Dredging contractors thus have a vested interest in completing dredging in the shortest timeframe possible. However, the dredging rate has a strong influence on numerous environmental impacts related to dredging (e.g. generation of suspended sediment plumes). Despite these certainties, the limited options for other mitigation measures means the significance assessment for this impact will remain **MODERATE** with mitigation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Decrease in aquatic ecological function and productivity due to the physical disturbance, injury and displacement of benthic biological resources by dredging
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Difficult to impossible
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance with mitigation	MODERATE
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that affect benthic biological resources in the Port of Richards Bay. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging, and capital dredging for other planned infrastructure developments outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on benthic biological resources and ecological productivity will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Maintenance and capital dredging for other infrastructure developments, if they coincide, will not spatially overlap with dredging for the Berth 605 Project due to the physical separation between dredging sites. However, simultaneous dredging will degrade benthic biological resources and decrease ecological productivity over a wider part of the port compared to sequential dredging campaigns. Depending on the infrastructure developments that occur simultaneously, the cumulative effect could be moderately to highly adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on benthic biological resources and related ecological productivity could be moderately adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute positively to benthic ecology and related ecological productivity in the port since the lengthened 600 Berth Basin will provide additional estuarine habitat to support larger populations of benthic biological resources, even though these will be periodically disturbed through tugboat-assisted vessel manoeuvring and maintenance dredging.

Recommended environmental monitoring

Newly dredged sediment in the lengthened 600 Berth Basin will be colonised by benthic biological resources over time—the process is well-documented in the scientific literature and, importantly, also in the Port of Richards Bay (including the existing 600 Berth Basin). It is not thus considered necessary to monitor the colonisation of newly dredged sediment by benthic biological resources for compliance purposes. However, monitoring the rate of colonisation after dredging has ceased will provide important data that can be used to inform the likely colonisation rates of sediment in newly created basins for other planned infrastructure developments in the port—the opportunity to monitor benthic macrofauna colonisation of newly created habitat is rare and should be pursued for this reason alone, but also has relevance to the long-term development plans for the port.

Impact 15: Decrease in aquatic ecological function and productivity due to a deterioration in water quality related to increased suspended sediment concentrations and related turbidity during dredging

Impact description

The resuspension of sediment and a related increase in turbidity in the water column is an unavoidable consequence of dredging, excavation and construction operations in aquatic systems. No dredging or in-water excavation and construction technology can eliminate sediment resuspension. The volume of sediment that is resuspended at any point in time during dredging or in-water excavation and construction depends on many factors, such as the nature of the material that is being dredged, excavated, or otherwise disturbed (particle size, solids concentration, bulk density, mineralogy, *etc.*), the depth of the water column, prevailing currents and other forms of turbulence, the type of equipment used for dredging and in-water excavation (mechanical versus hydraulic dredging, dredging rate, *etc.*), and the skill and experience of the dredge or excavator operator (rate at which dredge bucket or grab is lifted from the water, *etc.*) (USACE, 2007).

The highest suspended sediment concentrations and turbidity are invariably found near (~50 m) a dredging operation, where the concentration can be $>300 \text{ mg.L}^{-1}$ depending on the dredging method and nature of the sediment that is being dredged (USACE, 2007). The highest suspended sediment concentrations and related turbidity are usually found in the middle to lower part of the water column if the dredging method is hydraulic but may be high near the bottom and at the surface for mechanical dredging due to the dredge bucket impacting on the bottom and overflow when it leaves the water. Fine-grained sediment (mud) is far more readily resuspended and remains in suspension for far longer than does coarse grained sand, and it is dispersed further from a dredging operation by currents (Soulsby, 1997). In most dredging operations in non-riverine environments, the bulk of the resuspended sediment usually settles within ~100-200 m of a dredging operation, if not nearer (USACE, 2007). However, fine-grained particles can remain in suspension in the water column for hours to days and may be dispersed over a considerable distance—many kilometres in some cases—depending on prevailing currents. That said, although a turbid plume may be visible a considerable distance down current of a dredging operation the mass of fine-grained sediment in suspension that causes the plume to be visible is usually very low, to a degree it is often difficult to distinguish the mass of sediment in suspension from the baseline (Hitchcock and Drucker, 1996; USACE, 2007). The fine-grained sediment will settle in areas where and when the current flow can no longer overcome the effects of gravity on the particles. The newly deposited material may be resuspended and dispersed further afield if the current strength increases for some reason, but eventually it will settle and accumulate on the bottom.

An increase in the suspended sediment concentration above the baseline poses numerous potential impacts to biological resources. In general, the higher the suspended sediment concentration and the longer the exposure period the greater the risk to biological resources (Berry *et al.*, 2003; Wenger *et al.*,

2018). Many biological resources, including those found in estuaries, estuarine bays and ports, can withstand intense 'short-term' increases in the suspended sediment concentration above the baseline without deleterious effects, such as those that might occur during a high river discharge event in an estuary or from maintenance dredging and propeller wash. However, biological resources will be adversely impacted by suspended sediment concentrations that are above the baseline for an extended period. The environmental impacts of increased suspended sediment concentrations include:

- Suspended sediment can cause 'shading' (reduced light transmission) in the water column, limiting the ability of phytoplankton, microphytobenthos and macroalgae to photosynthesise. In increasingly turbid environments, the primary productivity of microphytobenthos and macroalgae in intertidal habitats may be skewed to low tide exposure. The consequence is a diminished primary productivity (Guarini *et al.*, 2002; Spilmont *et al.*, 2006; Drylie *et al.*, 2018). A diminished primary productivity will affect the dissolved oxygen concentration in the water column and reduce available food resources for secondary consumers. A diminished microphytobenthic biomass and productivity can also lead to an increased nutrient exchange from intertidal and shallow subtidal sediment (Pratt *et al.*, 2014).
- Benthic diatoms produce extracellular polymeric substances that create a biofilm on the sediment surface, increasing the critical threshold for erosion and thereby reducing sediment resuspension and bed erosion (Andersen *et al.*, 2010; Malarkey *et al.*, 2015; Parsons *et al.*, 2016). This is important for intertidal sand and mudflat stability. If light penetration is diminished, these diatoms may be lost, and erosion may progress.
- Suspended sediment can clog or physically damage the feeding and respiratory organs (e.g. gills) of invertebrates and fish (Servizi and Martens, 1987; Kerr, 1995; Bash *et al.*, 2001; Wilber and Clarke, 2001; Hess *et al.*, 2015), with implications for their respiration, nitrogenous excretion, ion exchange, and ultimately their fitness (Appleby and Scarratt, 1989; Wong, *et al.*, 2013).
- Suspended sediment can impair the growth, condition and reproduction, and in extreme cases affect the survival of suspension feeding invertebrates because they must process larger amounts of the sediment to obtain the organic matter on which they rely amongst the sediment compared to normal conditions. This causes them to expend more metabolic energy than they can replace by food intake. The excess energy expenditure reduces the energy available for essential physiological activities, like growth and reproduction (Widdows *et al.*, 1979; Essink and Bos, 1985; Navarro and Widdows, 1997; Urrutia *et al.*, 1997).
- Suspension feeders may reduce the pumping rate of water across their feeding organs or cease pumping if the suspended sediment concentration is 'high', with implications for their growth, condition, reproduction and ultimately their fitness (Foster-Smith, 1976).
- An increase in the suspended sediment concentration can hinder the ability of fish and piscivorous birds that hunt by sight to capture their prey, affecting their foraging success or leading to a shift in their foraging strategy and ultimately affecting their fitness (Breitburg, 1988; Hecht and van der Lingen, 1992; de Jonge *et al.*, 1993; Wilber and Clarke, 2001; Utne-Palm, 2002; De Robertis *et al.*, 2003; Hedrick *et al.*, 2006; Johansen and Jones, 2013; Wenger *et al.*, 2017). The effects of reduced visibility are likely to vary between trophic guilds due to prey size and feeding strategy (Wenger *et al.*, 2017). For example, piscivores are likely to be more sensitive to reduced visibility due to their feeding strategy of hunting prey from a distance (Ranåker *et al.*, 2014). Planktivorous fish are more likely to detect their prey at a shorter distance and experience less interference from suspended sediment or low light conditions (Utne-Palm, 2002). In some instances, mild turbidity favours the feeding success of planktivores since the suspended sediment can aid in the discrimination of plankton from the background (Ohata *et al.*, 2014; Wenger *et al.*, 2014).
- Fish and piscivorous birds may avoid areas of high suspended sediment concentration, restricting their access to normal foraging areas that can ultimately affect their fitness (Collin and Hart, 2015; Wenger *et al.*, 2012; Wenger *et al.*, 2017).
- Not all fish are adversely affected by suspended sediment. Some estuarine species prefer relatively

turbid waters due to their foraging strategy (Blaber and Blaber, 1980; Cyrus and Blaber, 1987; Wilber and Clarke, 2001). Increased turbidity may be favourable for predator avoidance (Miner and Stein, 1996), although increased turbidity can also increase predation due to prey not recognising predators (Ferrari *et al.*, 2010) and not initiating a flight response (Kimbell and Morrell, 2015). The larval and juvenile stages of some fish may gain an advantage by avoiding predation in turbid waters (Utne-Palm, 2001).

The outputs of the numerical modelling of suspended sediment concentrations in the water column in the Port of Richards Bay related to dredging for the Berth 605 Project are provided in Figures 91-102. High suspended sediment concentrations are anticipated over a large part of the 600 Berth Basin for periods long enough (>20 days) to assume they will have a significant adverse effect on benthic biological resources through acute sublethal or chronic lethal and sublethal exposure. However, little increase in the suspended sediment concentration is expected outside of the 600 Berth Basin.



Figure 91. 80th percentile exceedance contours of suspended sediment concentration in surface waters within the Port of Richards Bay, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 92. 80th percentile exceedance contours of suspended sediment concentration in bottom waters within the Port of Richards Bay, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 93. 99th percentile exceedance contours of suspended sediment concentration in surface waters within the Port of Richards Bay, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 94. 99th percentile exceedance contours of suspended sediment concentration in bottom waters within the Port of Richards Bay, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 95. 80th percentile exceedance contours of suspended sediment concentration in surface waters within the Port of Richards Bay, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 96. 80th percentile exceedance contours of suspended sediment concentration in bottom waters within the Port of Richards Bay, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 97. 99th percentile exceedance contours of suspended sediment concentration in surface waters within the Port of Richards Bay, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).



Figure 98. 99th percentile exceedance contours of suspended sediment concentration in bottom waters within the Port of Richards Bay, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

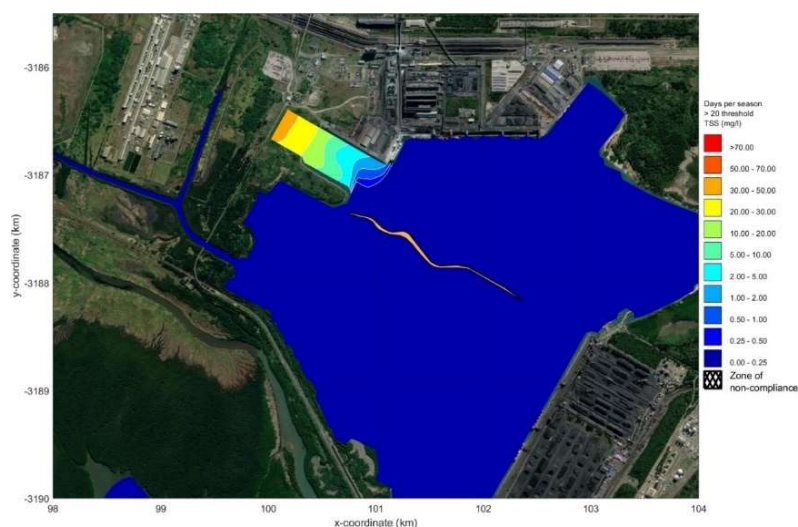


Figure 99. Days of exceedance contours of suspended sediment threshold of 20 mg.L⁻¹ in surface waters within the Port of Richards Bay (van Ballegooyen *et al.*, 2025).

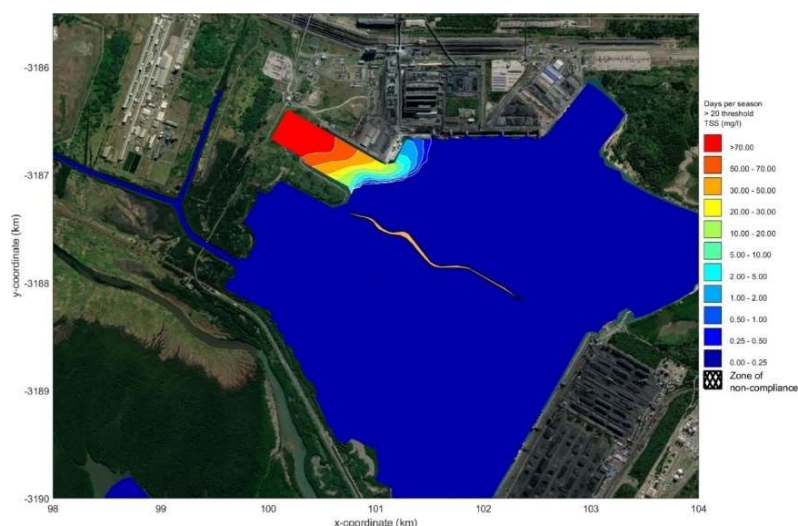


Figure 100. Days of exceedance contours of suspended sediment threshold of 20 mg.L⁻¹ in bottom waters within the Port of Richards Bay (van Ballegooyen *et al.*, 2025).



Figure 101. Days of exceedance contours of suspended sediment threshold of 80 mg.L⁻¹ in surface waters within the Port of Richards Bay (van Ballegooyen *et al.*, 2025).

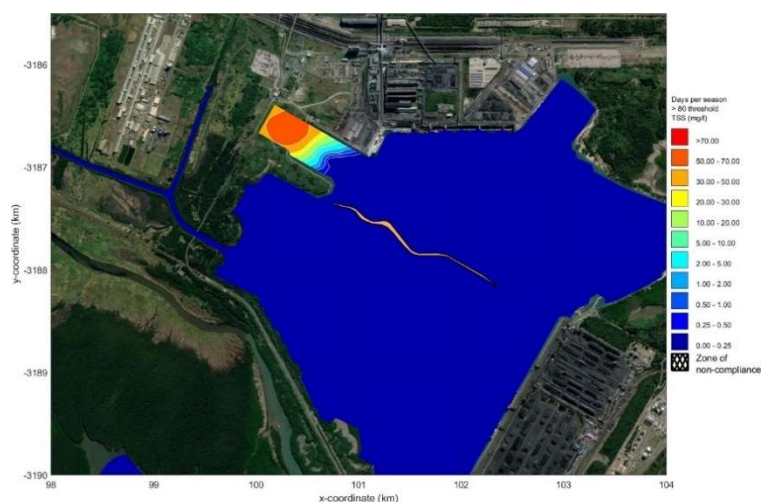


Figure 102. Days of exceedance contours of suspended sediment threshold of 80 mg.L^{-1} in bottom waters within the Port of Richards Bay (van Ballegooyen *et al.*, 2025).

Impact significance assessment without mitigation

Although the most significant increase in the suspended sediment concentration and related turbidity in the water column in the Berth 605 Project footprint is anticipated very near the active dredging operation, resuspended fine-grained sediment will invariably be dispersed over a wider area. It is highly unlikely, however, that resuspended sediment will be dispersed from the port by tides and wind driven currents. In the highly unlikely event it is dispersed this far, the volume of sediment reaching the nearshore coastal marine environment will be insignificant in the context of other sources of suspended sediment to this environment. The impact of increased suspended sediment concentrations and related turbidity on water quality due to dredging is thus anticipated to be restricted to the port—the spatial extent of this impact is thus **local** but probably largely site only based on the outputs of numerical modelling by van Ballegooyen *et al.* (2025) (see Figures 91-102). It is not anticipated that pelagic and benthic biological resources beyond the western part of the 600 Berth Basin will be exposed to elevated suspended sediment concentrations and related turbidity for the duration of dredging—estimated at 4.5 months—since suspended sediment will be dispersed in different directions depending on prevailing currents. Intertidal areas will also not be exposed to resuspended sediment at low tide, providing some respite for intertidal biological resources. For the purposes of numerical modelling of resuspended sediment dispersion, van Ballegooyen *et al.* (2025) assumed that dredging will proceed from 0h00 hours to 18h30 hours, cease, and proceed again only at 0h00 hours daily. If this is the case, there will be a 5.5-hour window for remobilised suspended sediment to disperse. Dredging will, nevertheless, result in a more prolonged and frequent increase in the suspended sediment concentration and related turbidity, and hence a more prolonged and frequent exposure of biological resources at any affected position compared to existing natural and anthropogenic events. The duration of this impact is considered short-term due to the anticipated 4.5 month dredging period. However, fine-grained material is likely to dominate the sediment deposited on the bottom and will have the potential to be resuspended by natural (currents) and anthropogenic causes (vessel propeller wash) over a longer period until the sediment is dispersed. The impact duration is thus considered **medium-term**. High suspended sediment concentrations are expected over a large part of the 600 Berth Basin for periods long enough (>20 days) to suspect these will have a significant adverse effect on biological resources through acute sublethal or chronic lethal and sublethal exposure. The magnitude of the loss in ecological function and productivity in the port is thus anticipated to be **moderate**. The impact is **recoverable** since suspended sediment concentrations and related turbidity will return to the baseline when dredging ceases—monitoring for the Berth 306 Project in the Port of Richards Bay showed this occurred within a matter of days. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and measures that will be implemented to minimise environmental impacts.
- Dredging methods that resuspend the least quantity of fine-grained sediment should be used. However, it is acknowledged that the dredging method will be dictated by the nature of the material that needs to be dredged or removed—at this point in time a cutter-suction dredger has been identified as the most suitable dredging technology.
- Dredging near intertidal sediment habitat should ideally be performed at low tide to limit the dispersion of suspended sediment to intertidal areas. However, it is acknowledged that this is probably impractical and it will prolong the dredging period, in turn prolonging environmental impacts.
- An environmental valve ('green valve') should be used in barges—these valves reduce air entrainment to limit the dispersion of overflowing sediment-water mixtures.
- Joints on pipes from the cutter suction dredger to barges must be properly sealed so that sediment is not lost into the surrounding water column.
- The dredging footprint should be restricted to the smallest practical area and (*i.e.* avoid over-dredging) to minimise the quantity and period over which sediment is resuspended into the water column.
- Barge loading must be controlled to prevent the overflow or leakage of sediment from barge compartments during non-dredging transit at the dredging site and during transit to the dredged spoil disposal site off the Richards Bay coast.
- Barges must not be overfilled.
- If feasible, a silt curtain should be installed across the narrow channel that links the 600 and 700/800 Berth Basins and Kabeljous Flats in the event a turbidity >25 NTU is consistently measured in surface and mid-water depths in water within and near the channel. This turbidity limit is ~4-5 times higher than the turbidity usually measured in the 600 Berth Basin (CSIR, unpublished data).
- A water quality monitoring programme should be implemented to identify if agreed-upon water quality targets are breached. The water quality targets should trigger a management response in the event they are breached. The response should be outlined in an Environmental Monitoring Programme protocol.

Impact significance assessment with mitigation

The mitigation measures are intended to minimise the resuspension of sediment into the water column during dredging. This can be achieved by minimising the duration and spatial extent of dredging, thereby reducing the timeframe and spatial scale of resuspended sediment impacts, and by minimising sediment losses from dredgers and barges during transit to the dredged spoil disposal site off the Richards Bay coast. A detailed method statement will only be developed by the dredging contractor(s) when Environmental Authorisation is secured. In the absence of this information, it is impossible to assume all recommended mitigation measures are feasible and will/can be implemented. It can, however, be reasonably be concluded the dredging contractor(s) will restrict dredging to the dredging footprint and to the shortest timeframe practical for financial reasons since dredging contracts are usually structured around deliverables rather than a daily rate. Dredging contractors thus have an incentive to complete dredging in the shortest time possible, albeit within an agreed upon dredging rate to limit environmental impacts. Given these uncertainties, the significance assessment for this impact with mitigation remains **MODERATE**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Decrease in aquatic ecological function and productivity due to a deterioration in water quality related to increased suspended sediment concentrations and related turbidity during dredging
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate

IMPACT DESCRIPTION	ASSESSMENT
Pre-Mitigation Significance Assessment	
Magnitude	Moderate
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Moderate
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance with mitigation	MODERATE
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that generate suspended sediment plumes that degrade water quality and affect biological resources. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging, and capital dredging for other planned infrastructure development as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on water quality degradation, and the impairment of biological resources and ecological productivity will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Suspended sediment plumes generated by maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap with plumes generated during the development of Berth 605 due to the physical separation between dredging sites. The greatest likelihood for spatial overlap is for the development of Berths 802 and 803 in the 700/800 Berth Basin and when maintenance dredging occurs in the latter basin. However, even if suspended sediment plumes do not spatially overlap, simultaneous dredging will degrade water quality and adversely affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. Depending on the infrastructure developments that occur simultaneously, the cumulative effect could be moderately to highly adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources and ecological productivity is also likely to be moderately adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent possible, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation in the port through increased suspended sediment concentrations related to the increased requirement for tugboat assisted vessel manoeuvring and maintenance dredging. However, the increase is anticipated to be of a low environmental significance.

Recommended environmental monitoring

The suspended sediment concentration and related turbidity in the water column should be measured periodically during dredging to confirm or refute the outputs of three-dimensional numerical modelling and

the impact significance assessment. The positions where water quality is monitored must focus on protecting the most sensitive ecological habitats near the project footprint, namely intertidal sediment habitat on the Sandspit, intertidal and shallow subtidal sediment habitat on the Kabeljous Flats, and mangroves fringing the Kabeljous Flat and on the Sandspit. A gradient monitoring design is recommended, whereby monitoring stations are positioned at increasing distances from the Berth 605 dredging/development footprint in the 600 Berth Basin, and encompassing sensitive habitats. The distance between dredging and excavation operations and the first monitoring stations is recommended at 200 m, meaning the area between would be regarded as a highly impacted area. Suspended sediment concentrations should meet agreed-upon thresholds 90% of the time at this distance from dredging and excavation operations. Stations must also be placed 500 m from the dredging footprint, just north of the narrow channel that links the 600 and 700/800 Berth Basins and Kabeljous Flats, and within the narrow channel. The suspended sediment concentration should not exceed agreed-upon thresholds at the latter stations more than 10% of the time—the recommended threshold is 25 mg.L⁻¹. If thresholds are exceeded in the narrow channel, regular measurements may need to be made to identify when to cease and reinstate dredging. This would be most effectively done using instruments deployed permanently at strategic positions in the 600 Berth Basin and linked telemetrically to a central control point. Alerts when the suspended concentration is above an agreed-upon threshold would be sent automatically (e.g. via cellular phone) to site managers and the dredging contractor(s), triggering a management/dredging response.

Regulatory authorities usually impose a limit on the suspended sediment concentration for dredging compliance monitoring rather than a turbidity limit. The reason is suspended sediment concentrations correlate well with environmental impacts and are broadly comparable from site to site and sediment to sediment. A suspended sediment concentration of 100 mg.L⁻¹ at one site, for example, will have about the same potential for impact as the same concentration at another site with different sediment grain size characteristics since approximately the same volume of sediment will be present in the water column. In contrast, a turbidity of 50 NTU in one suspension is not necessarily comparable in suspended sediment concentration or potential environmental impact to another suspension with a turbidity of 50 NTU because turbidity is influenced by numerous properties of the material in suspension, such as its particle size and composition. The major problem with imposing a limit on the suspended sediment concentration for dredging compliance monitoring is that suspended sediment concentrations cannot be determined quickly, because water samples require transport to and subsequent analysis in a laboratory. Depending on the location of the laboratory relative to the dredging operation it can take anywhere between 12-72 h to receive the results. In the meantime, the suspended sediment concentration in the water body of interest may have changed. Suspended sediment concentrations cannot, therefore, be used to detect and correct short-term problems or dredging permit violations. It also becomes difficult to regulate a dredging operation because the economic ramifications are significant when a dredging contractor is required to cease operations based on the potential violation of a suspended sediment concentration limit, but which must be verified based on results that may only be forthcoming several days later.

Due to these problems a turbidity limit is often substituted for a suspended sediment concentration limit in dredging permits for dredging environmental monitoring programmes. The rationale is that there is often a strong linear relationship between turbidity and suspended sediment concentrations, meaning turbidity measurements can be used as a proxy for the suspended sediment concentration. Turbidity can be measured quickly—within a few minutes—using any one of numerous *in situ* or onsite laboratory/vessel-based turbidimeters. The turbidity be converted to an estimated suspended sediment concentration using a pre-established relationship between turbidity and suspended sediment concentrations. This approach is recommended for compliance/impact monitoring for the development of Berth 605. There is no universal relationship between turbidity and suspended sediment concentrations. Rather, this varies from place to place because the relationship is determined by the particle size of sediment, the particle composition and water colour amongst other variables. The CSIR (2013) established a relationship between turbidity and

suspended sediment concentrations for the Port of Richards Bay, but this was based on a limited data set that was considered to possibly be unsuitable for compliance/impact monitoring purposes, because it was largely developed using data for the Richards Bay Coal Terminal Basin. It is thus recommended that a relationship between turbidity and suspended sediment concentrations be established for the Port of Richards Bay by using sediment collected in the Berth 605 Project footprint and in areas where dredging will be required for other planned projects. The relationship can then be used to estimate suspended sediment concentrations for the development of Berth 605 and other planned infrastructure projects, providing a consistent monitoring tool going forward. Establishing a robust relationship will require in the order of 150 samples, using sediment collected at strategic positions to apply to the entire port.

Impact 16: Decrease in aquatic ecological function and productivity in subtidal habitats due to the deposition of sediment resuspended by dredging

Impact description

Sediment that is resuspended into the water column during dredging for the Berth 605 Project will settle on the bottom in subtidal parts of the Port of Richards Bay, both within and outside the dredging footprint. Coarse, heavy sediment particles will settle within seconds near the point of dredging. In most dredging operations in non-riverine environments, the bulk of the resuspended sediment usually settles within ~100-200 m of a dredging operation, if not nearer (USACE, 2007). However, fine-grained particles can remain in the water column for hours to days and may be dispersed over a considerable distance—many kilometres in some cases—depending on prevailing hydrodynamic conditions. The fine-grained sediment will ultimately settle in areas where and when the current flow can no longer overcome the effects of gravity on the particles. The newly deposited material may be resuspended and dispersed further if the current strength increases for some reason, but it will eventually settle and accumulate on the bottom.

Most benthic biological resources live in the upper 10 cm of sediment and rely on a connection (*e.g.* burrows, porewater diffusion) to the sediment-water interface for ventilation (respiration), feeding and breeding (Miller *et al.*, 2002). The excessive deposition of sediment on the bottom can lead to the burial, smothering and crushing of benthic biological resources, including invertebrate infauna, poorly mobile, sessile, or sedentary epifauna, and the eggs of invertebrates and fish that develop on the bottom. In extreme cases, sediment deposition can lead to the complete loss of benthic ecology. The deposition of muddy sediment on sandy sediment is generally considered to present a greater ecological challenge than the reverse (Diaz and Boesch, 1977; Boon and Dalfsen, 2022) and has been negatively correlated to benthic biological resource species diversity and abundance (Thrush *et al.*, 2003; Pratt *et al.*, 2014) and ecosystem functioning (nutrient regeneration, sediment oxygen consumption, chlorophyll-*a* concentration) (Pratt *et al.*, 2014). The excessive deposition of mud on sandy sediment can lead to the clogging of the spaces between sand grains. The physical barrier formed at the sediment-water interface can displace biological resources that live between the sand grains and inhibit the exchange of oxygen at the sediment-water interface, leading to the suffocation of burrowing biological resources and reducing the aerobic mineralisation of particulate organic matter and other compounds in the sediment (Norkko *et al.*, 2002; Hohaia *et al.*, 2014; Colden and Lipcius, 2015).

Many benthic biological resources can migrate upwards through an appreciable depth (~15-30 cm) of deposited sediment and may be relatively unimpacted by sediment deposition within reasonable limits (Maurer *et al.* 1979, 1981a,b, 1982, 1986; Roberts *et al.*, 1998; Miller *et al.*, 2002; Fredette and French, 2004; Wilber *et al.*, 2007; Powilleit *et al.*, 2009). Maurer *et al.* (1980, 1981a,b, 1982) reported that the bivalve mollusc *Mercenaria mercenaria* and gastropod *Nucula proxima* could migrate vertically up to 16 cm when inundated with sand, the crustacean amphipod *Parahastorius longimerus* and xanthid crab *Neopanope sayi* could migrate through 7-30 cm, and the polychaetes *Scoloplos fragilis* and *Nereis succinea* could manage 30 cm. Other benthic biological resources are less tolerant of burial and smothering and may be significantly impacted by even a thin layer of deposited sediment (Schaffner, 1993; Wilber and Clarke,

2007; Hendrick *et al.*, 2016). However, even benthic biological resources that are tolerant of sediment deposition and can migrate through appreciable depths of deposited sediment may be adversely affected by the increased energy expenditure required for frequent repositioning relative to the sediment-water interface and/or the maintenance of burrows to prevent infilling, requiring that they shift their energy budget from other functions such as growth or reproduction. If the deposited sediment has a different grain size to that which existed before deposition, it may alter the physical properties of the sediment to such a degree the benthic biological resources that prefer to inhabit sediment of a fairly specific grain size are displaced due, for example, their need to maintain an open burrow or their mode of feeding (Holland *et al.*, 2005; Smit *et al.*, 2008; Boon and Dalfsen, 2022).

The consequence of excessive sediment deposition, therefore, is usually an altered species diversity, abundance and biomass of benthic biological resources (Bolam and Rees, 2003; Bolam *et al.*, 2011; Bolam *et al.*, 2021). This has implications for ecosystem functioning—fish that rely on invertebrates in an affected area as a food resource, for example, will be deprived of the resource. The severity of the effects depends on the thickness of sediment deposition and the intensity and frequency of deposition events—biological resources have been shown to tolerate the slower addition of thin layers of sediment better than the same thickness of sediment deposited in a pulse.

Benthic biological resources colonise areas where sediment has been deposited or otherwise disturbed and will recover over time to a species composition, abundance and biomass that is comparable to that which existed before deposition provided the physical properties of the sediment are not immeasurably different to that which existed prior to deposition. The recovery of estuarine benthic biological resources from sediment deposition related disturbance is faster than in other habitats—expected to take months rather than years. Benthic biological resources in subtidal sediment habitat in deepwater basins and channels in the Port of Richards Bay are undoubtedly habituated to and tolerant of a degree of sediment deposition since sediment is frequently resuspended by vessel propeller wash and less often by maintenance dredging (see Figures 36 and 37). The habituation and tolerance will facilitate recovery.

van Ballegooyen *et al.* (2025) used three-dimensional numerical modelling to simulate the dispersion and deposition of sediment resuspended into the water column in the Port of Richards Bay during dredging for the Berth 605 Project. The simulation period was 155-days. The outputs of the modelling are provided in a separate comprehensive report by van Ballegooyen *et al.* (2025), to which the reader is referred for more detailed information. The following is extracted from the van Ballegooyen *et al.* (2025) report.

The measures of impact that were applied to the numerical modelling outputs comprise:

- Exceedance contours (99th, 95th, 90th, 80th percentile) of elevation in suspended sediment concentrations, where exceedances were calculated only for the dredging period (~139 days of the full 155 day model simulation period) since suspended sediment concentrations decrease rapidly upon the cessation of dredging and dredged spoil disposal—see CSIR (2008) for an example of such a decrease for the Port of Richards Bay and the nearshore marine environment off the Richards Bay coast. The reported 95th, 90th and 80th percentile exceedance contours for the elevation in suspended sediment concentrations represent concentrations that are exceeded for a cumulative period of 4.5 days, 9 days and 18 days per season, respectively. The 99th percentile exceedance contour is deemed to represent the maximum suspended sediment concentration likely to occur within a season—here deemed to be 90-day period. However, given the 139-day period of dredging simulated in the numerical model, the same 95th, 90th and 80th percentile exceedance contours represent elevations in suspended sediment concentrations that are exceeded for 7 days, 14 days and 28 days, respectively, over the full dredging and dredged spoil disposal period for the Berth 605 Project. The 80th percentile contour of the suspended sediment concentration, therefore, can be considered indicative of more ‘chronic’ rather than short-term ‘acute’ impacts. These contours of days of exceedance of the threshold of concern

have been determined for surface waters, mid-column waters, and near-bottom waters.

- Cumulative days of exceedance per season of the threshold of concern for elevation in suspended sediment concentration in the water column are relevant to the impact under consideration (e.g. visual impacts, marine ecological impacts). The contours of days of exceedance of the threshold of concern were determined for surface waters, mid-column waters and near-bottom waters. The days of exceedance contours provide insight into the cumulative persistence and/or likely regularity with which suspended sediment plumes will be observed in these environments.
- Maximum sedimentation thickness occurring during the full model simulation of 155 days.

Several environmental thresholds (limits) exist for assessing ecological impacts associated with suspended sediment in the water column. Those selected for the numerical modelling are:

- A 20 mg.L⁻¹ suspended sediment concentration limit suggested by Steffani *et al.* (2003), which represents a conservative lower threshold below which impacts were not expected to occur in ecologically sensitive areas in Table Bay and Algoa Bay (see also TNPA, 2009). The limit constitutes a low risk, monthly average goal that was used in a previous capital dredging study for the Port of Richards Bay (van Ballegooyen *et al.*, 2015).
- An 80 mg.L⁻¹ suspended sediment concentration limit, also suggested by Steffani *et al.* (2003), which they considered to represent a high-risk situation (albeit for environments where strong river/estuarine inflows are not expected) and one that is likely to require mitigation. The applicability of this limit in this project is uncertain and is likely to be overly conservative.
- A 100 mg.L⁻¹ suspended sediment concentration limit that, based on a literature review (EMBECON, 2004), represents limited risks for biological resources. This is also the limit suggested in CSIR (2013) for assessing potential dredging impacts within the Port of Richards Bay and used in CSIR (2004) to assess impacts in nearshore environments for shoreline discharges of dredged material.
- A 150 mg.L⁻¹ suspended sediment concentration limit suggested in CSIR (2013) as being applicable for assessing impacts on the Kabeljous Flats within the port and in the Bhizolo-Manzanyama Canal complex.

A suspended sediment concentration limit of 25 mg.L⁻¹ has also been used in previous studies (van Ballegooyen and Jacobs, 2020), although mainly to assess potential suspended sediment impacts of dredged material disposal onto the northern shoreline of Richards Bay (north of Dolphin Viewing Pier) in an attempt to mitigate ongoing shoreline erosion of these beaches (van Ballegooyen *et al.*, 2025). This represents one of the limits (CCME, 2002) reported in the new South African Water Quality Guidelines for Coastal Marine Waters (DFFE, 2022).

To assess the potential ecological impacts associated with the deposition of resuspended sediment, the numerical model results are presented as the near maximum (99th percentile) thickness of sediments anticipated to be deposited on the seabed based on the full simulation period of 155 days. This allows for a ~3-week period of re-distribution of the sediment from the dredging site into the surrounding environment in the Port of Richards Bay (to the extent that this occurs) and onto the surrounding seabed around the dredged spoil disposal site off the Richards Bay coast. This provides a conservative assessment of smothering impacts in the long-term. A comprehensive account of the re-distribution of sediment from the dredged spoil disposal site is provided in a companion specialist study of the changes in the wave climate and adjacent shoreline morphology (van Ballegooyen *et al.*, 2025), based on available data and insights from numerical modelling studies.

The maximum sediment thickness predicted for the full simulation period suggests there will be an accumulation of relatively unconsolidated mud on the bottom within the inner third of the 600 Berth Basin, decreasing to 10-20 cm at the outer margin of the basin and <1-2 cm toward the turning circle and into the 700/800 Berth Basin. The deposited sediments will comprise mainly fine-grained material from the lean

mixture overboard releases assumed in the numerical modelling, comprising relatively unconsolidated fine-grained material—assumed in the model to have a dry density of 465 kg.m^3 and wet bulk density of the order of $1\,300 \text{ kg.m}^3$. The layer of fine-grained unconsolidated material will be easily remobilised by propeller wash and lead to chronic and relatively high suspended sediment concentrations in the water column until the material is removed to the offshore dredged spoil disposal site, presumably as a final clean-up operation as part of the capital dredging operations but possibly more cost-effectively as part of maintenance dredging should this be allowed by existing permitted maintenance dredging and disposal volumes on the existing authorised dredged spoil disposal site. A detailed assessment of such operations was not included in the present study.

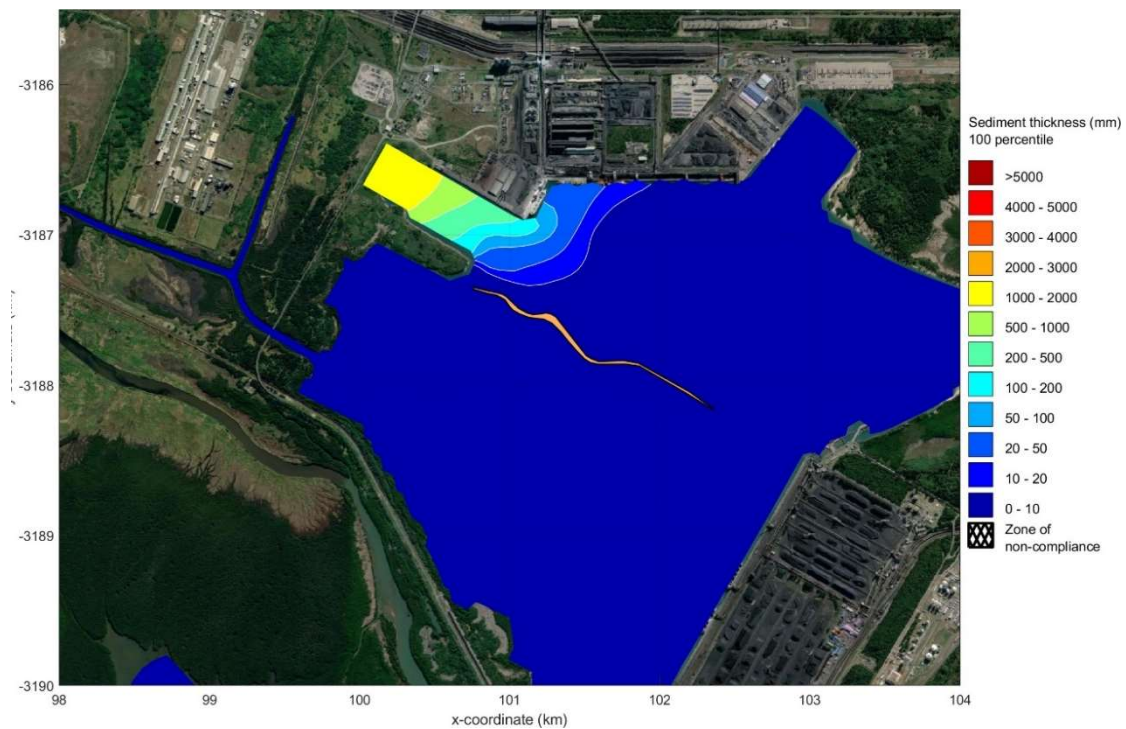


Figure 103. 99%tile sediment thickness on the seabed within the port (van Ballegooyen *et al.*, 2025).

Impact significance assessment without mitigation

As discussed above, dredging for the Berth 605 Project will resuspend sediment into the water column in the Port of Richards Bay—this is an unavoidable consequence of dredging. Based on the findings of studies elsewhere in the world, and for the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay, most of the resuspended sediment is expected to settle on the bottom near the dredging operation. This is supported by the outputs of three-dimensional numerical modelling by van Ballegooyen *et al.* (2025), as discussed above. Resuspended sediment will nevertheless disperse and deposit on the subtidal bottom outside the dredging footprint. The bulk of the sediment is not anticipated to disperse and deposit over a large distance from the active dredging operation and the impact spatial extent is thus anticipated to be mainly site only (within 600 Berth Basin) but possibly **local** (within the Port of Richards Bay). Benthic biological resources ‘near’ the dredging footprint are anticipated to be exposed persistently to depositing sediment, but this will decrease with increasing distance from the dredging operation. Dredging will, nevertheless, result in more prolonged and frequent sediment deposition compared to other anthropogenic impacts or natural events that currently affect the area, such as vessel propeller wash and maintenance dredging. Sediment that deposits on the bottom will bury and smother benthic biological resources in areas where the deposition is anticipated by the numerical modelling to be most intense, with the attendant detrimental environmental impacts outlined above. The volume of sediment settling on the bottom outside the dredging footprint is anticipated to be fairly high—potentially 10-20 cm at the outer margin of the 600 Berth Basin. As stated above, benthic biological resources in subtidal areas outside the

dredging footprint where sediment is anticipated to deposit are probably habituated to, and tolerant of a degree of sediment deposition, due for example to the deposition of sediment resuspended by vessel propeller wash and maintenance dredging. However, the modelled sediment thicknesses might exceed the tolerances of sensitive benthic biological resources. The CSIR (2005) classified the ecological (conservation) significance of 12 habitat types within the Port of Richards Bay. Deepwater sediment habitat was rated the least important. This habitat supports a lower species diversity and biomass of benthic biological resources and is not as important in the lives of fish and other pelagic biological resources (*e.g.* swimming prawns) than most other habitat types in the port. Deepwater sediment habitat represents the largest aquatic area that will be affected by the physical effects of sediment deposition for the Berth 605 Project. Although resuspended sediment will deposit on the bottom and will **definitely** affect benthic biological resources, the magnitude of the impact on aquatic ecological function and productivity is anticipated to be **moderate** rather than high for the above reasons. The duration of the dredging is expected to last ~4.5 months. However, the sediment is likely to be more fine-grained than is currently the case and the recovery of benthic biological resources is expected to take longer—recovery is nevertheless expected to occur within the **medium-term**. The impact is **recoverable** since sediment resuspension and deposition will cease when dredging ceases and disturbed benthic biological resources will re-establish and recover to the extent allowed by ongoing port related activities that disturb these communities. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the procedures that will be implemented to minimise environmental impacts.
- Dredging methods that resuspend the least quantity of sediment into the water column should be used, but it is acknowledged the dredging method will be dictated by the nature of the material that needs to be dredged.
- Dredging should ideally be performed in winter when ecological productivity and the recruitment of biological resources are generally lowest. However, it is acknowledged that this might not be possible and should not be a factor driving the decision on when the project is initiated.
- The dredging footprint must be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the quantity of sediment that is resuspended into the water column.
- There should be no overflow or leakage from barge compartments during non-dredging transit at the dredging site and during transit to the dredged spoil disposal site off the Richards Bay coast.
- If feasible, a silt curtain should be installed across the narrow channel between the 600 and 700/800 Berth Basins and the Kabeljous Flats if water quality surveys (see Impact 15) reveal the regular incidence of unacceptably high suspended sediment concentrations in the channel.

Impact significance assessment with mitigation

The mitigation measures outlined above are aimed at limiting the quantity of sediment that is resuspended into the water column during dredging since it is this sediment that will deposit on the bottom in the subtidal and affect benthic biological resources. Assuming the above mitigation measures are implemented the extent for this impact might be reduced to site only. However, the significance assessment for the impact after mitigation will remain **MODERATE**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Decrease in aquatic ecological function and productivity in subtidal habitats due to the deposition of sediment resuspended by dredging
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	

IMPACT DESCRIPTION	ASSESSMENT
Magnitude	Moderate
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Recoverable
Duration	Medium-term
Probability	Possible
Significance with mitigation	MODERATE
Confidence in assessment	Medium

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other operations and activities in the Port of Richards Bay that generate suspended sediment plumes that will deposit on the bottom and affect benthic biological resources. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging, and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on benthic biological resources and ecological productivity will be negligible when compared to capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Suspended sediment deposition areas for maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap with sediment deposition areas for the Berth 605 Project due to the physical separation between dredging sites. The greatest likelihood for spatial overlap is for the development of Berths 802 and 803 in the 700/800 Berth Basin, and when maintenance dredging occurs in the 700/800 Berth Basin. However, even if sediment deposition areas do not spatially overlap, simultaneous deposition due to dredging will affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. Depending on the infrastructure developments that occur simultaneously, the cumulative effect could be low to moderately adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on biological resources and ecological productivity could also be low to moderately adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent possible, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

An increase in the amount of sediment resuspended and deposited by additional tugboat-assisted vessel manoeuvring and maintenance dredging needs for the operational Berth 605 will interact cumulatively with longer-term infrastructure development, if only minimally.

Recommended environmental monitoring

There is no specific requirement to monitor the impact of resuspended sediment deposition on benthic biological resources since the effects are well documented in the scientific literature. Notably, studies in the Port of Richards Bay—including the development of the 600 Berth Basin and Berth 306 at the Richards Bay Coal Terminal Basin (CSIR, 2008)—have shown that benthic biological resources that are disturbed in this way are not completely lost and/or will recover over time. There is thus certainty that benthic biological resources in affected areas will recover if no new significant anthropogenic disturbances are introduced.

However, monitoring benthic biological resource impacts during dredging, and recovery after dredging will provide valuable insights into recovery rates. These findings can be used to inform the significance of the likely environmental impacts of capital dredging campaigns for future infrastructure development in the port.

Impact 17: Decrease in aquatic ecological function and productivity in intertidal habitats due to the deposition of sediment resuspended by dredging

Impact description

Some of the fine-grained sediment that will be resuspended into the water column during dredging for the Berth 605 Project will inevitably settle in intertidal areas in parts of the Port of Richards Bay. The most significant settlement is likely to occur in the intertidal in the 600 Berth Basin, but potentially also in the intertidal on parts of the Kabeljous Flats near the point where a small channel connects the 600 Berth Basin and the flats, and on parts of the Sandspit. The deposition of sediment in the intertidal can have numerous detrimental consequences. Fine-grained muddy sediment that deposits on sandy sediment—which is the primary component of sediment in the intertidal in large parts of the Port of Richards Bay and in the 600 Berth Basin—can lead to the clogging of the spaces between sand grains. The physical barrier that is formed at the sediment-water interface by the clogging can displace biological resources that live between the grains and inhibit the exchange of oxygen with the overlying water. This can lead to the suffocation of the biological resources and reducing the aerobic mineralisation of particulate organic matter and other compounds in the sediment (Norkko *et al.*, 2002; Hohaia *et al.*, 2014; Colden and Lipcius, 2015).

The deposition of sediment in the intertidal can impact on microphytobenthos. Laboratory experiments have revealed that the deposition of sediment beyond certain thresholds reduces the biomass of microphytobenthos, affecting ecosystem processes (*e.g.* Larson and Sundbäck, 2012). Microphytobenthos can migrate through deposited sediment, but newly deposited sediment provides a less stable and more porous substrate, which can hinder their re-establishment and growth. Estimates of microphytobenthos recovery after simulated sediment deposition in the laboratory vary widely—from no response to about seven weeks. However, in certain circumstances microphytobenthic biomass may increase due to indirect effects, such as enhanced nutrient availability (Alsterberg *et al.*, 2007; Larson and Sundbäck, 2008; Sundbäck *et al.*, 2010; Larson and Sundbäck, 2012). As discussed elsewhere in this specialist study, microphytobenthos produce extracellular polymeric substances (mucopolysaccharides) that form a biofilm on sediment. The biofilm promotes sediment stability and increases the threshold for erosion, reducing sediment resuspension and erosion in the process (Malarkey *et al.*, 2015; Parsons *et al.*, 2016). The loss of microphytobenthos can thus lead to the increased erosion and instability of intertidal and shallow subtidal sediment.

As discussed elsewhere in this specialist study, most biological resources inhabit the top 10 cm of sediment and rely on a connection (*e.g.* burrows) to the sediment-water interface for ventilation (respiration), feeding and breeding (Miller *et al.*, 2002). The excessive deposition of fine-grained sediment (mud) on sandy sediment can clog the spaces between sediment grains, displacing the biological resources that live between the grains and impeding the exchange of oxygen with the overlying water, leading to the suffocation of the biological resources. Frequent repositioning to maintain a relative distance to the sediment-water interface or increased maintenance activities to prevent the infilling of burrows requires that biological resources divert their energy budget from other functions, such as growth or reproduction.

Benthic biological resources in the intertidal parts of the Berth 605 Project footprint are undoubtedly habituated to, and thus tolerant of a certain amount of sediment deposition, such as that generated by vessel propeller wash. However, the amount deposited is undoubtedly very small and does not remain in the intertidal, evident in the sediment in the intertidal being comprised of sand.

Dredging for the Berth 605 Project will resuspend sediment into the water column in the Port of Richards Bay—this is an unavoidable consequence of dredging. Most of the sediment is anticipated to settle near the dredging operation. However, fine-grained sediment will be dispersed by currents over a wider area and some will invariably settle in the intertidal near the dredging operation when it is inundated by tides, and potentially also on the Kabeljous Flats and Sandspit (see discussion of numerical modelling outputs in Impacts 15 and 16). The volume of sediment that is anticipated to settle in the intertidal is small and will be temporary in the 600 Berth Basin considering wave action is likely to disperse the sediment at each rise of the tide. However, the quantity of sediment deposited as a result of the proposed dredging is expected to exceed that currently accumulating in these habitats from existing natural and anthropogenic sources (*e.g.* vessel propeller wash, maintenance dredging). The sediment is also anticipated to deposit more often than is the case for present conditions.

Impact significance assessment without mitigation

The numerical modelling by van Ballegooyen *et al.* (2025) did not specifically focus on sediment deposition in the intertidal. As stated above, some of the fine-grained sediment that will be resuspended into the water column during dredging for the Berth 605 Project will inevitably settle in the intertidal in parts of the Port of Richards Bay and will affect biological resources and related ecological function and productivity. However, the impact is anticipated to be site only, but **local** at most, even though the most intense deposition is anticipated near the active dredging operation (*i.e.* site only). Intertidal benthic biological resources near the dredging operation will probably be exposed to high volumes of depositing sediment at times. The CSIR (2005) classified the ecological (conservation) significance of 12 habitat types within the Port of Richards Bay. Intertidal beach habitat was rated the second least important. This habitat was considered to support a lower species diversity and biomass of benthic biological resources and was not considered to be as important in the lives of fish and other pelagic biological resources (*e.g.* swimming prawns) as many other habitats in the port. The magnitude of the impact on ecological function and productivity is thus anticipated to be **low**, but is **very likely**. The potential for this impact will persist throughout the dredging period and is thus **short-term** in duration—any deposited fine-grained material remaining in the intertidal in the 600 Berth Basin will be eroded by wave action. The impact is **recoverable** since it will cease when dredging ceases and benthic biological resources in the intertidal will recover over time. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredging methods that resuspend the least quantity of sediment into the water column should be used, although it is acknowledged the dredging method will be dictated by the nature of the material that needs to be dredged or removed.
- Dredging should ideally be performed in winter when ecological productivity and the recruitment of biological resources are generally at their lowest. However, it is acknowledged that this might not be possible. Dredging in summer will, nevertheless, have little influence on the significance assessment for this impact.
- The dredging footprint must be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the quantity of sediment that is resuspended into the water column.
- There should be no overflow or leakage of dredged sediment from barge compartments during non-dredging transit at the dredging site and during transit to the dredged spoil disposal site off the Richards Bay coast.
- If feasible, a silt curtain should be deployed across the narrow channel between the 600 and 700/800 Berth Basins and the Kabeljous Flats if water quality surveys (see Impact 15) reveal consistently unacceptably (and unexpectedly) high suspended sediment concentrations within the channel.

Impact significance assessment with mitigation

The mitigation measures outlined above are aimed at limiting the quantity of sediment that is resuspended into the water column during dredging since it is this sediment that will disperse and deposit in the intertidal and adversely affect benthic biological resources. Assuming the above mitigation measures are implemented the extent for this impact might be reduced to site only. In this case the significance assessment for the impact after mitigation is **LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Decrease in aquatic ecological function and productivity in intertidal habitats due to the deposition of sediment resuspended by dredging
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Local
Reversibility	Recoverable
Duration	Short-term
Probability	Very likely
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Recoverable
Duration	Short-term
Probability	Very likely
Significance with mitigation	LOW
Confidence in assessment	Medium

Potential for cumulative effects

Capital dredging for the Berth 605 Project will coincide with the tugboat assisted manoeuvring of vessels in the 600 and 700/800 Berth Basins and may coincide with maintenance dredging in other parts of the Port of Richards Bay. It is possible that sediment resuspended and deposited in the intertidal by vessel propeller wash and maintenance dredging will magnify the impact of sediment deposition due to dredging for the proposed project, and *vice versa*, but the significance would be very low.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

Recommended environmental monitoring

The periodic analysis of the chlorophyll-*a* concentration in sediment sampled at strategically positioned stations in the intertidal of the Sandspit is recommended. It is important to recognise that chlorophyll-*a* concentrations in the intertidal are naturally variable, so the measurements will only be useful in identifying major decreases in concentration. Records of intertidal benthic fauna that are visible on the sediment surface and the number of burrow openings of larger burrowing benthic fauna (*e.g.* sandprawns) should be made when the sediment samples for chlorophyll-*a* analysis are collected. Sediment cores should be collected at strategically positioned stations in the intertidal habitat and photographed, to provide a record of fine-grained sediment deposition and whether this material is accumulating excessively. However, cores should only be collected in areas where there is a visible increase in the amount of fine-grained material in the sandy intertidal.

Impact 18: Remobilisation of oxygen depleting substances from sediment/soil during dredging

Impact description

The remobilisation of inorganic and organic oxygen demanding substances from sediment into the water column is an unavoidable consequence of dredging. Inorganic oxygen demand is caused by abiotic (non-biological) reactions. The most important are the oxidation of (metal)sulphides, reduced iron and manganese, and ammonia (Stumm and Morgan, 1996). The degree to which the dissolved oxygen concentration is depressed depends on the quantity of these compounds remobilised from sediment and conditions in the water column—principally the dissolved oxygen concentration. Inorganic oxygen demanding reactions take place within minutes to hours of the remobilisation or exposure of the compounds (Stumm and Lee, 1961; Chen and Morris, 1972). Reduced iron and manganese are usually oxidised within a few minutes to insoluble oxides/hydroxides that rapidly precipitate and are deposited on sediment, and in turn adsorb substantial amounts of other compounds, including metals. The oxidation of (metal)sulphides is slower. Laboratory based studies have shown that the oxidation of copper, cadmium and lead sulphides may take >8 hours under certain conditions. Once oxidised, the metals are rapidly scavenged and coprecipitated with iron and manganese hydroxides, or are complexed with particulate organic matter (Balistrieri *et al.*, 1981; Engel *et al.*, 1981; Goosens and Zwolsman, 1996; Hirst and Aston, 1983; Maddock *et al.*, 2007; Moore *et al.*, 1988; Prause *et al.*, 1985; Simpson *et al.*, 1998, 2000; Caetano and Vale, 2003; Morgan *et al.*, 2012). Organic (biochemical) oxygen demanding reactions are caused by the oxygen consumption of bacteria that degrade particulate organic matter are far slower than inorganic oxygen demanding reactions, typically proceeding over a time scale of days (Baird and Smith, 2000).

Studies on the effects of dredging operations on dissolved oxygen in the water column have yielded variable results. Brown and Clark (1968) recorded decreases of 16-83% in dissolved oxygen concentration near dredging operations, while LaSalle (1989), Cabrita (2014) and Consulim *et al.* (2023) found no discernible effect or a very small effect. Morgan *et al.* (2012) found no evidence that the dredging of sulphide rich sediment in an estuary significantly depressed the dissolved oxygen concentration.

A lower dissolved oxygen concentration directly impacts on water quality and may indirectly impact on biological resources that rely on an adequate supply of oxygen for their survival, depending on the magnitude and duration of the dissolved oxygen depression, the absolute dissolved oxygen concentration in the water column before and during dredging, and the dissolved oxygen requirements and tolerances of individual biological resources. Sessile and poorly mobile biological resources that live in and on sediment in deeper water are most susceptible since the dissolved oxygen concentration usually decreases from the surface to the bottom of the water column and they are unable to escape marked decreases in dissolved oxygen concentration. However, these biological resources are also often amongst the most tolerant to a low dissolved oxygen concentration because the concentration is usually lowest in sediment and at the sediment-water interface where they live. Mobile biological resources, such as fish, can avoid or leave areas of low dissolved oxygen concentration provided this does not occur throughout the water column over a wide area—they may be unable to avoid or leave these areas if they are trapped in channels, for example.

Sediment sampled in the Berth 605 Project footprint in 2024 was found to not be enriched with particulate organic matter (CSIR, 2024). However, sediment in parts of the 600 Berth Basin was found to be enriched by such in some earlier surveys, but usually to a low magnitude (CSIR, unpublished data). Sediment in parts of the 600 Berth Basin nearer the quay wall is currently tending toward becoming anoxic, evident in sediment sampled in 2024 (CSIR, 2024) emitting a slight rotten egg (hydrogen sulphide) aroma when it was retrieved. Hydrogen sulphide is highly unstable in oxic environments, and its oxidation exerts an oxygen demand. As far as the scientists that prepared this specialist study could establish there is no recent information on nutrient concentrations in sediment porewater in the Port of Richards Bay. However, the nutrient concentrations are not anticipated to be abnormally high based on the usually low to (at most)

moderate particulate organic matter content in the sediment.

The situation is different for soil in the Berth 605 Project footprint since at least the surface ~15 cm of soil is likely to contain a higher amount of organic matter than sediment in the 600 Berth Basin. The organic matter represents the decomposing matter shed from plants, and root material. The intent is to strip the topsoil and vegetation and dispose of it elsewhere (WSP, 2024). However, if the soil is stockpiled in water in the Assembly Basin and small tidally influenced pool inland of this basin, the decomposition of the organic matter will exert a biochemical oxygen demand substantially above that which currently exists. However, it is difficult to anticipate the oxygen demand of this organic matter in the absence of more detailed studies.

Dissolved oxygen challenges during dredging are less likely to occur in well oxygenated waters. The water column in and near the Berth 605 Project footprint is usually well oxygenated (see Section 5.1.8 of this specialist study). The dissolved oxygen concentration in and near the dredging footprint is invariably $\geq 5 \text{ mg.L}^{-1}$, a limit that is usually considered adequate for the maintenance of most aerobic (oxygen requiring) aquatic biological resources (USEPA, 2003). That said, Izegaegbe *et al.* (2020) recorded a dissolved oxygen concentration as low as 0.5 mg.L^{-1} at a station in the innermost part of the 600 Berth Basin alongside Berth 606. However, they did not state if this was in bottom water. This appears to be the lowest dissolved oxygen concentration recorded in the port based on available information, but is a highly anomalous and certainly does not represent the usual condition in the port. Based on a review of the scientific literature, Vaquer-Sunyer and Duarte (2008) recommend a precautionary dissolved oxygen concentration of 4.6 mg.L^{-1} to avoid catastrophic mortality events in marine biological resources due to hypoxia, which corresponds to the 90th percentile of the distribution of mean lethal concentrations for the biological resources examined. In other words, this limit would be expected to protect marine biological resources apart from the 10% of most sensitive species. Steckbauer *et al.* (2011) considered this dissolved oxygen concentration limit to be quite high, particularly for warm coastal waters. They recommended a concentration of 3.5 mg.L^{-1} as an operational oxygen threshold to designate hypoxic waters. This threshold represents the 88th percentile of the distribution of mean lethal oxygen concentrations expected to marine biological resources apart from the 12% of most sensitive species.

Impact significance assessment without mitigation

Dredging for the Berth 605 Project will remobilise inorganic and organic oxygen demanding substances from sediment into the water column. This is an unavoidable consequence of dredging. The remobilisation is likely to occur intermittently since it is unlikely there are significant quantities of oxygen demanding substances in sediment and soil strata that have not been exposed to an anthropogenic influence in geological time—these strata constitute a fairly large proportion of the sediment and soil that will be dredged and excavated. Based on the usually high dissolved oxygen concentration in the water column in the 600 Berth Basin, and tidal and wind generated wave replenishment of dissolved oxygen, it seems unlikely the release of oxygen demanding substances into the water column during dredging will depress the concentration to a degree this will pose a significant risk to pelagic and benthic biological resources. However, there is some uncertainty in this context regarding soil if it is stockpiled in water in the Assembly Basin for a long enough period to allow microbes to degrade particulate organic matter in the soil. The anoxia in sediment that could arise in this case could be considerable. In this event it is **likely** the dissolved oxygen concentration will be affected. The magnitude of the oxygen depression is nevertheless anticipated to be very low, to at most **low**. The spatial extent of the dissolved oxygen concentration depression is anticipated to be **site only** (600 Berth Basin). Any depression in the dissolved oxygen concentration that does manifest will likely be **short-term** since currents and wind will replenish the oxygen, and oxygen demanding compounds are unlikely to be released persistently throughout the dredging period. The impact is **reversible** since the dissolved oxygen concentration will return to the baseline when dredging ceases. The significance assessment for this impact without mitigation is thus **LOW**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- As little soil as possible should be stockpiled in the Assembly Basin, but that which is stockpiled should contain as little organic matter (plant remains) as possible by removing the vegetation and topsoil and disposing/using the topsoil beneficially elsewhere.
- If suspended sediment concentrations are regularly elevated at the point where the Assembly Basin joins the 600 Berth Basin during soil stockpiling in the Assembly Basin, then, if feasible, a silt curtain should be strung to separate these basins and restrict suspended sediment concentrations and associated particulate organic matter to the Assembly Basin to the greatest extent possible.
- Complete dredging in the shortest timeframe possible to limit the time that biological resources might be exposed to depressed dissolved oxygen concentrations.

Impact significance assessment with mitigation

If the mitigation measures outlined above are implemented the magnitude for this impact should be reduced to very low. The significance assessment with mitigation will, however, remain **LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Remobilisation of oxygen depleting substances from sediment during dredging
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Short-term
Probability	Definite
Significance without mitigation	LOW
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Short-term
Probability	Definite
Significance with mitigation	LOW
Confidence in assessment	Medium

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that remobilise or disturb sediment and release oxygen demanding substances into the water column. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging and capital dredging for other planned infrastructure development as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on water quality degradation will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). The effects of the remobilisation of oxygen demanding substances by maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap due to the physical separation between dredging sites. However, even if there is no spatial overlap, simultaneous dredging will degrade water quality and adversely affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. Depending on the infrastructure developments that occur simultaneously, the cumulative adverse effect could be low but probably very low. If capital dredging campaigns do not overlap temporally, the prolonged

(several years) impact on water quality, biological resources and ecological productivity could also be low, but probably very low.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation in the port through increased sediment remobilisation related to the increased requirement for tugboat assisted vessel manoeuvring and maintenance dredging. However, the cumulative effect is anticipated to be very low.

Recommended environmental monitoring

The dissolved oxygen concentration at and near active dredging operations should be measured periodically to confirm the significance assessment for this impact. If the measurements show the dissolved oxygen concentration is regularly or periodically substantially depressed below 5 mg.L⁻¹ then the dredging rate should be reduced, or dredging should be performed in short cycles.

Impact 19: Nutrient remobilisation from sediment/soil during dredging

Impact description

Dredging remobilises nutrients that are dissolved in water between sediment grains (porewater), while particulate organic matter that is exposed by dredging is remineralised (transformed to its simplest inorganic forms), adding nutrients into the water column (Wainright and Hopkinson, 1997; Morgan *et al.*, 2012; Gibson *et al.*, 2015). An increase in nutrient concentrations above the baseline directly impacts on water quality and may indirectly impact on biological resources. A small magnitude, or short-term increase in nutrient concentrations above the baseline can positively impact on primary productivity by increasing nutrient availability to microalgae and macroalgae. A marked or prolonged increase in concentrations above the baseline, in contrast, can stimulate the excessive growth of microalgae and macroalgae, leading to eutrophication that in turn can lead to a host of detrimental ecological effects that include depleting the dissolved oxygen concentration in the water column and sediment. As far as the CSIR scientists that prepared this specialist study could establish there is no recent information on nutrient concentrations in sediment porewater in the Port of Richards Bay. Nutrient concentrations in the water column in parts of the port are occasionally elevated, most notably in the Bhizolo-Manzanyama Canal complex and 600 Berth Basin (see Section 5.1.8 of this specialist study). However, a factor mitigating against the accumulation of nutrients to high concentrations in sediment porewater in parts of the Berth 605 Project dredging footprint is vessel propeller wash disturbance of the sediment, which will turn over the biologically active layer. Nutrient concentrations are not anticipated to be elevated in the porewater of sediment over a large part of the dredging footprint because of the propeller disturbance.

Impact significance assessment without mitigation

Dredging for the Berth 605 Project will invariably remobilise nutrients directly from sediment porewater into the water column and expose particulate organic matter in sediment that will in time be degraded and remineralised. This is an unavoidable consequence of dredging. However, it is not anticipated that nutrient remobilisation will be continuous since there should be no nutrients, nor a high particulate organic matter content in sediment and soil strata in the Berth 605 development footprint that have not been exposed during the Anthropocene. Based on the total organic content of surficial sediment in the Berth 605 Project dredging footprint it is unlikely the remineralisation of particulate organic matter will substantially increase nutrient concentrations above the baseline. It is also considered unlikely that nutrients released directly

from porewater will elevate nutrient concentrations in the water column substantially above the baseline—this conclusion is based on nutrient concentrations measured during dredging for the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008). The soil will have a higher particulate organic matter content, particularly in the surface layer. However, the topsoil and related vegetation will be stripped and disposed elsewhere (WSP, 2024). The magnitude of this impact is thus anticipated to be **low**. Nutrients released directly from sediment porewater or through the remineralisation of particulate organic matter exposed by dredging are expected to be diluted and dispersed by currents. The increase in nutrient concentrations above the baseline is thus likely to be **temporary** in duration. Any increase in nutrient concentrations above the baseline is anticipated to be **site only** (within 600 Berth Basin). The remobilised nutrients will add to the occasionally elevated nutrient concentrations in the water column in the Port of Richards Bay, and more specifically in the 600 Berth Basin, and could thus **possibly** contribute to the stimulation of microalgae such that they reach bloom status. This impact is **reversible** since nutrient concentrations will return to the baseline when dredging ceases. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Complete dredging in the shortest time possible to limit the amount of time that primary producers might be exposed to elevated nutrient concentrations.
- Restrict dredging to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the remobilisation of nutrient concentrations from sediment.
- The sediment/soil should ideally be dredged in winter when the primary productivity is at its lowest, but it is acknowledged that it will probably not be feasible.
- The surface vegetation must be removed and disposed and should not be deposited in the port if excavated soil is temporarily stockpiled in the Assembly Basin.

Impact significance assessment with mitigation

The significance assessment for this impact with mitigation remains **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Nutrient remobilisation from sediment/soil during dredging
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance with mitigation	VERY LOW
Confidence in assessment	Medium

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that remobilise and disturb sediment and release nutrients into the water column. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging, and capital dredging for other planned infrastructure development as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on water quality degradation will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). The effects of the remobilisation of nutrients by maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap due to the physical separation between dredging sites. However, even if there is no spatial overlap, simultaneous dredging will degrade water quality and adversely affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. Depending on the infrastructure developments that occur simultaneously, the cumulative adverse effect could be low but probably very low. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources, and ecological productivity could also be low, but will probably be very low.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation in the port through increased sediment remobilisation related to the increased requirement for tugboat assisted vessel manoeuvring and maintenance dredging. However, the cumulative effect is anticipated to be very low.

Recommended environmental monitoring

The chlorophyll-*a* concentration at and near active dredging operations should be measured periodically to confirm the significance assessment for this impact. If the measurements show the chlorophyll-*a* concentration is consistently >5 mg.L⁻¹ then the dredging rate should be reduced, or dredging should be performed in short cycles.

Impact 20: Remobilisation of noxious substances from sediment/soil during dredging

Impact description

Sediment is an important fate for many noxious chemicals that are anthropogenically introduced into riverine, estuarine and marine systems, since the chemicals are hydrophobic and/or particle reactive. Consequently, the concentrations of these chemicals are usually orders of magnitude higher in sediment than they are in the overlying water column. The noxious chemicals, or at least a large proportion thereof, are usually immobilised in sediment by their complexation and precipitation with sulphides and iron and manganese oxides/hydroxides, and/or by their adsorption onto sediment grains and particulate organic matter to form chemical-particle complexes. The complexes are generally stable and largely insoluble in the low oxygen or anoxic conditions that usually prevail a few centimetres beneath the sediment surface, limiting their ability to present a toxic risk unless they are ingested by biological resources that feed by ingesting sediment and extracting organic matter from the sediment before egesting it (Goossens and Zwolsman, 1996; Eggleton and Thomas, 2004; Burgess *et al.*, 2013). The concentrations of noxious chemicals in porewater are consequently also often low, even in quite significantly contaminated sediment.

Dredging alters the physicochemical properties of sediment. The oxygen that permeates newly dredged sediment destabilises many chemical complexes through the process of oxidation, resulting in the dissociation and transfer of the chemicals into the water column (Calmano *et al.*, 1993; Eggleton and Thomas, 2004; Sturve *et al.*, 2005; Bocchetti *et al.*, 2008; Knott *et al.*, 2009; Yeager *et al.*, 2010; Cabrita, 2014; Rocha *et al.*, 2016; Layglon *et al.*, 2020). Metal-sulphide complexes, for example, are unstable in oxidising environments, leading to a potential initial dissociation of metals into the dissolved phase during dredging (Kalnejais *et al.*, 2007; De Jonge *et al.*, 2012; Simpson *et al.*, 2012). The rate of metal dissociation is strongly influenced by the properties of sediment, including its grain size, and the presence of sulphides, particulate organic matter, and iron and manganese oxides/hydroxides (Goossens and Zwolsman, 1996; Eggleton and Thomas, 2004; Atkinson *et al.*, 2007; Cantwell *et al.*, 2008). It also depends on the metal—arsenic and zinc, for example, dissociate more readily than do other metals.

The behaviour of noxious chemicals after remobilisation from sediment is complex, governed by the properties of the chemicals themselves and various biogeochemical modifying factors such as the salinity, pH and dissolved oxygen concentration of the water column (Eggleton and Thomas, 2004). The noxious chemicals may be dispersed by currents in the dissolved form, or they may again become bound to suspended and bedded particulate matter. Metals adsorbed to or coprecipitated with iron and manganese sulphides are rapidly oxidised (within minutes) following remobilisation due to their solubility in oxic conditions. The iron and manganese are equally rapidly re-precipitated and deposited as insoluble oxides/hydroxides, onto which other metals become absorbed at varying rates and degrees. The scientific literature suggests that only a small proportion of the metals remobilised when sediment is disturbed by dredging dissolve into the water column due to their tendency to rapidly adsorb onto iron and manganese oxides/hydroxides, even though the total metal concentration in remobilised (suspended) sediment may be high. An increase in dissolved metal concentrations above the baseline is thus usually only evident relatively near dredging operations for short periods in quiescent environments (*e.g.* Hall, 1989; Goossens and Zwolsman, 1996; Van den Berg, 2001; Simpson *et al.*, 2000; Caetano and Vale, 2003; Maddock *et al.*, 2007).

Many organic chemicals, such as polycyclic aromatic hydrocarbons, pesticides and polychlorinated biphenyls, are generally not very soluble in water, but rather are hydrophobic ('water hating')—it is this hydrophobicity that accounts for their propensity to accumulate in sediment. Direct toxicity in biological resources by their exposure to dissolved concentrations of these noxious chemicals in the water column because of dredging is less likely than for metals. This is because the time it takes for the chemicals to dissociate from the resuspended sediment and particulate organic matter onto which they are bound is often longer than the time it takes for the particles to settle from the water column and be reincorporated into the sediment. Nevertheless, particulate bound organic chemicals suspended in the water column can be toxic to biological resources (Anchor QEA, 2003).

The toxicity of remobilised noxious chemicals depends strongly on their form. Noxious chemicals in the dissolved form are bioavailable and may cause acute toxic effects, such as mortality, if their concentrations exceed the tolerances of biological resources, or they may be bioaccumulated by biological resources and cause sub-lethal toxicity, such as a reduced growth rate or increased susceptibility to other stressors (*e.g.* Sved and Roberts, 1995; Gregg *et al.*, 1997; Cruz-Rodríguez and Chu, 2002; Geffard *et al.*, 2007; Tolhurst *et al.*, 2007; Lotufo *et al.*, 2010). The loss of biological resources through mortality by exposure to noxious chemicals affects other biological resources by, for example, depleting their food resources. Many noxious chemicals are problematic from a biomagnification perspective. These chemicals increase in concentration through successive trophic levels of food webs and in this way can pose a toxic risk to higher level consumers (*e.g.* sharks, dolphins), and to humans that consume contaminated fish and shellfish.

Impact significance assessment without mitigation

Sediment and soil sampled in the Berth 605 Project footprint in 2024 was metal contaminated (CSIR, 2024). Based on the findings of earlier surveys (see Sections 5.1.9 and 5.1.11 of this specialist study), sediment in the Berth 605 Project footprint is undoubtedly also contaminated by polycyclic aromatic hydrocarbons and butyltins and probably by pesticides, amongst other possible noxious chemicals. A large proportion of the sediment and soil that will be dredged (deeper strata) is not expected to be contaminated since it has not been exposed during the Anthropocene. The concentrations of some metals in sediment and soil sampled in the Berth 605 Project footprint in 2024 were above metal Action Levels that the Department of Forestry, Fisheries and the Environment uses to decide if sediment identified for dredging is suitable for open water disposal. In cases where metal concentrations are above Action Level II, which was the case at most stations in the Berth 605 Project footprint in 2024, the sediment is identified as unsuitable for open water disposal since the metals may pose an unacceptable hazard to biological resources at the disposal site. Chemicals in surficial sediment and soil in the Berth 605 Project footprint will invariably be remobilised into the water column by dredging. However, toxicity testing of the sediment and soil (CSIR, 2024; see also Sections 5.1.9 and 5.1.11 of this specialist study) suggests it is improbable, but nevertheless **possible**, that noxious chemicals will be remobilised at concentrations and/or in forms that will pose a toxic risk to biological resources apart possibly when soil from a small area of the footprint is deposited in water. The magnitude of the toxicity is anticipated to be **very low**. Noxious chemicals could potentially be remobilised from sediment throughout the dredging period as surface soil and sediment is dredged, but any increase in their concentration above the baseline is anticipated to be **temporary** since the chemicals are likely to be rapidly diluted and scavenged from the water column and be re-deposited on the sediment, and/or to be transformed to less toxic forms (*e.g.* hydrogen sulphide) relatively soon after remobilisation. Impacts related to noxious chemical remobilisation during dredging are thus anticipated to be **site only** (within 600 Berth Basin). The impact is **reversible** since the remobilisation of noxious chemicals will cease when dredging ceases. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Note

Dredging for the Berth 605 Project will remove chemically contaminated sediment from the dredging footprint—a beneficial (positive) environmental impact. However, unless the sources of chemical contaminants that have resulted in the contamination of sediment are properly controlled, the newly exposed sediment in the lengthened 600 Berth Basin will become contaminated over time and the beneficial effect will be short-lived. There is no evidence that contaminant source control will be altered or improved in the short-term. The impact would thus have a VERY LOW to at most LOW positive significance was it to be assessed.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- TNPA must secure a permit from the Department of Forestry, Fisheries and the Environment for the disposal of dredged material at an authorised dredged spoil disposal site off the Richards Bay coast. The sediment testing for the permit must include toxicity testing.

Impact significance assessment with mitigation

The mitigation measures are unlikely to materially alter the significance assessment for this impact, which remains **VERY LOW** with mitigation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Remobilisation of noxious substances from sediment/soil during dredging
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that remobilise noxious chemicals from sediment into the water column. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging and capital dredging for other planned infrastructure development as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on water quality degradation, and the impairment of biological resources and ecological productivity will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Remobilised noxious chemical plumes generated by maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap with plumes generated during the development of Berth 605 due to the physical separation between dredging sites. The greatest likelihood for spatial overlap is for the development of Berth 802 and 803 in the 700/800 Berth Basin and when maintenance dredging occurs in this same basin. However, even if noxious chemical plumes do not spatially overlap, simultaneous dredging will degrade water quality and adversely affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. Nonetheless, the cumulative effect is likely to be very low. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources and ecological productivity is also likely to be very low. This conclusion is based on toxicity testing of sediment sampled in the port over several years, which has shown an almost complete absence of sediment toxicity. Thus, while noxious chemical concentrations are high in sediment in some parts of the port earmarked for infrastructure development in the short-term, the chemicals are either not in a bioavailable form, or if they are, they are remobilised at such low concentrations that they do not cause toxicity even to sensitive sea urchin embryos and larvae.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation in the port through increased noxious chemical concentrations related to the increased requirement for tugboat assisted vessel manoeuvring and maintenance dredging. However, the cumulative effect is likely to be very low.

Recommended environmental monitoring

Water samples collected at two-week intervals near the active dredging operation and from the dredging support barge overflow during the first two months of dredging should be tested for toxicity to confirm the significance assessment for this impact. The testing should be performed on raw and centrifuged samples using sea urchin embryo-larval development and 4-day water only amphipod survival tests. If the testing does not reveal evidence for toxicity, then the testing should be terminated.

Impact 21: Bioaccumulation and biomagnification of noxious chemicals remobilised from sediment by biological resources

Impact description

Noxious chemicals remobilised into the water column during the dredging of contaminated sediment are potentially available for uptake (bioaccumulation) by biological resources. Bioaccumulation depends on biological resources encountering the noxious chemicals in a bioavailable form, that is, in a form that can cross biological membranes. If the rate of bioaccumulation exceeds the rate that biological resources can depurate or detoxify the chemicals, they will (bio)accumulate the chemicals in their tissue. However, biological resources do not have the ability to depurate and detoxify many synthetic noxious chemicals since they have not evolved the physiological and molecular mechanisms to deal with these non-natural chemicals. The bioaccumulated noxious chemicals may pose a direct hazard and risk to biological resources, and indirectly to higher trophic level biological resources since consumers are exposed to noxious chemicals in their food. Some noxious chemicals, such as mercury, polychlorinated biphenyls and organochlorine pesticides, can biomagnify in food webs. In other words, noxious chemicals are passed from one trophic level to the next and in this way their concentration increases through the food web. Fish and/or shellfish with high noxious chemical burdens in their bodies pose a health hazard to higher level predators, such as seabirds and dolphins, and to humans that might consume them.

As far as the CSIR scientists that prepared this specialist study could establish, mussels and oysters are not harvested in the Port of Richards Bay for human consumption—if they are it is not a common practice. However, recreational angling is very popular in the port and anglers retain caught fish for consumption. Subsistence fishing might be practiced in the port, while fish and shellfish are caught illegally in the Bhizolo-Manzanyama Canal complex and on the Kabeljous Flats. These fish and shellfish are retained for consumption.

There is little information on noxious chemical concentrations in fish in the Port of Richards Bay, but a reasonable amount for shellfish (specifically mussels). The CSIR analysed the concentrations of metals in fish caught near the port entrance in 2023 and 2024 (CSIR, 2024). The findings showed that recreational and subsistence fishers face potential chronic and/or carcinogenic health risks depending on the species and quantity of fish they ingest. However, there was no definitive evidence the fish had accumulated anomalously high metal concentrations in their tissue because of exposure to metal contaminants, although this possibility cannot be entirely discounted. Furthermore, while a risk was identified, in many cases a person would need to ingest a relatively large quantity of fish tissue per week, yet most people are unlikely to ingest these quantities. The CSIR analysed metal and hydrocarbon concentrations in mussels sampled on hard structures—usually navigation markers—in the port (unpublished data). There was evidence that mussels sampled from navigation markers in the 600 and 700/800 Berth Basins occasionally had chromium concentrations substantially higher than mussels elsewhere in the port, but other metals were typically recorded at comparable concentrations. The presumption is that the chromium is derived from spilled chromium ore that is exported through the port.

Impact significance assessment without mitigation

Dredging for the Berth 605 Project will remobilise noxious chemicals from sediment into the water column. The noxious chemicals may become bioavailable and be bioaccumulated by plankton, fish and shellfish, and potentially higher trophic level biological resources. However, the results of toxicity testing revealed that noxious chemicals in the sediment were not in a bioavailable form, or at least not at concentrations that resulted in a toxic effect in sea urchin embryos and larvae (Section 5.1.9 and 5.1.11 of this specialist study; see also CSIR (2024)). It thus seems improbable, but nevertheless **possible** that the dredging of sediment in the Berth 605 Project footprint will remobilise such high concentrations of noxious chemicals from the sediment that this will lead to plankton, fish and shellfish bioaccumulating the noxious chemicals in their tissue to a substantially higher concentration than is currently the case (ongoing maintenance dredging of surficial sediment in the proposed dredging footprint present the same impacts as capital dredging, albeit at a lower magnitude). The additional risk posed to the health of humans that consume fish and shellfish from the Port of Richards Bay because of the Berth 605 Project is thus anticipated to be low. The magnitude of this impact is thus considered **low**—but will probably be very low. The potential for the bioaccumulation of noxious chemicals due to dredging will be restricted to fish and shellfish in the Port of Richards Bay. The spatial extent of this impact is thus **local**, notwithstanding the fact some fish that bioaccumulate certain noxious chemicals in their tissue will migrate from the estuary and in this way could transfer the chemicals to the marine environment. The potential for this impact will persist for the dredging period. The duration of this impact is thus **short-term**. The impact is **reversible** since the remobilisation of noxious chemicals from sediment will cease when dredging ceases, although certain noxious chemicals bioaccumulated by fish and shellfish will remain in their tissue after dredging ceases. The significance assessment for this impact without mitigation is **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- TNPA must secure a permit from the Department of Forestry, Fisheries and the Environment for the disposal of dredged material at an authorised dredged spoil disposal site off the Richards Bay coast. The sediment testing for the permit must include toxicity testing.

Impact significance assessment with mitigation

The mitigation measures are unlikely to materially alter the significance assessment for this impact, which remains **LOW** with mitigation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Bioaccumulation and biomagnification of noxious chemicals remobilised from sediment by fish and shellfish
Aspects affected	Aquatic biological resources, Ecological productivity, Human health
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Difficult
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Local
Reversibility	Reversible
Duration	Short-term
Probability	Possible
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Local
Reversibility	Reversible

IMPACT DESCRIPTION	ASSESSMENT
Duration	Short-term
Probability	Possible
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with other port operations and activities that remobilise noxious chemicals into the water column that in turn could be bioaccumulated by biological resources. These include tugboat-assisted vessel manoeuvring (propeller wash), maintenance dredging and capital dredging for other planned infrastructure development as outlined in the Port of Richards Bay Masterplan. Tugboat-assisted vessel manoeuvring will coincide with the development of Berth 605, but the added effect on noxious chemical remobilisation will be negligible when compared to maintenance and capital dredging. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Remobilised noxious chemical plumes generated by maintenance dredging and capital dredging for other infrastructure developments, if they coincide, may not spatially overlap with plumes generated during the development of Berth 605 due to the physical separation between dredging sites. The greatest likelihood for spatial overlap is for the development of Berth 802 and 803 in the 700/800 Berth Basin and when maintenance dredging occurs in this same basin. However, even if noxious chemical plumes do not spatially overlap, simultaneous dredging will degrade water quality and adversely affect biological resources and ecological productivity over a wider part of the port compared to sequential dredging campaigns. However, the cumulative effect is likely to be very low. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources, and ecological productivity is also likely to be very low. This conclusion is based on toxicity testing of sediment sampled in the port over several years, which has shown an almost complete absence of sediment toxicity. Thus, while noxious chemical concentrations are high in sediment in some parts of the port earmarked for infrastructure development in the short-term, the chemicals are either not in a bioavailable form, or if they are, they are remobilised at such low concentrations that they do not cause toxicity even to sensitive sea urchin embryos and larvae.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation in the port through increased suspended sediment concentrations related to the increased requirement for tugboat assisted vessel manoeuvring and maintenance dredging. However, the cumulative effect is likely to be very low.

Recommended environmental monitoring

None.

Impact 22: Ecological impacts due to a deterioration in water quality related to increased suspended sediment concentrations during dredged material disposal

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. Dredged material is disposed from dredging vessels or barges through two half doors or valves on the hull

depending on the material and vessel design. The sediment in a hopper or barge compartment is a dense slurry that behaves as a dense fluid when it is released into less dense seawater. Studies have shown that most of the sediment reaches the seabed as a fluid mass. However, some sediment is resuspended into the water column from the descending mass because of friction with, and the entrainment of surrounding seawater into the mass (Figure 104).

Estimates of the volume of sediment that is resuspended from the mass during its descent to the bottom range from <1-5% (Truitt, 1986; USACE, 2001). The variation within this range is a function of many environmental factors, including water depth, the type of material being disposed, and the current velocity. Dredging vessels and barges may dispose sediment while moving, and at the end of a disposal event usually pass water through the hopper or compartment to remove sediment trapped in door hinges and so on, which also promotes the resuspension of sediment. Sediment is further resuspended into the water column when the fluid sediment mass impacts the bottom and surges laterally as a density current under its own momentum (Figure 104). Very fine-grained material resuspended into the water column in this way may spread a few hundred meters from the impact point. The fine fraction of sediment in the deposited mass will also be eroded and resuspended into the water column by currents over a longer timeframe if the disposal site is in a dispersive environment.

An increase in the suspended sediment concentration and related turbidity during the open water disposal of dredged sediment is largely restricted to the lower part (15-20%) of the water column, and declines by orders of magnitude toward the surface (Truitt, 1988). The increase in the suspended sediment concentration can be intense depending on the nature and volume of the material disposed, and characteristics of the dredged spoil disposal site (Palanques *et al.*, 2022). However, studies have shown that the suspended sediment concentration and associated turbidity decreases rapidly after a dredged sediment disposal event, usually returning to the baseline within tens of minutes but at times up to a few hours (USACE, 1976; LTMS, 1998; Anchor QEA, 2003; Roman-Sierra *et al.*, 2011; USACE, 2015). However, in large volume dredging projects and dredged material disposal in quiescent environments, the disposal events may be so frequent that the suspended sediment concentration does not approach the baseline until after dredged material disposal ceases (Palanques *et al.*, 2022).

An increase in the suspended sediment concentration and related turbidity in the water column due to dredged sediment disposal can have the same environmental consequences as those that occur when sediment is resuspended at a dredging site (see Impact 15), but the impacts are usually less significant because of the larger dilution and dispersion potential at open water dredged spoil disposal sites.

van Ballegooyen *et al.* (2025) used three-dimensional numerical modelling to simulate the resuspension of sediment in the water column when sediment dredged and soil and rock excavated in the development footprint for the Berth 605 Project is disposed at the existing open water dredged spoil disposal site off the Richards Bay coast (the reader should refer to Impact 15 for a discussion on the numerical modelling approach). The numerical modelling outputs are provided in Figures 105-123. The numerical modelling suggests that the disposal of dredged material will elevate the suspended sediment concentration in the water column over a wide area, to varying degrees. The suspended sediment concentrations are anticipated to be highest near the bottom and to decrease sharply toward the surface of the water column, in agreement with measurements made during dredged material disposal events. The numerically modelled suspended sediment concentrations, while not persistently high, are nevertheless high enough to suggest they could have a significant acute sublethal or chronic lethal and sublethal effect on benthic and pelagic biological resources relatively near (1-2 km) the dredged spoil disposal site.

The CSIR (2008) monitored the effect of dredged material disposal during the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay over a large area in the nearshore marine

environment off the Richards Bay coast. These empirical data provide a point for comparison with the numerical model predictions. The positions where water quality was monitored before, during and after dredged material disposal are provided in Figure 78. A summary of the depth averaged turbidity measured in the water column is provided in Figure 124. The turbidity in the nearshore marine waters rarely was >15 NTU, which is surprisingly low when compared to the turbidity measured at the same time in the Port of Richards Bay, and, more notably, in the Mhlathuze Estuary. The turbidity was typically higher during dredged material disposal, which is logical. However, the highest depth averaged turbidity was measured in December 2004 and May 2005, before dredged material disposal proceeded. Thus, while the lower turbidity measured after compared to during dredged material disposal suggests the elevated turbidity was a consequence of dredged material disposal, the high turbidity prior to dredged material disposal confounds the issue. Nonetheless, based on a relationship established between turbidity and suspended sediment concentrations for the Port of Richards Bay, the turbidity recorded by the CSIR (2008) was unlikely to translate into such high suspended concentrations as those predicted by numerical modelling (van Ballegooyen *et al.*, 2025). This is supported by the suspended sediment concentrations measured in surface, mid-water and bottom water samples at the time (Figure 84).

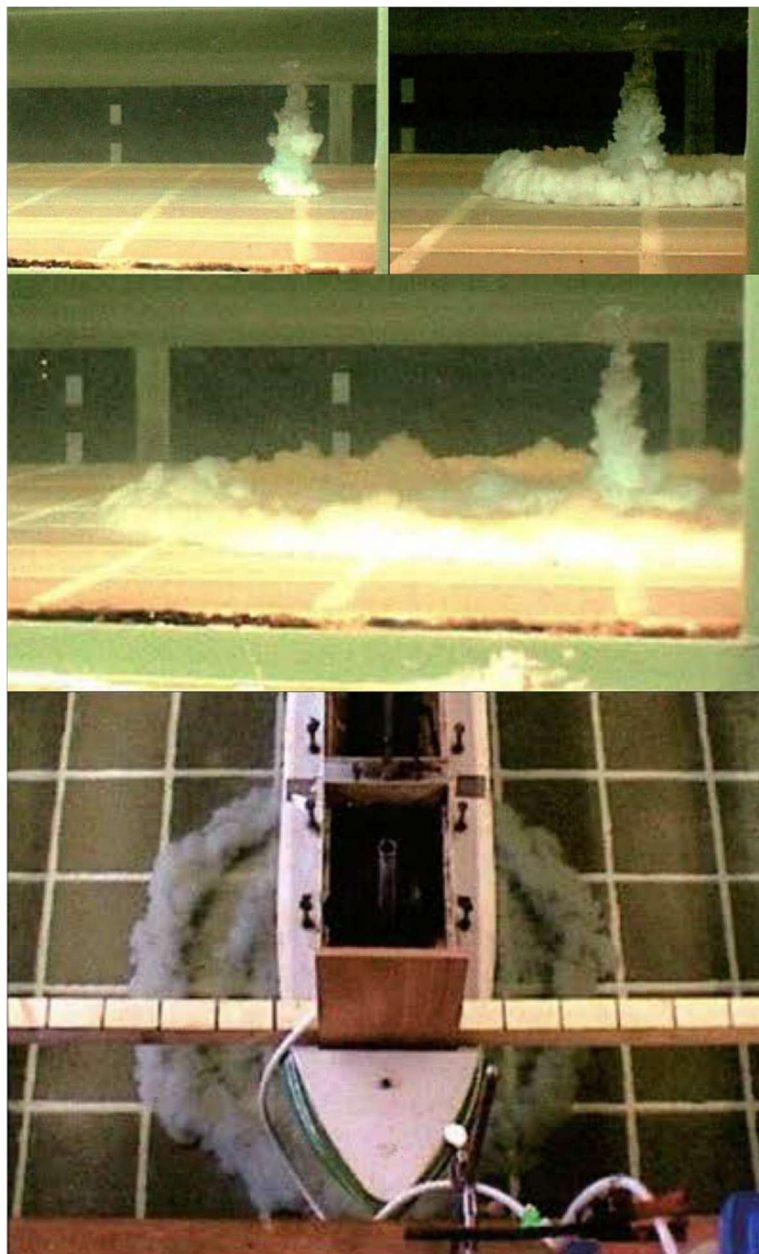


Figure 104. Photographs of the lateral surge of dredged material disposal simulated in the laboratory in no current flow conditions (from Boot, 2000).

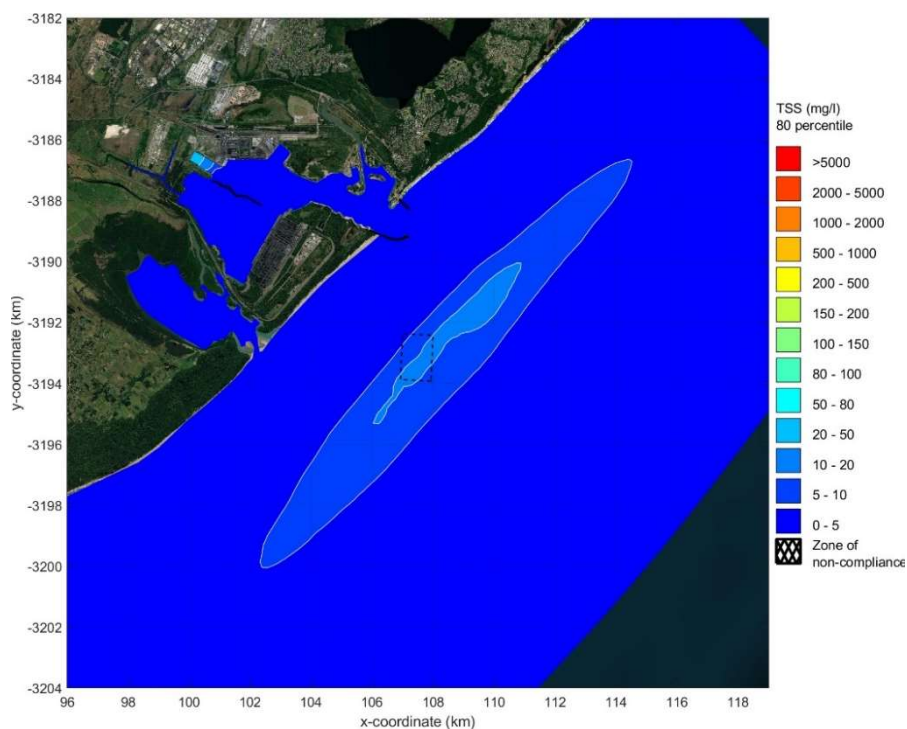


Figure 105. 80th percentile exceedance contours of the suspended sediment concentration in surface waters, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

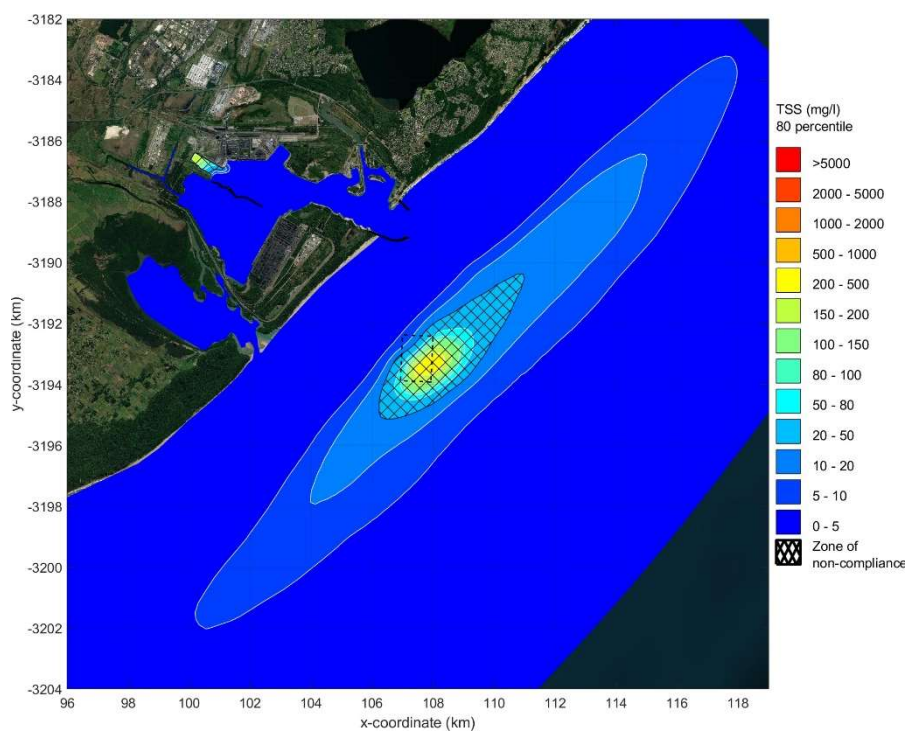


Figure 106. 80th percentile exceedance contours of the suspended sediment concentration in bottom waters, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

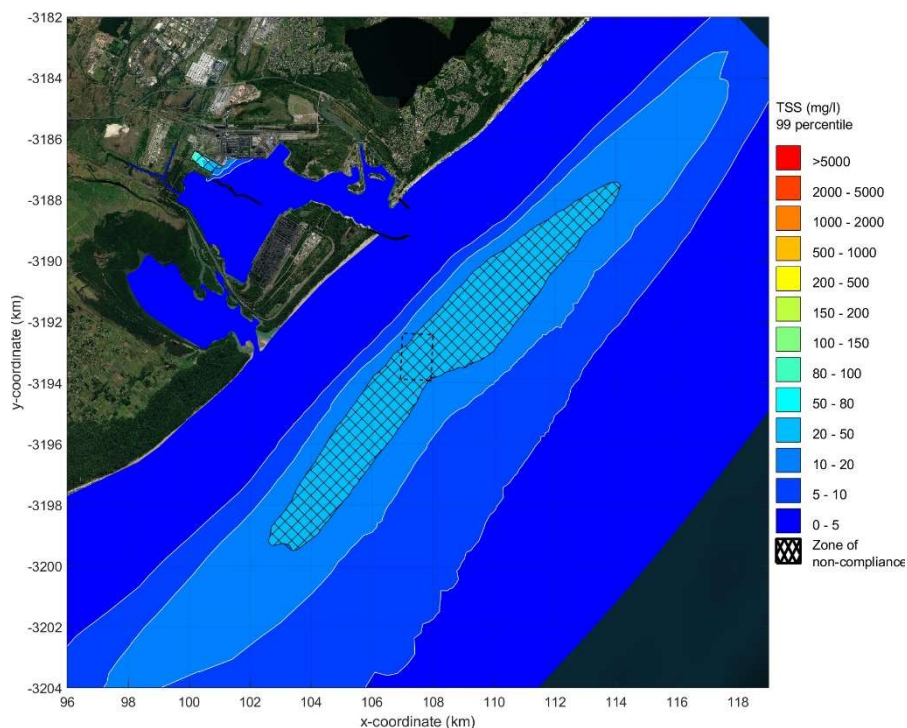


Figure 107. 99th percentile exceedance contours of the suspended sediment concentration in surface waters, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

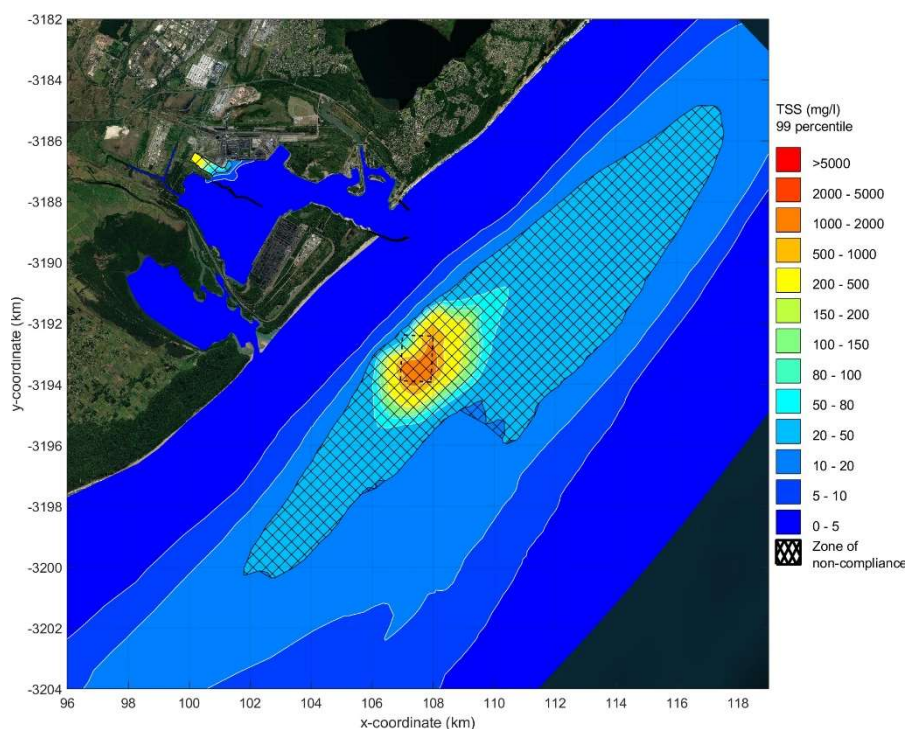


Figure 108. 99th percentile exceedance contours of the suspended sediment concentration in bottom waters, indicating the zone of non-compliance with a 20 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

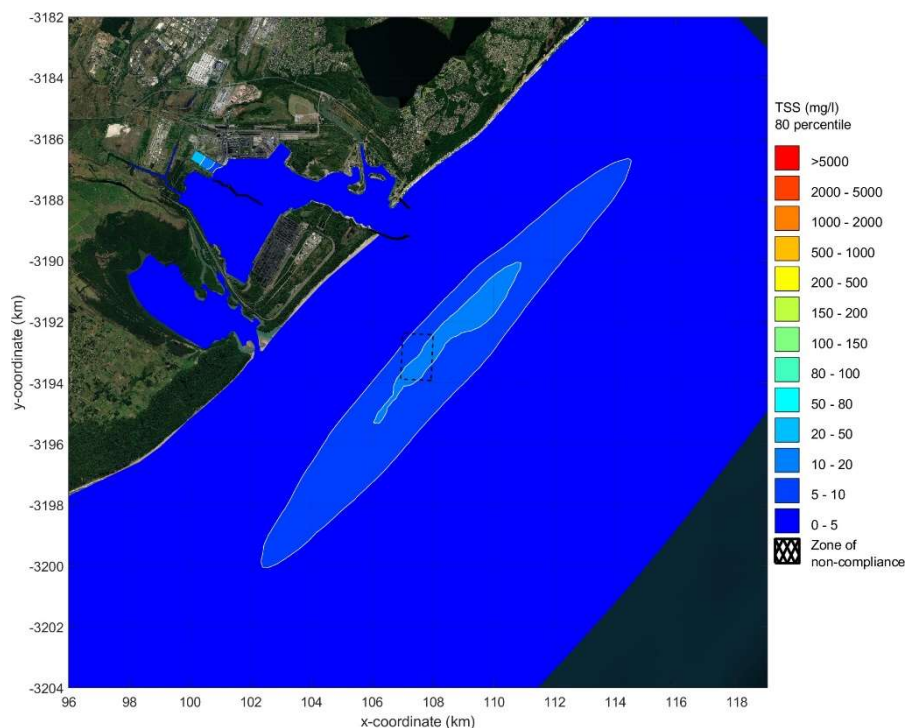


Figure 109. 80th percentile exceedance contours of the suspended sediment concentration in surface waters, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

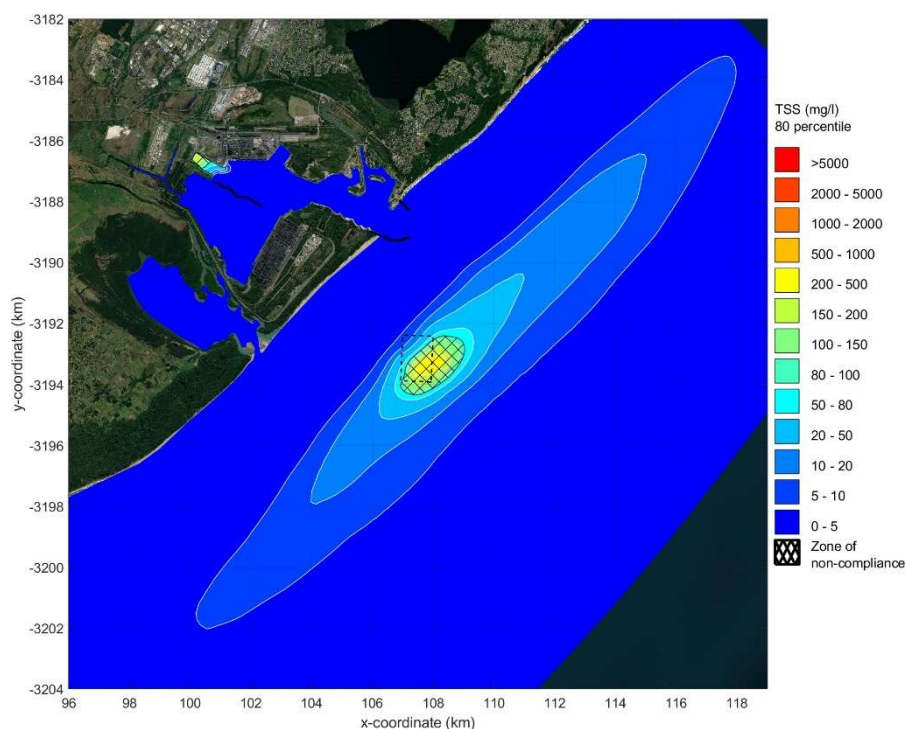


Figure 110. 80th percentile exceedance contours of the suspended sediment concentration in bottom waters, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

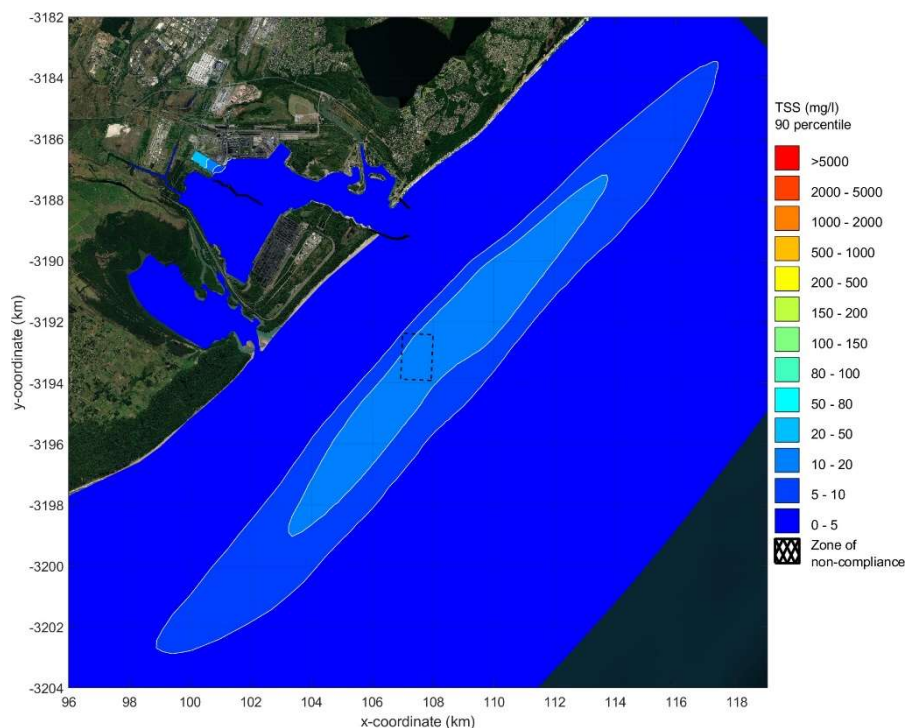


Figure 111. 99th percentile exceedance contours of the suspended sediment concentration in surface waters, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

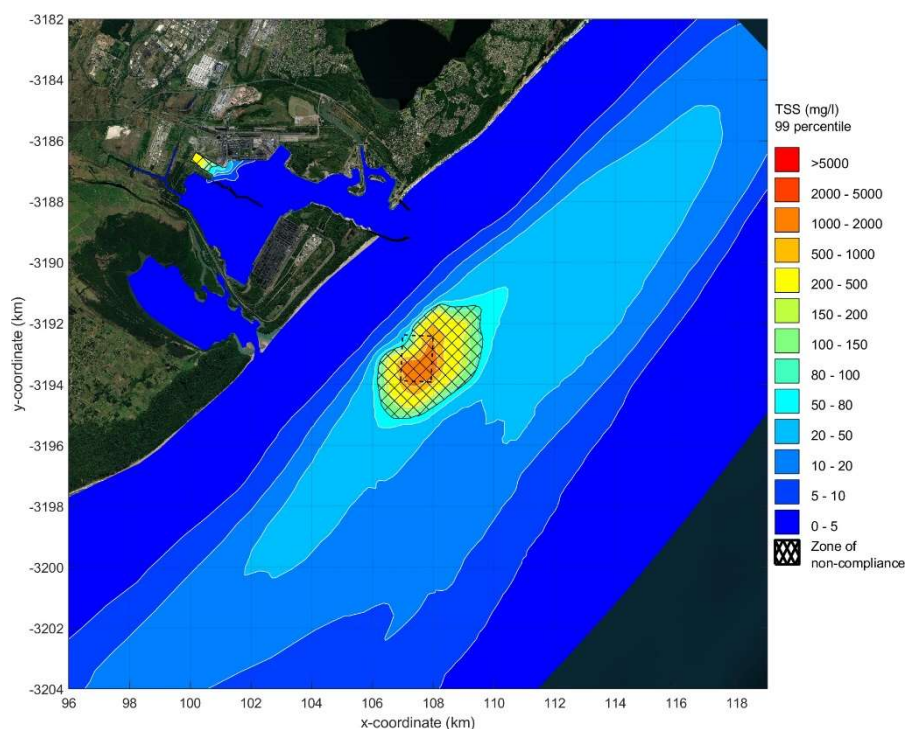


Figure 112. 99th percentile exceedance contours of the suspended sediment concentration in bottom waters, indicating the zone of non-compliance with a 80 mg.L⁻¹ threshold (van Ballegooyen *et al.*, 2025).

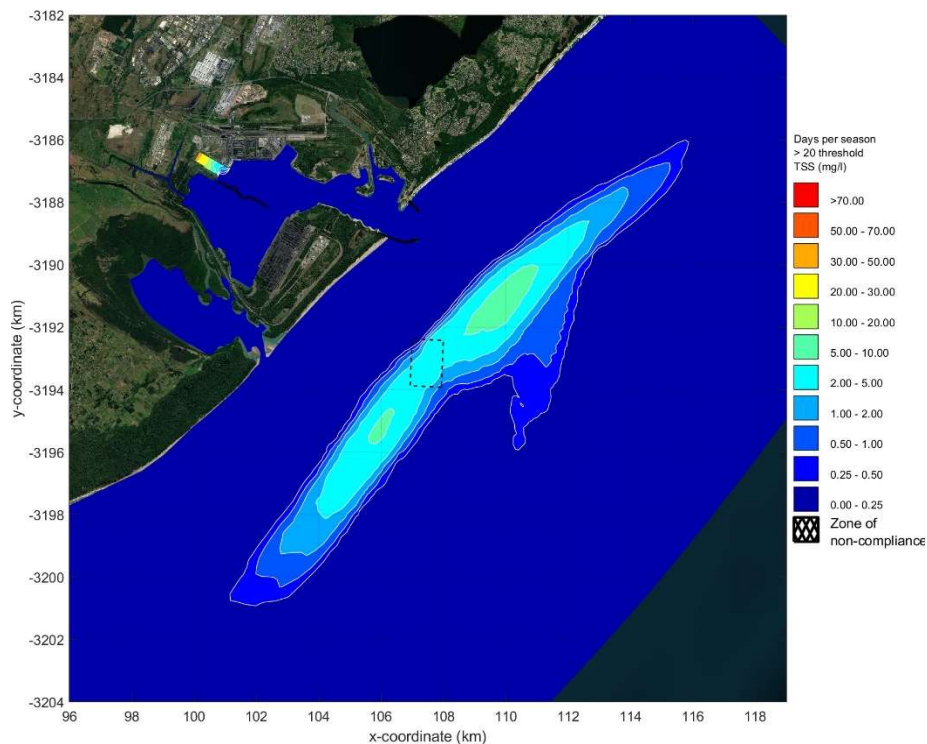


Figure 113. Days of exceedance of the suspended sediment concentration threshold of 20 mg.L⁻¹ in surface waters (van Ballegooyen *et al.*, 2025).

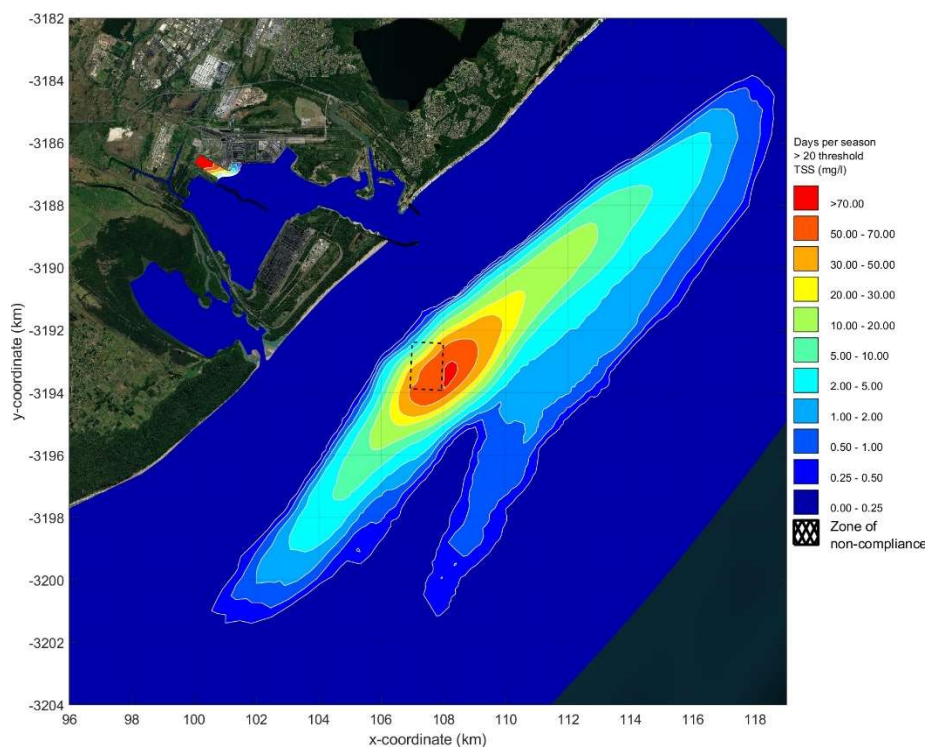


Figure 114. Days of exceedance of the suspended sediment concentration threshold of 20 mg.L⁻¹ in bottom waters (van Ballegooyen *et al.*, 2025).

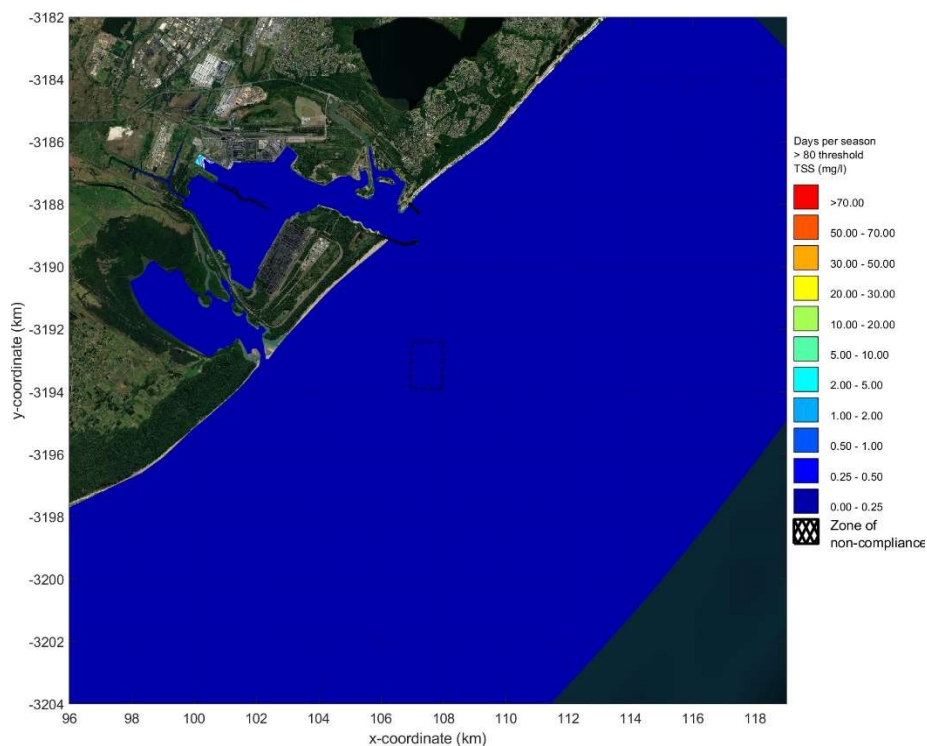


Figure 115. Days of exceedance of the suspended sediment concentration threshold of 80 mg.L⁻¹ in surface waters (van Ballegooyen *et al.*, 2025).

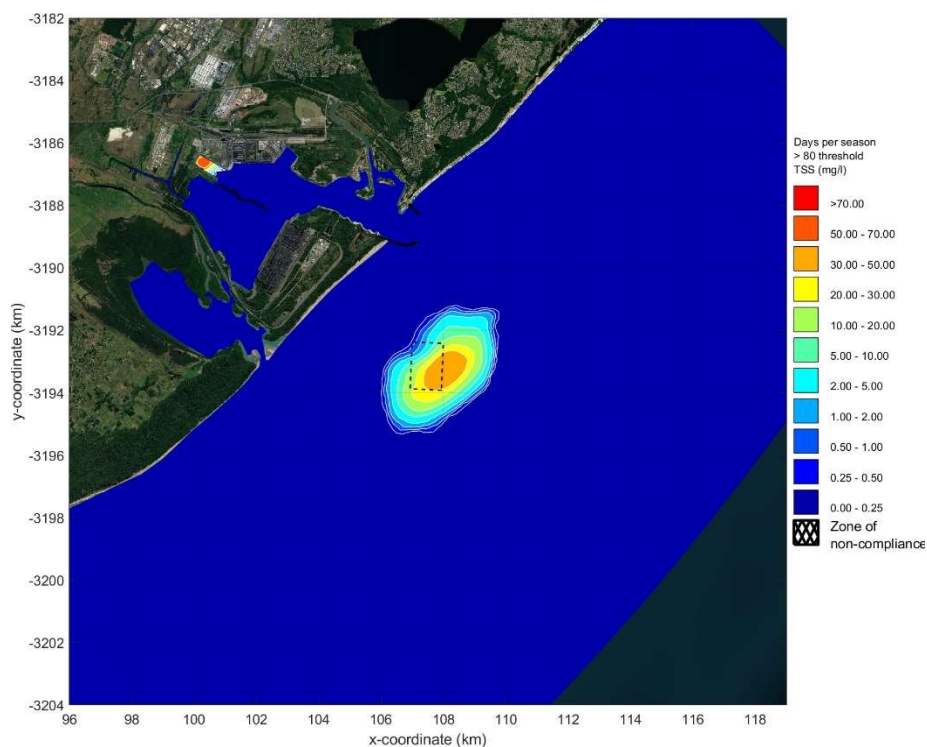


Figure 116. Days of exceedance of the suspended sediment concentration threshold of 80 mg.L⁻¹ in bottom waters (van Ballegooyen *et al.*, 2025).

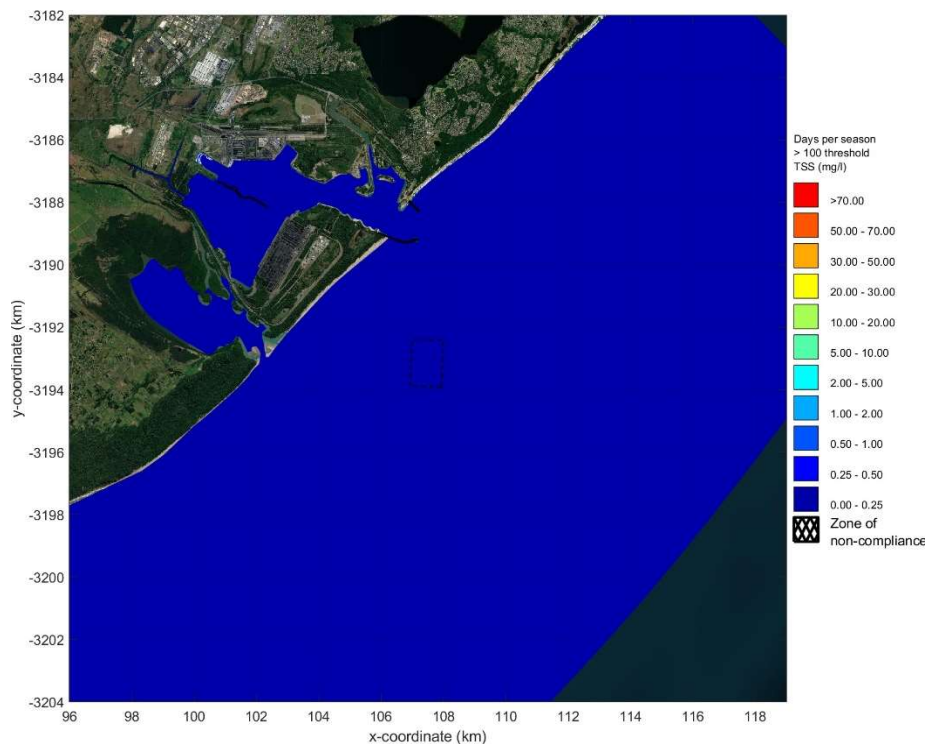


Figure 117. Days of exceedance of the suspended sediment concentration threshold of 100 mg.L⁻¹ in surface waters (van Ballegooyen *et al.*, 2025).

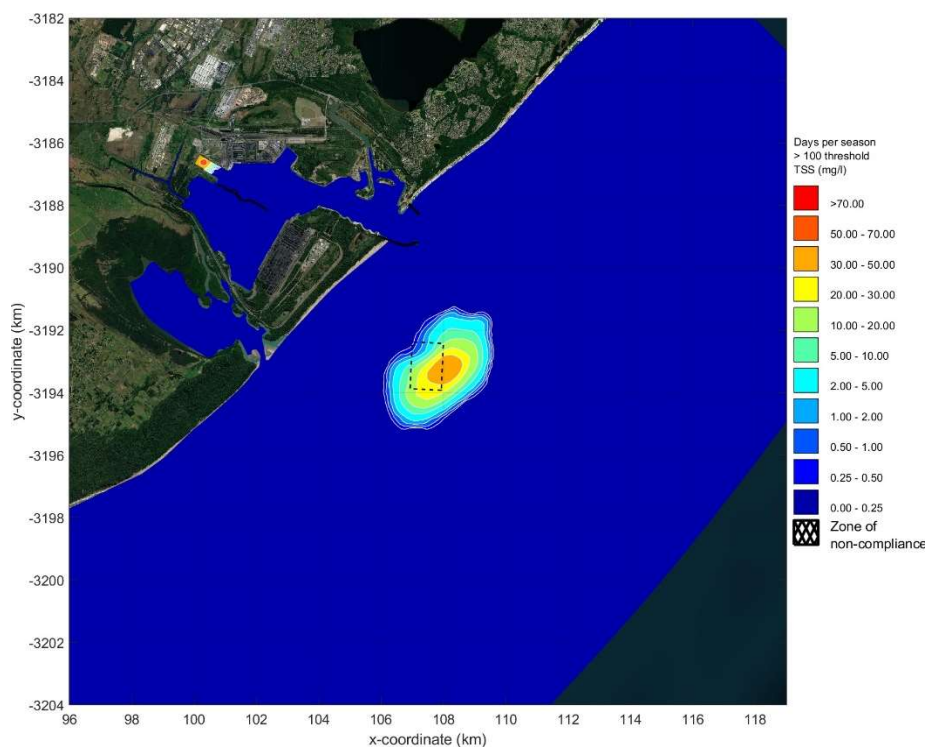


Figure 118. Days of exceedance of the suspended sediment concentration threshold of 100 mg.L⁻¹ in bottom waters (van Ballegooyen *et al.*, 2025).

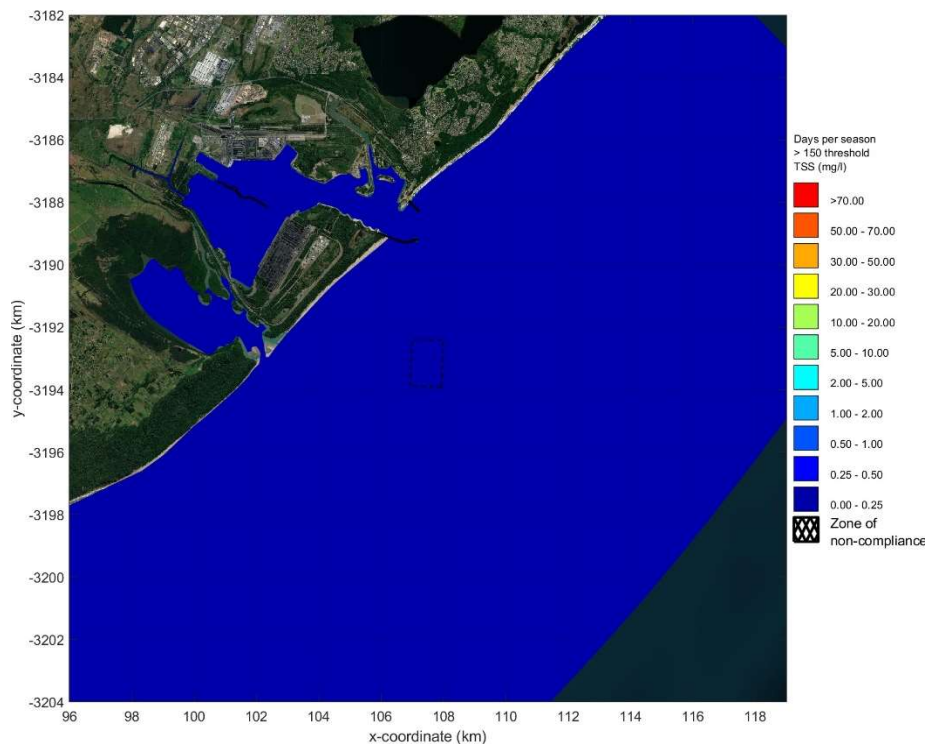


Figure 119. Days of exceedance of the suspended sediment concentration threshold of 150 mg.L⁻¹ in surface waters (van Ballegooyen *et al.*, 2025).

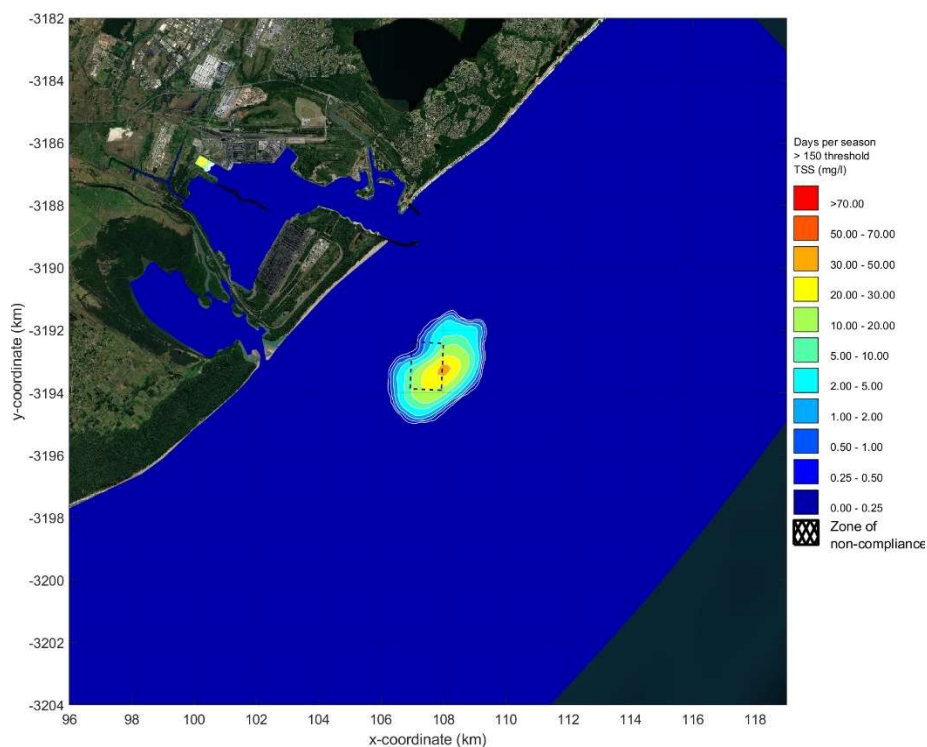


Figure 120. Days of exceedance of the suspended sediment concentration threshold of 150 mg.L⁻¹ in bottom waters (van Ballegooyen *et al.*, 2025).

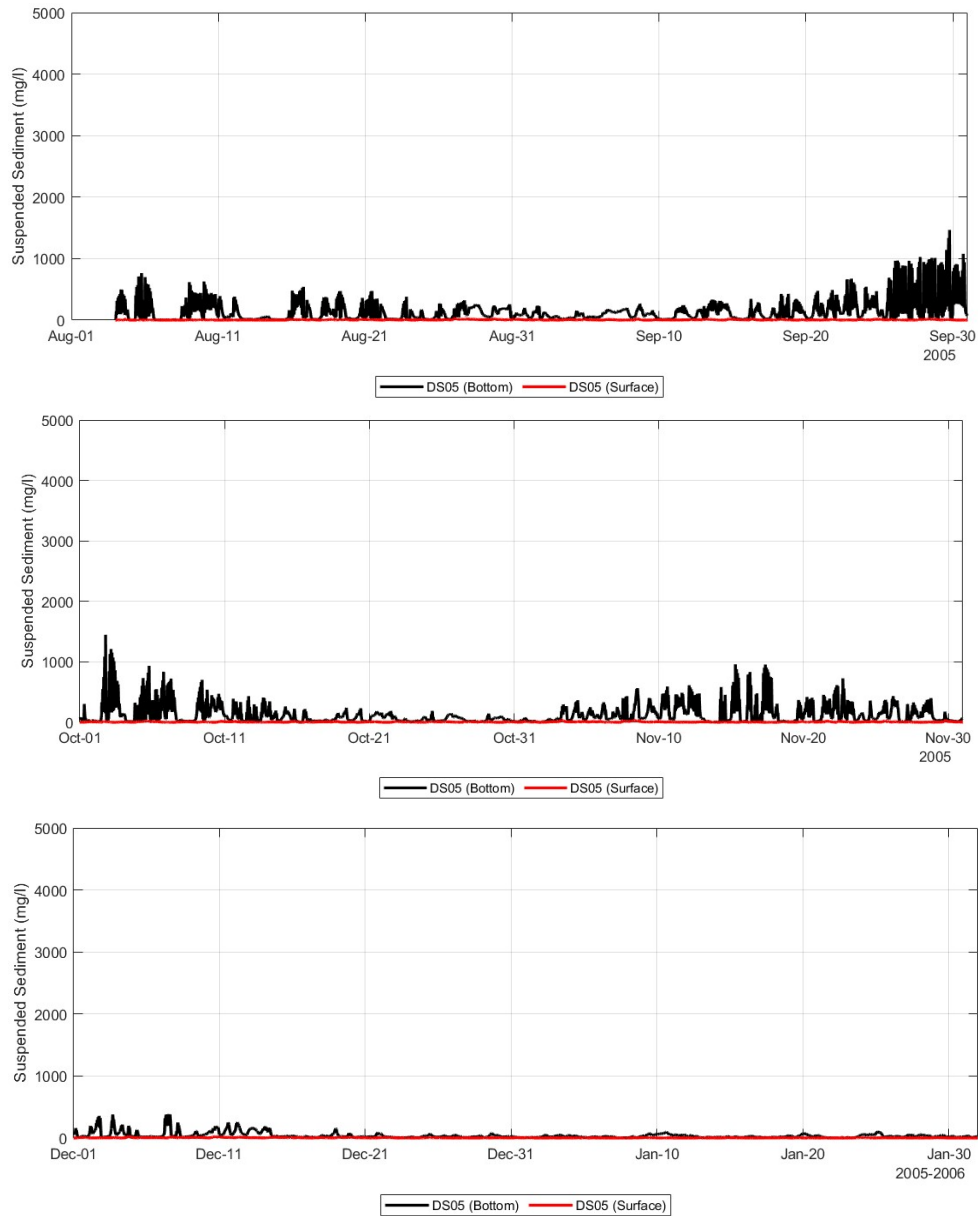


Figure 121. Time series of the suspended sediment concentration at a position approximately 0.3 km east of the dredged spoil disposal site (van Ballegooyen *et al.*, 2025).

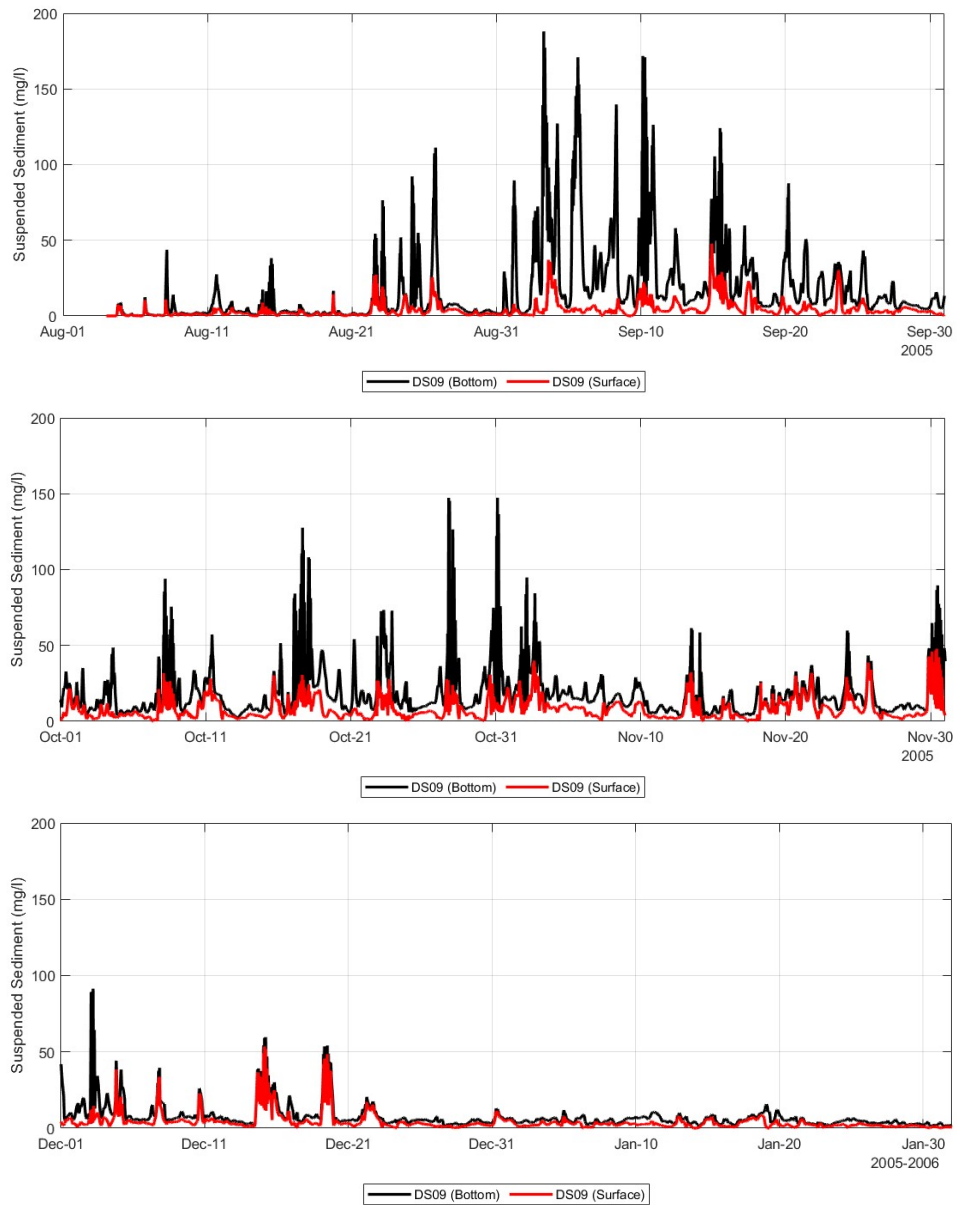


Figure 122. Time series of the suspended sediment concentration at a position approximately 0.8 km southwest of the dredged spoil disposal site (van Ballegooyen *et al.*, 2025).

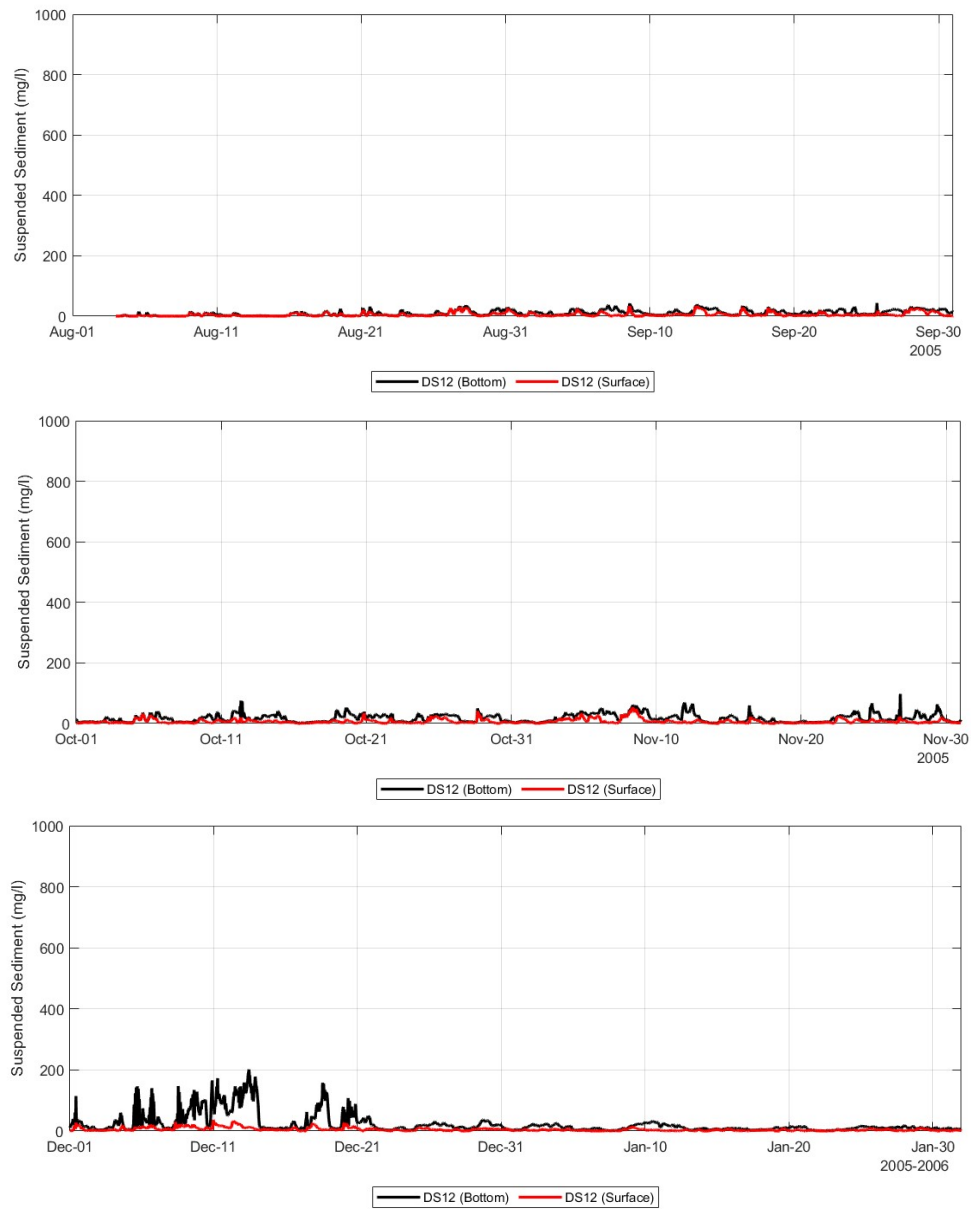


Figure 123. Time series of the suspended sediment concentration at a position approximately 1.2 km northeast of the dredged spoil disposal site (van Ballegooyen *et al.*, 2025).

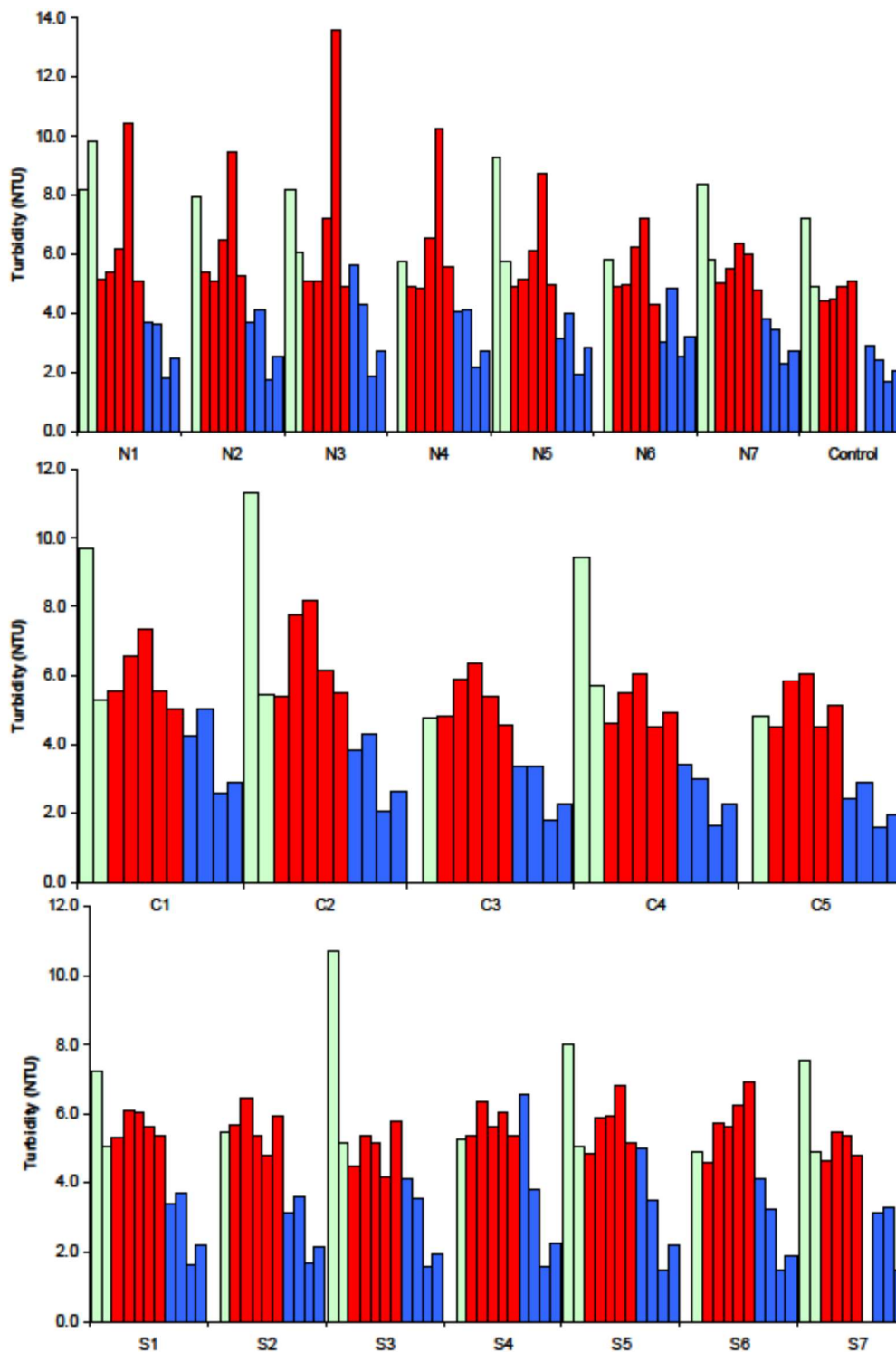


Figure 124. Depth averaged turbidities (NTU) at stations in the nearshore marine environment off the Richards Bay coast before (■ - December 2004-May 2005), during (■ - early September-December 2006), and after (■ - April 2006-November 2007) dredged material disposal for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008).

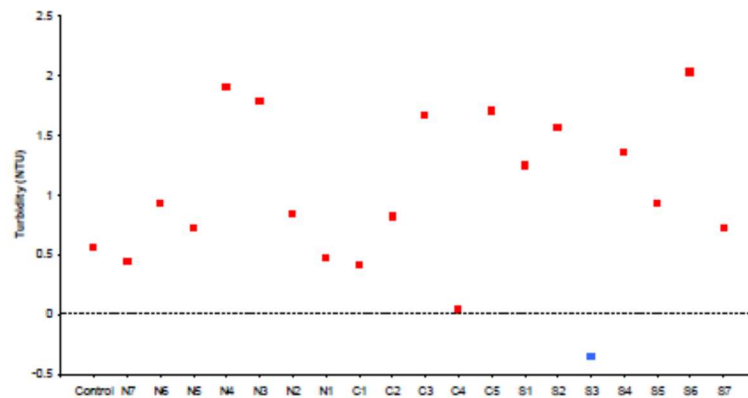


Figure 15: Differences in turbidities at offshore sites during dredging and non-dredging periods, ■ indicates higher average turbidity during dredging, ■ indicates lower average turbidity during dredging.

Figure 124. Differences in the turbidity at stations in the nearshore marine environment off the Richards Bay coast during and outside dredged spoil disposal periods for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008). ■ - indicates higher average turbidity during dredged material disposal; ■ - indicates lower average turbidity during dredged material disposal.

Impact significance assessment without mitigation

The disposal of dredged material for the Berth 605 Project will lead to an increase in the suspended sediment concentration and related turbidity above the baseline in the water column at and near the dredged spoil disposal site off the Richards Bay coast –this is an unavoidable consequence of the open water disposal of dredged sediment. The findings of studies elsewhere in the world show that the concentration increase is usually restricted to a relatively small area near the point of disposal and returns to the baseline soon after a disposal event, but some fine-grained material may be dispersed over a wide area depending on prevailing conditions. Importantly, this was also evident in the nearshore marine environment during dredged material disposal for the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008). As stated above, three-dimensional numerical modelling by van Ballegooyen *et al.* (2025) suggests the suspended sediment concentration in the bottom layer of the water column will be above the baseline over a relatively wide area near the dredged spoil disposal site. Although the increase in the suspended sediment concentration above the baseline is not expected to be persistently high, the modelled concentrations are nevertheless high enough to suspect they may have acute sublethal or chronic lethal and sublethal effects on benthic and pelagic biological resources relatively near (1-2 km) the dredged spoil disposal site. Suspended sediment concentrations above the baseline are not anticipated to persist in the water column for an extended period after each disposal event. Dredged sediment will also not be disposed continuously, and changes in the current direction and hence dispersion of the suspended sediment will provide pelagic and benthic biological resources at any point near the dredged spoil disposal site with some respite from exposure to suspended sediment. Nevertheless, frequent disposal events and the longer-term erosion of deposited sediment means a duration rating for this impact of **medium-term** and a spatial extent rating of **local** are warranted. Three-dimensional numerical modelling suggests the suspended sediment concentration is not anticipated to fall within ranges where acute lethal risks are likely, but acute sublethal and chronic lethal and sublethal risks are possible. The impact is thus anticipated to be of a **medium** intensity. The impact is **recoverable** since it will largely cease when dredged material disposal ceases. The significance assessment for this impact without mitigation is **MODERATE**.

Mitigation measures

Recommended mitigation measures for this impact are provided below. The mitigation measures are aimed at limiting the amount of sediment that is resuspended into the water column and propagated by currents from the dredged spoil disposal site, at limiting losses of sediment from dredgers and barges during transit to the disposal site, and at limiting the amount of time that pelagic and benthic biological resources are exposed to elevated suspended sediment concentrations.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredging should be completed within the shortest timeframe possible to reduce the period over which biological resources at and near the dredged spoil disposal site are exposed to suspended sediment concentrations and related turbidity above the baseline.
- The dredging footprint should be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the amount of sediment that needs to be disposed at the dredged spoil disposal site and hence the period over which biological resources at and near the dredged spoil disposal site are exposed to suspended sediment concentrations and related turbidity above the baseline.
- There should be no overflow or leakage of sediment from barge compartments during non-dredging transit at the dredging site and during transit to the dredged spoil disposal site.
- Barges should not be overfilled such that dredged material is washed overboard.
- The dredged sediment should be disposed on designated cells on the disposal site, in a rotational manner, to avoid the persistent exposure of biological resources at and near the dredged spoil disposal site to suspended sediment concentrations and related turbidity above the baseline.
- Dredged sediment should be disposed if dolphins or whales are observed within ~200-300 m of the point of disposal.

Impact significance assessment with mitigation

The mitigation measures are unlikely to have a major influence on the significance of this impact. The significance assessment for this impact thus remains **MODERATE** with mitigation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Deterioration in water quality related to increased suspended sediment concentrations during dredged spoil disposal
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	High
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	High
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance with mitigation	MODERATE
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with maintenance dredging and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all the material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual, temporally separated projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect could be highly adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources and ecological productivity is also likely to be highly adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation at the dredged spoil disposal site through the increased need for maintenance dredging in the lengthened 600 Berth Basin.

Recommended environmental monitoring

The suspended sediment concentration and turbidity should be measured near the dredged spoil disposal site at two-weekly intervals for the first two months of dredged material disposal. Measurements should be made over a 60 second period at the surface, middle and bottom of the water column. A decision should be made on the frequency of measurements, based on the findings of these initial surveys. The survey positions should correspond to those used by the CSIR (2008), excluding sites more than 5 km from the dredged spoil disposal site.

Impact 23: Remobilisation of oxygen depleting substances from sediment during dredged material disposal

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. Inorganic and organic oxygen depleting substances will be remobilised into the water column during dredged sediment disposal, with the same potential environmental consequences as those that might occur when sediment is resuspended by dredging (see Impact 18). The scientific literature suggests that the open water disposal of dredged material has a minimal influence on the dissolved oxygen concentration in the water column because disposal events are short-lived, most of the sediment reaches the bottom, and the amount of oxygen depleting substances released is small relative to the dilution achieved in the water column at dredged spoil disposal sites. Studies at open water dredged spoil disposal sites have shown that the dissolved oxygen depletion in the disposal plume can at times fall to 0 mg.L⁻¹, but this is a very rare event and in most cases the depression is localised and usually difficult to discriminate from the baseline (Slotta *et al.*, 1973; Westley *et al.*, 1973; USACE, 1976; USACE, 1998). Lee *et al.* (1978) measured changes in the dissolved oxygen concentration in the water column during more than ten open water dredged sediment disposal events before, during and after the passage of suspended sediment plumes, and found that the dissolved oxygen concentration was initially rapidly depressed for 5-10 minutes, followed by a 5-10 times slower rate of dissolved oxygen consumption.

The dissolved oxygen concentration in the water column at and very near the dredged spoil disposal site off the Richards Bay coast appears to have been last measured in 2004-2008 during dredged material disposal for the development of Berth 306 at the Richards Bay Coal Terminal in the Port of Richards Bay (CSIR, 2008). The positions where the measurements were made is provided in Figure 78. The lowest concentration recorded was 3.78 mg.L⁻¹ (a measurement made at the surface at Station N2). However, the water column was usually well oxygenated—of the 416 measurements, two were <5 mg.L⁻¹ and 34 were <6 mg.L⁻¹. In other words, most measurements were indicative of well-oxygenated water. As mentioned elsewhere, a dissolved oxygen concentration of ≥5 mg.L⁻¹ is considered adequate to sustain aerobic aquatic life. The dissolved oxygen concentration was generally lowest in the bottom part of the water column, but the average concentration was indistinguishable from that in the middle and surface of the water column.

Inorganic and organic oxygen depleting substances will be remobilised from sediment during dredged material disposal and these substances will depress the dissolved oxygen concentration in the water column. However, any such depression is anticipated to be **temporary** (tens of minutes), limited to discrete disposal events, **site only** in spatial extent, and of a **very low** magnitude. This is because the quantity of oxygen depleting substances remobilised into the water column is anticipated to be small, the dilution potential of the receiving environment is high, and the water column is usually well oxygenated. It is thus **improbable** that the dissolved oxygen depression will be of a magnitude that will pose a risk to biological resources near the dredged spoil disposal site. The impact is **reversible** since the dissolved oxygen concentration in the water column is anticipated to return to the baseline shortly after each disposal event. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredging should be completed within the shortest timeframe possible to reduce the period over which biological resources at and near the dredged spoil disposal site are exposed to dissolved oxygen concentrations sediment concentrations depressed below the baseline.
- The dredging footprint should be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the amount of sediment that needs to be disposed at the dredged spoil disposal site and hence the period over which biological resources at and near the dredged spoil disposal site are exposed to dissolved oxygen concentrations sediment concentrations depressed below the baseline.
- Barges should not be overfilled such that dredged material is washed overboard.
- The dredged sediment should be disposed on designated cells on the disposal site, in a rotational manner, to avoid the persistent exposure of biological resources at and near the dredged spoil disposal site to dissolved oxygen concentrations sediment concentrations depressed below the baseline.
- Vegetation should be removed from the terrestrial part of the project footprint, so that as little organic material as possible is disposed at the open water dredged spoil disposal site.

Impact significance assessment with mitigation

The significance assessment for this impact with mitigation will remain **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Remobilisation of oxygen depleting substances from sediment during dredged spoil disposal
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity

IMPACT DESCRIPTION	ASSESSMENT
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Improbable
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Improbable
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project will coincide with maintenance dredging and may coincide capital dredging for other planned infrastructure developments outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect is likely to be low at most. The reason is that sediment in the identified infrastructure development areas is not significantly enriched with particulate organic matter, nor is it likely to hold large amounts of other oxygen depleting substances (CSIR, unpublished data). If capital dredging campaigns do not occur simultaneously, the prolonged (several years) impact on water quality, biological resources, and ecological productivity is also likely to be low at most for the same reasons given above.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard.

The operational Berth 605 will contribute to water quality degradation at the dredged spoil disposal site off the Richards Bay coast through the increased need for maintenance dredging in the lengthened 600 Berth Basin and related disposal of dredged material at an open water disposal site.

Recommended environmental monitoring

The dissolved oxygen concentration should be measured near the dredged spoil disposal site at two-weekly intervals for the first two months of dredged material disposal. Measurements should be made over a 60 second period at the surface, middle and bottom of the water column. A decision should be made on the frequency of measurements thereafter based on the findings of the initial surveys. The survey positions should correspond to those used by the CSIR (2008), excluding sites more than 5 km from the dredged spoil disposal site.

Impact 24: Remobilisation of nutrients from sediment during dredged material disposal

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. Nutrients in porewater in the sediment will be remobilised into the water column during open water disposal and could have the same environmental consequences as those that might occur when nutrients are remobilised from resuspended sediment during dredging (see Impact 19). Note that this assessment assumes topsoil and vegetation (a source of nutrients on decomposition) will be removed from the site prior to dredging.

Impact significance assessment without mitigation

Nutrient concentrations in coastal waters along the Richards Bay coast are usually low. Only near the points where wastewater is discharged through the uMgeni-uThukela Water outfalls to the north of the entrance to the Port of Richards Bay are nutrient concentrations elevated (see Section 5.1.8 of this specialist study). Nutrients will be remobilised from sediment during dredged material disposal and over the longer-term through the remineralisation of particulate organic matter in sediment that deposits on the bottom at the dredged material disposal site. However, any increase in nutrient concentrations above the baseline is anticipated to be **site only** in spatial extent, **temporary** in duration, of a **very low** magnitude, and it is **improbable** that this will stimulate the growth of microalgae much above the baseline. The impact is **reversible** since nutrient concentrations in the water column are anticipated to return to the baseline shortly after each disposal event and will for all intents and purposes cease once dredged material disposal ceases. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredging must be completed within the shortest time possible to reduce the period over which nutrient concentrations might be released from sediment into the water column.
- The dredging footprint should be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the amount of sediment that needs to be disposed at the dredged spoil disposal site.
- Vegetation should be removed from the terrestrial part of the project footprint, so that as little organic material as possible is disposed at the open water dredged spoil disposal site.

Impact significance assessment with mitigation

The significance assessment for this impact with mitigation will remain **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Remobilisation of nutrients from sediment during dredged spoil disposal
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Improbable

IMPACT DESCRIPTION	ASSESSMENT
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Improbable
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project will coincide with maintenance dredging and may coincide capital dredging for other planned infrastructure developments outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect is likely to be low at most. The reason is that sediment in the identified infrastructure development areas is not significantly enriched with particulate organic matter, nor is it likely to hold large amounts of other oxygen depleting substances (CSIR, unpublished data). If capital dredging campaigns do not occur simultaneously, the prolonged (several years) impact on water quality, biological resources, and ecological productivity is also likely to be low at most for the same reasons given above.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard.

The operational Berth 605 will contribute to water quality degradation at the dredged spoil disposal site off the Richards Bay coast through the increased need for maintenance dredging in the lengthened 600 Berth Basin and related disposal of dredged material at an open water disposal site.

Recommended environmental monitoring

No monitoring is required due to the **VERY LOW** significance assessment for this impact with mitigation.

Impact 25: Remobilisation of noxious substances from sediment during dredged material disposal

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing open water dredged spoil disposal site off the Richards Bay coast. Noxious chemicals present in sediment porewater or adsorbed to sediment may be remobilised into the water column and may have similar environmental consequences as those that might occur when noxious chemicals are remobilised from resuspended sediment during dredging (see Impact 20). The scientific literature indicates that dredged sediment disposal seldom causes a significant increase in noxious chemical concentrations in the water column at open water dredged spoil disposal sites. This is because disposal events are short-lived, most of the sediment reaches the bottom and little is resuspended, and relative to the dilution achieved at dredged spoil disposal sites the noxious chemical remobilisation is negligible.

Impact significance assessment without mitigation

The sediment in the Berth 605 Project footprint is contaminated by metals and polycyclic aromatic hydrocarbons. The sediment is also probably contaminated by organometallic chemicals (tributyltin) and pesticides, amongst other noxious chemicals (see Sections 5.1.9 and 5.1.11 of this specialist study; see also CSIR, 2024). Soil in the Berth 605 Project footprint is also metal contaminated and is probably contaminated by other chemicals deposited from the atmosphere. Noxious chemicals will thus probably be remobilised into the water column during dredged material disposal. However, the toxicity testing of sediment and soil collected in the Berth 605 Project footprint showed that noxious chemicals will not be remobilised at concentrations and in forms that pose a risk of direct toxicity to biological resources apart possibly when soil from a small area in the footprint is placed in water (CSIR, 2024). It is thus **improbable** that noxious chemicals will be remobilised during dredged sediment disposal into the water column at concentrations and in a form that presents a risk of significant direct toxicity to biological resources. The magnitude of this impact is thus anticipated to be **very low**. Noxious chemicals could be remobilised from dredged material throughout the dredged material disposal period, but any increase in their concentration above the baseline is anticipated to be **temporary** since the chemicals are expected to be rapidly diluted and dispersed in the receiving water or to be transformed to less toxic forms (*e.g.* hydrogen sulphide) relatively soon after remobilisation. Furthermore, a large proportion of the sediment and soil that will be dredged (deeper strata) is not expected to be contaminated since it has not been exposed during the Anthropocene. The spatial extent for this impact is anticipated to be **site only** due to the anticipated rapid dilution and transformation of noxious chemicals remobilised from the sediment—less than two dilutions were necessary to reduce elutriates of the most toxic sediment sample to render it non-toxic (CSIR, 2024). The impact is **reversible** since the remobilisation of noxious chemicals will cease when dredged spoil disposal ceases (but see potential impact of remobilisation from deposited sediment below). The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Ensure that dredged sediment is disposed evenly over the dredged sediment disposal site to disperse and dilute noxious chemical concentrations.

Impact significance assessment with mitigation

The significance assessment for this impact will not change with mitigation and thus remains **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Remobilisation of noxious substances from sediment during dredged material disposal
Aspects affected	Water quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Recoverable
Duration	Temporary
Probability	Possible
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	

IMPACT DESCRIPTION	ASSESSMENT
Magnitude	Very low
Extent	Site only
Reversibility	Recoverable
Duration	Temporary
Probability	Possible
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with maintenance dredging and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual, temporally separated projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect is likely to be low at most but probably very low. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources, and ecological productivity is also likely to be low at most but probably very low. This conclusion is based on toxicity testing of sediment sampled in the port over several years, which has shown an almost complete absence of sediment toxicity. Thus, while noxious chemical concentrations are high in sediment in some parts of the port earmarked for infrastructure development in the short-term, the chemicals are either not in a bioavailable form or if they are they are remobilised at such low concentrations that they do not cause toxicity even to sensitive sea urchin embryos and larvae.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to water quality degradation at the dredged spoil disposal site through the increased need for maintenance dredging in the lengthened 600 Berth Basin.

Recommended environmental monitoring

No monitoring of noxious chemicals in the water column is required due to the **VERY LOW** significance assessment for this impact with mitigation. However, the periodic (monthly intervals) toxicity testing of water samples collected near the dredged spoil disposal site should be performed to confirm this assessment is valid. The testing should be performed on raw and centrifuged water samples using sea urchin embryo-larval development and 4-day water only amphipod survival tests.

Impact 26: Deterioration in sediment quality on the dredged spoil disposal site due to the disposal of contaminated dredged material

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing open water dredged spoil disposal site off the Richards Bay coast. The transfer of noxious chemicals in contaminated dredged material to open water dredged spoil disposal sites is an unavoidable consequence if open water disposal is approved (Stronkhorst *et al.*, 2003; De Witte *et al.*, 2016; Donázar-Aramendía *et al.*, 2020; Tao *et al.*, 2021). Benthic biological resources that survive or avoid

the physical effects of dredged material disposal (*e.g.* burial, smothering) and those that invade or colonise the deposited sediment may be exposed to noxious chemicals in the sediment. The noxious chemicals may pose an acute or chronic toxic risk to the biological resources. The noxious chemicals may also be bioaccumulated by biological resources and enter food webs in the area (Donázar-Aramendía *et al.*, 2020). Sediment is usually gradually eroded from open water dredged spoil disposal sites by currents, in turn gradually exposing deeper contaminated sediment, potentially prolonging the period that biological resources are exposed to noxious chemicals. Noxious chemicals adsorbed onto sediment that is eroded and dispersed from a dredged spoil disposal site by currents are dispersed into the surrounding area, exposing biological resources over a wider area to the chemicals. However, noxious chemical concentrations in secondarily deposited sediment will be lower than in sediment deposited at the time of disposal due to dilution in the surrounding environment.

Impact significance assessment without mitigation

Surficial sediment and soil sampled across large parts of the Berth 605 Project footprint in 2024 was contaminated by metals, and the sediment also by polycyclic aromatic hydrocarbons (see Sections 5.1.9 and 5.1.11 of this specialist study; see also CSIR, 2024). The sediment in parts of the 600 Berth Basin was also found to be contaminated by metals, polycyclic aromatic hydrocarbons, and other noxious chemicals in earlier surveys (see Sections 5.1.9 and 5.1.11 of this specialist study). The disposal of sediment that is dredged and soil that is excavated in the Berth 605 Project footprint will transfer any noxious chemicals in the sediment and soil to the dredged spoil disposal site off the Richards Bay coast. This is an unavoidable consequence of the open water disposal of contaminated sediment and soil. However, toxicity testing of the sediment and soil showed that it was not toxic apart from the soil at one station (CSIR, 2024). However, the elutriate toxicity testing of soil at this station showed only two dilutions of the elutriate was required to render it non-toxic. A large portion of the sediment and soil that will be dredged and excavated is from strata that have not previously been exposed to anthropogenic contaminants. This sediment will dilute noxious chemical concentrations in contaminated sediment and soil disposed at the dredged spoil disposal site. It is thus unlikely, but nevertheless **possible** that noxious chemicals in the sediment and soil will pose a toxic hazard to benthic biological resources on and near the dredged spoil disposal site. Based on the results of toxicity testing, the magnitude of this impact is anticipated to be **very low**. The impact is anticipated to be **site only** in spatial extent since although noxious chemicals in fine-grained sediment with which most toxic chemicals associate will be eroded from the site over time, this will dilute the noxious chemical concentrations and further reduce the potential for toxicity. Benthic biological resources are anticipated to be exposed to noxious chemicals in the sediment in the long-term since the erosion of sediment and soil from the dredged spoil disposal site is expected to be protracted, but the actual potential for toxicity will be **temporary**. The impact is **reversible** since contaminated sediment will be eroded from the dredged spoil disposal site over time when dredging ceases. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures are thus outlined below. It is not possible to mitigate this impact once dredged material has been disposed, so mitigation measures are aimed at minimising the potential impact.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- TNPA must secure a permit from the Department of Forestry, Fisheries and the Environment for the open water disposal of sediment before capital dredging proceeds for infrastructure developments.
- Dredged sediment must be disposed in designated cells on the dredged spoil disposal site following a

pre-approved sequence that avoids disposal in adjacent cells for successive disposal events and ensures the dredged sediment is disposed as evenly as possible across the site, avoiding the disposal of the potentially most contaminated sediment in a restricted part of the dredged spoil disposal site.

- Dredging vessel and barge tracks must be examined to ensure dredged material is disposed as evenly as possible across the dredged spoil disposal site.

Impact significance assessment with mitigation

The significance assessment for this impact will not change with mitigation and thus remains **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Deterioration in sediment quality on dredged spoil disposal site due to the disposal of contaminated dredged material
Aspects affected	Sediment quality, Aquatic biological resources, Ecological productivity
Stage	Construction
Character	Negative
Ease of mitigation	Difficult
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Temporary
Probability	Possible
Significance with mitigation	VERY LOW
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the development of Berth 605 may coincide with capital dredging for other infrastructure developments in the Port of Richards Bay, as outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). Regardless of whether dredged material disposal from multiple short-term infrastructure developments overlaps or occurs sequentially, it is highly unlikely noxious chemicals transferred to the dredged spoil disposal site will pose a toxic hazard to biological resources on and near the disposal site unless there is a marked change in the types of noxious chemicals introduced to the port's waters. This conclusion is based on the toxicity testing of sediment sampled in the port over several years, which has shown an almost complete absence of sediment toxicity (CSIR, unpublished data). Thus, while noxious chemical concentrations are high in sediment in some parts of the port earmarked for infrastructure development in the short-term, the chemicals are either not in a bioavailable form or if they are they are remobilised at such low concentrations they do not cause toxicity even to sensitive sea urchin embryos and larvae. Anticipating the effects of noxious chemical transfer to the disposal site related to dredging for medium- and long-term infrastructure developments outlined in the Port of Richards Bay Masterplan is impossible since it will depend on whether there are changes in the types and quantities of noxious chemicals accumulating in sediment in the port and the rate at which contaminated sediment is eroded from the dredged spoil disposal site.

Recommended environmental monitoring

Sediment should be sampled on and near the dredged spoil disposal site and analysed for the concentrations of a suite of metals and polycyclic aromatic hydrocarbons to confirm the significance assessment for this impact. The monitoring will have the added benefit of acting as a tracer for identifying

the dispersion and transport of dredged material from the dredged spoil disposal site. Sediment samples should be collected at ~6-month intervals before and after dredged spoil disposal for the Berth 605 Project.

Impact 27: Physical disturbance of benthic biological resources by disposed dredged material

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. Surveys elsewhere in the world have shown that most of the sediment disposed from dredging vessels and barges reaches the bottom as a fluid mass. An unavoidable consequence of dredged sediment disposal at open water dredged spoil disposal sites is thus the burial, smothering and crushing of benthic biological communities, including benthic invertebrate infauna and poorly mobile epifauna, bottom-dwelling fish and the eggs of invertebrates and fish that are deposited and develop until hatching on the seabed (Miller *et al.*, 2002). Similar, but usually far less pronounced impacts can occur to benthic biological resources near a dredged spoil disposal site when there is overspill of disposed sediment or when deposited sediment is eroded from a disposal site by currents (Essink, 1999; Miller *et al.*, 2002; Stronkhorst *et al.*, 2003; Bolam *et al.*, 2011; Boon and Dalfsen, 2022). Most benthic biological resources live in the top 10 cm of sediment and rely on a connection (*e.g.* burrows) to the sediment-water interface for ventilation (respiration), feeding and breeding (Miller *et al.*, 2002). The ‘excessive’ deposition of fine-grained sediment (mud) on sandy sediment can lead to the clogging of the spaces between sand grains, displacing the biological resources that live between the sand grains and retarding the exchange of oxygen with the overlying water, leading to the suffocation of infauna. Frequent repositioning to maintain a relative distance to the sediment-water interface, or the need by burrowing organisms to increase maintenance to prevent the infilling of burrows, requires that the organisms decrease their energy allotment to other functions, such as growth or reproduction. If the deposited sediment has a different grain size to the sediment that existed before deposition then it may alter the physical properties of the sediment to a degree that the bottom-dwelling biological resources that prefer to live in or on sediment of a fairly specific grain size for various reasons are excluded (Holland *et al.*, 2005; Smit *et al.*, 2006; Smit *et al.*, 2008; Boon and Dalfsen, 2022). The deposition of muddy sediment on sandy sediment is generally more problematic than the reverse (Diaz and Boesch, 1977; Boon and Dalfsen, 2022).

Many benthic invertebrate infauna and epifauna can migrate upwards through deposited sediment and may be relatively unimpacted within reasonable limits (Maurer *et al.* 1979, 1981a, 1981b, 1982, 1986; Fredette and French, 2004; Wilber *et al.*, 2007). Maurer *et al.* (1979), for example, found that some benthic invertebrates can migrate through as much as ~30 cm of deposited sediment, although other invertebrates are less tolerant of burial and smothering and may be significantly affected by even a thin layer of placed sediment (Schaffner, 1993; Wilber and Clarke, 2007; Hendrick *et al.*, 2016). The consequence of sediment disposal impacts is an altered species composition, abundance and biomass of benthic biological resources on and near dredged spoil disposal sites (Miller *et al.*, 2002; Bolam and Rees, 2003; Stronkhorst *et al.*, 2003; Bolam *et al.*, 2011; Donázar-Aramendía *et al.*, 2018; Donázar-Aramendía, 2020; Bolam *et al.*, 2021; Tao *et al.*, 2021; Boon and Dalfsen, 2022), with attendant impacts to other ecosystem processes (*e.g.* fish that rely on invertebrates in the affected area as a food resource will be deprived of this resource and essentially suffer habitat displacement). It should, however, be noted that it is not always possible to determine if the changes in biological resources at dredged spoil disposal sites is a consequence of the physical effects of sediment disposal or other features of the disposed sediment that might also affect biological resources, such as the presence of toxic chemicals in the sediment.

Benthic biological resources impacted by the disposal of dredged sediment recover after such a disturbance. Some benthic biological resources will recolonise newly deposited sediment within hours to days after disposal ceases, but recovery to a comparable species composition, abundance and biomass to that which existed before disposal takes longer (potentially years depending on the habitat) (Newell *et al.*, 1998; Gilkinson *et al.*, 2005; Stronkhorst *et al.*, 2003). Initial recolonisation likely occurs by invasion (or active immigration) by motile biological resources (*e.g.* amphipods, crabs; Morton, 1977; van Moorsel 1993, 1994; Hall, 1994) from less disturbed or undisturbed areas nearby and by larval settlement from the water column (Skilleter, 1998). Short-lived species and/or species with a high reproduction rate (so-called opportunists; includes amphipods, various worms) recover more rapidly than slower growing, longer-lived species (*e.g.* gastropods, large worms). If the physical properties of the deposited sediment are substantially different to that at a site prior to sediment disposal, the benthic invertebrates that colonise the site may differ to the those that were present originally (Tao *et al.*, 2021).

van Ballegooyen *et al.* (2025) used three-dimensional numerical modelling to simulate the deposition of sediment on the bottom when sediment dredged and soil and rock excavated in the development footprint for the Berth 605 Project is disposed at the existing authorised open water dredged spoil disposal site off the Richards Bay coast. The reader should refer to Impact 15 for a discussion on the numerical modelling approach. The numerical modelling output is provided in Figure 125. To assess the potential ecological impacts associated with smothering effects, the numerical model results are presented as the near maximum (99th percentile) thickness of sediments deposited on the seabed based on the full simulation period of 155 days. This allows for about a 3-week period—a 139-day dredged spoil disposal period was modelled—of re-distribution of the sediments from the dredged spoil disposal site to the extent that this occurs. The numerical modelling suggests that there will be some overspill, or erosion of deposited sediment from the dredged spoil disposal site such that the sediment thickness within 500-1000 m of the disposal site will increase by ~10-20 cm, but up to about 1 m in places. The accumulation on the dredged spoil disposal site will be far more significant, at 3-4 m over the southeastern half of the site where it is recommended that most of the dredged material be deposited.

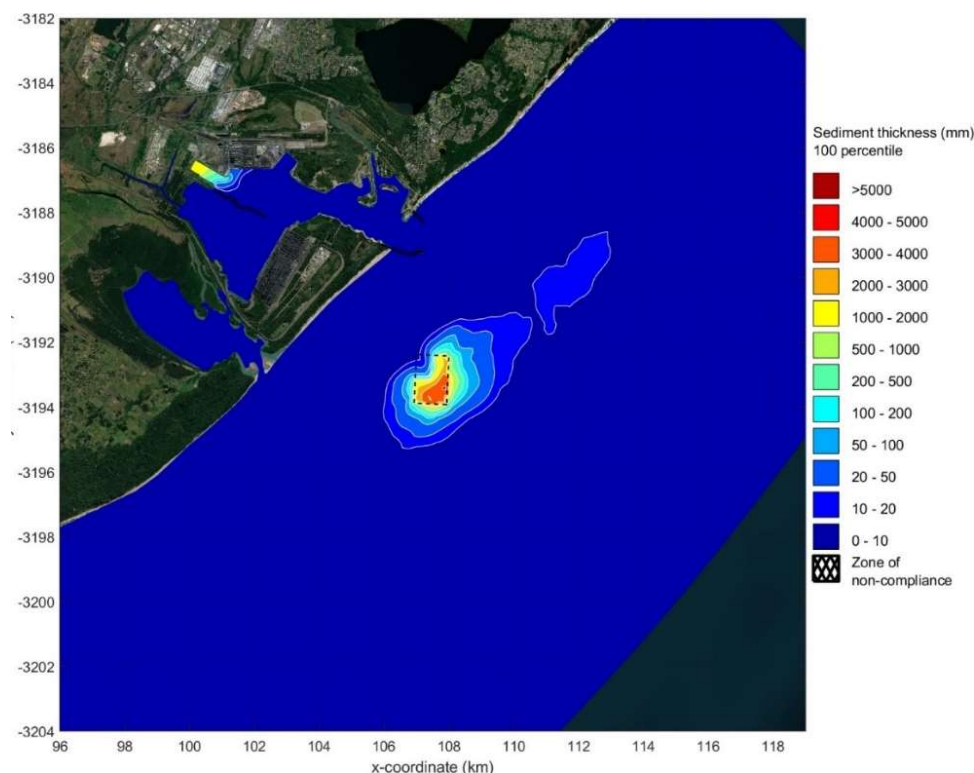


Figure 125. 99thtile sediment thickness on the seabed (van Ballegooyen *et al.*, 2025).

A detailed assessment of the dispersal of material from the dredged spoil disposal site indicates the fairly rapid removal of maintenance dredged material but a much slower rate for capital dredged material, possibly due to the large quantities that will be disposed over a short period leading to the mounding of material that is then less easily eroded because capital dredged material typically contains less fine-grained material than does maintenance dredged material and also may contain significant quantities of rock or coarser-grained material derived from the dredging of rock. The dispersion of rock and coarser-grained material from the site will be much slower, if at all.

Impact significance assessment without mitigation

The disposal of material dredged for the development of Berth 605 in the Port of Richards Bay at the existing open water dredged spoil disposal site off the Richards Bay coast will bury, smother and crush benthic biological resources at and possibly very near the site if there is material overflow. This is a predictable and unavoidable consequence of the open water disposal of dredged material. van Ballegooyen *et al.* (2025) used three-dimensional numerical modelling simulated the fate of sediment dredged for the development of Berth 605 at the dredged spoil disposal site. The modelling showed that most of the sediment will reach the bottom, which is consistent with the findings of studies elsewhere in the world. Significant sediment deposition is anticipated to be limited to the dredged spoil disposal site and a relatively narrow boundary margin or spreading zone. Surveys of benthic macrofaunal communities near the dredged disposal site before, during and after the disposal of material dredged for the Berth 306 development at the Richards Bay Coal Terminal in the Port of Richards Bay by the CSIR (2008) revealed that impacts were evident in benthic macrofaunal communities near the disposal site. However, the impacts were restricted to a relatively small area near the disposal site and there was not a complete loss of benthic ecology apart from on the disposal site.

Accepting a similar outcome for sediment dredged for the Berth 605 Project, the impact to benthic biological resources is anticipated to be local, but possibly **regional** in spatial extent (*i.e.* >2 km from dredged spoil disposal site). The disposal of ~4.3 million m³ of dredged sediment across the allotted dredged spoil disposal area, assuming no loss of sediment during its descent to the seabed and no loss once on the seabed due to erosion by currents, will raise the seabed by ~1-7 m (van Ballegooyen *et al.*, 2025). This will far exceed the 15-30 cm depth through which some forms of benthic macrofauna are considered able to migrate. There is also a large amount of rock that will need to be disposed for the development of Berth 605. The magnitude of this impact is thus anticipated to be very high for benthic biological resources on the dredged spoil disposal site—there will most likely be a complete loss of benthic ecology on the dredged spoil disposal site. However, the consequence for ecological productivity in the greater area is anticipated to be **moderate** as the benthic macrofaunal community on probably near the dredged spoil disposal site is already disturbed by ongoing maintenance dredged material disposal. Benthic biological resources will recolonise sediment and rock deposited on the dredged spoil disposal site after dredging ceases provided there is no further disturbance—this is unlikely considering the ongoing need for the disposal of maintenance dredged sediment. It is unlikely the benthic biological resources will return to a species composition, abundance and biomass like that which currently exists if rock is exposed at the sediment surface. The sediment in a substantial part of the Berth 605 dredging footprint is also muddier than on the dredged spoil disposal site, which may retard the recovery of benthic biological resources. The impact is thus considered **medium-term**. The impact is potentially **recoverable** if the disposed rock alters the seabed to a degree the benthic biological resource community is totally different to that which currently exists—but there are existing reefs on the disposal site. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts.
- Dredged material must be disposed in designated cells on the dredged spoil disposal site following a pre-approved sequence that avoids disposal in adjacent cells for successive disposal events, to ensure the sediment is disposed as evenly as possible across the site. This may provide an opportunity for benthic biological resources that are able to migrate through deposited sediment.
- Dredging vessel and barge tracks must be examined to ensure dredged sediment is disposed as evenly as possible across the dredged spoil disposal site.
- A record of the volume of sediment during each disposal event.
- The dredging footprint should be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the amount of sediment that needs to be disposed at the dredged spoil disposal site.

Impact significance assessment with mitigation

The significance assessment for this impact with mitigation remains **MODERATE**. The significant assessment score with mitigation is at the cusp of a moderate and high significance assessment and could also be considered as having a high significance assessment.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Smothering and disturbance of benthic biological resources by disposed dredged material
Aspects affected	Physical processes, Aquatic biological resources, Ecological productivity
Stage	Construction/Dredging
Character	Negative
Ease of mitigation	Easy
Pre-Mitigation Significance Assessment	
Magnitude	Medium
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Medium
Extent	Local
Reversibility	Recoverable
Duration	Medium-term
Probability	Definite
Significance with mitigation	MODERATE
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with maintenance dredging and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual, temporally separated projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect is likely to be highly adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources and ecological productivity is also likely to be highly adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to the degradation of benthic biological resources on the dredged spoil disposal site through the increased need for maintenance dredging in the lengthened 600 Berth Basin.

Recommended environmental monitoring

Benthic macrofaunal communities should be sampled on and near the dredged spoil disposal site. Sediment samples should be collected at ~6-month intervals before and after dredged spoil disposal for the Berth 605 Project.

Impact 28: Change in hydrodynamic conditions due to accumulation of dredged material at dredged spoil disposal site

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing open water dredged spoil disposal site off the Richards Bay coast. As discussed elsewhere in this specialised study, most of the material disposed from dredgers and barges reaches the bottom. Sediment is not immediately eroded even if the disposal site is situated in a dispersive environment, while rocks may never be removed. The consequence is a change in the bathymetry of the seabed that can have implications for local currents and wave climates depending on the volume of material disposed and the depth of the water column.

The disposal of dredged material for the Berth 306 Project resulted in the formation of a large mound of material in part of the dredged spoil disposal site, to a degree it was necessary for the South African Maritime Safety Authority to issue a maritime notice on the navigation hazard posed by the mound. This said, this reflects 'short dumping', that is, a poor dredged material disposal strategy. Changes to the bathymetry of the seabed can refract and amplify waves, currents and sediment transport patterns to a degree this causes or enhances shoreline erosion. The erosion of the shoreline to the north of the entrance channel to the Port of Richards Bay is currently a major challenge, to a degree the main bathing beach has essentially disappeared over time, and port and municipal infrastructure is being threatened.

An increase in the rate of shoreline erosion because of the Berth 605 Project will thus be problematic and will diminish the available habitat for sandy beach biological resources, including birds.

The disposal of the ~4.3 million m³ of (bulked) material that will need to be dredged for the development of Berth 605 across the existing dredged spoil disposal site off the Richards Bay coast, taking account of differences in bathymetry across the site, is anticipated to raise the seabed on the site by ~1-7 m (van Ballegooyen *et al.*, 2025). The change is not expected to increase the wave height much more than ~10 cm and will lead to a small change in wave direction (Figures 126 and 127). Nevertheless, the altered wave climate is anticipated to affect the longshore transport of sediment along parts of the Richards Bay shoreline and will result in shoreline accretion and/or erosion relative to the existing condition. van Ballegooyen *et al.* (2025) numerically modelled the shoreline changes that might arise because of the altered wave climate. The modelling considered cross shore profiles at various positions along the coast (Figure 128). The modelling outputs suggest the changes in wave climate due to dredged material disposal will have varying impacts on sediment transport at different locations along the shore relative to the

existing sediment transport and shoreline regime. In the southernmost areas (Locations 1-4), the predicted effects on sediment transport are generally minimal and accretion is anticipated along parts of the shoreline (Figure 129).

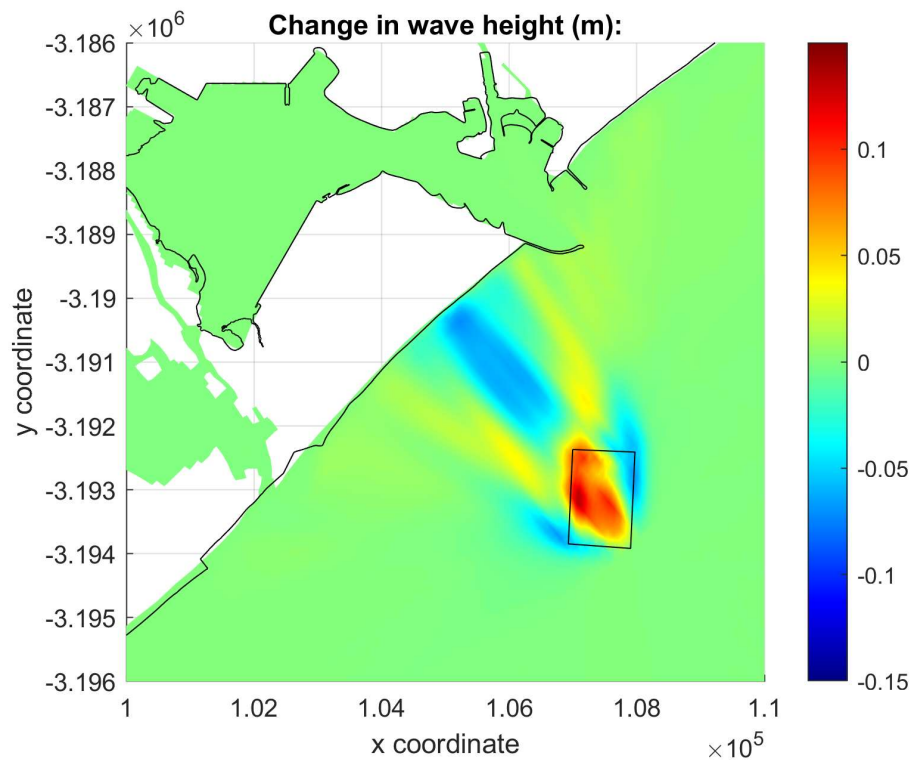


Figure 126. Modelled changes in wave height (m) associated with the disposal of dredged material on the existing dredged spoil disposal site off the Richards Bay coast (van Ballegooyen *et al.*, 2025).

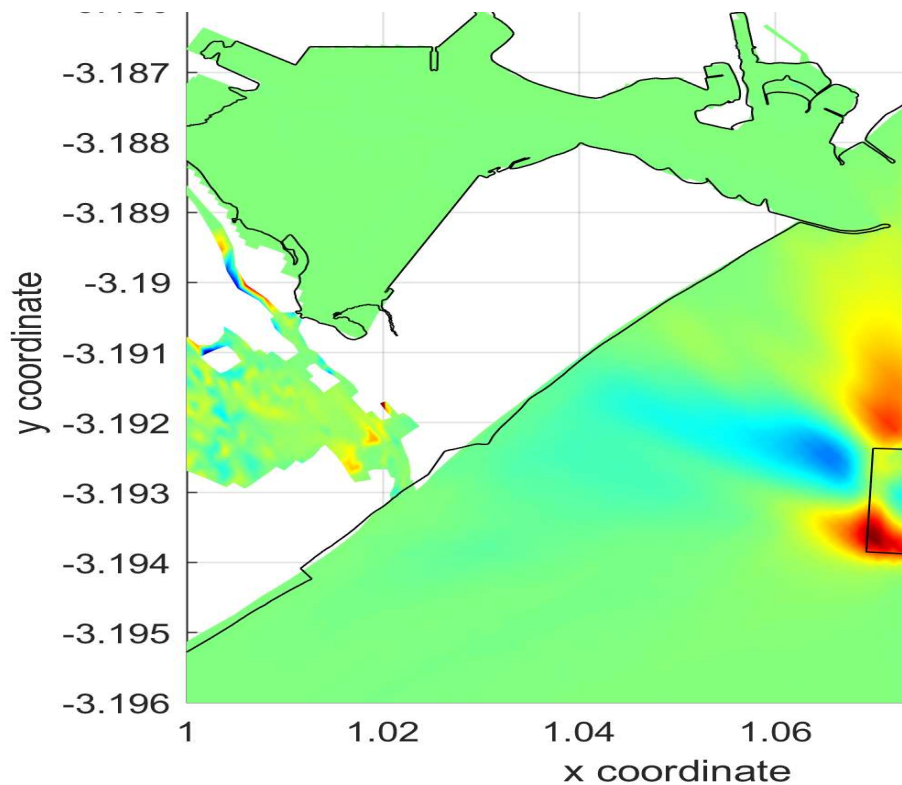


Figure 127. Modelled changes in wave direction (degrees from True North) associated with the disposal of dredged material on the existing dredged spoil disposal site off the Richards Bay coast (van Ballegooyen *et al.*, 2025).



Figure 128. Cross-shore profile locations (van Ballegooyen *et al.*, 2025).



Figure 129. Modelled shoreline erosion and accretion resulting from the disposal of dredged material for the Berth 605 Project (van Ballegooyen *et al.*, 2025).

Further north of the Mhlathuze estuary mouth (Locations 5-9), more pronounced effects are anticipated. Erosion requiring intervention (sand nourishment) could be required in the narrowest beach segment between Locations 6-7 due to localised transport changes, since the beach here is (presently) relatively narrow. Erosion of 8.5 and 9.1 m of shoreline is predicted by the numerical modelling at these locations respectively. In areas near the southern breakwater to the Port of Richards Bay (Locations 9-11) the numerical modelling predictions indicate slightly more severe erosion of 10.9-13.0 m. However, the existing beach here is very wide and can likely accommodate erosion of up to 13.0 m.

A slight increase in northerly sediment transport is anticipated for locations north of the Dolphin Viewing Pier—the change will likely induce erosion. To prevent the erosion, the quantity of sediment bypassed around the pier may need to be increased accordingly. However, since the change in transport is a small proportion of the total annual volume (estimated at 800 000 m³), the required additional sand supply to the northern beaches is expected to be in the order of a few tens of thousands of m³ per year.

Impact significance assessment without mitigation

The disposal of soil, sediment and rock excavated and dredged for the Berth 605 Project at the existing authorised dredged spoil disposal site is **very likely** to alter the wave regime to a degree this affects sediment transport and shoreline erosion and accretion patterns. The changes in sediment transport and shoreline accretion, and particularly erosion, will affect shoreline biological resources. The changes are anticipated to be **regional** in spatial extent, but of a **low** magnitude since shoreline biological resources will adapt to the changes—in the case of erosion subtidal biological resources will derive a benefit and *vice versa*. The impact will probably be **long-term** since it will take time for material to be eroded from the dredged spoil disposal site and the wave regime to return to a 'normal' state. The impact is **recoverable** since sediment will be eroded from the dredged spoil disposal site and conditions should return to a 'normal' state. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

van Ballegooyen *et al.* (2025) recommend that material dredged for the Berth 605 development be disposed on the dredged spoil disposal site in a manner that considers the existing bathymetry. It is assumed that this recommendation will be followed, which is thus considered embedded mitigation. Other mitigation measures for this impact are outlined below.

- The dredging contractor(s) must develop a method statement that outlines how dredging will proceed and the measures that will be implemented to minimise environmental impacts—in this case to limit the degree of shoreline erosion.
- The tracks of dredging vessels and barges should be audited by TNPA and/or an Environmental Control Officer to ensure dredged sediment is disposed according to pre-approved sequence and position dictated by modelling by van Ballegooyen *et al.* (2025).

Impact significance assessment with mitigation

If the mitigation is implemented the significance assessment is not expected to markedly alter the impact significance, which thus remains **MODERATE**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Change in hydrodynamic conditions due to accumulation of dredged material at dredged spoil disposal site
Aspects affected	Physical processes, Aquatic biological resources, Ecological productivity
Stage	Construction/Dredging, Operation
Character	Negative
Ease of mitigation	Difficult
Pre-Mitigation Significance Assessment	
Magnitude	Low

IMPACT DESCRIPTION	ASSESSMENT
Extent	Regional
Reversibility	Recoverable
Duration	Long-term
Probability	Very likely
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Regional
Reversibility	Recoverable
Duration	Long-term
Probability	Very likely
Significance with mitigation	MODERATE
Confidence in assessment	Medium

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with maintenance dredging and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. An estimated 10°million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual, temporally separated projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect on shoreline dynamics may be highly adverse. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on shoreline dynamics may also be highly adverse.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed. This must include the use of an alternate dredged spoil disposal site.

Recommended environmental monitoring

The bathymetry of the existing open water dredged spoil disposal site should be surveyed at regular intervals going forward. The surveys will serve two main purposes. First, they will identify if disposed dredged material has accumulated (mounded) to a degree a notice to mariners is required (as was the case when dredged material was disposed for the Berth 306 development). Second, they will identify areas where material dredged in future dredging campaigns should be preferentially disposed to ensure there is no mounding on the disposal site and to encourage dispersion of deposited sediment, so that the wave climate is not unduly affected.

Erosion or accretion patterns of the shoreline in the Richards Bay area should also be monitored, using satellite imagery/remote sensing, to identify if mitigation through beach nourishment more than that which occurs currently is required.

Impact 29: Bioaccumulation and biomagnification of noxious chemicals in disposed dredged material by biological resources

Impact description

The sediment that is dredged and soil and rock that is excavated for the development of Berth 605 will be disposed at the existing open water dredged spoil disposal site off the Richards Bay coast. Noxious chemicals in the sediment may be remobilised into the water column during disposal and will accumulate

on the seabed along with disposed sediment, from where they may be remobilised into the water column over time as the sediment is gradually eroded by currents. The noxious chemicals may be bioaccumulated by biological resources and enter the food web in the nearshore marine environment off the Richards Bay coast. The consequences will be the same as those outlined in Impact 21.

Impact significance assessment without mitigation

Toxicity testing showed that sediment and soil sampled in the Berth 605 development footprint was not toxic apart from the soil at one station, which showed a very low level of toxicity (see Section 5.1.9 and 5.1.11 of this specialist study; see also CSIR, 2024). Noxious chemicals were thus not released from the sediment and soil at a high enough concentration and/or in forms that caused toxicity to sensitive sea urchin embryos and larvae. Biological resources can only experience toxicity if noxious chemicals are in forms that can cross biological membranes, that is, in a bioavailable form. Although the toxicity testing results cannot be used to disprove that noxious chemicals remobilised from sediment will not be bioaccumulated by biological resources in the nearshore marine environment off the Richards Bay coast, the results of the testing suggest it is **improbable** they will be bioaccumulated to a high concentration. The magnitude is thus **very low**. Although the potential for this impact will persist until disposed dredged sediment is eroded from the dredged spoil disposal site, that is, over the **long-term**, it will be restricted to the **local** area and is **recoverable**. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

No mitigation is necessary considering the **VERY LOW** significance assessment for this impact without mitigation. However, it is good environmental practice to implement mitigation even in these circumstances. Recommended mitigation measures for this impact are thus outlined below.

- TNPA must secure a permit from the Department of Forestry, Fisheries and the Environment for the disposal of dredged material at an authorised dredged spoil disposal site off the Richards Bay coast. The sediment testing for the permit should include toxicity testing—see CSIR (2024) for recommended scope of analyses and testing.

Impact significance assessment with mitigation

The mitigation measures are unlikely to have a major effect on the impact significance, which remains **VERY LOW** with mitigation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Bioaccumulation and biomagnification of noxious chemicals by biological resources
Aspects affected	Aquatic biological resources, Ecological productivity, Human health
Stage	Construction
Character	Negative
Ease of mitigation	Easy
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Improbable
Significance without mitigation	Very low
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Improbable
Significance with mitigation	Very low
Confidence in assessment	High

Potential for cumulative effects

Capital dredging for the Berth 605 Project may, or will coincide with maintenance dredging and capital dredging for other planned infrastructure developments as outlined in the Port of Richards Bay Masterplan. An estimated 10 million m³ of material will need to be dredged for the development of Berths 207, 210, 709, 710, 802 and 803 (PRDW, 2024). It is likely that virtually all this material will be disposed at one or more open water dredged spoil disposal sites off the Richards Bay coast. Simultaneous dredging and dredged material disposal will magnify the impact of individual, temporally separated projects. Depending on the infrastructure developments that occur simultaneously and hence the volume of dredged material that is disposed simultaneously, the cumulative effect is likely to be low at most. If capital dredging campaigns do not overlap temporally, the prolonged (several years) impact on water quality, biological resources and ecological productivity is also likely to be low at most. This conclusion is based on toxicity testing of sediment sampled in the port over several years, which has shown an almost complete absence of sediment toxicity. Thus, while noxious chemical concentrations are high in sediment in some parts of the port earmarked for infrastructure development in the short-term, the chemicals are either not in a bioavailable form or if they are they are remobilised at such low concentrations that they do not cause toxicity even to sensitive sea urchin embryos and larvae.

To mitigate cumulative effects, capital dredging for the Berth 605 Project, maintenance dredging and capital dredging for other planned infrastructure developments should be scheduled to avoid temporal overlap to the extent practical, although maintenance dredging should not be delayed if this may pose a navigation hazard. If avoiding overlap is not feasible, a more detailed evaluation of cumulative effects and the identification of mitigation measures for dredging-related impacts for simultaneous infrastructure developments should be performed.

The operational Berth 605 will contribute to the degradation of biological resources through the increased need for maintenance dredging in the lengthened 600 Berth Basin.

Any noxious chemicals that are remobilised from the dredged material will contribute to the noxious chemical load introduced to the nearshore marine environment off the Richards Bay coast by the discharge of wastewater through the uMgeni-uThukela Water outfalls. The analysis of metal concentrations in fish caught near the wastewater discharge points has not revealed anomalously high concentrations in the fish apart from a few instances, but it is difficult to attribute this to wastewater discharge since the range of natural variability in the fish is not yet fully understood (CSIR, 2024).

Recommended environmental monitoring

No monitoring is necessary due to the **VERY LOW** significance assessment for this impact with and without mitigation.

Impact 30: Decrease in tidally influenced pool and related ecological value and productivity

Impact description

The small tidally influenced pool inland of the Assembly Basin provides unique, ecologically valuable and productive habitat in the Berth 605 Project development footprint (see Section 5.5 of this specialist study). The pool will be destroyed if Berth 605 is developed. The loss of the pool will result in the loss of a modestly sized stand of mangroves that fringe the pool and sediment and water habitat, all of which support a high abundance and species diversity of benthic and pelagic invertebrates and fish.

Impact significance assessment without mitigation

The loss of the small tidally influenced pool will have a **permanent, definite, local** impact on plant, invertebrate and fish populations in the Port of Richards Bay. However, because the absolute size of the

pool is small in comparison to other habitat in the port and will be compensated to some degree by the lengthened 600 Berth Basin, the magnitude of the population and ecological productivity loss is considered **medium**. The loss of the biological resources and ecological productivity is **irreversible** unless compensated for by similar habitat creation. The significance assessment for this impact without mitigation is thus **HIGH**.

Mitigation measures

- If feasible, similar habitat to that which currently exists in the small tidally influenced pool should be created—potentially in an area to the south of the existing pool—by excavating virgin land and ensuring there is a permanent tidal connection to the 600 Berth Basin through a channel. However, the final design should be based on the most feasible area for habitat creation. Ideally, the habitat should be larger than that of the existing tidally influenced pool.
- An effort should be made to relocate easily collected biological resources from the small tidally influenced pool to the extent possible. These biological resources would include large gastropods. Fish should also be forced from the pool to the extent possible before it is dredged. However, it will be impossible to collect most invertebrate biological resources, such as borrowing crabs and prawns, and swimming prawns.
- TNPA will need to secure a permit from the Department of Forestry, Fisheries and the Environment for the removal of mangroves fringing the small tidally influenced pool (and Assembly Basin). Although it is theoretically feasible to transplant adult mangroves, this will involve habitat disturbance at the transplant site with no certainty on success and is not recommended—the effort and costs would be better invested in creating similar habitat to that which currently exists in the small tidally influenced pool.

Impact significance assessment with mitigation

The loss of the small tidally influenced pool and related biodiversity and ecological productivity could be compensated for by creating a similar habitat adjacent to the lengthened 600 Berth Basin. However, there is currently no commitment in the Berth 605 Project for such compensation. Consequently, the significance assessment for this impact remains **HIGH**, but would be reduced to LOW if similar habitat were established as compensation.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Loss of tidally influenced pool and related ecological value and productivity
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Construction and Operational
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Medium
Extent	Local
Reversibility	Irreversible
Duration	Permanent
Probability	Definite
Significance without mitigation	HIGH
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Local
Reversibility	Irreversible
Duration	Permanent
Probability	Definite
Significance with mitigation	HIGH
Confidence in assessment	High

Potential for cumulative effects

The loss of the habitat in the small tidally influenced pool and related ecological productivity will add to the anticipated loss of mangrove and intertidal and shallow subtidal sediment habitat through short- and medium-term infrastructure developments outlined in the Port of Richards Bay Masterplan, including the development of Berths 207, 210, 709 and 710. Although the contribution of the Berth 605 development to the cumulative loss of this habitat and related ecological productivity will be small in the context of the other infrastructure developments, the ecological consequence of the cumulative loss for short- and medium-term infrastructure developments will be high to very high. Long-term infrastructure development in the port will, in contrast, result in a substantial gain in intertidal and shallow subtidal sediment habitat, and if properly designed, also in mangrove habitat. There will thus be a long-term increase in habitat for biological resources and ecological productivity of a potentially very high significance.

Recommended environmental monitoring

If similar habitat is created to compensate for the loss of the small tidally influenced pool, colonisation of the habitat by biological resources should be monitored over time to not only demonstrate that it has achieved the intended goal of creating ecologically valuable habitat, but as importantly as a guide to inform similar habitat creation that might be considered elsewhere in the port in future.

Impact 31: Ecological effects of a change in hydrodynamic functioning in the port

Impact description

The development of Berth 605 requires the lengthening of the 600 Berth Basin, by excavating into the land to the west of the basin. The larger area and water volume will alter hydrodynamic conditions in the basin. A change in hydrodynamic conditions can affect water and sediment quality by altering the residence time of water, that is, how long a water parcel, starting from a specified location, remains in a waterbody before exiting. Many ecological processes are also influenced by the residence time of water. Poor circulation combined with excessive nutrient loading, for example, can promote the development of microalgal blooms, with attendant adverse ecological impacts. Currents promote the ventilation of water with oxygen and influence the dilution and dispersion of contaminants. Low current speeds and stagnant water promote the settlement of particulate matter associated contaminants from the water column such that they accumulate on the bottom, potentially adversely affecting benthic biological resources.

The changes that might occur to the hydrodynamic functioning of the Port of Richards Bay through the development of Berth 605 are anticipated to be inconsequential (Roy van Ballegooyen (WSP), personal communication). Any changes that do occur are unlikely to materially alter the flushing potential in the 600 Berth Basin and consequently are not anticipated to result in any large-scale changes in water quality, sediment quality, or to alter sediment erosion and deposition patterns.

Impact significance assessment without mitigation

Any changes to the hydrodynamic functioning of the Port of Richards Bay because of the development of Berth 605 will have an **improbable, site only, low** magnitude, but **long-term** effect on water quality, sediment quality and biological resources. The significance assessment for this impact without mitigation is thus **VERY LOW**.

Mitigation measures

Mitigation measures for this impact are outlined below. Mitigation involves ensuring there are no impediments to water movement in the 600 Berth Basin.

- The dredged area must correspond to the dredging plans.
- The dredged footprint must avoid leaving indentations in the slopes leading to intertidal and shallow subtidal sandbanks and on the bottom of channels to avoid effects on currents that lead to altered

erosion or deposition.

- There must be no major indentations on the bottom that will alter current flows and affect erosion and deposition patterns, or trap water such that low dissolved oxygen concentrations develop.

Impact significance assessment with mitigation

If the mitigation measures are implemented, the significance assessment for this impact with mitigation will remain **VERY LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Ecological effects of a change in hydrodynamic functioning in the port
Aspects affected	Aquatic biological resources, Ecological productivity, Hydrodynamic processes
Stage	Operational
Character	Negative
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Irreversible
Duration	Long-term
Probability	Improbable
Significance without mitigation	VERY LOW
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Irreversible
Duration	Long-term
Probability	Improbable
Significance with mitigation	VERY LOW
Confidence in assessment	Medium

Potential for cumulative effects

It is impossible to estimate the cumulative effects of changes to the hydrodynamic functioning of the port by considering other planned infrastructure developments outlined in the Port of Richards Bay Masterplan since the plan may change as new information comes to the fore. Three dimensional-numerical modelling will be integral to understanding the potential implications of planned future developments on the hydrodynamic functioning of the port, and for understanding implications for water and sediment quality and biological resources. Long-term infrastructure development in the port will result in a substantial extension of the port, but with a narrow navigation channel and numerous dead-end basins. This has the potential to lead to a high residence time, with potentially significant implications for water and sediment quality and biological resources. It is recommended that TNPA commission a study to investigate the potential implications of progressive infrastructure development on the hydrodynamic functioning to identify if the plans should be modified to avoid 'dead water' conditions. Such studies have no bearing on the Berth 605 project, but this project will have a bearing on the studies. It is also recommended that TNPA commission a study on strategies for mitigating water and sediment quality degradation and for promoting ecological productivity by adopting working with nature principles in future infrastructure development.

Recommended environmental monitoring

Bathymetric surveys routinely performed in the Port of Richards Bay by TNPA to guide maintenance dredging requirements will inform on anomalous sediment deposition and erosion patterns.

Impact 32: Ecological effects of increased need for maintenance dredging and dredged sediment disposal

Impact description

The development of Berth 605 requires the lengthening of the 600 Berth Basin, by excavating into land to the west of the basin. As is the case in other parts of the Port of Richards Bay, it is inevitable that sediment will deposit and accumulate on the bottom in the lengthened basin over time and will require periodic maintenance dredging to allow the safe movement of vessels. The dredged sediment will need to be disposed at an open water dredged spoil disposal site off the Richards Bay coast. The environmental consequences of maintenance dredging and dredged sediment disposal will be the same as those that currently exist for maintenance dredging in the 600 Berth Basin, but will obviously be more intense since the dredging period will be longer and a larger volume of dredged sediment will need to be disposed at an open water dredged spoil disposal site off the Richards Bay coast.

Impact significance assessment without mitigation

The environmental consequences of a longer annual maintenance dredging period and increased volume of maintenance dredged sediment requiring disposal in open water will remain **site only** in spatial extent, **temporary** (water quality) to **short-term** (biological resources) in duration, both within the port and at the dredged spoil disposal site. The magnitude of ecological impacts related to the increased need for maintenance dredging and dredged sediment disposal will be **low**. The impact is **reversible** since benthic biological resources will recolonise the disturbed habitat. The significance assessment for this impact without mitigation is **LOW**.

Mitigation measures

- A permit from the Department of Forestry, Fisheries and the Environment for the open water dredged material disposal should be secured at the required intervals (currently permits are valid for 2 years).
- The dredging footprint must be restricted to the smallest area and depth possible (*i.e.* do not over dredge) to minimise the period over which environmental impacts may manifest.
- An environmental valve ('green valve') must be used in trailer suction hopper dredgers.
- There must be no overflow or leakage from hopper compartments during non-dredging transit between the 600 Berth Basin and dredged spoil disposal site off the Richards Bay coast.

Impact significance assessment with mitigation

The mitigation measures outlined above are currently implemented by TNPA dredgers and are thus assumed to be embedded mitigation. The significance assessment for this impact with mitigation thus remains **LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Ecological effects of increased maintenance dredging and dredged sediment disposal regimes
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Operational
Character	Positive
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Short-term
Probability	Definite
Significance without mitigation	LOW
Post-Mitigation Significance Assessment	
Magnitude	Low

IMPACT DESCRIPTION	ASSESSMENT
Extent	Site only
Reversibility	Reversible
Duration	Short-term
Probability	Definite
Significance with mitigation	LOW
Confidence in assessment	High

Potential for cumulative effects

Maintenance dredging for the lengthened 600 Berth Basin will invariably coincide with maintenance dredging elsewhere in the port, and with capital dredging for future infrastructure developments in the short-, medium-, and long-term as outlined in the Port of Richards Bay Masterplan if these developments are commissioned. The additional environmental effects contributed by maintenance dredging of the 600 Berth Basin are anticipated to be low.

Recommended environmental monitoring

TNPA must continue to secure a permit from the Department of Forestry, Fisheries and the Environment for the open water disposal of maintenance dredged sediment before maintenance dredging proceeds. The permit application requires information on sediment quality in the proposed dredging areas.

Impact 33: Gain in intertidal and subtidal sediment habitat

Impact description

The development of Berth 605 requires the lengthening of the 600 Berth Basin through the excavation of land to the west of the basin. The lengthened basin will result in a net gain in intertidal and subtidal sediment habitat in the Port of Richards Bay. The new intertidal and subtidal sediment habitat will be colonised and exploited by aquatic biological resources, which will contribute to the port's ecological productivity of the port. Deepwater sediment habitat, which will account for the largest gain in sediment habitat, was classified by the CSIR (2005) as the least ecologically valuable habitat in the port. Intertidal beach habitat was identified as the second least ecologically valuable habitat. Macrocrustacea and especially juvenile fish show a greater dependency on shallow sandbanks and mudflats compared to deepwater basins. Although the intertidal and shallow subtidal sediment habitat will offer some benefit to macrocrustacea and juvenile fish, the intertidal area will have the same morphology as the intertidal habitat that currently exists in the 600 Berth Basin. In other words, the intertidal and shallow subtidal sediment habitat will be narrow, especially at low tide, due to the sharp drop-off into deeper water. The habitat will thus hold less value for macrocrustacea and juvenile fish than other types of shallow water habitat in the port since these biological resources will be highly exposed to predators at low tide. Additionally, the steep slope means wind driven waves will impact with a high energy on the shoreline, preventing the accumulation of fine-grained sediment and potentially render the habitat unstable for some biological resources. Nevertheless, Cyrus and Vivier (2014, 2021) and Malan *et al.* (2023) recorded a reasonable species diversity, although generally low abundance, of macrocrustacea and fish in the 600 Berth Basin, although this was largely in the more sheltered Assembly Basin. Therefore, while the habitat will not be devoid of ecological value, it may not be of a particularly high ecological importance.

Impact significance assessment without mitigation

The gain in intertidal and subtidal sediment habitat will have **definite, long-term, positive** impact on the ecological productivity and functioning of the Port of Richards Bay. It is difficult to estimate if the gain will compensate for the loss of similar habitat in the small tidally influenced pool inland of the Assembly Basin—which provides ecologically highly valuable and productive habitat—and in the Assembly Basin. The subtidal sediment habitat will also be susceptible to contaminant accumulation—including coal particles and dust—and will be disturbed by vessel propeller wash and maintenance dredging, degrading its value for biological resources. The contribution of biological resources that colonise the new intertidal and subtidal sediment

habitat to the ecological productivity and functioning of the port is thus considered **very low** in magnitude and to affect the **local** environment in the port. The significance assessment for this impact without mitigation is thus **LOW**.

Mitigation measures

- The ecological value of the intertidal habitat in the expanded 600 Berth Basin to macrocrustaceans and fish can be enhanced by ensuring it has a shallow slope and by creating habitat complexity by excavating small, shallow, but permanently inundated channels extending from the water's edge toward the land.
- If possible, the intertidal area should be as wide as possible, to create habitat for benthic biological resources and birds.

Impact significance assessment with mitigation

No commitment has yet been made to modifying intertidal sediment habitat in the lengthened 600 Berth Basin to improve its ecological value. The significance of this impact will thus remain **LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Gain in intertidal and subtidal sediment habitat
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Operational
Character	Positive
Ease of mitigation	Moderate
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-
Duration	Long-term
Probability	Very likely
Significance without mitigation	LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-
Duration	Long-term
Probability	Very likely
Significance with mitigation	LOW
Confidence in assessment	Medium

Potential for cumulative effects

There will be a considerable loss in intertidal and subtidal sediment habitat in the short- and medium-term in the Port of Richards Bay if infrastructure developments outlined in the Port of Richards Bay Masterplan are commissioned. The intertidal sediment habitat created through the lengthening of the 600 Berth Basin will be lost over time since the southern shore of the basin is identified for future infrastructure development. The cumulative contribution of intertidal and subtidal sediment habitat gain due to the development of Berth 605 will thus be high in the short- to medium-term as it will compensate for some of the losses that will accompany other short- to medium-term planned infrastructure developments.

Recommended environmental monitoring

It is not necessary to monitor the colonisation of sediment in the lengthened 600 Berth Basin by benthic biological resources since the colonisation of newly dredged/exposed sediment is well documented in the scientific literature and, importantly, is known for the Port of Richards Bay—including the 600 Berth Basin when it was developed. There is thus no doubt that benthic biological resources will colonise the sediment. However, monitoring benthic biological resource colonisation of subtidal sediment in the lengthened basin will provide valuable insights into colonisation rates that can be used to inform on the environmental

impacts of capital dredging campaigns for other planned infrastructure developments in the port that involve the development of new habitat. A properly planned and executed monitoring programme can thus eliminate the need for certain types of monitoring for future infrastructure development projects.

Impact 34: Gain in hard substrate habitat

Impact description

The construction of Berth 605 will result in the gain in hard substrate (quay wall, rip rap) habitat in the Port of Richards Bay. The new habitat will be exploited by aquatic biological resources such as barnacles, oysters and sponges. The biological resources that colonise existing hard substrates in the port are usually found on rocky substrates in the marine environment. These biological resources are usually not found in estuaries for various reasons, including the general absence of hard substrate in estuaries and their inability to tolerate the variable salinity regimes that usually characterise these systems—many marine biological resources are stenohaline. They can exploit hard substrate habitat in the Port of Richards Bay because of the stable water column salinity, which approximates that of seawater.

Impact significance assessment without mitigation

The ecological value of artificial hard substrate in ports that are developed in estuaries is usually not rated highly since it usually entails the loss of more ecologically valuable estuarine sediment and vegetation. Hard substrate in the form of quay walls holds little ecological value to South African estuarine biological resources since this substrate is not common in estuaries. Few estuarine biological resources have thus evolved to colonise hard substrates—some (*e.g.* oysters) do nonetheless use mangrove trees stems and prop-roots as a substrate. The biological resources that will colonise the Berth 605 quay wall and western shore rip-rap revetment will make a **very likely, long-term** contribution to the ecological productivity of the Port of Richards Bay. The gain in ecological productivity is a **positive** environmental impact. It is difficult to estimate the impact and magnitude of the gain in ecological productivity. The biological resources are, however, anticipated to make a **very low** magnitude contribution in the **local** port environment. The significance assessment for this impact without mitigation is thus **LOW**.

Mitigation measures

- Various engineering interventions can be used to improve the ecological/habitat value of artificial hard substrates in ports. These include roughening the surface of quay walls and providing artificial habitat that simulates rock pool environments.

Impact significance assessment with mitigation

As stated above, several engineering interventions can be used to improve the habitat/ecological value of artificial hard substrates in ports. These have not gained traction in South Africa, and indeed in many parts of the world, probably due to financial considerations. However, where implemented such interventions have been shown to sustain a high biodiversity. No habitat improving engineering interventions are included in the Berth 605 Project design. The significance assessment for this impact with mitigation thus remains **LOW**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Gain in hard substrate (quay wall) habitat
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Operational
Character	Positive
Ease of mitigation	Difficult
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-

IMPACT DESCRIPTION	ASSESSMENT
Duration	Long-term
Probability	Very likely
Significance without mitigation	LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-
Duration	Long-term
Probability	Very likely
Significance with mitigation	LOW
Confidence in assessment	High

Potential for cumulative effects

There will be a considerable increase in the amount of hard substrate—largely quay wall—habitat in the Port of Richards Bay in the short-, medium- and long-term if planned infrastructure developments outlined in the Port of Richards Bay Masterplan are commissioned. The gain in hard substrate habitat through the lengthening of the 600 Berth Basin will make a small contribution toward the gain in this habitat type and related ecological productivity in the port. As stated above, although hard substrate habitat is not particularly valued habitat in an estuarine context, it is not devoid of ecological value.

Recommended environmental monitoring

There is no specific requirement to monitor the colonisation of the Berth 605 quay wall and the rip-rap rock revetment by biological resources, as this process is well documented in the scientific literature. Importantly, it is already known for the Port of Richards Bay—including the 600 Berth Basin—that aquatic biological resources readily colonise new quay walls and other hard substrata. It is, therefore, predictable that biological resources will similarly colonise the Berth 605 quay wall and associated hard substrata created by the development. This said, periodic surveys for non-native (alien) species should be considered since hard substrate is a preferred habitat for many such species. At least 12 non-native species are known from hard substrates in the Port of Richards Bay (Peters *et al.*, 2017). TNPA has commissioned surveys for non-native species in the Port of Richards Bay in the past. Berth 605 should be considered for inclusion in future surveys.

Impact 35: Gain in open water habitat

Impact description

The development of Berth 605 will require the lengthening of the 600 Berth Basin by excavating land to the west of the existing 600 Berth Basin. The lengthened basin will result in a gain in open water habitat of ~80 000 m² that will be used by pelagic biological resources, such as phytoplankton, zooplankton and fish. The consequent increase in the population sizes of these biological resources will contribute to the ecological functioning and productivity in the Port of Richards Bay.

Impact significance assessment without mitigation

The gain in open water habitat will represent a positive environmental impact. It is difficult to estimate the extent to which biological resources that will exploit the new open water habitat will contribute to the ecological productivity of the Port of Richards Bay. The CSIR (2005) classified open water habitat as one of the least ecologically important habitats in the port. However, the habitat rating was not based on the consideration of holo- and meroplankton, which are likely to derive the most benefit of the new habitat. Consequently, while biological resources that exploit the habitat will make a **very likely, long-term**, but probably **very low** magnitude contribution to the ecological productivity in the **local** port environment. The significance assessment for this impact without mitigation is thus **LOW**.

Mitigation measures

- None—mitigation measures to protect water and sediment quality during the operational phase due to other impacts will protect the value of the open water habitat for aquatic biological resources.

Impact significance assessment with mitigation

Little can be done to directly enhance the ecological value of open water habitat apart from mitigation measures that protect and promote good water and sediment quality. Mitigation measures in this context are outlined in other environmental impacts in this specialist study. The impact significance assessment for this impact with mitigation will remain **LOW**, but if water and sediment quality is not protected will be VERY LOW.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Gain in open water habitat
Aspects affected	Aquatic biological resources, Ecological productivity
Stage	Operational
Character	Positive
Ease of mitigation	
Pre-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-
Duration	Long-term
Probability	Very likely
Significance without mitigation	LOW
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Local
Reversibility	-
Duration	Long-term
Probability	Very likely
Significance with mitigation	LOW
Confidence in assessment	Moderate

Potential for cumulative effects

There will be a considerable decrease in the amount of open water habitat in the Port of Richards Bay in the short- and medium-term if infrastructure developments outlined in the Port of Richards Bay Masterplan are commissioned. However, there will be a large increase in open water habitat if the long-term plans are commissioned. The gain in open water habitat through the lengthening of the 600 Berth Basin will make a minor contribution toward compensating cumulative losses of open water habitat in the short- and medium-term.

Recommended environmental monitoring

It is not necessary to monitor planktonic and pelagic biological resources that will exploit open water habitat in the lengthened 600 Berth Basin—other indicators are likely to provide a more reliable measure of impacts than often variable planktonic communities.

Impact 36: Increased load of contaminants introduced into the port by surface runoff

Impact description

Surface (stormwater) runoff from hardstand and other impervious surfaces constructed for Berth 605 and the Container Handling Facility will be directed into the Port of Richards Bay, providing a pathway into the port for contaminants in the broadest sense arising from general port operations that deposit on the hardstand and impervious surfaces. The contaminants may arise from spillages and leaks from vehicles, trucks and cranes, rusting and decaying infrastructure, and bulk product spillages on quays amongst other sources. Potential pollutants include hydrocarbons, metals and particulate material. If coal exports

continue at neighbouring berths in the 600 Berth Basin, then it is inevitable windblown coal dust will deposit on hardstand and other impervious surfaces at Berth 605 and the Container Handling Facility and will then be transported into the port by surface runoff. Windblown coal dust is presently effectively trapped by vegetation and soil in the land part of the Berth 605 Project footprint.

Contaminants introduced to the port by surface runoff from hardstand and other impervious surfaces will degrade water and sediment quality in the port and may adversely affect biological resources. A surface runoff discharge point (outfall) at the point where Berths 609 and 701 meet in the 700/800 Berth Basin is known to introduce contaminants into the port, which have impacted on water and sediment quality and biological resources in that area. The impact is evident in often-higher concentrations of certain nutrients and metals in the water column in that area compared to other parts of the port, and sediment in that area being a hotspot for certain metals and polycyclic aromatic hydrocarbons (see for example Figure 57).

Impact significance assessment without mitigation

It is difficult to estimate the contribution that contaminants introduced into the port aquatic environment via surface runoff from hardstand and other impervious surfaces at Berth 605 and the Container Handling Facility will make to water and sediment quality and biological resource impairment. The berth and Container Handling Facility will handle containers, which are not a major source of contaminants themselves unless they contain hazardous materials that spill, but container handling will involve the use of straddle carriers and cranes amongst other equipment that may be a contaminant source (*e.g.* oil leaks). Surface runoff from the operational Berth 605 and Container Handling Facility is anticipated to have a **very likely, long-term**, but **low** magnitude and **site-only** impact on water and sediment quality and biological resource impairment. The impact will be somewhat recoverable if mitigation is implemented and contaminants that accumulate in sediment will be periodically removed by maintenance dredging. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

- Include engineering designs in quay to trap suspended particulate matter and hazardous substances in surface runoff—or at least the first flush event—so this matter does not enter the port’s aquatic environment.
- Wherever possible use pervious paving to trap accumulated particulate matter and contaminants, although it is acknowledged that this might not be possible due to the surface of the quay needing to support a large weight that is beyond the capacity of such paving. However, it could be used on pedestrian walkways and small vehicle parking areas.
- Ensure quay and other impervious surfaces are regularly cleaned to limit the mobilisation of accumulated particulate matter and contaminants into the port by surface runoff. The material should be discarded at a landfill.
- Hydrocarbons, hydraulic fluids and so on that may be leaked from quayside equipment and machinery should be cleaned up timeously. Standard Operating Procedures for spill cleanup should be defined, and spill cleanup kits should be available at the quayside and Container Handling Facility.

Impact significance assessment with mitigation

The Berth 605 stormwater reticulation system design does not include engineering designs for the retention of particulate matter and hazardous substances that may be washed from hardstand and other impervious surfaces into the port aquatic environment by surface runoff. This and the fact that existing ‘housekeeping’ practices at neighbouring berths in the 600 Berth Basin do not effectively control the deposition of particulate matter on the quay surfaces and there are no apparent short-term plans for changes to these practices means the significance assessment for this impact will remain **MODERATE**.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Increased load of contaminants introduced into the port by surface runoff
Aspects affected	Water quality, Sediment quality, Aquatic biological resources, Ecological productivity
Stage	Operational
Character	Negative
Ease of mitigation	Easy
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Very likely
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Very likely
Significance with mitigation	MODERATE
Confidence in assessment	High

Potential for cumulative effects

There will be a considerable increase in hardstand and impervious surface cover in the Port of Richards Bay over the short-, medium- and long-term if the infrastructure developments outlined in the Port of Richards Bay Masterplan are commissioned. Contaminants introduced via surface runoff from hardstand and other impervious surfaces constructed for Berth 605 and the Container Handling Facility will add to the quantity of contaminants introduced via surface runoff and other pathways elsewhere in the port, contributing to water and sediment quality degradation, biological resource impairment, and a decline in ecological productivity. It is difficult to assess the cumulative effect save to state that surface runoff is regarded as one of the most important pathways for a very wide range of contaminants into the aquatic environment in ports. Future developments should thus include new approaches for managing these contaminants, such as pervious walkways and parking areas and vegetated swales where possible.

Recommended environmental monitoring

The physical and chemical properties of surface runoff from Berth 605 and the Container Handling Facility should be periodically monitored (e.g. quarterly basis) for contaminants that might arise from port related activities and sources. The results should be used to determine if additional mitigation and source control are required to reduce the amount of contaminants entering the port aquatic environment.

Impact 37: Introduction of artificial light into port aquatic environment

Impact description

Artificial light at night is known to have several, largely negative, consequences for aquatic biological resources (including waterbirds), although quantitative studies on invertebrates and fish are limited. The body of information is, however, growing rapidly. The impacts of artificial light principally involve a disruption to the natural circadian rhythm—or light-dark body clock—of biological resources and their disorientation by, or attraction to artificial light. Some species of zooplankton and small-bodied shoaling fish are attracted to artificial light and then become susceptible to intensified predation by other fish, creating the potential for the unnatural top-down regulation of fish populations (Becker *et al.*, 2013; Davis *et al.*, 2014). The use of artificial light to aggregate fish and squid near commercial fishing vessels is based on their or their prey's attraction to artificial light. Artificial light suppresses the diel migration of certain zooplankton, which usually remain in deeper waters in the day to avoid visual predators and ascend to feed at night under the cover of dark. Altered diel migration patterns affect the feeding of the zooplankton

(Ludvigsen *et al.*, 2018). Other examples of artificial light effects include altering the activity and circadian rhythm of intertidal isopods (Duarte *et al.*, 2019) and the shoreline migration and homing of certain intertidal (talitrid) amphipods (Torres *et al.*, 2020).

However, biological resources are not universally adversely affected by artificial light. The benefit that some predatory fish may experience was mentioned above, albeit through artificial light. Artificial light has also been shown to accelerate the development and metamorphosis of shellfish larvae (Zhang *et al.*, 2023). There appears to be no evidence that adult marine megafauna, including mammals, are attracted to artificial light. However, turtle hatchlings are known to be disoriented by artificial light, causing them to move away from the sea on which they depend and may lead to their death or increased predation (Kamrowski *et al.*, 2012).

The operation of Berth 605 and related quayside and Container Handling Facility infrastructure will increase the amount of artificial light that is cast at night onto the water surface in the Port of Richards Bay (Figure 130). The artificial light will be cast by, amongst other sources, lighting on large vessels alongside the quay, from quayside lights, and from vehicles and other general lighting sources (*e.g.* offices). Dredging vessels and safety lighting at the construction site will also cast artificial light at night during the construction phase for the Berth 605 Project, but this will be short-lived in comparison to operational phase lighting and is not considered as other impacts during the construction phase will have more significant impacts on the aquatic environment. Dredging and/or dredging support vessels in transit to the dredged spoil disposal site off the Richards Bay coast at night are likely to only display navigation lights, but may turn on additional lighting at the disposal site to ensure the dredged material is properly cleared from hoppers/holds. Relatively slow-moving plankton, fish and squid would be unable to maintain position alongside such a moving vessel and are unlikely to be significantly attracted if lights are turned on during the fairly short disposal period at the dredged spoil disposal site. The impact of artificial light during dredged spoil disposal is thus also not considered significant. Also not considered is the effect of artificial light on birds since this is dealt with in a separate specialist study for the Berth 605 Project.



Figure 130. Artificial light cast into the Port of Richards Bay at night (Photo: Bronwyn MacCallum).

Impact significance assessment without mitigation

To the best of the knowledge of the CSIR scientists that prepared this specialist study, there have been no studies on the influence of artificial light on aquatic biological resources in the Port of Richards Bay—nor indeed in any other South African port. It is difficult to estimate the ecological impact of artificial light related to the Berth 605 Project in the absence of light illuminance measurements and documented responses of biological resources in the port to artificial light. Based on the scientific literature and magnitude of the Berth 605 development, however, a **very likely, long-term**, but **site only** and **low** magnitude impact on non-avian aquatic biological resources is anticipated. The significance assessment for this impact without mitigation is thus **MODERATE**.

Mitigation measures

Mitigation measures for some artificial light sources on the quayside is relatively easy, but for work safety reasons may be difficult for other light sources. If feasible, mitigation measures could include:

- Directional lighting that faces away from the port's aquatic environment.
- Light shielding to direct lighting downward to the quay surface.
- Limiting lighting that is not essential for safety purposes at night to times when it is required (*e.g.* when a vessel is being loaded/offloaded).
- Using blackout blinds on office windows.
- The crew of dredging and/or dredging support vessels must keep a lookout for and document the presence of megafauna that might be attracted to the vessels when artificial lights are turned on during dredged material disposal at the dredged spoil disposal site off the Richards Bay coast.

Impact significance assessment with mitigation

If the mitigation measures are implemented, the magnitude of this impact could be reduced to **LOW**. However, the confidence in this assessment is low.

IMPACT DESCRIPTION	ASSESSMENT
Potential impact	Introduction of artificial light to port aquatic environment
Aspects affected	Ambient light environment, Aquatic biological resources, Ecological productivity
Stage	Operational/Construction
Character	Negative
Ease of mitigation	Easy/Difficult
Pre-Mitigation Significance Assessment	
Magnitude	Low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Very likely
Significance without mitigation	MODERATE
Post-Mitigation Significance Assessment	
Magnitude	Very low
Extent	Site only
Reversibility	Reversible
Duration	Long-term
Probability	Very likely
Significance with mitigation	LOW
Confidence in assessment	Low

Potential for cumulative effects

Operations at Berth 605 will add to the quantity of artificial light that is cast into the aquatic environment in the Port of Richards Bay (Figure 130) and to that which will be cast when future infrastructure developments outlined in the Port of Richards Bay Masterplan are commissioned. Sensitive biological resources will invariably be affected by the increase in artificial light, but assessing the cumulative effect is

difficult due to lack of information on existing artificial light impacts in the port. Nevertheless, in the medium- to long-term artificial light impacts will probably be of a moderate significance for non-avian aquatic biological resources.

Recommended environmental monitoring

None. Environmental monitoring of artificial light in the Port of Richards Bay is difficult since there are no control sites for comparative purposes because artificial lights on quays and vessels are not turned off at night for safety reasons. However, the effects of artificial light mitigation that might be implemented on existing quays would provide information on the benefits of mitigation in the port—again acknowledging that turning off lights may be a challenge in an operational port for safety reasons.

TNPA might wish to encourage academic research on the effects of artificial light in the port, if not necessarily replicating that on quaysides (*e.g.* performed from small research boats), so that an appreciation of this impact can be developed. However, the research is not a necessity for the approval of the Berth 605 Project.

8. Conclusions and Recommendations

8.1 Environmental impact statement

The Berth 605 Project in the Port of Richards Bay is needed to provide a dedicated container handling facility in the port. Development of the berth will require an extensive capital dredging campaign that will result in the temporary removal and remodification of sediment habitat in the project footprint, including ecologically important intertidal and shallow subtidal sediment habitat. However, the project will result in a net gain in estuarine habitat since it entails the excavation of land near the existing 600 Berth Basin to accommodate the new berth.

The development of Berth 605 will have unavoidable impacts on the biophysical environment within the Port of Richards Bay and in the adjacent marine environment through the disposal of dredged material. A total of 37 potential environmental impacts associated with the project were identified. Thirteen of these were scoped out from detailed assessment either because they are considered relatively easy to manage or because they cannot be adequately assessed with the currently available information (Table 3). Of the remaining 24 impacts, nine are anticipated to be of a **VERY LOW**, five of a **LOW**, nine of a **MEDIUM** and one of **HIGH** environmental significance. No environmental fatal flaws were identified in relation to estuarine and marine ecology. Although most of the identified impacts will have negative consequences for the biophysical environment, three will have positive (beneficial) consequences. The negative consequences can be mitigated to an acceptable degree if proposed or other effective mitigation measures are implemented. In the case of the three positive impacts, appropriate measures could enhance their ecological benefit.

TNPA has outlined infrastructure development plans for the Port of Richards Bay in the short-, medium- and long-term. These include a substantially larger port footprint in the existing estuarine area in the short- and medium term (present through to 2052), and a much larger extension of the port (estuarine area) through expansion inland in the longer-term. Any proposal for port expansion is associated with concerns and uncertainties on what the future state of the estuarine environment will be, and on the loss of ecological goods and services. This situation will not change unless there are plans in place to identify expansion plans that have commitments to protect and sustain ecological processes and biodiversity.

The Port of Richards Bay presents an interesting case since, as mentioned above, the long-term development plan for the port will witness a major gain in estuarine habitat. However, in the short- to medium-term there will be a substantial decrease in ecologically valuable habitat and related ecological

functioning—the primary goal should be to ensure that as much of the habitat diversity, habitat area, and ecological productivity is maintained until long-term plans are implemented, and then to ensure that the long-term plans add ecologically valuable and functional habitat.

8.2 Environmental impact mitigation

Mitigation of the impacts that were assessed as being of a medium, and high environmental significance will be necessary to minimise disturbance to ecological, commercial, and social receptors, or in the case of beneficial impacts to enhance their outcomes to the degree possible. An important mitigation measure, if feasible, is the compensation of ecologically valuable and productive habitat in the small tidally influenced pool connected indirectly to the 600 Berth Basin. Equivalent, or similar habitat could potentially be created along the south-southwestern part of the lengthened 600 Berth Basin by excavating into the surrounding land during the development of Berth 605. However, there are other potential areas where compensatory habitat could be created—the feasibility of habitat compensation is currently being investigated by TNPA. Ideally, the compensatory habitat should cover a larger area than the existing tidally influenced pool. Provided the excavated area is of a depth that it does not drain dry at low tide and there is a permanent tidal connection to the 600 Berth Basin, there is every reason to believe the compensatory habitat would be similarly colonised by mangroves and other biological resources over time and would make as important an ecological contribution per unit area to the port as the existing tidally influenced pool. If habitat compensation is feasible, the impact identified as being of a high significance will be reduced to low.

8.3 Environmental monitoring recommendations

The capital dredging required for the proposed Berth 605 Project will impact on biological resources in the Port of Richards Bay and in the marine environment off the Richards Bay coast. The impacts will occur directly through the physical destruction and modification of habitat and indirectly through the impairment of water and sediment quality and the displacement of biological resources from habitat and food resources. Unless managed, some of the identified environmental impacts will be significant. The monitoring of environmental impacts during and after dredging has ceased is thus recommended. The purpose here is not to provide a sampling design for the environmental monitoring programme as this will be formulated as part of the Environmental Monitoring Plan. Rather, the purpose is to highlight those components of the natural environment the CSIR scientists that prepared this report consider the most important and to caution against common approaches to monitoring for such projects in South Africa. A common approach is to monitor an extensive suite of water, sediment and biological indicators in and near the dredging footprint and dredged spoil disposal site. Although there is nothing inherently wrong with a wide-ranging and comprehensive monitoring approach, the outcomes and management benefits of the monitoring are frequently not realised. One of the main challenges in monitoring dredging operations in estuaries is the inherent biophysical variability in these systems, which has the potential to obfuscate the detection of impacts that can be attributed to dredging projects alone unless the sampling design is properly formulated. The scientists that prepared this report thus recommend the monitoring programme focus on key physical, chemical and/or biological indicators that will provide clear evidence for impacts rather than monitoring for a wide range of indicators in the hope some will reveal an impact. Important here is to consider that certain chemical and especially biological indicators require several days to weeks to analyse. While this information might inform future dredging operations, it does little to inform or manage dredging operations in real time. For purposes of operational management, the focus should be on indicators that can be measured in real time, notably total suspended solids via turbidity. Thresholds for sensitive environmental areas need to be established to manage dredging and dredged spoil disposal impacts.

Table 3. Summary of environmental impacts that might or will arise if the Berth 605 Project proceeds and their significance assessment with and without mitigation.

Impact	Impact description	Without mitigation	With mitigation
1	Entry of non-hazardous solid waste from dredging, construction and support vessels	Screened out	
2	Entry of non-hazardous solid waste from construction sites on land	Screened out	
3	Entry of hazardous substances into the port due to spills, leaks and discharges from dredging, construction and support vessels	Screened out	
4	Entry of hazardous substances into the port due to spills and leaks at construction sites on land	Screened out	
5	Entry of construction material and demolition debris into the port	Screened out	
6	Navigation hazard posed by dredging, construction and support vessels	Screened out	
7	Marine megafauna strikes by dredging, construction and support vessels	Screened out	
8	Introduction of non-native aquatic biological resources	Screened out	
9	Increased vessel traffic	Screened out	
10	Noise from dredging, construction and support vessels	Screened out	
11	Underwater construction noise	Screened out	
12	Increased operational noise	Screened out	
13	Loss of recreation and tourism opportunities	Screened out	
14	Decrease in aquatic ecological function and productivity due to the physical disturbance, injury and displacement of benthic biological resources by dredging	N3 - Moderate	N3 - Moderate
15	Decrease in aquatic ecological function and productivity due to a deterioration in water quality related to increased suspended sediment concentrations and related turbidity during dredging	N3 - Moderate	N3 - Moderate
16	Decrease in aquatic ecological function and productivity in subtidal habitats due to the deposition of sediment resuspended by dredging	N3 - Moderate	N3 - Moderate
17	Decrease in aquatic ecological function and productivity in intertidal habitats due to the deposition of sediment resuspended by dredging	N3 - Moderate	N3 - Moderate
18	Remobilisation of oxygen depleting substances from sediment during dredging	N2 - Low	N2 - Low
19	Nutrient remobilisation from sediment/soil during dredging	N1 - Very Low	N1 - Very Low
20	Remobilisation of noxious substances from sediment/soil during dredging	N1 - Very Low	N1 - Very Low
21	Bioaccumulation and biomagnification of noxious chemicals remobilised from sediment by biological resources	N1 - Very Low	N1 - Very Low
22	Deterioration in water quality related to increased suspended sediment concentrations during dredged spoil disposal	N3 - Moderate	N3 - Moderate
23	Remobilisation of oxygen depleting substances from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
24	Remobilisation of nutrients from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
25	Remobilisation of noxious substances from sediment during dredged spoil disposal	N1 - Very Low	N1 - Very Low
26	Deterioration in sediment quality on dredged spoil disposal site due to the disposal of contaminated dredged material	N1 - Very Low	N1 - Very Low
27	Physical disturbance of benthic biological resources by disposed dredged material	N3 - Moderate	N3 - Moderate
28	Change in hydrodynamic conditions due to accumulation of dredged material at dredged spoil disposal site	N3 - Moderate	N3 - Moderate
29	Bioaccumulation and biomagnification of noxious chemicals in disposed dredged material by biological resources	N1 - Very Low	N1 - Very Low
30	Loss of tidally influenced pool and related ecological value and productivity	N4 - High	N4 - High
31	Ecological effects of a change in hydrodynamic functioning in the port	N1 - Very Low	N1 - Very Low

Impact	Impact description	Without mitigation	With mitigation
32	Ecological effects of increased need for maintenance dredging and dredged sediment disposal	N3 - Moderate	N3 - Moderate
33	Gain in intertidal and subtidal sediment habitat	P2 - Low	P2 - Low
34	Gain in hard substrate habitat	P2 - Low	P2 - Low
35	Gain in open water habitat	P2 - Low	P2 - Low
36	Increased load of contaminants introduced into the port by surface runoff	N3 - Moderate	N3 - Moderate
37	Introduction of artificial light into port aquatic environment	N3 - Moderate	N2 - Low

9. Literature Cited

- Adams, J.B., 2016. Distribution and status of *Zostera capensis* in South African estuaries - A review. South African Journal of Botany 107, 63-73.
- Allan, D.G., 2009. Port of Richards Bay, Richards Bay Bayside Container Project (RBBCP) studies to be conducted in the Port of Richards Bay, KwaZulu-Natal. Unpublished report to ACER (Africa).
- Allsopp, M., Walters, A., Santillo, D., Johnston, P., 2006. Plastic debris in the world's oceans. World 43.
- Alsterberg, C., Sundbäck, K., Larson, F., 2007. Direct and indirect effects of an antifouling biocide on benthic microalgae and meiofauna. Journal of Experimental Marine Biology and Ecology 351, 56-72.
- Anchor QEA, 2003. Literature review of effects of resuspended sediments due to dredging operations. Prepared for Los Angeles Contaminated Sediments Task Force, Los Angeles, CA.
- Appleby, J.A., Scarratt, D.J., 1989. Physical effects of suspended solids on marine and estuarine fish and shellfish, with special reference to ocean dumping: A literature review. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1681.
- Atkins, S., Cantor, M., Pillay, N., Cliff, G., Keith, M., Parra, G.J., 2016. Net loss of endangered humpback dolphins: integrating residency, site fidelity, and bycatch in shark nets. Marine Ecology Progress Series 555, 249-260.
- Atkins, S., Pillay, N., Peddemors, V.M., 2004. Spatial Distribution of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) at Richards Bay, South Africa: Environmental. Aquatic Mammals 30, 84-93.
- Atkins, S., Pillay, N., Peddemors, V.M., 2004. Spatial distribution of Indo-Pacific humpback dolphins (*Sousa chinensis*) at Richards Bay, South Africa: environmental influences and behavioural patterns. Aquatic Mammals 30, 84-93.
- Atkinson, C., Jolley, R., Simpson, S., 2007. Effect of overlying water pH, dissolved oxygen, salinity and sediment disturbances on metal release and sequestration from metal contaminated marine sediments. Chemosphere 69, 1428-37.
- Atkinson, C.A., Jolley, D.F., Simpson, S.L., 2007. Effect of overlying water pH, dissolved oxygen, salinity and sediment disturbances on metal release and sequestration from metal contaminated marine sediments. Chemosphere 69, 1428-1437.
- Baird, R.B., Smith, R.K., 2002. Third century of biochemical oxygen demand. Virginia: Water Environment Federation.
- Balistreri, L.S., Murray, J.W., 1983. Metal solid interactions in the marine environment: Estimating apparent equilibrium binding constants. Geochimica et Cosmochimica Acta 47, 1019.
- Barlow, R., Kyewalyanga, M., Sessions, H., van den Berg, M., Morris, T., 2008. Phytoplankton pigments, functional types, and absorption properties in the Delagoa and Natal Bights of the Agulhas ecosystem. Estuarine, Coastal and Shelf Science 80, 201-211.
- Bash, J., Berman, C., Bolton, S., 2001. Effects of turbidity and suspended solids on salmonids. Washington State Transportation Center (TRAC) Report No. WA-RD 526.1, Olympia, WA. USA.
- Becker, A., Whitfield, A.K., Cowley, P., Jarnegren, J., Næsje, T.F., 2013. Potential effects of artificial light associated with anthropogenic infrastructure on the abundance and foraging behaviour of estuary associated fishes. Journal of Applied Ecology 50, 43-50.
- Beckley, L.E., van Ballegooyen, R.C., 1992. Oceanographic conditions during three ichthyoplankton surveys of the Agulhas Current in 1990/91. South African Journal of Marine Science 12, 83-93.
- Begg G.W., 1978. The Estuaries of Natal. Natal Town and Regional Planning Report 41, 1-657.
- Begg G.W., 1984. The Estuaries of Natal (Part II). Natal Town and Regional Planning Report 55, 1-631.
- Bender, M.E., Roberts, M.H., de Fur, P.O., 1987. Unavailability of polynuclear aromatic hydrocarbons from coal particles to the eastern oyster. Environmental Pollution 44, 243-260.
- Benitez-Polo, Z., Velasco, L., 2020. Effects of suspended mineral coal dust on the energetic physiology of the Caribbean scallop *Argopecten nucleus* (born, 1778). Environmental Pollution 260, 114000.
- Berry, K.L., Hoogenboom, M.O., Flores, F., Negri, A.P., 2016. Simulated coal spill causes mortality and

- growth inhibition in tropical marine organisms. *Scientific Reports* 6, 25894.
- Berry, W., Rubinstein, N., Melzian, B., Hill, B., 2003. The biological effects of suspended and bedded sediment (SABS) in aquatic systems: A review. United States Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Laboratory, Atlantic Ecology Division, Narragansett, RI, USA.
- Best, P.B., Peddenmors, V. M., Rice, N., 2001. Mortalities of right whales and related anthropogenic factors in South African waters, 1963-1998. *Journal of Cetacean Research and Management*, 2, 171-176.
- Blaber, S.J.M., Blaber, T.G., 1980. Factors affecting the distribution of juvenile estuarine inshore fish. *Journal of Fish Biology* 17, 143-162.
- Bocchetti, R., Fattorini, D., Pisanelli, B., Macchia, S., Oliviero, L., Pilato, F., Pellegrini, D., Regoli, F., 2008. Contaminant accumulation and biomarker responses in caged mussels, *Mytilus galloprovincialis*, to evaluate bioavailability and toxicological effects of remobilized chemicals during dredging and disposal operations in harbour areas. *Aquatic Toxicology* 89, 257-266.
- Bolam, S.G., Rees, H.L., 2003. Minimizing impacts of maintenance dredged material disposal in the coastal environment: a habitat approach. *Environmental Management* 32, 171-188.
- Bolam, S.G., Rees, H.L., Somerfield, P., Smith, R., Clarke, K.R., Warwick, R.M., Atkins, M., Garnacho, E., 2006. Ecological consequences of dredged material disposal in the marine environment: a holistic assessment of activities around the England and Wales coastline. *Marine Pollution Bulletin* 52, 415-426.
- Bolam, S.G., Barry, J., Bolam, T., Mason, C., Rumney, H.S., Thain, J.E., Law, R.J., 2011. Impacts of maintenance dredged material disposal on macrobenthic structure and secondary productivity. *Marine Pollution Bulletin* 62, 2230-2245.
- Bolam, S.G., McIlwaine, P., Garcia, C., 2021. Marine macrofaunal traits responses to dredged material disposal. *Marine Pollution Bulletin* 168, 112412.
- Bolton, J.J., Stegenga, H., 2002. Seaweed species diversity in South Africa. *South African Journal of Marine Science* 24, 9-18.
- Boon, A.R., Dalfsen, J., 2022. Long-term changes in the macrobenthic assemblages at a harbour sediment disposal site in the southern North Sea. *Marine Environmental Research* 178, 105663.
- Boot, M., 2000. Near-field verspreiding van het overvloeiverlies van een sleepopperzuiger. MSc Dissertation, Delft University of Technology.
- Braulik, G.T., Findlay, K., Cerchio, S., Baldwin, R., 2015. Assessment of the conservation status of the Indian Ocean humpback dolphin (*Sousa plumbea*) using the IUCN red list criteria. *Advances in Marine Biology* 72, 119-141.
- Braulik, G.T., Findlay, K., Cerchio, S., Baldwin, R., Perrin, W., 2017. *Sousa plumbea*. The IUCN Red List of Threatened Species 2017: e.T82031633A82031644.
- Breitbart, D.L., 1988. Effects of turbidity on prey consumption by striped bass larvae. *Transactions of the American Fisheries Society*, 117, 72-77.
- Brown, C.L., Clark, R., 1968. Observations on dredging and dissolved oxygen in a tidal waterway. *Water Resources Research* 4, 1382.
- Burgess, R.M., Berry, W.J., Mount, D.R. and Di Toro, D.M., 2013. Mechanistic sediment quality guidelines based on contaminant bioavailability: equilibrium partitioning sediment benchmarks. *Environmental Toxicology and Chemistry* 32, 102-114.
- Cabon, J.Y., Burel, L., Jaffrennou, C., Giamarchi, P., Bautin, F., 2007. Study of trace metal leaching from coals into seawater, *Chemosphere* 69, 1100-1110.
- Cabrita, M.T., 2014. Phytoplankton community indicators of changes associated with dredging in the Tagus estuary (Portugal). *Environmental Pollution* 191, 17-24.
- Caetano, M., Vale, C., 2002. Retention of arsenic and phosphorus in iron-rich concretions of Tagus salt marshes, *Marine Chemistry* 79, 261-271.
- Calmano, W., Hong, J., Förstner, U., 1993. Binding and mobilisation of heavy metals in contaminated

- sediments affected by pH and redox potential. *Water Science and Technology* 28, 223-235.
- Cantwell, M., Burgess, R., King, J., 2008. Resuspension of contaminated field and formulated reference sediments Part I: evaluation of metal release under controlled laboratory conditions. *Chemosphere* 73, 1824-31.
- Carter, R., d'Aubrey, J., 1988. Inorganic nutrients in Natal continental shelf waters. In: Schumann, E.H. (Ed.). *Physical Oceanography off Natal*. E.H. Lecture notes on coastal and estuarine studies. 26. Coastal Ocean Studies off Natal, South Africa. Springer-Verlag, Berlin.
- Carter, R., Schleyer, M.H., 1988. Plankton distributions in Natal coastal waters. In: Lecture notes on coastal and estuarine studies (EH Schuman, Ed.). Coastal Ocean Studies off Natal, South Africa. Springer-Verlag.
- Carter, R.A., 1977. The distribution of calanoid copepods in the Agulhas Current system off Natal, South Africa. MSc Dissertation, University of Natal, Durban, South Africa.
- CCME (Canadian Council of Ministers of the Environment), 2002. Canadian water quality guidelines for the protection of aquatic life: Total particulate matter. In: Canadian Environmental Quality Guidelines, 1999. Winnipeg: Canadian Council of Ministers of the Environment.
- CEDA (Central Dredging Association), 2011. Underwater sound in relation to dredging. Central Dredging Association Position Paper. Prepared by the CEDA Working Group on Underwater Sound under the remit of the CEDA Environment Commission.
- Chen, K.Y., Morris, J.C., 1972. Kinetics of oxidation of aqueous sulfide by O₂. *Environmental Science and Technology* 6, 529-537.
- Clarke, D., Dickerson, C., Reine, K., 2002. Characterization of underwater sounds produced by dredges. *Dredging 2002*, ASCE, Orlando, Florida, USA.
- Coetzee, J.C., Merckle, D., Hutchings, L., van der Lingen, C.D., van den Berg, M., Durholtz, M.D., 2010. The 2005 KwaZulu-Natal sardine run survey sheds new light on the ecology of small fish off the east coast of South Africa. *African Journal of Marine Science* 32, 337-360.
- Colden, A.M., Lipcius, R.N., 2015. Lethal and sublethal effects of sediment burial on the eastern oyster *Crassostrea virginica*. *Marine Ecology Progress Series* 527, 107-117.
- Collin, S.P., Hart, N.S., 2015. Vision and photoentrainment in fishes: The effects of natural and anthropogenic perturbation. *Integrative Zoology* 10, 15-28.
- Collocott, S.J., Vivier, L., Cyrus, D.P., 2014. Prawn community structure in the subtropical Mfolozi–Msunduzi estuarine system, KwaZulu-Natal, South Africa. *African Journal of Aquatic Science* 39, 127-140.
- Consulim, C.E.N., Pareschi, D.C., Masutti, M.B., Gonçalves, C., Silvério, P.F., 2023. Assessing water quality changes caused by dredging operations in Santos Estuary, São Paulo, Brazil. *COGNITIONIS Scientific Journal* 6, 591-608.
- Costa, P.M., Neuparth, T.S., Caeiro, S., 2011. Assessment of the genotoxic potential of contaminated estuarine sediments in fish peripheral blood: Laboratory versus in situ studies. *Environmental Research* 111, 25-36.
- Cruz-Rodríguez, L., Chu, F., 2002. Heat-shock protein (HSP70) response in the eastern oyster, *Crassostrea virginica*, exposed to PAHs sorbed to suspended artificial clay particles and to suspended field contaminated sediments. *Aquatic Toxicology* 60, 157-68.
- CSIR (Council for Scientific and Industrial Research), 2000. Extension of Richards Bay Coal Terminal: Physical Effects of Dredging. CSIR Report ENV-SC 99090.
- CSIR (Council for Scientific and Industrial Research), 2005. Strategic Environmental Assessment: Port of Richards Bay, State of the Environment, CSIR Report No. ENV-D-C 2004-022, Durban, South Africa.
- CSIR (Council for Scientific and Industrial Research), 2008. Biomonitoring of dredging operations associated with the development of Berth 306, Richards Bay. CSIR Report CSIR/NRE/ECO/ER/2008/0131/C.
- CSIR (Council for Scientific and Industrial Research), 2013. Port of Richards Bay capacity expansion programme: Turbidity and total suspended solids. CSIR Report CSIR/NRE/ECOS/ER/2013/0027/C.
- CSIR (Council for Scientific and Industrial Research), 2013. Richards Bay Expansion Programme: Metal

- contamination of sediment and implications for dredging - technical report. CSIR Report CSIR/NRE/ECOS/ER/2013/0022/C.
- CSIR (Council for Scientific and Industrial Research), 2023. Richards Bay outfalls environmental monitoring programme: 2022/23 survey. CSIR Report CSIR/SPLA/SECO/ER/2023/0027/C.
- CSIR (Council for Scientific and Industrial Research), 2024. Richards Bay outfalls environmental monitoring programme: 2023/24 survey. CSIR Report CSIR/SPLA/SECO/ER/2024/0013/C.
- CSIR (Council for Scientific and Industrial Research), 2024. Scoping and Environmental Impact Reporting Process for the Development of New Berth 605 and Associated Infrastructure to Support the Container Handling Facility, Port of Richards Bay, KwaZulu-Natal: Sediment and soil quality in the proposed Berth 605 development footprint in the Port of Richards Bay. CSIR Report CSIR/SPLS/SE/ER/2024/1044/B.
- Cyrus, D.P., 1988. Turbidity and other physical factors in Natal estuarine systems. *Journal of the Limnological Society of Southern Africa* 14, 60-71.
- Cyrus, D.P., Blaber, S.J.M., 1987a. The influence of turbidity on juvenile marine fishes in estuaries. Part 2. Laboratory studies, comparisons with field data and conclusions. *Journal of Experimental Marine Biology and Ecology* 109, 71-91.
- Cyrus, D.P., Blaber, S.J.M., 1987b. The influence of turbidity on juvenile marine fishes in estuaries. Part 1. Field studies at Lake St. Lucia on the southeastern coast of Africa. *Journal of Experimental Marine Biology and Ecology* 109, 53-70.
- Cyrus, D.P., Forbes, A.T., 1996. Preliminary results on the role of KwaZulu-Natal harbours as nursery grounds for juveniles of selected marine organisms which utilise estuaries. *South African Journal of Wildlife Research* 26, 26-33.
- Cyrus, D.P., MacKay, C.F., Weerts, S.P., Viljoen, A., 1999. A preliminary assessment of the ecological impacts of dredge spoil disposal on Richards Bay beaches CRUZ Investigational Report No. 81.
- Cyrus, D.P., MacKay, C.F., Weerts, S.P., Viljoen, A., 2000. An assessment of the impact of a quantified spoil disposal activity on the Central Beach, Richards, Bay, using selected biotic indicator groups. CRUZ Investigational Report No. 90:
- Cyrus, D.P., Vivier, L., 2009a. Due Diligence Investigation for the Expansion of Richards Bay Harbour: Overall Assessment of Estuarine and Wetland Components. CRUZ Investigational Report 139.
- Cyrus, D.P., Vivier, L., 2009b. Expansion of Richards Bay Harbour: Issues related to the Diversion of the Mhlathuze River. CRUZ Investigational Report 136.
- Cyrus, D.P., Vivier, L., 2014a. Review of Abiotic and Biotic Reports produced for Priority Habitats in Transnet Capital Projects Richards Bay Port Expansion Project.
- Cyrus, D.P., Vivier, L., 2014b. Aquatic Vegetation and Fish associated with Berth 600 Series Extension in Transnet Capital Projects Richards Bay Port Expansion Project. Report No. 17.
- Cyrus, D.P., Vivier, L., 2019. Ecological Status and Importance of the Bhizolo and Manzanynama Canals, Port of Richards Bay (Late Low Flow Assessment). CRUZ Environmental Report 30.
- Cyrus, D.P., Vivier, L., 2020. Ecological Status and Importance of the Bhizolo and Manzanynama Canals, Port of Richards Bay (High Flow & Overall Assessment). CRUZ Environmental Report 31.
- Cyrus, D.P., Vivier, L., 2021a. CRUZ Environmental - Investigational Report No. 37. Proposed Development of the Nseleni Independent Floating Power Plant, Port of Richards Bay: 2. Assessment of Impacts on the Estuarine Environment. Report produced for Nseleni Power Corporation (Pty) Ltd & Anchor Energy LNG (Pty) Ltd through SE Solutions (Pty) Ltd.
- Cyrus, D.P., Vivier, L., 2021b. CRUZ Environmental - Investigational Report No. 36. Proposed Development of the Nseleni Independent Floating Power Plant, Port of Richards Bay: 1. Ecological Status of the Estuarine Area associated with the Development. Report produced for Nseleni Power Corporation (Pty) Ltd & Anchor Energy LNG (Pty) Ltd through SE Solutions (Pty) Ltd.
- Cyrus, D.P., Wepener, V., 1998. The impact of dredger spoil on selected components of the Mhlathuze estuary biota. CRUZ Investigational Report No. 52.
- de Freitas, A.J., 1986. Selection of nursery areas by six southeast African Penaeidae. *Estuarine, Coastal and*

Shelf Science 23, 901-908.

- De Jonge, M., Teuchies, J., Meire, P., Blust, R., Bervoets, L., 2012. The impact of increased oxygen conditions on metal-contaminated sediments part I: effects on redox status, sediment geochemistry and metal bioavailability. *Water Research* 46, 2205-14.
- De Jonge, V., Essink, K., Boddeke, R., 1993. *The Dutch Wadden Sea: A changed ecosystem*. Netherlands-Wetlands: Springer.
- de Lecea, A.M., Cooper, R., Smit, A.J., 2015. Identifying the drivers of the pelagic ecosystem of an oligotrophic bight (KwaZulu-Natal, South Africa) using stable isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$) and C:N ratio analysis. *Marine and Freshwater Research*: DOI: 10.1071/MF15256.
- De Robertis, A., Ryer, C.H., Veloza, A., Brodeur, R.D., 2003. Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. *Canadian Journal of Fisheries and Aquatic Sciences* 60, 1517-1526.
- De Witte, B., Ruttens, A., Ampe, B., Waegeneers, N., Gauquie, J., Devriese, L., Cooreman, K., Parmentier, K., 2016. Chemical analyses of dredged spoil disposal sites at the Belgian part of the North Sea. *Chemosphere* 156, 172-180.
- DFFE (Department of Forestry, Fisheries and the Environment), 2019. uMhlathuze and Richards Bay Estuarine Management Plan.
- DFFE (Department of Forestry, Fisheries and the Environment), 2018. *South African Water Quality Guidelines for Coastal Marine Waters - Natural Environment and Mariculture Use*. Cape Town.
- Diaz, R.J., Boesch, D.F., 1977. Impact of fluid mud dredged material on benthic communities of the tidal James River, Virginia. Technical Report D-77-45, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Donázar-Aramendía, I., Sanchez-Moyano, J.E., Garcia-Asencio, I., Miro, J.M., Megina, C., Garcia-Gomez, J.C., 2020. Environmental consequences of dredged-material disposal in a recurrent marine dumping area near to Guadalquivir estuary, Spain *Marine Pollution Bulletin* 161, 111736.
- Donázar-Aramendía, I., Sánchez-Moyano, J.E., García-Asencio, I., Miró, J.M., Megina, C., García-Gómez, J.C., 2018. Maintenance dredging impacts on a highly stressed estuary (Guadalquivir estuary): a BACI approach through oligohaline and polyhaline habitats. *Marine Environmental Research* 140, 455-467.
- Drylie, T.P., Lohrer, A.M., Needham, H.R., Bulmer, R.H., Pilditch, C.A., 2018. Benthic primary production in emerged intertidal habitats provides resilience to high water column turbidity. *Journal of Sea Research* 142, 101-112.
- Dye, A.H., McLachlan, A., Wooldridge, T., 1981. The ecology of sandy beaches in Natal. *South African Journal of Zoology* 16, 200-209.
- EAS, 1996. An environmental review of the Master Plan for the Port of Richards Bay. Environmental Advisory Services Investigational Report No. 89.
- Eggleton, J., Thomas, K.V., 2004. A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International* 30, 973-980.
- Engel, D.W., Sunda, W.G., Fowler, B.A., 1981. Factors affecting trace metal uptake and toxicity to estuarine organisms: I. environmental parameters. *Biological Monitoring of Marine Pollutants*, New York, NY.
- Essink, K., 1999. Ecological effects of dumping of dredged sediments; options for management. *Journal of Coastal Conservation* 5, 69-80.
- Everett, B.I., Fennessy, S.T., 2007. Assessment of recreational boat angling in a large estuarine embayment in KwaZulu-Natal, South Africa. *African Journal of Marine Science* 29, 411-422.
- Findlay, K.P., Best, P.B. 2016. Distribution and seasonal abundance of large cetaceans in the Durban whaling grounds off KwaZulu-Natal, South Africa, 1972-1975. *African Journal of Marine Science* 38, 249-262.
- Forbes, A., Demetriades, N., Cyrus, D., 1996. Biological significance of harbours as coastal habitats in KwaZulu-Natal, South Africa. *Aquatic Conservation* 6, 331-341.
- Forbes, A., Demetriades, N.T., 2010. *Estuaries of Durban, KwaZulu-Natal, South Africa*. Report for the Environmental Management Department, eThekweni Municipality. Second Edition. Marine and

Estuarine Research, Durban.

- Forbes, A.T., and Benfield, M.C., 1986. Penaeid prawns in the St Lucia Lake System: Post-larval recruitment and the bait fishery. *South African Journal of Zoology* 21.
- Forbes, A.T., and Cilliers, G., 1999. Macrocrustacea of the Mhlathuze Estuary. In: Quinn N. 2000. Mhlathuze System Ecological Reserve Study: Report on Estuary Freshwater Requirements Mhlathuze Estuary. DWAF Main Report W120-00-1499.
- Forbes, A.T., Demetriades, N.T. 2005. A review of the commercial, shallow water penaeid prawn resource of South Africa: Status, Fisheries, Aquaculture and Management. Marine and Estuarine Management Specialist Report Prepared for Ezemvelo KZN Wildlife.
- Forbes, A.T., Demetriades, N.T., 2006. Transnet-eThekweni Municipality Planning Initiative. Specialist Report - Environment. Report for Transnet-eThekweni Municipality Planning Initiative.
- Forbes, A.T., Demetriades, N.T., Cyrus, D.P., 1996. Biological significance of harbours as coastal habitats in KwaZulu-Natal, South Africa. *Aquatic Conservation. Marine and Freshwater Ecosystems* 6, 331-41.
- Forbes, A.T., Demetriades, N.T., Cyrus, D.P., 1996. Biological significance of harbours as coastal habitats in KwaZulu-Natal, South Africa. *Aquatic Conservation: Marine and freshwater ecosystems* 6, 331-341.
- Forbes, A.T., Niedinger, S., Demetriades, N.T., 1994. Recruitment and utilisation of nursery grounds by penaeid prawn postlarvae in Natal, South Africa. In: Dyer, KR and Orth, R. (Eds.) *Changes in fluxes in estuaries: Implications from science to management*. Olsen and Olsen, Fredensborg.
- Forbes, A.T., Niedinger, S., Demetriades, N.T., 1994. Recruitment and utilization of nursery grounds by penaeid prawn postlarvae in Natal, South Africa. In: Dyer, KR and Orth, R. (Eds.) *Changes in fluxes in Estuaries: Implications from Science to Management*. Olsen and Olsen, Fredensborg.
- Foster-Smith, R.L., 1976. Some mechanisms for the control of pumping activity in bivalves. *Marine Behavioral Physiology* 4, 41-60.
- Fredette, T.J., French, G.T., 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. *Marine Pollution Bulletin* 49, 93-102.
- Geffard, A., Geffard, O., Amiard, J., His, E., Amiard-Triquet, C., 2007. Bioaccumulation of metals in sediment elutriates and their effects on growth, condition index, and metallothionein contents in oyster larvae. *Archives of Environmental Contamination and Toxicology* 53, 57-65.
- Gibson, B.D., Ptacek, C.J., Blowes, D.W., Daugherty, S.D., 2015. Sediment resuspension under variable geochemical conditions and implications for contaminant release. *Journal of Soils and Sediments* 15, 1644-1656.
- Gilkinson, K.G., Gordon Jr., D.C., MacIsaac, K.G., McKeown, D.L., Kenchington, E.L.R., Bourbonnais, C., Vass, P.W., 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, eastern Canada *ICES Journal of Marine Science* 62, 925-947.
- Gill, A.E., Schumann, E.H., 1979. Topographically induced changes in the structure of an inertial jet: Application to the Agulhas Current. *Journal of Physical Oceanography* 9, 975-991.
- Goossens, H., Zwolsman, J., 1996. An evaluation of the behaviour of pollutants during dredging activities. *Terra et Aqua* 62, 20-28.
- Green, A.N., MacKay, C.F., 2016. Unconsolidated sediment distribution patterns in the KwaZulu-Natal Bight, South Africa: The role of wave ravinement in separating relict versus active sediment populations. *African Journal of Marine Science* 38, S65-S74.
- Gregg, J., Fleeger, J., Carman, K., 1997. Effects of suspended, diesel-contaminated sediment on feeding rate in the darter goby, *Gobionellus boleosoma* (Teleostei: Gobiidae). *Marine Pollution Bulletin* 13, 269-75.
- Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings-entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364, 2013-2025.
- Grindley, J. R., Wooldridge, T.H., 1974. The plankton of Richards Bay. *Hydrobiological Bulletin* 8, 201-212.
- Guastella, L., Roberts, M., 2016. Dynamics and role of the Durban cyclonic eddy in the KwaZulu-Natal Bight

- ecosystem. *African Journal of Marine Science* 38, S23-S42.
- Hall, L., 1989. The effects of dredging and reclamation on metal levels in water and sediments from an estuarine environment off Trinidad, West Indies. *Environmental Pollution* 56, 189-207.
- Hall, L., 1994. Physical disturbance and marine communities: life in unconsolidated sediments. *Oceanography and Marine Biology: An Annual Review* 32, 179-239.
- Hamilton, P.B., Rolshausen, G., Uren Webster, T.M., Tyler, C.R., 2017. Adaptive capabilities and fitness consequences associated with pollution exposure in fish. *Philosophical Transactions of the Royal Society B: Biological Sciences* 372, 1712.
- Harris, J.M., Livingstone, T., Lombard, A.T., Lagabrielle, E., Haupt, P., Sink, K., Mann, B., Schleyer, M., 2011. Marine Systematic Conservation Assessment and Plan for KwaZulu-Natal - Spatial priorities for conservation of marine and coastal biodiversity in KwaZulu-Natal. Ezemvelo KZN Wildlife.
- Harris, L.R., 2012. An ecosystem-based spatial conservation plan for the South African sandy beaches. PhD Dissertation, Nelson Mandela University, Port Elizabeth, South Africa.
- Harris, S.A. and Cyrus, D.P., 1999. Composition, abundance and seasonality of fish larvae in the mouth of Durban Harbour, KwaZulu-Natal, South Africa. *African Journal of Marine Science*, 21.
- Hecht, T., Van der Lingen, C.D., 1992. Turbidity-induced changes in feeding strategies of fish in estuaries. *South African Journal of Zoology* 27, 95-107.
- Hedrick, K.P., Robinson, R.B., Tschantz, B., Moore, S.E., 2006. Impact of tunnel reconstruction on stream water quality in Great Smoky Mountains National Park. *Journal of Hydrologic Engineering* 11, 570-577.
- Hemens, J., Simpson, D.E., McClurg, T.P., 1970. Detailed survey of Richards Bay. Progress Report, CSIR/NIWR. 20th Steering Committee Meeting: Marine disposal of effluents. 20, 1-28.
- Hendrick, V.J., Hutchison, Z.L., Last, K.S., 2016. Sediment burial intolerance of marine macroinvertebrates. *PLoS ONE* 11(2), e0149114.
- Hennig, H.F., 1985. Review of metal concentrations in southern African coastal waters, sediments and organisms. South African National Scientific Programmes Report No. 108. CSIR, Pretoria.
- Hess, S., Wenger, A.S., Ainsworth, T.D., Rummer J.L., 2015. Exposure of clownfish larvae to suspended sediment levels found on the Great Barrier Reef: Impacts on gill structure and microbiome. *Scientific reports* 5.
- Hirst, J., Aston, S., 1983. Behaviour of copper, zinc, iron and manganese during experimental during experimental resuspension and reoxidation of polluted anoxic sediments. *Estuarine, Coastal and Shelf Science* 16, 549-558.
- Hitchcock, D.R., Drucker, B.S., 1996. Investigation of benthic and surface plumes associated with marine aggregate mining in the United Kingdom. In: *The Global Ocean-Towards Operational Oceanography. Proceedings of the Oceanology International 1996 Conference*. Spearhead, Surrey.
- Hohaia, A., Vopel, K., Pilditch, C.A., 2014. Thin terrestrial sediment deposits on intertidal sandflats: effects on pore water solutes and juvenile bivalve burial behaviour. *Biogeosciences* 11, 2225-35.
- Holland, G.J., Greenstreet, S.P.R., Gibb, I.M., Fraser, H.M., Robertson, M.R., 2005. Identifying sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment. *Marine Ecology Progress Series* 303, 269-282.
- Hutchinson, T.H., Lyons, B.P., Thain, J.E., Law, R.J., 2013. Evaluating legacy contaminants and emerging chemicals in marine environments using adverse outcome pathways and biological effects-directed analysis. *Marine Pollution Bulletin* 74, 517-525.
- Hyslop, B.T., Davies, M.S., 1999. The effect of colliery waste on the feeding of the lugworm *Arenicola marina*. *Journal of Sea Research* 42, 147-155.
- Izegaegbe, J., Vivier, L., Mzimela, H.M., 2023. Metal contamination in sediments and its impact on the macrobenthic community of Richards Bay Harbour, South Africa. *African Journal of Aquatic Science* 48, 123-137.
- Izegaegbe, J.I., Vivier, L., Mzimela, H.M., 2020. Spatial and temporal distribution of macrobenthic fauna of subtropical Richards Bay Harbour, South Africa. *Regional Studies in Marine Science* 36, 2352-4855.

- Jackson, L.F., Lipschitz, S., 1984. Coastal Sensitivity Atlas of Southern Africa. Department of Transport. South Africa.
- Jaffrennou, C., Giamarchi, P., Cabon, J.Y., Stephan, L., Burel-Deschamps, L., Bautin, F., Le Floch, S., 2007. Simulations of accidental coal immersion. Marine Pollution Bulletin 54, 1932-1939.
- Jairam, S., 2005. The commercial and recreational marine skiboat linefisheries of Richards Bay. MSc Dissertation, University of KwaZulu-Natal.
- Jerling, H.L., 2008. The zooplankton community of Richards Bay Harbour and adjacent Mhlathuze Estuary, South Africa. African Journal of Marine Science 30, 55-62.
- Jewitt, D., 2018. Vegetation type conservation targets, status and level of protection in KwaZulu-Natal in 2016. Bothalia 48, a2294.
- Johansen, J., Jones, G., 2013. Sediment-induced turbidity impairs foraging performance and prey choice of planktivorous coral reef fishes. Ecological Applications 23, 1504-1517.
- Kalnejais, L.H., Martin, W.R., Signell, R.P., Bothner, M.H., 2007. Role of sediment resuspension in the remobilization of particulate-phase metals from coastal sediments. Environmental Science and Technology 41, 2282-2288.
- Kamrowski, R., Limpus, C., Moloney, J., Hamann, M., 2012. Coastal light pollution and marine turtles: assessing the magnitude of the problem. Endangered Species Research 19, 85-98.
- Keith, M., Atkins, S., Johnson, A.E., Karczmarski, L., 2013. Area utilization patterns of humpback dolphins (*Sousa plumbea*) in Richards Bay, KwaZulu-Natal, South Africa. Journal of Ethology 31, 261-274.
- Kerr, S.J., 1995. Silt, turbidity and suspended sediments in the aquatic environment: an annotated bibliography and literature review. Ontario Ministry of Natural Resources, Southern Region Science and Technology Transfer Unit Technical Report TR-008.
- Knott, N., Aulbury, J., Brown, T., Johnston, E., 2009. Contemporary ecological threats from historical pollution sources: impacts of large-scale resuspension of contaminated sediments in sessile invertebrate recruitment. Journal of Applied Ecology 46, 770-81.
- La Salle, M., 1990. Physical and chemical alterations associated with dredging. In: Simenstad C, editor. Workshop on the effects of dredging on anadromous Pacific Coast fishes. Washington Sea Grant Program, Seattle, WA, United States.
- Lamont, T., van den Berg, M.A., Barlow, R.G., 2016. Agulhas Current influence on the shelf dynamics of the KwaZulu-Natal Bight. Journal of Physical Oceanography 46, 1323-1338.
- Larson, F., Sundback, K., 2008. Role of microphytobenthos in recovery of functions in a shallow-water sediment system after hypoxic events. Marine Ecology Progress Series 357, 1-16.
- Larson, F., Sundback, K., 2012. Recovery of microphytobenthos and benthic functions after sediment deposition. Marine Ecology Progress Series 446, 31-44.
- Lauret-Stepler, M., Bourjea, J., Roos, D., Pelletier, D., Ryan, P., Ciccione, S., GRIZEL, H., 2007. Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. Endangered Species Research 3, 217-227.
- Layglon, N., Misson, B., Durieu, G., Coclet, C., D'Onofrio, S., Dang, D.H., François, D., Mullot, J.-U., Mounier, S., Lenoble, V., 2020. Long-term monitoring emphasizes impacts of the dredging on dissolved Cu and Pb contamination along with ultraplankton distribution and structure in Toulon Bay (NW Mediterranean Sea, France). Marine Pollution Bulletin 156, 111196.
- Lee, G.F., Jones, R.A., Saleh, F.Y., Mariani, G.M., Homer, D.H., Butler, J.S., Bandyopadhyay, P., 1978. Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release during Open Water Disposal of Dredged Sediment and Environmental Impact of Open Water Dredged Materials Disposal, Vol. II: Data Report. Technical Report D-78-45, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Leuci, R., Young, P., Smith, A., 2004. A GIS project concerning regional seafloor geology and bathymetry of the continental shelf off Richards Bay and Thukela: Explanatory Report. Marine Geoscience Unit. Council for Geoscience. Confidential Report 2004-0228.

- Limburg, K.E., Waldman, J.R., 2009. Dramatic declines in North Atlantic diadromous fishes. *BioScience* 59, 955-965.
- Long, E., MacDonald, D., Smith, S., Calder, F., 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19, 81-97.
- Lotufo, G., Blackburn, W., Marlborough, S., Fleeger, J., 2010. Toxicity and bioaccumulation of TNT in marine fish in sediment exposures. *Ecotoxicology and Environmental Safety* 73, 1720-1772.
- LTMS, 2001. Long-Term Management Strategy for Dredging and Disposal, San Francisco Bay Region. Management Plan. Prepared by USACE and USEPA.
- Luschi, P., Lutjeharms, J.R.E., Lambardi, P., Mencacci, R., Hughes, G.R., Hays, G.C., 2006. A review of migratory behaviour of sea turtles off southeastern Africa. *South African Journal of Science* 102, 51-58.
- Lutjeharms, J.R., 2006. The coastal oceans of south-eastern Africa (15, W). *The Sea* 14, 783-834.
- Lutjeharms, J.R.E., Cooper, J. and Roberts, M., 2000. Upwelling at the inshore edge of the Agulhas Current. *Continental Shelf Research* 20, 737-761.
- Lutjeharms, J.R.E., Valentine, H.R. and Van Ballegooyen, R.C., 2000b. The hydrography and water masses of the Natal Bight, South Africa. *Continental Shelf Research* 20, 1907-1939.
- Lutjeharms, J.R.E., van Ballegooyen, R.C., 1988. The Retroflection of the Agulhas Current. *Journal of Physical Oceanography* 18, 1570-1583.
- MacDonald, D.D., Ingersoll, C.G., Berger, T.A., 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology* 39, 20-31.
- Maddock, J., Carvalho, M., Santelli, R., Machado, W., 2007. Contaminant metal behaviour during re-suspension of sulphidic estuarine sediments. *Water, Air and Soil Pollution* 181, 193-200.
- Malan, A., Clark, B.M., 2023. Port of Richards Bay Masterplan: Sediment Characterisation Study. Report no. 2106/1 prepared by Anchor Environmental Consultants (Pty) Ltd for Exigent (Pty) Ltd.
- Malan, O.G., Schumann, E.H., 1979. Natal shelf circulation revealed by Landsat imagery. *South African Journal of Science* 75, 136-137.
- Malarkey, J., Baas, J.H., Hope, J.A., Aspden, R.J., Parsons, D.R., Peakall, J., Paterson, D.M., Schindler, R.J., Ye, L., Lichtman, I.D., Bass, S.J., Davies, A.G., Manning, A.J., Thorne, P.D., 2015. The pervasive role of biological cohesion in bedform development. *Nature Communications* 6, 6257.
- Mann, B.Q., Buxton, C.D., Pollard, D., Carpenter, K.E. 2014. *Acanthopagrus vagus*. The IUCN Red List of Threatened Species. e.T170173A1287308. <http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T170173A1287308.en>. Accessed 20 March 2023.
- Mann, B.Q., Pradervand, P., 2007. Declining catch per unit effort of an estuarine-dependent fish, *Rhabdosargus sarba* (Teleostei: Sparidae), in the marine environment following closure of the St Lucia Estuarine System, South Africa. *African Journal of Aquatic Science* 32, 133-138.
- Marshall, D.J., Rajkumar, A., 2003. Imposex in the indigenous *Nassarius kraussianus* (Mollusca: Neogastropoda) from South African harbours. *Marine Pollution Bulletin* 46, 1150-1155.
- Martin, A.K., Flemming, B.W., 1988. Physiography, structure and geological evolution of the natal continental shelf. In: Schumann, E.H. (Ed.), *Coastal ocean studies off Natal, South Africa. Lecture Notes on Coastal and Estuarine Studies* 26. Berlin: Springer-Verlag.
- Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., Wethe, C., Lord, C., Church, T.M., 1986. Vertical migration and mortality of marine benthos in dredged material: a synthesis. *Internationale Revue der gesamten Hydrobiologie* 71, 50-63.
- Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., 1980. Vertical migration and mortality of benthos in dredged material - Part 1: Mollusca. *Marine Environmental Research* 4, 299-319.
- Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., 1981. Vertical migration and mortality of benthos in dredged material - Part 2: Crustacea. *Marine Environmental Research* 5, 301-317.
- Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., 1982. Vertical migration and mortality of benthos in dredged material - Part 3: Polychaeta. *Marine Environmental Research* 6, 49-68.

- McClurg, T.P., 1988. Benthos of the Natal continental shelf. In: Coastal Ocean Studies off Natal, South Africa. E.H. Schumann (Ed.) Lecture notes on Coastal and Estuarine Studies No 26. Springer-Verlag, Berlin.
- Mehlhorn, P., Viehberg, F., Kirsten, K., Newman, B., Frenzel, P., Gildeeva, O., Green, A., Hahn, A., Haberzettl, T., 2021. Spatial distribution and consequences of contaminants in harbour sediments - A case study from Richards Bay Harbour, South Africa Marine Pollution Bulletin 172, 112764.
- Meyer, A.A., Lutjeharms, J.R.E., De Villiers, S., 2002. The nutrient characteristics of the Natal Bight, South Africa. Journal of Marine Systems 35, 11-37.
- Millard, N.A.H., Harrison, A.D., 1954. The ecology of South African estuaries: Part V. Richards Bay. Transactions of the Royal Society of southern Africa 34, 157-179.
- Miller, D.C., Muir, C.L., Hauser, O.A., 2002. Detrimental effects of sedimentation on marine benthos: what can be learned from natural processes and rates? Ecology and Engineering 19, 211-232.
- Mills, K.A., 2005. The use of transplanted brown mussels (*Perna perna*) as indicators of marine health in Richards Bay Harbour. Unpublished MSc Dissertation. University of Johannesburg, Johannesburg, South Africa.
- Moore, J.N., Ficklin, W.H., Johns, C., 1988. Partitioning of arsenic and metals in reducing sulfidic sediments. Environmental Science and Technology 22, 432-437.
- Morgan, B., Rate, A.W., Burton, E.D., 2012. Water chemistry and nutrient release during the resuspension of FeS-rich sediments in a eutrophic estuarine system. Science of the Total Environment 432, 47-56.
- Mortimer, J., 1984. Marine Turtles in the Republic of the Seychelles: Status and Management Report on Project 1809 (1981-1984). International Union for Conservation of Nature and Natural Resources World Wildlife Fund.
- Morton, J.W., 1977. Ecological effects of dredging and dredge spill disposal: a literature review. US Fish and Wildlife Service, Technical Papers, No. 94, 1-33.
- Mostert, T.H.C., 2014. Vegetation and Wetland Delineation of Priority Habitats in Transnet Capital Projects Richards Bay Port Expansion Project. CRUZ Environmental Report 12.
- Naidoo, G., Chirkoot, D., 2004. The effects of coal dust on photosynthetic performance of the mangrove *Avicennia marina* in Richards Bay, South Africa. Environmental Pollution 127, 359-366.
- Naidoo, G., Naidoo, Y., 2005. Coal dust pollution effects on wetland tree species in Richards Bay, South Africa. Wetlands Ecology and Management 13, 359-366.
- Navarro, J.M., Widdows, J., 1997. Feeding physiology of *Cerastoderma edule* in response to a wide range of seston concentrations. Marine Ecology Progress Series 152, 175-186.
- Nel, R., Punt, A.E., Hughes, G.R., 2013. Are coastal protected areas always effective in achieving population recovery for nesting sea turtles? PLoS one 8, e63525.
- Newell, R.C., Seiderer, L.J., Hitchcock, D.R., 1998. The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology: Annual Review 36, 127-178.
- Nhleko, J. and Cyrus, D.P., 2008. Estuarine Association and the Influence of Selected Physical Factors on Fish Species Composition of KwaZulu-Natal Estuaries. BSc Honours Project, University of Zululand, South Africa.
- NOAA Marine Debris Program (National Oceanic and Atmospheric Administration Marine Debris Program), 2014a. Report on the Occurrence and Health Effects of Anthropogenic Debris Ingested by Marine Organisms. Silver Spring, MD.
- NOAA Marine Debris Program (National Oceanic and Atmospheric Administration Marine Debris Program), 2014b. Report on the Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States. Silver Spring, MD.
- NOAA Marine Debris Program (National Oceanic and Atmospheric Administration Marine Debris Program), 2016. Report on Marine Debris Impacts on Coastal and Benthic Habitats. Silver Spring, MD: National Oceanic and Atmospheric Administration Marine Debris Program.

- NOAA Marine Debris Program (National Oceanic and Atmospheric Administration Marine Debris Program), 2017. Report on Marine Debris as a Potential Pathway for Invasive Species. Silver Spring, MD: National Oceanic and Atmospheric Administration Marine Debris Program.
- Norkko, A., Thrush, S.F., Hewitt, J.E., Cummings, V.J., Norkko, J., Ellis, J.I., Funnell, G.A., Schultz, D., MacDonald, I., 2002. Smothering of estuarine sandflats by terrigenous clay: the role of windwave disturbance and bioturbation in site-dependent macrofaunal recovery. *Marine Ecology Progress Series* 234, 23-42.
- Oleksiak, M.F., 2008. Changes in gene expression due to chronic exposure to environmental pollutants. *Aquatic toxicology* 90, 161-171.
- Oliff, W.D., 1973. Chemistry and productivity at Richards Bay. NPRL Oceanography Division Contract Report CFIS 37B, Durban.
- Palanques, A., Guillén, J., Puig, P., Durán, R., 2022. Effects of long-lasting massive dumping of dredged material on bottom sediment and water turbidity during port expansion works. *Ocean and Coastal Management* 223, 106113.
- Parsons, D.R., Schindler, R.J., Hope, J.A., Malarkey, J., Baas, J.H., Peakall, J., Manning, A.J., Ye, L., Simmons, S., Paterson, D.M., Aspden, R.J., Bass, S.J., Davies, A.G., Lichtman, I.D., Thorne, P.D., 2016. The role of biophysical cohesion on subaqueous bed form size. *Geophysical Research Letters* 43, 1566-1573.
- Pearce, A.F., 1977. The shelf circulation off the east coast of South Africa. CSIR Professional Research Series 1.
- Pearce, B.C., McBride, J., 1977. A preliminary study on the occurrence of coal dust in Roberts Bank sediments and the effect of coal dust on selected fauna. FMS Technical Report Series PAC/T 77-17 1-43.
- Pereira, M.A.M., Videira, E.J.S., Louro, C.M.M., 2008. Sea turtles of Mozambique: Report. In: Pereira, M.A.M. (Ed.). Cabo Delgado Biodiversity and Tourism.
- Plön, S., Atkins, S., Conry, D., Pistorius, P., Cockcroft, V., and Child, M., 2016. A conservation assessment of *Sousa plumbea*. In: The Red List of Mammals of South Africa, Swaziland and Lesotho, Eds M.F. Child, D. Raimondo, E.D.L. San, L. Roxburgh, H. Davies-Mostert (South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust).
- Popper, A.N., Hawkins A.D., (Eds.), 2016. The effects of noise on aquatic life II. Springer, New York.
- Powilleit, M., Kleine, J., Leuchs, H., 2006. Impacts of experimental dredged material disposal on a shallow, sublittoral macrofauna community in Mecklenburg Bay (western Baltic Sea). *Marine Pollution Bulletin* 52, 386-396.
- Pratt, D.R., Pilditch, C.A., Lohrer, A.M., Thrush, S.F., 2014. The effects of short-term increases in turbidity on sandflat microphytobenthic productivity and nutrient fluxes. *Journal of Sea Research* 92, 170-177.
- Prause, B., Rehm, E., Schulzbaldes, M., 1985. The remobilization of Pb and Cd from contaminated dredge spoil after dumping in the marine environment. *Environmental Technology Letters* 6, 261-266.
- PRDW, 2024. Provision of Environmental Services for Environmental Specialist Studies for the KZN Logistics Hub Programme: Port of Richards Bay. Part 2: Engineering Inputs to the Dredge Disposal Strategy. SAR220014-RP-CE-002-R4-Part2.docx
- Pretorius, M., Huggett, J.A., Gibbons, M.J., 2016. Summer and winter differences in zooplankton biomass, distribution and size composition in the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science* 38 sup1, S155-S168.
- Ramsay, P.J., MacHutchon, M.R., 2005. Baseline geophysical survey of the offshore physical monitoring site associated with the development of Berth 306 - Richards Bay. Marine GeoSolutions Report No. 2005-008.
- Ramsay, P.J., MacHutchon, M.R., 2006. Post disposal geophysical survey of the offshore physical monitoring site associated with the development of Berth 306 - Richards Bay. Marine GeoSolutions Report No. 2006-002.
- Ramsay, P.J., Smith, A.M. and Mason, T.R., 1996. Geostrophic sand ridge, dune fields and associated

- bedforms from the northern KwaZulu-Natal shelf, South-east Africa. *Sedimentology* 43, 403-419.
- Raw, J.L., Perissinotto, R., Taylor, R.H., Miranda, N.A.F., Peer, N., 2014. Decline of *Terebralia palustris* in South African mangroves. *African Journal of Marine Science* 36, 517-522.
- Reine, K.J., Clarke, D., Dickerson, C., 2012. Characterization of underwater sounds produced by a hydraulic cutterhead dredge fracturing limestone rock. ERDC TN-DOER-E34.
- Richardson, W.J., 1995. Marine mammals and noise. San Diego, California, Academic Press.
- Riddin, T., Adams, J., Rajkaran, A., Machite, A., Peer, N., Suárez, E.L., 2024. 'IUCN Red List of Ecosystems, Mangroves of the Agulhas. IUCN Red List of Ecosystems Assessments.
- Roberts, R.D., Gregory, M.R., Foster, B.A., 1998. Developing an efficient macrofauna monitoring index from an impact study - a dredge spoil example. *Marine Pollution Bulletin* 36, 231-235.
- Rocha, T.S., Sales, E.A., Beretta, M., Oliveira, I.B., 2016. Effects of dredging at Aratu port in All Saints Bay, Brazil: monitoring the metal content in water and sediments. *Environmental Monitoring and Assessment* 188, 394.
- Roman-Sierra, J., Navarro, M., Muñoz-Perez, J.J., Gomez-Pina, G., 2011. Turbidity and other effects resulting from Trafalgar Sandbank Dredging and Palmar Beach Nourishment. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 137, 332-343.
- Roos, C., 2010. Characterising the scale and significance of persistent organic pollutants in South African sediments. PhD Thesis, North-West University, South Africa.
- Schaffner, L.C., 1993. Baltimore Harbor and channels aquatic benthos investigations at the Wolf Alternate Disposal Site in lower Chesapeake Bay. Final report prepared by the College of William and Mary and the Virginia Institute of Marine Science for the US Army Corps of Engineers, Baltimore District.
- Scharler, U.M., Ayers, M.J., de Lecea, A.M., Pretorius, M., Fennessy, S.T., Huggett, J.A., MacKay, C.F., Muir, D., 2016. Riverine influence determines nearshore heterogeneity of nutrient (C, N, P) content and stoichiometry in the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science* 38, S193-S203.
- Schoeman, R.P., Patterson-Abrolat, C., Plön, S., 2020. A global review of vessel collisions with marine animals. *Frontiers in Marine Science* 7, 292.
- Schumann, E.H., 1988. Physical oceanography off Natal. In: Schumann, E.H. (Ed.), *Coastal ocean studies off Natal, South Africa. Lecture Notes on Coastal and Estuarine Studies* 26. Berlin: Springer-Verlag.
- SE Solutions, 2024. Proposed Nseleni Independent Floating Power Plant (NIFPP) and associated infrastructure for the evacuation of power from the NIFPP to the National Grid, Port of Richards Bay, KwaZulu-Natal and Proposed Liquid Natural Gas (LNG) receiving and storage facility and associated physical infrastructure to support the Nseleni Independent Floating Power Plant, Port of Richards Bay, KwaZulu-Natal. Final Environmental Impact Assessment (EIA) Report.
- Servizi, J.A., Martens, D.W., 1987. Some effects of suspended Fraser River sediments on sockeye salmon (*Oncorhynchus nerka*). *Canadian Special Publication of Fisheries and Aquatic Sciences* 96, 254-264.
- Simpson, S.L., Apte, S.C., Batley, G.E., 1998. Effect of short-term resuspension events on trace metal speciation in polluted anoxic sediments. *Environmental Science and Technology* 32, 620-625.
- Simpson, S.L., Apte, S.C., Batley, G.E., 2000. Effect of short-term resuspension events on the oxidation of cadmium, lead, and zinc sulfide phases in anoxic estuarine sediments. *Environmental Science and Technology* 34, 4533-4537.
- Simpson, S.L., Ward, D., Strom, D., Jolley, D.F., 2012. Oxidation of acid-volatile sulfide in surface sediments increases the release and toxicity of copper to the benthic amphipod *Melita plumulosa*. *Chemosphere* 88, 953-61.
- Sink, K.J., Branch, G.M., Harris, J.M., 2005. Biogeographic patterns in rocky intertidal communities in KwaZulu-Natal, South Africa. *African Journal of Marine Science* 27, 81-96.
- Skilleteer, G., 1998. Ecology of Benthic Invertebrates in Moreton Bay. In: Tibbetts, I.R., Hall, N.J., Dennison, W.C. (Eds.) *Moreton Bay and Catchment*. Brisbane, The University of Queensland.
- Slotta, L.S., Sollitt, C.K., Bella, D.A., Hancock, D.R., McCauley, J.E., Parr, R., 1973. Effects of Hopper Dredging

- and In-Channel Spoiling in Coos Bay, Oregon. Schools of Engineering and Oceanography, Oregon State University, Corvallis, OR.
- Smit, M.G., Holthaus, K.I., Trannum, H.C., Neff, J.M., Kjeilen-Eilertsen, G., Jak, R.G., Singaas, I., Huijbregts M.A., Hendriks, A.J., 2008. Species sensitivity distributions for suspended clays, sediment burial, and grain size change in the marine environment. *Environmental Toxicology and Chemistry* 27, 1006-1012.
- Soulsby, R.L., 1998. *Dynamics of Marine Sands*. Thomas Telford, England.
- Southall, B.I., Bowles, A.E., Elison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R.J., Kastak, D., Ketten, D.R., Miller, J.H., Hachtigall, P.E., Richardson, W.J., Thomas, J.A., Tyack, P., 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33, 411-521.
- Steckbauer, A., Duarte, C.M., Carstensen, J., Vaquer-Sunyer, R., Conley, D.J., 2011. Ecosystem impacts of hypoxia: Thresholds of hypoxia and pathways to recovery. *Environmental Research Letters* 6, 025003.
- Steffani, N., Pulfrich, A., Carter, R., Lane, S., 2003. Environmental impact assessment for the expansion of the container terminal stacking area at the Port of Cape Town - Marine ecological aspects. PISCES Environmental Services, R Carter Specialist Consultant and Sue Lane and Associates.
- Stronkhorst, J., Ariese, F., Van Hattum, B., Postma, J., De Kluijver, M., Den Besten, P., 2003. Environmental impact and recovery at two dumping sites for dredged material in the North Sea. *Environmental Pollution* 124, 17-31.
- Stumm, W., Lee, G.F., 1961. Oxygenation of ferrous iron. *Industrial and Engineering Chemistry* 53, 143-146.
- Stumm, W., Morgan, J.J., 1996. *Aquatic Chemistry*. In: *Chemical Equilibria and Rates in Natural Waters*. John Wiley, New York.
- Sturve, J., Berglund, A., Balk, L., Broeg, K., Böhmert, B., Massey, S., Savva, D., Parkkonen, J., Stephensen, E., Koehler, A., Förlin, L., 2005. Effects of dredging in Goteborg Harbor, Sweden, assessed by biomarkers in eelpout (*Zoarces viviparus*). *Environmental Toxicology and Chemistry* 24, 1951-1961.
- Sundbäck, K., Alsterberg, C., and Larson, F., 2010. Effects of multiple stressors on marine shallow-water sediments: response of microalgae and meiofauna to nutrient-toxicant exposure. *Journal of Experimental Marine Biology and Ecology* 388, 39-50.
- Sved, D., Roberts, Jr M., 1995. A novel use for the continuous-flow serial diluter: aquatic toxicity testing of contaminated sediments in suspension. *Water Research* 29, 1169-77.
- Tao, W., Jiang, Z., Peng, X., Yang, Z., Cai, W., Yu, H., Ye, J., 2021. Impact of dredged material disposal on heavy metal concentrations and benthic communities in Huangmao Island marine dumping area near Pearl River Estuary. *Applied Science* 11, 9412.
- Thompson, R.C., Moore, C., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health: current consensus and future trends. *Philosophical Transactions of the Royal Society B* 364, 2153-2166.
- Thrush, S., Hewitt, J., Cummings, V., Ellis, J., Hatton, C., Lohrer, A., Norkko, A., 2004. Muddy waters: elevating sediment input to coastal and estuarine habitats. *Frontiers in Ecology and the Environment* 2, 299-306.
- TNPA (Transnet National Ports Authority), 2009. Ngqura Operational Environmental Management Plan (OEMP), TNPA Report (version 1: 13 September 2009).
- Tolhurst, L., Barry, J., Dyer, R., Thomas, K., 2007. The effect of resuspending sediment contaminated with antifouling paint particles containing Irgarol 1051 on the marine macrophyte *Ulva intestinalis*. *Chemosphere* 68, 1519-24.
- Truitt, C.L., 1986. Fate of Dredged Material During Open Water Disposal. *Environmental Effects of Dredging Technical Note EEDP-01-2*. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Truitt, C.L., 1988. Dredged material behaviour during open water disposal. *Journal of Coastal Research* 4, 389-397.
- Turpie, J.K., Adams, J.B., Joubert, A., Harrison, T.D., Colloty, B.M., Maree, R.C., Whitfield, A.K., Wooldridge, T.H., Lamberth, S.J., Taljaard, S., van Niekerk, L., 2002. Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA* 28, 191-206.
- Urrutia, M.B., Iglesias, J.I.P., Navarro, E., 1997. Feeding behaviour of *Cerastoderma edule* in a turbid

- environment: physiological adaptations and derived benefit. *Hydrobiologia* 355, 173-180.
- USACE (U.S. Army Corps of Engineers), 1976a. Dredge Disposal Study, San Francisco Bay and Estuary: Appendix C, Water Column. San Francisco District.
- USACE (U.S. Army Corps of Engineers), 1976b. Dredge Disposal Study, San Francisco Bay and Estuary: Appendix I, Pollutant Availability Study. San Francisco District.
- USACE (U.S. Army Corps of Engineers), 1998. Monitoring Report for 1995 and 1996 - San Francisco Deep Ocean Disposal Site (SF-DODS). Prepared by EPA Region 9.
- USEPA (United States Environmental Protection Agency), 2003. Ambient water quality criteria for dissolved oxygen, water clarity and chlorophyll-a for the Chesapeake Bay and its tidal tributaries. EPA 903-R-03-002. US EPA Region III, Annapolis, MD, Region III Water Protection Division, Philadelphia, PA, and Office of Water, Office of Science and Technology, Washington, DC.
- Utne-Palm, A., 2002. Visual feeding of fish in a turbid environment: Physical and behavioral aspects. *Marine and Freshwater Behaviour and Physiology* 35, 111-128.
- van Ballegooyen, R.C., Newman, B., Shabangu, P., Jacobs, G., 2015. Port of Richards Bay Capacity Expansion EIA: Dredging and Dredge Spoil Disposal Modelling Specialist Study. Joint WSP/CSIR Report CSIR/NRE/ECO/ER/2015-001.
- van Ballegooyen, R., Jacobs, G., Smith, G., Fourie, S-K., van der Walt, D., 2025. Berth 605, Port of Richards Bay EIA Specialist Studies: Dredging and Dredge Material Disposal Modelling Study, WSP Report XRB.E.0030-T001-RPT-0106.
- van den Berg, G.A., Meijers, G.G.A., Van der Heijdt, L.M., Zwolsman, J.J.G., 2001. Dredging-related mobilisation of trace metals: A case study in the Netherlands. *Water Research* 35, 1979-1986.
- van der Molen, J.S., Scharler, U.M., Muir, D., 2016. Species composition, abundance and biomass of microphytoplankton in the KwaZulu-Natal Bight on the east coast of South Africa. *African Journal of Marine Science* 38, S139-S153.
- van Moorsel, G.W.N.M., 1993. Long-term recovery of geomorphology and population development of large molluscs after gravel extraction at the Klaverbank (North Sea). Rapport Bureau Waardenburg bv, Culemborg, The Netherlands.
- van Moorsel, G.W.N.M., 1994. The Klaver Bank (North Sea), geomorphology, macrobenthic ecology and the effect of gravel extraction. Rapport Bureau Waardenburg and North Sea Directorate (DNZ), Ministry of Transport, Public Works and Water Management, The Netherlands.
- van Niekerk, L., Adams, J.B., James, N.C., Lamberth, S.J., MacKay, C.F., Turpie, J.K., Rajkaran, A., Weerts, S.P., Whitfield, A.K., 2020. An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management. *African Journal of Aquatic Science* 45, 199-216.
- van Niekerk, L., Adams, J.B., Lamberth, S.J., MacKay, C.F., Taljaard, S., Turpie, J.K., Weerts, S.P., Raimondo, D.C., 2019. South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A. South African National Biodiversity Institute, Pretoria.
- Vanderlaan, A., Taggart, C., 2007. Vessel collisions with whales: The probability of lethal injury based on vessel speed. *Marine Mammal Science* 23, 144-156.
- Vaquer-Sunyer, R., Duarte, C.M., 2008. Thresholds of hypoxia for marine biodiversity. *Proceedings of the National Academy of Science USA* 105, 15452-15457.
- Vermeulen, E., Jouve, E., Best, P., Cliff, G., Dicken, M., Kotze, D., McCue, S., Meÿer, M., Seakamela, M., Thompson, G., Thornton, M., Wilkinson, C., 2022. Mortalities of southern right whales (*Eubalaena australis*) and related anthropogenic factors in South African waters, 1999-2019. *Journal of Cetacean Research and Management* 23, 2149-169.
- Viljoen, M.J., 2019. Determining production characteristics of dusky kob, *Argyrosomus japonicus*, grown in sea cages under commercial conditions in Richards Bay, South Africa. MSc Dissertation, University of Stellenbosch, Stellenbosch, South Africa.

- Vivier, L., 2012. Survey of the macrobenthos and sediment metal concentrations of the Bhizolo and Manzanyama canals, Port of Richards Bay. CRUZ Investigational Report 140.
- Vivier, L., Cyrus, D.P., 2009. Ecological Importance of the Intertidal Kabeljous Flats, Port of Richards Bay. CRUZ Investigational Report 132.
- Vivier, L., Cyrus, D.P., 2009a. Ecological Importance of the Kabeljous Flats, Port of Richards Bay. CRUZ Investigational Report 133.
- Vivier, L., Cyrus, D.P., 2009b. Ecological Importance of the Bhizolo and Manzanyama Canals, Port of Richards Bay. CRUZ Investigational Report 133.
- Vivier, L., Cyrus, D.P., 2014. The Benthic Invertebrate Fauna associated with the T-Jetty Extension in Transnet Capital Projects Richards Bay Port Expansion Plan. CRUZ Environmental Report 16.
- Vivier, L., Cyrus, D.P., 2014a. Benthic Invertebrate Fauna associated with the Finger Jetty in Transnet Capital Projects Richards Bay Port Expansion Project. Report No. 16.
- Vivier, L., Cyrus, D.P., 2014b. Fish and Benthic Invertebrate Fauna associated with Intertidal Mangroves and Sandflats in Transnet Capital Projects: Richards Bay Port Expansion Project. Report No 15.
- Wainright, S.C., Hopkinson, C.S., 1997. Effects of resuspension on organic matter processing in coastal environments: a simulation model. *Journal of Marine Systems* 11, 353-368.
- Wainright, S.C., Hopkinson, C.S., 1997. Effects of resuspension on organic matter processing in coastal environments: a simulation model. *Journal of Marine Systems* 11, 353-368.
- Weerts, S.P., 2002. Habitat utilisation by juvenile fish in Mhlathuze Estuary and Richards Bay Harbour. MSc thesis. University of Zululand, KwaDlangewa.
- Weerts, S.P., 2006. Monitoring the effects of dredging activities associated with the development of Berth 306, Port of Richards Bay: Interim Report 1.
- Weerts, S.P., Cilliers, G. and Cyrus, D.P. 2003. Estuarine macrocrustacea of Richards Bay Harbour, South Africa, with particular reference to the penaeid prawns. *African Zoology* 38, 285-296.
- Weerts, S.P., Cyrus, D.P., 1998/1999. A review of the fishes of the Mhlathuze Estuary. *Southern African Journal of Aquatic Sciences* 24, 99-110.
- Weerts, S.P., Cyrus, D.P., 2002. Occurrence of young and small-sized fishes in different habitats within a subtropical South African estuary and adjacent harbour. *Marine and Freshwater Research* 53, 447-456.
- Weerts, S.P., MacKay, C.F., 2019. Habitat lost and habitat gained. Development drives estuary type change - the case of Richards Bay. In: *South African National Biodiversity Assessment 2018: Technical Report*.
- Weerts, S.P., Newman, B.K., 2009. Port of Richards Bay: Basic assessment of potential aquatic ecological impacts of proposed geotechnical surveys. CSIR Report No. CSIR/NRE/CO/ER/2009/0008/C.
- Wenger, A.S., Harvey, E., Wilson, S., Rawson, C., Newman, S.J., Clarke, D., Saunders, B. J., Browne, N., Travers, M.J., McIlwain, J.L., Erftemeijer, P.L.A., Hobbs, J.-P.A., Mclean, D., Depczynski, M., Evans, R., 2017. A critical analysis of the direct effects of dredging on fish. *Fish and Fisheries* 19, 967-985.
- Wenger, A.S., Rawson, C.A., Wilson, S., Newman, S.J., Travers, M.J., Atkinson, S., Browne, N., Clarke, D., Depczynski, M., Erftemeijer, P.L.A., Evans, R.D., Hobbs, J.P.A., McIlwain, J.L., McLean, D.L., Saunders, B.J., Harvey, E., 2018. Management strategies to minimize the dredging impacts of coastal development on fish and fisheries. *Conservation Letters* 11, 1-10.
- Westley, R.E., Finn, E., Carr, M.I., Tarr, M.A., Schotz, A.I., Goodwin, L., Stenberg, R.W., Collias, E.E., 1973. Evaluation of effects of channel maintenance dredging and disposal on the marine environment in southern Puget Sound, Washington. Washington Department of Fisheries, Olympia, WA USA.
- Widdows, J., Bayne, B.L., Livingstone, D.R., Newell, R.I.E., Donkin, P., 1979. Physiological and biochemical responses of bivalve molluscs to exposure to air. *Comparative Biochemistry and Physiology* 62A, 301-308.
- Wilber, D.H., Clarke, D.G., 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management* 21, 855-875.
- Wilber, D.H., Clarke, D.G., 2007. Defining and assessing benthic recovery following dredging and dredged

- material disposal. 2007 World Organization of Dredging Associations (WODA) Conference, Lake Buena Vista, Florida.
- Wilber, D.H., Clarke, D.G., Rees, S.I., 2007. Responses of benthic macroinvertebrates to thin-layer disposal of dredged material in Mississippi Sound, USA. *Marine Pollution Bulletin* 54, 42-52.
- Winkler, C., Panigada, S., Murphy, S., Ritter, F., 2020. Global Numbers of Ship Strikes: An Assessment of Collisions Between Vessels and Cetaceans Using Available Data in the IWC Ship Strike Database. Report to the International Whaling Commission.
- Wong, C.K., Pak, A.P., Liu, X.J., 2013. Gill damage to juvenile orange-spotted grouper *Epinephelus coioides* (Hamilton, 1822) following exposure to suspended sediments. *Aquaculture Research* 44, 1685-1695.
- Wooldridge, T., Dye, A.H., McLachlan, A., 1981. The ecology of sandy beaches in Transkei. *South African Journal of Zoology* 16, 210-217.
- WSP, 2024. Provision of Detailed Engineering Design, Construction Planning and Project Execution for New Berth 605 at the Port of Richards Bay - Concept Design Report. Document No: XRB.E.0030-T001-RPT-0014.
- Yeager, K.M., Brinkmeyer, R., Rakocinski, C.F., Schindler, K.J., Santischi, P.H., 2010. Impacts of dredging activities on the accumulation of dioxins in surface sediments of the Houston Ship Channel, Texas. *Journal of Coastal Research* 26, 743-752.

10. Glossary of Terms

Abiotic factors	The physical, chemical, and other non-living components of the environment in which organisms live. These include all aspects of the climate, geology, and atmosphere that affect ecological systems.
Activity (Development)	An action either planned or existing that may result in environmental impacts through pollution or resource use. The terms 'activity' and 'development' are often freely interchanged.
Acute effect	Adverse (lethal) effects caused, for example, by exposure to contaminants or physical processes. The term can be used to define either the exposure or the response to an exposure (effect). The effects usually occur over a short-period.
Acute toxicity	The discernible adverse effects induced in an organism within a short period of time of exposure to a chemical. For aquatic animals, this usually refers to continuous exposure to the chemical in water for a period of up to four days, and usually up to 10-days for exposure to sediment.
Acute toxicity test	A method used to determine the concentration of a substance that produces a toxic effect on a specified percentage of test organisms in a short period of time. For aquatic animals, this usually refers to continuous exposure to the chemical in water for a period of up to four days, and usually up to 10-days for exposure to sediment.
Adsorption/adsorb	Bonding of chemicals onto the surfaces of suspended particles by way of physical, chemical, and biological processes.
Adverse effect	Change in the morphology, physiology, growth, development, reproduction, or life span of an organism, system, or (sub)population that results in an impairment of functional capacity, an impairment of the capacity to compensate for additional stress, or an increase in susceptibility to other influences.
Aerobic	Occurring in the presence of oxygen. An aerobic environment is one characterised by the presence of free oxygen (O ₂), in contrast to an anaerobic environment which is one devoid of free oxygen.
Aliquot	A sub-sample of the original sample.
Alkaline	Having the properties of a base, a pH greater than 7.
Alternative	A possible course of action, in place of another, of achieving the same desired goal of the proposed project. Alternatives can refer to any of the following but are not limited to: site alternatives, site layout alternatives, design or technology alternatives, process alternatives or a no-go alternative.
Ambient	Environmental or surrounding conditions.
Ammonia (NH ₃)	A chemical combination of nitrogen and hydrogen that occurs extensively in nature. It is a water-soluble gas that behaves as a weak base. It can exert toxic effects on aquatic life. Synonymous with the obsolete term free and saline and ammonia.
Ammonium (NH ₄ ⁺)	The protonated form and conjugate acid of ammonia. It predominates under low-pH conditions.
Anaerobic	Occurring in the absence of oxygen. An anaerobic environment is characterised by the absence of free oxygen.
Anaerobic (anoxic) sediment	Aquatic sediments that have a high organic matter content. The organic matter is subject to a bacterial decay process that causes the oxygen level in sediments to sharply decline, producing anaerobic conditions. If this situation continues, hydrogen sulphide can form which combines with iron to give the sediments a black appearance.
Analyte	A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.
Anoxic (anoxia)	A condition where very little to no oxygen (typically <0.5 mg.L ⁻¹) is present in a waterbody or in water between the grains of sediment.
Anthropogenic	Made, introduced into the environment, and/or caused by human activities, as pertaining to contaminants/pollutants.

Aquatic ecosystem	All the living and non-living material interacting within an aquatic system (e.g. pond, lake, river, ocean).
Assemblage	An association of interacting populations in a habitat (e.g. an assemblage of benthic invertebrates on the seabed).
Backfill	The word is used in two contexts; to refill an excavated area with uncontaminated soils; and the material used to refill an excavated area.
Bacteria	Single-celled organisms that generally reproduce by fission. Some are pathogenic (disease causing), but most are free-living, with some being saprophytic (feed on dead or decaying organic matter).
Ballast water	Use of water in specialised ballast tanks to aid in controlling a ship's trim and draft, especially when sailing empty or with light cargoes.
Baseline	Information gathered at the beginning of a study which describes the existing state of the environment before a project, against which predicted changes (impacts) are measured.
Baseline	A reference condition against which changes, or trends are judged - usually a set of conditions that exist at a particular point in time.
Bathymetry	Measurement of the depth of water in oceans, rivers, or lakes.
Benthic	Pertaining to the environment inhabited by biological resources living on or in the bottom.
Benthos	Living organisms (e.g. algae and animals) associated with the bottom.
Benthic macrofauna	Invertebrate animals that live in or on the bottom.
Bioaccumulate	The process by which chemical substances are taken up by living things and retained.
Bioavailability	A measure of the physiochemical access that a chemical or toxicant has to the biological processes of an organism. The less the bioavailability of a toxicant, the less its toxic effect on an organism.
Bioavailable	A substance in a chemical and physical form that allows it to affect organisms or be accumulated by them.
Bioavailable	A substance in a chemical and physical form that allows it to affect organisms or be accumulated by them.
Biodiversity	The diversity, or variety, of plants, animals and other living things in a particular area or region. It encompasses habitat diversity, species diversity, and genetic diversity.
Biofouling	Biological organisms that colonise and inhabit man made structures in oceans and seas.
Biogeochemistry	The relationship between geochemistry and the biology of a region.
Biological community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Biomass	Total weight of biological resources per unit area or volume of water or sediment.
Biota	All living things, including microorganisms, plants and animals in a given region.
Bioturbation	The displacement and mixing of sediment particles by biological resources (e.g. through burrowing).
Bivalve	A mollusc with a hinged double shell.
Bloom (microalgal)	An unusually large number of organisms per unit of water, usually microalgae, made up of one or a few species.
Catchment	A catchment is a basin shaped area of land, bounded by natural features such as hills or mountains from which surface and sub surface water flows into streams, rivers, wetlands, and estuaries. Water flows into, and collects in, the lowest areas in the landscape. It may also refer to the area served by surface drainage channels and canals, including surface runoff (stormwater) reticulation systems.
Cetacea	Order of marine mammals containing dolphins, whales and porpoises.
Chart Datum	The level of water that charted depths displayed on nautical charts are measured from.
Chlorophyll-a	Chlorophyll-a is the green pigment found in all plants and in nearly all algae. Chlorophyll-a allows plants and algae to use sunlight in the process of

	photosynthesis for growth. The concentration of chlorophyll-a in estuarine, coastal or marine waters is used as an indicator of photosynthetic plankton biomass.
Chronic Toxicity	The response of an organism to long-term exposure to a chemical substance. Among others, the responses that are often measured in chronic toxicity tests include lethality, decreased growth, and impaired reproduction.
Coliform bacteria	A group of bacteria primarily found in human and animal intestines and wastes. These bacteria are widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria. <i>Escherichia coli</i> (<i>E. coli</i>) is one of the faecal coliform bacteria widely used for this purpose.
Colony forming unit (CFU)	A unit (measurement) of density used to estimate bacteria concentrations in ocean water. The number of bacterial cells that grow to form entire colonies, which can then be quantified visually.
Community	Any group of organisms belonging to several different species that co-occur in the same habitat or area. An association of interacting assemblages in any given water body.
Community composition	All the types of biological taxa present in a community.
Community structure	All the types of taxa present in a community and their relative abundances.
Concentration	The quantifiable amount of a substance in water, food or sediment.
Construction Phase	The stage of project development comprising site preparation as well as all construction activities associated with the development.
Contaminant	Biological (e.g. bacterial and viral pathogens) and chemical introductions capable of producing an adverse response (effect) in a biological system, seriously injuring structure and/or function.
Cope	The top edge of a quay or jetty adjacent to a berth.
Counterfort wall	A counterfort retaining wall is a cantilever wall with counterforts, or buttresses, attached to the inside face of the wall to further resist lateral thrust. Some common materials used for retaining walls are treated lumber, concrete block systems, poured concrete, stone, and brick
Critical Habitat	Specific areas within the geographical area occupied by a species at the time of listing that contain physical or biological features essential to conservation of the species and that may require special management considerations or protection.
Crustaceans	Arthropods such as crabs and prawns that have jointed appendages and hard outer shells.
CSIR	Council for Scientific and Industrial Research
Cumulative effects/impact	Effects on the environment resulting from actions that are individually minor but that add up to a greater total effect as they take place over a period of time.
Demersal	The part of the water column that is near to the seabed and the benthos. Demersal fish are those that spend most of their life cycle on or near the seabed.
Detritus	Unconsolidated sediments composed of both inorganic and dead and decaying organic material.
Detection limit	The smallest concentration or amount of a substance that can be reported as present with a specified degree of certainty by analytical procedures.
Direct impacts	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (e.g. between occupation of a site and the pre-existing habitats, or between an effluent discharge and receiving water quality). These impacts are usually associated with the construction, operation, or maintenance of an activity, and are generally obvious and quantifiable.
Dissolved oxygen	Oxygen that is dissolved in water and therefore freely available for plants (phytoplankton), shellfish, fish, and other animals to use.
Diatoms	A single-celled algae that has a cell wall of silica.
Diversity	A measurement of community structure that describes the abundances of different species within a community, considering their relative rarity or commonness.

Ecological processes	Processes which play an essential part in maintaining ecosystem integrity. Four fundamental ecological processes are the cycling of water, the cycling of nutrients, the flow of energy and biological diversity (as an expression of evolution).
Ecology	The study of the interrelationships of organisms with and within their physical surroundings.
Ecosystem	Any system in which living organisms and their immediate physical, chemical and biological environment are interactive and interdependent.
Enterococci	Any streptococcal bacteria normally found in the human intestinal tract. Usually non-pathogenic.
Emergency Response Plan	Plan to address contingencies associated with process upset and accidental circumstances.
Environmental Impact Assessment	The process of predicting and evaluating the social and environmental impacts and risks of a proposed project, and identifying mitigation measures that will enable the Project to meet the requirements of stakeholders, applicable laws and regulations, and any additional requirements for social or environmental performance identified by the Project, and so that impacts are as low as technically and financially feasible.
Environmental Impact	A change to the environment (biophysical, social and/ or economic), whether adverse or beneficial, wholly or partially, resulting from an organisation's activities, products or services.
Environmental indicator	A measurable feature or features that provide managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality.
Environmental management	Ensuring that environmental concerns are included in all stages of development, so that development is sustainable and does not exceed the carrying capacity of the environment.
Environmental Management Programme	A detailed plan of action prepared to ensure that recommendations for enhancing or ensuring positive impacts and limiting or preventing negative environmental impacts are implemented during the life cycle of a project. This EMP focuses on the construction phase, operation (maintenance) phase and decommissioning phase of the proposed project.
Environmental value	Anything a community agrees a body of water should be protected for. This might include an ecosystem, industry, agriculture, recreation, and its spiritual and cultural uses/importance.
Epifauna	Animals that live at or on the sediment or rock surface, being either attached (sessile) or capable of movement.
Epifauna/epibenthic animals	The animals that live on the surface of sediments or on and among rocks and other structures.
<i>Escherichia (E.) coli</i>	A type of faecal coliform bacteria which is found in large numbers in the faeces of humans and other mammals, and birds. It serves as a reliable indicator of recent faecal contamination of water.
Estuaries	A partly enclosed body of water that has one or more rivers flowing into it and is connected to the open sea. Estuaries thus receive fresh water from inland and salt water from the sea. Tides influence how much (and how far) salt water intrudes into the estuary and river.
Eutrophication	A condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g. phytoplankton). Algal decomposition may lower dissolved oxygen concentrations. Although eutrophication is a natural process in the aging of lakes and some estuaries, it can be accelerated by both point and non-point sources of nutrients.
Faecal coliform	A type of bacteria found in faecal material of humans and other mammals. It serves as a reliable indicator of recent faecal contamination of water.
Fauna	The animal life of a region.
Flocculation	The coagulation and agglomeration of colloidal and finely divided suspended matter to form flocs.
Flora	The plant life of a region.
Food chain	The transfer of food energy from plants through herbivores to carnivores. An example: algae being eaten by zooplankton (grazers; herbivores) which in

	turn are eaten by small fish (planktivores; predators) which are then eaten by larger fish (piscivores; fish eating predators) and eventually by people or other predators (fish-eating birds, mammals).
Food web	The interlocking patterns formed by a series of interconnected food chains.
Geochemical	Principles of physical chemistry and geology affecting minerals and rocks.
Grab	A mechanical device designed to collect bottom sediment samples. The device consists of a pair of hinged jaws and a release mechanism that allows the opened jaws to close and entrap a sediment sample once they touch bottom.
Gravity wall	Retaining wall of heavy cross-section that resists horizontal actions by means of dead weight and friction.
Guideline	A numerical concentration limit or narrative statement recommended to support and maintain a designated water use.
Habitat	A place where the physical and biological elements of ecosystems provide an environment and elements of the food, cover and space resources needed for plant and animal survival.
Hazardous waste	Substances classified as hazardous wastes possess at least one of four characteristics of ignitability, corrosivity, reactivity or toxicity – or appear on special lists.
Heavy metal	An imprecise term with no sound terminological or scientific basis, used loosely to refer to metals that are toxic.
Highest Astronomical Tide	The elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum Epoch.
Hopper	Tank on a dredger that receives and contains dredge spoil.
Hopper overwash	The practice of allowing low concentration sediment slurry to flow overboard allowing the build-up of more concentrated slurries in the hopper.
Hydrocarbons	Organic compounds consisting exclusively of the elements carbon and hydrogen and including such substances as paraffin, benzene and fuel oil. Some are obtained by cracking larger molecules (e.g. petrol).
Hydrophobic	Having little or no affinity for water, repels or does not absorb water.
Hypoxia	The condition of low dissolved oxygen in aquatic systems (typically with a concentration <2 mg.L ⁻¹ but >0.5 mg.L ⁻¹).
Ichthyofauna	Fish.
Ichthyoplankton	Fish, fish larvae and fish eggs in the plankton.
Impact	Any alteration of existing conditions, adverse or beneficial, caused directly or indirectly by a project.
Impairment	A detrimental effect on the biological integrity of a water body caused by an impact.
Indirect impacts	Impacts that result from other activities that are encouraged to happen as a consequence of the Project (e.g. in-migration for employment placing a demand on resources). Indirect impacts can also be referred to as induced or secondary impacts. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or which occur at a different place as a result of the activity.
Infauna	Animals that live in sediment.
<i>In situ</i>	In the natural habitat as opposed to in a laboratory or controlled situation.
Indicator	Characteristics for the environment, both abiotic and biotic, that can provide quantitative information on condition or state of an ecosystem. They include biological indicators (e.g. species composition, species abundance) and physical or chemical indicators (e.g. dissolved oxygen concentration, temperature). These often represent the targets, or water quality objectives, that need to be met to achieve the desired level of ecosystem protection.
Infauna	Those animals that live within bottom sediment.
Infauna	Animals of any size that within sediment. They move freely through interstitial spaces between sedimentary particles, or they build burrows or tubes.
Inorganic	Any compound lacking carbon.
Intertidal	The area of the shore that is above water at low tide and under water at high tide.

Invasive or alien species	Species introduced outside its normal distribution. Its establishment and spread modifies ecosystems, habitats or species. Aliens are called invasive when they spread rapidly and outcompete indigenous species.
Invertebrate	An animal without a backbone (e.g. a starfish, crab, or worm).
Laydown areas	An area that has been cleared for the temporary storage of equipment and supplies.
Macroalgae	A member of the macroscopic algal life of an area, especially of a body of water; large aquatic algae.
Macrophyte	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Mangrove	Kinds of trees up to medium height, and shrubs, which grow in saline coastal sediment habitats in the tropics and subtropics.
Mean High Water Spring	The highest level which spring tides reach on average over a period
Mean Low Water Spring	The lowest level which spring tides reach on average over a period
Median	The median is the middle value in a data set ranked from lowest to highest.
Method detection limit	The minimum concentration of a substance that can be measured and reported with 99% confidence that the concentration is greater than zero.
Micro/Algal bloom	A heavy growth of algae in and on a body of water; usually results from high nitrate and phosphate concentrations entering water bodies from farm fertilizers and detergents; phosphates also occur naturally under certain conditions.
Microalgae	Photosynthetic microscopic organisms and are also known as phytoplankton.
Microbiology	The study of micro-organisms.
Microorganism	A living organism invisible or barely visible to the naked eye because of its small size; some, however, produce colonies of macroscopic size.
Mitigate	Implementation of practical measures designed to avoid, reduce or remedy adverse impacts or enhance beneficial impacts of an action.
Monitoring	Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things.
Normalise	Perform a data calculation to express results in terms of a reference parameter or characteristic.
Nutrient enrichment	A term that describes the addition of too much nutrient (nitrogen, phosphorus and carbon), to waterbodies from human actions and the resulting responses that typically leads to changes in plant and animal communities and degradation of water and sediment quality.
Nutrients	Essential chemicals (e.g. nitrogen and phosphorus) needed by plants for growth.
Organochlorides	A group of organic (carbon-containing) insecticides that also contain chlorine. These chemicals tend not to break down easily in the environment. DDT, Toxaphene and Endosulfan are all organochlorides.
Pathogen	An agent such as a virus, bacterium or fungus that can cause diseases in humans. Pathogens can be present in municipal, industrial, and non-point-source discharges.
Pelagic	The part of the water column in the open sea that is not closely associated with the seabed.
Pelagic zone	Water body in oceans, seas or lakes that is not close to the bottom or shore, i.e. the water column extending from the surface to near the seabed.
Percentile	A value on a scale of 100 that indicates the percent of a distribution that is equal to or below it.
pH	pH is a measure of acidity or alkalinity of water on a log scale from 1 (extremely acidic) through 7 (neutral) to 14 (extremely alkaline).
Porewater	The water in the interstices of sediment particles in unconsolidated sediments such as sands and mud.
Photosynthesis	The conversion of carbon dioxide to carbohydrates in the presence of chlorophyll using light energy.
Physico-chemical	Measurement of both physical properties (e.g. temperature, salinity) and chemical determinants (e.g. metals and nutrients) to characterise the state of

	an environment.
Phytoplankton	Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.
Pile cap	A reinforced or mass concrete connecting beam cast around the head of a group of piles enabling it to act as a single unit to support the imposed load.
Plankton	Microscopic animals (zooplankton) or plants (phytoplankton) that inhabit the pelagic zone of water bodies.
Pollution	The Paris Convention defines pollution as the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as hazards to human health, harm to living resources and to marine ecosystems, damage to amenities or interference with other legitimate uses of the sea.
Polychlorinated biphenyls (PCBs)	A group of toxic chemicals used for a variety of purposes including electrical applications, carbonless copy paper, adhesives, hydraulic fluids, and caulking compounds. PCBs do not breakdown easily and are listed as cancer-causing agents under Proposition 65
Polycyclic aromatic hydrocarbon	A class of chemical compounds composed of fused six-carbon rings. Polycyclic aromatic hydrocarbons are commonly found in petroleum oils (e.g. gasoline and fuel oils) and are emitted from various combustion processes (e.g. automobile exhausts, electric companies).
Population	An aggregate of interbreeding individuals of a biological species within a specified location.
Primary production	The first stage in the production of organic matter, mainly because of phytoplankton and algal growth.
Producers	Organisms able to build up their body substance from inorganic materials.
Propeller wash	The disturbed mass of water pushed aft (or fore when in reverse) by the propeller of watercraft.
Quay	A structure built parallel to the bank of a waterway for use as a landing place.
Recruitment	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion, and migration.
Redox potential	An expression of the oxidising or reducing power of a solution relative to a reference potential.
Reference toxicant	A chemical used to access the constancy of response of a given species of test organisms to that chemical. It is assumed that any change in sensitivity to the reference substance will indicate the existence of some similar change in degree of sensitivity to other chemicals/effluents whose toxicity is to be determined.
Replicate	Taking more than one sample or performing more than one analysis. In chemical analysis and toxicity testing a duplicate.
Salinity	A measurement of the amount of salt in water.
Seagrass	Flowering rooted plants (angiosperms) from one of four plant families all in the order Alismatales (in the class of monocotyledons), which grow in marine, fully saline environments.
Sediment	Mud, sand, silt, clay, shell debris, and other particles that settle on the bottom of rivers, lakes, estuaries, and oceans.
Sheet pile wall	Sheet pile walls are constructed by driving prefabricated sections into the ground. Soil conditions may allow for the sections to be vibrated into ground instead of it being hammer driven. The full sheet pile wall is formed by connecting the joints of adjacent sheet pile sections in sequential installation.
Significance	An impact is significant if, in isolation or in combination with other impacts, it should be taken into account in the decision-making process. The degree of significance depends on the combination of impact magnitude and probability of impact occurrence.
Species	A category of biological classification ranking immediately below the genus, comprising related organisms potentially capable of interbreeding. A species is identified by a two part name; the name of the genus followed by a Latin or Latinised un-capitalised noun agreeing grammatically with the genus name.
Species richness	The number of species per unit area.

Station	A sampling location within a study area or site, where physical, chemical, or biological sampling and/or testing occurs.
Subtidal	The area below low tide that is always submerged.
Supratidal	The area above the high tide water line that extends upland. The area is seldom covered by water unless during flooding or storms, but can receive water from wave splash.
Surficial	The layer at the top of the sediment body, usually millimetres to centimetres thick.
Taxon (taxa)	Any group of organisms considered to be sufficiently distinct from other groups to be treated as a separate unit (e.g. species, genera, families).
Thermocline	A layer of rapid temperature change in the water column.
Total Suspended Solids	A measure of the total weight of particles in the water column, and is analysed in the laboratory from field samples.
Toxic	Poisonous, carcinogenic, or otherwise directly harmful to life.
Toxicant	A chemical capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death (e.g. pesticides and metals).
Toxicity	A measure of the impact on a chosen biological process or condition.
Trophic level	The position occupied by an organism in the food chain, e.g. green plants occupy the first trophic level, herbivores the second, and carnivores which eat herbivores the third.
Tubular pile	A pile consisting of a steel tube driven into the ground and filled with concrete after the enclosed earth has been removed.
Turbidity	Turbidity is a measure of water clarity or murkiness. It is an optical property that expresses the degree to which light is scattered and absorbed by molecules and particles.
Water column	A conceptual column of water from the surface to the bottom.
Water quality	Water quality describes the condition of a water body and its related suitability for different purposes (also known as environmental values). In a healthy water body, the water quality supports a rich and varied community of organisms, sustains public health and/or agricultural applications.
Water Quality Guideline	A parameter concentration (e.g. nitrate) or narrative statement (e.g. no algal blooms) that is used to assess whether a declared water value is being sustained. If the guideline is not met, the water maybe under threat and investigation is warranted to ascertain if the cause is anthropogenic or due to natural phenomena.

