ASSESSMENT OF SEDIMENT QUALITY IN THE PORT OF EAST LONDON – 2024

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Report prepared for:

Mr Basil Ngcobo
Chief Engineer
Transnet National Ports Authority

Ms Cebile Nzuza
Senior Manager: Environment and Sustainability
Transnet National Ports Authority

Report prepared by:

Coastal Systems and Earth Observation Research Group
Sustainable Ecosystems
CSIR

Report authors:

Brent Newman
Sebastian Brown

Contact person:

Brent Newman
Coastal Systems and Earth Observation Research Group
CSIR
Postnet Suite 367
Private Bag x10
Musgrave Road
Durban 4062
South Africa
Telephone: (031) 242 2377
Email: Bnewman@csir.co.za

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Executive Summary

Background

In accordance with the National Environmental Management Act: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008), Transnet National Ports Authority makes an annual application to the Department of Forestry, Fisheries and the Environment for a permit (the Department refers to these as dumping permits) to cover the open water disposal of sediment that is maintenance dredged in the Buffalo River estuary. The permit does not cover the act of dredging itself, but the open water disposal (dumping) of dredged material.

Report Purpose

The decision by the Department of Forestry, Fisheries and the Environment to provide a dumping permit is based partly on the concentrations of metals in sediment identified for dredging.

The purpose of this report is to provide the findings of the physical and chemical analysis of sediment sampled in the Buffalo River estuary in 2024, in support of a permit application for the open water disposal of maintenance dredged sediment.

Methods

Sediment was collected at 11 positions (stations) in the Buffalo River estuary on 22 May 2024. The grain size, total organic content, and metal concentrations in the sediment were analysed in the laboratory. The total organic content and metal concentrations were compared to baselines established for the estuary, to identify if they were above the baseline.

Key Findings

- The sediment at most stations in the estuary was dominated by mud. Only near the estuary mouth was the sediment dominated by sand.
- The total organic content at two stations above the port area in the estuary was above the baseline, to a degree that is indicative of moderate or high enrichment.
- The concentrations of metals in the sediment at most stations were within the baseline range. The sediment across large parts of the estuary was not metal contaminated.
- The concentrations of two or more metals in the sediment at two stations above the port area, at a station near the dry dock, and at a station near Victoria Slipway were above the baseline.
- The most common contaminants of the sediment were barium, copper, chromium, and zinc.
- Barium was the most often enriched metal, at four of the 11 stations, followed by cobalt, lead, and zinc at three stations each.
- The Department of Forestry, Fisheries and the Environment uses Action Levels to decide if sediment identified for dredging in South African ports is suitable for open water disposal.
- There are two guidelines, known as the Level I and Level II.
- Sediment with metals at a concentration below the Level I is suitable for open water disposal.
- Sediment with metals at a concentration between Level I and Level II is cause for concern, the degree of concern increasing as the concentrations approach the Level II. Further testing may be requested to determine if metals in the sediment pose a toxic risk to sediment-dwelling organisms.
- Sediment with metals at a concentration above the Level II is considered unsuitable for open water disposal unless other evidence (*e.g.* toxicity testing) shows the sediment was not toxic.
- The copper concentration in the sediment near the dry dock exceeded the Level II.
- Sediment across most of the estuary is thus suitable for disposal at the open water dredged material disposal site off East London.

Table of Contents

1. Background and Report Purpose

Sediment naturally accumulates in ports. The sediment may originate on land, from where it is transported by rivers and surface (stormwater) runoff into a port, or it may originate in the sea, from where it is entrained into a port by tidal action. Irrespective of its origin, if sediment is allowed to accumulate unchecked in a port a situation may be reached wherein the depth of navigation channels, turning basins, berths, and other waters are reduced to the extent that safe vessel movement is not possible. Port authorities thus maintain navigation channels, berths, and basins to their design depths by maintenance dredging. In many ports and navigable waterways, maintenance dredging is required on an on-going basis. The material dredged in coastal ports is usually disposed at open water dredged spoil disposal sites. In some countries, contaminated sediment is disposed in confined land or waterside facilities (*e.g.* capping). The latter is not a practice that has been followed to date in South Africa and virtually all dredged sediment is disposed at open water spoil disposal sites (a minor volume is used for shoreline nourishment or port construction).

Dredging poses numerous environmental impacts. These include an increase in the suspended sediment concentration and turbidity in the water column, the removal, injury, and disturbance of biological communities in the dredging footprint, and the remobilisation of toxic chemicals that might have accumulated in sediment into the water column. There is no environmental legislation that governs the act of dredging in South Africa, but the dredging party is expected to exercise a duty of care to limit environmental degradation. The National Environmental Management Act: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008) governs the open water disposal of dredged material. The open water disposal of dredged material requires a permit from the Department of Forestry, Fisheries and the Environment. The permitting procedure is in line with the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 1972 (the London Convention) and 1996 Protocol thereto, to which South Africa is a signatory. To comply with the Act, Transnet National Ports Authority makes an annual application to the Department to dispose of sediment maintenance dredged in the Buffalo River estuary at a registered open water dredged spoil disposal site off the East London coast. The Department decides if dredged sediment may be disposed at open water dredged spoil disposal sites based largely on metal concentrations in the sediment.

The findings of the physical and chemical analysis of sediment sampled in the Buffalo River estuary in May 2024 are discussed in this report. The purpose is to provide Transnet National Ports Authority with some of the information that is required for the completion of a permit application to the Department of Forestry, Fisheries and the Environment to cover the open water disposal of sediment maintenance dredged in the Buffalo River estuary for the next permit cycle. The report also provides officials from the Department of Forestry, Fisheries and the Environment with information for reaching an informed decision on the application.

2. Material and Methods

2.1. General description of the Port of East London

The Port of East London is situated in the Buffalo River estuary, in the city of East London on the southeast coast of South Africa (27°55'S, 33°01'E; Figure 1). The estuary bisects the port into what are traditionally referred to as the West and East Banks, although these technically lie on a north-south axis as the estuary lies on a general west-east axis (see Figure 1). The entrance channel is dredged to a depth of about 12 m, with draughts at berths for large cargo vessels ranging between about 8 - 10.5 m. The port has twelve commercial berths, one repair quay and a graving dock. Six berths are situated on the West Bank and six on the East bank, offering a total quay length of about 2.4 km. A repair quay and the graving dock are situated on the East Bank, the latter with a docking length of about 200 m.

A variety of cargo is imported and exported through the port, of which vehicles and vehicle components, grain and containerised traffic are the most important. Grain exports (primarily maize) are

Figure 1. Aerial view of the Buffalo River estuary, showing the positions where sediment was sampled in May 2024.

facilitated through the largest grain silo on the South African coast. The silo is on the West Bank, near the port entrance. A multi-level car terminal with storage for about 2800 vehicles and a throughput of about 50 000 vehicles per year is also situated on the West Bank. Containerised traffic and break-bulk cargo are handled at the Combi Terminal on the East Bank.

The immediate surroundings of the port are heavily urbanised, consisting of a mainly residential and light industrial type on the East Bank and an industrial type on the West Bank. Several small streams and creeks drain surface runoff from the surroundings to the port.

2.2. Fieldwork

Sediment was sampled on 22 May 2024 at 11 positions (hereafter referred to as stations) identified by Transnet National Ports Authority, based largely on anticipated maintenance dredging requirements (Figure 1; see Appendix 1 for station Global Positioning System coordinates). The sediment at each station was analysed for its grain size and total organic content, and for the concentrations of 15 metals.

The upper 5 - 10 cm of sediment was sampled using a van Veen grab. Three grab samples were collected at each station. On retrieval, water overlying sediment in the grab was bled through a bleeder hole in upper corners of the grab, taking care to lose as little fine-grained material as possible in the process. The sediment from the three grab samples was composited in a glass bowl and inspected. If the sediment contained a large amount of gravel and stones, plastic items, or other anomalous material, the sediment was discarded, and three further grab samples were collected after moving the vessel a few meters from the designated station. If the sediment was deemed acceptable it was homogenised in the glass bowl using a high-density polyethylene scoop until it was of a uniform colour and texture. Small stones, plastic items, and other material not representative of the sediment was removed if encountered. Characteristics of the sediment, such as its colour, texture, and aroma were noted on field data sheets and the sediment was photographed. The sediment was again homogenised. Aliquots of the sediment were then distributed between pre-cleaned high-density polyethylene and amber glass jars depending on the required analyses. The sediment was homogenised between the transfer of aliquots to sample jars to prevent layering. The samples were held on ice in the field and frozen (-18°C) on

return to the laboratory apart from the sediment destined for toxicity testing, which was refrigerated at 4°C. The grab and sediment processing equipment was rinsed in site water, scrubbed with a brush if necessary and rinsed again in site water, sprayed with acetone, and again rinsed in site water before sampling the sediment at a new station to limit cross contamination.

2.3. Laboratory analyses

2.3.1. Analytical laboratory

Metal analyses on the sediment were performed at the Environmental Chemistry Laboratory at the CSIR campus in Stellenbosch. The laboratory is accredited by the South African National Accreditation System (SANAS) for the analysis of marine water, sediment, and biological tissue. The laboratory SANAS accreditation certificate is provided in Appendix 2.

2.3.2. Grain size composition

Sediment grain size composition was determined by wet and dry sieving the sediment into seven grain size classes according to the Wentworth Scale, namely mud (<0.063 mm), very fine-grained sand (0.063 -0.125 mm), fine-grained sand (0.125 - 0.250 mm), medium-grained sand (0.25 - 0.50 mm), coarse-grained sand (0.5 - 1.0 mm), very coarse-grained sand (1.0 - 2.0 mm) and gravel (>2.0 mm).

2.3.3. Total organic content

An aliquot of the sediment was oven dried and weighed. Particulate organic matter in the sediment was then degraded using hydrogen peroxide, which was added until effervescence ceased. The sediment was then rinsed in distilled water, dried, and weighed. The difference in dry weight before and after particulate organic matter degradation was taken as the total organic content.

2.3.4. Metals

The sediment was freeze dried and ball milled. About 1 g of the sediment was weighed into a digestion vessel and digested in a mixture of HNO_3-HCl-H_2O_2 according to USEPA method 3050B. This is a 'near-total' digestion method that dissolves most elements that could be 'environmentally available', but it is not designed to dissolve metals tightly incorporated in silicate structures (*i.e.* refractive metals). The digestate was filtered (0.45 µm), diluted to volume with Milli-Q water, and the concentrations of various major, minor and trace metals detected and quantified using Inductively Coupled Plasma Optical Emission (ICP-OES) and Mass Spectroscopy (ICP-MS). Mercury was analysed using a direct mercury analyser (DMA).

Method blanks were analysed to assess laboratory contamination. The precision and extraction efficiency of the analytical procedures was evaluated by analysing marine sediment reference standard PACS-2 (National Research Council of Canada) and laboratory duplicates. Since the reference material is certified for total digestion but a near-total extraction procedure was used in this study, the recovery of several refractory metals (*e.g.* aluminium, chromium) was somewhat below 100% (Appendix 3). However, the recoveries are within limits defined by the CSIR for quality assurance and quality control purposes based on the results of repeated analysis of the CRM. All metals were at a concentration below the method detection limit in method blanks. The Relative Standard Deviation for laboratory duplicates was within the data quality objective of 10% (Appendix 3).

Although arsenic is technically a metalloid (*i.e.* semi-metal), in the interests of simplicity it is referred to as a metal in this report.

3. Results and Discussion

3.1. Grain size composition

In a geologically homogenous area, grain size is the most important factor that controls the natural concentrations of metals in sediment because aluminosilicates, the major natural metal-bearing phase of sediment, predominate in clay. Sand, in contrast, is comprised largely of metal deficient quartz (silica) and acts as a diluent of metal concentrations. Muddy sediment thus naturally has a higher metal content than sandy sediment. Mud also sequesters metals that are anthropogenically introduced in solution to surface waters because of the large surface area provided by the grains for adsorption and because their surface is electrically charged, rendering them chemically reactive. Metals and other particle reactive contaminants

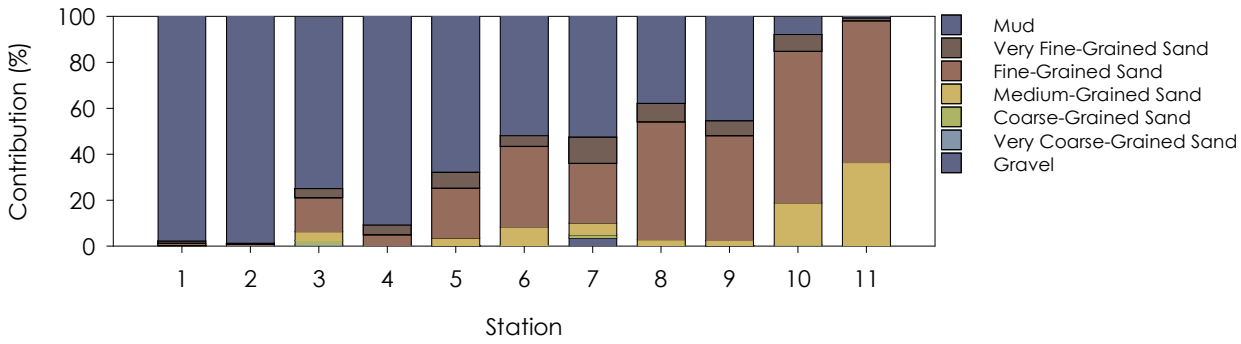

Figure 2. Contribution of various grain sizes to the bulk weight of sediment sampled in the Buffalo River estuary in May 2024.

also attach to, and are transported with suspended particulate matter in the water column, ultimately settling and accumulating in depositional zones. These are areas where the sediment is dominated by fine-grained material (*e.g.* mud) and form where water currents are so weak that fine-grained suspended material and any associated contaminants settle from the water column. Generally, therefore, naturally occurring and anthropogenically introduced metal concentrations are highest in muddy sediment and lowest in sandy sediment. There may be exceptions in ports since coarse-grained sediment may contain high metal concentrations due, for example, to the inclusion of metal flecks and metal-impregnated antifouling coating flakes from vessel maintenance operations, and metal concentrate and ore particles spilled during the loading of vessels.

The grain size of sediment thus provides important information for identifying areas in the Buffalo River estuary where particle reactive contaminants have a propensity to accumulate. Anomalously high metal concentrations in sandy sediment also provides indirect information on the likelihood the metals were present as a solid (*i.e.* a largely non-bioavailable form), which has implications for understanding the toxicological risk.

The sediment at most stations sampled in the Buffalo River estuary in May 2024 was dominated by mud (Figure 2; data in Appendix 3). Only at Stations 8 to 11 in and near the port entrance was the sediment dominated by sand. The contribution of mud generally progressively decreased from Station 1 upstream of the port proper to Station 11 in the estuary entrance.

The findings for the May 2024 survey are consistent with those of previous surveys. The high mud fraction of sediment across large parts of the Buffalo River estuary reflects its depositional nature, which is a characteristic feature of estuaries. This indicates there is a high propensity for the retention of particle reactive contaminants introduced in solution to the estuary.

3.2. Total organic content

Particulate organic matter in sediment also provides a site for the adsorption of contaminants, including metals such as cadmium and mercury and organic contaminants such as polycyclic aromatic hydrocarbons. Metals and other contaminants that are particle reactive attach to and are transported with suspended particulate organic matter in the water column, ultimately settling and accumulating in depositional zones. Due to its fine-grained nature, particulate organic matter is deposited on and winnowed from sediment concurrently with mud depending on the prevailing current regime. Mud and particulate organic matter tend, therefore, to accumulate in or be depleted from sediment in the same areas. The total organic content of sediment thus provides important information for identifying major sources of, and depositional zones for particulate organic matter in the Buffalo River estuary, and therefore, for identifying parts of the estuary that are susceptible to the accumulation of contaminants that preferentially adsorb onto this matter. The total organic content is also monitored to determine if the sediment is so enriched with particulate organic matter that its exposure during dredging will likely result in an excessive oxygen demand by microorganisms that degrade this matter. Since dissolved oxygen is a fundamental requirement for

the survival of most forms of aquatic life an excessive oxygen demand is of obvious ecological concern.

In aquatic ecosystems where the sediment is not enriched with particulate organic matter from anthropogenic sources there is often a strong positive relationship between the mud fraction and total organic content of the sediment due to the similar deposition and winnowing from sediment of these fine-grained particles by currents. The relationship is beneficial since it can be used to identify sediment that has an anomalous total organic content. Scientists from the Coastal Systems and Earth Observation research group of the CSIR have defined a baseline model for the total organic content of sediment in the Port of East London (Figure 4). The baseline model comprises a linear regression and 99% prediction limits (oblique solid and dashed lines respectively in Figure 4). The regression defines the average total organic content at co-occurring mud fractions in sediment at baseline locations in the Port of East London, while the upper and lower prediction limits define the range around the average in which 99% of measurements should fall if the sediment is not enriched with particulate organic matter and the data are normally distributed. A total organic content that plots above the upper prediction limit indicates the sediment has a total organic content in excess of the baseline and is thus deemed to be enriched with particulate organic matter. The magnitude of the enrichment was quantified by calculating an Enrichment Factor. An Enrichment Factor ≤1 indicates the total organic content is lower than the concentration predicted at the upper prediction limit of the baseline model and is thus within the baseline range while an Enrichment Factor >1 indicates the total organic content is in excess of the concentration expected for baseline sediment at the corresponding mud fraction in the sediment sample. An Enrichment Factor of two, for example, means the total organic content is twice as high as the total organic content predicted for sediment for baseline sediment with the corresponding mud fraction.

Superimposing the total organic content of sediment sampled in the Buffalo River estuary in May 2024 onto the baseline model identifies the

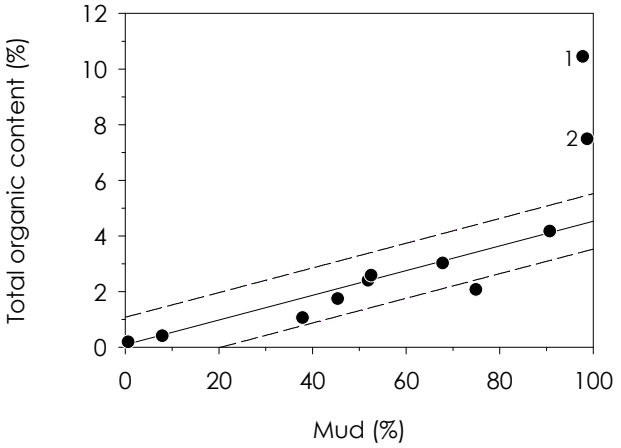

Figure 3. Baseline model for total organic content in sediment in the Buffalo River estuary, with the total organic content in sediment sampled in the estuary in May 2024 superimposed. Some data points are highlighted by station identifiers.

sediment at Stations 1 and 2 as moderately to highly enriched with particulate organic matter (Figure 3; data in Appendix 3). The findings for the May 2024 survey are consistent with those of previous surveys from the perspective that sediment across most of the Buffalo River estuary has often not been enriched with particulate organic matter apart from upstream of the port proper. The particulate organic material in this part of the estuary is derived largely from plant remains, which are undoubtedly introduced to the estuary via the Buffalo River.

3.3. Metals

It is easy to determine if sediment is contaminated by some chemicals since they do not occur naturally in the environment but are manmade. The mere presence of these chemicals in sediment indicates it is contaminated. Determining if sediment is metal contaminated is more complicated because metals are a ubiquitous, naturally occurring component of sediment. The mere presence of metals in sediment does not automatically imply it is contaminated. Metal concentrations in uncontaminated sediment can vary naturally by several orders of magnitude over a relatively small spatial scale depending on the sediments mineralogy, granulometry and organic content amongst other factors (Loring and Rantala, 1992; Kersten and Smedes, 2002). High metal concentrations in sediment do not imply contamination but might simply reflect the mineralogy of the parent material and its grain size

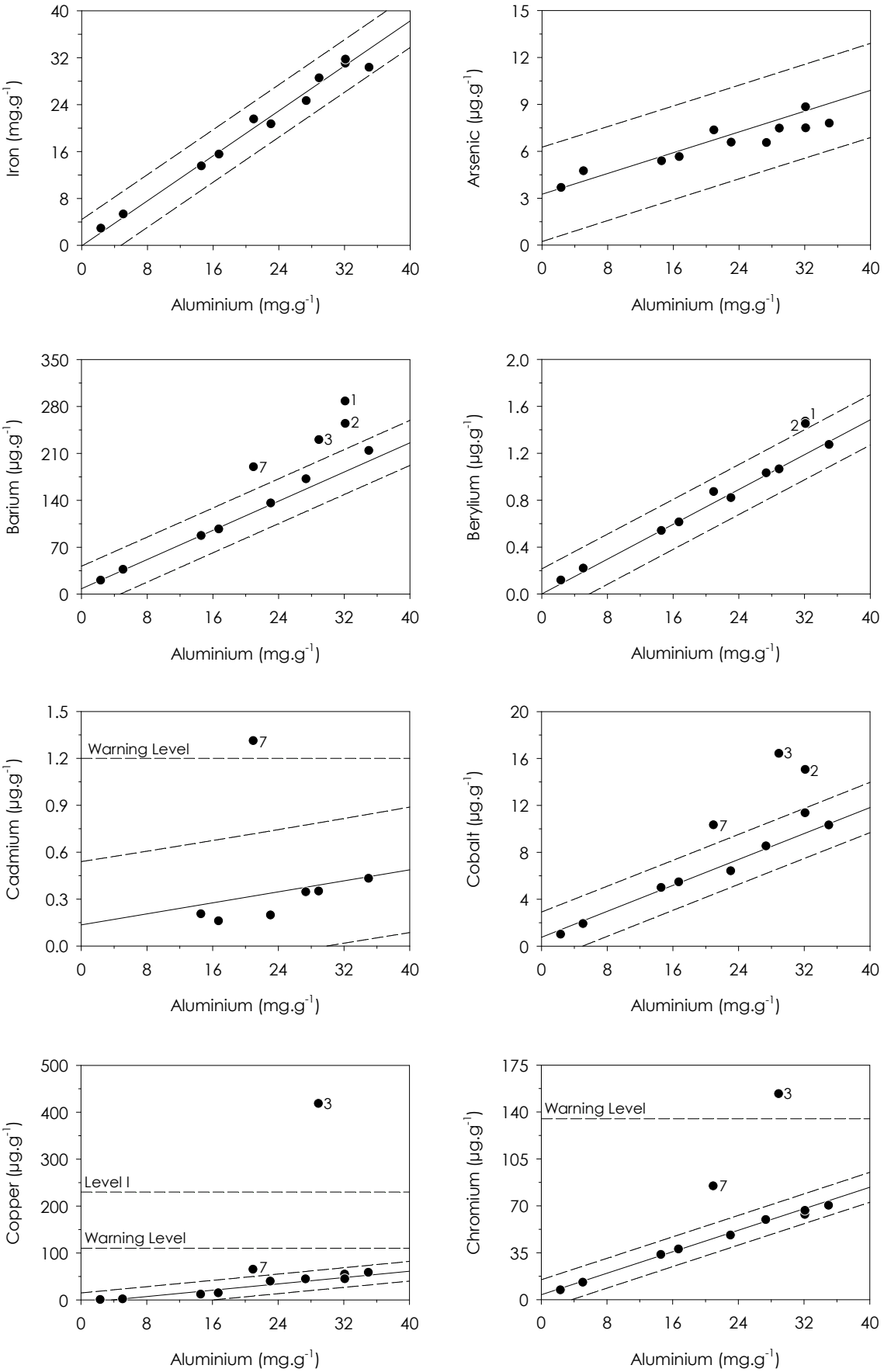

Figure 4. Baseline metal concentration models for sediment in the Buffalo River estuary, with metal concentrations in sediment sampled in the estuary in May 2024 superimposed. Sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal are included if they fall within the y-axis range. Some metal concentrations are highlighted by station identifiers.

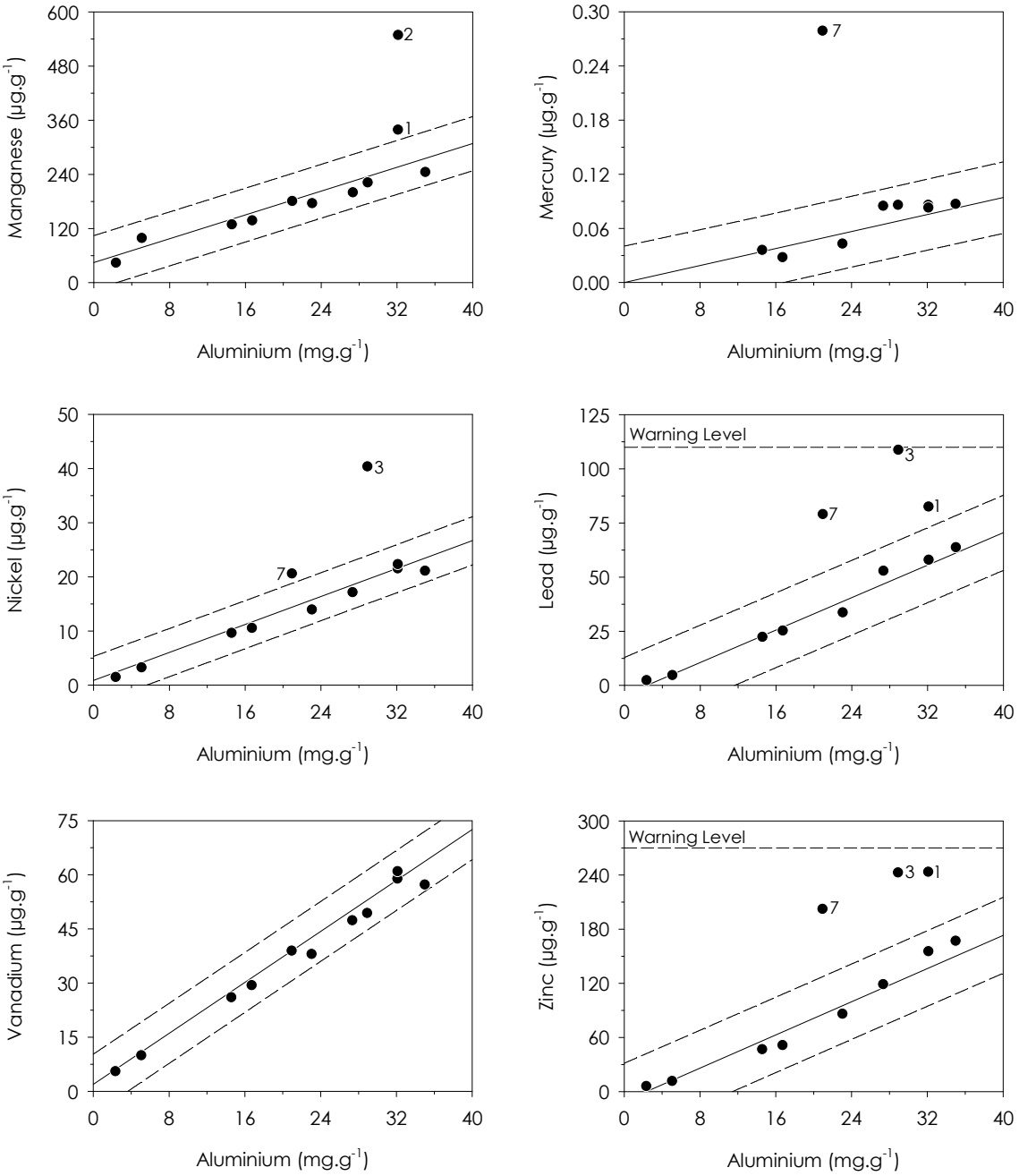

Figure 4 continued. Baseline metal concentration models for sediment in the Buffalo River estuary, with metal concentrations in sediment sampled in the estuary in May 2024 superimposed. Sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal are included if they fall within the y-axis range. Some metal concentrations are highlighted by station identifiers.

and organic content.

As a further complication, despite input and transport dissimilarities, naturally occurring and anthropogenically introduced metals tend to accumulate in the same areas (Hanson *et al.*, 1993). As a result of these complexities, an identical metal concentration in two sediment samples from the same aquatic system may reflect contamination in one instance but not the other, because of a difference in the grain size and organic content of the sediment. A low metal concentration might reflect contamination, but a higher concentration might not for the same reason.

To meaningfully interpret metal concentrations in sediment it is necessary to compensate for factors that control their natural variation before background or baseline concentrations can be differentiated from enriched concentrations, which might reflect contamination. This is usually accomplished by the procedure of geochemical

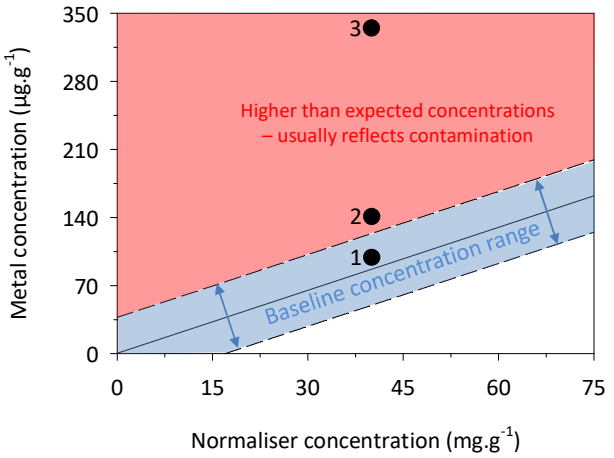

Figure 5. Schematic of a baseline metal concentration model. The oblique solid line and flanking dashed lines are the linear regression and upper and lower 99% prediction limits respectively. The prediction limits define the baseline concentration range for a metal in sediment at any co-occurring aluminium concentration (blue shaded area). If a metal concentration falls within the prediction limits, as is the case for hypothetical concentration 1, then the metal is present at a baseline concentration (not contaminated). If a metal concentration falls above the upper dashed line (*i.e.* upper prediction limit), as is the case for hypothetical concentrations 2 and 3, then the metal is present at an enriched concentration. Hypothetical metal concentration 2 is only slightly higher than the upper prediction limit and reflects a low degree of contamination. Hypothetical metal concentration 3 far exceeds the upper prediction limit and represents a much higher degree of contamination.

normalisation, wherein metal concentrations are mathematically normalised to a co-occurring conservative element in the sediment that provides a tracer of crustal decomposition (Hanson *et al.*, 1993; Kersten and Smedes, 2002). The purpose of geochemical normalization is to compensate for the variables that influence the natural variation of metal concentrations in sediment (principally grain size) such that after normalization concentrations in equally contaminated or uncontaminated sediment with a different granulometry do not differ significantly (Kersten and Smedes, 2002).

In a geologically homogenous area, metals are usually found at relatively constant proportions in uncontaminated sediment (Wedepohl, 1995; Kersten and Smedes, 2002), with their absolute concentration largely controlled by the sediment grain size (Horowitz, 1991; Loring, 1991). There is usually a strong linear relationship between metal concentrations and the silt and clay (mud) fraction, and between concentrations of different metals in sediment. It is these relationships that provide the basis for geochemical normalization, wherein the relationships between a metal and an element that provides a conservative tracer of the natural metal-bearing phases of sediment is modelled through simple linear regression analysis (Hanson *et al.*, 1993; Kersten and Smedes, 2002). Simple linear regression models and associated prediction limits that describe the relationship between a metal and co-occurring normaliser are referred to as baseline metal concentration models, or simply baseline models.

Scientists from the Coastal Systems and Earth Observation research group of the CSIR have defined baseline models for metals in sediment in all South African ports. The models define the range in concentrations that can be expected for any metal in baseline sediment of a differing grain size. The procedure used to define the baseline models is too voluminous to discuss in this report. Briefly, metal concentrations were plotted against corresponding aluminium concentrations and a simple linear regression and 99% prediction limits were fitted to the data. Metal concentrations falling outside the prediction limits were deemed outliers and trimmed, starting with the concentration with the largest residual, reiterating the regression, and proceeding in this way until all concentrations fell within the prediction limits. The models represent baseline rather than background concentrations as some concentrations in the models may reflect low magnitude contamination of sediment considering the sediment was sampled in a port. It is not possible to discriminate perfectly between background and contaminated sediment.

The baseline models for the Buffalo Riber estuary are provided in Figure 4, with aluminium normalised metal concentrations measured in sediment sampled in the estuary in May 2024 superimposed (data in Appendix 4). Aluminium was used as the normaliser of metal concentrations because it is (a) highly refractory, (b) is structurally combined to the major metal-bearing phases of sediment, (c) co-varies in proportion to naturally occurring concentrations of other metals, (d) is insensitive to inputs from anthropogenic sources, and (e) is stable and not subject to environmental

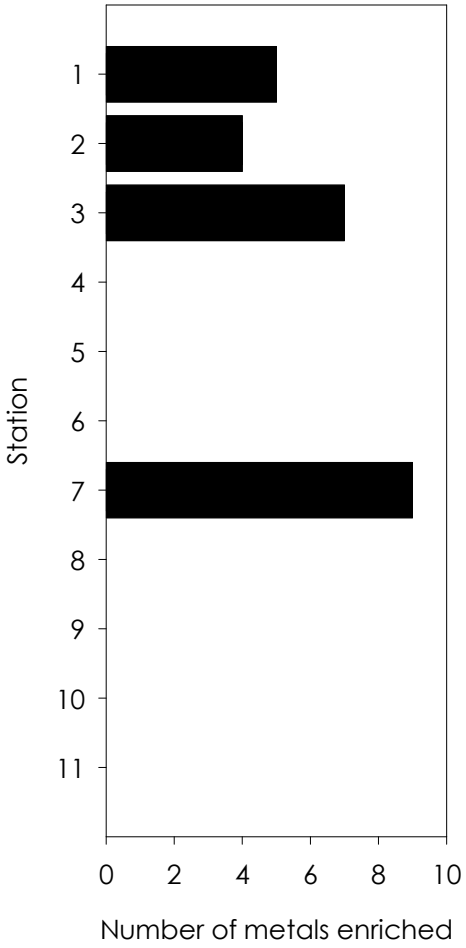

Figure 6. The number of metals enriched in sediment sampled in the Buffalo River estuary in May 2024.

influences such as reduction/oxidation, adsorption/desorption and other diagenic processes that may alter sediment concentrations. Aluminum is used as a proxy for the granulometric variation of sediment, and more specifically the variation in the silt and clay (mud) fraction.

To demonstrate this point the aluminium concentration in sediment sampled in the Buffalo River estuary in May 2024 is very strongly positively correlated to the mud fraction ($r = 0.982$, $p < 0.001$). The choice of aluminium as the normaliser of metal concentrations in sediment in the Buffalo River estuary is thus founded on valid geochemical principles.

As stated above, the baseline models comprise a regression line and upper and lower 99% prediction limits (oblique solid and dashed lines in Figures 6 and 7). The regression line defines the average concentration for a metal at co-occurring aluminium concentrations in sediment at baseline locations, while the upper and lower prediction

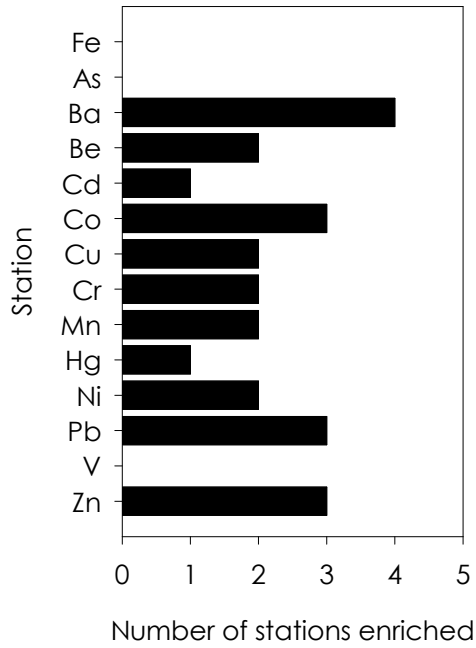

Figure 7. The number of stations in the Buffalo River estuary where sediment sampled in May 2024 was enriched by various metals.

limits define the range in which 99% of concentrations should fall if the sediment is not enriched and the concentrations used to define the baseline model are normally distributed. Metal concentrations that exceed the upper prediction limit when superimposed onto a baseline model are in excess of the baseline and indicate the sediment is enriched (see Figure 7). A concentration that exceeds the upper prediction limit does not imply it was enhanced by an anthropogenic contribution but rather that it is atypical of the data used to define the model. Several reasons other than an anthropogenic input can result in a metal concentration exceeding the upper prediction limit. These include analytical variability and errors, poor model assumptions, the probability that metal concentrations in some samples will naturally exceed the upper prediction limit (in a normally distributed population, at the 99% prediction limit one in every 100 concentrations could conceivably naturally exceed the limit), and natural enrichment not captured by the baseline data set (Schropp *et al.*, 1990; Rae and Allen, 1993).

The interpretation of whether metal enrichment reflects contamination thus requires consideration of ancillary factors that include biogeochemical processes that may naturally lead to the enrichment of some metals, the absolute difference between a metal concentration and upper

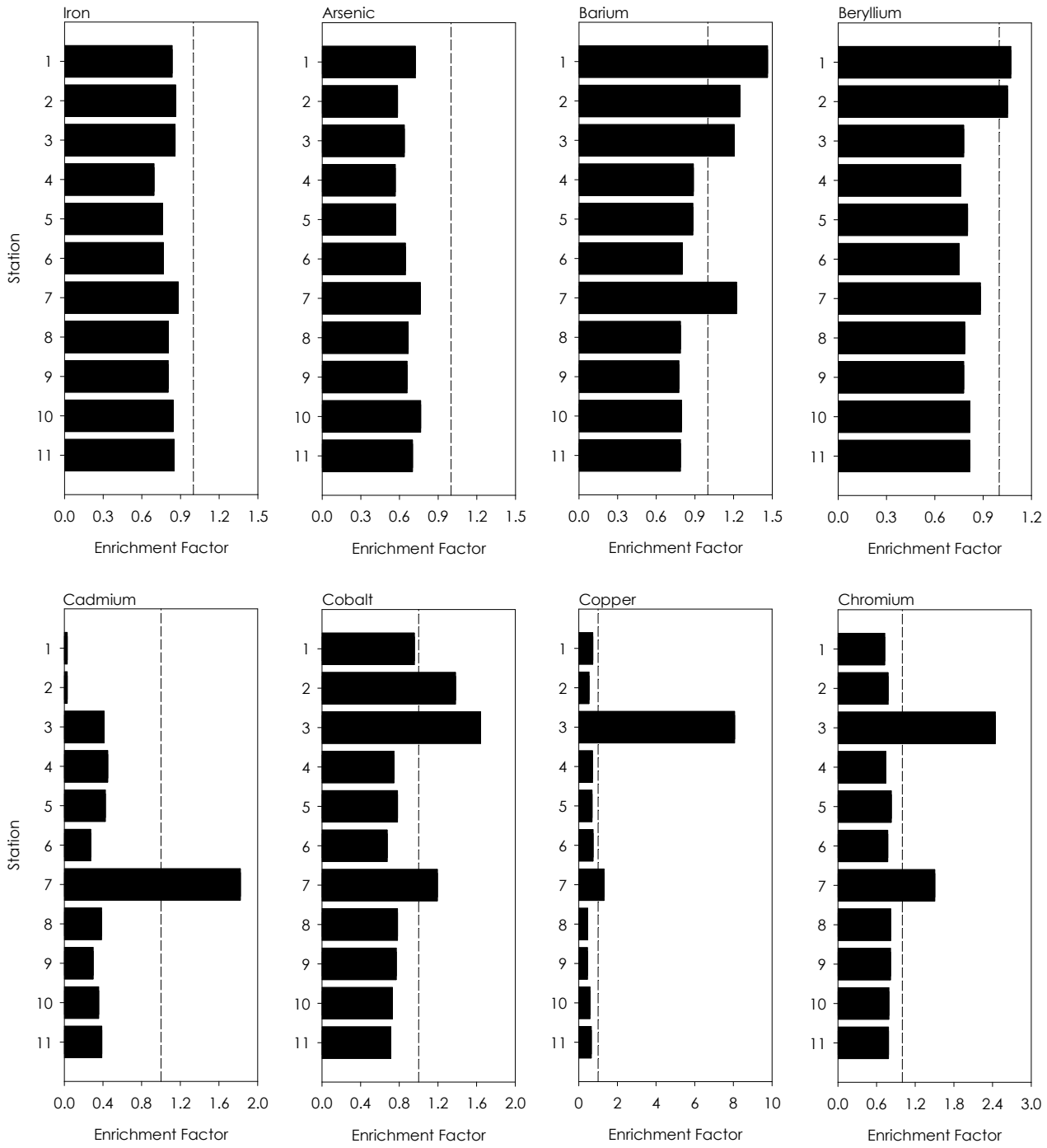

Figure 8. Enrichment Factors for metals in sediment sampled in the Buffalo River estuary in May 2024. The dashed lines represent an Enrichment Factor = 1. An Enrichment Factor >1 indicates the metal was at a concentration exceeding the baseline and may indicate contamination.

prediction limit, the location of enriched sediment relative to known or potential anthropogenic sources of metals, and an assessment of the number of metals in a sediment sample that exceed upper prediction limits. The larger the difference between a metal concentration and upper prediction limit (see Figure 7) and the greater the number of metals enriched in a sediment sample the more likely this reflects contamination. This is because the sediment in ports is most commonly enriched by several metals rather than a single metal, particularly if the anthropogenic sources are diffuse (*e.g.* stormwater runoff). This said, enrichment of sediment by one metal may occur in areas where metal ores are exported and there are few other anthropogenic sources of metals in the area. However, even in these cases other metals are commonly enriched in the sediment as they are impurities of ores.

The concentrations of most metals in the sediment sampled at most stations in the Buffalo River

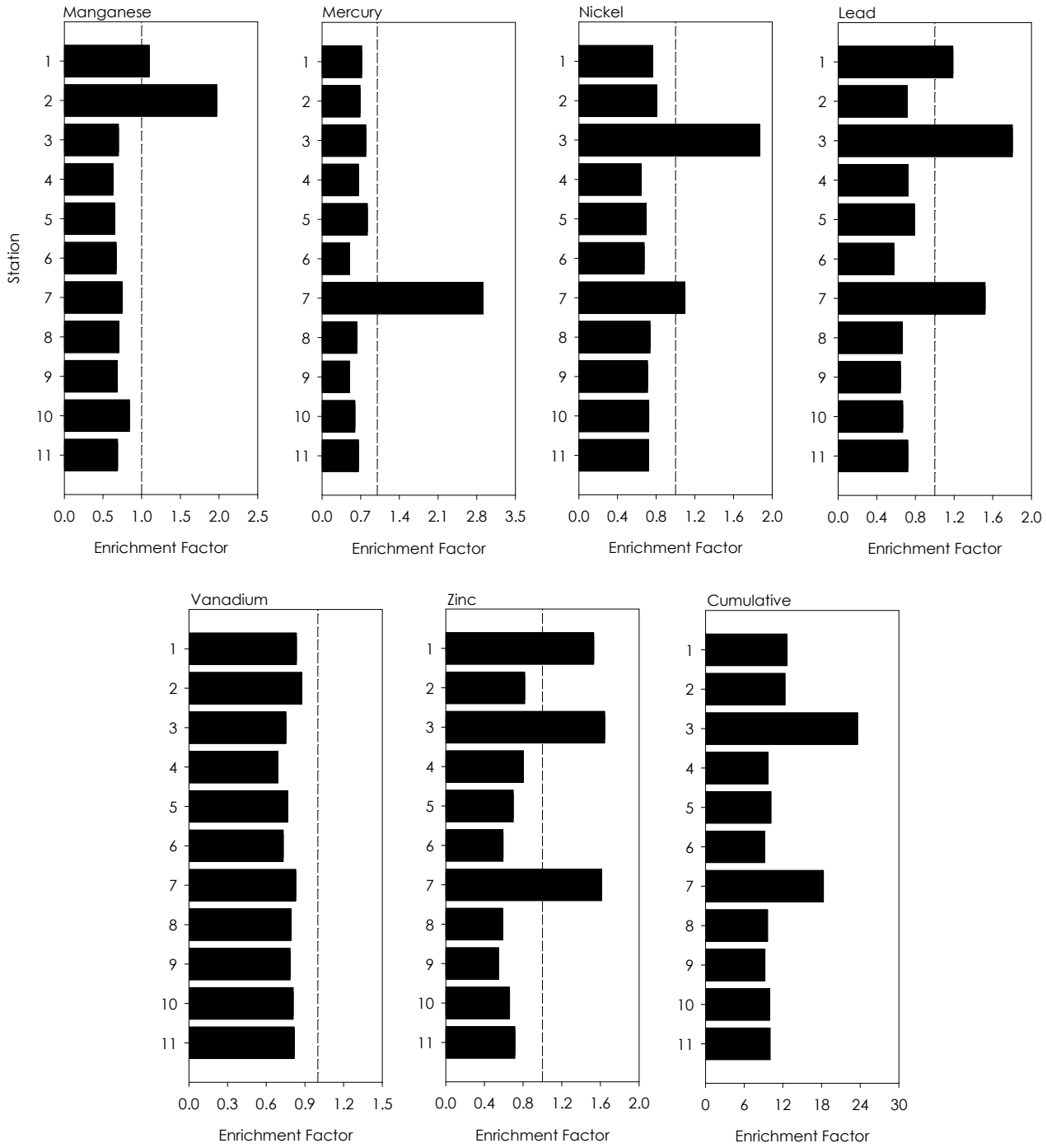

Figure 8 continued. Enrichment Factors for metals in sediment sampled in the Buffalo River estuary in May 2024. The dashed lines represent an Enrichment Factor = 1. An Enrichment Factor >1 indicates the metal was at a concentration exceeding the baseline and may indicate contamination.

estuary in May 2024 fall within the baseline model prediction limits, that is, they are within the expected baseline range for sediment in the estuary (Figure 4). The concentrations of two or more metals in the sediment sampled at Stations 1, 2, 3, and 7 did, however, exceed baseline model upper prediction limits. The sediment with the highest number of metals (nine) at an enriched concentration was sampled at Station 7 at the Victoria Slipway, followed by seven metals at Station 3 off the Dry Dock, five metals at Station 1, and four metals at Station 2, both of the latter in the estuary beyond the port proper (Figures 4 and 6). The sediment sampled at Stations 4, 5, 6, 8, 10, and 11 was not metal enriched. In the case of Stations 3 and 7, the enrichment by some metals was significant and certainly reflects contamination rather than enrichment through natural biogeochemical processes. The enrichment at Stations 1 and 2 probably reflects contamination, but was of a far lower magnitude compared to Stations 3 and 7 (see further below).

Barium was the most often enriched metal, at four of the 11 stations, followed by cobalt, lead, and zinc at three stations each (Figure 7). Iron, arsenic, and vanadium were never at an enriched concentration (Figure 7).

The Cumulative Enrichment Factor, which is the sum of the Enrichment Factors for all metals in sediment at a station, provides additional understanding on metal enrichment of sediment. From this perspective the most metal contaminated sediment was at (in order) Stations 3 and 7 (Figure 8).

3.4. Comparison of metal concentrations to Action Levels

The Department of Forestry, Fisheries and the Environment uses an Action List (sediment quality guidelines) to decide if sediment identified for dredging in South African ports is suitable for open water disposal. However, there are only guidelines for metals. There are three guidelines, known as the Warning Level, Level I, and Level II (Table 1). The Warning Level provides a warning of incipient metal contamination but is not used for decision-making. Sediment with metals at a concentration below the Level I is suitable for open water disposal. Sediment with metals at a concentration between the Level I and Level II is cause for concern, with the degree of concern increasing as the concentrations approach the Level II. Further testing may be requested to determine if metals in the sediment pose a toxic risk to sediment-dwelling organisms, but in practice this has not been implemented. Sediment with metals at a

Table 1. Action List used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is of a suitable quality for open water disposal. Concentrations are in $\mu g.g^{-1}$.

Metal	Warning Level	Level I	Level II
Arsenic	42	57	93
Cadmium	1.2	5.1	9.6
Chromium	135[a]/250[b]	260	370
Copper	110	230	390
Mercury	0.43	0.84	1.5
Nickel	62[a]/88[a]	140	370
Lead	110	218	530
Zinc	270	410	960

a - for Eastern and Western Cape, b - for KwaZulu-Natal

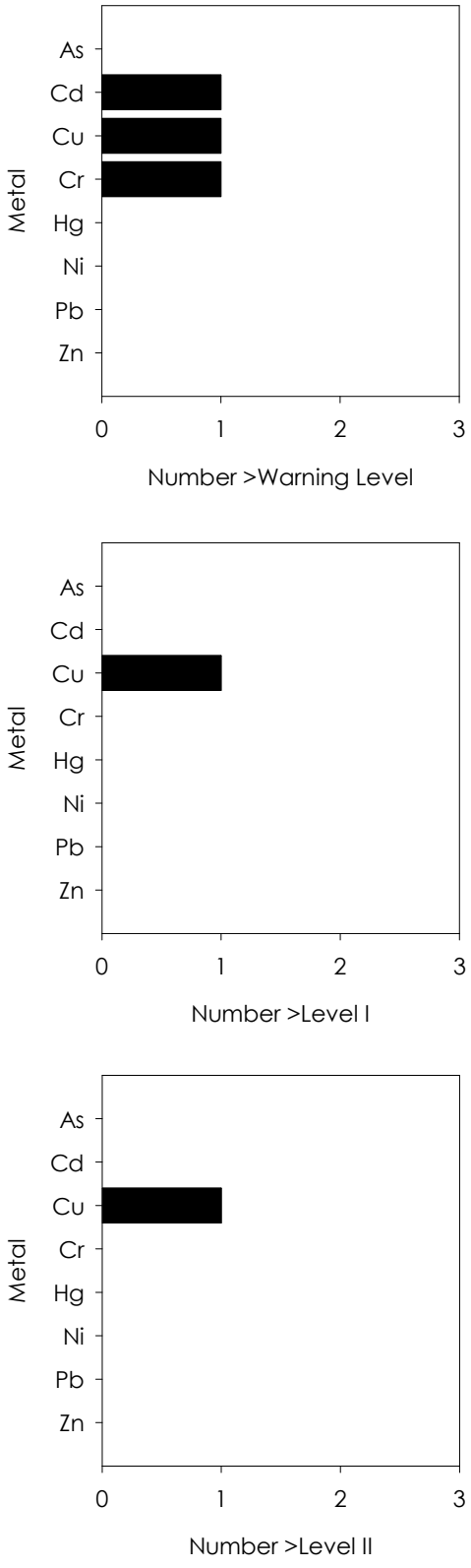

Figure 9. The number of stations at which metals in sediment sampled in the Buffalo River estuary in May 2024 were at a concentration that exceeded the Warning Level, Level I and Level II of the sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal.

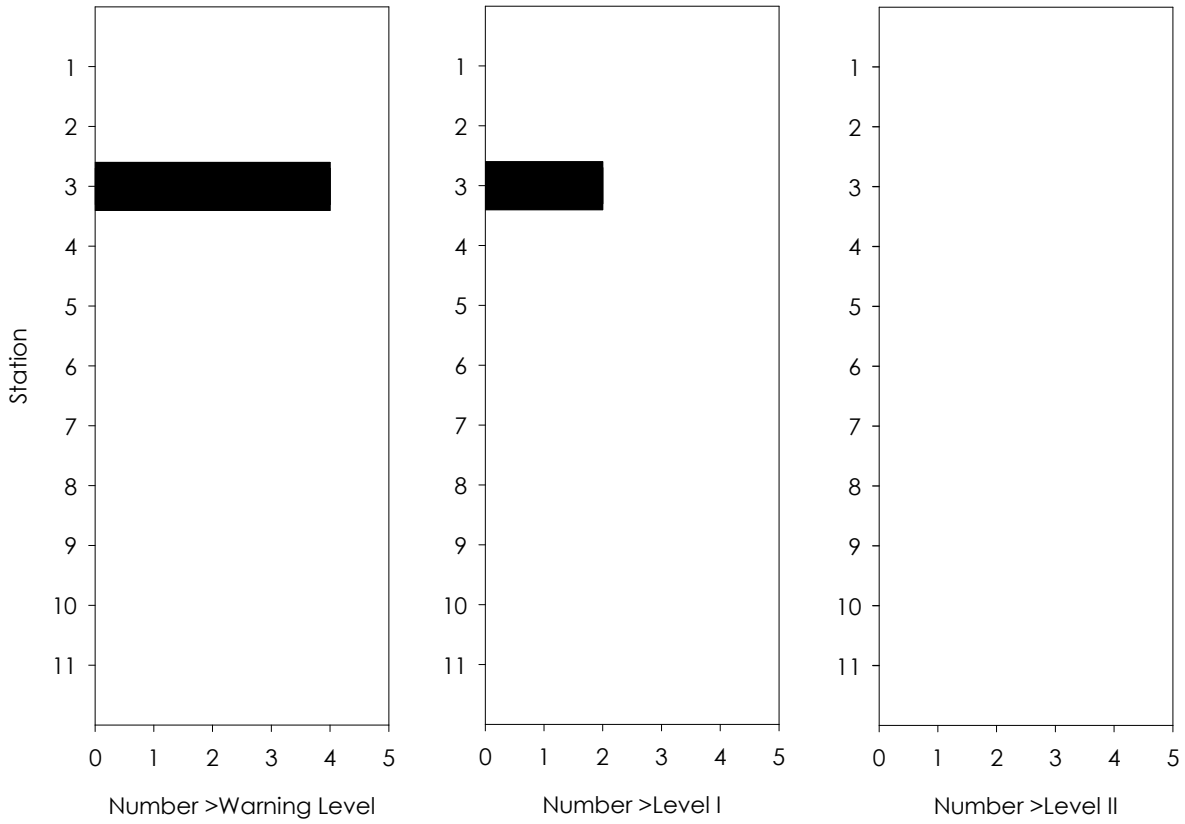

Figure 10. The stations at which metals in sediment sampled in the Buffalo River estuary in May 2024 were at a concentration that exceeded the Warning Level, Level I and Level II of the sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal.

concentration above the Level II is unsuitable for open water disposal unless other evidence (*e.g.* toxicity testing) shows the metals are not toxic due, for example, to the metals being present in metal flecks or metal-impregnated paint flakes and the entire concentration thus not being in a bioavailable form.

The number of metals in sediment sampled in the Buffalo River estuary in May 2024 that were at a concentration above the Warning Level, Level I, and Level II is provided is provided in Figures 9 and 10. The concentration of cadmium at Station 7 and copper and chromium concentration at Station 3 exceeded the Warning Level. The copper concentration in the sediment at Station 3 also exceeded the Level I and Level II.

4. Conclusions

The sediment at four stations sampled in the Buffalo River estuary in May 2024 was metal enriched. The most significant enrichment, which reflects contamination, was at Station 3 off the Dry Dock and Station 7 near the Victoria Slipway. The most significant metal contaminants of sediment were cadmium, copper, chromium, mercury, and zinc. The metal contamination at Station 3 probably reflects the inclusion of metal flecks and/or metal impregnated antifouling coating flakes in the sediment. This conclusion is based on the fact significant metal contamination was restricted to sediment this area, an unlikely situation in the event of significant diffuse sources of metals in an aquatic ecosystem. The same conclusion probably applies to the sediment near Victoria Slipway.

The trend in metal enrichment of sediment sampled in the Buffalo River estuary in May 2024 is generally consistent with the trends for earlier surveys. Thus, sediment in certain parts of the estuary has more often and more significantly enriched (contaminated) than in other parts, most notably near the Dry Dock and Victoria Slipway. The overwhelming feature of earlier surveys, however, is that the sediment across most of the Buffalo River estuary was not metal contaminated, but when it was the contamination was usually of a low magnitude.

The risk posed by metals in sediment was estimated by comparing their concentration to Action Levels that are used by the Department of Forestry, Fisheries and the Environment to determine if sediment identified for dredging in South African ports is suitable for open water disposal. The copper concentration in sediment sampled off the Dry Dock exceeded the Level II. Based on the findings of this survey, it appears that the disposal of sediment dredged in the Buffalo River estuary is unlikely to pose a significant toxicological risk when it is disposed at the open water dredged material disposal site, even though sediment off the Dry Dock and at Victoria Slipway was contaminated. The sediment is likely to be contaminated in a small area around the latter sites and the contamination is likely to reflect the inclusion of metals in solid particles rather than as diffuse sourced contaminants. The disposal site is in a dispersive environment and contaminants that do reach the seabed are likely to be winnowed and diluted by the prevailing currents. This conclusion is based on the fact earlier surveys revealed there is virtually no mud in the sediment at the dredged material disposal site and metal concentrations in the sediment were very low.

5. References

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6. Appendices

Appendix 1

Global Positioning System coordinates of stations sampled in the Buffalo River estuary in May 2024.

Station	Latitude	Longitude
1	33° 01'32.68"S	27°52'54.44"E
2	33° 01'26.25"S	27°53'24.43"E
3	33° 01'20.59"S	27°53'51.88"E
4	33° 01'24.52"S	27°53'55.20"E
5	33° 01'28.96"S	27°54'07.19"E
6	33° 01'28.63"S	27°54'23.31"E
7	33° 01'33.90"S	27°54'22.19"E
8	33° 01'37.63"S	27°54'50.92"E
9	33° 01'42.05"S	27°54'34.53"E
10	33° 01'41.20"S	27°55'07.40"E
11	33° 01'39.13"S	27°55'30.66"E

Appendix 2

Copy of South African National Accreditation System (SANAS) certificate for the environmental chemistry laboratory at the CSIR campus in Stellenbosch.

sanas
South African National Accreditation System

CERTIFICATE OF ACCREDITATION

In terms of section 22(2) (b) of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act, 2006 (Act 19 of 2006), read with sections 23(1), (2) and (3) of the said Act, I hereby certify that:-

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
ANALYTICAL LABORATORY

STELLENBOSCH

Facility Accreditation Number: **T0093**

is a South African National Accreditation System accredited facility
provided that all conditions and requirements are complied with

This certificate is valid as per the scope as stated in the accompanying schedule of accreditation, Annexure "A", bearing the above accreditation number for

CHEMICAL ANALYSIS

The facility is accredited in accordance with the recognised International Standard

ISO/IEC 17025:2017

The accreditation demonstrates technical competency for a defined scope and the operation of a quality management system

While this certificate remains valid, the Accredited Facility named above is authorised to use the relevant accreditation symbol to issue facility reports and/or certificates

Mr T Baleni
Acting Chief Executive Officer

Effective Date: 01 August 2023
Certificate Expires: 31 July 2028

Appendix 3

Quality Assurance and Quality Control Results

Recovery (%) of metals from standard reference material PACS-3 (National Research Council of Canada).

Replicate	Al	Fe	As	Be	Cd	Cu	Cr	Mn	Hg	Ni	Pb	V	Zn
1	45.9	82.0	65.7	59.9	96.0	88.3	70.3	63.6	108.3	80.7	81.0	71.6	88.4
2	44.9	80.9	64.7	58.7	95.9	87.6	69.4	63.4	97.2	78.7	83.2	70.5	88.2
Mean	45.4	81.5	65.2	59.3	96.0	88.0	69.9	63.5	102.7	79.7	82.1	71.0	88.3
Standard deviation	0.7	0.8	0.7	0.9	0.1	0.5	0.6	0.1	7.8	1.4	1.5	0.7	0.2
Minimum	44.9	80.9	64.7	58.7	95.9	87.6	69.4	63.4	97.2	78.7	81.0	70.5	88.2
Maximum	45.9	82.0	65.7	59.9	96.0	88.3	70.3	63.6	108.3	80.7	83.2	71.6	88.4
Precision	1.6	0.9	1.1	1.5	0.1	0.6	0.9	0.2	7.6	1.8	1.9	1.0	0.2

Laboratory duplicate report for metals in sediment sampled in the Buffalo River estuary in May 2024. RSD = Relative Standard Deviation. ND = no data.

Metal	Original Result µg.g^{-1}	Duplicate Result µg.g^{-1}	RSD %	Acceptable RSD %	Original Result µg.g^{-1}	Duplicate Result µg.g^{-1}	RSD %	Acceptable RSD %
Al	31958	32626	1.5	10	5026	5021	0.1	10
Fe	30858	31262	0.9	10	5320	5364	0.6	10
As	8.7	9.0	2.3	10	4.7	4.8	0.1	10
Ba	286.4	289.2	0.7	10	36.2	36.7	0.8	10
Be	1.460	1.485	1.2	10	0.220	0.218	0.5	10
Cd	<0.1	<0.1	-	10	<0.1	<0.1	-	10
Co	11.3	11.4	0.6	10	1.9	1.9	0.1	10
Cu	53.8	55.6	2.3	10	1.9	1.7	7.8	10
Cr	63.3	63.8	0.5	10	12.8	13.1	2.0	10
Mn	335.9	341.3	1.1	10	98.9	100.0	0.8	10
Hg	0.084	0.088	2.8	10	ND	ND	-	10
Ni	21.4	21.7	0.9	10	3.4	3.2	4.7	10
Pb	73.7	72.6	1.0	10	4.8	4.7	0.4	10
V	58.5	59.3	1.1	10	9.9	10.0	0.7	10
Zn	241.3	245.9	1.3	10	11.6	11.9	1.6	10

Appendix 4

Contribution (%) of grain size class fractions and total organic content to the bulk weight and mean grain size (mm) of sediment sampled in the Buffalo River estuary in May 2024.

Station	Gravel	Very coarse-grained sand	Coarse-grained sand	Medium-grained sand	Fine-grained sand	Very fine-grained sand	Mud	Total Organic Content
1	0.00	0.00	0.00	0.25	1.01	1.01	97.74	10.45
2	0.00	0.00	0.00	0.00	0.85	0.49	98.66	7.49
3	0.00	0.83	1.75	3.67	14.83	4.00	74.92	2.07
4	0.00	0.00	0.00	0.31	4.65	4.34	90.70	4.17
5	0.00	0.00	0.25	3.30	21.68	6.98	67.79	3.02
6	0.00	0.13	0.38	7.93	35.00	4.69	51.87	2.40
7	3.54	0.39	0.95	5.22	25.93	11.45	52.53	2.59
8	0.00	0.00	0.11	2.78	51.22	8.01	37.88	1.06
9	0.00	0.06	0.17	2.33	45.55	6.52	45.38	1.75
10	0.00	0.13	0.67	18.11	65.86	7.34	7.88	0.41
11	0.00	0.00	0.17	36.23	61.66	1.34	0.61	0.19

Appendix 5

Metal concentrations (Al and Fe as $mg.g^{-1}$, other metals as $\mu g.g^{-1}$ dry weight) in sediment sampled in the Buffalo River estuary in May 2024. Al = aluminium, Fe = iron, As = arsenic, Ba = barium, Be = beryllium, Cd =cadmium, Co = cobalt, Cu = copper, Cr = chromium, Mn = manganese, Hg = mercury, Ni = nickel, Pb = lead, V = vanadium, Zn = zinc, < = concentration below the method detection limit as indicated. Bold text in coloured cells indicates the concentration exceeds 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 of a suitable quality for open water disposal.

Station	Al	Fe	As	Ba	Be	Cd	Co	Cu	Cr	Mn	Hg	Ni	Pb	V	Zn
1	32.10	31.06	8.8	288	1.47	<0.1	11.4	54.7	63.5	339	0.086	21.5	82.6	58.9	243.6
2	32.11	31.74	7.5	254.7	1.45	<0.1	15.1	44.7	66.5	549	0.083	22.3	58.0	61.0	155.4
3	28.90	28.56	7.5	230.4	1.07	0.351	16.4	418.7	153.7	222	0.086	40.4	108.8	49.4	242.8
4	34.99	30.36	7.8	214.2	1.27	0.432	10.3	58.6	70.3	245	0.087	21.1	63.8	57.3	167.1
5	27.34	24.68	6.6	171.9	1.03	0.346	8.5	44.6	59.7	200	0.085	17.2	52.9	47.4	118.8
6	23.04	20.71	6.6	135.9	0.82	0.198	6.4	39.8	48.1	176	0.043	14.0	33.7	38.0	86.2
7	20.94	21.53	7.4	189.9	0.87	1.313	10.3	65.2	84.8	181	0.279	20.6	79.1	39.0	202.5
8	14.56	13.54	5.4	87.3	0.54	0.205	5.0	12.0	33.6	129	0.036	9.6	22.4	26.0	46.8
9	16.71	15.54	5.7	97.2	0.61	0.160	5.5	14.7	37.8	138	0.028	10.5	25.3	29.4	51.4
10	5.06	5.34	4.8	36.9	0.22	<0.1	1.9	1.8	12.9	99	<0.01	3.3	4.7	9.9	11.7
11	2.33	2.92	3.7	20.7	0.12	<0.1	1.0	0.5	7.2	44	<0.01	1.5	2.4	5.5	6.0
Warning Level	-	-	42	-	-	1.2	-	110	135	-	0.43	62	110	-	270
Level I	-	-	57	-	-	5.1	-	230	260	-	0.84	140	218	-	410
Level II	-	-	93	-	-	9.6	-	390	370	-	1.50	370	530	-	960