ASSESSMENT OF SEDIMENT QUALITY IN THE PORT OF EAST LONDON – 2025

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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.

This report presents the results of the physical and chemical analysis of sediment within the Port of East London in 2025. The aim is to provide Transnet National Ports Authority with information required to complete a permit application for the open water disposal of sediment maintenance dredged in the estuary and to assist officials from the Department of Forestry, Fisheries and the Environment in making an informed decision on the application.

Methods

Sediment samples were collected at 11 positions (stations) within the Buffalo River estuary on 9 July 2025. 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 was dominated by mud. Only near the estuary mouth was the sediment dominated by sand.
- The total organic content at four stations was above the baseline, to a degree that is indicative of low, moderate, or high enrichment.
- The concentrations of metals in the sediment at most stations were within the baseline range. The sediment in parts of the estuary included in the survey was thus 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.
- Barium, cobalt, and zinc were enriched at three stations each, while copper, chromium, nickel, and lead were enriched 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.
- No metal concentrations in sediment within the estuary in 2025 exceeded the Level I or Level II.
- Sediment across the estuary is thus suitable for disposal at the open water dredged spoil disposal site off the East London coast.

Table of Contents

Units of Measurement

Distance/Length

m	metre
cm	centimetre
mm	millimetre
µm	micrometre

Area

ha	hectare

Duration/Time

h	hour

Temperature

^{o}C	degrees Celsius

Mass

kg	kilogram
g	gram
mg	milligram
µg	microgram

Concentration

$mg.g^{-1}$	milligrams per gram
$\mu g.g^{-1}$	micrograms per gram

Mathematical

%	percent
<	less than
>	greater than
≤	less than or equal to
~	about/approximately

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. Regardless of the source, if the sediment is allowed to accumulate unchecked in a port a situation may be reached wherein the depth of navigation channels, turning basins, berths, and so on are reduced to the extent that safe vessel movement is compromised. Port authorities thus maintain navigation channels, berths, and basins at their design depths through maintenance dredging. In many ports and navigable waterways, maintenance dredging is required on an on-going basis. The material that is dredged in coastal ports is typically disposed at open water dredged spoil disposal sites. In some countries, highly contaminated dredged sediment is placed in confined land or waterside facilities (e.g. capping). The latter is not a practice that has been followed to date in South Africa, where virtually all dredged sediment is disposed at designated open water dredged 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 related turbidity in the water column, the removal, injury, and disturbance of benthic biological communities in the dredging footprint, and the remobilisation of toxic chemicals that might have accumulated in sediment into the water column. Although there is no specific environmental legislation governing the act of dredging in South Africa, dredging operations are subject to the general duty of care to avoid or minimise environmental degradation. The open water disposal of dredged material in South Africa is regulated under the National Environmental Management: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008). The open water disposal of dredged material requires a permit from the Department of Forestry, Fisheries and the Environment. The permitting process is consistent 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 part of the Buffalo River estuary in which the Port of East London is situated at a designated open water dredged spoil disposal site off the East London coast. The Department decides if dredged sediment may be disposed at the open water dredged spoil disposal sites based largely on metal concentrations in the sediment.

This report presents the results of the physical and chemical analysis of sediment sampled within the Port of East London in 2025. The aim is to provide Transnet National Ports Authority with information required to complete a permit application for the open water disposal of sediment maintenance dredged in the port area of the estuary and to assist officials from the Department of Forestry, Fisheries and the Environment in making 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 2025.

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 ~2800 vehicles and a throughput of ~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 9 July 2025 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. Upon retrieval, water overlying sediment in the grab was bled through a bleeder hole located in upper corner 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, it was discarded. The vessel was repositioned ~10 m from the designated station and three further grab samples were collected. This process was repeated if necessary. 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 during homogenisation. Characteristics of the sediment, such as its colour, texture, and aroma, were recorded 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 jars. The sediment was repeatedly homogenised between the transfer of aliquots to sample jars to prevent layering in the glass bowl. The samples were held on ice in the field and frozen (-18°C) on return to the laboratory. The grab and sediment processing

equipment were 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

An aliquot of the sediment was oven dried at 70°C and its mass recorded. The sediment was then wet sieved through 0.063 mm mesh size sieve. The retained sediment was oven dried, reweighed, and then passed through sieves with mesh sizes of 0.125, 0.250, 0.50, 1.0, and 2.0 mm. The weight of the sediment retained in each sieve was recorded and expressed as a fraction (%) of the bulk sediment dry weight.

2.3.3. Total organic content

Aliquots of sediment were oven dried at 60°C, lightly disaggregated using a mortar and pestle, and weighed into a flat-bottomed flask. Organic matter in the sediment was then decomposed by adding hydrogen peroxide and heating to 70°C. After complete reaction with the hydrogen peroxide, which was added until frothing ceased, the sample was dried in an oven at 60°C and re-weighed. The difference in weight before and after organic matter decomposition was used to determine the total organic content. The total organic content is reported as a fraction (%) of the bulk sediment dry weight.

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 certified reference material. 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. The reason is aluminosilicates, which are the major natural metal-bearing phase of sediment, are concentrated in clay. In contrast, sand consists predominantly of quartz (silica), a metal-deficient mineral that effectively dilutes metal concentrations in 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 negatively electrically charged, rendering them chemically reactive for positively charged

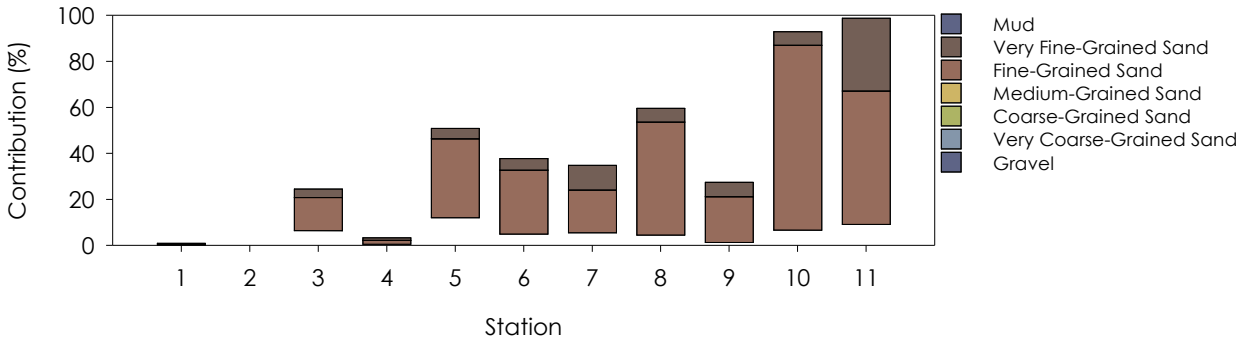

Figure 2. Contribution of various grain sizes to the bulk weight of sediment sampled in the Buffalo River estuary in 2025.

metals. Metals and other particle reactive chemical contaminants also attach to and are transported with suspended particulate matter in the water column and ultimately settle and accumulate in depositional zones when this fine-grained matter settles on the bottom. Depositional zones are areas where the sediment is dominated by fine-grained material (e.g. mud) and form where water currents are so weak they are unable to keep fine-grained material and any associated contaminants in suspension, which settle on the bottom. Consequently, naturally occurring and anthropogenic metal concentrations are commonly highest in muddy sediment and lowest in sandy sediment. There may be exceptions in ports since coarse-grained (sandy) sediment may contain high metal concentrations due, for example, to the inclusion of metal flecks and metal-impregnated antifouling coating flakes arising from vessel maintenance operations or metal concentrate and ore particles spilled during the loading and offloading of vessels.

The grain size composition of sediment thus provides important information for identifying areas in the Buffalo River estuary where particle reactive contaminants might accumulate most significantly. Anomalously high metal concentrations in sandy sediment also provide indirect evidence that the metals were present as solid particles, such as metal flecks. This has implications for understanding the toxicological risk since particulate metals are unlikely to be bioavailable.

The sediment at most stations within the Buffalo River estuary in 2025 was dominated by mud (Figure 2; data in Appendix 3). Only at Stations 8, 10, and 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 port entrance.

The findings for the 2025 survey are consistent with those of earlier surveys. The high mud content of sediment across large parts of the Buffalo River estuary reflects its depositional nature, which is a characteristic feature of estuaries. It also obviously reflects a source of mud sized material to the port, which is likely to be the Buffalo River most importantly but also several smaller streams that flow into the port. This indicates there is a high propensity for the retention of particle reactive contaminants if they are introduced in solution to the estuary.

3.2. Total organic content

Particulate organic matter in sediment provides a substrate for the adsorption of contaminants, including metals such as cadmium and mercury, and hydrophobic organic contaminants such as polycyclic aromatic hydrocarbons. Metals and other particle-reactive contaminants readily adsorb onto suspended particulate organic matter in the water column, facilitating their transport and eventual accumulation in depositional zones. Due to its fine-grained nature, particulate organic matter is deposited onto and winnowed from sediment concurrently with mud, depending on the prevailing hydrodynamic 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 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, a strong positive correlation typically exists between the mud fraction and total organic content of the sediment. The relationship arises because of the similar deposition and winnowing dynamics of these fine-grained particles in response to currents. The relationship is advantageous 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 Buffalo River estuary, using the results from previous monitoring and research (Figure 4). The baseline model consists of a linear regression and 99% prediction limits (oblique solid and dashed lines, respectively, in Figure 4). The regression line defines the average total organic content at a given mud fraction in sediment at baseline locations in the estuary, 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 residuals are normally distributed. A total organic content that plots above the upper prediction limit is interpreted as enriched with particulate organic matter relative to the baseline. 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 above the

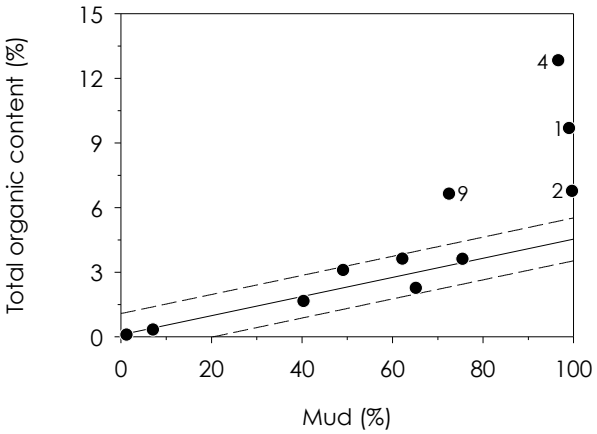

Figure 3. Baseline model for total organic content in sediment in the Buffalo River estuary, with the total organic content in sediment sampled in the estuary in 2025 superimposed. Some data points are highlighted by station identifiers.

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 that predicted for baseline sediment with the same mud fraction.

Superimposing the total organic content of sediment within the Buffalo River estuary in 2025 onto the baseline model identifies the sediment at Stations 1 and 4 as highly enriched with particulate organic matter while low to moderate enrichment was evident at Stations 2 and 9 (Figure 3; data in Appendix 3).

The findings for the 2025 survey are consistent with those of earlier surveys from the perspective that sediment across most of the Buffalo River estuary was often not 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 identify if sediment is contaminated by certain chemicals since they are manmade and do not occur naturally in the environment. The mere presence of these chemicals in sediment provides unequivocal evidence of contamination. In contrast, determining if sediment is metal contaminated is far more complicated because they are a ubiquitous, naturally occurring component of

sediment. The mere presence of metals in sediment does not automatically imply contamination. 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 do not imply contamination but might simply reflect the mineralogy of the parent material and its grain size and organic content. As a further complication, naturally occurring and anthropogenically introduced metals tend to accumulate in the same areas (Hanson et al., 1993). Thus, two sediment samples from the same aquatic system, with identical metal concentrations, may differ in terms of contamination status due to differences in their grain size and organic content. Conversely, a sample with a lower metal concentration may reflect contamination, whereas a higher concentration in another sample may not.

To meaningfully interpret metal concentrations in sediment it is necessary to account for the factors that influence 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 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 normalisation is to compensate for the factors that influence the natural variation of metal concentrations in sediment (principally grain size). After normalisation, metal concentrations in equally contaminated or uncontaminated sediment with a differing granulometry should 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 grain size (Horowitz, 1991; Loring, 1991). There is thus typically a strong linear relationship between metal concentrations and the mud fraction, and one another, in sediment. It is these relationships that provide the basis for geochemical normalisation, wherein the relationships between metals and another element that serves 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 South African ports. The models define the range in concentrations that can be expected for a metal in baseline sediment with 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. Nevertheless, the baseline models provide a practical and scientifically defensible tool for identifying metal concentrations in sediment that exceed expected concentrations, and that may, therefore, reflect contamination. The linear regressions for the baseline models were also compared to linear regressions defined using least absolute deviation regression, which as less susceptible (robust) to the presence of outliers. The relationships were generally very similar. The limitation of least absolute deviation regression is the difficulty in defining prediction limits.

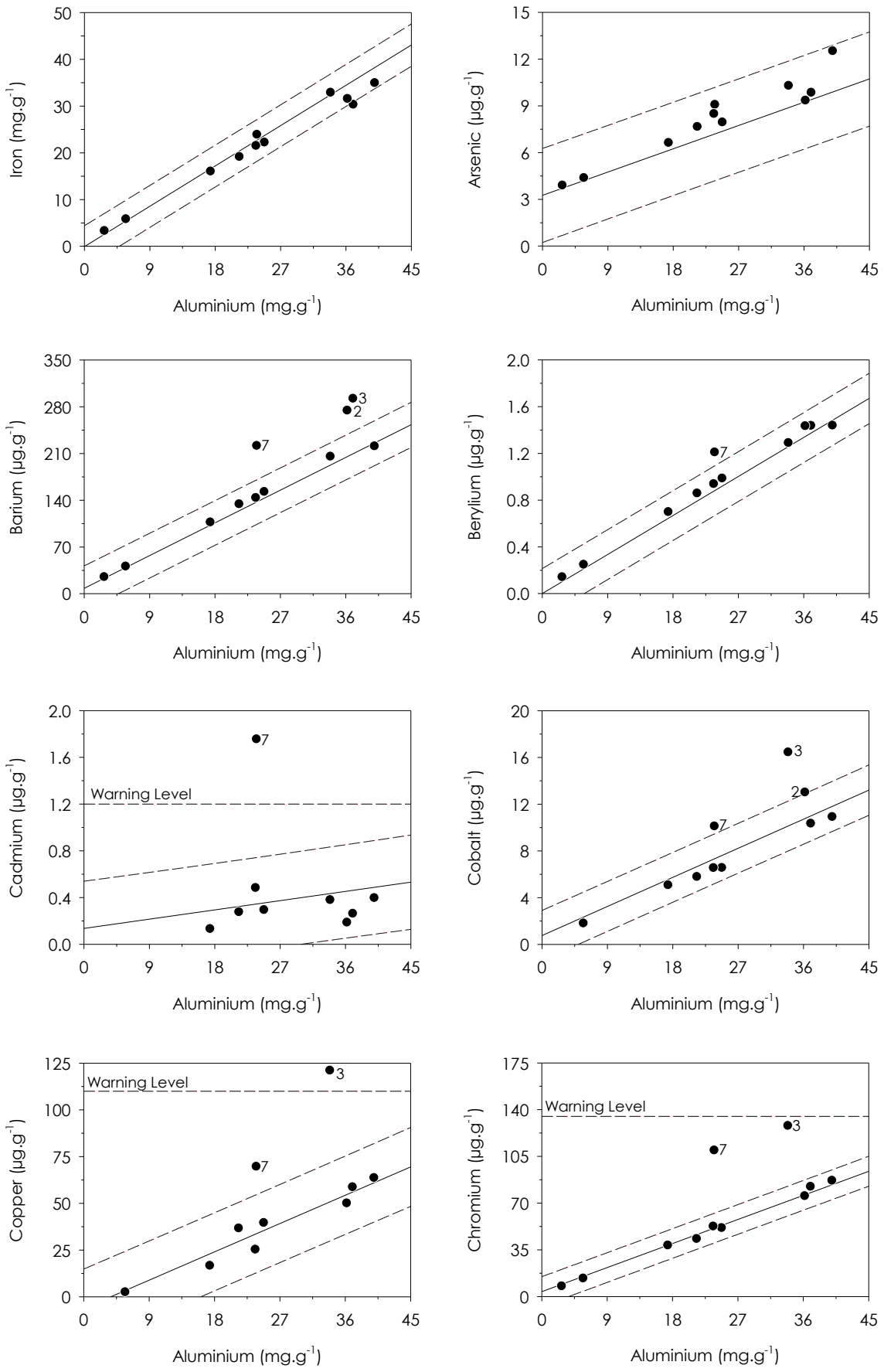

Figure 4. Baseline metal concentration models for sediment in the Buffalo River estuary, with metal concentrations in sediment sampled in the estuary in 2025 superimposed. Sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for 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.

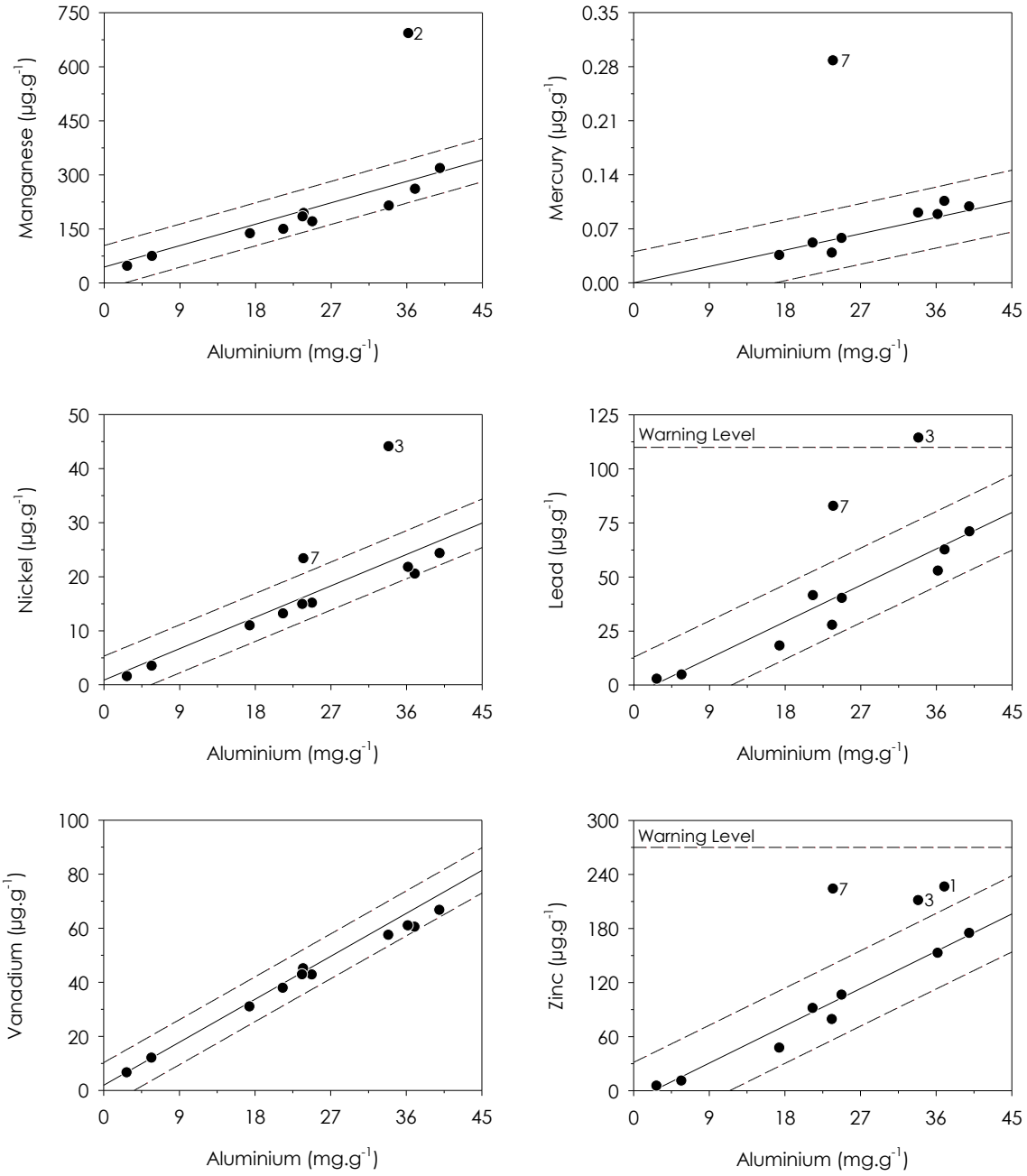

Figure 4 continued. Baseline metal concentration models for sediment in the Buffalo River estuary, with metal concentrations in sediment sampled in the estuary in 2025 superimposed. Sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified 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.

The baseline models for the Buffalo River estuary are provided in Figure 4, with aluminium normalised metal concentrations in sediment within the estuary in 2025 superimposed (data in Appendix 5). Aluminium was used as the normaliser of metal concentrations since it meets all the requirements of an effective normaliser, namely (a) it is 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 influences such as reduction/ oxidation, adsorption/desorption and other diagenic processes that may alter sediment concentrations. The normaliser is a proxy for the granulometric variation of sediment, more specifically the mud fraction. To demonstrate this, the aluminium concentration and mud fraction in sediment within the Buffalo River estuary in 2025 was very strongly positively correlated ($r = 0.979$, $p < 0.001$). The use of aluminium as the normaliser of metal concentrations in sediment in the estuary is thus founded on valid geochemical principles.

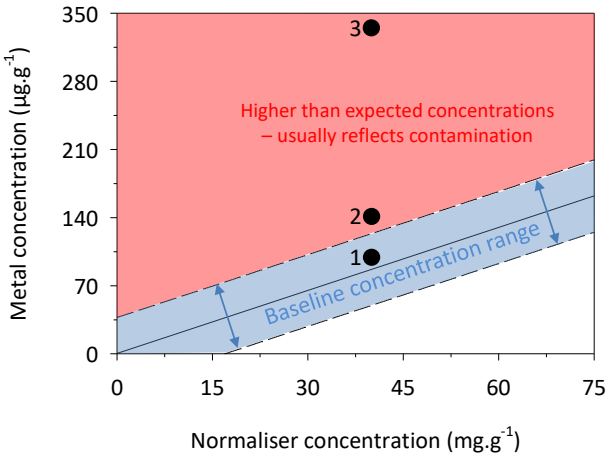

Figure 5. Schematic of a baseline metal concentration model. The oblique solid line and flanking dashed lines are the linear regression and upper and lower 99% prediction limits respectively. The prediction limits define the baseline concentration range for a metal in sediment at any co-occurring aluminium 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.

As noted 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 expected average concentration of a metal at any given aluminium concentration in sediment from baseline (largely uncontaminated) locations, while the upper and lower prediction 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 plot above the upper prediction limit when superimposed onto a baseline model are interpreted as enriched with relative to the baseline (see Figure 7). A metal concentration above the upper prediction limit does not automatically imply it was enhanced by an anthropogenic contribution, but rather that it is atypical of the data that define the model. Several reasons other than an anthropogenic contribution can result in a metal concentration exceeding the upper prediction limit. These include analytical variability and measurement error, 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 that is not captured by the baseline data set (Schropp et al., 1990; Rae and Allen, 1993).

Interpreting whether metal enrichment reflects contamination requires consideration of ancillary factors, including biogeochemical processes that naturally lead to the enrichment of certain metals in sediment, the absolute difference between a metal concentration and upper prediction limit, the location of enriched sediment relative to known or potential anthropogenic sources of metals, and 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 commonly enriched by several rather than one metal, due to the multitude of anthropogenic metal sources in these environments.

The concentrations of most metals in the sediment at most stations within the Buffalo River estuary in 2025 fall within the baseline model prediction limits. In other words, the concentrations are within the baseline range for sediment in the estuary. The concentrations two or more metals in the sediment at Stations 1, 2, 3, and 7 did, however, exceed baseline model upper prediction limits. The sediment with the highest number of metals (ten) at an enriched concentration was at Station 7 near the Victoria Slipway, followed by six metals at Station 3 near the Dry Dock, three metals at Station 2, and two metals at Station 1, both of the latter in the estuary upstream of the port proper (Figures 4 and 6). The sediment at other stations 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

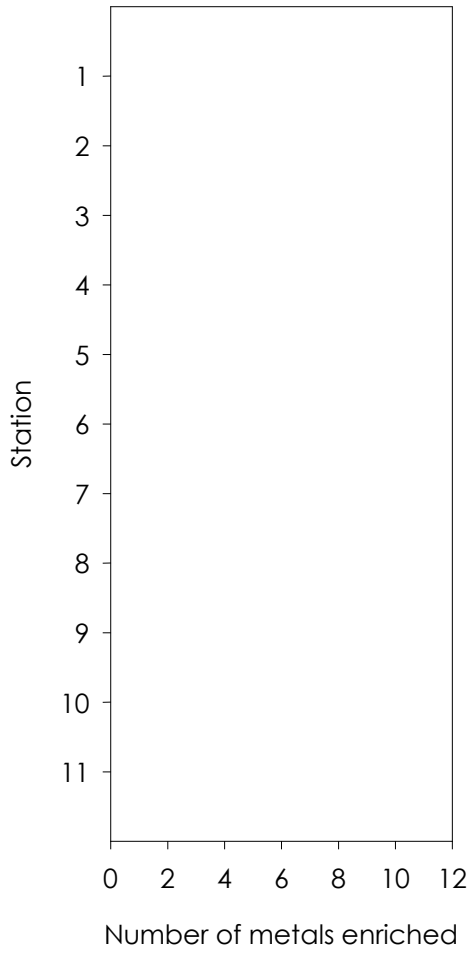

Figure 6. The number of metals enriched in sediment sampled in the Buffalo River estuary in 2025.

Stations 1 and 2 may reflect contamination, but was of a far lower magnitude compared to Stations 3 and 7 apart from manganese at Station 2 (see further below). However, the manganese enrichment probably does not represent contamination. This metal is highly susceptible to natural enrichment as it is mobile in anoxic sediment, which was the case at this station. The sediment at Station 1 was, however, also anoxic yet manganese was not enriched here.

Barium, cobalt, and zinc were the most often enriched metals, each at three of the 11 stations, followed by copper, chromium, nickel, and lead at two 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

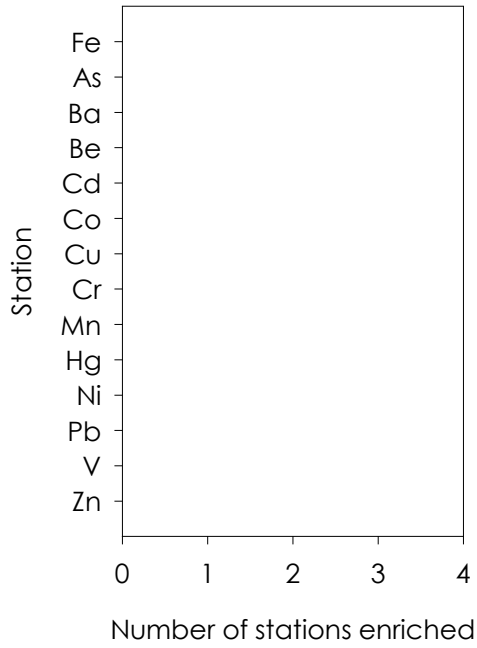

Figure 7. The number of stations in the Buffalo River estuary where sediment sampled in 2025 was enriched by various metals.

sediment was at (in order) Stations 7 and 3 (Figure 8).

3.4. Comparison of metal concentrations to Action Levels

The Department of Forestry, Fisheries and the Environment use an Action List (sediment quality guidelines) to decide if sediment identified for dredging in South African ports is suitable for open water disposal. Currently, 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. 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

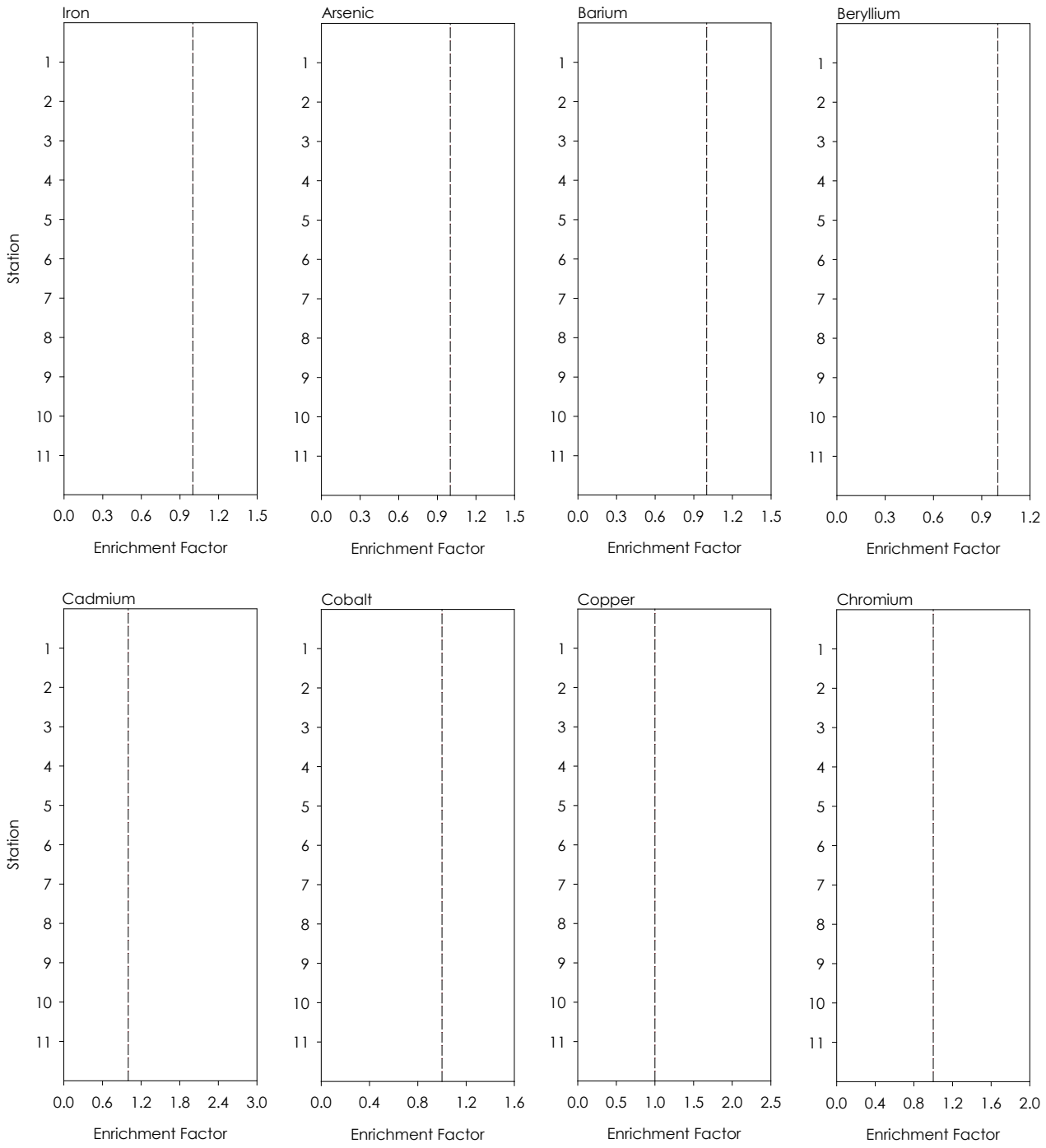

Figure 8. Enrichment Factors for metals in sediment sampled in the Buffalo River estuary in 2025. The dashed lines represent an Enrichment Factor = 1. An Enrichment Factor >1 indicates the metal was at a concentration exceeding the baseline and may indicate contamination.

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.

The number of metals in sediment within the Buffalo River estuary in 2025 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 copper and lead at Station 3 and cadmium at Station 7 were above the Warning Level. No metal concentrations were above the Level I and Level II.

4. Conclusions

The sediment at three stations within the Buffalo River estuary was metal enriched in 2025. The highest enrichment, which reflects contamination, was at Station 3 near the Dry Dock and Station 7 near the Victoria Slipway. The most significant metal contaminants of sediment were cadmium,

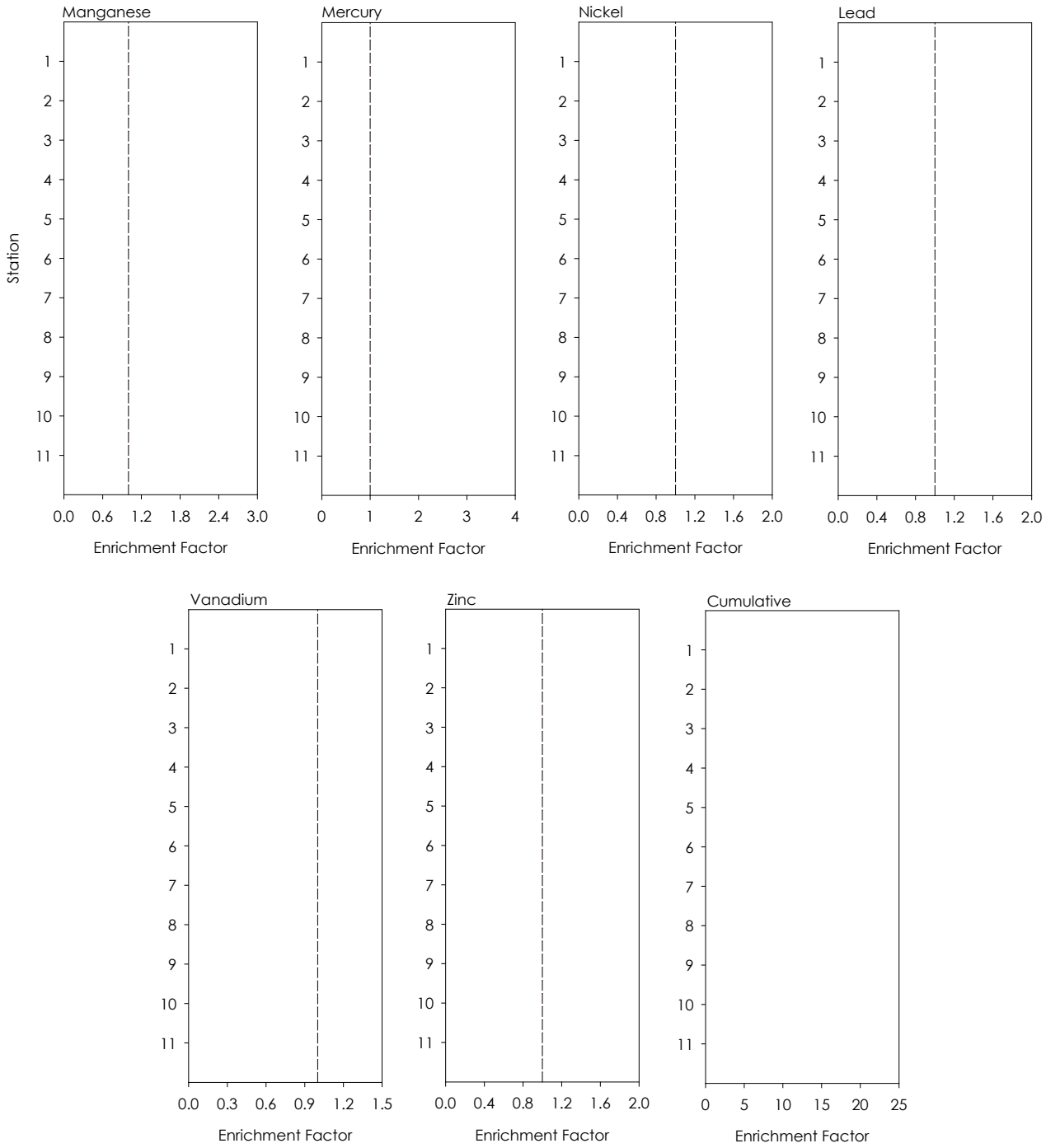

Figure 8 continued. Enrichment Factors for metals in sediment sampled in the Buffalo River estuary in 2025. The dashed lines represent an Enrichment Factor = 1. An Enrichment Factor >1 indicates the metal was at a concentration exceeding the baseline and may indicate contamination.

copper, chromium, mercury, and lead. The metal contamination at Station 3 near the Dry Dock undoubtedly reflects the inclusion of metal flecks and/or metal impregnated antifouling coating flakes in the sediment, derived from Dry Dock operations. 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 contamination at Station 7 also probably reflects the inclusion of metals in particulate form in the sample, a conclusion based on the wide variation in metal concentrations at this station amongst surveys, but the source of the metals is uncertain.

The trend in metal enrichment of sediment within the Buffalo River estuary in 2025 is generally consistent with trends for earlier surveys. Thus, sediment in parts of the estuary was more often and more significantly enriched (contaminated) than in other parts, most notably near the Dry Dock

and Victoria Slipway. The overwhelming feature of both the 2025 and 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. No metal concentrations were above the Level I or Level II. The disposal of sediment dredged in the Buffalo River estuary is thus 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.

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

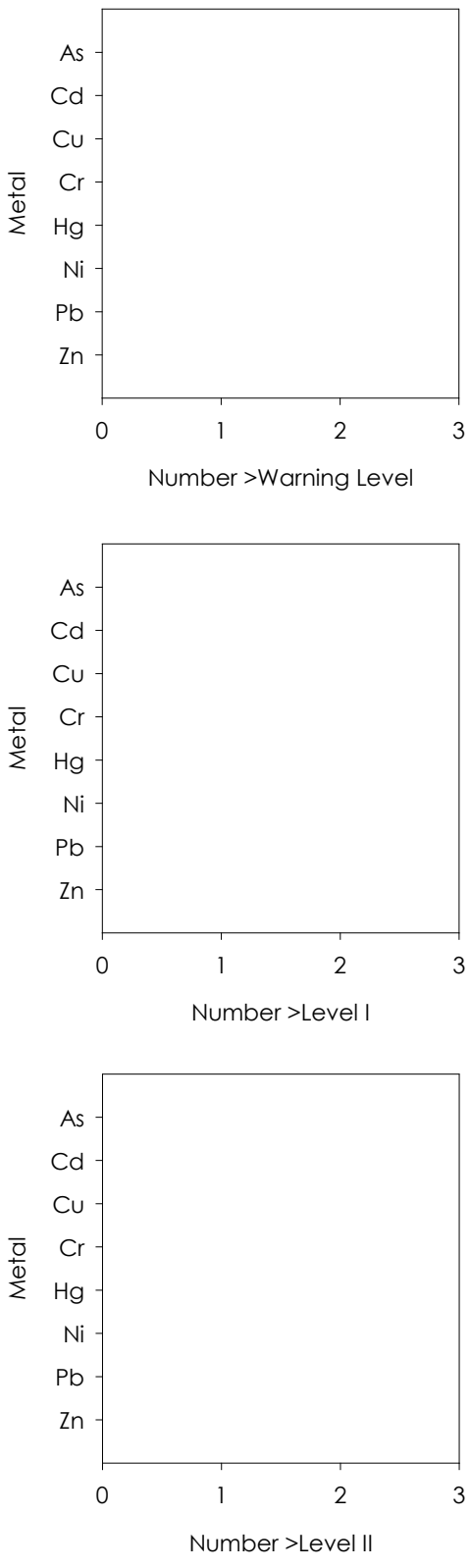

Figure 9. The number of stations at which metals in sediment sampled in the Buffalo River estuary in 2025 were at a concentration that exceeded the Warning Level, Level I and Level II of the sediment quality guidelines used by the Department of Forestry, Fisheries and the Environment to decide if sediment identified for dredging in South African ports is suitable for open water disposal.

5. References

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6. Appendices

Appendix 1

Global Positioning System coordinates of stations sampled in the Buffalo River estuary in 2025.

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	45.3	81.1	78.8	56.4	95.5	92.5	69.0	63.1	93.4	79.6	81.9	70.5	92.1
2	45.3	82.6	78.6	55.9	94.6	92.4	69.4	62.9	95.3	78.8	82.9	70.5	92.4
Mean	45.3	81.8	78.7	56.1	95.1	92.5	69.2	63.0	94.3	79.2	82.4	70.5	92.3
Standard deviation	0.0	1.0	0.1	0.3	0.6	0.0	0.3	0.1	1.3	0.6	0.7	0.0	0.3
Minimum	45.3	81.1	78.6	55.9	94.6	92.4	69.0	62.9	93.4	78.8	81.9	70.5	92.1
Maximum	45.3	82.6	78.8	56.4	95.5	92.5	69.4	63.1	95.3	79.6	82.9	70.5	92.4
Precision	0.0	1.1	0.0	0.1	0.3	0.0	0.1	0.0	1.8	0.3	0.5	0.0	0.1

Laboratory duplicate report for metals in sediment sampled in the Buffalo River estuary in 2025. 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	51560	54091	3.4	10	33583	34171	1.2	10
Fe	29890	30890	2.3	10	23876	24041	0.5	10
As	9.7	10.1	2.6	10	9.1	9.1	0.2	10
Ba	287	299	2.9	10	219	225	1.9	10
Be	1505	1575	3.2	10	1216	1208	0.4	10
Cd	261	268	1.6	10	1596	1920	13.0	10
Co	10	10	1.6	10	10	10	0.4	10
Cu	57	60	3.5	10	69	70	0.7	10
Cr	62	64	2.3	10	106	114	5.0	10
Mn	258	264	1.6	10	192	196	1.3	10
Hg	52	52	0.6	10	-	-		10
Ni	20	21	2.2	10	23	24	2.1	10
Pb	42	44	2.9	10	54	60	6.7	10
V	57	58	1.5	10	43	43	0.1	10
Zn	223	230	2.4	10	219	230	3.6	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 2025.

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	0.51	0.25	98.99	9.69
2	0.00	0.00	0.00	0.11	0.22	0.00	99.67	6.77
3	0.88	1.25	1.18	3.16	14.41	3.68	75.44	3.62
4	0.00	0.00	0.17	0.35	1.74	1.13	96.61	12.83
5	0.00	0.22	0.65	11.24	34.30	4.52	49.09	3.09
6	0.00	0.00	0.31	4.68	27.74	5.10	62.17	3.62
7	1.12	0.59	0.69	3.19	18.56	10.69	65.16	2.26
8	0.00	0.19	0.52	3.81	49.18	5.97	40.34	1.66
9	0.00	0.00	0.27	1.09	19.84	6.32	72.49	6.64
10	0.00	0.00	0.25	6.44	80.36	5.88	7.07	0.33
11	0.09	0.13	0.39	8.60	57.98	31.60	1.21	0.09

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 2025. 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	36.98	30.39	9.9	293	1.4	0.26	10.4	58.8	82.6	261.2	0.106	20.6	62.7	60.5	226
2	36.17	31.63	9.4	275	1.4	0.19	13.0	50.2	75.5	693.6	0.089	21.8	52.9	61.0	153
3	33.86	32.96	10.3	206	1.3	0.38	16.5	121.2	128.1	214.6	0.091	44.1	114.4	57.5	211
4	39.93	35.00	12.5	221	1.4	0.40	10.9	63.8	87.0	318.6	0.099	24.4	71.1	66.8	175
5	21.29	19.20	7.7	135	0.9	0.28	5.8	36.8	43.4	149.8	0.052	13.2	41.5	37.9	92
6	24.75	22.27	8.0	153	1.0	0.30	6.6	39.7	51.6	170.8	0.058	15.2	40.3	42.9	106
7	23.71	23.96	9.1	222	1.2	1.76	10.1	69.8	109.7	194.0	0.288	23.4	82.8	45.1	224
8	17.33	16.08	6.6	107	0.7	0.13	5.1	16.8	38.5	137.8	0.036	11.0	18.2	31.0	48
9	23.59	21.57	8.5	144	0.9	0.48	6.6	25.4	52.7	184.6	0.039	14.9	27.8	42.9	79
10	5.67	5.89	4.4	41	0.2	<0.1	1.8	2.7	13.8	75.0	<0.01	3.5	4.8	12.1	11
11	2.72	3.37	3.9	25	0.1	<0.1	<2	<2	7.9	47.3	<0.01	1.6	2.9	6.6	5
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