Appendix C Port Beach Sand Nourishment via Dredging – Sediment Colour Investigation

Port Beach Sand Nourishment via Dredging – Sediment Colour Investigation

Reference: R-1770_00-3
Date: December 2021

Document Control Sheet

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Document:	R-1770_00-3
Title:	Port Beach Sand Nourishment via Dredging – Sediment Colour Investigation
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Client:	Fremantle Ports
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REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
A – Technical and Editorial review	26/07/2021	M Capill		B Fennell	
B –Client Manger Review	31/08/2021	A Gartner			
0 – Director Review	13/09/2021				

DISTRIBUTION

Destination	Revision										
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Acronyms and Measurement Units

Acronyms	
a*	Red green coordinate
b*	Yellow blue coordinate
CIE	Commission Internationale de l'Eclairage
CoF	City of Fremantle
DoT	Western Australian Department of Transport
DWC	Deep Water Channel
L	Sunlight treatment
L*	lightness
LA	Sunlight and Agitation treatment
NAGD	National Assessment Guidelines for Dredging
PB	Port Beach
RGB	Red Green Blue
SAP	Sampling and Analysis Plan
SAPIR	Sampling and Analysis Plan Implementation Report
SPC	Success and Parmelia Channels
WA	Western Australia
Measurement units	
Δ	Delta
°C	Degrees Celsius

1 Introduction

Port Beach in Fremantle, Western Australia (WA) has undergone a sustained period of seasonal retreat, which has changed the coastal profile from having seasonally wide beaches to a narrower beach strip, characterised at times by dune scarps, rock exposure and damage to infrastructure. Such changes are undesirable from economic, social and environmental perspectives. Fremantle Ports, in partnership with City of Fremantle (CoF) and the WA Department of Transport (DoT), have identified sand nourishment as a viable option to minimise future coastal erosion at Port Beach. Potential sand sources that have been identified for the nourishment works include utilising sediments sourced via dredging of Fremantle Ports' Success and Parmelia Channels (SPC) and Deep Water Channel (DWC); however, since initial Project planning commenced, it has been resolved that DWC is the preferred sand source option.

In order to assess the physical and chemical suitability of sediments from the proposed SPC and DWC dredging areas for nourishment purposes, marine sediment sampling and analysis was undertaken in March 2020 (Figure 1-1 and Figure 1-2). While sediments from the proposed SPC and DWC dredging areas met required environmental quality guidelines for toxicants, there was variability observed in the colour of the sediments from the proposed SPC and DWC dredging areas compared to Port Beach (BMT 2020a). Colour is an important consideration from a social amenity perspective, although is not required to be considered as part of the NAGD (CA 2009) or Contaminated Sites Guidelines (DER 2014) assessments.

Port Beach is a popular beach in the Perth metropolitan area with high social amenity value and the colour of the sediments to be utilised for the nourishment of Port Beach presents an important planning consideration from a social amenity perspective. Since the initial assessment of sediment colour presented within the SAPIR (BMT 2020a) was based on a limited set of qualitative observations (using the Munsell system), an additional sediment colour investigation involving Commission Internationale de l'Eclairage (CIE)[1] colour testing of sediment samples was completed to:

(1) provide a quantitative assessment of the scale of colour differences between sediment samples from the proposed SPC and DWC dredging areas and Port Beach

(2) determine the potential capacity for the colour of sediments from the proposed SPC and DWC dredging areas to change over time from natural weathering processes and become more comparable to Port Beach sediments.

The methods and results of the sediment colour investigation are presented within this report.

[1] Commission Internationale de l'Eclairage (CIE; translated as the International Commission on Illumination), is the body responsible for international recommendations for photometry and colorimetry. In 1931, the CIE standardised colour order systems by specifying the light source (or illuminants), the observer and the methodology used to derive values for describing colour, regardless of industry or use case.

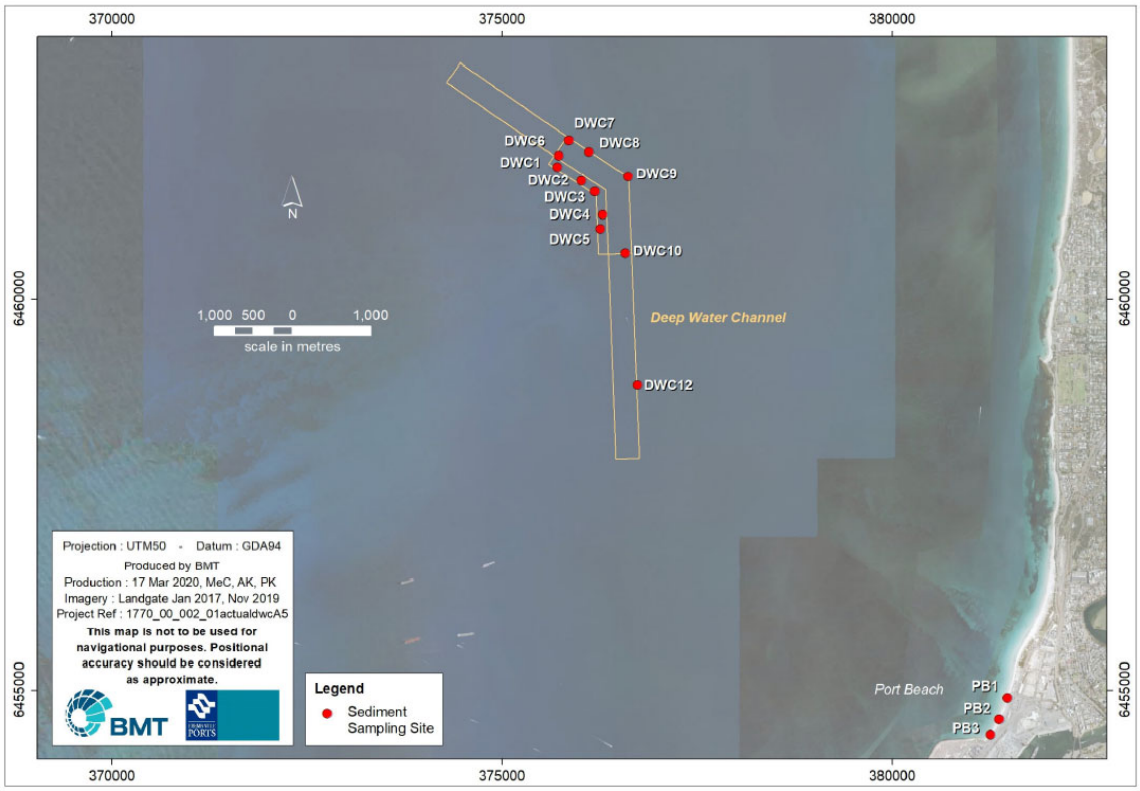


Figure 1-1 Sediment sampling sites at Deep Water Channel (DWC) and Port Beach (PB)

Figure 1-2 Sediment sampling sites at Success and Parmelia Channels (SCP)

2 Methods

2.1 Sediment sample collection

Sediment samples were collected using Scuba on 4–5 March 2020. Sampling methods are detailed in the sediment Sampling and Analysis Plan (SAP; BMT 2020b, Appendix A), prepared in accordance with the National Assessment Guidelines for Dredging (NAGD; CA 2009) and the Contaminated Sites Guidelines (DER 2014). A full description of results of the implementation of the SAP is presented within the SAP Implementation Report (SAPIR; BMT 2020a). A sub-set samples collected during this sampling campaign (Section 2.3) were further analysed for colour in-line with procedures described below.

2.2 CIE colour testing of sediment samples

CIE colour testing offers more precision in colour measurement than qualitative observations using the Munsell system because the parameters are based on the spectral power distribution of the light emitted from a coloured object and are factored by sensitivity curves which have been measured for the human eye (i.e., has been designed to approximate human vision). CIE colour testing involves the evaluation of colour using a measurement instrument that provides three coordinates to locate colour in a colour space. Colour difference can be defined as the numerical comparison of a samples colour to 'the standard'; it indicates the differences in absolute colour coordinates and is referred to as Delta (Δ).

The CIE L*a*b* is a widely adopted colour space applied in industry for colour control and management. In the CIE L*a*b* colour space, L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate. Deltas for L* (ΔL*), a* (Δa*) and b* (Δb*) may be positive or negative and are interpreted as follows:

- ΔL* (L* sample – L* standard) = difference in lightness and darkness (positive value = lighter; negative value = darker)
- Δa* (a* sample – a* standard) = difference in red and green (positive value = redder; negative value = greener)
- Δb* (b* sample – b* standard) = difference in yellow and blue (positive value = yellower; negative value = bluer)

The total difference, Delta E (ΔE*), is always positive and is determined as follows:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

Sediment samples that were subject to CIE colour testing by the laboratory Microanalysis Australia for this sediment colour investigation are detailed in Section 2.3 and the laboratory report are appended to this report (Appendix B). Sediment samples for CIE colour testing were ground with a mortar and pestle until a fine powder. The ground samples were packed into a test holder using gentle hand pressure against a new glass slide to provide a flat, blemish free test surface. Samples were then analysed between 21-23°C at ambient humidity using a Elrepho 2000 Datacolour

instrument. The instrument was calibrated against a barium sulphate standard prior to analysis. The standard illuminant D65 was used.

2.3 Sediment sample weathering experiment

To determine the potential capacity for the colour of sediments from the proposed SPC and DWC dredging areas to change over time from natural weathering processes and become more comparable to Port Beach sediments, a sediment sample weathering experiment was completed. The sediment sample weathering experiment was conducted over a 12 month duration and involved exposing sediment samples to the treatments presented in Table 2-1.

Table 2-1 Sample treatments for the sediment sample weathering experiment

Treatment	Description
Sunlight (L)	Sediment samples were exposed to natural ambient sunlight throughout the duration of the monitoring period. Sediment samples were stored in clear plastic containers to avoid contamination from other external constituents (e.g., dust) that may influence sample colour.
Sunlight + agitation (LA)	Sediment samples were exposed to natural ambient sunlight throughout the duration of the monitoring period as described above. In addition, on one occasion every two months, the sediment samples were physically agitated in site seawater for ~8 hours to mimic potential washing and abrasion of sediments within the natural swash zone. Physical agitation of the samples was undertaken using a tumbler (small machine that turns a barrel round and round non-stop). After completion of physical agitation of the samples, sediments were dried prior to any further analysis.

Prior to initiating the sediment sample weathering experiment, CIE colour testing was completed from a subsample of sediments from Port Beach (to provide the standard) and the proposed SPC and DWC dredging areas (to provide the baseline). During the sediment sample weathering experiment, subsamples of the sediments from each treatment were collected at two-monthly intervals for CIE colour testing. Qualitative assessments of samples were also made using the Munsell system and the samples were photographed. In addition, Red Green Blue (RGB) values were provided by the analysis laboratory for the CIE colour testing.

The sediment sample weathering experiment was based on representative composite sediment samples as follows:

- one composite sample for Port Beach sediments from sites PB1-3 (Figure 1-1)
- one composite sample for SPC sediments from sites SPC1-8 (Figure 1-2)
- two composite samples for DWC sediments from sites DWC1-5 and DWC6-8 (Figure 1-1).

The colour of sediments from Port Beach and SPC were consistent amongst sites within the sampling areas (BMT 2020a); therefore, one composite sample was considered suitable for the sediment sample weathering experiment. At DWC, there was variability in the colour of sediments observed between sites within the sampling area (BMT 2020a); therefore, two separate composite samples were made for the different colour groups observed within the sampling area that were the most different to the colour of Port Beach sediments. Sediments from sites DWC9-10 were excluded from

the sediment sample weathering experiment because they were comparable to the composite sample DWC1-5. Sediments from site DWC12 were also excluded from the sediment sample weathering experiment because they were comparable to Port Beach sediments and considered to not require further investigation.

The sediment sample analysis plan for the sediment sample weathering experiment is presented in Table 2-2.

Table 2-2 Sediment sample analysis plan for the sediment sample weathering experiment

Sample	Treatment	Time (months)						
		0	2	4	6	8	10	12
PB1-3	Sunlight (L)	✓	–	–	–	–	–	–
	Sunlight + agitation (LA)		–	–	–	–	–	–
SPC1-8	Sunlight (L)	✓	✓	✓	✓	✓	✓	✓
	Sunlight + agitation (LA)		✓	✓	✓	✓	✓	✓
DWC1-5	Sunlight (L)	✓	✓	✓	✓	✓	✓	✓
	Sunlight + agitation (LA)		✓	✓	✓	✓	✓	✓
DWC6-8	Sunlight (L)	✓	✓	✓	✓	✓	✓	✓
	Sunlight + agitation (LA)		✓	✓	✓	✓	✓	✓
Total number of samples for colour analysis		4	6	6	6	6	6	6

Note:

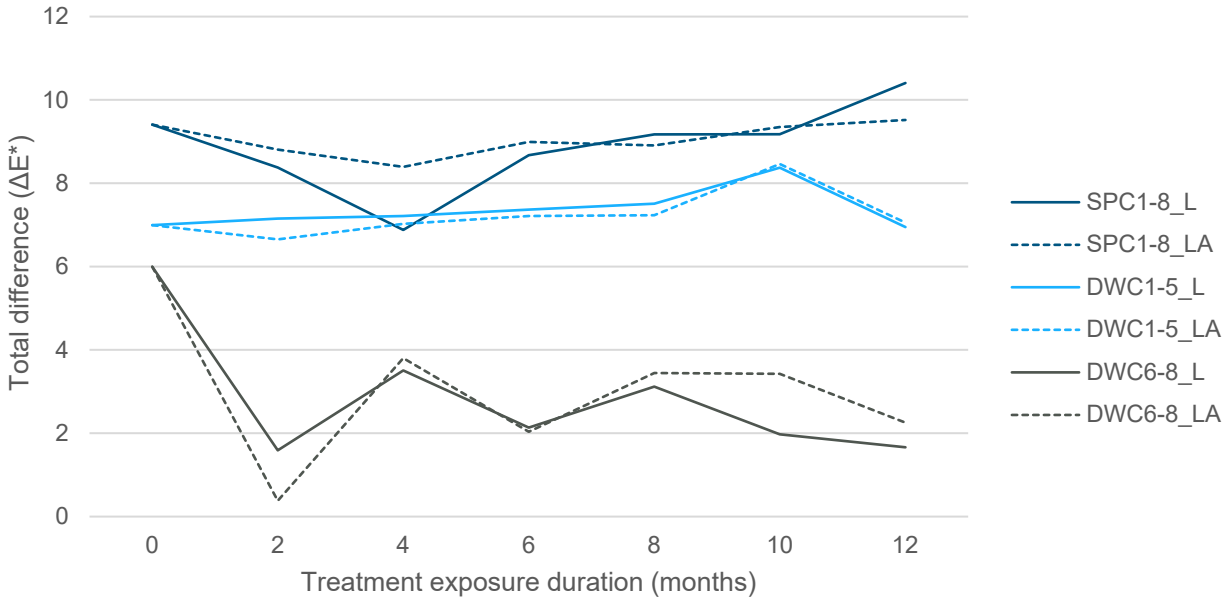
1. '✓' = indicates sample was analysed; '–' = indicates sample was not analysed; 'L' = sunlight treatment; 'LA' = sunlight and agitation treatment.

3 Results

Total difference (ΔE*) in the colour of sediment samples from the SPC and DWC areas between treatments and over time compared to Port Beach sediments (the standard) are presented in Figure 3-1. These results indicate that the colour of sediment from sample DWC6-8 had the lowest total difference (ΔE*; i.e., were most similar) and the colour of sediment from sample SPC1-8 had the greatest total difference (ΔE*; i.e., were least similar) to Port Beach sediments (the standard; Figure 3-1). While there were changes to the total difference (ΔE*) of the colour of sediments for all samples over the 12 month exposure duration, no clear pattern was observed (Figure 3-1). There was also no clear trend observed between the different treatments (light [L] vs light and agitation [LA]) for any of the samples relative to Port Beach sediments (the standard), but the treatments of each sample generally followed a similar trend over time (Figure 3-1).

The total difference (ΔE*) of the colour of sediment samples from the proposed SPC and DWC dredging areas between treatments and over time compared to the respective sample at 0 months (the baseline) are presented in Figure 3-2. The total difference (ΔE*) slightly increased in sediment sample DWC6-8 LA by 2.3 over 12 months when compared to the sample at 0 months (the baseline). The sediment samples SPC1-8 and DWC1-5 both reached maximum total difference (ΔE*) at 10 months then the total difference (ΔE*) trend reduced or plateaued at 12 months.

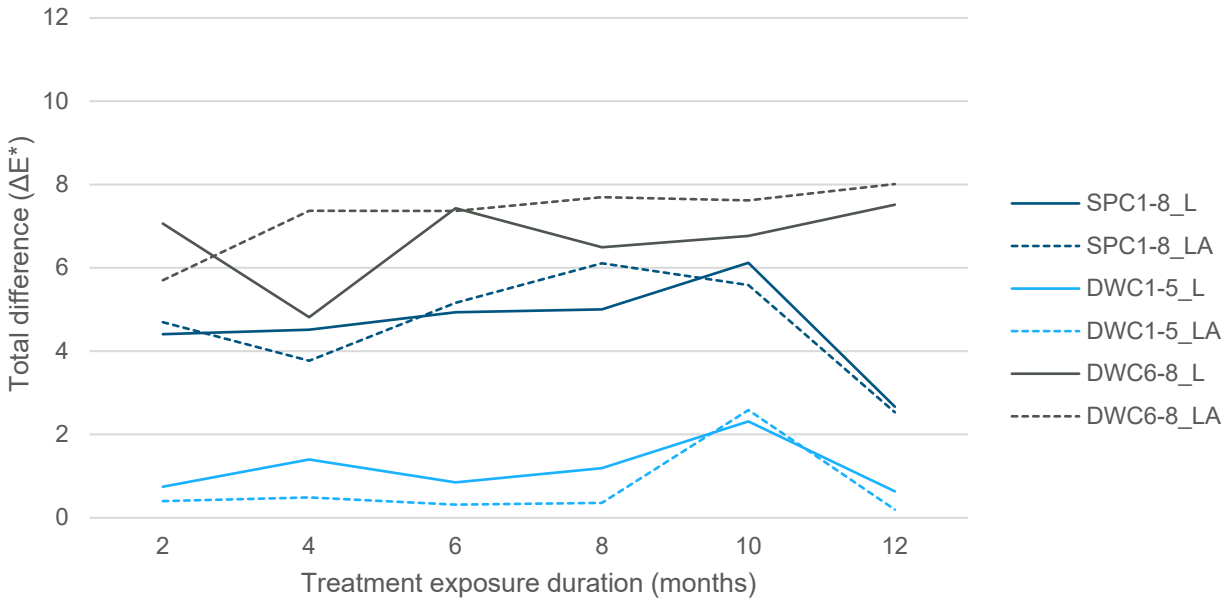
The CIE colour coordinates, Munsell colour, RGB colour coordinates and photographs of the sediment samples from Port Beach, Success and Parmelia Channels and Deep Water Channel are provided in Table 3-1.



Note:

1. 'L' = sunlight treatment; 'LA' = sunlight and agitation treatment.

Figure 3-1 Total difference (ΔE*) of the colour of sediment samples from Success and Parmelia Channels and Deep Water Channel between treatments and over time compared to Port Beach sediments (the standard)



Note:

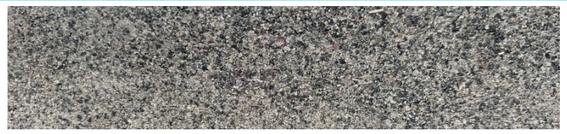
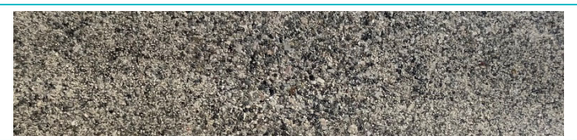
1. 'L' = sunlight treatment; 'LA' = sunlight and agitation treatment.

Figure 3-2 Total difference (ΔE*) of the colour of sediment samples from Success and Parmelia Channels and Deep Water Channel between treatments and over time compared to the respective sample at 0 months (the baseline)

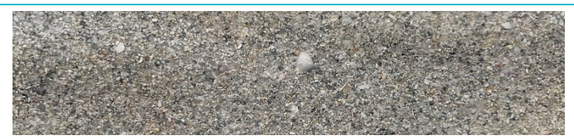
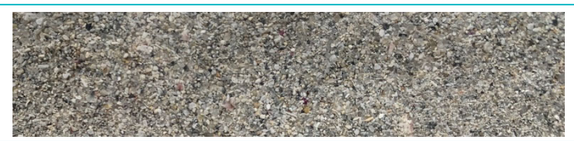
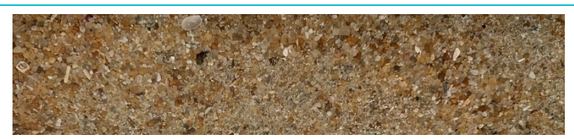
Table 3-1 CIE colour coordinates, Munsell colour, RGB colour coordinates and photographs of the sediment samples from Port Beach, Success and Parmelia Channels and Deep Water Channel

Sample	Treatment	Time	CIE colour coordinates			Munsell colour	RGB colour coordinates			RGB colour	Photograph
			L	a	b		R	G	B		
Port Beach											
PB1-3	Baseline	0 months	85.86	1.35	10.20	2.5Y 8/1	225	213	194		
Success and Parmelia Channels											
SPC1-8	Baseline	0 months	78.89	-0.10	4.05	5Y 6/1	198	195	186		
SPC1-8_L	Sunlight	2 months	83.01	-0.3	2.5	5Y 6/1	208	207	200		
SPC1-8_LA	Sunlight + agitation	2 months	83.11	-0.3	2.0	5Y 6/1	208	207	202		
SPC1-8_L	Sunlight	4 months	83.36	0.45	3.85	5Y 6/1	212	207	199		
SPC1-8_LA	Sunlight + agitation	4 months	82.41	-0.4	2.75	5Y 6/1	207	205	198		
SPC1-8_L	Sunlight	6 months	83.40	-0.3	2.1	5Y 6/1	209	208	202		
SPC1-8_LA	Sunlight + agitation	6 months	83.48	-0.4	1.7	5Y 6/1	209	208	203		
SPC1-8_L	Sunlight	8 months	83.24	-0.45	1.60	5Y 6/1	207	207	202		

Results

Sample	Treatment	Time	CIE colour coordinates			Munsell colour	RGB colour coordinates			RGB colour	Photograph
			L	a	b		R	G	B		
SPC1-8_LA	Sunlight + agitation	8 months	84.48	-0.50	1.60	5Y 6/1	210	210	205		
SPC1-8_L	Sunlight	10 months	84.36	-0.30	1.30	5Y 6/1	210	210	206		
SPC1-8_LA	Sunlight + agitation	10 months	83.72	-0.30	1.25	5Y 6/1	208	208	204		
SPC1-8_L	Sunlight	12 months	80.12	-0.40	1.70	5Y 6/1	199	198	193		
SPC1-8_LA	Sunlight + agitation	12 months	80.75	-0.35	2.35	5Y 6/1	201	200	194		
Deep Water Channel											
DWC1-5	Baseline	0 months	86.195	-0.25	3.4	5Y 7/1	218	216	208		
DWC1-5_L	Sunlight	2 months	86.93	-0.2	3.3	5Y 7/1	220	218	210		
DWC1-5_LA	Sunlight + agitation	2 months	86.28	0.0	3.7	5Y 7/1	219	216	207		
DWC1-5_L	Sunlight	4 months	87.47	0.3	3.25	5Y 7/1	223	219	211		
DWC1-5_LA	Sunlight + agitation	4 months	86.68	-0.2	3.4	5Y 7/1	219	217	209		

Results

Sample	Treatment	Time	CIE colour coordinates			Munsell colour	RGB colour coordinates			RGB colour	Photograph
			L	a	b		R	G	B		
DWC1-5_L	Sunlight	6 months	86.99	-0.3	3.1	5Y 7/1	220	218	210		
DWC1-5_LA	Sunlight + agitation	6 months	86.32	-0.1	3.2	5Y 7/1	218	216	208		
DWC1-5_L	Sunlight	8 months	87.32	-0.20	3.00	5Y 7/1	220	218	211		
DWC1-5_LA	Sunlight + agitation	8 months	86.43	-0.15	3.15	5Y 7/1	218	216	208		
DWC1-5_L	Sunlight	10 months	88.23	-0.10	2.30	5Y 7/1	222	221	215		
DWC1-5_LA	Sunlight + agitation	10 months	88.53	-0.10	2.30	5Y 7/1	223	221	215		
DWC1-5_L	Sunlight	12 months	85.59	-0.05	3.40	5Y 7/1	216	213	205		
DWC1-5_LA	Sunlight + agitation	12 months	86.11	-0.10	3.30	5Y 7/1	217	215	207		
DWC6-8_L	Baseline	0 months	86.01	0.30	4.3	10YR 7/4	219	215	205		
DWC6-8_L	Sunlight	2 months	87.05	1.9	11.1	10YR 7/4	230	216	196		

Results

Sample	Treatment	Time	CIE colour coordinates			Munsell colour	RGB colour coordinates			RGB colour	Photograph
			L	a	b		R	G	B		
DWC6-8_LA	Sunlight + agitation	2 months	85.63	1.3	9.9	10YR 7/4	224	213	194		
DWC6-8_L	Sunlight	4 months	88.72	0.8	8.25	10YR 7/4	231	222	206		
DWC6-8_LA	Sunlight + agitation	4 months	89.63	1.5	10.6	10YR 7/4	237	224	204		
DWC6-8_L	Sunlight	6 months	87.55	1.9	11.4	10YR 7/4	232	218	196		
DWC6-8_LA	Sunlight + agitation	6 months	87.46	1.9	11.4	10YR 7/4	232	217	196		
DWC6-8_L	Sunlight	8 months	88.97	1.25	10.00	10YR 7/4	233	221	202		
DWC6-8_LA	Sunlight + agitation	8 months	89.14	1.65	11.20	10YR 7/4	235	222	200		
DWC6-8_L	Sunlight	10 months	87.75	1.65	10.70	10YR 7/4	231	218	198		
DWC6-8_LA	Sunlight + agitation	10 months	89.15	1.70	11.10	10YR 7/4	235	222	201		
DWC6-8_L	Sunlight	12 months	85.31	2.15	11.55	10YR 7/4	226	210	189		

Results

Sample	Treatment	Time	CIE colour coordinates			Munsell colour	RGB colour coordinates			RGB colour	Photograph
			L	a	b		R	G	B		
DWC6-8_LA	Sunlight + agitation	12 months	84.73	2.10	12.00	10YR 7/4	224	209	187		

Note:

1. ‘CIE’ = Commission Internationale de l’Eclairage; ‘RGB’ = Red Green Blue; ‘L’ = sunlight treatment; ‘LA’ = sunlight and agitation treatment.

4 Discussion

This investigation used CIE colour testing of sediment samples to provide a more precise colour measurement than qualitative observations using the Munsell system. The CIE parameters are based on the spectral power distribution of the light emitted from a coloured object and are factored by sensitivity curves which have been measured for the human eye (i.e., has been designed to approximate human vision). As such, CIE provides a quantitative approach that enables the scale of colour difference between sediment samples from the proposed dredge source areas and Port Beach to be compared in a much less subjective manner than traditional techniques. The outcomes of this investigation are intended to inform the potential capacity for the colour of sediments from the proposed dredging areas to change over time from natural weathering processes and become more comparable to Port Beach sediments.

The results from the CIE colour assessment show that the colour coordinates samples collected from DWC6-8 are the most comparable (lowest ΔE) to the Port Beach standard (Sample PB1-3). It should be noted that sediments from sites DW9-10 were excluded from the weathering experiment because they were considered comparable to the proposed capital bend sediments while sediments from DWC12 are considered comparable to Port Beach Nourishment Area and therefore didn't require further assessment. As such and if practical, from an aesthetics viewpoint, it would be ideal that dredging for sand nourishment of Port Beach target areas around sites DWC6-8, DW9-10 and DWC12. The colour coordinates found in the in the SPC 1-8 resulted in the highest ΔE, which means this area has sediments that were the least comparable colour to the sediment found at Port Beach (PB1-3).

The sediment weathering experiment was conducted to assess the potential capacity for the sediment to change colour over time when exposed to natural weathering with two treatment types, light (L) and light and agitation (LA). The results showed that sediments from the sampling sites can change over time, but a longer duration may be required to see stronger trends in sediment colour weathering. DWC6-8 did not show trends of colour weathering over time as the ΔE plateaued after 6 months of exposure to the weathering experiment. The other sites DWC1-5 and SPC1-8 showed colour difference after 8 months, so this may indicate that the sediment colour has the potential to bleach and/or change in colour, but a longer time period may be needed to assess this change.

5 Conclusion

Overall, this study has provided a quantitative assessment of the scale of colour differences between sediment samples from the proposed DWC and SPCs dredge areas in comparison to the Port Beach nourishment area. The results show that sediment found in the DWC are the most comparable to the sediment found at Port Beach and therefore should be considered as a suitable dredging area for the Port Beach sand nourishment. It may be recommended in future sediment sample weathering experiments to extend the duration more than 12 months as results did not show significant changes in colour of sediment samples when exposed to light and/or light and agitation treatments.

Sand nourishment for Port Beach is important from environmental, economic and social perspectives to restore coastal profiles from seasonal erosion. Therefore, results from the sediment colour investigation are important to act as a baseline study for future experiments in sand nourishment projects and to educate beach users and the local community about the sand nourishment selection process.

6 References

BMT (2020a) Port Beach Nourishment – Sediment Sampling and Analysis Plan Implementation Report. Prepared for Fremantle Ports by BMT, Report No. R-1770_00-1_DRAFT, Perth, Western Australia, April 2020

BMT (2020b) Port Beach Nourishment – Sediment Sampling and Analysis Plan. Prepared for Fremantle Ports by BMT, Report No. R-1770_00-1, Perth, Western Australia, February 2020

CA (2009) National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra, Australian Capital Territory

DER (2014) Assessment and management of contaminated sites. Contaminated sites guidelines. Department of Environment Regulation, Western Australia, December 2014

Appendix A Sediment Sampling and Analysis Plan

Port Beach Nourishment – Sediment Sampling and Analysis Plan

R-1770_00-1

February 2020

Document Control Sheet

Project	Port Beach Nourishment Planning
Report Title	Port Beach Nourishment – Sediment Sampling and Analysis Plan
Client	Fremantle Ports
Report No.	R-1770_00-1
Date	February 2020

Distribution

Revision	Author	Recipients	Organisation	No.copies & format	Date
A	M Capill	L Synnot	BMT	1 x .docm	27/02/20
B	M Capill	A Gartner	BMT	1 x .docm	27/02/20
C	M Capill	D Doak	Fremantle Ports	1 x .docm	28/02/20
0	M Capill	D Doak	Fremantle Ports	1 x .pdf	03/03/20

Revisions

Revision	Reviewer	Intent	Date
A	L Synnot	Technical and Editorial review	27/02/20
B	A Gartner	Client Manager review	28/02/20
C	D Doak	Client review	03/03/20

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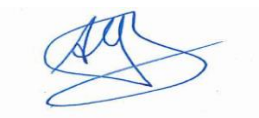

Director (or delegate)
Date: 03/03/2020

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List of Terms and Abbreviations

BTEX	Benzene, toluene, ethylbenzene, xylene
CEC	Cation exchange capacity
CoC	Chain of Custody
DWC	Deepwater Channel
EILs	Ecological Investigation Levels
ESLs	Ecological Screening Levels
GDA	Geocentric Datum of Australia
GPS	Geographical positioning system
HILs	Health Investigation Levels
JHA	Job Hazard Analysis
L	Litre
m	Metre
m^3	Cubic metre
NAGD	National Assessment Guidelines for Dredging
NATA	National Association of Testing Authorities
PAHs	Polycyclic aromatic hydrocarbons
PSD	Particle size distribution
PVC	Polyvinyl chloride
QA/QC	Quality assurance and quality control
SAP	Sampling and Analysis Plan
SPCs	Success and Parmelia Channels
TOC	Total organic carbon
TPHs	Total petroleum hydrocarbons
TRHs	Total recoverable hydrocarbons
UTM	Universal Transverse Mercator
WA	Western Australia

1 Introduction

1.1 Background

Port Beach in Fremantle, Western Australia (WA; Figure 1.1) has undergone a sustained period of seasonal retreat, which has changed the coastal profile from having seasonally wide beaches to a narrower beach strip, characterised at times by dune scarps and rock exposure. Such changes are undesirable from both a social and environmental perspective.

Fremantle Ports, along with the City of Fremantle and Department of Transport, have identified sand nourishment as a viable option to minimise future coastal erosion of Port Beach. It is understood that the most likely sand source for nourishment is to utilise sediments sourced via dredging of the Deepwater Channel (DWC) and Success and Parmelia Channels (shown in Section 2; Figure 2.1).

Source: MP Rogers & Associates (2019)

Figure 1.1 Port Beach, Fremantle

1.2 Purpose of this document

This sediment Sampling and Analysis Plan (SAP) describes sediment sampling methods and analyses within the areas applicable to the sand nourishment campaign.

This SAP has been prepared with reference to the National Assessment Guidelines for Dredging (NAGD; CA 2009) and the Contaminated Sites Guidelines (DER 2014). The NAGD (CA 2009) provides a useful framework for the sampling of marine sediments to adequately characterise physical and chemical properties of the material to be dredged, and the Contaminated Sites Guidelines (DER 2014) provide guidance for the disposal of sediments onshore.

This SAP provides:

- a description of the proposed dredging and disposal and the relevant legislation and guidelines
- a review of existing information on sediment characteristics within the dredging and disposal areas, and potential sources of contamination
- an outline of the proposed sampling program with information on the number, type and location of samples required to adequately characterise the sediments for dredging and disposal
- the proposed methods for sampling, sample preservation, transportation and storage to ensure the integrity of the samples
- the proposed quality assurance and quality control (QA/QC) procedures

Sediment sampling results will be presented in a SAP Implementation Report to determine the suitability of sediments sourced via dredging of the DWC and SPCs for nourishment of Port Beach, and inform potential marine environmental approvals.

2 Project Description

2.1 Dredging and disposal

While the detailed dredge design (e.g. footprints, volumes and depths) is yet to be finalised, Fremantle Ports has provided estimates from concept design for the volume of dredge material potentially available from the DWC and SPCs for nourishment of Port Beach (Table 2.1 and Figure 2.1).

For the DWC, it is estimated ~252,807 m^3 of sediments are available for nourishment of Port Beach; assuming a maintenance dredging total volume of ~30,191 m^3 from within the existing DWC and capital dredging of ~222,616 m^3 involving widening of the DWC for additional sand source; referred to as the proposed 'Capital Bend' (Table 2.1 and Figure 2.1).

Within the SPCs, it is estimated ~84,615 m^3 of sediment accretion is potentially available for nourishment of Port Beach (Table 2.1).

Table 2.1 Estimated volumes of sediment that could be available to dredge from Deepwater Channel and Success and Parmelia Channels to nourish Port Beach

Channel[1]	Dredge area	Volume (m^3)[2]
Deepwater	Straight North	0
	Bend	27,952
	Straight South	2239
	Capital Bend	222,616
	Sub-total	**252,807**
Success and Parmelia	Success North West	1371
	Success North East	301
	Success South West	65,217
	Parmelia North East	3203
	Parmelia South West	14,523
	Subtotal	**84,615**
Total		**337,422**

Notes:
1. Refer to Figure 2.1 for channel locations.
2. Volumes have been estimates based on Fremantle Port's current working design at the time of preparing this SAP.

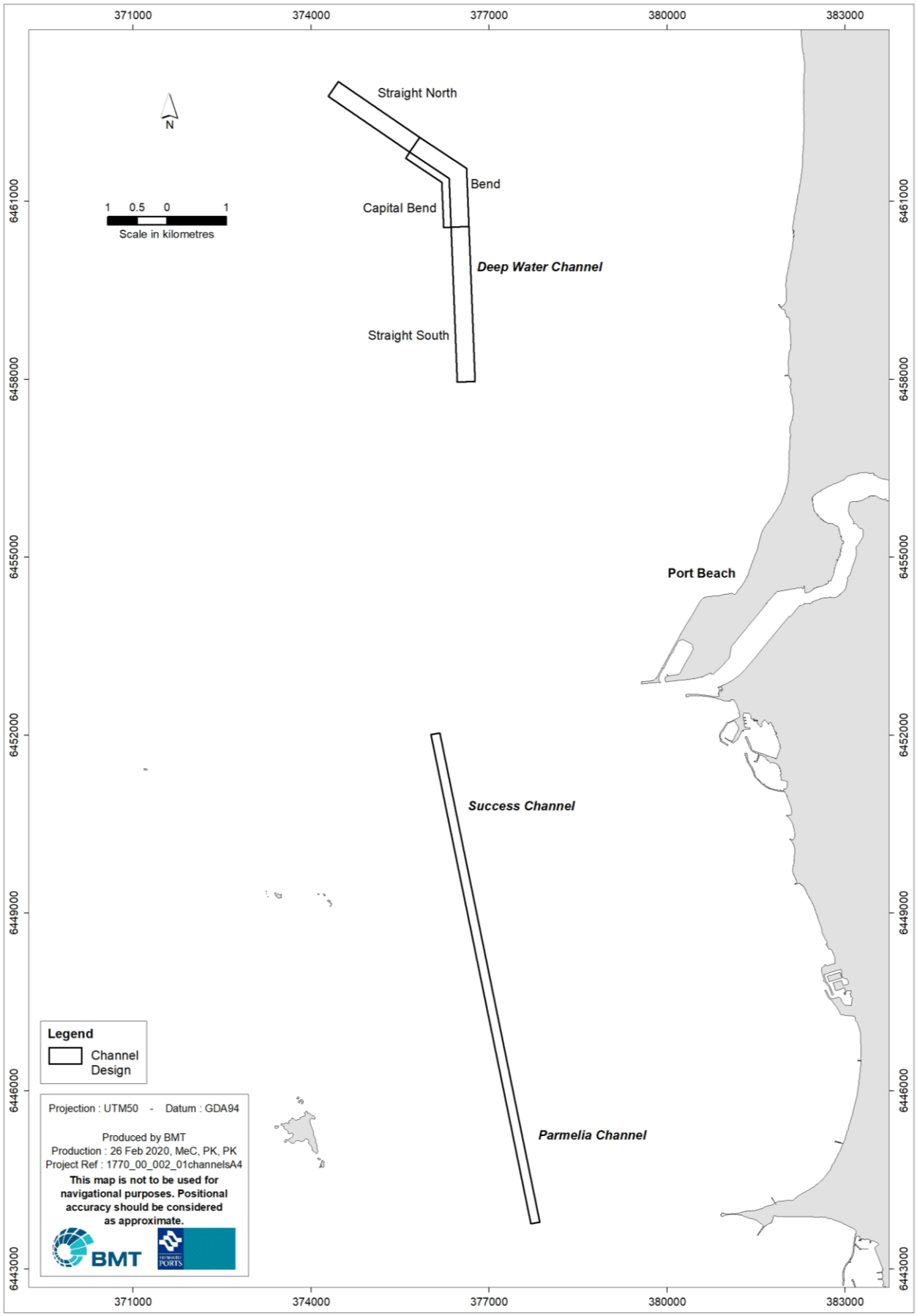

Figure 2.1 Location of the proposed Deepwater Channel and Success and Parmelia Channels dredge areas and Port Beach

2.2 Relevant legislation and guidelines

The environmental legislation and guidelines applicable to the SAP for the proposed sand nourishment campaign involving dredging and disposal are outlined below:

- NAGD (CA 2009)
- *Contaminated Sites Act 2003* (WA)
- Contaminated Sites Guidelines (DER 2014)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

Refer to Appendix A for further details.

2.3 Review of existing sediment data and potential contamination sources

2.3.1 Dredging areas

Sediments from the DWC and SPCs have previously been sampled and analysed for a range of potential contaminants of concern identified from relevant cause-effect pathways during Fremantle Ports' Marine Quality Monitoring Program annuals surveys. A review of the historical Fremantle Ports' MQMP sediment quality data was completed to provide rational for contaminant analytes requiring assessment[1] (Table 2.2).

Table 2.2 Review of the contaminants of potential concern in sediments from the proposed dredge areas at Deepwater Channel and Success and Parmelia Channels

Contaminants of potential concern	Risk rating	Reasons for risk ratings	Assessment required?
Metals	Medium	Potential source from vessel operations. Although there have been no relevant guideline exceedances for concentrations of metals in shipping channel sediments during Fremantle Ports' MQMP annual surveys over the past five years (BMT 2019,20), assessment will be completed regardless as vessel operations are ongoing and dredged sediments will be disposed to a public beach.	Yes
Hydrocarbons	Medium	Potential source from vessel operations. Although there have been no relevant guideline exceedances for concentrations of hydrocarbons in shipping channel sediments during Fremantle Ports' MQMP annual surveys over the past five years (BMT 2019,20), assessment will be completed regardless as vessel operations are ongoing and dredged sediments will be disposed to a public beach.	Yes
Tributyltin (found in antifoulant paint commonly applied to vessels before it was globally banned in 2008)	Low	Potential source from vessel operations but considered low risk due to no relevant guideline exceedances of tributyltin concentrations in shipping channel sediments during Fremantle Ports' MQMP annual surveys over the past five years (BMT 2019,20). Unlikely for further input since tributyltin was globally banned in 2008.	No
Pesticides/Herbicides	Low	Potential input from nearby river catchment but considered low risk due to no relevant guideline exceedances for concentrations of organochlorine pesticides in shipping channel sediments during	No

[1] Contaminates not included in Table 2.2 are considered very low risk and do warrant review and/or assessment.

Contaminants of potential concern	Risk rating	Reasons for risk ratings	Assessment required?
		Fremantle Ports' MQMP annual surveys over the past five years (BMT 2019,20).	
Nutrients	Low	Potential input from accumulation of seagrass wrack in the shipping channels, however; placement of material with high wrack content to Port Beach is not desirable from a social aesthetic perspective and this material will be actively avoided.	No

2.3.2 Nourishment area

Port Beach is bordered by natural dune vegetation with no identified cause-effect pathways for potential contaminants of concern. Sediments from the nourishment area at Port Beach are therefore anticipated to comprise of clean marine sands.

3 Field Sampling Program

3.1 Timing

The field sampling program is anticipated to be completed over two days on the 4–5 March 2020 (timings may be subject to change depending on weather).

3.2 Sampling design

3.2.1 Sampling locations

In accordance with the NADG (CA 2009), a minimum of 22 sampling locations are required at the DWC assuming a proposed dredge volume in the range of 223,000–264,000 m^3, while 17 sampling locations are required at the SPCs assuming a proposed dredge volume in the range of 83,000–92,000 m^3. Under the NAGD assessment framework (CA 2009), both proposed dredge areas are classified as 'probably clean' based on historical sediment quality data collected annually for Fremantle Ports' MQMP that is completed in accordance with EPA (2005) standard manual of operating procedures (refer to Section 2.3.1). Where good quality data are available to support the site classification, the number of sampling locations may be halved (CA 2009). Therefore, conservatively 12 sampling locations for the DWC and eight sampling locations for the SPCs are proposed to characterise the physical and chemical properties of the dredge material (Table 3.1 and Figure 3.1).

At the Port Beach nourishment area, sediments will be sampled from three locations with reference to the Contaminated Sites Guidelines (DER 2014) to asses potential risks of placement of dredged material to a public beach (Table 3.1 and Figure 3.1).

Sediment sampling sites were positioned within the relevant areas using geographic information system software (Figure 3.1). For the proposed dredge areas, sediment sampling sites were placed randomly within identified areas of sediment accretion above channel design, where applicable[2], to adequately characterise the sediments available for nourishment. The coordinates of the proposed sampling sites and target sampling depths are listed in Table 3.1.

[2] Sediment sampling sites were randomly positioned within the proposed 'Capital Bend' dredge area that is not within the limits of the existing DWC design.

Table 3.1 Proposed sediment sampling site coordinates and target sampling depths from within the proposed Deepwater Channel and Success and Parmelia Channels dredge areas and the Port Beach nourishment area

Area[1]	Site[1]	Coordinates (UTM50 GDA94)[1,2]		Target sampling depth (m)[3]
		Easting	Northing	
Deepwater Channel (dredge area)	DWC1	375688	6461693	1.0
	DWC2	376000	6461527	1.0
	DWC3	376184	6461377	1.0
	DWC4	376272	6461076	1.0
	DWC5	376242	6460888	1.0
	DWC6	375712	6461842	1.0
	DWC7	375844	6462030	1.0
	DWC8	376108	6461881	1.0
	DWC9	376604	6461551	1.0
	DWC10	376571	6460577	1.0
	DWC11	376433	6458854	1.0
	DWC12	376721	6458896	1.0
Success and Parmelia Channels (dredge area)	SPC1	376227	6451740	1.0
	SPC2	376114	6451562	1.0
	SPC3	376490	6449708	1.0
	SPC4	376623	6449078	1.0
	SPC5	376866	6447875	1.0
	SPC6	377457	6445725	1.0
	SPC7	377512	6444719	1.0
	SPC8	377576	6444421	1.0
Port Beach (nourishment area)	PB1	381548	6455142	0.2
	PB2	381422	6454779	0.2
	PB3	381227	6454426	0.2

Notes:
1. Refer to Figure 3.1 and Figure 3.2 for sediment sampling site locations.
2. Site locations may be subject to change depending on safe accessibility at the time of sample collection.
3. Target sampling depths as recommended by the NAGD (CA 2009) to adequately characterise material to be dredged (applies to the dredge areas only).
4. Additional samples may be collected within the DWC and SPCs following collection of initial samples depending on timing.
5. 'UTM' = Universal Transverse Mercator; GDA = Geocentric Datum of Australia.

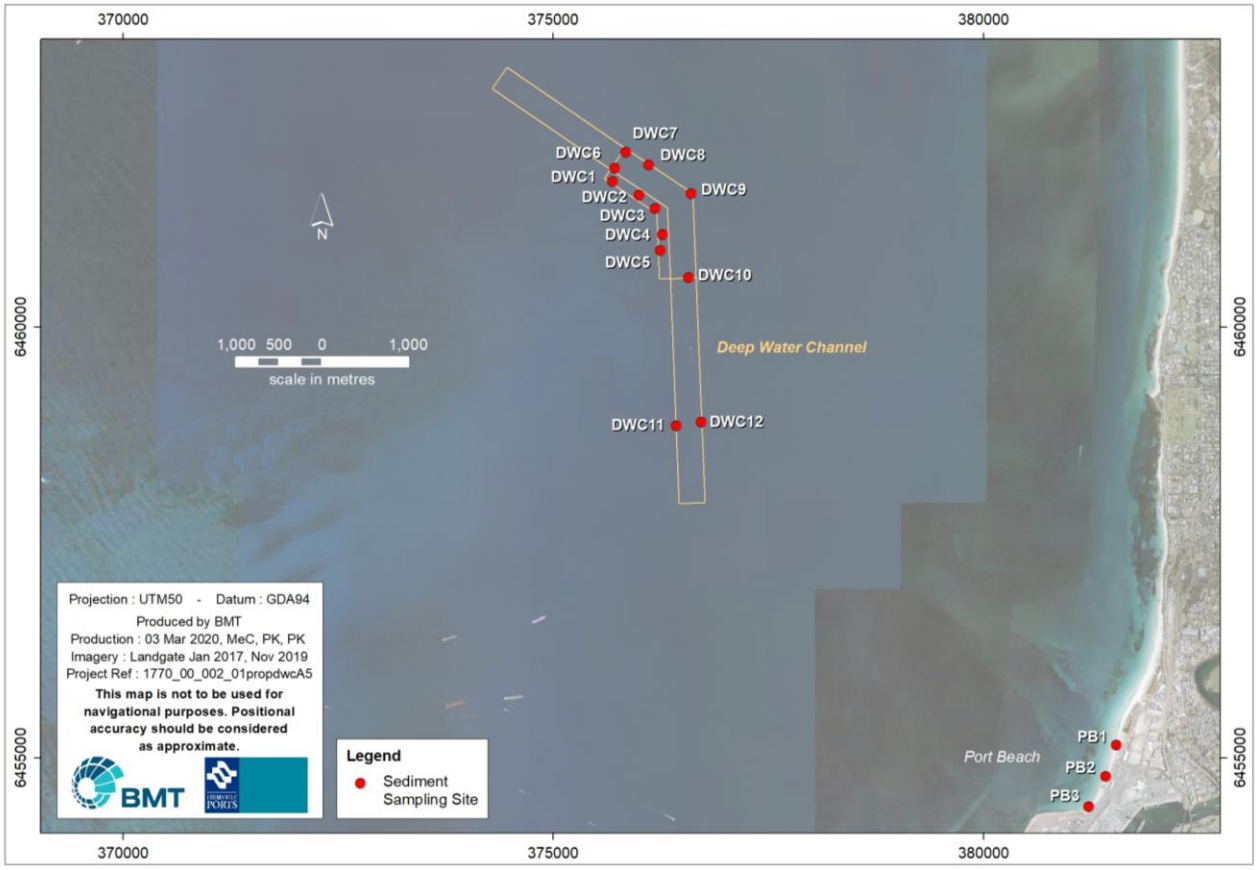

Figure 3.1 Sediment sampling sites within the proposed Deepwater Channel dredge area and Port Beach nourishment area

Figure 3.2 Sediment sampling sites within the proposed Success and Parmelia Channels dredge area

3.2.2 QA/QC samples

The NAGD (CA 2009) recommends two types of QA/QC samples that will be included in the field sediment sampling program:

- Triplicate: at 10% of sampling sites, three separate samples will be collected from the same site to determine the variability of the physical and chemical sediment characteristics at the scale of sampling.
- Split: at 5% of sampling sites, the sample shall be thoroughly mixed then split into three sub samples to assess laboratory variation, with two of the three samples analysed at the primary laboratory (intra-laboratory splits) and the third sample analysed by a reference laboratory (interlaboratory split).

For the proposed sampling design, one triplicate sample and one split sample will be collected from each channel. This will result in eight additional samples for analyses (refer to Section 3.2.3).

3.2.3 Samples to be analysed

In total, 51 samples will be collected from the relevant areas including QA/QC samples (Table 3.2). All samples collected will be sent to the relevant laboratories for the appropriate physical and chemical analyses, as outlined in Section 4.

Table 3.2 Proposed number of samples to be collected from within the proposed Deepwater Channel and Success and Parmelia Channels dredge areas and the Port Beach nourishment area for analysis

Area[1]		Number of samples	Number of additional QA/QA samples[2]	Total
Deepwater Channel (dredge area)	Surface (0–0.5 m)	12	4	16
	Depth (0.5–1 m)	12	–	12
Success and Parmelia Channels (dredge area)	Surface (0–0.5 m)	8	4	12
	Depth (0.5–1 m)	8	–	8
Port Beach (nourishment area)		3	–	3
Total		**43**	**8**	**51**

Notes:
1. Refer to Figure 3.1, Figure 3.1 and Table 3.1 for explanation of sampling areas and sites.
2. QAQC analyses will be undertaken in surface samples only (0–0.5 m)
3. 'QA/QC' = quality assurance and quality control.

3.3 Field operations and procedures

3.3.1 Health and safety

Prior to the commencement of sampling, a Field Operations Plan and a Job Hazard Analysis (JHA) shall be completed to identify and address the workplace health and safety associated with the survey. All field personnel shall be required to review and sign the Field Operations Plan and JHA. In the event of delays during the field survey, sampling will recommence as soon as safely possible.

3.3.2 Sediment collection and processing

A hand-held geographical positioning system (GPS) will be used to locate the proposed sediment sampling sites (Figure 3.1). Sites may be manually re-positioned if required (some foreseen reasons include restricted site access due to safety issues, moored vessels, if target sampling depths cannot be reached, or if the there is only wrack material at the site etc.). The 'actual' location of each site will be recorded on the GPS (accuracy ±5 m) to confirm the sampled location.

Sediments from within the proposed dredging areas will be collected using a Polyvinyl chloride (PVC) corer (50 mm inside diameter in accordance with the NAGD [CA 2009]). The field personnel will obtain the sediment core sample by using a stainless-steel slide hammer to drive the PVC corer into the sediment to the target sampling depth (Table 3.1) or until refusal. The top of the PVC corer will be filled with seawater and a bung inserted to create a vacuum to retain the sample before

extraction from the seabed. The field personnel will then insert a second bung into the bottom of the corer when the opening is still just below the surface of the seabed to avoid loss of sediment during extraction. One core will be collected from each sampling site with exception to the triplicate QA/QC sampling sites (refer to Section 3.2.2). At the Port Beach nourishment area, surface sediment scrapes to a maximum depth of 20 cm will be collected.

Following collection, sediment samples will be extracted into a glass mixing bowl and photographed. Before sample processing, a field sediment inventory and description log will be completed. For volatile substances (hydrocarbons), sub-samples will be extracted (using a Teflon spoon) from the sample and placed into the appropriate container(s) immediately (Section 3.3.5). The remaining sample will be homogenised (using a Teflon or while plastic spoon) until the colour and texture is uniform. Subsamples for the remaining analytes requiring laboratory analysis (refer to Section 4.1) will be extracted (using a Teflon or white plastic spoon) from the homogenised sample and placed into the appropriate container(s) (Section 3.3.5). It is noted that additional sample from each site will be collected and stored for; 1) assessment of the compatibility of channel sediment colour in comparison to the colour of sediments from the Port Beach nourishment area (colour to be assessed after sediments have dried), and 2) elutriate analysis, if required (refer to Section 4.2).

3.3.3 Cross contamination control

To avoid cross-contamination among sampling areas and sites, all sampling equipment will be washed with Decon 90 after each sampling site and rinsed with site water. Field personnel handling the samples will wear a pair of latex-free and powder-free gloves, changing these between sample collections at each site.

3.3.4 Seawater collection

Approximately 1 L of seawater per sediment sample will be collected to have available for elutriate analysis, if required (refer to Section 4.2). Seawater will be collected from away from potential contamination sources and any localised turbidity. The collected seawater will be stored appropriately further analyses, if required.

3.3.5 Sample storage, transport and laboratory receipt

The required sample volumes and containers for each analyte will be provided by the relevant laboratories along with storage methods and the appropriate holding times. In the field, samples will be stored in eskies on ice until they are able to be moved into a refrigerator and/or freezer (as appropriate) at the end of the sampling day. When transporting the samples to the relevant laboratories, samples will be consigned with a Chain of Custody (CoC) form to laboratories to allow sample tracking and ensure the correct sample analyses, storage, and holding times. In the event that any sample holding times are exceeded, BMT will discuss sample integrity with the relevant laboratory and derive a contingency plan for sample analysis. The client will be advised of any such contingencies.

4 Analysis Plan

4.1 Laboratory analysis and QA/QC

In recognition of the low risk of contamination (Section 2.3), a risk-based approach has been adopted when selecting analytes for analyses of sediment samples. The sediment samples from the relevant areas will be tested for a range of different analytes based on the identified potential contaminants of concern requiring assessment from a review of historical data and relevant cause affect pathways of potential contamination (Section 2.3). A summary of the number of samples from the relevant areas that will be tested for each analyte is provided in Table 4.1. The complete analyte analysis is presented in Table 4.2.

For the proposed dredge areas, all sediment samples will be analysed for particle size distributions (PSD) and total organic carbon (TOC) while half of the surface samples and none of the bottom samples will be analysed for cation exchange capacity (CEC) and pH (Table 4.2)[3]. All surface samples and half of the depth samples will be analysed for concentrations of metals (Table 4.2). Half of the surface and depth samples will be analysed for concentrations of hydrocarbons (Table 4.2). Remaining samples will be stored for additional analysis in the event that contaminant concentrations exceed the relevant sediment quality guidelines (refer to Section 4.2). Sediment samples from the Port Beach nourishment area will only be analysed for PSD[4] and a selected range of metal analytes to determine site-specific Ecological Investigation Levels (EILs) as per NEPC (2013) (refer to Section 4.3 and Appendix A).

Sediment sample analyses will be undertaken by National Association Testing Authorities (NATA) accredited laboratories with completion of test blanks, spikes and standards and complete laboratory duplicates. Detailed laboratory method statements used for analyses of sediment samples and laboratory QA/QC procedures are available on request.

Table 4.1 Summary of the number of samples from within the proposed Deepwater Channel and Success and Parmelia Channels dredge areas and the Port Beach nourishment area to be analysed for each analyte

Analyte[1]	Deepwater Channel (dredge area)[2]		Success and Parmelia Channels (dredge area)[2]		Port Beach (nourishment area)[2]
	Surface (0–0.5 m)	Depth (0.5–1 m)	Surface (0–0.5 m)	Depth (0.5–1 m)	
PSD	14	12	10	8	3
TOC	16	12	12	8	–
pH	6	–	4	–	–
CEC	6	–	4	–	–
Metals[4]	16	6	12	4	3
Hydrocarbons[5]	10	6	4	4	–

Notes:
1. Refer to Section 2.3 for analyte selection rational.
2. Refer to Figure 3.1, Figure 3.2 and Table 3.1 for explanation of sampling areas and sites.
3. 'PSD' = particle size distribution; 'TOC' = total organic carbon; 'CEC' = cation exchange capacity.
4. Metals = arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.
5. Hydrocarbons = polycyclic aromatic hydrocarbons, total recoverable hydrocarbons/total petroleum hydrocarbons and benzene, toluene, ethylbenzene and xylene.
6. QAQC sample analyses for hydrocarbons will only be undertaken on DWC sediments and split samples will not be analysed for PSD.
7. The information presented in this summary table is based on the selected analyte analysis plan presented in Table 4.2.
8. The information presented in this summary table includes QA/QC samples for surface samples only (0–0.5 m; refer to Section 3.2.2).

[3] PSD, TOC, CEC and pH provide a measure of contaminant mobility within the sediment and to inform calculation of site-specific Ecological Investigation Levels (refer to Section 4.3 and Appendix A). PSD will also be used to calculate particle settling times to provide an indication of potential turbidity generated from dredging and disposal activities (refer to Section 4.3).
[4] PSD data from the nourishment area will aid the assessment of the compatibility of the disposal area to receive dredged material and the compatibility/movement of material following disposal (refer to Section 4.3).

Table 4.2 Selected analyte analysis plan for sediment samples collected from within the proposed Deepwater Channel and Success and Parmelia Channels dredge areas and the Port Beach nourishment area

Area[2]	Sample[2]	PSD[1,7,9]	TOC[1,7]	pH[1,7]	CEC[1,7]	Metals[1,4,5]	Hydrocarbons[1,6]
Deepwater Channel (dredge area)	DWC1_0–0.5	✓	✓	✓	✓	✓	
	DWC1_0.5–1	✓	✓			✓	
	DWC2_0–0.5*	✓	✓			✓	✓
	DWC2_0.5–1	✓	✓				✓
	DWC3_0–0.5	✓	✓	✓	✓	✓	
	DWC3_0.5–1	✓	✓			✓	
	DWC4_0–0.5	✓	✓			✓	✓
	DWC4_0.5–1	✓	✓				✓
	DWC5_0–0.5	✓	✓	✓	✓	✓	
	DWC5_0.5–1	✓	✓			✓	
	DWC6_0–0.5	✓	✓			✓	✓
	DWC6_0.5–1	✓	✓				✓
	DWC7_0–0.5	✓	✓	✓	✓	✓	
	DWC7_0.5–1	✓	✓			✓	
	DWC8_0–0.5	✓	✓			✓	✓
	DWC8_0.5–1	✓	✓				✓
	DWC9_0–0.5	✓	✓	✓	✓	✓	
	DWC9_0.5–1	✓	✓			✓	
	DWC10_0–0.5**	✓	✓			✓	✓
	DWC10_0.5–1	✓	✓				✓
	DWC11_0–0.5	✓	✓	✓	✓	✓	
	DWC11_0.5–1	✓	✓			✓	
	DWC12_0–0.5	✓	✓			✓	✓
	DWC12_0.5–1	✓	✓				✓
Success and Parmelia Channels (dredge area)	SPC1_0–0.5	✓	✓	✓	✓	✓	✓
	SPC1_0.5–1	✓	✓			✓	✓
	SPC2_0–0.5*	✓	✓			✓	
	SPC2_0.5–1	✓	✓				
	SPC3_0–0.5	✓	✓	✓	✓	✓	✓
	SPC3_0.5–1	✓	✓			✓	✓
	SPC4_0–0.5	✓	✓			✓	
	SPC4_0.5–1	✓	✓				
	SPC5_0–0.5	✓	✓	✓	✓	✓	✓
	SPC5_0.5–1	✓	✓			✓	✓
	SPC6_0–0.5**	✓	✓			✓	
	SPC6_0.5–1	✓	✓				
	SPC7_0–0.5	✓	✓	✓	✓	✓	✓
	SPC7_0.5–1	✓	✓			✓	✓
	SPC8_0–0.5	✓	✓			✓	
	SPC8_0.5–1	✓	✓				
Port Beach (nourishment area)	PB1	✓				✓	
	PB2	✓				✓	
	PB3	✓				✓	

Notes:
1. Refer to Section 2.3 for analyte selection rational.
2. Refer to Figure 3.1, Figure 3.1 and Table 3.1 for explanation of sampling areas and sites.
3. 'PSD' = particle size distribution; 'TOC' = total organic carbon; 'CEC' = cation exchange capacity; '*' = triplicate QA/QC sample (refer to Section 3.2.2); '**' = split QA/QC sample (refer to Section 3.2.2).
4. Metals = arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

5. Only four metal analytes (chromium, copper, nickel and zinc) are required for sediment samples from Port Beach disposal area to determine site-specific Ecological Investigation Levels as per NEPC (2013) (refer to Section 4.3 and Appendix A).
6. Hydrocarbons = polycyclic aromatic hydrocarbons, total recoverable hydrocarbons/total petroleum hydrocarbons and benzene, toluene, ethylbenzene and xylene.
7. Analytes provide a measure of contaminant mobility within the sediment and to inform calculation of site-specific Ecological Investigation Levels (refer to Section 4.3 and Appendix A).
8. The information presented in this analyte analysis plan table considers QA/QC samples (refer to Section 3.2.2).
9. Only one of the split QA/QC samples will be analysed for PSD.

4.2 Staged approach to sample analysis

In the event that contaminant concentrations exceed the relevant sediment quality guidelines (refer to Section 2.2), bioavailable and elutriate testing will be completed for the relevant sample(s) (Figure 4.1). Additional held depth layers and samples will also be analysed for concentrations of the contaminant(s) exceeding the relevant sediment quality guidelines, as required (Figure 4.1). In accordance with the NAGD (CA 2009), if elutriate or bioavailable contaminant concentrations for the relevant sample(s) exceed the appropriate water quality guideline (refer to Section 2.2), further bioavailability and/or ecotoxicity testing may need to be considered. The client will be advised if bioavailable and elutriate testing is required and will not be undertaken until approval is granted.

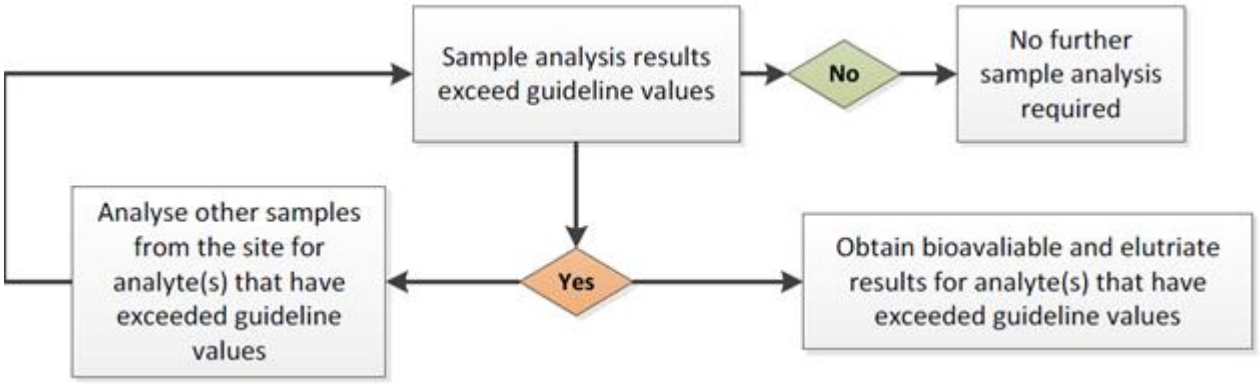

Figure 4.1 Staged approach to sample analysis

4.3 Data analysis and QA/QC

PSD data from samples in the proposed dredging areas and nourishment area will be used to calculate particle settling times to provide an indication of potential turbidity generated from dredging and disposal activities. Information on the method used to calculate particle settling times is provided in Appendix B. The PSD data from the nourishment area will aid the assessment of the compatibility of the disposal area to receive dredged material and the compatibility/movement of material following disposal. Sediments from the dredging areas will be assessed against the NAGD Screening Levels (CA 2009) and the Contaminated Sites Guidelines EILs, Ecological Screening Levels (ESLs) and Health Investigation Levels (HILs; NEPC 2013, DER 2014). For selected samples, the concentrations of organic analytes (hydrocarbons) will be normalised to 1% TOC to provide a measure of their bioavailability and to allow assessment against the NAGD Screening Levels (CA 2009). Where appropriate, test statistics will be calculated for the concentrations of each analyte for comparison against guidelines values.

Further detail on data analysis methods and the screening thresholds for each analyte is provided in Appendix B. If the analyte concentrations meet the relevant guidelines, sediments will be considered suitable for dredging and disposal. Suitability to utilise sediments sourced via dredging of the DWC and SPCs for nourishment of Port Beach will also be dependent on physical characteristics (i.e. similar colour and physical composition).

The analyte concentrations in the QA/QC triplicate and split samples will be analysed using the methods specified by the NAGD (CA 2009) to determine the relevant percent differences (splits) and relative standard deviations (triplicates). Refer to Appendix B for further details.

5 References

ANZG (2018) Australian & New Zealand Guidelines for Fresh and Marine Water Quality. Available from < http://www.waterquality.gov.au/anz-guidelines> [Accessed 24 February 2020]

BMT (2019) Summary of environmental guideline exceedances from 2019 Fremantle Ports Marine Quality Monitoring Program. Prepared for Fremantle Ports by BMT, Technical Note No. Tn-1762_00-1, Perth, Western Australia, August 2019

BMT (2020) Summary of environmental guideline exceedances from 2015-2018 Fremantle Ports Marine Quality Monitoring Programs. Prepared for Fremantle Ports by BMT, Technical Note No. Tn-0634_10-1, Perth, Western Australia, February 2020

CA (2009) National Assessment Guidelines for Dredging, Prepared by Commonwealth of Australia, Canberra, ACTDER (2014) Assessment and management of contaminated sites.

DER (2014) Assessment and management of contaminated sites. Contaminated sites guidelines. Department of Environment Regulation, Perth, Western Australia, December 2014

NEPC (2013) National Environment Protection (Assessment of Site Contamination) Measure Amendment 2013 (No. 1), National Environment Protection Council, Schedule 2013

MP Rogers and Associates (2019) Port Beach Coastal Adaption Options. Report R1189 Rev 1, prepared for City of Fremantle, Fremantle, Western Australia, September 2019

Appendix A Relevant legislation and guidelines

Legislation and Guidelines

National Assessment Guidelines for Dredging

The National Assessment Guidelines for Dredging (NAGD; CA 2009) in support of the EP Sea Dumping Act provide a framework for environmental impact assessment and permitting of the ocean disposal of dredged material and include information on:

- evaluating alternatives to ocean disposal
- assessing sediment quality
- assessing dredging and disposal sites
- assessing potential impacts on the marine environment and other users
- determining management and monitoring requirements.

Although ocean disposal is not proposed for the Project, the guidelines provide a useful reference for the assessment and management of dredging operations and have been used to inform this sediment Sampling and Analysis Plan (SAP).

Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Contaminants in sediments that exceed NAGD Screening Levels require elutriate testing to assess potential impacts to marine water quality from release contaminants during dredging and disposal (CA 2009). The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) are applied to assess water quality impacts from physical/chemical stressors and/or toxicants.

Default guidelines values (DVG) for physical and chemical stressors are available for marine geographic regions from regional reference site data in surface and bottom waters. The DGV for toxicants are derived for differing levels of species protection and the associated level of protection that is applied depends on the current or desired condition of the ecosystem that is assigned. For the Project area, the 95% protection level for a 'slightly-moderately' disturbed ecosystem will be applied.

Contaminated Sites Act 2003 (WA) and Contaminated Sites Guidelines

The disposal of potentially contaminated dredge sediments to land may create or disturb a contaminated site. The identification, management and remediation of contaminated sites is governed by the WA *Contaminated Sites Act 2003 (CS Act*). The Contaminated Sites Guidelines (DER 2014) provide guidance on the assessment and management of contaminated sites under the CS Act. While land disposal of dredged material is not specifically considered in the guidelines, there is a risk to human health and the environmental from the disposal of contaminated dredged material to land that should be assessed.

Assessment involves a preliminary disposal site investigation and the comparison of dredged sediment contamination levels against the National Environment Protection (Assessment of Site Contamination) Measure guidelines (as referenced in the Contaminated Sites Guidelines (DER 2014)) to assess the ecological and human health risks associated with material once disposed to land (NEPC 2013).

References

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available from www.waterquality.gov.au/anz-guidelines [Accessed 24 February 2020]

CA (2009) National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra, Australian Capital Territory

DER (2014) Assessment and management of contaminated sites. Contaminated Sites Guidelines. Department of Environment Regulation, Western Australia, December 2014

NEPC (2013) National Environment Protection (Assessment of Site Contamination) Measure Amendment 2013 (No. 1), National Environment Protection Council, Schedule 2013

Appendix B Data analysis methods

Data Analysis Methods

Particle settling times

The particle settling velocities will be used to calculate the time for 50% and 90% of the particles to settle out of 1 m of water for each sample using. Settling velocity will not be not calculated for sediment samples >45% silt and clay content as Stokes' Law is not applicable for material with high fines content.

Normalisation of organics

Total organic carbon (TOC) is the main binding constituent for organic substances in marine sediments. The NAGD (CA 2009) requires organics (total petroleum hydrocarbons and polycyclic aromatic hydrocarbons) to be normalised to 1% TOC for appropriate comparison to the NAGD Screening Levels (CA 2009). The normalised results allow for comparison of different sediment samples and provide an indication of the bioavailability of organic analytes. A TOC greater than 1% increases the binding capacity of organics to become less biologically available, therefore normalisation will reduce the measured value proportionally (the reverse also applies). Normalisation is appropriate over a TOC range of 0.2–10%. For TOC <0.2% or TOC >10%, the maximum and minimum values of 0.2 and 10% TOC will be used for normalisation, respectively. Where the organic data are below the laboratory limit of reporting (LoR), normalisation will not be completed.

Calculation of 95% upper confidence limit (UCL)

Contaminant concentrations in sediment samples will be compared to the NAGD Screening Levels (CA 2009) that requires calculation of the 95% upper confidence limit (UCL) of the mean (CA 2009). The data will first be tested for normality using the software ProUCL 4.0 (USEPA 2007). The software determines the appropriate method for calculating the 95% UCL depending on the distribution of the data and dataset size, including the proportion of values below the LoR (which introduces statistical complexities into analyses). These methods may include parametric (such as Student's t-UCL) or nonparametric (such as bootstrap) methods. Where there are not enough samples to complete the calculations, the individual sample concentrations will be compared to the NAGD Screening Levels (CA 2009).

Ecological investigation levels, ecological screening levels and health investigation levels

Contaminant concentrations in sediment samples will be assessed against Ecological Investigation Levels (EILs), Ecological Screening Levels (ESLs), and Health Investigation Levels (HILs) from the NEPC (2013) guidelines as referenced in DER (2014) contaminated sites guidelines. Calculation of EILs (for chromium III, copper, nickel, lead and zinc) require the addition of ambient background analyte concentrations (from reference site data) to define contaminant limits for ecological investigation. These calculations also factor the physical sediment properties affecting mobility of metals (i.e. TOC, cation exchange capacity [CEC], pH and % clay) as per DER (2014) and NEPC (2013).

The maximum and the 95% UCL of the arithmetic mean of sediment contaminant concentrations will be compared to EILs for areas of urban residential/public open space, ESLs, and HILs for category "C" (NEPC 2013). For assessment against the relevant EILs, ESLs and HILs, the following criteria are specified in NEPC (2013):

- standard deviation of the sample data must be less than 50% of the relevant value
- no single value must exceed 250% of the relevant value.

Australian & New Zealand Guidelines for Fresh and Marine Water Quality

If required, mean elutriate contaminant concentrations will be compared to ANZG (2018) marine water quality guidelines as per NAGD (CA 2009). The species level of protection applied to contaminants reflects the level of disturbance within the surrounding marine environment. For the Project area, the 95% protection level for a 'slightly-moderately' disturbed ecosystem will be applied.

Analysis of analyte concentrations below the limit of reporting

Generally, half the laboratory LoR value will be used as a substitute for data below the LoR in accordance with the NAGD (CA 2009). A large proportion of data below the LoR has the capacity to bias subsequent analyses leading to underestimation of contamination. USEPA (2007) does not consider a 95% UCL of the mean calculated based upon few detected values to provide reliable estimates. Therefore, where the data contain values below the LoR, the following protocol will be applied (based on ANZG 2018):

- Where >25% of concentrations are below the LoR, descriptive statistics (means and percentiles) or inferential analysis (including the calculation of confidence limits) will not be calculated. Instead, individual sample results will be compared to the guideline values and discussed accordingly.
- Where ≤25% but >0% of concentrations are below the LoR, confidence limits will be calculated via two methods; once using the normalised estimate based on half the LoR as the replacement value and once using zero as a replacement value. This information will be used to inform the interpretation of results, in particular, whether the choice of replacement value affected the outcome of the analysis.

Guidelines and Screening Thresholds

Proposed analytes for all sediment samples and the relevant guidelines for assessment are provided below.

Analyte	Units	LoR[1]	NAGD Screening Level[2]	ANZG[3]	EIL[4,5]	ESL	HIL[6]
Metals							
Arsenic	mg/kg	0.5	20	n/a	50	n/a	300
Cadmium	mg/kg	0.1	1.5	n/a	n/a	n/a	90
Chromium	mg/kg	0.2	80	n/a	TBC	n/a	n/a
Copper	mg/kg	0.5	65	n/a	TBC	n/a	17000
Lead	mg/kg	0.5	50	n/a	270	n/a	600
Mercury	mg/kg	0.1	0.15	n/a	n/a	n/a	80
Nickel	mg/kg	0.5	21	n/a	TBC	n/a	1200
Zinc	mg/kg	0.5	200	n/a	TBC	n/a	n/a
Elutriate metals							
Arsenic	µg/L	1	n/a	n/a	n/a	n/a	n/a
Cadmium	µg/L	0.1	n/a	5.5	n/a	n/a	n/a
Chromium	µg/L	1	n/a	n/a	n/a	n/a	n/a
Copper	µg/L	1	n/a	1.3	n/a	n/a	n/a
Lead	µg/L	0.2	n/a	4.4	n/a	n/a	n/a
Mercury	µg/L	0.1	n/a	0.4	n/a	n/a	n/a
Nickel	µg/L	1	n/a	70	n/a	n/a	n/a
Zinc	µg/L	1	n/a	15	n/a	n/a	n/a
PAHs							
Benzo[a]pyrene	mg/kg	0.1	n/a	n/a	n/a	0.7	n/a
Naphthalene	mg/kg	0.1	n/a	n/a	170	n/a	n/a
Total PAHs (18 PAHs)	mg/kg	0.1 (individual PAHs)	10	n/a	n/a	n/a	300
Total PAHs (16 PAHs)	mg/kg	0.1 (individual PAHs)	n/a	n/a	n/a	n/a	300
Carcinogenic PAHs	mg/kg	0.1 (individual PAHs)	n/a	n/a	n/a	n/a	3
TRHs[9]							
C_6–C_{10}	mg/kg	25	n/a	n/a	n/a	n/a	n/a
C_6–C_{10} (less BTEX, coarse/fine)	mg/kg	25	n/a	n/a	n/a	180	n/a
>C_{10}–C_{16}	mg/kg	50	n/a	n/a	n/a	n/a	n/a
>C_{10}–C_{16} (less naphthalene)	mg/kg	50	n/a	n/a	n/a	120	n/a
>C_{16}–C_{34} (coarse)	mg/kg	100	n/a	n/a	n/a	300	n/a
>C_{16}–C_{34} (fine)	mg/kg	100	n/a	n/a	n/a	1300	n/a
>C_{34}–C_{40} (coarse)	mg/kg	100	n/a	n/a	n/a	2800	n/a
>C_{34}–C_{40} (fine)	mg/kg	100	n/a	n/a	n/a	5600	n/a
TPHs							
Total TPH (C_6-C_{40})	mg/kg	275	550	n/a	n/a	n/a	n/a
BTEX[9]							
Benzene (coarse)	mg/kg	0.5	n/a	n/a	n/a	50	n/a
Benzene (fine)	mg/kg	0.5	n/a	n/a	n/a	65	n/a
Toluene (coarse)	mg/kg	0.5	n/a	n/a	n/a	85	n/a
Toluene (fine)	mg/kg	0.5	n/a	n/a	n/a	105	n/a
Ethylbenzene (coarse)	mg/kg	0.5	n/a	n/a	n/a	7	n/a
Ethylbenzene (fine)	mg/kg	0.5	n/a	n/a	n/a	125	n/a
Xylene (coarse)	mg/kg	1.0	n/a	n/a	n/a	105	n/a
Xylene (fine)	mg/kg	1.0	n/a	n/a	n/a	45	n/a

Notes:

1. Laboratory limits of reporting are based on those achieved by the primary laboratory (ChemCentre).
2. National Assessment Guidelines for Dredging Screening Levels (CA 2009).
3. ANZG (2018) marine water quality guidelines. Guidelines are default guidelines for toxicants (elutriate metals) in marine waters: 95% species protection level for a ‘slightly-moderately’ disturbed ecosystem is applicable to the Project area.
4. Ecological investigation levels and ecological screening levels from NEPC (2013) for "urban residential/public open space".
5. 'TBC' = EIL guideline value to be calculated based on added concentrations (i.e. the EIL = added contaminant limit + ambient background concentration) and the specific sediment characteristics that determine the mobility of the metal analytes (i.e. TOC, cation exchange capacity, pH and % clay) as per DER (2014) and NEPC (2013).
6. Health investigation levels for category "C" from NEPC (2013).
7. 'LoR' = laboratory limit of reporting, 'NAGD' = National Assessment Guidelines for Dredging, 'EIL' = ecological investigation level, 'ESL' = ecological screening level, 'HIL' = health investigation level; 'PAHs' = polycyclic aromatic hydrocarbons; 'TRHs' = total recoverable hydrocarbons; 'TPHs' = total petroleum hydrocarbons; 'BTEX' = benzene, toluene, ethylbenzene and xylene.
9. Guideline values have been derived for coarse- or fine-grained soils (the appropriate guideline value will be determined from the sample particle size distributions).

Data Quality Assurance/Quality Control (QA/QC)

The precision of the sediment analyses will be determined by quantifying the differences between the concentrations of analytes in the QA/QC samples, using the methods outlined in the NAGD (CA 2009). The relative percent difference (RPD) will be calculated for the analyte concentrations in the split samples (both inter-laboratory and intra-laboratory splits) and the relative standard deviation (RSD) will be calculated for analyte concentrations in the triplicate samples.

The RPD will be calculated as follows:

$$RPD\ (\%) = \frac{(difference\ between\ split\ samples\ x\ 100)}{(average\ of\ split\ samples)}$$

The acceptable RPD range of split samples depends upon the concentration levels detected relative to the LoR as follows (Australian Department of the Environment, pers. comm. 12 August 2014):

- 0–100% RPD when the average concentration is <5 times the LoR
- 0–75% RPD when the average concentration is 5 to 10 times the LoR
- 0–50% RPD when the average concentration is >10 times the LoR.

If the RPD for a measured analyte falls outside of these limits, the value of the measured analyte will be flagged as an estimate rather than a precise value (CA 2009).

The RSD will be calculated as follows:

$$RSD\ (\%) = \frac{(standard\ deviation\ of\ triplicate\ samples)x\ 100}{(average\ of\ triplicate\ samples)}$$

The triplicate samples should agree within an RSD of ±50%. RSDs greater than 50% may indicate that the sediments are heterogeneous or greatly differ in grain size (CA 2009). RPD and RSD will only be calculated if all QA/QC sample concentrations are above the LoR. If one or more of the analyte concentrations are below the LoR, the individual concentrations will be compared to assess the magnitude of the differences between them.

References

ANZG (2018) Australian & New Zealand Guidelines for Fresh and Marine Water Quality. Available from < http://www.waterquality.gov.au/anz-guidelines> [Accessed 24 February 2020]

CA (2009) National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra, Australian Capital Territory

DER (2014) Assessment and management of contaminated sites. Contaminated sites guidelines. Department of Environment Regulation, Western Australia, December 2014

NEPC (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1) National Environment Protection Council, 2013

USEPA (2007) ProUCL version 4.0. Available from <http://www.epa.gov/esd/tsc/ software.htm>. United States Environmental Protection Authority

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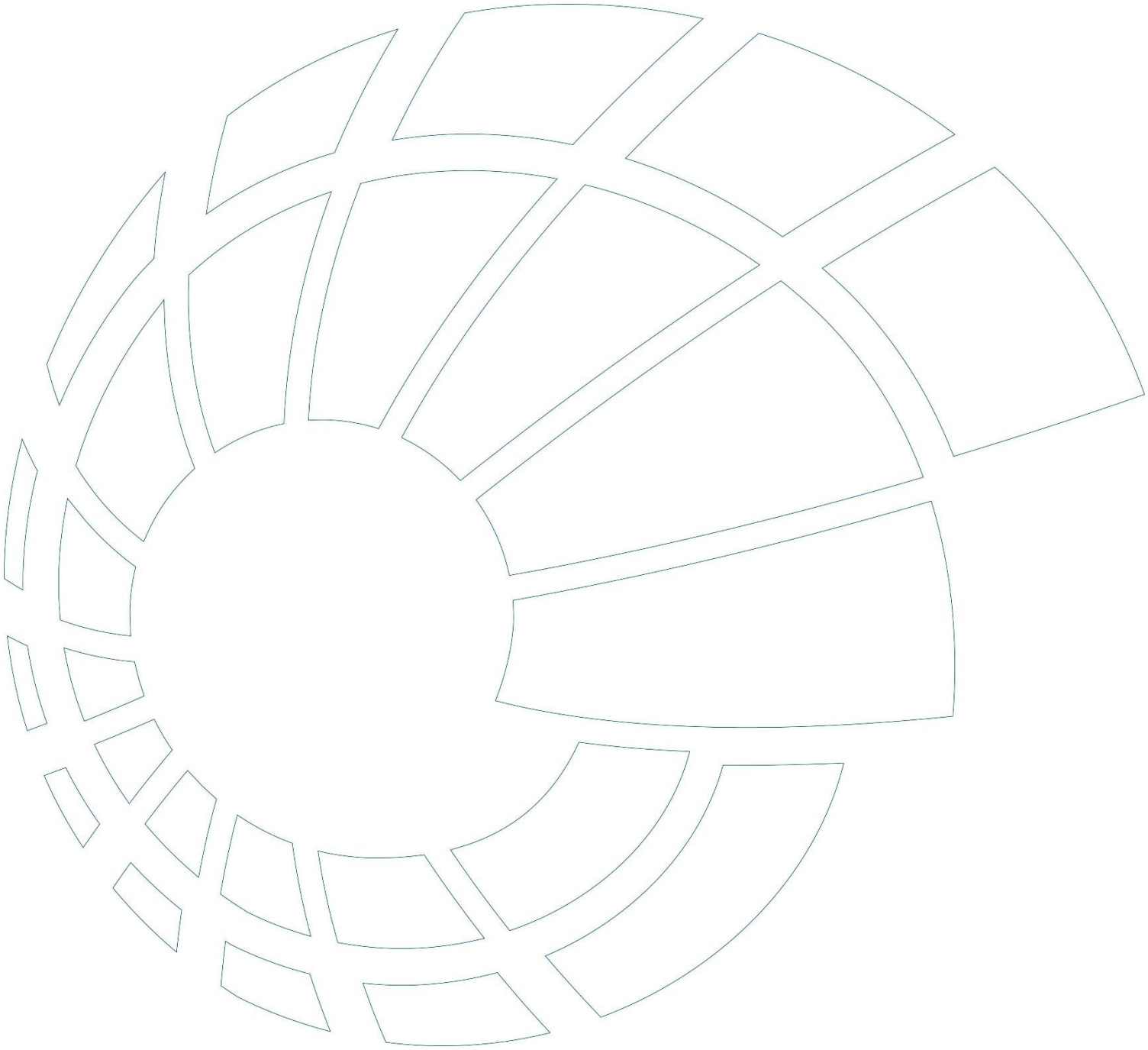

Appendix B Microanalysis Laboratory Reports

37 Kensington Street
East Perth
WA 6004

Client: BMT Western Australia Pty Ltd
Job number: 20_0936
Sample: Various
Client ID: Various
Date: 30/06/2020
Analysis: **ISO Brightness (R457), Yellowness (DIN6167) and CIE Colour (D65/10)**

Sample preparation
The samples were ground with a mortar and pestle until a fine powder. The sample was packed into the test holder using gentle hand pressure against a new glass slide to provide a flat, blemish free test surface.

Analysis
The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 23 °C at ambient humidity. The instrument was calibrated against a barium sulphate standard prior to analysis. Standard illuminant D65 was used.

Summary
The results were determined to be:

				CIE Colour Coordinates			RGB Colour Coordinates			
Client ID	**Lab ID**	**ISO Brightness**	**Yellowness**	**L**	**a**	**b**	**R**	**G**	**B**	**Colour**
PB1-3	20_0936_01	57.285	21.345	85.86	1.35	10.2	225	213	194	
SPC1-8	20_0936_02	51.25	8.74	78.89	-0.10	4.05	198	195	186	
DWC1-5	20_0936_03	64.95	6.79	86.195	-0.25	3.4	218	216	208	
DWC6-8	20_0936_04	54.47	9.495	86.01	0.30	4.3	219	215	205	

Analyst: Benjamin Rainer, Diploma(Laboratory Techniques)

Report: Benjamin Rainer, Diploma(Laboratory Techniques)

Approved: Ian Davies, B.Sc.(Chemistry)

37 Kensington Street
East Perth
WA 6004

Client: BMT Commercial Australia Pty Ltd
Job number: 20_1373
Lab ID: 20_1373_01 to 20_1373_06

Date received: 04/09/2020
Date analysed: 21/09/2020
Date reported: 21/09/2020

Client ID: Various (See table)
Analysis: **ISO Brightness (R457), Yellowness (DIN6167) and CIE Colour (D65/10)**
Revision no.: 0
Comments: None

Sample preparation

The samples were tested as received, packed into the test holder using gentle hand pressure against a new glass slide to provide a flat, blemish free test surface.

Analysis

The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 21°C at ambient humidity. The instrument was calibrated against a barium sulphate standard prior to analysis. Standard illuminant D65 was used.

Summary

The results were determined to be

				CIE Colour Coordinates			RGB Colour Coordinates			
Client ID	**Lab ID**	**ISO Brightness**	**Yellowness**	**L**	**a**	**b**	**R**	**G**	**B**	**Colour**
SPC1-8_L 3/09/2020	20_1373_01	59.89	4.98	83.01	-0.3	2.5	208	207	200	
SPC1-8_LA 3/09/2020	20_1373_02	60.54	3.94	83.11	-0.3	2.0	208	207	202	
DWC1-5_L 3/09/2020	20_1373_03	66.58	6.35	86.93	-0.2	3.3	220	218	210	
DWC1-5_LA 3/09/2020	20_1373_04	64.70	7.73	86.28	0.0	3.7	219	216	207	
DWC6-8_L 3/09/2020	20_1373_05	58.50	23.20	87.05	1.9	11.1	230	216	196	
DWC6-8_L 3/09/2020	20_1373_05 Q	58.92	22.43	87.10	1.7	10.7	230	217	197	
DWC6-8_LA 3/09/2020	20_1373_06	57.19	20.71	85.63	1.3	9.9	224	213	194	

Analyst: Harrison Pitts, B.Sc.(Archaeology)

Report: Harrison Pitts, B.Sc.(Archaeology)

Approved: Rick Hughes, B.Sc.(Hons)Physics, MAIP

37 Kensington Street
East Perth
WA 6004

Client: BMT Commercial Australia Pty Ltd
Job number: 20_1793
Lab ID: Various – see table
Client ID: Various – see table
Analysis: ISO Brightness (R457), Yellowness (DIN6167) and CIE Colour (D65/10)
Revision no.: 0
Comments: None

Date received: 5/11/2020
Date analysed: 10/11/2020
Date reported: 19/11/2020

Sample preparation
The sample was tested as received. The sample was packed into the test holder using gentle hand pressure against a new glass slide to provide a flat, blemish free test surface.

Analysis
The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 23.8 °C at ambient humidity. The instrument was calibrated against a barium sulphate standard prior to analysis. Standard illuminant D65 was used.

Summary

The results were determined to be:

				CIE Colour Coordinates			RGB Colour Coordinates			
Client ID	**Lab ID**	**ISO Brightness**	**Yellowness**	**L**	**a**	**b**	**R**	**G**	**B**	**Colour**
SPC1-8_L 3/09/2020	20_1793_01	59.165	8.385	83.365	0.45	3.85	212	207	199	
SPC1-8_LA 3/09/2020	20_1793_02	58.595	5.515	82.415	-0.4	2.75	207	205	198	
DWC1-5_L 3/09/2020	20_1793_03	67.51	6.935	87.47	0.3	3.25	223	219	211	
DWC1-5_LA 3/09/2020	20_1793_04	65.885	6.785	86.68	-0.2	3.4	219	217	209	
DWC6-8_L 3/09/2020	20_1793_05	64.455	16.97	88.72	0.8	8.25	231	222	206	
DWC6-8_LA 3/09/2020	20_1793_06	63.815	21.6	89.635	1.5	10.6	237	224	204	

Analyst: James Nicolas, B.A.

Report: James Nicolas, B.A.

Approved: Ian Davies, B.Sc.(Chemistry)

37 Kensington St
East Perth
WA 6004

Client: BMT Commercial Australia Pty Ltd
Client address: Level 8, 200 Creek St BRISBANE QLD 4000
Job Number: 21_0031
Lab ID: 21_0031_01 to _06
Client ID: *Various*

Date received: 6/01/2021
Date analysed 7/01/2021
Date reported: 13/01/2021
Revision: 0

Analysis: **ISO Brightness (R457), Yellowness (DIN6167) and CIE Colour (D65/10)**

Sample Preparation: The sample was tested as received. The sample was packed into the test holder using a back pressing kit to provide a flat, blemish free test surface.

Analysis: The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 21°C at ambient humidity. The instrument was calibrated against a barium sulphate standard prior to analysis. Standard illuminant D65 was used.

Results:

				CIE Colour Coordinates			RGB Colour Coordinates			
Client ID	Lab ID	ISO Brightness	Yellowness	L	a	b	R	G	B	Colour
SPC1-8_L	21_0031_01	61.01	4.12	83.40	-0.3	2.1	209	208	202	
SPC1-8_LA	21_0031_02	61.36	3.41	83.48	-0.4	1.7	209	208	203	
DWC1-5_L	21_0031_03	66.82	6.16	86.99	-0.3	3.1	220	218	210	
DWC1-5_LA	21_0031_04	65.45	6.37	86.32	-0.1	3.2	218	216	208	
DWC6-8_L	21_0031_05	59.11	23.63	87.55	1.9	11.4	232	218	196	
DWC6-8_LA	21_0031_06	59.00	23.60	87.46	1.9	11.4	232	217	196	

Analysts: Emily Narustrang, Benjamin Rainer, Diploma(Laboratory Techniques)

Reported: Benjamin Rainer, Diploma(Laboratory Techniques)

Approved: Ian Davies, B.Sc.(Chemistry)

37 Kensington St
East Perth
WA 6004

Client:	BMT Commercial Australia Pty Ltd	**Date received:**	22/02/2021
Client address:	Level 8, 200 Creek St BRISBANE QLD 4000	**Date analysed:**	26/02/2021
Job Number:	21_0292	**Date reported:**	04/03/2021
Lab ID:	21_0292_01 to 21_0292_06	**Revision no.:**	0
Client ID:	Various, See table below		

Analysis: **ISO Brightness (TAPPI T 525), Yellowness (DIN 6167) and CIE L*a*b* (DIN 6174) with sRGB calculation (ASTM E308-18 and IEC 61966-2-1)**

Comments: None.

Sample Preparation: The sample was tested as received. The sample was packed into the test holder using a back pressing kit to provide a flat, blemish free test surface.

Procedure: The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 23°C at ambient humidity.
The instrument was calibrated against a barium sulphate standard prior to analysis. Two pulsed xenon lamps were used to simulate the D65 standard illuminant and colour data computed by CIE 1964 Supplementary Standard Observer (10°). The sample was diffusely illuminated and viewed at an angle of 0°.

Results:

				CIE Colour Coordinates			sRGB Colour Coordinates			
Lab ID	**Client ID**	**ISO Brightness**	**Yellowness**	**L***	**a***	**b***	**R**	**G**	**B**	**Colour**
21_0292_01	SPC1-8_L 22/02/2021	61.25	2.90	83.24	-0.45	1.60	207	207	202	
21_0292_02	SPC1-8_LA 22/02/2021	63.69	2.73	84.48	-0.50	1.60	210	210	205	
21_0292_03	DWC1-5_L 22/02/2021	67.54	5.98	87.32	-0.20	3.00	220	218	211	
21_0292_04	DWC1-5_LA 22/02/2021	65.64	6.34	86.43	-0.15	3.15	218	216	208	
21_0292_05	DWC6-8_L 22/02/2021	63.18	20.45	88.97	1.25	10.00	233	221	202	
21_0292_06	DWC6-8_LA 22/02/2021	62.33	22.73	89.14	1.65	11.20	235	222	200	

Analyst:	Emily Narustrang
Reported:	Emily Barker, B.Sc.(Nanotechnology)(Hons)
Approved:	Ian Davies, B.Sc.(Chemistry)

37 Kensington St
East Perth
WA 6004

Client:	BMT Commercial Australia Pty Ltd	**Date received:**	29/04/2021
Client address:	Level 8, 200 Creek StBRISBANE QLD 4000	**Date analysed:**	30/04/2021
Job Number:	21_0704	**Date reported:**	06/05/2021
Lab ID:	21_0704_01 to 21_0704_06	**Revision no.:**	0
Client ID:	See table below		

Analysis: **ISO Brightness (TAPPI T 525), Yellowness (DIN 6167) and CIE L*a*b* (DIN 6174) with sRGB calculation (ASTM E308-18 and IEC 61966-2-1)**

Comments: None.

Sample Preparation: The sample was tested as received. The sample was packed into the test holder using a back pressing kit to provide a flat, blemish free test surface.

Procedure: The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at 22°C at ambient humidity.
The instrument was calibrated against a barium sulphate standard prior to analysis. Two pulsed xenon lamps were used to simulate the D65 standard illuminant and colour data computed by CIE 1964 Supplementary Standard Observer (10°). The sample was diffusely illuminated and viewed at an angle of 0°.

Results:

				CIE Colour Coordinates			sRGB Colour Coordinates			
Lab ID	**Client ID**	**ISO Brightness**	**Yellowness**	**L***	**a***	**b***	**R**	**G**	**B**	**Colour**
20_0704_01	SPC1-8_L	63.52	2.60	84.36	-0.30	1.30	210	210	206	
20_0704_02	SPC1-8_LA	62.44	2.41	83.72	-0.30	1.25	208	208	204	
20_0704_03	DWC1-5_L	70.06	4.78	88.23	-0.10	2.30	222	221	215	
20_0704_04	DWC1-5_LA	62.47	22.51	88.53	-0.10	2.30	223	221	215	
20_0704_05	DWC6-8_L	60.23	22.05	87.75	1.65	10.70	231	218	198	
20_0704_06	DWC6-8_LA	70.73	4.65	89.15	1.70	11.10	235	222	201	

Analyst: Bodean Welsh, Cert IV(Laboratory Techniques)
Reported: Benjamin Rainer, Diploma(Laboratory Technology)
Approved: Ian Davies, B.Sc.(Chemistry)

37 Kensington St
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WA 6004

Client:	BMT Commercial Australia Pty Ltd	**Date received:**	22/06/2021
Client address:	Level 8, 200 Creek St, BRISBANE QLD 4000	**Date analysed:**	28/06/2021
Job Number:	01 to 06	**Date reported:**	28/06/2022
Lab ID:	21_1021	**Revision no.:**	0
Client ID:	see below		

Analysis: **ISO Brightness (TAPPI T 525), Yellowness (DIN 6167) and CIE L*a*b* (DIN 6174) with sRGB calculation (ASTM E308-18 and IEC 61966-2-1)**

Comments:

Sample Preparation: The sample was tested using following preparation, the sample was ground in a mortar and pestle. Then sample was packed into the test holder using a back pressing kit to provide a flat, blemish free test surface.

Procedure: The sample was analysed using an Elrepho 2000 Datacolour instrument. The sample was analysed at °C at ambient humidity.
The instrument was calibrated against a barium sulphate standard prior to analysis. Two pulsed xenon lamps were used to simulate the D65 standard illuminant and colour data computed by CIE 1964 Supplementary Standard Observer (10°). The sample was diffusely illuminated and viewed at an angle of 0°.

Results:

				CIE Colour Coordinates			sRGB Colour Coordinates			
Lab ID	**Client ID**	**ISO Brightness**	**Yellowness**	**L***	**a***	**b***	**R**	**G**	**B**	**Colour**
21_1021_01	SPC1-8_L	55.42	3.43	80.12	-0.40	1.70	199	198	193	
21_1021_02	SPC1-8_LA	55.97	4.73	80.75	-0.35	2.35	201	200	194	
21_1021_03	DWC1-5_L	63.75	6.98	85.59	-0.05	3.40	216	213	205	
21_1021_04	DWC1-5_LA	64.80	6.79	86.11	-0.10	3.30	217	215	207	
21_1021_05	DWC6-8_L	54.88	24.76	85.31	2.15	11.55	226	210	189	
21_1021_06	DWC6-8_LA	53.59	25.49	84.73	2.10	12.00	224	209	187	

Analyst: Jess Kern, Cert IV (Laboratory Techniques)

Reported: Jess Kern, Cert IV (Laboratory Techniques)

Approved: Ian Davies, B.Sc.(Chemistry)

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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