Old Bar Beach Sediment Tracing
Final Report

Greater Taree City Council

4 May 2016

8A0406

Issue D (Final)

Royal HaskoningDHV
Enhancing Society Together

HASKONING AUSTRALIA
MARITIME & AVIATION

Level 14, 56 Berry Street
NORTH SYDNEY NSW 2060
+61 (0)2 8854 5000
www.royalhaskoningdhv.com

Document title	Old Bar Beach Sediment Tracing Final Report
Status	Issue D (Final)
Date	4 May 2016
Project name	Old Bar Sediment Tracing
Project number	8A0406
Client	Greater Taree City Council
Reference	8A0406/REP Final/PJL/Sydney

Issue History

Issue	Status	Drafted by	Checked by	Approved by	Date
A	Preliminary Draft for ETS/Council review	Patrick Lawless			29 July 2015
B	Draft	Patrick Lawless	Peter Horton		22 October 2015
C	Revised Draft (incorporating Sampling Exercise 5 results)	Patrick Lawless	Peter Horton		5 February 2016
D	Final	Patrick Lawless	Gary Blumberg	Gary Blumberg	4 May 2016

Haskoning Australia has prepared this document for Greater Taree City Council with financial assistance from the NSW Government through its Coast & Estuary Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

EXECUTIVE SUMMARY

Background

There is a long history of erosion/recession at Old Bar Beach, with some of the highest recession rates on the NSW coast. With significant threats to coastal properties at Old Bar, Greater Taree City Council (Council) and the NSW Office of Environment and Heritage (OEH) investigated structural options available to protect public and private assets. While a rock revetment could feasibly protect property, this could potentially have an impact on beach amenity. A possible solution to preserve beach amenity would be to undertake beach nourishment, however a better understanding of the complex sediment transport processes in the region was required to fully assess the feasibility of any beach nourishment strategy. Understanding the sediment transport pathways and loss mechanisms also assists in assessing the feasibility of other possible coastal management strategies.

Working with OEH and MidCoast Water, Council engaged Royal HaskoningDHV and ETS to undertake a sand tracing study aimed at improving the understanding of sediment transport processes at Old Bar Beach.

Tracer Deployment and Sampling

The first step involved the deployment of various coloured fluorescent sand tracer material at three locations on Old Bar Beach, namely:

- Taree-Old Bar Surf Life Saving Club (SLSC) – yellow tracer, deployed May 2014;
- Northern end of beach, south of Farquhar Inlet – red tracer, deployed May 2014;
- MidCoast Water Exfiltration Ponds – orange tracer, deployed July 2014.

Five (5) sampling exercises were subsequently undertaken between July 2014 and September 2015 within both the onshore and offshore environments. The sampling region extended from the southern side of Wallabi Point to the southern end of Manning Point Beach, including the Farquhar Inlet entrance area. The collected samples were subsequently analysed to assess the transport directions of the tracer material under the local coastal processes.

Prevailing Conditions and Morphology

Prevailing conditions during the study period (May 2014 to September 2015) were generally characterised by mild to average wave conditions except for a single large storm event in August 2014 which had an estimated average recurrence interval (ARI) of 4 years. Based on a comparison of beach surveys undertaken in November 2013 and March 2015, it is evident that slight accretion of dune profiles generally occurred between the orange tracer release site and Old Bar Public School, while slight recession generally occurred between the school and Taree-Old Bar SLSC. The entrance to Farquhar Inlet migrated southwards throughout the study period which is indicative of a closing entrance state.

Tracer Results and Inferred Sediment Transport Processes

The results from each sampling exercise demonstrated that the yellow, red and orange tracer material was transported widely during the study period, with sediment transport occurring both alongshore and offshore from the tracer release sites. Although deployed three months later, transport of the orange tracer was greater than the yellow and red tracer, which suggests that the most significant erosion occurred around the southern end of Old Bar Beach.

Predominantly northwards alongshore transport was consistently inferred from the results for each sampling exercise. This included inshore bypassing of Urana Bombora from the yellow, orange and red tracer release sites, which indicated that this feature was not a barrier to alongshore sediment transport in either direction over the study period. Furthermore, northwards transport of material from each release site continued at least 2 km past the entrance to Farquhar Inlet (to the limit of sampling), which indicated that northwards sediment transport at least partially bypassed the inlet, with only some tracer material being captured within the inlet, over the study period.

The Farquhar Inlet results confirmed that sand eroded from the entire length of Old Bar Beach migrated to the entrance area over timescales in the order of several months to years. This transport was most evident for the red tracer material during the study period, although quantities of yellow and orange tracer were also recorded inside the entrance area by the end of the study period. It is likely that the amount of tracer material that is transported to the entrance area will continue to increase over time, although this would need to be confirmed by further investigations to determine whether Farquhar Inlet is a significant sink for sediment eroded from Old Bar Beach.

Some alongshore transport appeared to occur to the south during the study period, most notably during summer and likely as a result of the more easterly wave direction during this period. Overall, it appeared that the southwards transport occurred at a slower rate than the dominant northwards transport, that is there was a net northwards alongshore transport over the study period.

Significant offshore transport and deposition occurred for each tracer, particularly as a result of the significant storm event in August 2014. This was most notable from the orange release site and was probably related to the development of large rip cell(s), which carried sediment offshore to water depths of at least -11 m AHD.

Some onshore recovery of sand eroded from the beach and transported offshore during the August 2014 storm event could be inferred from the results of sampling exercises in November-December 2014 and March 2015. However, tracer material was recorded in samples collected around and offshore of an estimated “inner” depth of closure at -12 m AHD, which provides evidence of possible permanent offshore sand losses from Old Bar Beach due to storm activity. This is considered to be an important factor contributing to the observed high recession rates at Old Bar Beach.

The net northwards transport of material past Urana Bombora may also be contributing to the observed high recession rates at Old Bar Beach, if this transport is occurring at a higher rate than the alongshore supply of material entering the Old Bar Beach system past Saltwater Point and Wallabi Point from the south. However, geological and geomorphic evidence suggests that observed northwards longshore transport is likely to be associated with material eroded from the local embayment, with little evidence of any strong net littoral drift.

There is no clear evidence from the sediment tracing that the observed recession, particularly at the northern end of Old Bar Beach, would be caused by a longshore transport mechanism. The clearest evidence for the cause of recession at Old Bar Beach from the sediment tracing is that it is related to cross-shore processes which move sand well offshore to depths where it may never return (or it may take many years to return) to the sub-aerial beach.

Influence of Particle Size

Particle size analysis results for each tracer released indicated that under the conditions experienced during the study period, it was predominantly fine sediment that was transported alongshore and offshore from Old Bar Beach. Medium sized tracer particles also dispersed relatively widely alongshore, albeit to a much lesser degree than the fine sized tracer and typically confined to the intertidal beach and inshore areas shallower than 5 m near the respective tracer release sites. Alongshore transport of the coarse tracer particles was minor and was typically confined to the intertidal beach in the immediate vicinity of the tracer release sites. Transport of the medium and coarse sized red and yellow tracer particles into the Farquhar Inlet entrance area was also evident in the Sampling Exercise 5 results.

Implications for Coastal Management at Old Bar Beach

These observations may have implications for any future beach nourishment implemented at Old Bar Beach. For example, if nourishment was to be undertaken in the vicinity of Taree-Old Bar SLSC or the MidCoast Water Exfiltration Ponds, in general it could be expected that the nourishment sand would be readily transported offshore and to the north during storm conditions, particularly for the finer sand fractions. However, consideration could be given to sourcing medium and coarse sized sand for the nourishment material to increase the longevity of nourished profiles, potentially from Farquhar Inlet.

The results of this study can be utilised to inform assessment of other coastal management options that may be considered for Old Bar Beach. For example:

- The predominance of northwards longshore transport inferred from the tracer results is likely to be associated with material eroded from the local embayment rather than evidence of any strong net littoral drift. Therefore, groynes are unlikely to be effective in combatting ongoing recession within the embayment. However, it could be expected that a small degree of accretion would occur on the updrift (southern) side of groynes, which could be constructed adjacent to critical areas to selectively build up sand reserves in these areas.

- The cross-shore sediment losses inferred from the tracer results could be reduced at localised sections of the beach with emergent offshore breakwaters of suitable scale, crest level and construction material. However, the considerable complexities surrounding regional coastal processes at Old Bar Beach means that the ability to predict shoreline response to an artificial reef structure(s) at this location would be highly uncertain.

- Seawalls of suitable scale, construction material and crest/toe levels remain a valid and proven coastal protection option for beaches where cross-shore losses are a dominant process, which is the case at Old Bar Beach as demonstrated by the tracer results.

Conceptual Model of Sediment Transport Processes

A conceptual description of the key sediment transport processes inferred from the tracer study is presented in **Figure ES1**.

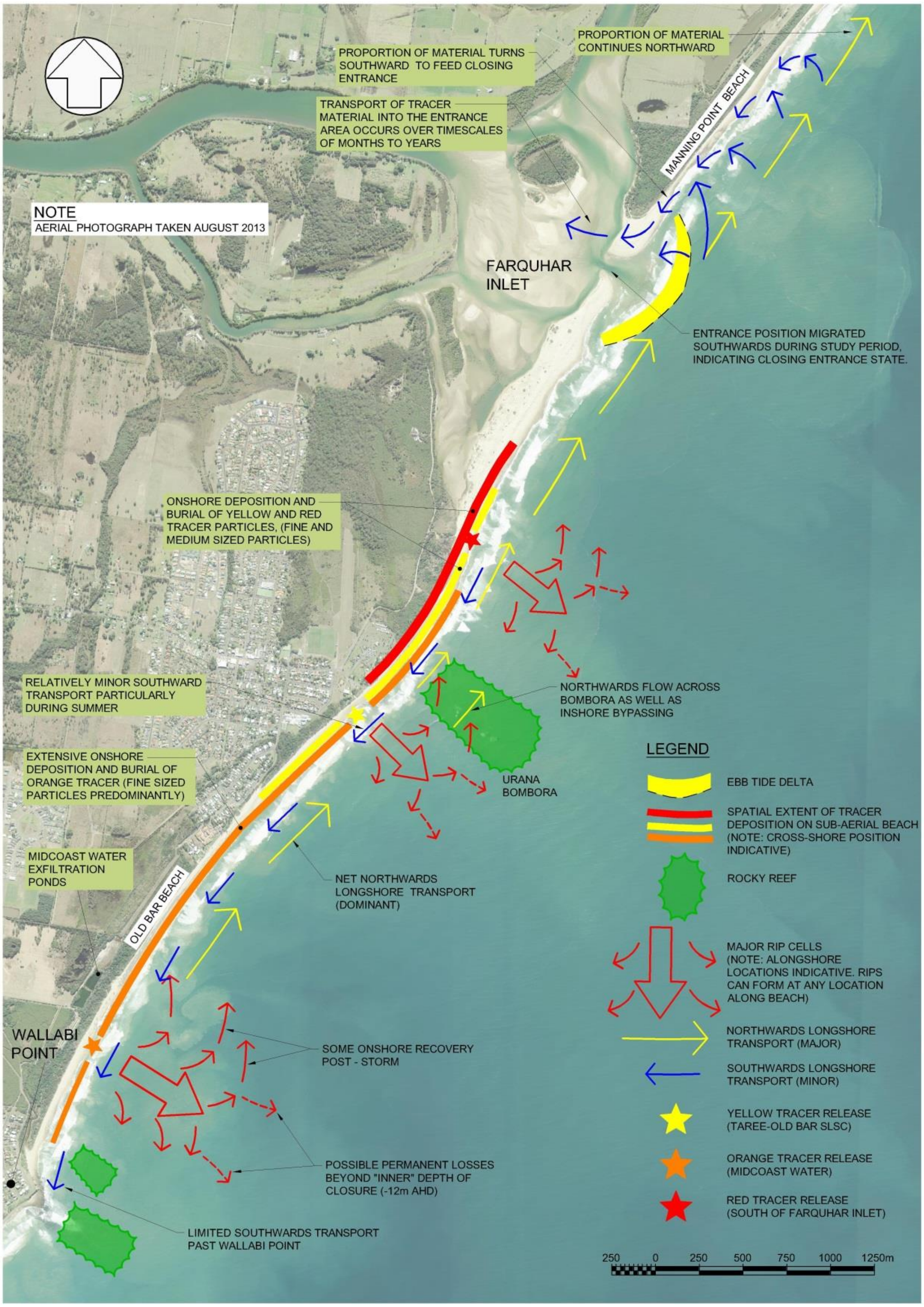


Figure ES1: Conceptual description of sediment transport processes inferred from tracer results

CONTENTS

APPENDICES

1 INTRODUCTION

1.1 Project Background

There is a long history of erosion/recession and threat to coastal properties at Old Bar Beach. Up to 2004 the beach was receding at a rate of approximately 0.5 m/year. Between 2004 and 2013 there was a substantial acceleration in the rate of recession which was typically 2 m/year and in some places as high as 4 m/year. The long-term recession rates at Old Bar Beach are currently some of the highest on the NSW coast. In 2008, three houses at the southern end of the Old Bar township were threatened by coastal storms and demolished. Following the most recent assessment of coastline hazards (WorleyParsons, 2010a), it is evident that a significant amount of private and public property is under threat at Old Bar if these high recession rates continue.

The coastline management process for Greater Taree was commenced in 2008. This progressed to the completion of a Coastline Hazard Definition Study (WorleyParsons, 2010a), a Coastline Management Study (WorleyParsons, 2010b) and a Draft Coastal Zone Management Plan (CZMP) (WorleyParsons, 2013). These investigations described a range of possible options to manage the erosion/recession risks, all of which were high cost and difficult to implement.

More recently, OEH and Council investigated a proposed rock revetment coastal protection as a management option (Royal HaskoningDHV, 2013). However, this option was not endorsed by the NSW Government. Until recently, planned retreat was recommended as the preferred strategy, a default position based upon the cost of other options and absence of any other viable option contained within the CZMP. A revised version of the CZMP, which facilitates a range of flexible responses to the changing coastline, was adopted by Council on 17 June 2015 (revised in September 2015) and is currently awaiting certification by the NSW Minister for Planning.

Beach amenity impacts would be expected if Old Bar Beach continues to recede at present rates, with or without a coastal protection structure in place. It is recognised that if the proposed rock revetment option is implemented, the sandy foreshore at Old Bar would be expected to disappear (be underwater) within approximately 10 to 20 years (Royal HaskoningDHV, 2013).

A possible solution to preserve beach amenity would be to undertake beach nourishment, either as a stand-alone measure or in combination with a coastal protection structure. However, a better understanding of regional sediment transport processes was considered to be required to fully assess the feasibility of beach nourishment at Old Bar Beach. In particular, it was not clear whether nourishment sand would be expected to remain in the beach compartment for sufficiently extended periods, and whether this material would be transported under predominantly longshore or cross-shore processes. Understanding the transport pathways and destinations of nourishment sand may also permit design of sustainable backpass amenity nourishment which is successfully used elsewhere along the NSW coastline.

Council, in conjunction with OEH and MidCoast Water, engaged Royal HaskoningDHV (RHDHV) and ETS to undertake a sediment tracing study to improve the understanding of sediment transport processes at Old Bar Beach, with particular emphasis on the feasibility of a possible beach nourishment scheme. Sediment tracers provide unequivocal and tangible data on actual sediment transport on a site-specific basis.

1.2 Study Scope and Objectives

1.2.1 Study Scope

The study initially involved the placement of tracer material at three locations along Old Bar Beach, namely:

- yellow tracer seaward of Taree-Old Bar SLSC;
- red tracer at the northern end of the beach, south of Farquhar Inlet; and,
- orange tracer seaward of the MidCoast Water Exfiltration Ponds.

The yellow and red tracer material was deployed in May 2014, while the orange tracer material was deployed in July 2014.

Following the deployment of tracer material, a total of five sampling exercises were undertaken from July 2014 to September 2015 to ascertain the transport of the tracers under natural processes. The timing of these sampling exercises was as follows:

- Sampling Exercise 1 – July 2014;
- Sampling Exercise 2 – September 2014;
- Sampling Exercise 3 – November-December 2014;
- Sampling Exercise 4 – March 2015; and,
- Sampling Exercise 5 – September 2015.

The selection of sample locations for each sampling exercise required a flexible approach that considered the expected sediment transport pathways and extents during the preceding period. This was based on recorded offshore wave data, observed erosion or accretion, and results from any preceding sampling exercises. Site conditions at the time of sampling also influenced adopted sample locations. The timing of each sampling exercise was influenced by boat availability and weather conditions.

Samples were generally collected from within a sampling region which comprised numerous shore-normal transects located within an area extending from near Wallabi Point in the south to the northern side of Farquhar Inlet in the north. Spacing between adjacent transects varied from 125 m to 500 m. Several samples were also taken within the entrance to Farquhar Inlet. For each transect, up to eight (8) samples were collected at the following approximate positions:

- Mean High Water (MHW, at about 0.5 m AHD);
- Mean Sea Level (MSL, at about 0 m AHD);
- Mean Low Water (MLW, at about -0.5 m AHD);
- -2 m AHD;
- -4 m AHD;
- -7 m AHD;
- -11 m AHD; and,

- -14 m AHD.

The sampling region, tracer deployment locations and initially proposed sampling locations are depicted on **Figure 1**. Sample locations and transects for each sampling exercise are described in **Section 6.1**.

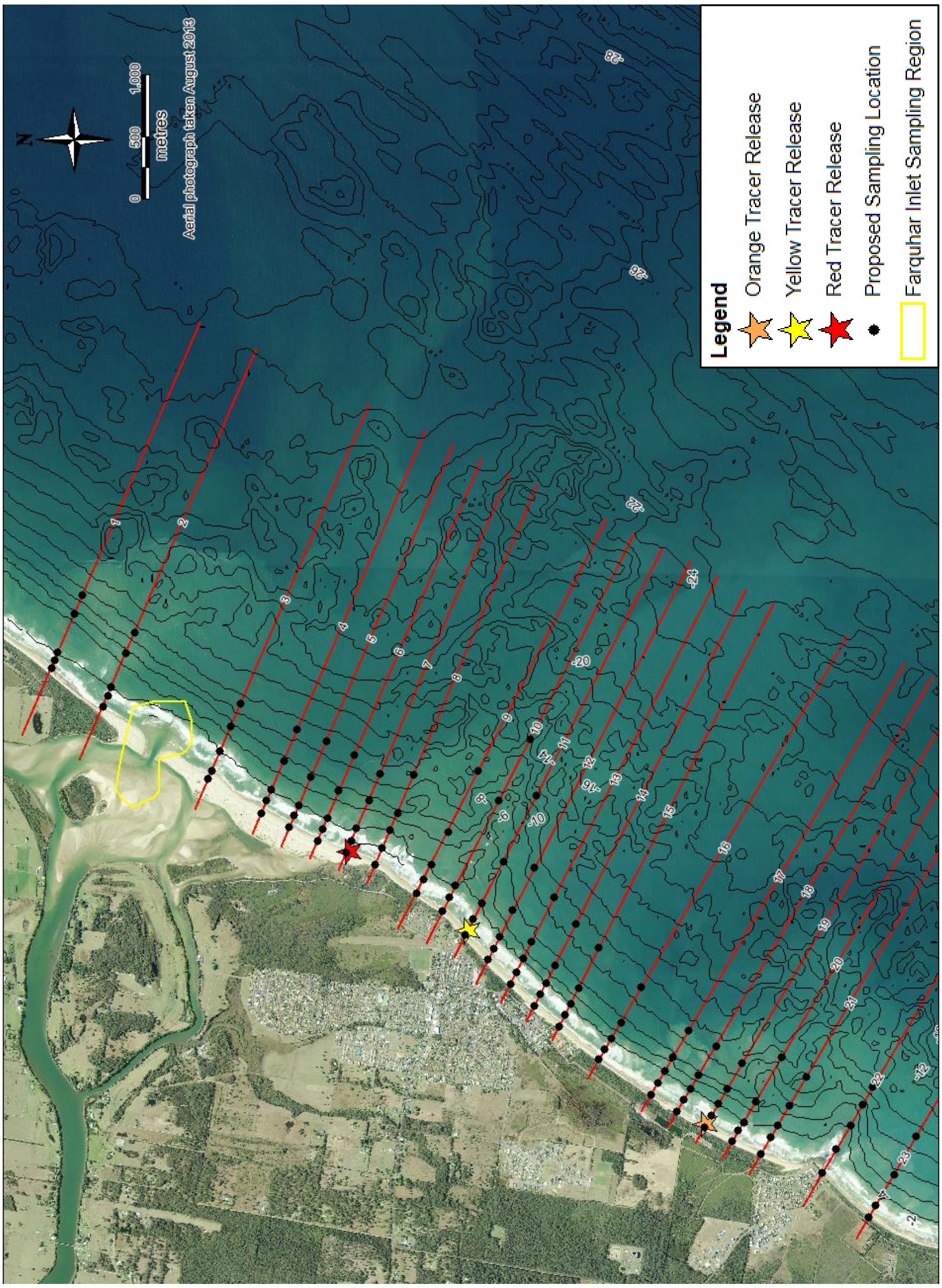


Figure 1: Sampling region and tracer release locations, with 23 transects depicted (seabed contours at 2 m intervals and to AHD)

1.2.2 Study Objectives

The primary objective of the Old Bar Beach sediment tracing study described herein was to improve the understanding of sediment transport processes at Old Bar Beach. This information may be used to:

- better understand the sand loss mechanisms that are contributing to the observed high recession rates at Old Bar Beach;
- inform assessment of the various coastal protection options available for Old Bar Beach; and,
- assess the technical feasibility of beach nourishment as a strategy to provide amenity benefits to Old Bar Beach, with respect to the sediment transport aspects.

1.3 Scope of this Report

In this report, all project activities completed during the study period are described, including:

- background sampling and analysis;
- tracer manufacture and placement; and,
- sample collection and analysis for each sampling exercise.

The scope of this report also includes:

- characterisation of prevailing conditions during the study period based on:
    - analysis of offshore wave data;
    - observations of beach change; and,
    - comparison of beach surveys undertaken in 2013 and 2015;
- interpretation of tracer results and inferred sediment transport processes; and,
- assessment of study findings with regard to the various coastal protection options available for Old Bar Beach.

1.4 Acknowledgements

RHDHV and ETS gratefully acknowledge the assistance of the following people during the completion of the investigations reported herein:

- Richard Pamplin (Council), for steering the project, and for his ongoing support throughout this investigation;
- Michael Griffith (Council), for providing ongoing logistical support throughout the project, including coordination and participation in fieldwork activities;
- Peter Evans and Bruce Coates (OEH), for their assistance in designing the study, and ongoing technical support with the interpretation of local coastal processes;
- MidCoast Water, for their financial contribution to the project and for providing an excavator which greatly assisted with the orange tracer deployment;
- Noel and Dan Gogerly, local fishermen from the Forster-Tuncurry region, who provided excellent field support for the sampling activities.

2 EXISTING CONCEPTUAL UNDERSTANDING OF SEDIMENT DYNAMICS

2.1 Introduction

An important first step in the Old Bar Beach sediment tracing study was to ascertain the existing level of understanding regarding coastal processes and associated sediment dynamics at the study site. This informed the design of the study program, and also highlighted knowledge gaps that the sediment tracing study could fill. This was particularly relevant for Old Bar Beach where sediment transport processes are highly complex and sediment loss mechanisms are not fully understood.

Various descriptions of sediment dynamics at Old Bar Beach are available from a number of different sources. A review of these sources is presented in the following sections.

2.2 Old Bar Coastal Erosion Study (Sinclair Knight & Partners, 1981)

In the *Old Bar Coastal Erosion Study* (SKP, 1981) a conceptual coastal processes model for Old Bar was presented, mostly based on:

- a geomorphological/geological assessment of the area;
- analysis of photogrammetric data collected between 1940 and 1979;
- analysis of historical aerial photography;
- wave and storm surge analysis; and
- historical assessment of the status of Farquhar Inlet in relation to observed erosion/accretion trends.

A summary of the key observations outlined in SKP (1981) for Old Bar Beach is as follows:

- Variations in the wave energy distribution along the beach exist because of the nearshore reef system, which may influence erosion rates.
- Adjacent to Old Bar, although a very slight dominance of northerly longshore transport exists, the potential for longshore transport in both directions is nearly equal.
- Further south the net direction of longshore sediment transport along Old Bar Beach is to the south.
- Accordingly, long term recession is expected to occur at the northern section of the beach (beyond which northward and southward transport is balanced, but at which the long term direction is to the south) while progradation is expected at the southern end adjacent to Wallabi Point.
- Refraction analysis and wave directions observed in aerial photographs indicate that the nearshore reef at Old Bar modifies the local inshore wave climate in a way similar to the more prominent rocky headlands located further south.
- The reef system is responsible for a weak sedimentary compartment at Old Bar such that erosional tendencies at the beach are dictated by local refraction effects.
- It is possible that sand taken offshore in rip cells and deposited over the reef might not return to the beach under favourable conditions due to the barrier effect of the upward projection of segments/sections of the reef.

- The offshore sediment distribution patterns show that any net sand losses to offshore areas must form as a thin veneer over the existing sediments out to depths of 20-25 m.

2.3 Black Head to Crowdy Head Coastal Hazard Definition Study (WorleyParsons, 2010a)

2.3.1 Preamble

In the *Black Head to Crowdy Head Coastline Hazard Definition Study* (WorleyParsons, 2010a) it was noted that the regional coastal processes compartment between Black Head and Crowdy Head is highly complex due to the presence of Farquhar Inlet and Harrington Entrance, as well as a number of control features including Wallabi Point and Urana Bombora.

WorleyParsons (2010a) presented conceptual process models for Old Bar Beach under both ambient and storm conditions. Attempts to explain recent increases in beach recession were also presented, and the potential influence of Farquhar Inlet and Racecourse Creek on sediment dynamics at Old Bar Beach was also investigated. A summary of the key findings reported by WorleyParsons (2010a) is presented below.

WRL undertook a peer review of WorleyParsons (2010a), and noted that the coastal processes presented for Old Bar Beach were speculative but plausible (WRL, 2010).

2.3.2 Conceptual Processes Model – Ambient Conditions

The conceptual processes model prepared by WorleyParsons (2010a) for Old Bar Beach under ambient conditions is presented in **Figure 2**, which can be summarised as follows:

- Net northward sediment transport occurs along the beach, while refraction and diffraction effects cause lateral expansion flow to the south and localised accretion at the southern end.
- Sediment bypassing of Urana Bombora occurs to the north along the inshore zone, likely representing a net loss of sand from the beach compartment. This is largely due to the bombora generally not being emergent above -2.5 m AHD, which limits the effectiveness of this feature to form a barrier to sediment transport.
- Nearshore conditions are characterised by significant longshore currents and high suspended sediment loads. This may be related to the relatively deep nearshore area (trough) and steep beach face, whereby waves approach the shoreline relatively unrefracted and break in a narrow high energy surf zone at a relatively large angle to the shoreline promoting high longshore currents with a high sediment load.

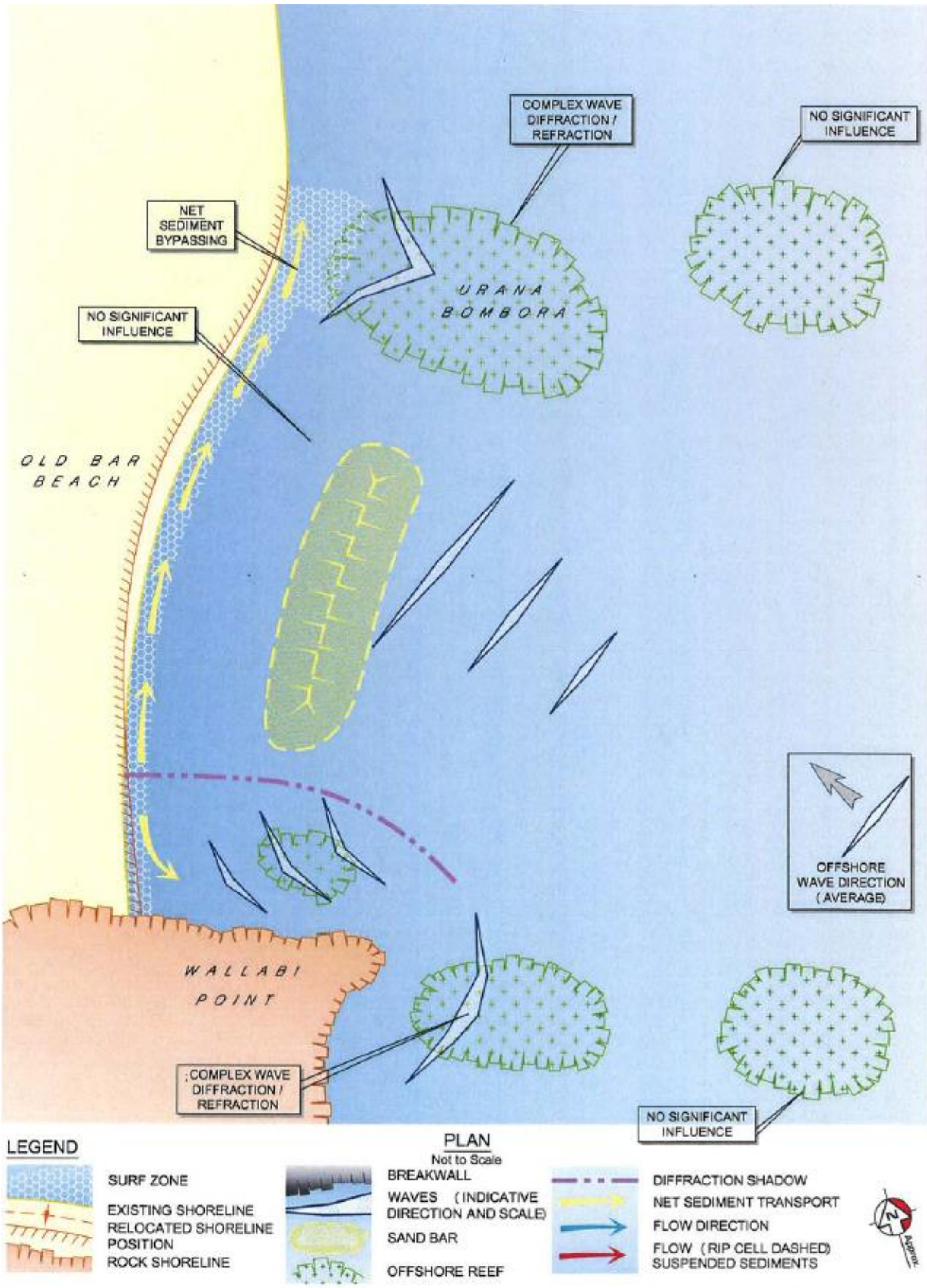


Figure 2: Old Bar Beach Conceptual Processes Model – Ambient Conditions (Source: WorleyParsons, 2010a)

2.3.3 Conceptual Processes Model – Storm Conditions

The conceptual processes model prepared by WorleyParsons (2010a) for Old Bar Beach under storm conditions is presented in **Figure 3**, and can be summarised as follows:

- Waves generally approach the inshore zone from the east due to wave refraction associated with the extensive nearshore reef systems, which may lead to southerly sediment transport along the SW-NE oriented Old Bar Beach.
- A differential in water levels would occur as a result of wave setup on Urana Bombora due to wave focusing on the reef and the width of the surf zone in this area. This would result in a 'flow' of water south from the bombora, creating the potential for southward sediment transport in this area.
- Significant potential for sediment entrainment in the surf zone occurs as a result of the typical beach state (longshore bar and trough), while the steep beach face and relatively low, narrow berm would be readily eroded during periods of elevated water levels.
- Wave diffraction caused by Urana Bombora drives sediment transport to the north and south (of the reef). The resulting salient removes sand from the section of beach south of the reef while limiting sediment supply from the north. Sand from the salient feature can be mobilised to the north under ambient conditions resulting in a loss of sediment from the Old Bar Beach system.
- For storm waves from the ESE sector, a large rip cell forms at the southern end of the beach carrying sediment offshore which may then be effectively lost from the system.
- For storm waves from the SE sector, significant volumes of sediment may be transported offshore to the north in a major rip cell which forms immediately south of the entrance to Racecourse Creek. This sediment may be deposited against the southern side of Urana Bombora or recirculated to the nearshore zone by flow across the bombora, resulting in sediment transport north and south of the bombora at the shoreline. Under these conditions, there is a net loss of sediment from Old Bar Beach (both offshore and through transport to the north of Urana Bombora).
- For South and SSE storm events the loss mechanism is similar to ambient conditions, with northward flowing longshore currents inshore of Urana Bombora.
- Due to the submarine embayed form of Old Bar Beach and resultant large rip cell formation during SE and ESE storm events, offshore transport is the dominant loss mechanism.
- For storm events with wave directions other than SE and ESE, Urana Bombora is less effective in influencing the refraction of wave energy, and longshore transport is the dominant mechanism. Under these storm conditions, inshore bypassing of the bombora occurs, while overtopping due to suspended sediment load in flows is another bypassing mechanism.

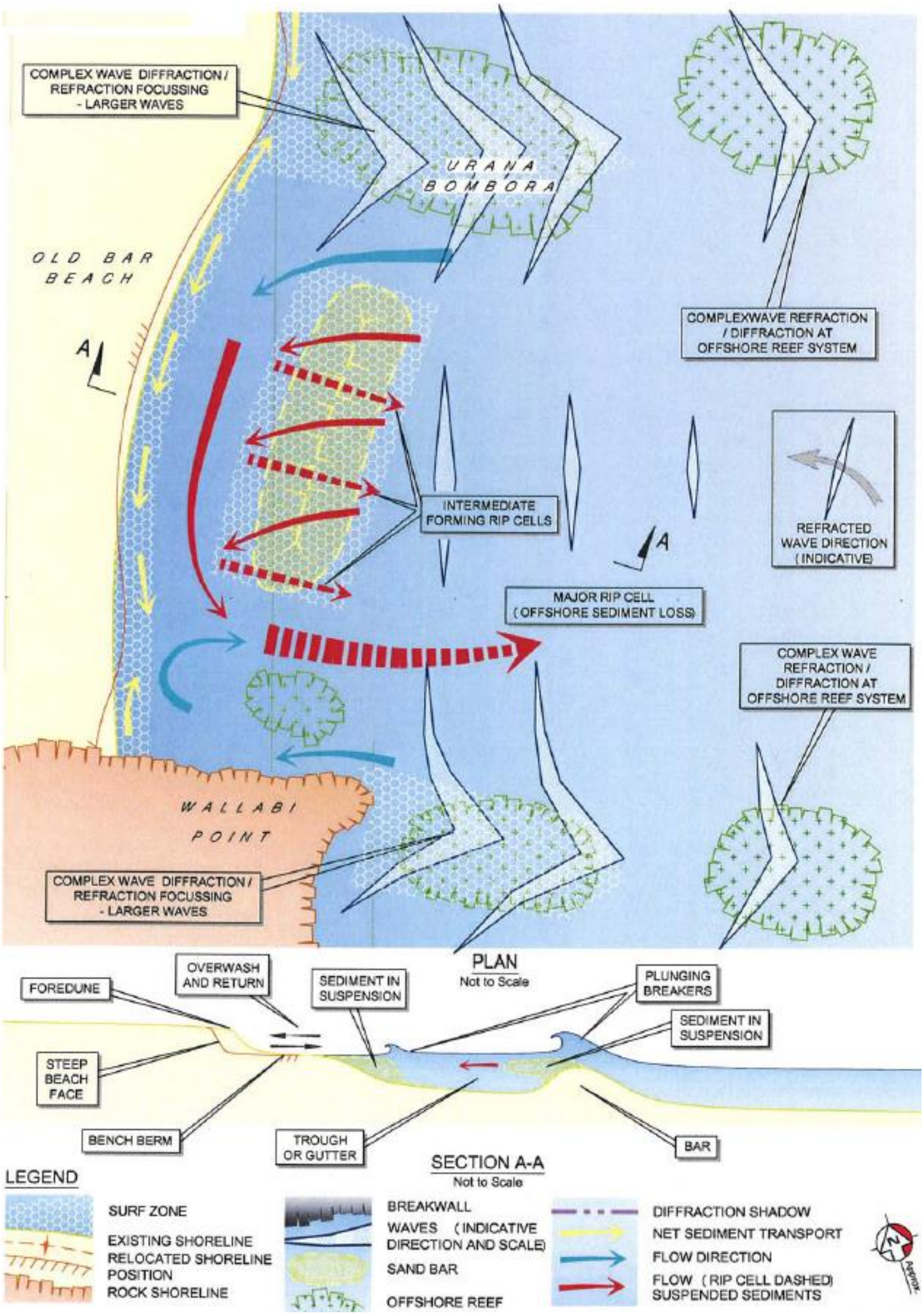


Figure 3: Old Bar Beach Conceptual Processes Model – Storm Conditions (Source: WorleyParsons, 2010a)

2.3.4 Influence of Farquhar Inlet and Racecourse Creek

WorleyParsons (2010a) analysed specific periods of photogrammetric data in an attempt to identify any relationship between the observed erosion at Old Bar Beach and the entrance state of Farquhar Inlet. The influence of stabilisation works at the entrance to Racecourse Creek was also investigated, however this was not found to have any significant influence on sand volumes along Old Bar Beach. In particular, it was noted that the observed dune stabilisation in the immediate vicinity of the creek entrance could be attributed to stabilisation of the creek alignment (relating to catchment flows) and not because of the constructed gabion wall acting as a groyne to stabilise longshore sediment transport.

WorleyParsons (2010a) postulated that Farquhar Inlet acted as a significant sediment sink during and following closure, resulting in recession of Old Bar Beach. This was due to a reduction in nearshore sand shoals (ebb tide delta) and infilling of the inlet through aeolian processes, which reduces sand volumes in the nearshore zone offshore from the entrance. This process changes the nearshore bathymetry that otherwise combines with Urana Bombora to stabilise (relatively) Old Bar Beach by supplying sand during southerly bypassing, and reducing the rate of northerly bypassing of Urana Bombora.

Farquhar Inlet has been progressively closing during the study period assessed herein, with the entrance opening migrating to the south. The conceptual processes model prepared by WorleyParsons (2010a) for Farquhar Inlet during ‘closing’ is presented in **Figure 4**, and can be summarised as follows:

- Net sediment transport occurs to the north, bypassing the entrance along the ebb tide delta.
- On the northern side of the entrance, sediment is recirculated back towards the inlet as it re-joins the beach from the ebb tide delta.
- Infilling of the entrance continues to occur from the north due to this recirculation effect and the ebb flow from the estuary is concentrated along the southern bank, which continues the migration of the entrance to the south.

The influence of Farquhar Inlet on erosion at Old Bar Beach was also discussed in Gordon (2013). In general, it was surmised that the inlet takes sand in from the south (Old Bar Beach) and then discharges sand offshore during flood events where some moves off to the north while the rest goes back to re-form the entrance shoals and berm. The implication of this for Old Bar Beach is that it tends to experience intermittent phases of recession which occur after, but are linked to, major floods.

As part of the sediment tracing study herein it is investigated whether material eroded from Old Bar Beach enters the Farquhar Inlet entrance area. There were no significant flood events during the study period so it has not been possible to assess whether sediment from Farquhar Inlet that was eroded from Old Bar Beach is jetted offshore during flood events.

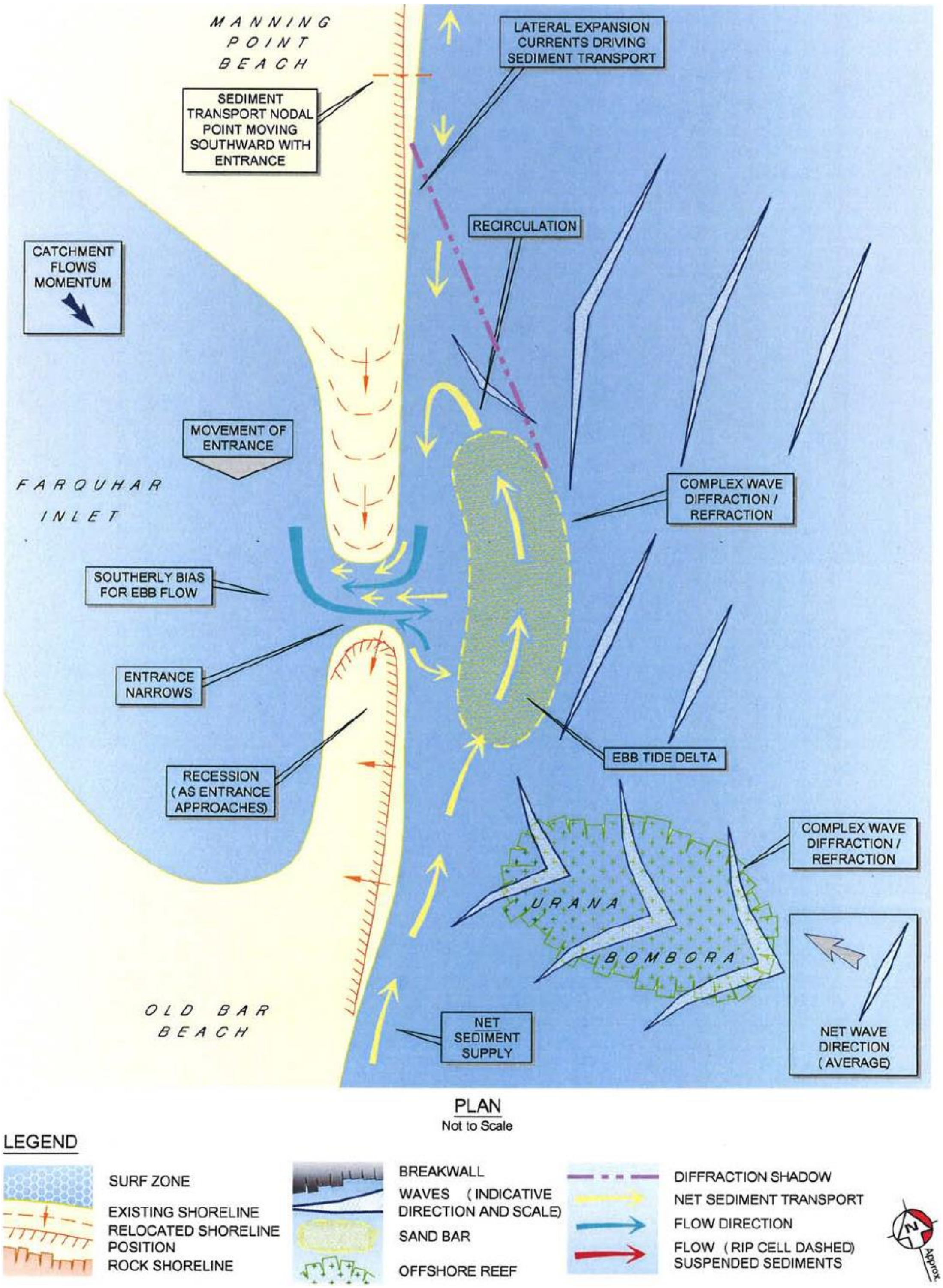


Figure 4: Farquhar Inlet Conceptual Processes Model – 'Closing' (Source: WorleyParsons, 2010a)

2.4 Old Bar Beach Stabilisation Investigation Feasibility Study (ASR, 2011)

In ther *Old Bar Beach Stabilisation Investigation Feasibility Study* (ASR, 2011), it was suggested that the ongoing recession at Old Bar Beach was being caused by cross-shore sediment transport during storms. In addition, the observed beach recession was attributed to erosion of the "old bar" itself, i.e. the submerged river delta offshore. Offshore reefs comprised of river stones cemented together with mud stone are elevated above the sandy seabed, and it has been reported that pieces of this reef have washed up on the beach since the area was first settled in the 1940's. Reduced elevation of the offshore "old bar" would increase the potential for wave energy transmission to the shoreline and lead to beach recession.

WRL undertook a peer review of ASR (2011), and noted that the postulated mechanism for erosion at Old Bar Beach (i.e., erosion of the "old bar") was plausible (WRL, 2012). WRL also noted that that this mechanism could be exacerbated by sea level rise of 1 to 3 mm/year which has been occurring over the past 50 years (You *et al.*, 2009), leading to greater wave transmission or reduced wave transformation over the nearshore reef. However, WRL (2012) suggested that other potential mechanisms for recession at Old Bar Beach, such as those presented in WorleyParsons (2010a), should also be considered.

2.5 Existing Understanding of Sediment Dynamics to Inform Sediment Tracing Study

Based on the information provided above, it is clear that the sediment transport processes at Old Bar Beach are highly complex, with a range of processes dominating under different prevailing conditions. Despite the investigations undertaken to date, it is evident that these processes are not fully understood. A key objective of this sediment tracing study is to improve this level of understanding by providing evidence of the key processes that prevail during the study period.

There appear to be a number of mechanisms which can potentially transport significant volumes of sand outside the beach compartment, leading to ongoing shoreline recession. These mechanisms are discussed further below. Conversely, sand supply to Old Bar Beach does not occur at a significant rate due to sand drift from the south, and instead appears to primarily rely on southward transport during storm events, although it is noted that northward transport is most likely to occur during storms from the S and SE sectors. In addition, major storm events may be associated with the development of significant rip cells that transport sand outside the beach compartment, and therefore should not be viewed as a mechanism for sand supply.

Indeed, cross-shore sediment transport during storm events is considered to be a major sand loss mechanism for the Old Bar Beach compartment, particularly under prevailing SE and ESE wave directions which are most likely to result in the formation of large scale rip cells. Such conditions can transport significant quantities of sand to water depths beyond the littoral zone where it is effectively lost from the system, leading to further shoreline recession.

Sediment transport processes during storm events have been assessed as part of this sediment tracing study. This includes transport directions for a significant SE storm event, and cross-shore transport due to likely rip cells.

The influence of Farquhar Inlet also appears to be important, with evidence that Old Bar Beach recedes in response to a closing of the entrance, and that the recession process may continue for an extended period due to the time lag in the morphological response. While the opening of Farquhar Inlet during flood events can discharge significant quantities of sand into the nearshore and offshore zones[1], much of this material appears to move off to the north while the rest goes back to re-form the entrance shoals and berm.

In addition, sand that enters Farquhar Inlet following entrance opening is likely to predominantly come from the beaches and dunes to the south, most notably Old Bar Beach (Gordon, 2013). Given that the entire region consists of complex reefs with only a thin veneer of sand making up the beach and nearshore zone (Coffey and Partners, 1981), and also considering the lack of significant longshore transport from the south, the main source of material supplying the net northward longshore transport is likely to come from the sub-aerial beach system at Old Bar (Gordon, 2013).

As part of this sediment tracing study, samples were collected inside the Farquhar Inlet entrance area. Given that the entrance has been closing during the study period, the tracer results for these samples were used to assess whether Old Bar Beach onshore sand deposits are potential source(s) for entrance infilling.

While the nearshore bathymetry indicates that Old Bar Beach is essentially embayed between Wallabi Point and Urana Bombora, it is noted that the effectiveness of the bombora to form a barrier to sediment transport is likely limited by the relatively low elevation of this feature (i.e., below -2.5 m AHD). This would enable sediment bypassing to occur to the north along the inshore zone and also as overtopping due to suspended sediment load in flows. This bypassing would represent a net loss of sand from the Old Bar Beach compartment and may become more significant in response to projected sea level rise. Sediment transport directions in the vicinity of this area have been assessed as part of this sediment tracing investigation.

[1] It is estimated that approximately 2 million m^3 of material was jetted offshore onto the shallow reefs as a result of the June 2011 flood, estimated to be a 1 in 20 year (5% ARI) event (Gordon, 2013).

3 BACKGROUND SAMPLING AND ANALYSIS

3.1 Purpose

Background sampling and analysis was carried out before the commencement of the tracer deployment in order to determine whether there was any background fluorescent material present in the natural sediment that may interfere with analysis of the introduced tracer. The background samples were collected before any tracer mixing or release took place.

If possible, background samples are also collected at the investigation design stage in order to optimise the choice of fluorescent tracer particles to be used. However, this was not possible for this study due to timing constraints, particularly related to the need to deploy tracer material prior to the winter of 2014.

3.2 Sampling Details

3.2.1 Sample Locations

Background samples were collected along the beach and offshore at each transect in the proposed sampling region (**Section 1.2.1**). A total of 46 background samples were taken at the locations indicated in **Figure 5**.

Background beach samples were collected near the water line at each transect. Each sample location was accessed using a 4WD vehicle provided by Council.

In general, offshore background samples were collected along each transect in the proposed sampling region, typically at a depth of around -8 m AHD. However, some of the proposed sampling locations over the rocky reef needed to be re-located in order to find nearby sand material for sampling.

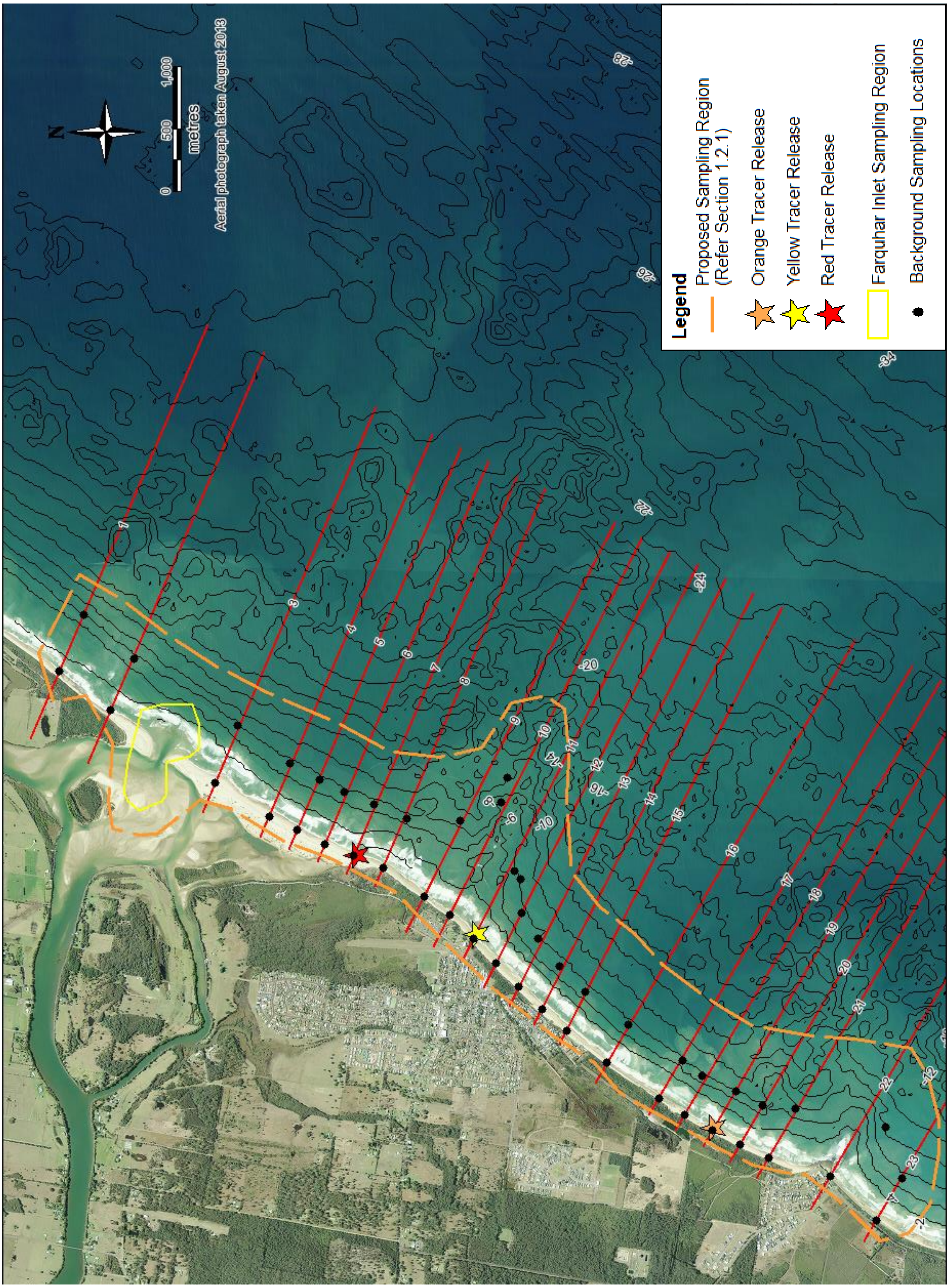


Figure 5: Background sampling locations, May 2014

3.2.2 Beach Sampling

Background beach samples were collected on 13 May 2014. Weather during the sampling was fine, and nearshore wave heights were around 1 m. Staff present included Patrick Lawless (RHDHV), Jon Marsh (ETS), Michael Griffith (GTCC) and Christopher Ross (GTCC).

Samples were transferred from the upper 5-10 cm of the beach surface into plastic containers using a stainless steel spoon. The spoon was rinsed in seawater following collection of each sample to minimise the risk of cross-contamination between sites. Each sample container was clearly labelled and stored in a plastic zip-lock bag to preserve the sample in the event that the plastic container was damaged prior to analysis (e.g. during transit to the analytical laboratory).

A photograph taken during the background beach sampling is provided in **Figure 6**.

Figure 6: Background beach sampling, 13 May 2014

3.2.3 Offshore Sampling

Background offshore samples were collected on 14 May 2014. Weather during the sampling was fine, and nearshore wave heights were around 1 m. Staff present included Patrick Lawless (RHDHV), Jon Marsh (ETS) and Greg Crisp (McGlashan and Crisp Surveyors).

Samples were collected using a stainless steel *Shipek* grab sampler with bucket attachment. Sediment sampling was undertaken from a fibreglass fishing vessel. The grab sampler was lowered to the sea bed at each sampling location where the bucket attachment was triggered to close and penetrate the sediment.

Prior to sampling, the grab sampler bucket was thoroughly rinsed in seawater. This process was repeated between sampling locations to avoid any potential contamination between sites.

Samples were transferred from the grab sampler bucket into plastic containers using a stainless steel spoon. The spoon was also rinsed in seawater following collection of each sample to minimise the risk of cross-contamination between sites. Each sample container was clearly labelled and stored in a plastic zip-lock bag to preserve the sample in the event that the plastic container was damaged prior to analysis (e.g. during transit to the analytical laboratory).

A photograph taken during the background offshore sampling is provided in **Figure 7**.

Figure 7: Background offshore sampling, 14 May 2014

3.3 Background Sample Analysis

3.3.1 Analysis Method

All the collected samples were shipped to ETS's ISO 9001 certified laboratory in the UK. All samples were analysed for tracer particle counts, which were then converted into particle counts per square metre of the grab area.

The following analysis protocol was used for each sample:

1. All samples that arrived in bags or sample containers were individually checked for integrity and wiped down to remove any possible source of contamination.
2. The samples were then placed in order (according to the log sheet provided by the field team and given a unique ETS number) following the ETS Standard Operating Procedure (SOP) 'QA003 Receipt of Samples' document.
3. The total wet mass of sediment sample received was recorded.
4. The total contents of each sample container were mixed until homogeneous and two sub-samples were then removed for analysis; namely approximately 20 g for wet to dry weight ratio calculations and approximately 500 g wet mass for tracer count analysis. The remainder of the sample was re-sealed and stored for any subsequent re-sampling if required.
5. Wet to dry weight ratios
   i. A 30 mL weighing boat was labelled with a unique ETS reference number and weighed. The weight was recorded on a spreadsheet.
   ii. The 20 g sub-sample was transferred into the weighing boat and weighed. The mass was recorded on a spreadsheet. The sample was then dried to a constant mass in a drying oven.
   iii. Once dry, the sample was weighed immediately after being removed from the oven. The mass was recorded on a spreadsheet.
6. Tracer count analysis
   i. A foil tray was labeled and weighed. The mass was recorded on a spreadsheet.
   ii. The 500 g sub-sample was decanted into the foil tray.
   iii. The sample was then dried to a constant weight in a drying oven, normally overnight.
   iv. Once dry, the sample was weighed immediately after being removed from the oven. The weight was recorded on a spreadsheet.
   v. A smaller foil container was tared on the balance and 300 g of the dry sample was decanted into this and the sample weighed. The mass was recorded on a spreadsheet.
   vi. The 300 g sample was examined as a monolayer for all fluorescent particles on non-fluorescing material using a magnifying ultra-violet (UV) stereo inspection microscope. All fluorescent particle counts and size data were recorded on a spreadsheet.
7. All original paperwork, forms and printouts were kept in the relevant folder in the Laboratory in order to allow referral should the need arise. All data was then transferred and updated onto the ETS digital file server, with routine data backups every 24 hours.

3.3.2 Results

From analysis of the background samples it was observed that there was no natural fluorescence in the samples which could interfere with the analysis of the introduced fluorescent tracer particles used in this study.

4 TRACER MANUFACTURE AND DEPLOYMENT

4.1 Particle Sizing

4.1.1 Particle Size Distribution – Native Beach Material

In order for the sediment tracers to behave in the same way as the target sediment, it was important to ensure that the tracer particles had similar physical characteristics to the target sediment. Beach sampling and analysis for particle size distribution (PSD) was therefore undertaken prior to the manufacture of tracer material.

Beach samples were collected on 2 May 2014 by Michael Griffith (GTCC) and Christopher Ross (GTCC). Sampling was carried out at five locations along Old Bar Beach, including the three tracer deployment sites. Three samples were collected at each location at the following positions on the beach:

- near high water swash (top of wetted line on the beach);
- near mean sea level (about 20 m further seaward than the above sample); and,
- near low tide (about 10 m further seaward than the above sample).

All samples were analysed by the NATA accredited ALS Laboratory Group (Newcastle laboratories). Analysis was accredited for compliance with ISO/IEC 17025.

The laboratory Certificate of Analysis detailing the PSD results for each sample is provided in **Appendix A**. Further details of the sampling and analysis undertaken for PSD results are provided in **Appendix B**.

4.1.2 Adopted Particle Sizing – Tracer Material

Based on the assessment of particle size results for the native beach material outlined above, fine to medium sand-sized tracers (125 to 500 µm) were manufactured and utilised for this study.

The PSD of all three sand tracers was measured at the Faculty for Earth and Environmental Analysis (FEEA) at St. Andrews University in the United Kingdom, with the results presented in **Table 1**. FEEA has a Coulter LS230 laser granulometer which measures particle size by laser diffraction. Laser particle size analysis is based on the principle that particles scatter and diffract light at certain angles based on their size, shape and optical properties.

Table 1: Particle size distribution for each tracer

Tracer	Percentage of Tracer Fraction Retained on Sieve by Weight (%)						
	710µm	500µm	355µm	250µm	180µm	125µm	63µm
Yellow	0.1	2.4	15.0	21.7	41.1	19.5	0.2
Red	0.2	2.6	14.3	20.1	43.8	18.8	0.2
Orange	0.0	1.6	15.4	21.8	42.9	18.2	0.1

4.2 Tracer Manufacture

ETS' EcoTrace fluorescent sediment particle tracers are designed to be transported like natural sediment, thus assimilating the processes of tidal currents, wind and waves to give an integrated assessment of sediment transport. The tracers are a solid solution of fluorescent dyes in a thermoplastic polymer base. The Material Safety Data Sheet (MSDS) for the tracer material is provided in **Appendix C**.

The tracers are whole tracer particles and fluorescent throughout rather than a coating on natural sediment grains from the environment. Coated sediment grains can be abraded reducing recoverability and detection, whereas the ETS EcoTrace particles remain highly fluorescent and can be detected over long timescale projects in high energy environments even after some abrasion.

The EcoTrace particles do not contain any substances presenting a health hazard within the meaning of the Dangerous Substance Directive 67/548/EEC as amended by the Seventh Amendment 92/32/EEC, refer **Appendix C**.

Testing has also been carried out on the EcoTrace particles to assess potential impacts with regard to ecotoxicology and human consumption, as described in **Appendix D**.

ETS used a generic sediment particle density of 2.65 g/cm^3, equivalent to the density of silica, to provide comparable results of transport of the sediment tracers to natural sediment under typical conditions. The tracer particle density was measured by an external accredited laboratory Exova (Glasgow, UK), following procedures set out in British Standard BS812.

In order to ensure that tracer particles behave in the same way as target sediment, ETS routinely carries out additional tests to assess the physical behaviour of tracer particles and compares these with the sediment from a study site. For this study, fall velocity tests were conducted for the sand tracers, which are described in **Appendix E**.

The fall velocity tests provided a reliable comparison in the laboratory between natural sand-sized sediment collected from the study site and the sand-sized tracer particles used to mimic the sediment to ensure similar behaviour in the environment. The results of the fall velocity tests indicated that the sand-sized tracer particles had similar fall velocities to natural sand grains.

4.3 Tracer Deployment

Yellow, red and orange sand tracer material was deployed at the locations shown in **Figure 1** (**Section 1.2.1**). Deployment details are outlined in **Table 2**. Each tracer was deployed in two trenches, each about 0.5 m wide (cross-shore) and 0.3 m deep. These trenches were located at around MLW and about 3 m further landward.

Table 2: Tracer deployment details

	Yellow Tracer	Red Tracer	Orange Tracer
Deployment Date	15/5/14	15/5/14	17/7/14
Location Description	Taree-Old Bar SLSC	Northern end of beach, south of Farquhar Inlet	Mid Coast Water Exfiltration Ponds
Location	Latitude: 31.972°S Longitude: 152.592°E	Latitude: 31.963°S Longitude: 152.599°E	Latitude: 31.989°S Longitude: 152.576°E
Amount of Tracer	350 kg	250 kg	250 kg
Deployment Area	2 × 70 m long trenches	2 × 50 m long trenches	2 × 50 m long trenches

The yellow and red tracers were deployed in May 2014 following the completion of background sampling, while the orange tracer was deployed in July 2014 following the completion of the first sampling exercise.

As described in **Table 2**, the tracer was released into two alongshore trenches at each site. This was necessary to ensure that the tracer material would be subjected to swash, wave and tidal processes immediately following deployment. Placement was therefore undertaken around low tide to enable access to the placement locations.

Prior to release, the tracer particles were wetted and mixed with sand from the site to ensure they adsorbed the same electro-chemical charge as natural sand particles. This also prevented the tracer material from being blown away from the placement location by wind action.

Photographs taken during tracer deployment are provided in **Figure 8** (yellow tracer), **Figure 9** (red tracer) and **Figure 10** (orange tracer).

Figure 8: Yellow Tracer Deployment, 15 May 2014

Figure 9: Red tracer deployment, 15 May 2014

Figure 10: Orange tracer deployment, 17 July 2014

5 PREVAILING CONDITIONS

5.1 Offshore Waves

5.1.1 Wave Data Analysis

Manly Hydraulics Laboratory (MHL), which is part of NSW Public Works, operates a network of Waverider buoys in deep water along the NSW coast. Analysis of the collected data allows (amongst other things) the significant wave height (H_s), peak spectral wave period (T_p) and wave direction to be determined[2].

The nearest Waverider buoy to the study area is located in deep water offshore of Crowdy Head[3] , approximately 35 km north-east of the Taree-Old Bar SLSC. Data collected by this buoy is considered a good representation of the offshore wave climate at Old Bar.

Hourly wave data from the Crowdy Head Waverider buoy has been analysed for the following dates:

- between yellow/red tracer deployment and Sampling Exercise 1, i.e. 15 May 2014 to 16 July 2014;
- between Sampling Exercise 1 / orange tracer deployment and Sampling Exercise 2, i.e. 17 July 2014 to 11 September 2014[4];
- between Sampling Exercise 2 and Sampling Exercise 3, i.e. 12 September 2014 to 10 December 2014;
- between Sampling Exercise 3 and Sampling Exercise 4, i.e. 11 December 2014 to 12 March 2015;
- between Sampling Exercise 4 and Sampling Exercise 5, i.e. 13 March 2015 to 16 September 2015; and
- over the entire study period, i.e. 15 May 2014 to 16 September 2015.

It should be noted that this data has not been quality-controlled by MHL.

Statistics for H_s, T_p and wave direction for each period are summarised in **Table 3**, while the H_s and T_p time series data are plotted in **Figure 11** and **Figure 12** respectively. The long-term mean and 10% exceedance H_s and T_p values for the Crowdy Head data record are also provided in **Table 3**, and plotted in Figure 11 and Figure 12, to give an indication of wave conditions during the study period relative to long-term conditions.

---

[2] The significant wave height is the average height of the highest one-third of the waves in a particular record. The peak spectral wave period is determined by the inverse of the frequency at which the wave energy spectrum reaches its maximum.
[3] The Crowdy Head Waverider buoy has been operating since October 1985 (directional since August 2011), in a water depth of about 79 m.
[4] The Crowdy Head Waverider buoy did not collect data between 2/9/14 and 12/9/14.

Table 3: Crowdy Head offshore wave statistics

Period	Statistic	H_s (m)	T_p (s)	Wave Direction (deg TN)
Between yellow/red tracer deployment and Sampling Exercise 1 (15/5/14 to 16/7/14)	Minimum	0.5	3.5	-
	Maximum	3.0	16.0	-
	Mean	1.3	10.1	145
	Median	1.2	9.8	151
	10% Exceedance	1.9	12.9	-
Between Sampling Exercise 1 / orange tracer deployment and Sampling Exercise 2 (17/7/14 to 11/9/14[4])	Minimum	0.4	3.3	-
	Maximum	4.8	17.4	-
	Mean	1.9	11.1	145
	Median	1.8	10.8	150
	10% Exceedance	3.4	13.8	-
Between Sampling Exercise 2 and Sampling Exercise 3 (12/9/14 to 10/12/14)	Minimum	0.6	4.1	-
	Maximum	3.3	17.4	-
	Mean	1.5	9.4	123
	Median	1.3	9.3	133
	10% Exceedance	2.1	12.1	-
Between Sampling Exercise 3 and Sampling Exercise 4 (11/12/14 to 12/3/15)	Minimum	0.6	4.0	-
	Maximum	5.3	13.8	-
	Mean	1.6	9.6	113
	Median	1.5	9.8	109
	10% Exceedance	2.3	11.5	-
Between Sampling Exercise 4 and Sampling Exercise 5 (13/3/15 to 16/9/15)	Minimum	0.6	3.3	-
	Maximum	5.2	19.1	-
	Mean	1.7	10.8	142
	Median	1.6	10.8	150
	10% Exceedance	2.6	13.8	-
Entire study period (15/5/14 to 16/9/15)	Minimum	0.4	3.3	-
	Maximum	5.3	19.1	-
	Mean	1.6	10.3	134
	Median	1.5	10.3	141
	10% Exceedance	2.4	13.8	-
Long-term (October 1985 to December 2009) After Shand et al (2011)	**Mean**	**1.6**	**9.7**	**Not reported**
	10% Exceedance	**2.5**	**12.2**	

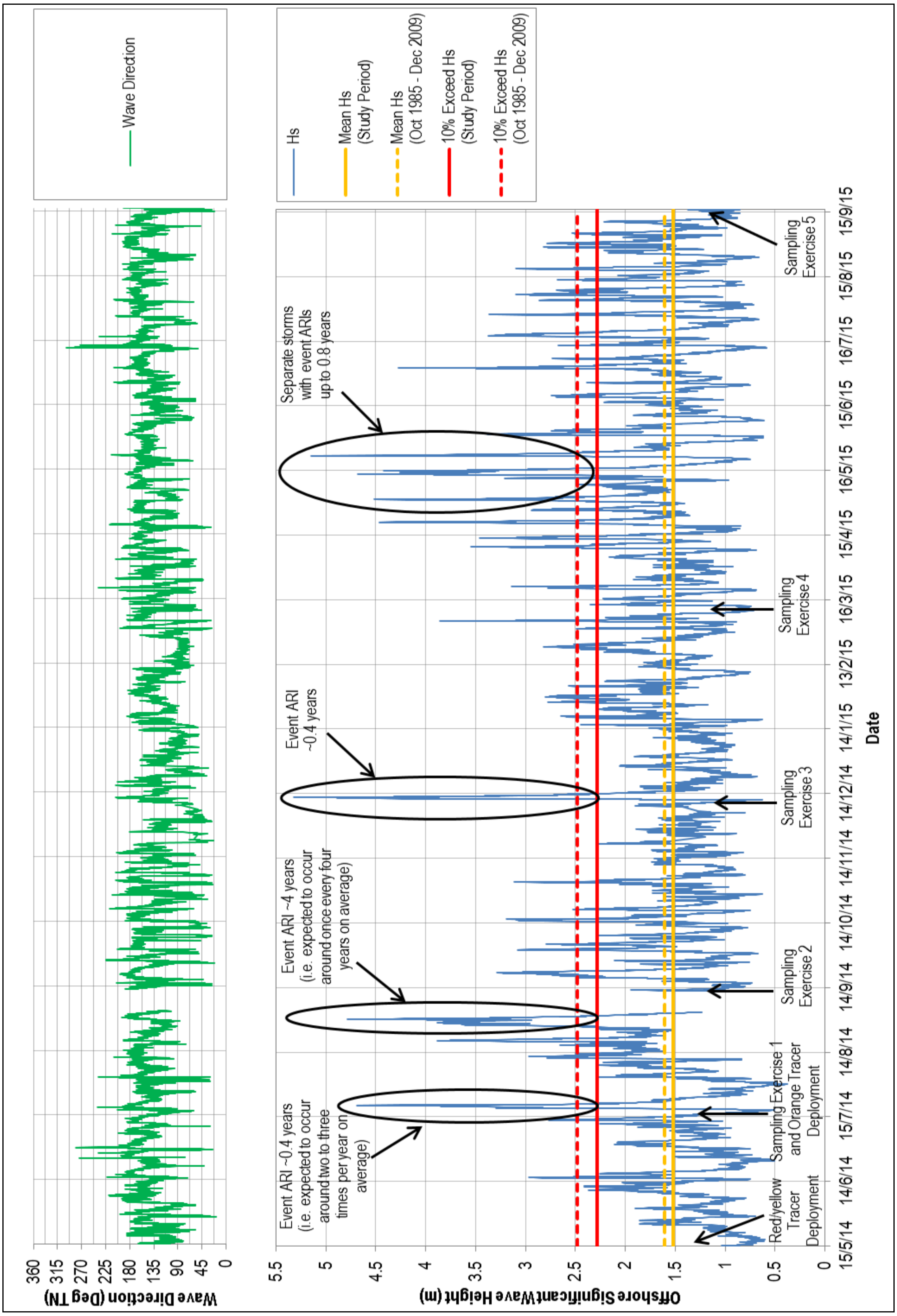


Figure 11: Crowdy Head offshore significant wave height (H_s) over study period

Royal HaskoningDHV

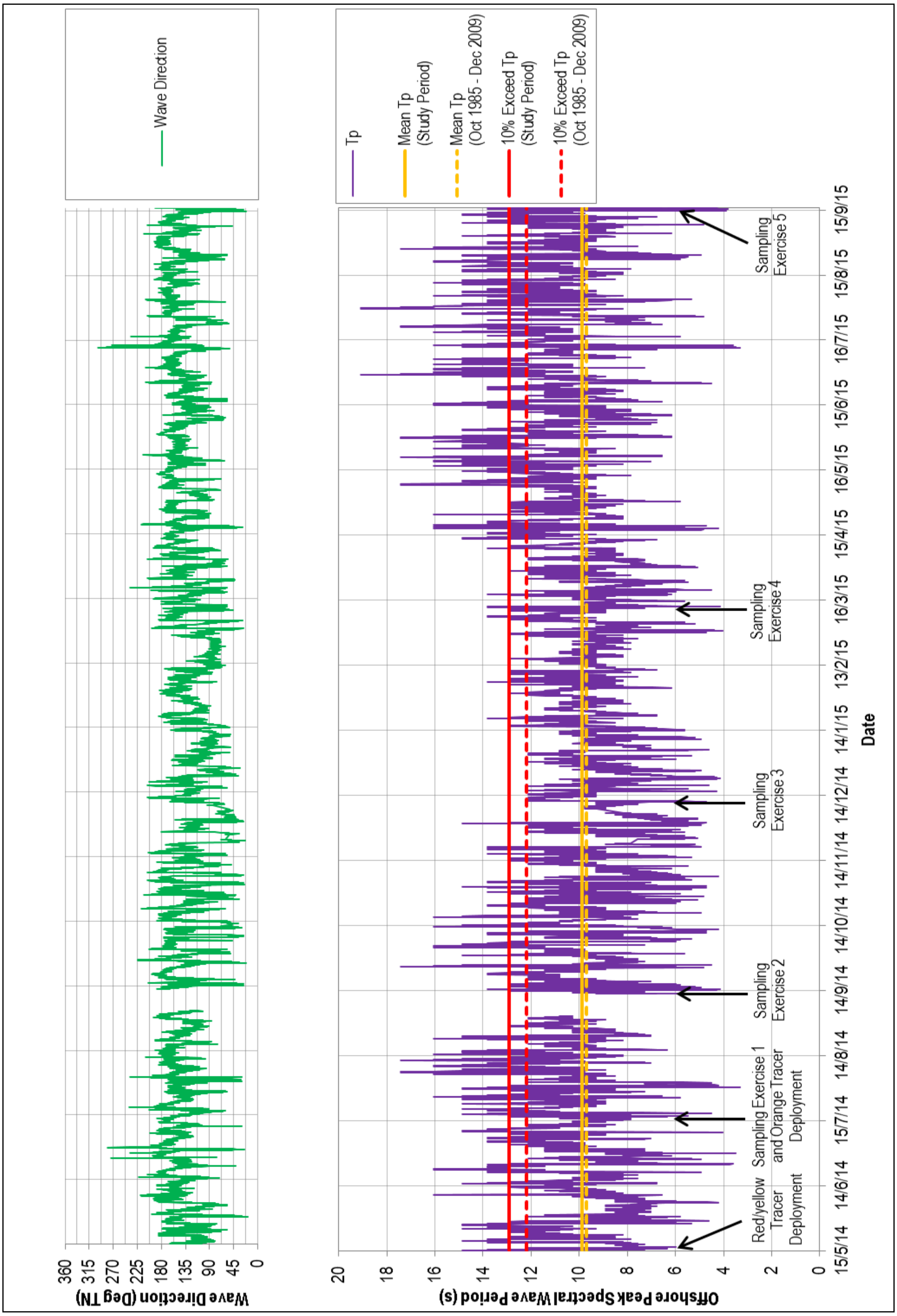


Figure 12: Crowdy Head offshore wave period (T_p) over study period

5.1.2 Summary of Key Observations

Key observations regarding wave conditions for each period analysed are summarised below.

Between yellow/red tracer deployment and Sampling Exercise 1 (15/5/14 to 16/7/14)

- The mean and 10% exceedance H_s values were lower than the corresponding long-term values, which indicate that offshore wave conditions during this period were relatively calm.
- The mean and 10% exceedance T_p values were slightly higher than the corresponding long-term values.
- Wave directions were generally limited to between the ESE and S sectors, with mean and median directions between SE and SSE.
- No major storm events were recorded during this period, which limited the likelihood of erosive conditions prevailing at Old Bar Beach. Peak wave conditions were recorded on 16/6/14, with H_s above 2.5 m for around 10 hours. However, the ARI for these conditions and duration was estimated to be less than 0.05 years (or 18 days)[5], which highlights the very minor nature of this event.

Between Sampling Exercise 1 / orange tracer deployment and Sampling Exercise 2 (17/7/14 to 11/9/14)

- The mean and 10% exceedance H_s and T_p values were higher than the corresponding long-term values.
- Wave directions were generally limited to between the ESE and S sectors, with mean and median directions between SE and SSE.
- A minor storm event was recorded between 19/7/14 and 20/7/14, with H_s above 3.0 m for around two days, and a maximum significant wave height of 4.7 m. The ARI for this storm was estimated to be less than 0.4 years (or two to three times per year)[5].
- A major storm event was recorded towards the end of August 2014, which resulted in erosion at Old Bar Beach. Significant wave heights above 3.0 m were recorded for around four days between 27/8/14 and 30/8/14. The ARI for this storm was estimated to be around 4 years[5]. The average T_p value during this storm was around 11 s, about 1 s higher in comparison to the long-term statistics (see Table 3). Wave directions associated with this storm event were initially from the ESE sector (27/8/14 to 28/8/14) before trending towards a more southerly approach (29/8/14 to 30/8/14).
- It should be noted that the severity of this storm event was mainly related to its long duration of wave heights above 3 m (i.e. four days). Lower ARI's would be estimated for this event if only the durations of larger wave heights are considered. For example:

[5] This estimation was based on ARI versus duration exceedance plots provided in Shand et al (2011) for the Crowdy Head Waverider Buoy data.

- significant wave heights above 3.5 m were recorded for a maximum duration of around 26 hours (between 28/8/14 2:00 and 29/8/14 4:00), which has a corresponding ARI of around 0.35 years (or once every four months)[5].
- significant wave heights above 4 m were recorded for a maximum duration of around 8 hours (between 29/8/14 23:00 and 30/8/14 7:00), which has a corresponding ARI of around 0.2 years (or once every ten weeks)[5].

Between Sampling Exercise 2 and Sampling Exercise 3 (12/9/14 to 10/12/14)

- The mean and 10% exceedance H_s and T_p values were slightly lower than the corresponding long-term values.
- Wave directions were generally limited to between the ENE and SSE sectors, with mean and median directions between ESE and SE.
- No major storm events were recorded during this period, which limited the likelihood of erosive conditions prevailing at Old Bar Beach. Peak wave conditions were recorded between 19/9/14 and 21/9/14, with H_s above 2.5 m for around two days. However, the ARI for these conditions was estimated to be less than 0.2 years (or five times per year)[5], which highlights the minor nature of this event.

Between Sampling Exercise 3 and Sampling Exercise 4 (11/12/14 to 12/3/15)

- The mean and 10% exceedance H_s and T_p values were slightly lower than the corresponding long-term values.
- Wave directions were generally limited to between the E and SE sectors, with mean and median directions approximately ESE. Periods of ENE wave conditions were also recorded.
- No major storm events were recorded during this period, which limited the likelihood of erosive conditions prevailing at Old Bar Beach. Peak wave conditions were recorded between 11/2/14 and 13/12/14, with H_s above 2.5 m for around two days, and a maximum H_s of 5.3 m. The ARI for these conditions was estimated to be less than 0.2 years (or five times per year)[5], which highlights the minor nature of this event.

Between Sampling Exercise 4 and Sampling Exercise 5 (13/3/15 to 16/9/15)

- The mean and 10% exceedance H_s values were approximately equal to the corresponding long-term values.
- The mean and 10% exceedance T_p values were slightly higher than the corresponding long-term values
- Wave directions were generally limited to between the ESE and SSE sectors, with mean and median directions approximately SE.
- No major storm events were recorded during this period, which limited the likelihood of erosive conditions prevailing at Old Bar Beach. Some minor storm events were recorded during April-May 2015, including:
  - significant wave heights above 3 m were recorded for a maximum duration of around 2.5 days (between 13/5/15 20:00 and 16/5/15 6:00), which has a corresponding ARI of around 0.8 years (or once every ten months)[5].

- significant wave heights above 5 m were recorded for a maximum duration of around 3 hours (between 20:00 and 23:00 on 22/5/15), which has a corresponding ARI of around 0.6 years (or once every seven months)[5].

Entire study period (15/5/14 to 16/9/15)

- The mean H_s value was 1.6 m, which was the same as the long-term value.
- The 10% exceedance H_s value (2.4 m) was slightly lower than the long-term value (2.5 m).
- The mean and 10% exceedance T_p values were slightly higher than the corresponding long-term values.
- Mean and median wave directions were approximately SE, although more easterly wave directionality was recorded during summer months.
- With the exception of the significant storm event towards the end of August 2014, the study period was largely devoid of major storm activity, while several minor storm events were recorded.
- Overall, wave conditions at Old Bar Beach during the study period were considered to be typical of long-term average conditions, with only a single major storm event in August 2014.

5.2 Beach Observations

5.2.1 Visual Observations

Visual observations of dunal sand profiles were undertaken to provide a qualitative indication of beach change during the study period.

The period from May to July 2014 (i.e. between yellow/red tracer deployment and Sampling Exercise 1) was likely neutral or slightly accretionary based on the appearance of dunal sand volumes at Old Bar Beach. This observation was consistent with the recorded wave conditions during this period, which were relatively calm and devoid of any major storm activity.

Conversely, the subsequent period (i.e. July to September 2014, between Sampling Exercise 1/orange tracer deployment and Sampling Exercise 2) had observed loss of dunal sand volumes. This observation was primarily attributed to the significant storm event which occurred at the end of August 2014.

Visual observations of Old Bar Beach in November 2014 indicated that the subsequent period (i.e. between Sampling Exercise 2 and Sampling Exercise 3) was accretionary in terms of dunal sand volumes. It is therefore evident that there was some degree of beach recovery following the major storm event in August 2014, which would be expected under wave forcing conditions that were typically calm and devoid of any major storm activity.

The subsequent period between Sampling Exercise 3 and Sampling Exercise 4 was also considered to be accretionary, with evidence of further beach recovery evident in March 2015. This observation was consistent with the recorded wave conditions during this period, which were relatively calm and devoid of any major storm activity, which is reasonably typical for the summer period.

Visual observations of Old Bar Beach in September 2015 indicated that minor erosion of dunal sand volumes occurred from March 2015 (i.e. between Sampling Exercise 4 and Sampling Exercise 5), although this was not considered to be significant.

A series of photographs taken seaward of the Meridian Resort during the study period is provided in **Figure 13**.

Figure 13: Views of Old Bar Beach near Meridian Resort during study period

Significant erosion was observed seaward of the Taree-Old Bar SLSC in September 2014, including exposure of underlying rock. Gradual recovery of sand volumes over the following two to six months can be inferred from photographs taken in November 2014 and March 2015 (**Figure 14**).

Figure 14: Views of Old Bar Beach near the Taree-Old Bar SLSC in September 2014, November 2014 and March 2015

It should also be noted that visual surface plumes of turbid water were observed during offshore sampling on 11/9/14, as shown in **Figure 15**. These plumes were observed at the southern end of the beach near Transect 17 and generally extended from the surf zone out to water depths of around 13 m. Given that wave conditions on 11/9/14 were mild (wave heights less than 1 m), it is not expected that wave forcing (and associated currents) was responsible for the observed plumes. Rather, it is considered likely that the observed plumes were caused by ongoing entrainment of fine sediment eroded from the beach during the preceding major storm event in late August 2014. This is discussed further in **Section 8.1**.


Figure 15: Turbid plumes observed offshore of Old Bar Beach, 11 September 2014

5.2.2 Comparison of Beach Surveys

OEH carried out detailed surveys of Old Bar Beach in November 2013 and March 2015. Comparison of these surveys has been undertaken to assess recent changes in dune positions and profiles at a number of locations along Old Bar Beach, which is presented in the Drawings provided in **Appendix F**.

The spatial coverage of both surveys is indicated on the Site Plan (Appendix F). The November 2013 survey extended northwards from Wallabi Point to just north of the Taree-Old Bar SLSC, while the March 2015 survey extended from just north of Wallabi Point to Farquhar Inlet.

The stretch of beach that was covered by both surveys therefore extends from just south of the orange tracer release site to just north of the yellow tracer release site, a shoreline distance of around 3 km. Since the November 2013 survey did not extend north of the Urana Bombora, it was not possible to assess beach profile change on the northern portion of Old Bar Beach, i.e. between Urana Bombora and Farquhar Inlet including the red tracer release site.

Comparison of beach profiles has been undertaken for 25 shore-normal chainage lines along the stretch of beach that was covered by both surveys. Beach profiles from OEH photogrammetry spanning the period 1940 to 2013 are also shown on each cross-section in the Drawings to provide an indication of long-term beach change, which is characterised by significant recession.

The positional movement of beach profiles between the two survey dates is summarised in **Table 4** for each chainage line. The positional movement has been measured at the 4 m AHD contour for the majority of chainage lines, which is considered to provide a reasonable indication of accretion or recession of Old Bar Beach during the intervening period (15 months). An elevation of 3 m AHD was adopted for chainage lines 500 S and 600 N, as noted in Table 4.

Table 4: Positional movement of 4 m AHD contour position between November 2013 and March 2015, measured at 25 chainage lines along Old Bar Beach

Chainage Line (refer Site Plan, Appendix F)	Seaward Movement of Profile at 4 m AHD, Nov 2013 to Mar 2015	Comments
0 S	-0.5 m	Recession
100 S	0.6 m	Accretion. Orange tracer release site.
200 S	1.2 m	Accretion
300 S	2.0 m	Accretion
400 S	2.3 m	Accretion
500 S	6.0 m	Accretion. Measured at 3 m AHD due to relatively low beach profiles.
600 S	-0.5 m	Recession
700 S	0 m	No change
800 S	-1.1 m	Recession
100 C	0.5 m	Accretion
300 C	1.0 m	Accretion
500 C	1.2 m	Accretion. Lewis Street
600 C	1.4 m	Accretion. Meridian Resort
680 C	4.0 m	Accretion
760 C	3.6 m	Accretion
900 C and 1000 C	N/A	Racecourse Creek entrance, low berm heights (below 2m AHD) - analysis not undertaken. 2013 beach profiles above the 2015 profiles.
900 C 1000 C	N/A N/A	Racecourse Creek. Low berm heights (below 2m AHD) - analysis not undertaken. 2013 beach profiles appear to be above the 2015 profiles.
1100 C	0.5 m	Accretion
0 N	0.4 m	Accretion
100 N	-0.5 m	Recession. Old Bar Public School.
200 N	-3.0 m	Recession
300 N	-1.1 m	Recession. Taree-Old Bar SLSC, yellow tracer release site.
400 N	-0.9 m	Recession
500 N	1.8 m	Accretion
600 N	-1.2 m	Recession. Measured at 3 m AHD because 2013 profile truncated below this elevation.

Between the orange tracer release site and Old Bar Public School, it is evident that the beach generally experienced slight accretion during the period November 2013 to March 2015. Accretion of up to around 4 m (at 4 m AHD) occurred along this stretch of Old Bar Beach, with the most notable accretion occurring in the vicinity of Lewis Street. Minor recession of up to around 1 m was also measured at several chainage lines.

Minor accretion of 0.6 m (at 4 m AHD) occurred near the orange tracer release site (Chainage 100 S) between November 2013 and March 2015. This suggests that beach profiles in this area did not experience any significant overall change during the study period. This is also apparent in the cross-section plot for Chainage 100 S (Appendix F).

Between Old Bar Public School and Taree-Old Bar SLSC, a trend towards recession could be inferred from the survey comparison. Recession of up to 3 m was measured at the 4 m AHD elevation, although recession distances of around 1 m were more typical, while accretion of 1.8 m was recorded at Chainage 500 N.

Recession of 1.1 m (at 4 m AHD) occurred near the yellow tracer release site (Chainage 300 N) between November 2013 and March 2015. However, it is noted that the 2015 profile sits above the 2013 profile below an elevation of 3 m AHD (refer cross-section plot for Chainage 300 N, Appendix F). This suggests that, in an overall sense, accretion occurred on the lower beach face during the study period. This would generally increase the likelihood of yellow tracer material on the beach being buried during the study period, notwithstanding the intermittent influence of high wave energy in the swash zone particularly during storms.

The recent southwards migration of the entrance to Farquhar Inlet can also be inferred from comparison of the March 2015 survey with the aerial photograph (dated August 2013) shown in the Site Plan (Appendix F). The southern bank of the entrance to Farquhar Inlet was around 450 m further south in March 2015 than it was in August 2013. Based on field observations made during this study, it is estimated that the entrance migrated southwards by around 200 m between September 2014 and September 2015. This southwards migration is indicative of a closing entrance. Sand reserves on the northern side of the entrance were also observed to build up during the study period as part of this process.

5.3 Summary of Prevailing Conditions

The prevailing conditions for each period analysed are summarised below.

Between yellow/red tracer deployment and Sampling Exercise 1 (15/5/14 to 16/7/14)

- Offshore wave conditions during this period were relatively calm, with no major storm events, thereby limiting the likelihood of erosive conditions at Old Bar Beach.
- Based on visual observations of the beach, it was considered that the period May to July 2014 was likely neutral or slightly accretionary in terms of dunal sand volumes.

Between Sampling Exercise 1 and Sampling Exercise 2 (17/7/14 to 11/9/14)

- Average offshore wave conditions during this period were slightly higher than the corresponding long-term values.
- A significant storm event was recorded towards the end of August 2014, which resulted in erosive conditions at Old Bar Beach.
- In addition, based on visual observations of the beach, it was considered that the period July to September 2014 was erosive in terms of dunal sand volumes. This observation can be primarily attributed to the significant storm event which occurred at the end of August 2014.
- Visual surface plumes of turbid water were observed during offshore sampling on 11/9/14, which were possibly due to ongoing entrainment of sediment eroded from the beach during the preceding major storm event in late August 2014.

Between Sampling Exercise 2 and Sampling Exercise 3 (12/9/14 to 10/12/14)

- Average offshore wave conditions during this period were slightly lower than the corresponding long-term values, with no major storm events recorded.
- Based on visual observations of the beach in November 2014, this period was considered to be accretionary in terms of dunal sand volumes.
- It is therefore evident that there was some degree of beach recovery following the major storm event in August 2014, which would be expected under calmer wave conditions, devoid of any major storm activity.

Between Sampling Exercise 3 and Sampling Exercise 4 (11/12/14 to 12/3/15)

- Average offshore wave conditions during this period were slightly lower than the corresponding long-term values, with no major storm events recorded.
- Based on visual observations of the beach in March 2015, it is evident that the period December 2014 to March 2015 was likely accretionary in terms of dunal sand volumes, which is fairly typical for summer months.

Between Sampling Exercise 4 and Sampling Exercise 5 (13/3/15 to 16/9/15)

- Average offshore wave conditions during this period were generally consistent with the corresponding long-term values, with a series of minor storm events recorded during April-May 2015.
- Based on visual observations of the beach in September 2015, this period was considered to be slightly erosive in terms of dunal sand volumes.

Entire study period (15/5/14 to 12/3/15)

- Offshore wave conditions during the study period were generally consistent with long-term average conditions.
- Neutral or slightly accretionary conditions would be expected to prevail throughout the majority of this period, with the exception of discrete and infrequent storm events, with the most notable event occurring towards the end of August 2014.
- Based on a comparison of beach surveys undertaken in November 2013 and March 2015, the following is noted:
  - Slight accretion of dune profiles generally occurred along Old Bar Beach between the orange tracer release site and Old Bar Public School.
  - Minor recession of dune profiles generally occurred between Old Bar Public School and Taree-Old Bar SLSC. While profile recession (at 4 m AHD) was measured near the yellow tracer release site, accretion of the lower beach face was also evident. This would generally increase the likelihood of yellow tracer material on the beach being buried during the study period.
  - Analysis of profile change to the north of Urana Bombora, including the red tracer release site, could not be undertaken due to the limited spatial coverage of the November 2013 survey.
- The entrance to Farquhar Inlet migrated southwards by a distance of around 200 m between September 2014 and September 2015, i.e. between Sampling Exercise 2 and Sampling Exercise 5. The total southwards migration between August 2013 and

September 2015 was around 450 m. Southwards migration is indicative of a closing entrance state.

6 SAMPLE COLLECTION AND ANALYSIS

6.1 Sample Locations

6.1.1 Sampling Exercise 1

The objective of the first sampling exercise was to assess movement of the yellow and red tracer particles between May and July 2014. The orange tracer material was deployed after the first sampling exercise was completed, and was therefore assessed based on results obtained from subsequent sampling exercises.

As noted in **Section 5**, conditions at Old Bar Beach between yellow/red tracer deployment and Sampling Exercise 1 were relatively calm. This provided an opportunity to assess sediment transport during relatively benign, or ambient, wave conditions. According to WorleyParsons (2010a), net northward sediment transport occurs at Old Bar Beach under ambient conditions. As such, the adopted sampling region for the first sampling exercise focused on an area from around 500 m south of the yellow tracer release site to the northern end of the beach at Farquhar Inlet, i.e. Transects 3 to 14 (**Figure 16**).

In general, seven (7) samples were collected along each of these transects at the following positions:

- Beach samples: MHW, MSL and MLW;
- Surf-zone samples: -2 m AHD;
- Offshore samples: -4 m AHD, -7 m AHD and -11 m AHD.

However, it is noted that some of the proposed sampling locations over the rocky reef (Transects 10, 11 and 12) needed to be re-located in order to find nearby sand material for sampling, or omitted.

A total of 82 samples were collected during the first sampling exercise. The locations of these samples are plotted in **Figure 16**. It should be noted that the three beach samples (MHW, MSL and MLW) are represented by one dot on the sub-aerial beach for each transect due to their close proximity.

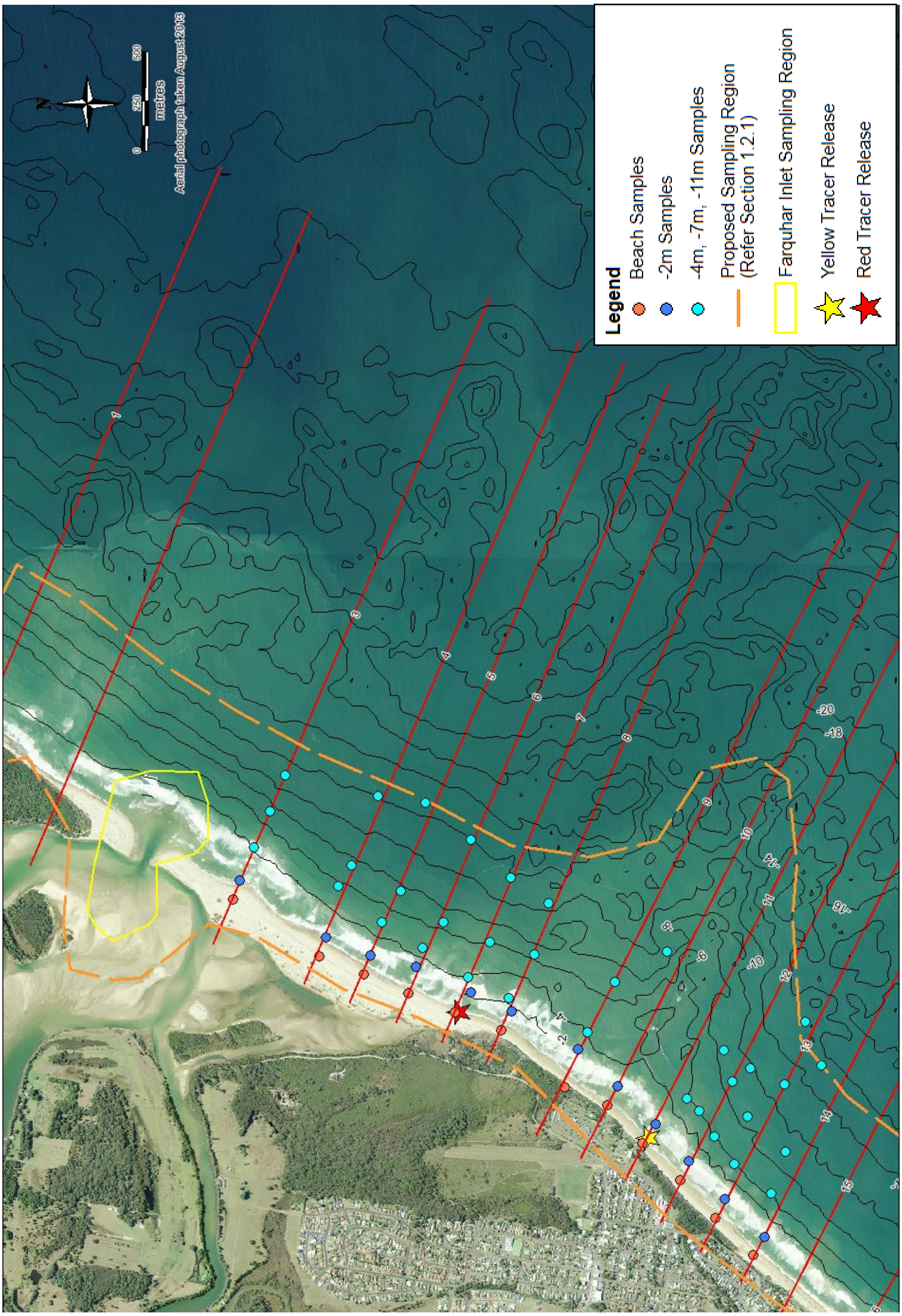


Figure 16: Sample Locations for Sampling Exercise 1

6.1.2 Sampling Exercise 2

The objective of the second sampling exercise was to assess movement of the yellow, red and orange tracer particles during the period July to September 2014.

As noted in Section 5, conditions at Old Bar Beach prior to Sampling Exercise 2 were particularly erosive, primarily due to the storm event which occurred at the end of August 2014. It was considered that offshore sediment transport would likely occur as a result of these conditions. Further, the results from Sampling Exercise 1 provided evidence of reasonably extensive longshore transport of the yellow and red tracers occurring under relatively calm conditions, so the sampling region for Sampling Exercise 1 (refer Section 6.1.1) was expanded to the north for Sampling Exercise 2 to include four transects (Transects 1, 2, 24 and 25), which covered around 2 km of the southern end of Manning Point Beach. A total of 25 transects were sampled (i.e. Transects 1 to 25). Sampling was also undertaken inside the Farquhar Inlet entrance area to assess whether the tracer material had been transported into this region.

In general, seven (7) samples were collected along each transect, extending between MHW and -11 m AHD. However, it was not possible to collect beach samples along Manning Point Beach and on the northern side of Farquhar Inlet because beach accessways were closed due to the erosion associated with the preceding storm event in August 2014.

A total of 168 samples were collected during Sampling Exercise 2, including nine (9) samples immediately inside[6] the entrance to Farquhar Inlet. The locations of these samples are plotted in **Figure 17**. It should be noted that the three beach samples (MHW, MSL and MLW) are represented by one dot on the sub-aerial beach for each transect due to their close proximity.

[6] The Farquhar Inlet sampling region adopted for Sampling Exercise 2 was extended further landward during subsequent sampling exercises.

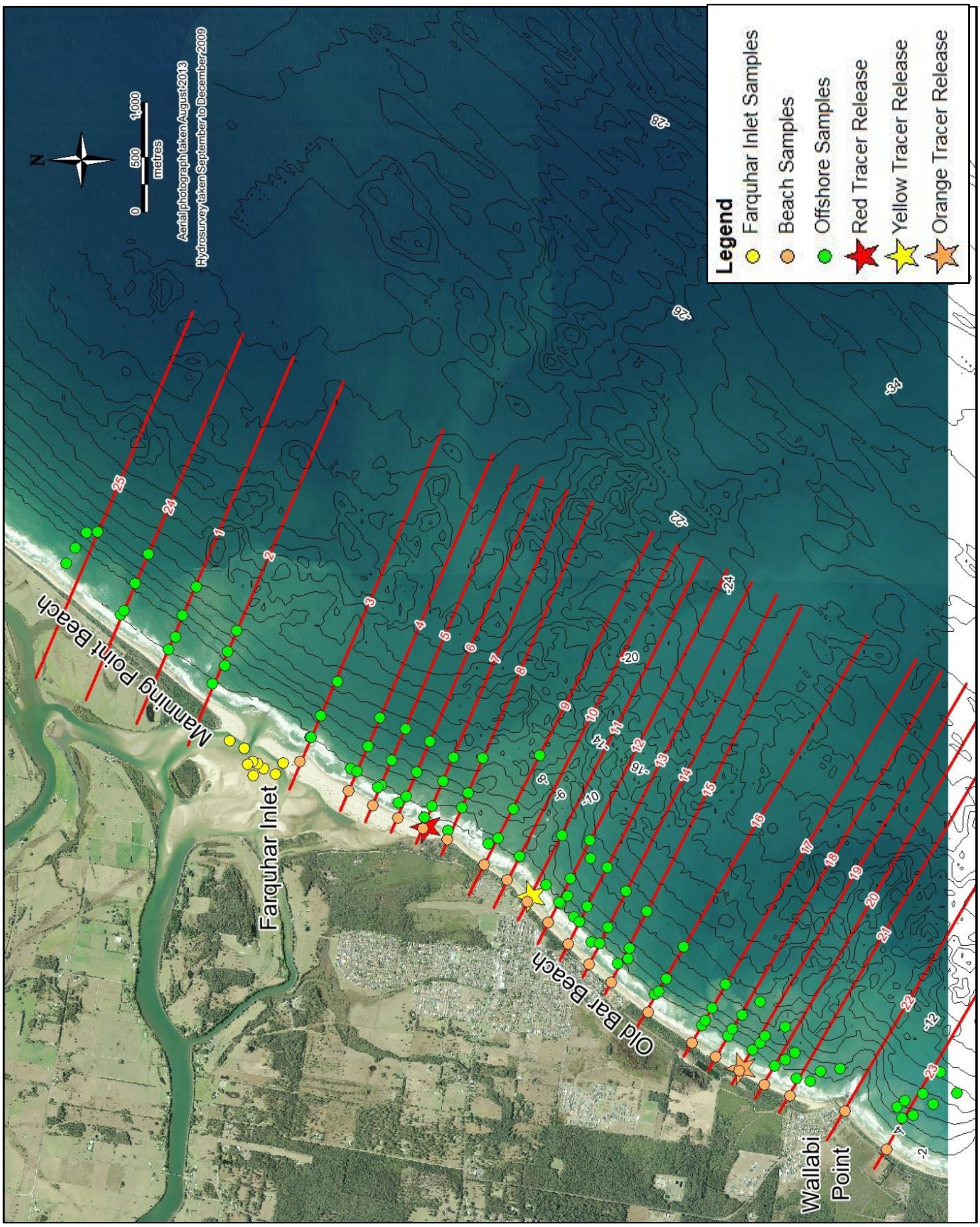


Figure 17: Sample Locations for Sampling Exercise 2

6.1.3 Sampling Exercise 3

The storm event which occurred at the end of August 2014 appeared to result in extensive alongshore and offshore sediment transport, based on the results from Sampling Exercise 2. In addition, the entire length of Old Bar Beach was generally observed to be in a relatively eroded state during Sampling Exercise 2.

In consideration of the above, the objective of Sampling Exercise 3 was to assess the post-storm transport of the yellow, red and orange tracer particles during the period September 2014 to December 2014. A number of sediment transport processes may occur at Old Bar Beach in the months following a storm event, including:

- onshore recovery of dunal sand volumes;
- transport of eroded sand from the beach into the entrance area of Farquhar Inlet, as per Gordon (2013);
- northwards transport of eroded sand from the beach beyond the entrance to Farquhar Inlet, i.e. along Manning Point Beach;
- permanent loss of eroded sand from the active beach system, for example:
  - offshore losses to water depths at or beyond the "inner" depth of closure[7];
  - offshore losses due to tidal/flood jetting from the entrance to Farquhar Inlet.

These mechanisms are discussed in **Section 8.1.3**.

As such, the sampling region for Sampling Exercise 2 (refer Section 6.1.2) was expanded for Sampling Exercise 3 to include:

- an additional transect extending from the entrance to Farquhar Inlet (Transect 26);
- several additional offshore samples located further offshore than previously sampled, i.e. beyond the estimated depth of closure of -12 m AHD.

It should also be noted that the sampling region was partly rationalised to permit collection of the above additional samples within the available budget. As a result, the following samples were not collected during Sampling Exercise 3:

- all samples along Transect 22, on the southern side of Wallabi Point[8];
- all MSL beach samples[9].

In general, six (6) samples were collected along each transect (i.e. Transects 1 to 26, excluding Transect 22) at the following positions:

- Beach samples: MHW and MLW;

---

[7] The "inner" depth of closure at Old Bar Beach is estimated to occur at around -12 m AHD, being the limit of wave breaking in extreme events and related seabed fluctuations (Royal HaskoningDHV, 2014). An "outer" closure depth at around -24 m AHD is estimated for Old Bar Beach, being the absolute limit of sand transport under cyclonic or extreme storm events. In general, once sand is transported offshore to depths at or beyond the "inner" closure depth, the potential for it to be re-worked back onto the sub-aerial beach is relatively limited, and may occur possibly over long timescales only. This sand may also be permanently lost from the system, contributing to recession.
[8] Tracer results from Sampling Exercise 2 indicated that negligible sediment transport occurred around Wallabi Point from the southern end of Old Bar Beach. Sampling along Transect 23 was retained to assess whether such transport may have occurred prior to Sampling Exercise 3.
[9] It was considered that the remaining MHW and MLW samples would be sufficient to provide an accurate indication of tracer counts in the sub-aerial beach zone.

- Offshore samples: -2 m AHD, -4 m AHD, -7 m AHD and -11 m AHD.

An additional 12 offshore samples were collected throughout the sampling region at water depths beyond the estimated depth of closure (-12 m AHD). These samples were typically collected at a bed elevation of around -14 m AHD, with one sample on Transect 3 also collected at a bed elevation of around -16 m AHD.

A total of 167 samples were collected during Sampling Exercise 3, including 11 samples in the vicinity of the entrance to Farquhar Inlet. The locations of these samples are plotted in **Figure 18**. It should be noted that the two beach samples (MHW and MLW) are represented by one dot on the sub-aerial beach for each transect due to their close proximity. The additional offshore samples collected during Sampling Exercise 3 (i.e. beyond the estimated closure depth of -12 m AHD) are denoted by red markers in Figure 18.

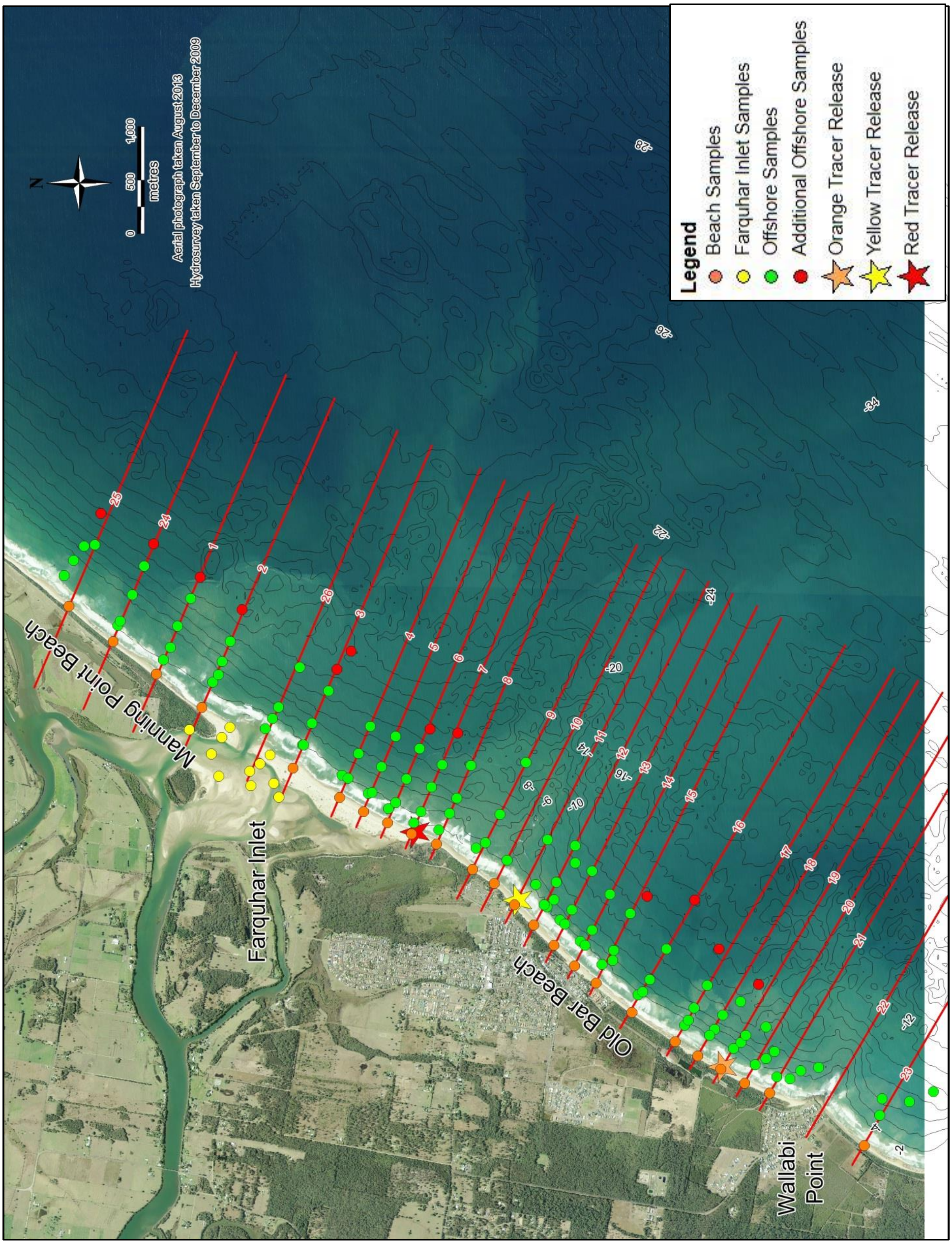


Figure 18: Sample Locations for Sampling Exercise 3

6.1.4 Sampling Exercise 4

The Sampling Exercise 3 sand tracer results indicated that some onshore recovery of sand occurred in the months following the significant storm event which occurred at the end of August 2014. However, these results also suggested that much of the tracer material transported offshore in August 2014 had remained in water depths around and beyond the estimated depth of closure, which provides evidence supporting the theory of permanent offshore sand losses from Old Bar Beach due to storm activity.

It was expected that further onshore transport of nearshore sand deposits would occur in the summer period, which is typically accretionary in terms of dunal sand volumes. As noted in Section 5, wave conditions during the period December 2014 to March 2015 were relatively calm, while visual observations indicated that some beach accretion may have occurred.

In addition, Sampling Exercise 4 provided an opportunity to evaluate whether beach nourishment would be an effective coastal management approach at Old Bar Beach. As such, investigations were undertaken to determine how much of the original tracer material released had remained on the beach and/or returned to shore during the summer period. A supplementary question that was addressed was what size fraction has remained and whether the appropriate size fraction is readily available locally, e.g. within Farquhar Inlet.

It should also be noted that, due to the timeframes involved between tracer deployment and Sampling Exercise 4[10], it is possible that burial of the tracer material would have occurred, which could not be assessed from surface sampling alone. For example, it is possible that any accretion of the beach may have occurred above the originally placed tracer material, which could not be detected in surface samples.

In consideration of the above, the objectives of Sampling Exercise 4 were as follows:

- assess whether ongoing onshore migration of sand occurred during the summer period;
- undertake a mass budget analysis which quantifies the amount of tracer material present on the beach at the time of sampling (for each size fraction) in comparison to the amount of tracer originally deployed;
- determine any vertical mixing or burial of the tracer material on the beach to more accurately quantify tracer results on the beach;
- undertake PSD analyses on a selection of samples collected within Farquhar Inlet and on the sandy beach to determine the suitability of sand within the entrance area for nourishment purposes (in terms of grain size).

As such, additional beach samples were added to the Sampling Exercise 3 sampling region (refer **Section 6.1.3**) for Sampling Exercise 4 to create a denser sampling region. This included:

- MSL samples for all transects sampled along Old Bar Beach during Sampling Exercise 3, i.e. Transects 3 to 21 (similar to Sampling Exercises 1 and 2);

[10] The timing of Sampling Exercise 4 (March 2015) was around 10 months following deployment of the yellow and red tracer material, and eight months following deployment of the orange tracer material.

- MHW, MSL and MLW samples for three (3) additional transects along Old Bar Beach where the adjacent transects were separated by 500 m, i.e. between Transects 3 and 4, Transects 15 and 16, and Transects 16 and 17, respectively;
- depth-averaged and surface samples (MHW, MSL and MLW) along transects separated by 125 m for a distance of 500 m north and south of each tracer release site, i.e. nine (9) transects per release site.

In general, the offshore sample locations from Sampling Exercise 3 were retained for Sampling Exercise 4.

A total of 314 samples were collected during Sampling Exercise 4, including 13 samples in the vicinity of the entrance to Farquhar Inlet. The locations of these samples are plotted in **Figure 19**. The additional beach sampling transects utilised during Sampling Exercise 4 are denoted by green lines in Figure 19.

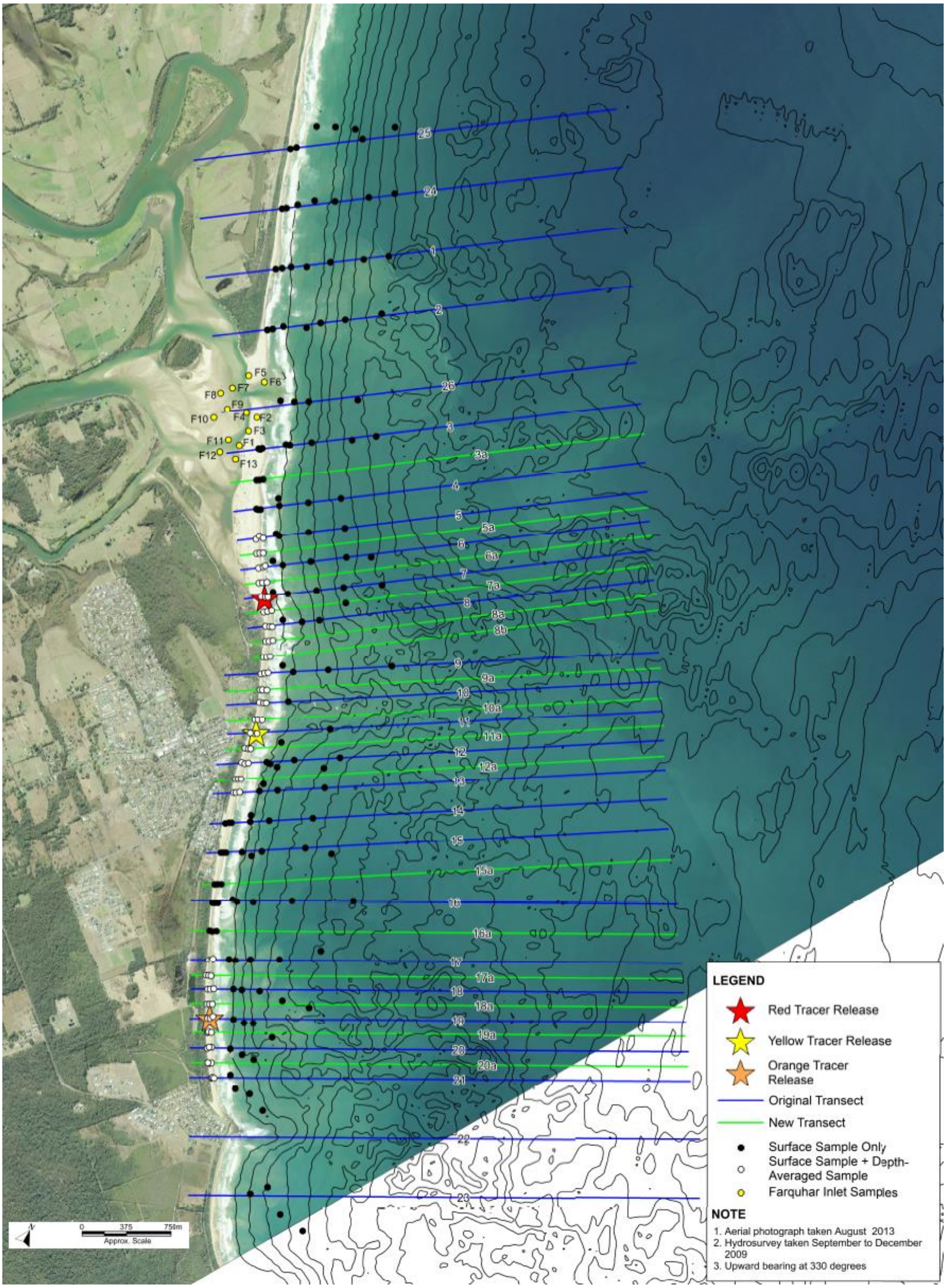


Figure 19: Sample Locations for Sampling Exercise 4

6.1.5 Sampling Exercise 5

Sampling Exercise 5 was undertaken in September 2015, i.e. six months after Sampling Exercise 4, and 16 months following study commencement. As such, Sampling Exercise 5 provided an opportunity to assess longer term sediment transport conditions at Old Bar Beach.

In addition, wave conditions during the study period prior to Sampling Exercise 4 were considered to be relatively mild compared to long-term conditions. Sampling Exercise 5 was therefore scheduled at the end of winter 2015 to provide the greatest opportunity for intervening storms to occur, which would enable further assessment of sediment transport due to storm activity. However, as described in **Section 5.1**, the prevailing wave conditions between Sampling Exercises 4 and 5 were generally consistent with long-term average conditions, and no major storm events were recorded.

While negligible transport into the Farquhar Inlet entrance area was observed for the yellow and orange tracers for Sampling Exercise 4 (as per the preceding sampling exercises), transport of the red tracer material to this area could be inferred from the results. This suggested that sand eroded from Old Bar Beach migrates to the entrance area, perhaps over timescales in the order of several months to years. Therefore, a key objective of Sampling Exercise 5 was to assess whether transport into Farquhar Inlet of the yellow and orange tracers (and ongoing transport of the red tracer) occurred prior to Sampling Exercise 5. Confirmation of a sediment transport pathway from Old Bar Beach to the entrance area would be necessary (as a minimum) for a sustainable backpass amenity nourishment strategy.

The depth-averaged sampling undertaken along the intertidal beach and inside the Farquhar Inlet entrance area during Sampling Exercise 4 was repeated for Sampling Exercise 5 to assess whether burial of the tracer material had occurred, and to undertake a mass budget analysis.

The Sampling Exercise 4 sampling region (refer **Section 6.1.4**) was retained for Sampling Exercise 5, with the exception of the following samples which were reallocated to allow for additional sampling inside Farquhar Inlet:

- all samples along Transect 24;
- MHWS samples for Transects 25, 1 and 2.

In general, the offshore sample locations from Sampling Exercises 3 and 4 were retained for Sampling Exercise 5.

A total of 313 samples were collected during Sampling Exercise 5, including 21 samples in the vicinity of the entrance to Farquhar Inlet (compared with 13 samples during Sampling Exercise 4). The locations of these samples are plotted in **Figure 20**. It is noted that the Farquhar Inlet samples were collected across a broader sampling region compared with the preceding sampling exercises. This was undertaken to provide a more comprehensive assessment of transport into the entrance area.

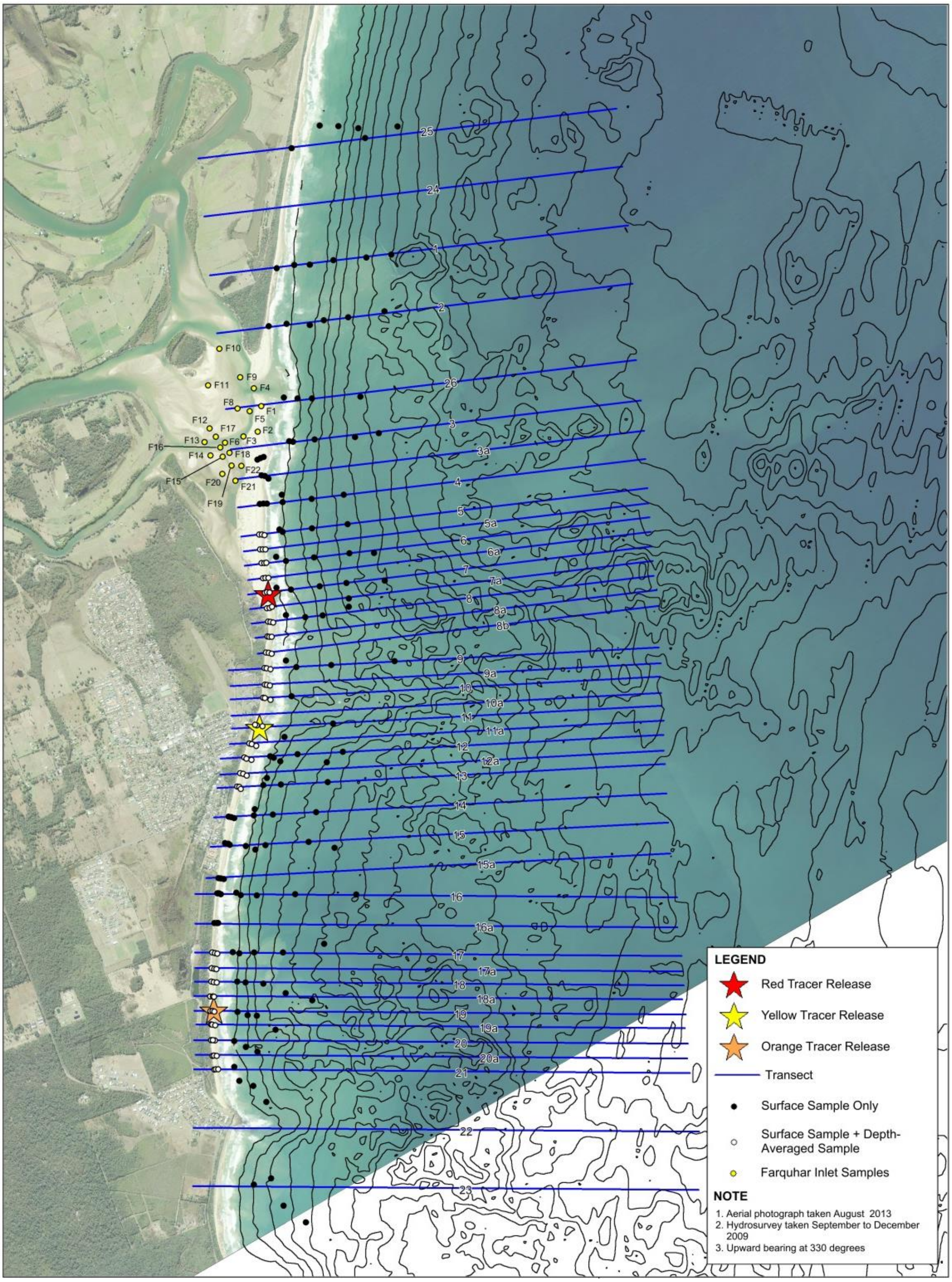


Figure 20: Sample Locations for Sampling Exercise 5

6.2 Sample Collection

6.2.1 Beach Sampling

The dates, personnel and site conditions during each beach sampling exercise are summarised in **Table 5**.

Table 5: Beach sampling details

Sampling Exercise	Date(s)	Personnel	Weather Conditions
Sampling Exercise 1	9/7/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC)	Fine Nearshore wave heights around 1 m
Sampling Exercise 2	10/9/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC)	Fine Nearshore wave heights around 1 m
Sampling Exercise 3	24/11/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC)	Mostly fine with a late thunderstorm Nearshore wave heights around 1 m
	25/11/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC)	Fine Nearshore wave heights around 1 m
Sampling Exercise 4	11/3/15 12/3/15	Patrick Lawless (RHDHV) Michael Griffith (GTCC)	Fine Nearshore wave heights around 1 m
Sampling Exercise 5	8/9/15 9/9/15	Patrick Lawless (RHDHV) Michael Griffith (GTCC)	Fine Nearshore wave heights around 1 m

Each beach sample location was accessed using a 4WD vehicle provided by Council. The Farquhar Inlet sample locations were accessed by foot during low tide from the northern end of Old Bar Beach.

Surface beach samples were collected as described in Section 3.2.2.

The depth-averaged beach samples collected during Sampling Exercise 4 were obtained by digging a small pit approximately 0.5 m deep[11] and 0.3 m wide, then transferring sand from the side of the pit into plastic containers using a stainless steel spoon. Care was taken to ensure that equal amounts of sediment were sampled along the entire vertical cross-section of the pit. The sediment in the plastic container was also homogenised to ensure that the sample was representative of depth-averaged conditions.

Similarly, the Farquhar Inlet samples collected during Sampling Exercise 4 were depth-averaged samples obtained by digging a small pit approximately 0.3-0.5 m deep, then transferring sand from the side of the pit into plastic containers using a stainless steel spoon. In comparison, the Farquhar Inlet samples collected during the preceding sampling exercises were surface samples obtained from the upper 5-10 cm of the surface. It was considered necessary to collect depth-averaged samples inside the entrance area during

[11] Sample material was collected from the upper sand layer only, which was less than 0.5 m deep at some of the sampling locations, being underlain by cobbles and gravel. Sample depths of less than 0.5 m were noted for the sampling locations where this occurred.

Sampling Exercise 4 to assess whether burial of the tracer material was occurring in this area.

Photographs taken during the Exercise 4 beach sampling and depth-averaged beach sampling, are provided in **Figure 21**.

Figure 21: Beach sampling (left: surface sampling; right: depth-averaged sampling), Exercise 4, 11 March 2015

The depth-averaged beach and Farquhar Inlet samples collected during Sampling Exercise 5 were obtained by vertically driving a 30 mm diameter polycarbonate tube through the beach profile over a distance of up to 0.5 m (or to refusal). A photograph taken during the Exercise 5 depth-averaged beach sampling is provided in **Figure 22**.

Sediment from the tube was transferred into plastic containers, with up to three cores taken per sample. The sediment in the plastic container was homogenised to ensure that the sample was representative of depth-averaged conditions.

For sample locations where it was not possible for the coring tube to penetrate the beach profile due to the presence of cobbles or coarse gravel, samples were collected by digging a small pit as per the method utilised during Sampling Exercise 4 as described above.

Figure 22: Sampling Exercise 5 depth-averaged sampling, 8 September 2015

6.2.2 Surf-zone Sampling (Sampling Exercise 1 only)

A bed elevation of -2 m AHD corresponds approximately with the outer edge of the surf zone during calm conditions. For Sampling Exercise 1 only, sample locations at -2 m AHD were accessed using an Inflatable Rescue Boat (IRB) provided and operated by volunteers from the Taree-Old Bar SLSC. For all subsequent sampling exercises, the surf-zone samples were collected as described in **Section 6.2.3**.

The Exercise 1 surf-zone samples were collected on 9 July 2014. Weather during the sampling was fine, with moderate onshore winds, and nearshore wave heights of around 1 m. Staff present included Patrick Lawless (RHDHV), Christopher Ross (GTCC) and two volunteers from Taree-Old Bar SLSC. To ensure the safety of the crew and for recovering the IRB, Michael Griffith (GTCC) monitored the sampling from the shore.

Samples were collected using a 30 cm long stainless steel dredge pipe with a 10 cm diameter opening, which was provided by MHL. The end of the dredge pipe was covered with geofabric material to permit drainage whilst still trapping fine particles. A photograph of the dredge pipe is provided in **Figure 23**.

Figure 23: Dredge pipe used for surf-zone sampling, 9 July 2014

Prior to sampling, the dredge pipe was thoroughly rinsed in seawater and new geofabric material was taped to the end of the pipe. This process was repeated between sampling locations to avoid any potential contamination between sites.

The dredge pipe was lowered to the sea bed at each sampling location, then dragged along the bed for several metres to collect the sediment. The dredge pipe was then hauled back onto the IRB where sub-sampling was carried out.

Samples were transferred from the dredge pipe into a stainless steel bowl and then into plastic containers using a stainless steel spoon. The spoon and bowl were also rinsed in seawater following collection of each sample to minimise the risk of cross-contamination between sites. Each sample container was clearly labelled and stored in a plastic zip-lock bag to preserve the sample in the event that the plastic container was damaged prior to analysis (e.g. during transit to the analytical laboratory).

6.2.3 Offshore Sampling

The dates, personnel and site conditions during each offshore sampling exercise are summarised in **Table 6**.

Table 6: Offshore sampling details

Sampling Exercise	Date/s	Personnel	Weather Conditions
Sampling Exercise 1	16/7/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC) Noel and Dan Gogerly (*skipper/deckhand*)	Fine Moderate onshore winds Nearshore wave heights around 1 m
Sampling Exercise 2	11/9/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC) Noel and Dan Gogerly (*skipper/deckhand*)	Fine Moderate onshore winds Nearshore wave heights around 1 m
Sampling Exercise 3	26/11/14	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Christopher Ross (GTCC) Bob McDonell (GTCC) Noel and Dan Gogerly (*skipper/deckhand*)	Overcast Moderate NE winds Seas and swell up to around 1.5 m
	10/12/14[12]		Fine Moderate onshore winds Nearshore wave heights around 1 m
Sampling Exercise 4	10/3/15	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Stuart Hood (GTCC) Noel and Dan Gogerly (*skipper/deckhand*)	Fine Light winds Nearshore wave heights around 1 m
Sampling Exercise 5	16/9/15	Patrick Lawless (RHDHV) Michael Griffith (GTCC) Bob McDonell (GTCC) Noel and Dan Gogerly (*skipper/deckhand*)	Fine Light winds Nearshore wave heights around 1 m

Offshore samples were collected as described in Section 3.2.3. Photographs taken during the Exercise 3 offshore sampling are provided in **Figure 24**.

Figure 24: Offshore sampling, 26 November 2014 (left) and 10 December 2014 (right)

[12] It was not possible to collect all samples on 26/11/14 due to poor weather conditions (strengthening NE winds and increasing wave heights). The sampling was cancelled to ensure the safety of all personnel. It would have been preferred to complete the offshore sampling work within a few days of this date; however weather conditions generally did not permit this until early December 2014. While the samples collected on 10/12/14 were subjected to additional sediment transport processes (in comparison to the samples collected between 24/11/14 and 26/11/14), it has been assumed that this would not have any significant implications for the data analysis presented herein.

6.3 Sample Analysis

All the collected samples were shipped to the ETS ISO 9001 certified laboratory in the UK. All samples were analysed for tracer particle counts, which were then converted into particle counts per square metre of the grab area.

The sample analysis methodology described in Section 3.3 was followed for the samples collected during each sampling exercise.

Particle sizing of tracer particles detected in each sample was carried out manually, concurrently with counting the different colours of sand tracer particles. Initially, ETS sized a range of sand particles using a fluorescence microscope and a calibrated graticule to cover the size bands reported, including:

- 'fine': 125-250 µm, i.e. equivalent to fine sand (Wentworth grain size classification, refer **Figure 25**);
- 'medium': 250-375 µm, i.e. finer fraction of medium sand (Wentworth grain size classification, refer **Figure 25**); and,
- 'coarse': 375-500 µm, i.e. coarser fraction of medium sand (Wentworth grain size classification, refer **Figure 25**).

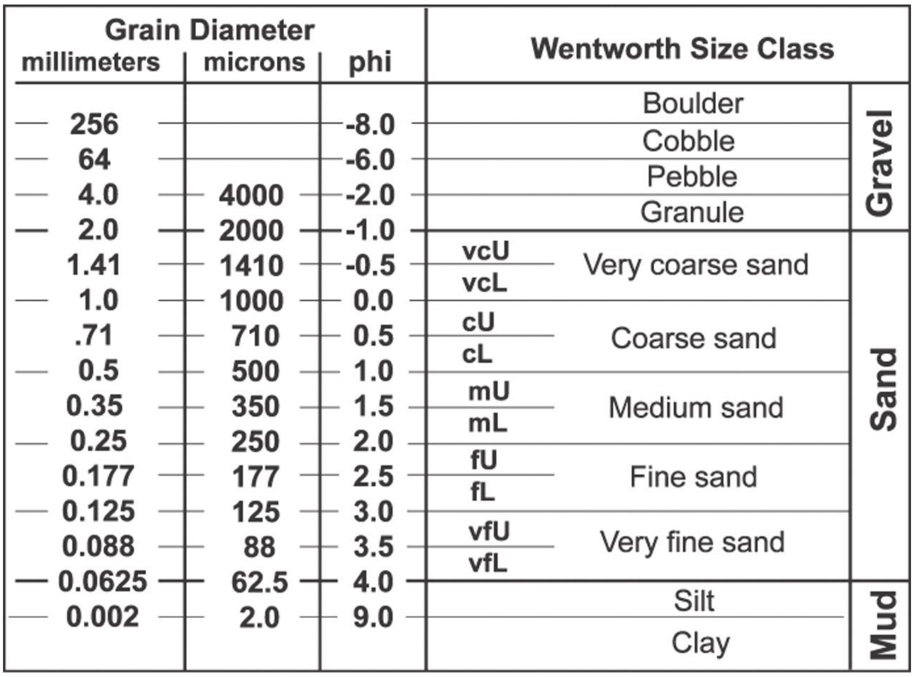


Figure 25: Wentworth grain size classification

Individual grains for each of these size bands were selected from each of the three tracer stocks (yellow, red and orange). These individual grains were mounted on microscope slides and used as a reference slide to size each fluorescent tracer particle detected in the samples for each colour.

7 RESULTS

7.1 Yellow Tracer (Surf Life Saving Club)

7.1.1 Preamble

Yellow tracer counts for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G1**, **Appendix G**.

Particle size analysis results for the yellow tracer material for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G2**.

Yellow tracer counts and particle size analysis results for the yellow tracer material for the depth-averaged beach samples collected during Sampling Exercises 4 and 5 are plotted in **Figure G3**.

Yellow tracer results for all samples collected during the study period are also tabulated in **Appendix G**.

7.1.2 Tracer Counts

A summary of the key results for each sampling exercise is provided below.

Sampling Exercise 1 (July 2014)

Positive counts[13] for the yellow tracer were recorded in 42 of the 82 samples collected and analysed for Sampling Exercise 1.

Relatively high yellow tracer counts were found in all beach sampling locations in the immediate vicinity of the yellow tracer release site at the Taree-Old Bar SLSC (Transects 9 to 12)[14] with high concentrations extending as far north as the red tracer release site. Furthermore, at least one positive sample was recorded in all transects sampled (Transects 3 to 14).

These results indicate significant transport of the yellow tracer from the source at the Taree-Old Bar SLSC. The results indicated movement and deposition of tracer along the beach and immediate nearshore areas primarily in a northerly direction, although some limited southerly transport was also observed, but over a much smaller distance than to the north. Higher concentrations were recorded in the more northerly transects away from the release site (Transects 3 to 10) than south (Transects 11 to 14) which suggests a stronger trend for northerly migration.

Sediment transport offshore from the beach was also observed, with a few positive samples recorded in deeper water, mostly to the north. However, for the results obtained during the

[13] A positive sample means either fine, medium or coarse sized tracer particles were detected. It was possible to have multiple size classes detected for a particular sample.
[14] The yellow tracer was deployed at approximately Transect 11 (refer Figure 1, Section 1.2.1).

first sampling exercise, offshore transport does not appear to be as significant as northward longshore transport at Old Bar Beach.

In terms of the samples where no tracer was detected, these were principally towards the south and offshore, which provides further evidence of the mainly longshore and nearshore northerly transport demonstrated by the positive tracer samples.

Sampling Exercise 2 (September 2014)

Positive counts for the yellow tracer were recorded in 45 of the 168 samples collected and analysed for Sampling Exercise 2.

The majority of positive samples were recorded between Transects 13 and 24 (moving south to north). This covered an area extending approximately 5 km alongshore from just south of the yellow tracer release site to the northern side of Farquhar Inlet, more than 1 km along Manning Point Beach. These results indicated significant dispersal from the release site both in a southerly and northerly direction, although higher concentrations of yellow tracer were recorded in the more northerly transects away from the release site than south which suggests a stronger trend for northerly migration.

Relatively high yellow tracer counts were measured in several beach sampling locations in the immediate vicinity of the yellow tracer release site (i.e. Transects 9 to 12), however the concentrations were lower than those measured in Sampling Exercise 1 for the same area. The data suggests that some of the tracer material remained in the intertidal beach system despite the significant erosion observed during Sampling Exercise 2 that was associated with the August 2014 storm event. It is also possible that some of this tracer material was transported back onto the beach in early September 2014 following the storm event, i.e. during the subsequent calm conditions prior to sampling on 10/9/15.

Strong evidence of offshore transport could also be inferred from the results, with positive yellow tracer counts recorded in six of the -11 m AHD samples[15], and eight of the -7 m AHD samples[16], mostly north of the tracer release site.

The data also indicated several positive counts to the south, although the concentrations measured were generally lower than to the north, extending approximately 500 m south from the yellow tracer release site along the beach and in the nearshore area. Only two very low concentration and positive samples were recorded south of this area, confirming virtually no transport of yellow tracer south towards and up to Wallabi Point either alongshore or in deeper waters offshore. This suggests that sediment transport during the preceding winter months was generally northwards excluding some dispersion and mixing immediately around the yellow release site.

Of the nine (9) samples collected inside Farquhar Inlet during Sampling Exercise 2, only one positive and very low count was obtained for the yellow tracer. This suggests that under the conditions experienced until September 2014, sediment transport from the yellow tracer

[15] Positive yellow tracer counts were recorded in the -11 m AHD samples collected along Transects 1, 3, 5, 6, 10 and 18.
[16] Positive yellow tracer counts were recorded in the -7 m AHD samples collected along Transects 2, 4, 5, 6, 7, 9, 13 and 24.

release site to the entrance area was likely negligible. However, it is also possible that the yellow tracer material had migrated into parts of the entrance area that were not sampled, or that yellow tracer transported into the entrance area was buried below the surface where samples were taken. This possibility is supported by the observation of a rapidly southwards migrating entrance during the study period, which is indicative of an infilling entrance.

Sampling Exercise 3 (November-December 2014)

Positive counts for the yellow tracer were recorded in 50 of the 167 samples collected and analysed for Sampling Exercise 3.

Once again, the majority of positive samples were recorded between Transects 13 and 4 (moving south to north). This covered an area extending approximately from 500 m to 750 m south of the yellow tracer release site, to the southern side of Farquhar Inlet. Several positive samples were also recorded on the northern side of Farquhar Inlet up to the most northerly limit of sampling, but were not consistently positive in all samples. These results continue to confirm and indicate significant dispersal from the release site in a predominantly northerly direction (at least 5 km), although minor southwards transport (up to 2 km) can also be inferred from the results, with the pattern of deposition principally along the shore and in nearshore areas. Similar to the results for Sampling Exercise 2, no yellow tracer was recorded around Wallabi Point or in offshore samples to the south, highlighting limited transport and deposition south of the yellow tracer release site.

Positive counts for the yellow tracer were recorded in 11 of the 49 samples collected along the intertidal beach during Sampling Exercise 3, with the majority of these samples collected between Transects 11 and 4 (moving south to north). These results indicate that the yellow tracer material on Old Bar Beach in November 2014 was generally confined to the northern end of the beach between the yellow tracer release site and Farquhar Inlet. However, it is noted that yellow tracer counts in the beach samples were relatively low in comparison to the results from previous sampling exercises, which suggests that the tracer material had possibly been mixed and buried as well as being transported away from the intertidal beach during the preceding study period.

Based on analysis of results for samples collected at bed elevations of around -2 m AHD and -4 m AHD, it is evident that a relatively high proportion of the positive samples were collected in the inshore zone. Positive counts for the yellow tracer were recorded in 23 of the 48 samples collected in this zone, while most of the highest yellow tracer counts were also recorded in these samples. It should be noted that the majority of sediment transport in the active beach system generally occurs within the inshore zone, i.e. between the intertidal beach and offshore bar. As such, it is evident that much of the yellow tracer material remained in the active beach system at the time of sampling in November-December 2014, and it is possible that this material will be subsequently transported back onto the intertidal beach under normal (accretionary) conditions expected during summer months and observed in the Sampling Exercise 4 data.

Similarly, positive yellow tracer counts were recorded in a reasonably high proportion of the -7 m AHD samples. Of the 24 samples collected at this depth, positive yellow tracer counts were recorded in 10 samples and these were also primarily located between Transects 13 and 4 (moving south to north).

Relatively minor sediment transport to the outer part of the active beach system can be inferred from the Sampling Exercise 3 results, with positive yellow tracer counts recorded in four of the 23 samples collected at a bed elevation of around -11 m AHD[17], and just one of the additional offshore samples collected beyond the estimated depth of closure[18].

Of the 11 samples collected around the entrance to Farquhar Inlet during Sampling Exercise 3, only one positive count was obtained for the yellow tracer, although it is noted that this sample was collected on the beach at the entrance mouth rather than within the entrance. This suggests that under the conditions experienced until November 2014[19], sediment transport from the yellow tracer release site to the entrance area was limited. It is noted that similar observations were made based on the results from Sampling Exercise 2.

Sampling Exercise 4 (March 2015)

Positive counts for the yellow tracer were recorded in 90 of the 314 samples collected and analysed for Sampling Exercise 4. This represents a very similar proportion of positive samples recorded compared with previous sampling rounds despite additional transects being sampled on the beach and depth-averaged samples being collected.

The highest yellow tracer counts were recorded between Transects 12 and 3 (moving south to north). This covers an area extending approximately 2.7 km from between the yellow tracer release site and the southern side of Farquhar Inlet. These results indicate that, at the time of sampling in March 2015, the majority of the detected yellow tracer material was located along the northern end of Old Bar Beach. This observation is similar to the previous three sampling exercises, although over time, slightly more positive samples have been measured towards the south as far Transect 21, but never further south up to or beyond Wallabi Point. Compared with previous results however, this data indicates far more positive albeit low counts towards the southern end of Old Bar Beach indicating a transport process and deposition to this area not previously observed or as clearly defined.

In general, the spatial distribution of positive yellow counts for Sampling Exercise 4 was similar to the results for Sampling Exercise 3, i.e.:

- significant dispersal from the release site in a predominantly northerly direction (at least 5 km up to the northerly limit of sampling), with minor southwards transport (up to 2.5 km);
- for the beach samples, positive yellow tracer counts were typically confined to the northern end of Old Bar Beach between the yellow release site and Farquhar Inlet;
- positive yellow tracer counts were recorded in a reasonably high proportion of the inshore (i.e., -2 m AHD and -5 m AHD) and -7 m AHD samples, and these samples were also typically collected along the northern end of Old Bar Beach, although positive counts were also recorded further south;
- negligible yellow tracer counts were recorded inside the entrance to Farquhar Inlet, with only one positive count obtained for the yellow tracer from a total of 13 samples collected in this area.

[17] Positive yellow tracer counts were recorded in the -11 m AHD samples collected along Transects 10, 13, 1 and 6.
[18] A positive yellow tracer count was recorded in the -14 m AHD sample collected along Transect 6.
[19] In essence, with Farquhar Inlet open and wave forcing representative of mild to average conditions punctuated by a single large storm event in August 2014.

However, it is noted that a reduced number of positive samples for yellow tracer were recorded in deeper water during Sampling Exercise 4 in comparison to the results for Sampling Exercise 3. A positive yellow tracer count was recorded in just one of the 35 samples collected at and beyond a bed elevation of around -11 m AHD[20], compared to five positive samples during Sampling Exercise 3. This suggests that ongoing onshore migration of the yellow tracer material occurred between December 2014 and March 2015.

Positive yellow tracer counts were recorded in 23 depth-averaged beach samples extending as far north as Transect 5 with the majority of these samples collected between Transects 11A and 8A (moving south to north), which covers an area extending approximately 1 km from just south of the yellow release site to near the Urana Bombora. These results indicate that some burial of the tracer had occurred in the vicinity of and to the north of the yellow release site.

Despite yellow tracer being measured in three surface samples in the vicinity of the orange tracer release site, no yellow tracer was measured in any of the depth-averaged samples in the same area. This highlights that detection of yellow tracer around the orange tracer release site was only surface with no deeper deposits detected. Conversely, positive depth-averaged beach samples recorded around the yellow tracer release site indicate that yellow tracer may have remained buried from the point it was released or been re-buried over the study period as a result of seasonal variations including accretion in the beach profile. Clearly, north of the yellow tracer release site and up to and north of the red release site, yellow tracer has been buried at some point during the study period, possibly during the more accretionary summer period.

However, it is noted that yellow tracer counts in all samples were relatively low in comparison to the results from previous sampling exercises, which suggests that, during the study period, the tracer material has:

- generally been transported away from the active beach system, and/or
- undergone burial in the nearshore and offshore regions.

Sampling Exercise 5 (September 2015)

Positive counts for the yellow tracer were recorded in 59 of the 313 samples collected and analysed for Sampling Exercise 5, compared with 90 positive counts (from 314 samples) for Sampling Exercise 4. This provides further evidence of the yellow tracer material being progressively transported away from the active beach system and/or buried offshore during the study period.

The majority of yellow tracer counts were recorded between Transects 12 and 26 (moving south to north). This covers an area extending approximately 3 km between the yellow tracer release site and just north of Farquhar Inlet. These results indicate that, at the time of sampling in September 2015, the majority of the detected yellow tracer material was located along the northern end of Old Bar Beach. Similar observations were inferred from the results for the previous sampling exercises.

[20] A positive yellow tracer count was recorded in the -11 m AHD sample collected along Transect 6.

Furthermore, it is noted that the minor southwards transport inferred from the Sampling Exercise 4 results was not evident in the results for Sampling Exercise 5, with Transect 14 representing the southward extent of positive yellow tracer counts, i.e. some 2.5 km north of Wallabi Point. This indicates that the yellow tracer material previously transported southwards was probably returned northwards following the summer period.

As per the results for Sampling Exercise 4, positive yellow counts in the offshore samples for Sampling Exercise 5 were predominantly recorded in the inshore (i.e., -2 m AHD and -5 m AHD) and -7 m AHD samples collected along the northern end of Old Bar Beach. Similarly, a positive yellow tracer count was recorded in just one of the 33 samples collected at and beyond a bed elevation of around -11 m AHD[21]. This suggests that significant offshore migration of the yellow tracer material did not occur between March 2015 and September 2015.

Of the 21 samples collected around the entrance to Farquhar Inlet, five positive counts were measured for the yellow tracer. This was the first time during the study period that reasonably significant concentrations of yellow tracer were recorded in the entrance area. This provides strong evidence that sand eroded from Old Bar Beach in the vicinity of Taree-Old Bar SLSC is at least partially transported to the entrance area, and that this transport occurs over timescales of several months to years.

Positive yellow tracer counts were recorded in 16 depth-averaged beach samples extending between Transects 11A and 5 (moving south to north), which covers an area extending approximately 1 km from just south of the yellow release site to around 500 m north of the red release site. However, compared to the results for Sampling Exercise 4, it appears that the amount of yellow tracer buried on the beach reduced between March 2015 and September 2015.

Furthermore, while the majority of positive depth-averaged beach samples collected during Sampling Exercise 4 were recorded north of Transect 11A, the positive depth-averaged samples for Sampling Exercise 5 were primarily recorded north of Transect 9a, a northwards shift of around 500 m. This observation is consistent with a predominantly northwards longshore transport mechanism which would, over time, progressively transport the yellow tracer further away from the release site in a northerly direction.

7.1.3 Particle Size Results

In general, the following observations could be made from the yellow particle size results for each sampling exercise:

- It was predominantly fine and medium sized tracer particles that were transported and deposited alongshore from the yellow tracer release site during the study period. This transport was principally northwards, but with some transport also to the south.
- Only fine sized tracer particles were transported into deeper water offshore.
- The highest medium sized yellow tracer counts were predominantly recorded in the vicinity of the yellow tracer release site, typically along the intertidal beach and the inshore zone. These results suggest that the transport of medium sized yellow tracer particles was typically confined to the inshore zone, with northwards

[21] A positive yellow tracer count was recorded in the -11 m AHD sample collected along Transect 4.

alongshore transport not continuing to the entrance to Farquhar Inlet until Sampling Exercise 5, and offshore transport being limited.

- Alongshore transport of the coarse sized yellow tracer particles was very minor, while offshore transport was not observed.

A summary of other key results for each sampling exercise is provided below.

Sampling Exercise 1 (July 2014)

- Fine sized yellow tracer particles were recorded in 41 of the 42 positive samples.
- Medium sized yellow tracer particles were recorded in 16 of the 42 positive samples and were predominantly found around the yellow tracer release site (Transects 9 to 12) and more northerly beach and nearshore samples (Transects 5 to 8) with no offshore transport observed.
- Coarse yellow tracer particles were only recorded in seven of the 42 positive samples between Transects 7 and 11. Further, each of these samples were collected along the beach or immediate nearshore, indicating a similar distribution to the medium-sized tracer particles although they were not distributed as far north or present in as many nearshore samples.
- Only one sample south of the release site contained medium and coarse yellow tracer particles; the remaining five positive samples contained fine yellow tracer particles only.

Sampling Exercise 2 (September 2014)

- Fine sized yellow tracer particles were recorded in 42 of the 45 positive samples, including the one positive sample collected inside the entrance to Farquhar Inlet.
- Medium sized yellow tracer particles were recorded in 12 of the 45 positive samples, extending over a similar area to the results from Sampling Exercise 1, suggesting little or no increase in the transport and deposition of medium sized yellow tracer particles between July and September 2015. These were predominantly found around the yellow tracer release site, between Transects 10 and 12.
- Six of the samples containing medium sized yellow tracer particles were collected on the intertidal beach, with the remaining six samples collected in inshore areas extending to bed elevations of -5 m AHD.
- Coarse yellow tracer particles were only recorded in two of the positive samples. Both of these samples were collected on the intertidal beach, at Transects 10 and 12 respectively (i.e. close to the yellow tracer release site at Transect 11.

Sampling Exercise 3 (November-December 2014)

- Fine sized yellow tracer particles were recorded in 43 of the 50 positive samples, including the one positive sample collected near the entrance to Farquhar Inlet.
- Medium sized yellow tracer particles were recorded in 16 of the 50 positive samples, extending slightly further north and south than the area defined in Sampling Exercises 1 and 2. Once again, medium sized yellow tracer particles were predominantly found around the yellow tracer release site, between Transects 12 and 5 (south to north).

- Six of the samples containing medium sized yellow tracer particles were collected on the intertidal beach, while the remaining 10 samples were collected in nearshore areas extending to water depths of -7 m AHD.
- Coarse yellow tracer particles were only recorded in one of the positive samples. This sample was collected in the surf zone (-2 m AHD) at Transect 8.

Sampling Exercise 4 (March 2015)

- Fine sized yellow tracer particles were recorded in 75 of the 90 positive samples, including the one positive sample collected near the entrance to Farquhar Inlet and also towards the south in the vicinity of the orange tracer release site.
- Medium sized yellow tracer particles were recorded in 27 of the 90 positive samples, with five of these recorded in depth-averaged samples around Transects 11 and 11A (i.e. nearby the yellow tracer release site). The highest medium yellow tracer counts were predominantly recorded in the vicinity of and to the north of the yellow tracer release site (i.e. between Transects 11 and 4), typically along the intertidal beach and the inshore zone, although several were also recorded to the south almost as far as the orange tracer release site.
- Only two coarse sized yellow tracer particles were recorded in the samples collected during Sampling Exercise 4. Both of these were depth-averaged samples collected around the MLW position; one was recovered adjacent to the yellow tracer release site with the other collected just south of the red tracer release site.
- The fact that several samples, in particular multiple depth-averaged samples, indicated both medium and coarse sized yellow tracer particles in the immediate vicinity of the yellow tracer release site strongly suggests that a proportion of the yellow sand tracer was not transported during the study period despite apparent erosion in August 2014.

Sampling Exercise 5 (September 2015)

- Fine sized yellow tracer particles were recorded in 47 of the 59 positive samples, including each of the positive samples collected near the entrance to Farquhar Inlet.
- Medium sized yellow tracer particles were recorded in 15 of the 90 positive samples, including one of the samples collected inside the entrance to Farquhar Inlet and three of the depth-averaged beach samples collected north of the yellow tracer release site between Transects 7A and 9A. Just one of the positive samples for medium sized yellow tracer was recorded offshore[22], with the remaining positive samples collected along the intertidal beach and inside Farquhar Inlet.
- Coarse sized yellow tracer particles were recorded in five of the samples collected during Sampling Exercise 5. Each of these samples was collected along the intertidal beach, covering an area extending between Transects 11A and 4. This included one depth-averaged sample at Transect 7.

[22] This sample was collected in the surf zone (-2 m AHD) at Transect 9.

7.2 Red Tracer (South of Farquhar Inlet)

7.2.1 Preamble

Red tracer counts for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G4**, **Appendix G**.

Particle size analysis results for the red tracer material for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G5**.

Red tracer counts and particle size analysis results for the red tracer material for the depth-averaged beach samples collected during Sampling Exercises 4 and 5 are plotted in **Figure G6**.

Red tracer results for all samples collected during the study period are also tabulated in **Appendix G**.

7.2.2 Tracer Counts

A summary of the key results for each sampling exercise is provided below.

<u>*Sampling Exercise 1 (July 2014)*</u>

In contrast to the yellow tracer results, the results of the red tracer released just south of Farquhar Inlet show that this section of Old Bar Beach had less net sediment transport than the yellow release site under the same metocean conditions experienced between May 2014 and July 2014. Positive counts for the red tracer were recorded in 29 of the 82 samples collected and analysed, in comparison to 42 positive samples recorded for the yellow tracer. Moreover, red tracer results that were positive were generally much lower in concentration than the yellow tracer results.

However, similar to the yellow tracer, the red tracer results also indicated longshore sediment transport in a net northerly direction, with the majority of positive samples and the highest concentrations measured on the beach to the north of the red release site[23]. Only seven (7) positive samples were recorded south of the red release site, again principally along the beach, with the southernmost sample found in Transect 13. In comparison, 20 positive samples were recorded north of the red release site.

Furthermore, the red tracer count results also indicated, as per the yellow tracer results, that under the conditions experienced between May 2014 and July 2014, there was some offshore movement of sand from the beach. However, this also appears to be of lower significance in comparison to the observed northward longshore transport. Negligible red tracer was measured nearshore or offshore south of the red tracer release site.

[23] The red tracer was deployed at approximately Transect 7 (refer **Figure 1**, **Section 1.2.1**).

Sampling Exercise 2 (September 2014)

Positive counts for the red tracer were recorded in 59 of the 168 samples collected and analysed for Sampling Exercise 2.

Positive samples were recorded between Transects 12 and 25 (moving south to north), again indicating significant transport from the release site. This covers an area extending approximately 5.5 km alongshore; i.e. from around 1.5 km south of the red tracer release site to the northern side of Farquhar Inlet, more than 2 km along Manning Point Beach.

Despite being released approximately 1.25 km further north than the yellow tracer, the southwards extent that the red tracer appeared to have been transported was similar to the yellow tracer, i.e. around Transects 12 and 13. This suggests that, for the conditions experienced prior to Sampling Exercise 2, there was a greater potential for southwards sediment transport in the vicinity of Urana Bombora than further south.

The highest red tracer counts were recorded between Transects 8 and 3 (moving south to north), suggesting a stronger trend for northerly transport. This covered an area extending between Urana Bombora and the entrance to Farquhar Inlet, i.e. the northern end of Old Bar Beach. It is also noted that the highest red tracer counts were generally recorded in samples collected along the intertidal beach and inshore zone. These results suggest that the majority of the detected red tracer material remained in the active beach/inshore zone along the northern end of Old Bar Beach.

Strong evidence of offshore transport from the red release site could also be inferred from the results, with positive red tracer counts recorded in six of the -11 m AHD samples[24], and eight of the -7 m AHD samples[25]. Similar results were observed for the yellow tracer in Sampling Exercise 2.

Of the nine (9) samples collected inside Farquhar Inlet during Sampling Exercise 2, only one positive count was recorded for the red tracer. As per the yellow tracer results, this suggests that under the conditions experienced until September 2014, sediment transport from the red tracer release site into the entrance area was likely negligible. This is surprising considering that the red tracer was recorded in all four transects north of the inlet in nearshore and offshore samples.

Sampling Exercise 3 (November-December 2014)

Positive counts for the red tracer were recorded in 48 of the 167 samples collected and analysed for Sampling Exercise 3.

Similar to the Sampling Exercise 2 results, positive counts for the red tracer were generally recorded between Transects 12 and 25 (moving south to north), which covers an area extending from around 1.5 km south of the red tracer release site to around 4 km north of the red tracer release site on Manning Point Beach. Only two positive samples were recorded further south on Transects 16 and 20 respectively, although the counts were very low and can possibly be considered as outliers. Higher concentrations of red tracer were recorded in

[24] Positive red tracer counts recorded in the -11 m AHD samples collected along Transects 1, 3, 7, 10, 16 and 25.
[25] Positive red tracer counts recorded in the -7 m AHD samples collected along Transects 1, 2, 4, 5, 6, 8, 9 and 24.

the more northerly transects away from the release site than south which once again confirms a stronger trend for northerly transport. Notably, as per previous datasets, virtually no red tracer deposition was recorded south of Transect 12 along the beach, nearshore or offshore excluding the two positive samples referred to above.

The highest red tracer counts were recorded between Transects 7 and 4 (moving south to north), i.e. along the northern end of Old Bar Beach. It is also noted that the highest red tracer counts were generally recorded in samples collected along the intertidal beach and inshore zone, i.e. inshore of the -5 m AHD contour. These results suggest that the majority of the red tracer material has remained and/or deposited within the most active part of the beach system along the northern end of Old Bar Beach, possibly as a result of the preceding metocean conditions (i.e. slightly below average wave conditions).

Positive red tracer counts were recorded in a reasonably high proportion of the -7 m AHD samples, although higher counts were generally recorded in the samples collected further inshore as noted above. Of the 24 samples collected at this depth, positive red tracer counts were recorded in nine samples and these were located between Transects 9 and 25 (moving south to north). Only two positive samples were recorded.

Relatively minor sediment transport to the outer part of the active beach system can be inferred from the results, with positive red tracer counts recorded in three of the 23 samples collected at a bed elevation of around -11 m AHD[26], and just one of the additional offshore samples collected beyond the estimated depth of closure[27]. This may be due to the preceding metocean conditions resulting in transport of sand back into the nearshore and intertidal beach areas, which would be expected for below average wave forcing.

Of the 11 samples collected around the entrance to Farquhar Inlet, only one positive count was obtained for the red tracer. As per the yellow tracer results, this suggests that under the conditions experienced until November 2014[19], sediment transport from the red tracer release site to the entrance area continued to be negligible. Similar observations were made based on the results from Sampling Exercise 2, although samples collected for the first time at the mouth of the inlet (a new transect - Transect 26) did indicate two positive samples in the nearshore area (ebb tide delta).

Sampling Exercise 4 (March 2015)

Positive counts for the red tracer were recorded in 89 of the 314 samples collected and analysed for Sampling Exercise 4.

The highest red tracer counts were recorded between Transects 10 and 5 (moving south to north), which covers an area extending from around 1 km south of the red tracer release site to just south of the entrance to Farquhar Inlet. It is also noted that the highest red tracer counts were generally recorded in samples collected along the intertidal beach and inshore zone, i.e. inshore of the -5 m AHD contour. This observation is possibly indicative of the preceding metocean conditions (i.e. below average wave conditions) and accretion on inter-tidal beaches and nearshore shoals. These results indicate that, at the time of sampling in

---

[26] Positive red tracer counts were recorded in the -11 m AHD samples collected along Transects 16, 5 and 3.
[27] A positive red tracer count was recorded in the -14 m AHD sample collected along Transect 3.

March 2015, the majority of the detected red tracer material was located in the most active part of the beach system along the northern end of Old Bar Beach.

The highest individual red tracer count was recorded in the MLW sample on Transect 7, which coincides with the tracer release site. Similar to the yellow tracer results, this indicates that a reasonably high proportion of the tracer material has not been transported from the tracer deployment location, suggesting a degree of longevity in dune profiles and material at this location for a proportion of the sand tracer placed.

Similar to the yellow tracer results for Sampling Exercise 4, it is noted that, in comparison to the results for the preceding sampling exercises, it is evident that greater southward dispersion and deposition of red tracer occurred. Positive red tracer counts were detected in several samples collected along the southern end of Old Bar Beach, extending some 3.5 km south of the red tracer release site as far as the MidCoast Water exfiltration ponds. These results indicate that while there is net northwards transport, some southwards transport also occurred from the northern side of Urana Bombora to the southern end of Old Bar Beach during the December 2014 to March 2015 period, which was characterised by below average wave conditions with a more easterly wave direction.

Of the 13 samples collected around the entrance to Farquhar Inlet, six positive counts were measured for the red tracer. In comparison to the red tracer results for preceding sampling exercises, and the results for the yellow and orange tracers up to Sampling Exercise 4, this observation provides the strongest evidence to date of sediment transport from the northern end of Old Bar Beach into the entrance area. This may indicate that timescales in the order of several months to years are involved in the transport of sand eroded from Old Bar Beach into the entrance area.

Similar to the surface beach samples, positive red tracer counts were recorded in the majority of depth-averaged beach samples between Transects 10A and 5A (moving south to north), which covered an area extending from around 1 km south of the red tracer release site to the northern end of Old Bar Beach. However, it is noted that the highest red tracer counts in the depth-averaged samples were recorded adjacent to and north of the red tracer release site, which suggests that a proportion of the red tracer remained, mixed and became buried on the beach near the release site and/or returned and became buried, possibly during accretionary summer conditions.

However, as per the yellow tracer results, it is noted that red tracer counts in all samples were relatively low in comparison to the results from previous sampling exercises, which suggests that, during the study period, the red tracer material has:

- generally been transported away from the active beach system, and/or
- undergone burial in the nearshore and offshore regions.

Sampling Exercise 5 (September 2015)

Positive counts for the red tracer were recorded in 68 of the 313 samples collected and analysed for Sampling Exercise 5, compared with 89 positive counts (from 314 samples) for Sampling Exercise 4. This provides further evidence of the red tracer material being progressively transported away from the active beach system and/or buried offshore during the study period, as per the yellow tracer.

Small positive counts for the red tracer were recorded on the sub-aerial beach as far south as Transect 17, around 1.5 km north of Wallabi Point. However, similar to the yellow tracer results, there was a clear reduction in red tracer material recorded along the southern end of Old Bar Beach during Sampling Exercise 5 in comparison to Sampling Exercise 4. This indicates that much of the red tracer material previously transported southwards was returned northwards following the summer period.

Indeed, the majority of positive red tracer counts for Sampling Exercise 5 were recorded between Transects 9 and 26, and inside the Farquhar Inlet entrance area. This covers an area extending from around 1.2 km south of the red release site near Urana Bombora to just north of Farquhar Inlet. Relatively small positive counts for the red tracer were also recorded offshore of Manning Point Beach to the northern limit of sampling

Similar to the yellow tracer results for Sampling Exercise 5, positive red counts in the offshore samples for Sampling Exercise 5 were predominantly recorded in the inshore (i.e., -2 m AHD and -5 m AHD) and -7 m AHD samples collected along the northern end of Old Bar Beach. Furthermore, positive red tracer counts were recorded in just two of the 33 samples collected at and beyond a bed elevation of around -11 m AHD[28]. This suggests that offshore migration of the red tracer material did not occur between March 2015 and September 2015.

Of the 21 samples collected around the entrance to Farquhar Inlet, eight positive counts were measured for the red tracer. In comparison to the results for Sampling Exercise 4, there was an increase in the number and magnitude of positive red tracer counts for Sampling Exercise 5, which provides evidence of an increase in the amount of red tracer material transported into the entrance area during the study period. Similar to the yellow tracer results, the red tracer material recorded inside the entrance area was predominantly observed in samples collected from the southern section of the entrance. It is also noted that several of the positive red counts inside the entrance area were recorded in areas not sampled previously, most notably around the southern extent of the entrance sampling region.

Positive red tracer counts were recorded in 21 of the 81 depth-averaged beach samples. While relatively small positive counts were recorded as far south as Transect 18a (i.e. just north of the orange release site), it is evident that the highest red tracer counts in the depth-averaged samples were recorded adjacent to and north of the red tracer release site, as per the Sampling Exercise 4 results. However, it appears that the amount of red tracer buried on the beach reduced between March 2015 and September 2015, similar to the yellow tracer.

7.2.3 Particle Size Results

In general, the following observations could be made from the red particle size results for each sampling exercise:

- It was predominantly fine sized tracer particles that were transported alongshore (both north and south) and offshore from the red tracer release site during the study period.

[28] Positive red tracer counts were recorded in the -11 m AHD samples collected along Transects 4 and 5.

- In comparison to the yellow tracer results, it was evident that the medium sized red tracer particles dispersed relatively widely.
- While the medium sized red tracer particles were predominantly recorded in samples collected in the intertidal beach and inshore zone, positive results were also obtained from samples collected further offshore and inside the Farquhar Inlet entrance area.
- These results suggest that the transport of medium sized red tracer particles has occurred both alongshore and offshore, although the majority of this transport was typically confined to the inshore zone.
- The coarse red tracer counts were primarily recorded on the intertidal beach in the vicinity of the red release site, although some minor offshore transport of the coarse sized red tracer particles could be also inferred from the results. Wider transport of the coarse sized red tracer was evident in the Sampling Exercise 5 results, including the Farquhar Inlet entrance area.

A summary of other key results for each sampling exercise is provided below.

Sampling Exercise 1 (July 2014)

- Fine sized red tracer particles were recorded in 21 of the 29 positive samples.
- Medium sized red tracer particles were found in the beach samples collected at the release site and up to 1.25 km north of the release site, along Transects 3 to 7, and in four nearshore samples (Transects 3, 4, 6, and 8). These results indicated that medium sized particles were measured relatively close to the entrance to Farquhar Inlet.
- Only four of the positive samples were found to contain coarse red tracer particles and these were all in the beach samples collected along transects adjacent to and up to 750 m north of the release site (Transects 4 to 7).

Sampling Exercise 2 (September 2014)

- Fine sized red tracer particles were recorded in 48 of the 59 positive samples, including the one positive sample collected inside the entrance to Farquhar Inlet.
- Medium sized red tracer particles were recorded in 29 of the 59 positive samples, covering an area extending between Transects 10 and 25 (moving south to north), i.e. the northern end of Old Bar Beach (including south of the red tracer release site), the entrance area of Farquhar Inlet, and the southern end of Manning Point Beach.
- Only nine of the positive samples were found to contain coarse red tracer particles and these were predominantly in the beach samples collected along transects nearest the release site (Transects 4 to 7). This was similar to the results for Sampling Exercise 1, despite increased wave activity and observed erosion of the beach during the preceding period. Two of these samples were collected in the inshore zone (at -2m AHD on Transect 7, and -5 m AHD on Transect 4).

Sampling Exercise 3 (November-December 2014)

- Fine sized red tracer particles were recorded in 29 of the 48 positive samples, including the one positive sample collected inside the entrance to Farquhar Inlet.

- Medium sized red tracer particles were recorded in 25 of the 48 positive samples, extending between Transects 12 and 24 (moving south to north), i.e. the northern end of Old Bar Beach and north of the entrance to Farquhar Inlet along Manning Point Beach. It is noted that the spatial extent of these medium sized red tracer particles was similar for Sampling Exercise 2.
- Only eight of the positive samples were found to contain coarse red tracer particles and these were predominantly in the beach samples collected along transects nearest the release site (between Transects 9 and 3, from south to north). Three of these samples were collected in the inner nearshore zone (at -2m AHD and -5 m AHD on Transect 8, and at -7 m AHD on Transect 3). This was the first time coarse sized red tracer particles were measured south of the red tracer release site indicating wider transport.

Sampling Exercise 4 (March 2015)

- Fine sized red tracer particles were recorded in 66 of the 89 positive samples, ranging from the far south of the sampling area adjacent to the orange tracer release site up to the far north along Manning Point Beach, including four of the positive samples collected inside the entrance to Farquhar Inlet.
- Medium sized red tracer particles were recorded in 39 of the 89 positive samples, with the highest results generally recorded on the intertidal beach between Transects 10 and 6 (moving south to north), i.e. in the immediate vicinity of the red tracer release site.
- Coarse sized red tracer particles were recorded in 10 of the 89 positive samples. As per the medium red tracer results, the coarse red tracer counts were primarily recorded on the intertidal beach between Transects 10 and 6 (moving south to north).
- Furthermore, several of the highest medium and coarse red tracer counts were recorded in depth-averaged samples collected on the beach, with most of the samples indicating medium size tracer particles, excluding a few samples to the south of the yellow tracer release site. This suggested that either a proportion of the material was not transported after initial placement and/or medium to coarser fractions returned during the spring/summer period and became buried due to accretionary processes.

Sampling Exercise 5 (September 2015)

- Fine sized red tracer particles were recorded in 37 of the 68 positive samples. Compared to the previous sampling exercises, this represents a reduced proportion of positive samples comprising fine sized red tracer, which suggests that the fine sized red tracer has been progressively transported away from the active beach system and/or buried offshore during the study period.
- Medium sized red tracer particles were recorded in 35 of the 68 positive samples. These samples were predominantly collected in the nearshore zone, inside Farquhar Inlet, and along the intertidal beach, including depth-averaged samples extending as far south as Transect 18a (i.e. just north of the orange release site).

- Coarse sized red tracer particles were recorded in 17 of the 68 positive samples, which represents a significant increase in the number and proportion of positive samples comprising coarse sized red tracer in comparison to preceding results. This included four of the samples collected inside Farquhar Inlet and several samples collected along the intertidal beach (including multiple depth-averaged samples) and some surf zone (-2m AHD) samples. While the majority of these samples were collected adjacent to and north of the red release site, coarse sized red tracer was also recorded as far south as Transect 16, around 2.5 km south of the red release site.

7.3 Orange Tracer (MidCoast Water Exfiltration Ponds)

7.3.1 Preamble

Orange tracer counts for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G7**, **Appendix G**.

Particle size analysis results for the orange tracer material for each of the sampling exercises (excluding depth-averaged beach samples for Sampling Exercises 4 and 5) are plotted in **Figure G8**.

Orange tracer counts and particle size analysis results for the orange tracer material for the depth-averaged beach samples collected during Sampling Exercises 4 and 5 are plotted in **Figure G9**.

Orange tracer results for all samples collected during the study period are also tabulated in **Appendix G**.

7.3.2 Tracer Counts

A summary of the key results for each sampling exercise is provided below.

Sampling Exercise 2 (September 2014)

Positive counts for the orange tracer were recorded in 57 of the 168 samples collected and analysed for Sampling Exercise 2.

In comparison with the red and yellow tracer results, wide dispersal of the orange tracer from the release site at the MidCoast Water Exfiltration Ponds[29] was evident primarily north of the release site. Positive samples were recorded along the entire intertidal length of Old Bar Beach (i.e. Transects 3 to 21), including south of the release site, as well as several samples collected offshore along the southern end of Manning Point Beach. Positive results for the orange tracer were not recorded in any of the samples collected inside Farquhar Inlet.

In contrast to the red and yellow tracer results, the highest concentrations of the orange tracer were not recorded in the active beach/nearshore zone in the immediate vicinity of the tracer release site. Rather, the highest concentrations of orange tracer were recorded in

[29] The orange tracer was deployed at approximately Transect 19 (refer Figure 1, Section 1.2.1).

offshore samples collected in deeper water north of the release site, particularly at bed elevations of around -7 m AHD and -11 m AHD, suggesting net northwards alongshore transport as well as significant offshore transport.

These results demonstrate that under the conditions experienced between July 2014 and September 2014, significant offshore and alongshore transport of the orange tracer material occurred. In particular, offshore transport appeared to be the dominant process for this part of Old Bar Beach. The alongshore transport predominantly occurred in a northerly direction, although some southwards transport was evident as far as Wallabi Point. It is noted that no orange tracer was measured south of Wallabi Point.

Sampling Exercise 3 (November-December 2014)

Positive counts for the orange tracer were recorded in 71 of the 167 samples collected and analysed for Sampling Exercise 3.

Wide dispersal of the orange tracer from the release site was evident, with the distribution and concentrations similar to the results for Sampling Exercise 2 for both the beach and nearshore/offshore samples. This possibly suggests little net change during more benign spring season metocean conditions after the August 2014 storm, indicating the significance of storm conditions for sediment transport leading to beach erosion/recession. Positive orange tracer counts were recorded along the entire length of Old Bar Beach (i.e. Transects 3 to 21), as well as several samples collected offshore of the southern end of Manning Point Beach, which indicates both northerly (at least 8 km) and southerly (around 1 km) alongshore transport. However, higher concentrations of orange tracer were recorded in the more northerly transects away from the release site than southern transects which suggests a stronger trend for northerly transport.

The highest orange tracer counts were recorded between Transects 20 and 7 (moving south to north). This covered an area extending from just south of the orange tracer release site to the northern side of the Urana Bombora, an alongshore distance of around 2 km. It is also noted that the highest orange tracer counts were generally recorded in samples collected within the inshore and inner nearshore zones, i.e. between bed elevations of -2 m AHD and -7 m AHD. These results suggest that the majority of the orange tracer material has remained in the active beach system along the entire length of Old Bar Beach.

Positive counts for the orange tracer were recorded in 12 of the 49 samples collected along the intertidal beach during Sampling Exercise 3, with the highest results recorded in samples collected between Transects 16 and 11 (moving south to north). In comparison to the results from Sampling Exercise 2, it is evident that higher orange tracer counts were generally recorded for beach samples collected during Sampling Exercise 3. This suggests that some onshore transport of the orange tracer occurred between September 2014 and November 2014, which is consistent with observations of accretion.

In contrast to the red and yellow tracer results, relatively significant offshore transport of the orange tracer can be inferred from the results. Positive counts for the orange tracer were recorded in 13 of the 23 samples collected at a bed elevation of around -11 m AHD, and also in four of the 12 additional offshore samples collected beyond the estimated depth of closure. Significant offshore transport of the orange tracer was also inferred from the Sampling Exercise 2 results, which was largely attributed to the storm event in August 2014.

This indicates that, at the time of sampling in November-December 2014, much of the orange tracer material transported offshore in August 2014 had remained in water depths around and beyond the "inner" depth of closure.

Positive results for the orange tracer were not recorded in any of the samples collected inside Farquhar Inlet. As per the yellow and red tracer results, this suggests that under the conditions experienced until December 2014[19], sediment transport from the orange tracer release site to the entrance area was likely negligible.
It is noted again, as per Sampling Exercise 2, that despite significant dispersal and transport to the north and partly south from the orange tracer release site, no orange tracer was measured south of Wallabi Point indicating no process or mechanism, during the period July 2014 to December 2014, for transport to the south around the headland.

Sampling Exercise 4 (March 2015)

Positive counts for the orange tracer were recorded in 106 of the 314 samples collected and analysed for Sampling Exercise 4.

The highest orange tracer counts were recorded between Transects 21 and 6 (moving south to north). This covered an area extending from Wallabi Point (approximately 500 m south of the orange release site) to approximately 500 m north of the red tracer release site, an alongshore distance of around 4.5 km. These results indicate that, at the time of sampling in March 2015, the orange tracer material was detected along almost the entire length of Old Bar Beach.

In general, the spatial distribution of positive orange counts for Sampling Exercise 4 was similar to the results for Sampling Exercise 3, i.e.:

- significant transport from the release site along the entire length of Old Bar Beach, as well as several samples collected offshore of the southern end of Manning Point Beach, and one sample on the southern side of Wallabi Point, which indicates both northerly (at least 8 km) and southerly (around 1.5 km) alongshore transport;
- the highest orange tracer counts were generally recorded within the inshore and inner nearshore zones over a wide area extending between the southern end of Old Bar Beach and the Urana Bombora, an alongshore distance of around 4 km;
- significant offshore transport of the orange tracer, albeit to a lesser extent than Sampling Exercise 3, with positive counts recorded in 11 of the 35 samples collected at and beyond a bed elevation of around -11 m AHD;
- positive orange tracer counts were recorded in a reasonably high proportion of the inshore (i.e., -2 m AHD and -5 m AHD) and -7 m AHD samples, and these samples were also typically found from the northern end of Old Bar Beach to south of the orange tracer release site;
- no orange tracer counts were recorded inside the entrance to Farquhar Inlet.

Positive orange tracer counts were recorded in the majority of depth-averaged beach samples in the vicinity of both the orange and yellow tracer release sites, surprisingly with similar concentrations, confirming the wide transport of the orange tracer. These results indicate that some burial of the orange tracer occurred along an extensive length of

Old Bar Beach. No orange tracer was measured in depth-averaged samples north of Transect 9 including the red tracer release site.

However, as per the yellow and red tracer results, it is noted that orange tracer counts in all samples were relatively low in comparison to the results from previous sampling exercises, which suggests that, during the study period, the orange tracer material has:

- generally been transported away from the active beach system, and/or
- undergone burial in the nearshore and offshore regions.

Sampling Exercise 5 (September 2015)

Positive counts for the orange tracer were recorded in 111 of the 313 samples collected and analysed for Sampling Exercise 5. While a similar number of positive samples were recorded for Sampling Exercise 4, it is evident that the highest orange tracer counts were recorded further north in Sampling Exercise 5, most notably on the northern side of Urana Bombora between Transects 4 and 6.

Furthermore, similar to the red and yellow tracer results, there was a clear reduction in orange tracer material recorded along the southern end of Old Bar Beach during Sampling Exercise 5 in comparison to the preceding sampling exercises. In particular, this included negligible orange tracer recorded offshore and south of the orange release site, which indicates that much of the orange tracer material previously transported offshore from the release site during the study period was subsequently transported northwards.

Positive counts for the orange tracer were recorded in nine of the 33 samples collected at and beyond a bed elevation of around -11 m AHD, which was similar to Sampling Exercise 4. This included the highest orange tracer count for Sampling Exercise 5, which was recorded at -11 m AHD on Transect 4. These observations provide further evidence of significant offshore transport of the orange tracer, which was not observed for the red and yellow tracers in Sampling Exercise 5.

Orange tracer material was recorded in beach samples collected along the entire length of Old Bar Beach, i.e. between Transects 21 and 3a (moving south to north). Similarly, orange tracer was recorded in depth-averaged beach samples extending between Transects 21 and 5a (moving south to north), which covers almost the entire length of the depth-averaged sampling region. This indicates that a proportion of the orange tracer material that was eroded from the release site subsequently dispersed reasonably evenly along the entire length of the sub-aerial beach, including mixing at depth.

Of the 21 samples collected around the entrance to Farquhar Inlet, two positive counts were recorded for the orange tracer. Similar to the yellow tracer, this represents the first time during the study period that orange tracer was recorded in the entrance area, albeit in relatively low quantities. This provides evidence that sand eroded from the southern end of Old Bar Beach is at least partially transported to the entrance area, and that this transport occurs over timescales of several months to years.

7.3.3 Particle Size Results

A summary of the key results for each sampling exercise is provided below.

Sampling Exercise 2 (September 2014)

Similar to the yellow and red tracer results, the orange tracer results for particle size analysis indicate that under the conditions experienced between July 2014 and September 2014, it was predominantly fine sediment that was transported alongshore and offshore from the orange tracer release site. Fine sized orange tracer particles were recorded in 41 of the 57 positive samples.

Medium sized orange tracer particles were recorded in 21 of the 57 positive samples collected during Sampling Exercise 2. Of these samples, 20 were collected between transects 13 and 21, with the remaining positive sample collected much further north (on Transect 5). These results indicate that the transport of medium sized orange tracer particles generally occurred in the vicinity of the release site along the main stretch of Old Bar Beach, i.e. between Wallabi Point and the Taree-Old Bar SLSC, in addition to limited transport of medium sized tracer particles into nearshore waters and slightly further offshore adjacent to the orange tracer release site.

Coarse orange tracer particles were only recorded in two of the positive samples. Both of these samples were collected on the beach, at transects 15 and 20 respectively (i.e. reasonably close to the orange tracer release site at Transect 19). These results indicated that alongshore transport of the coarse orange tracer particles was minor, while offshore transport was not observed.

Sampling Exercise 3 (November-December 2014)

Similar to the yellow and red tracer results, the orange tracer results for particle size analysis indicate that under the conditions experienced between July 2014 and November 2014[19], it was predominantly fine sediment that was transported alongshore and offshore from the orange tracer release site. Fine sized orange tracer particles were recorded in 57 of the 71 positive samples.

Medium sized orange tracer particles were recorded in 26 of the 71 positive samples. The majority of these samples (24) were collected between Transects 10 and 20, with the remaining positive samples collected on Transect 7. These results indicate that the medium sized orange tracer particles dispersed relatively widely, with positive results covering an area generally extending along the main stretch of Old Bar Beach, i.e. between Wallabi Point and the Taree-Old Bar SLSC.

Coarse orange tracer particles were recorded in 10 of the 71 positive samples. These samples were collected between Transects 13 and 19, an alongshore distance extending approximately 2 km north from the orange tracer release site. Five of these samples were collected on the beach, while the other five samples were collected in the inshore zone (at bed elevations of -2m AHD and -5 m AHD) between Transects 16 and 19. These results indicate that some minor offshore and alongshore transport of the coarse sized orange tracer particles has occurred.

Compared with the yellow tracer results (and to a lesser degree the red tracer results), medium and coarse sized orange tracer was transported over a wider area, possibly suggesting a higher energy environment and hence more significant longshore and cross-shore sediment transport for the same metocean conditions in the vicinity of the orange tracer release site.

Sampling Exercise 4 (March 2015)

The results demonstrated a notable increase in fine sized orange tracer particles being present exclusively in samples, with a decrease in the number of samples with any medium or coarse tracer particles. Fine sized orange tracer particles were recorded in 94 of the 106 positive samples.

Medium sized orange tracer particles were recorded in 20 of the 106 positive samples. Again, these particles were observed to be transported relatively widely covering an area that extended along most of Old Bar Beach although with positive results in isolated areas. Medium sized orange tracer particles were primarily measured around the orange tracer release site, immediately south of the yellow tracer release site and immediately north of the red tracer release site.

Coarse sized orange tracer particles were recorded in just two of the 106 positive samples collected during Sampling Exercise 4; one from close to the yellow tracer release site and the other in a depth-averaged beach sample approximately 400 m south of the orange tracer release site.

The depth-averaged beach samples were characterised by fine-sized orange tracer particles with the exception of one sample with coarse sized tracer and one with medium sized tracer present. The beach samples (surface and depth-averaged) and nearshore/offshore samples demonstrated predominantly fine orange tracer particles being present almost throughout the sampling region, possibly suggesting deposition and burial of fine sediment along the intertidal beach during the preceding relatively calm summer months.

Sampling Exercise 5 (September 2015)

Fine sized orange tracer particles were recorded in 81 of the 111 positive samples. This included each of the positive samples collected in deeper water at a bed elevation of around -11 m AHD, which indicates that it is the fine sized material that is predominantly transported offshore.

Medium sized orange tracer particles were recorded in 44 of the 111 positive samples, which was a notable increase compared to the preceding sampling exercises. Again, these particles were observed to be transported relatively widely covering an area that extended along most of Old Bar Beach, in nearshore waters and inside the Farquhar Inlet entrance area. This also included several of the depth-averaged beach samples extending as far north as Urana Bombora.

Coarse sized orange tracer particles were recorded in six of the 111 positive samples collected during Sampling Exercise 5. Four of these samples were collected along the intertidal beach, including one depth-averaged sample at Transect 13, approximately 2 km north of the orange release site. The remaining two positive samples were collected along the -7 m AHD contour at Transects 4 and 5, some 4.5 km north of the orange release site. Therefore, while high quantities of the coarse sized orange tracer were not detected (i.e. relative to the fine and medium sized particles), it is evident that these particles were transported over considerable distances prior to Sampling Exercise 5, including to the north of Urana Bombora.

7.4 Particle Size Distribution Analysis – Farquhar Inlet and Old Bar Beach

PSD analysis was undertaken for samples collected inside Farquhar Inlet and along the intertidal beach over the study area. The purpose of the PSD analysis was to assess whether sand from inside the inlet was similar to sand along Old Bar Beach and could potentially be used for beach nourishment, particularly assuming that sand from Old Bar Beach is transported and deposited within the inlet when the entrance is open (Gordon, 2013; WorleyParsons, 2010a). Indeed, initial sand tracer results, particularly for the red tracer, indicated that this process may occur over a period of several months to years.

A total of 24 samples collected from Farquhar Inlet were analysed, comprising 11 from Sampling Exercise 3 (surface samples) and 13 from Sampling Exercise 4 (depth-averaged samples).

Six beach samples were analysed for comparison with the inlet samples. These were collected on Transects 20, 18, 15, 14, 12 and 10, covering an area from immediately south of the orange tracer release site to immediately north of the yellow tracer release site.

The PSD analysis provided detailed data on the size fractions in the fine, medium and coarse size classes for sand, based on the Wentworth grain size classification (refer Figure 25, Section 6.3). Sieve sizes ranged from 63 µm to 1 mm. The data is summarised in **Appendix H**.

PSD results for surface samples collected inside Farquhar Inlet during Sampling Exercise 3 indicated that the majority of the samples comprised fine to medium sand, between 180 µm and 500 µm, although four of the 11 samples contained 50% (by weight) above 500 µm indicating coarse sand and above. None of the samples, except one, had >3% (by weight) below 180 µm, equivalent to finer fine sand and very fine sand.

PSD results for depth-averaged samples collected inside Farquhar Inlet during Sampling Exercise 4 were similar to Sampling Exercise 3, but with a slightly higher proportion of coarse sand (i.e. above 500 µm) in all samples, equivalent to a wider range of sediment from 180 µm to 71 µm. Five samples out of 13 indicated higher levels of coarse or very coarse sand (i.e. above 500 µm).

In terms of the PSD data for the surface beach samples, four out of the six samples analysed primarily consisted of fine and medium sand from 180 µm to 500 µm. Two samples (Transects 20 and 15) indicated approximately 5 to 10% (by weight) below 500 µm and 30 to 45% (by weight) below 1 mm respectively, i.e. comprised of mostly very coarse sand and gravel.

Median (d_{50}) particle sizes for each sample are summarised in **Table 7** (Farquhar Inlet surface samples, Sampling Exercise 3), **Table 8** (Farquhar Inlet depth-averaged samples, Sampling Exercise 4) and **Table 9** (Old Bar Beach samples, Sampling Exercise 4).

Table 7: Median (d_{50}) particle size for Farquhar Inlet surface samples, Sampling Exercise 3

Sample ID	3-F1	3-F2	3-F3	3-F4	3-F5	3-F6	3-F7	3-F8	3-F9	3-F10	3-F11
d_{50} (μm)	341	729	392	286	329	312	479	401	743	584	767

Table 8: Median (d_{50}) particle size for Farquhar Inlet depth-averaged samples, Sampling Exercise 4

Sample ID	4-F1	4-F2	4-F3	4-F4	4-F5	4-F6	4-F7	4-F8	4-F9	4-F10	4-F11	4-F12	4-F13
d_{50} (μm)	606	833	632	618	858	427	504	603	455	375	383	372	423

Table 9: Median (d_{50}) particle size for Old Bar Beach surface samples, Sampling Exercise 4

Sample ID	10_3	12_1	14_1	15_3	18_1	20_2
d_{50} (μm)	379	282	326	1259	278	1924

Median particle sizes of the 11 Farquhar Inlet surface samples ranged between 0.31 mm and 0.77 mm, while the median d_{50} value of these samples was 0.40 mm. In comparison, the median particle sizes of the 13 Farquhar Inlet depth-averaged samples ranged between 0.37 mm and 0.86 mm, while the median d_{50} value of these samples was 0.50 mm. The higher particle sizes in the depth-averaged samples indicated the presence of slightly coarser material at depth. The median d_{50} value of the 24 Farquhar Inlet samples was 0.47 mm.

Median particle sizes of four of the Old Bar Beach surface samples ranged between 0.28 mm and 0.38 mm, while the other two samples (Sample IDs 15_3 and 20_2) had much higher median particle sizes of 1.3 mm and 1.9 mm respectively. The coarser samples were representative of the gravel material that underlies sand along much of Old Bar Beach. The median d_{50} value of the six Old Bar Beach samples was 0.35 mm, which was around 0.12 mm smaller than the Farquhar Inlet samples.

Based on the PSD data from samples collected on Old Bar Beach and inside Farquhar Inlet, it is evident that the material sampled in the inlet, including with depth, was slightly coarser than the material sampled on Old Bar Beach. However, it is noted that the range of median particle sizes sampled in the inlet (0.31 mm to 0.86 mm) was comfortably within the relatively wide range of median particle sizes sampled on the beach (0.28 mm to 1.9 mm). In general, this would indicate that sediment from Farquhar Inlet would be suitable as beach nourishment material. The slightly coarser nature of the material from Farquhar Inlet would also be expected to result in an increased longevity of nourished beach profiles in comparison to a nourishment program that utilised finer material.

Based on the sand tracer results presented herein, particularly red sand tracer results, with the inlet open during the study period it was evident that a proportion of the material in Farquhar Inlet may have originated from Old Bar Beach. This would further support the concept of beach nourishment as a sustainable form of coastal management at Old Bar Beach. This is discussed further in **Section 9.4**.

7.5 Mass Budget Analysis

7.5.1 Calculation Method

A preliminary mass budget analysis was undertaken for the beach and Farquhar Inlet samples collected during Sampling Exercises 4 and 5. This assessment provided a 'first pass' estimation of the amount of tracer material present inside the entrance area and on the sub-aerial beach at the time of sampling (for each size fraction) in comparison to the amount of tracer originally deployed.

Due to the relatively broad sampling region adopted in the offshore zone, mass budgets were not calculated for the offshore samples. A sufficiently accurate mass budget for the offshore zone would require a denser sampling region and also sampling with depth to estimate the extent of burial of the tracer material.

Similarly, mass budget analyses were not undertaken for the sub-aerial beach and Farquhar Inlet for the first three sampling exercises because the sampling regions adopted for these exercises were not sufficiently dense and did not incorporate sampling with depth.

It should also be noted that the mass budget analysis undertaken for this study used a number of key assumptions that, while reasonable for the purposes of this investigation, would be expected to result in small error bands for the reported mass budget results. These assumptions are discussed below. More accurate mass budgets could be estimated for any future sampling exercises which include sampling at discrete depths to assess burial of the tracer, and adopting denser sampling regions. This is discussed further in **Section 8.3**.

Mass budgets for the beach samples were calculated for each tracer colour and size fraction in the following manner:

1. The tracer counts for beach samples (MHWS, MSL and MLWS) for each transect were averaged to determine the average tracer count per transect, expressed in units of 'total number of particles in sample'.
2. The average tracer count was divided by the sample volume to express the result as an average tracer concentration in units of 'particles per m^3'. For the purposes of this assessment, a constant sample volume was adopted, based on a typical sample quantity obtained in the field[30].

[30] It is estimated that this assumption may result in discrete errors of up to ±15% for each transect due to the variation in calculated dry sample mass, e.g. a calculated mass budget of 10% would likely fall within the range of 8.5-11.5%. However, it is not straightforward to estimate the volume for each sample without knowing the in situ dry

3. For each transect, a region was defined within which the average tracer concentration was assumed to be constant. Each region extended alongshore in both directions to the midway points between the adjacent transects, and in a cross-shore direction between the MHWS and MLWS sampling locations.
4. The area of each region was then multiplied by the typical sampling depth to determine the volume of sediment in each region[31].
5. The average tracer concentration for each transect was then multiplied by the respective region volume to estimate the total number of tracer particles in each region. These results were summed to estimate the total number of tracer particles present along the entire beach at the time of sampling.
6. The total number of tracer particles estimated to be present along the beach was divided by the total number of tracer particles released to determine the percentage by mass remaining for each tracer colour and size fraction along the entire beach at the time of sampling.

Mass budgets for the Farquhar Inlet samples were calculated for each tracer colour and size fraction in a similar manner as follows:

1. The tracer counts for all Farquhar Inlet samples were averaged to determine the average tracer count for the entrance area, expressed in units of 'total number of particles in sample'.
2. Step 2 as above.
3. A single region was defined for the entrance area wherein the average tracer concentration was assumed to be constant[32]. This region was generally bounded by the outer sampling locations adopted for Sampling Exercise 5, which covered an area of approximately 380,000 m^2[33].
4. The area of the region was then multiplied by the typical sampling depth to determine the volume of sediment in each region[31].
5. The average tracer concentration for the entrance area was then multiplied by the region volume to estimate the total number of tracer particles in the entrance.
6. The total number of tracer particles estimated to be present in the entrance was divided by the total number of tracer particles released to determine the percentage by mass remaining for each tracer colour and size fraction in the entrance area at the time of sampling.

---

density (which requires geotechnical testing), and/or directly measuring in situ sample volumes in the field (which would be difficult due to disturbance of the surrounding sediment during sampling). Notwithstanding this, assuming a constant sample volume is considered to be reasonable for the purposes of a preliminary mass budget analysis.

[31] For the surface beach samples, the sampling depth was reasonably constant at around 5 cm. For the depth-averaged samples (including Farquhar Inlet), the sampling depth was typically 0.5 m, although it is noted that some samples were collected over shallower depths of around 0.2 to 0.3 m. It is also possible that the tracer was mixed below 0.5 m depth in some locations. However, for the purpose of this assessment, a constant sampling depth of 0.5 m was adopted.

[32] It is acknowledged that the accuracy of this assessment could be improved by using more sophisticated averaging methods, such as Voronoi polygon maps which create polygons for each sample by plotting equal distance between sampling locations and using these areas and the results for each sample to estimate the mass budget. However, adopting a numerically averaged tracer concentration for the entire entrance area is considered to be reasonable for the purposes of a preliminary mass budget analysis.

[33] Based on the yellow and red tracer results for Sampling Exercise 5, it is considered likely that the tracer material has been transported beyond the sampling region adopted for Sampling Exercise 5, particularly in the southern reaches of the entrance area. Therefore, a mixing area of 380,000 m^2 is likely conservative.

7.5.2 Mass Budget Results

Mass budget estimates of the amount of tracer material present inside the Farquhar Inlet entrance area and on the sub-aerial beach at the time of sampling in comparison to the amount of tracer originally deployed are presented in **Table 10** and **Table 11** (respectively). Results are presented for each tracer colour and size fraction for Sampling Exercise 4 and Sampling Exercise 5.

Table 10: Mass budget results – Farquhar Inlet

Tracer Fraction and Colour		Sampling Exercise 4 (March 2015)	Sampling Exercise 5 (September 2015
TOTAL	Yellow	<1%	2%
	Red	5%	6%
	Orange	0%	<1%
Fine	Yellow	<1%	3%
	Red	6%	3%
	Orange	0%	<1%
Medium	Yellow	0%	1%
	Red	8%	14%
	Orange	0%	1%
Coarse	Yellow	0%	0%
	Red	0%	8%
	Orange	0%	0%

Table 11: Mass budget results – sub-aerial beach

Tracer Fraction and Colour		Sampling Exercise 4 (March 2015)	Sampling Exercise 5 (September 2015
TOTAL	Yellow	3%	1%
	Red	5%	3%
	Orange	3%	3%
Fine	Yellow	3%	2%
	Red	4%	3%
	Orange	4%	3%
Medium	Yellow	4%	2%
	Red	9%	6%
	Orange	3%	5%
Coarse	Yellow	<1%	<1%
	Red	3%	1%
	Orange	<1%	<1%

It can be seen that the amount of tracer material present inside the Farquhar Inlet entrance area increased between March 2015 and September 2015 for each colour, with around 6%

of the red tracer and 2% of the yellow tracer estimated to be within the entrance area some 16 months following tracer deployment. Based on these results, it is likely that the proportion of tracer material that is transported to the entrance area will continue to increase over time, although this would need to be confirmed by further investigations.

It is worth noting that reasonably high proportions of the medium and coarse sized red tracer were estimated to be present within the entrance area in September 2015. The red tracer mass budget estimates for the medium and coarse size fractions were around 14% and 8% respectively, while around 3% of the fine sized red tracer was present. This suggests that fine sized sediment eroded from Old Bar Beach is less likely to be transported to the entrance area compared with coarser fractions. This may be partly because finer sediments are more readily transported offshore and alongshore outside the Old Bar Beach system.

The mass budget results for the sub-aerial beach provide further evidence of a general reduction in the amount of tracer material present on the beach over time for each colour. For example, it is estimated that just 5% of the amount of red tracer material originally deployed in May 2014 was present along the sub-aerial portion of Old Bar Beach in March 2015, and this proportion reduced further to 3% by September 2015.

Clearly, based on these results, a significant proportion of the tracer material appears to have been progressively transported away from the active beach system and/or buried offshore during the study period. However, the amount of tracer material inside the Farquhar Inlet entrance area increased towards the end of the study period and it is possible that, over time, a significant proportion of the tracer material originally deployed will migrate to this area, particularly for the coarser fractions.

8 DISCUSSION ON SEDIMENT TRANSPORT PROCESSES

8.1 Inferred Sediment Transport Processes

8.1.1 Sampling Exercise 1

It is evident that the yellow tracer material was transported very widely between May 2014 and July 2014, although there were several high counts measured in the yellow release area itself. Transport occurred predominantly alongshore towards the north and into nearshore areas, with relatively minor transport occurring to the south and offshore into deeper water. It was predominantly fine particles that were transported alongshore and cross-shore into nearshore areas from the yellow tracer release site.

In comparison, the red tracer material was not recorded in as many samples as the yellow tracer, and was in much lower counts and mostly concentrated around the red release area. Nevertheless, the red tracer results also indicated predominantly northwards alongshore sediment transport between May 2014 and July 2014.

Given that the red and yellow tracers were both deployed at the same time and were subjected to the same prevailing weather and wave conditions, the Exercise 1 results suggested that the area around Taree-Old Bar SLSC was relatively energetic and the area around the red sand tracer release site was less energetic for the same metocean conditions. It is possible that the red sand tracer was buried by sand from the yellow release area given the relatively high counts of yellow tracer that were measured in the vicinity of the red release area. This observation is consistent with a predominantly northwards alongshore transport.

As noted in Section 5, wave conditions at Old Bar Beach between May 2014 and July 2014 were relatively calm. As such, the tracer results appeared to confirm that net northward sediment transport occurs at Old Bar Beach under ambient conditions, as postulated in WorleyParsons (2010a). However, the spatial extent of the observed longshore transport was greater than expected for the relatively calm prevailing conditions. For example, the northwards transport of yellow tracer material was at least 2.5 km over a period of two months.

For the conditions experienced between May 2014 and July 2014, it is possible that the transported sediment is either:

- accreting at the northern end of Old Bar Beach;
- migrating further north towards Manning Point Beach; and/or
- being deposited in or around the entrance to Farquhar Inlet.

This was investigated further based on results from subsequent sampling exercises, and is discussed in the following sections.

8.1.2 Sampling Exercise 2

The sediment transport processes that prevailed at Old Bar Beach prior to September 2014 have been inferred based on the results from Sampling Exercise 2, as described below. The significant storm event which occurred at the end of August 2014 is considered to be the dominant factor influencing the results from Sampling Exercise 2, although it is noted that significant alongshore transport occurs in the nearshore zone under ambient conditions, based on the results from Sampling Exercise 1. As such, the sediment transport processes outlined below can generally be attributed to major storm activity from the S to ESE sector. A conceptual description of these sediment transport processes is also presented in **Figure 26**.

It is evident that the yellow, red and orange tracer material dispersed widely prior to September 2014, with sediment transport occurring both alongshore and offshore from all three tracer release sites. The results indicated that the entire length of Old Bar Beach experienced erosion prior to September 2014, which is consistent with visual observations. Transport of the orange tracer was greater than the yellow and red tracer, which suggests that the most significant erosion occurred around the southern end of Old Bar Beach.

Alongshore transport occurred predominantly towards the north, with relatively minor transport occurring to the south for all three tracers. It is worth noting that the observed northwards transport of the orange and yellow tracer did not appear to weaken on the northern side of the Urana Bombora, which indicates that this feature did not significantly limit northwards transport of sand eroded from Old Bar Beach.

The northwards transport extended along the entire length of Old Bar Beach, beyond the entrance to Farquhar Inlet and along Manning Point Beach. Negligible transport into the entrance area was observed. This suggests that Farquhar Inlet was not a significant sink for sand eroded from Old Bar Beach during the study period prior to September 2014, with northwards transport appearing to continue uninterrupted past the entrance.

Relatively significant offshore transport also occurred for each tracer, most notably from the orange release site near the MidCoast Water Exfiltration Ponds. It is likely that large rip cell(s) formed at the southern end of Old Bar Beach in the vicinity of the orange release site during the storm event in late August 2014, which carried sediment offshore to water depths of at least -11 m AHD. Transport of orange tracer to the south did not extend to deposition to the south of Wallabi Point. The observed offshore transport of the yellow and red tracer indicates that similar rip cells may have also formed at other locations along Old Bar Beach.

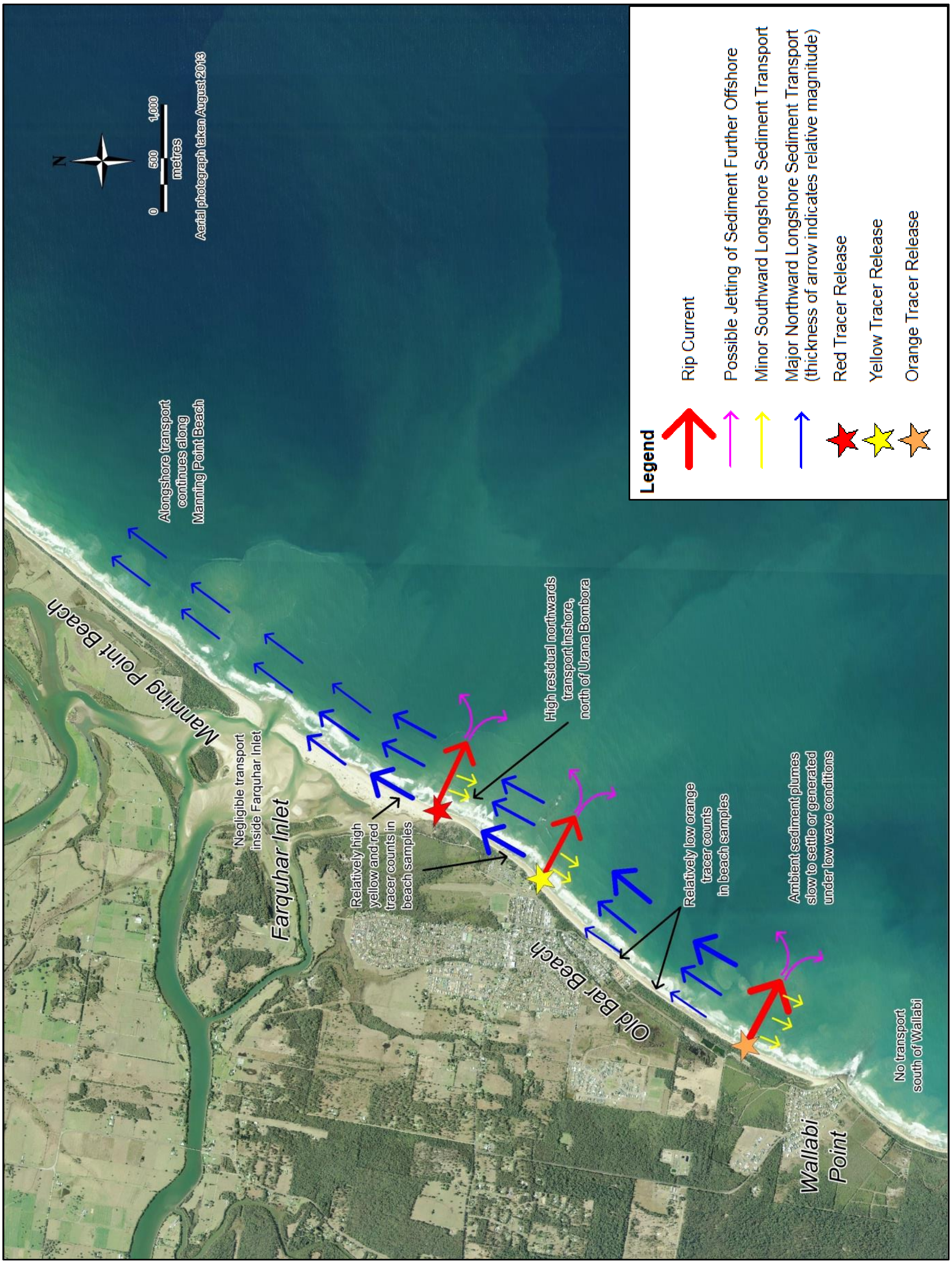


Figure 26: Conceptual description of sediment transport at Old Bar Beach prior to Sampling Exercise 2 (May to September 2014)

Based on the observation of sediment plumes during offshore sampling on 11/9/14 (refer Section 5.2.1), it appeared that finer sediment transported offshore from Old Bar Beach can remain entrained for extended periods following a major storm event, even under relatively calm wave conditions[34]. Sediment plumes were also evident in an aerial photograph of Old Bar Beach taken in May 1996, as shown in **Figure 27**. The plume in this photograph extended approximately 650 m offshore, which corresponded to a bed elevation of about -8m AHD.

Figure 27: Aerial photograph of Old Bar Beach showing sediment plumes, 31 May 1996 (Source: OEH)

[34] Wave conditions on 11/9/14 were mild (wave heights less than 1 m). As such, it is not expected that wave forcing (and associated currents) was the primary cause of the observed plumes. However, it is noted that spring tides were occurring around 11/9/14, which would have resulted in higher than average tidal currents at this time.

The presence of sediment plumes, particularly during relatively calm wave conditions, would suggest that the ambient currents (wave-driven and, to a lesser extent, tidal) at Old Bar Beach are of sufficient magnitude for transporting relatively large quantities of sediment throughout the inner nearshore zone, including relatively deep water. This would be most pronounced during and following storm events which mobilise sediment from the active beach zone.

Net northwards alongshore transport of sediment in the study area occurred during the study period prior to September 2014. The capacity for this sediment to return to Old Bar Beach was assessed in the subsequent sampling exercises.

8.1.3 Sampling Exercise 3

As per the preceding sampling exercises, the results from Sampling Exercise 3 indicated that the yellow, red and orange tracer material was transported widely prior to December 2014, with sediment transport occurring both alongshore and offshore from the tracer release sites.

Similarly, predominantly northwards alongshore transport can be inferred from the Sampling Exercise 3 results, with relatively minor transport to the south.

The significant storm event which occurred at the end of August 2014 was considered to be the dominant factor influencing the results from Sampling Exercise 2. As noted in **Section 6.1.3**, the primary objective of the third sampling exercise was to assess the post-storm transport of the yellow, red and orange tracer particles during the period September 2014 to December 2014. Wave conditions during this period were below long-term averages, while no major storm events were recorded, which limited the likelihood of observing significant transport of tracer material into deeper water.

A number of sediment transport processes may occur at Old Bar Beach in the months following a storm event, including:

- onshore migration of the nearshore bar and recovery of dunal sand volumes;
- transport of eroded sand into the entrance to Farquhar Inlet and/or northwards transport along Manning Point Beach;
- permanent loss of eroded sand from the active beach system, for example:
    - offshore losses to water depths at or beyond the “inner” depth of closure (-12 m AHD)[35];
    - offshore losses due to flood jetting from the entrance to Farquhar Inlet (if a flood event occurs).

The above processes are discussed below in terms of the results from Sampling Exercise 3.

[35] It is recognised that onshore re-working of material transported beyond the “inner” closure depth may occur, however the potential for this process to take place is considered to be relatively limited, and may only possibly occur over long timescales. Sand transported beyond the “inner” closure depth may essentially represent a permanent loss of sand from the beach system.

Onshore Recovery

As noted in Section 5.2.1, the period between Sampling Exercise 2 and Sampling Exercise 3 (September to November/December 2014) was considered to be accretionary in terms of dunal sand volumes. It is therefore evident that there was some degree of beach recovery following the major storm event in August 2014.

These observations were generally supported by the tracer results. In particular, the results for the orange tracer indicated onshore transport of this material, including medium and coarse-sized fractions. Relatively high concentrations of the red tracer were also recorded in the beach samples collected during Sampling Exercise 3.

Conversely, yellow tracer counts in the beach samples were relatively low in comparison to the results from previous sampling exercises, which suggests that the yellow tracer material was generally transported away from the intertidal beach in the months following tracer deployment, and did not migrate onto the beach during the generally accretionary conditions prior to December 2014. However, it is also possible that some burial of the yellow tracer occurred on the beach, which could not be detected in the surface sampling results.

Nevertheless, it is important to note that the highest concentrations of each tracer from Sampling Exercise 3 were typically recorded in samples collected at bed elevations of -2 m AHD, -5 m AHD and -7 m AHD. These samples generally cover the inshore and inner nearshore zones where the bulk of sediment transport ordinarily occurs. In comparison, the results for Sampling Exercise 2 included relatively high tracer concentrations in deeper water, which indicates that onshore migration of sand occurred during the intervening period.

As such, it is evident that much of the tracer material remained in the active beach system (i.e. extending from the intertidal beach to the inner nearshore zone) at the time of sampling in November-December 2014. It is possible that this material will be subsequently transported back onto the intertidal beach under calmer wave (accretionary) conditions that occurred during the summer months, which would represent further onshore recovery of dunal sand volumes. This was assessed as part of Sampling Exercise 4.

Transport into Farquhar Inlet

Farquhar Inlet has remained open during the study period, although it has migrated in a southwards direction which is indicative of a closing state[36]. The Inlet is understood to be mostly open, closing on average perhaps once every five years (WorleyParsons, 2010a).

Negligible transport into the entrance area was observed for each tracer, as per the results from previous sampling exercises. This suggests that Farquhar Inlet was not a significant sink for sand eroded from Old Bar Beach during the study period prior to December 2014, with northwards transport appearing to continue uninterrupted past the entrance. However, it is also possible that any tracer material transported into the entrance area became buried and was therefore not detected in the surface samples collected.

[36] The entrance to Farquhar Inlet migrated southwards by a distance of around 100 m between September 2014 and March 2015, i.e. between Sampling Exercise 2 and Sampling Exercise 4.

Permanent Losses

The “inner” depth of closure at Old Bar Beach is estimated to occur at around -12 m AHD, being the limit of wave breaking in extreme storms and related seabed fluctuations (Royal HaskoningDHV, 2014). Sediment particles which are transported offshore to such water depths (or deeper) may be permanently lost from the system, contributing to recession. While some onshore re-working of this material may occur, the potential for this to occur may be relatively limited and may only take place over long timescales.

In general, tracer concentrations for samples collected at a bed elevation of around -11 m AHD during Sampling Exercise 3 had decreased in comparison to the results from Sampling Exercise 2. It is possible that some of the material deposited around this water depth during the significant storm event in August 2014 migrated inshore during the subsequent relatively calm period, although it is evident that much of the material has remained at these locations. It is also possible that sediment transport further offshore occurred between September 2014 and November-December 2014 (e.g. due to rip currents).

Tracer material was observed in several samples collected further offshore in water depths beyond the estimated depth of closure, although tracer counts were not particularly high for these samples. This was most evident for the fine-sized orange tracer material. Presumably, this material was transported to these locations during the August 2014 storm event, from where it could not be transported onshore under the subsequent prevailing fair-weather conditions (i.e. until November-December 2014).

Overall, it is evident that, at the time of sampling in November-December 2014, the tracer material transported offshore in August 2014 had generally remained in water depths around and beyond the estimated depth of closure. This provides evidence of offshore sand losses from Old Bar Beach due to storm activity. However, it is possible that other processes may also have occurred, such as some minor onshore recovery, burial and/or transport further offshore.

Tracer concentrations offshore of the entrance to Farquhar Inlet in water depths seaward of the -11 m AHD contour were low, with the highest offshore tracer counts generally recorded further south along Old Bar Beach. This indicates that offshore transport of sediment from the entrance area due to flood jetting was negligible prior to Sampling Exercise 3. However, it should be noted that no significant flood events occurred during this period.

The predominantly northwards alongshore transport extended along the entire length of Old Bar Beach, beyond the entrance to Farquhar Inlet and along Manning Point Beach. Similar observations were made based on the results from Sampling Exercise 2. It is possible that some of this material continues northwards along Manning Point Beach.

However, as noted in Section 2.3.4, it is also possible that some of this material is recirculated back towards the inlet and contributes to infilling of the entrance (Worley Parsons, 2010a). While the general absence of positive tracer counts in the entrance area until December 2014 does not support this theory, it is clearly evident (based on visual observations) that the entrance has been infilling from the north. In any case, there does not appear to be any effective mechanism for material from the entrance area to return to Old Bar Beach.

8.1.4 Sampling Exercise 4

As per the preceding sampling exercises, the results from Sampling Exercise 4 indicated that the yellow, red and orange tracer material was transported widely prior to March 2015, with sediment transport occurring both alongshore and offshore from the tracer release sites.

While there was net northwards longshore transport, southwards transport also occurred for each tracer. It is worth noting that the observed southwards transport from the red tracer release site would likely involve bypassing of Urana Bombora to the south along the inshore zone. This may be related to wave diffraction in the lee of the bombora during storms, as per the conceptual processes model proposed by WorleyParsons (2010a) (refer Section 2.3.3).

Further, in comparison to the results from the preceding sampling exercises, the results from Sampling Exercise 4 provided the strongest evidence demonstrating southwards transport of the tracer material. This was likely due to the more easterly wave direction during the preceding summer months (including ENE waves) in comparison to the earlier study period which was typically characterised by waves approaching from the SE and SSE sectors. These observations also suggested that southwards longshore transport at Old Bar Beach occurs at a slower rate than the predominant northwards transport mechanism.

While negligible transport into the Farquhar Inlet entrance area was observed for the yellow and orange tracers for Sampling Exercise 4 (as per the preceding sampling exercises), transport of the red tracer material (both fine and medium sized) to this area could be inferred from the results. This suggests that sand eroded from Old Bar Beach migrates to the entrance area, although this may occur over timescales in the order of several months to years. This is discussed further below for the Sampling Exercise 5 results (**Section 8.1.5**).

Results from the depth-averaged sampling indicated that a proportion of each tracer has undergone burial on the intertidal beach during the study period, possibly during the more accretionary summer period. For the yellow and red tracers, this burial generally occurred adjacent to and north of the respective tracer release sites. However, burial of the orange tracer was evident in the vicinity of both the orange and yellow tracer release sites, surprisingly with similar concentrations, confirming that the transport and burial of the orange tracer occurred along an extensive length of Old Bar Beach.

8.1.5 Sampling Exercise 5

There was a clear reduction in the amount of tracer material recorded along the southern end of Old Bar Beach during Sampling Exercise 5 in comparison to Sampling Exercise 4. This indicates that the southwards alongshore transport observed during the summer period was not a prevailing process between March 2015 and September 2015, with the tracer material transported northwards under more typical SE wave conditions.

In comparison to the results for the preceding sampling exercises, there was an increase in the amount of red tracer material transported into the Farquhar Inlet entrance area prior to Sampling Exercise 5. Furthermore, Sampling Exercise 5 was the first time during the study period that significant concentrations of yellow tracer were recorded in the entrance area, while small amounts of orange tracer were also recorded for the first time. In particular, relatively high concentrations of the medium and coarse sized red tracer material were recorded inside the entrance area for Sampling Exercise 5. This suggests that coarser sand fractions are more likely to be transported from Old Bar Beach to the entrance area in comparison to the finer fractions, which may be more readily transported offshore and alongshore outside the Old Bar Beach system.

The Farquhar Inlet results for Sampling Exercise 5 confirm that sand eroded from Old Bar Beach migrates to the entrance area over timescales in the order of several months to years. This may include southwards recirculation of material that was transported northwards past the entrance area, as proposed by Worley Parsons (2010a). If this is correct, it is likely that the tracer material will continue to be transported to the entrance area over time beyond the study period considered herein. It is therefore possible that a reasonably significant proportion of the originally deployed tracer material will eventually migrate to the entrance area, particularly for the medium and coarse size fractions, which would generally support the notion of Farquhar Inlet as a source of material for any future nourishment activities. Future investigations would be required to assess this further (refer **Section 8.3**).

While offshore migration of the yellow and red tracer was not evident in the Sampling Exercise 5 results, reasonably significant offshore transport could be inferred for the orange tracer material. In particular, several of the highest orange tracer counts were recorded on the northern side of Urana Bombora at a bed elevation of around -11 m AHD. This provides further evidence that the bombora does not form a barrier to alongshore sediment transport.

The amount of tracer material present on the sub-aerial beach (surface and depth-averaged) generally appeared to reduce between March 2015 and September 2015. The spatial distribution of positive beach samples also generally shifted northwards during this period, which is consistent with a predominantly northwards longshore transport mechanism.

8.1.6 Summary of Key Observations

The results from each sampling exercise demonstrated that the yellow, red and orange tracer material was transported very widely during the study period, with sediment transport occurring both alongshore and offshore from the tracer release sites. The spatial extent of the observed longshore transport was greater than expected for the relatively calm prevailing conditions during the first two months of the study, with northwards transport of at least 2.5 km for the yellow tracer material between May and July 2014.

The results indicated that the entire length of Old Bar Beach has experienced erosion during the study period, which was characterised by wave forcing representative of mild to average conditions except for a single large storm event in August 2014. Transport of the orange tracer was greater than the yellow and red tracer, which suggested that the most significant erosion occurred around the southern end of Old Bar Beach.

Predominantly northwards alongshore transport was consistently inferred from the results for each sampling exercise. This included inshore bypassing of Urana Bombora from the yellow, orange and red tracer release sites, which indicated that this feature was not a barrier to alongshore sediment transport in either direction over the study period. Furthermore, northwards transport of material from each release site continued at least 2 km past the entrance to Farquhar Inlet (to the limit of sampling), which indicated that northwards sediment transport at least partially bypassed the inlet during the study period.

Some longshore transport occurred to the south. It is likely that this southwards transport can be related to more easterly wave directions during summer, including periods of ENE wave conditions. Overall, it appeared that the southwards transport occurred at a slower rate than the dominant northwards transport, that is there was a net northwards alongshore transport over the study period.

Significant offshore transport and deposition occurred for each tracer, particularly as a result of the storm event in August 2014 which had an estimated ARI of 4 years. This was most notable from the orange release site near the MidCoast Water Exfiltration Ponds. It is likely that large rip cell(s) formed at the southern end of Old Bar Beach in the vicinity of the orange release site during the storm event, which carried sediment offshore to water depths of at least -11 m AHD.

Some onshore recovery of sand eroded from the beach and transported offshore during the August 2014 storm event could be inferred from the results of sampling exercises in November-December 2014 and March 2015. However, tracer material was recorded in samples collected around and offshore of an estimated “inner” depth of closure at -12 m AHD, which provides evidence of possible permanent offshore sand losses from Old Bar Beach due to storm activity. This is considered to be an important factor contributing to the observed high recession rates at Old Bar Beach.

The net northwards transport of material past Urana Bombora may also be contributing to the observed high recession rates at Old Bar Beach, if this transport is occurring at a higher rate than the alongshore supply of material entering the Old Bar Beach system past Saltwater Point and Wallabi Point from the south. However, geological evidence suggests that the Tuncurry embayment located to the south of the study area acts as a sediment sink for the northwards littoral sediment transport in the region (Roy et al, 1997). This would result in negligible littoral transport entering the Old Bar Beach compartment from the south, as indicated in **Figure 28**.

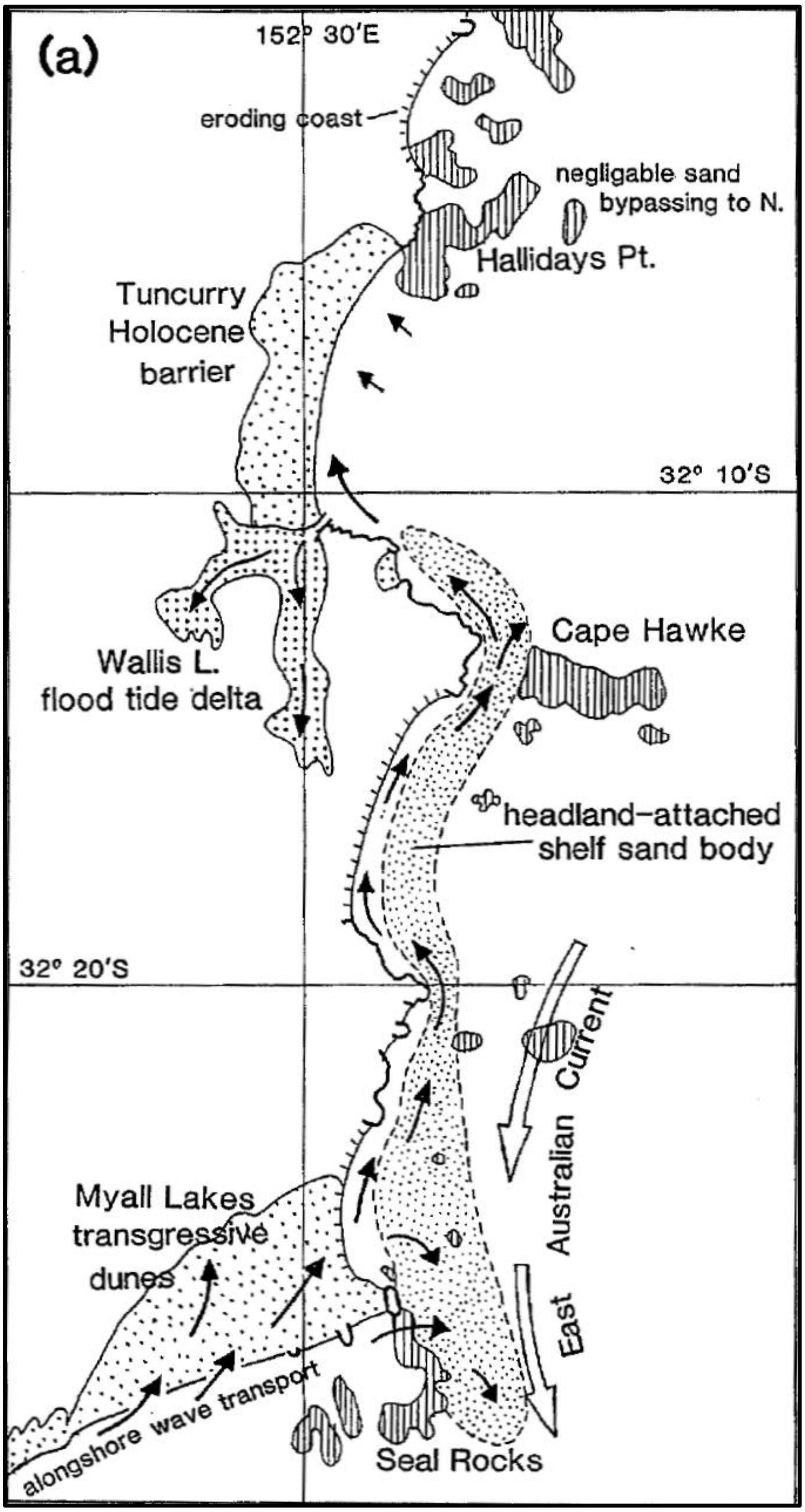


Figure 28: Distribution of main Holocene sediment units and sediment transport pathways on the Forster-Tuncurry coast and shelf (Roy et al, 1997)

Furthermore, the extensive reef extensions to the Saltwater Point and Wallabi Point promontories would significantly limit (perhaps entirely) any net northwards littoral drift of sediment into the Old Bar Beach system (**Figure 29**).

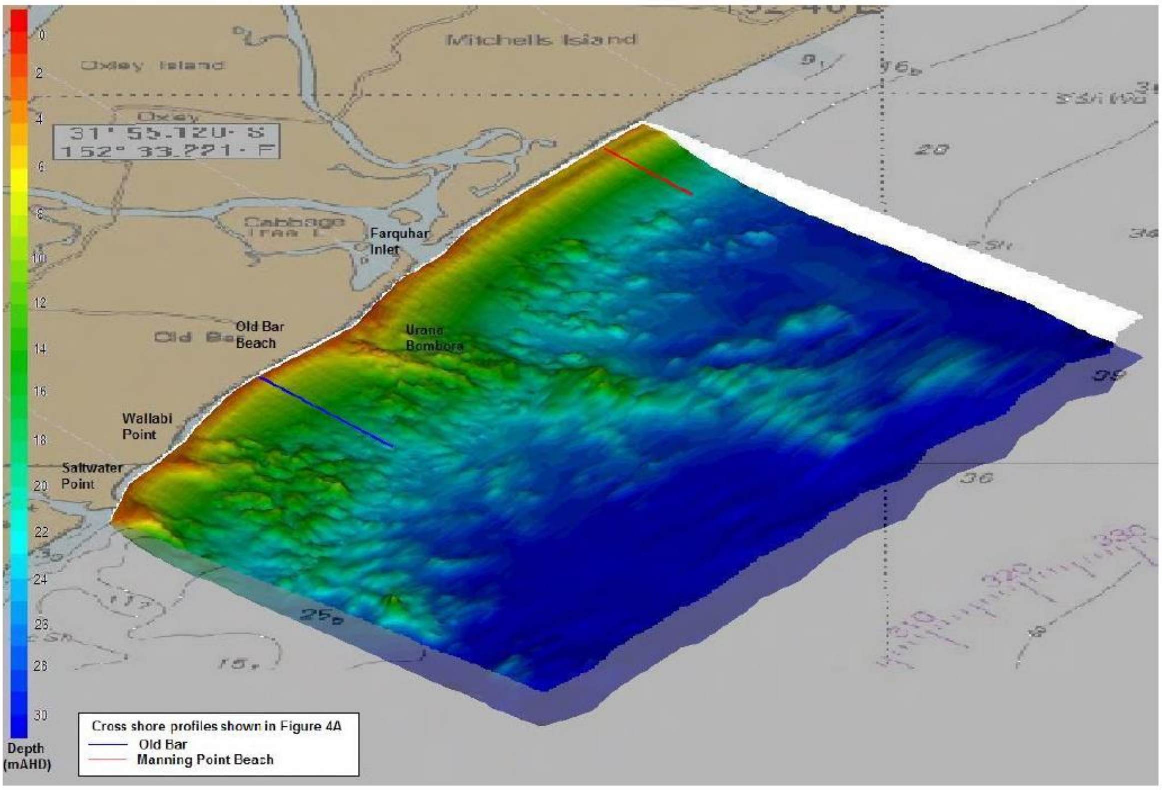


Figure 29: Shaded relief of the bathymetry in the study area indicating extensive nearshore reef formations (WorleyParsons, 2010)

Notwithstanding the above geological and geomorphic observations, there is no clear evidence from the sediment tracing that the observed recession, particularly at the northern end of Old Bar Beach[37], would be caused by a deficiency in the net longshore transport from the south. The clearest evidence for the cause of recession at Old Bar Beach from the sediment tracing is that it is related to cross-shore processes which move sand well offshore to depths where it may never return (or it may take many years to return) to the sub-aerial beach.

Farquhar Inlet has remained open during the study period, although it has been observed to migrate in a southwards direction (i.e. around 200 m between September 2014 and September 2015). The inlet is understood to be mostly open, closing on average perhaps once every five years (WorleyParsons, 2010a). Transport of the red tracer into the entrance area appeared to increase during the latter part of the study period, while yellow and orange tracer became evident inside the entrance area for the first time in Sampling Exercise 5.

[37] If recession of Old Bar Beach was being caused predominantly by a deficiency in the net longshore transport from the south, this would likely be evident in the beach morphology, with greater recession occurring at the southern end of the beach relative to the northern end. This is not the case at Old Bar Beach, which is characterised by reasonably consistent long-term recession rates along the entire beach length between Wallabi Point and Urana Bombora (RHDHV, 2014).

The Farquhar Inlet results confirmed that sand eroded from Old Bar Beach has migrated to the entrance area over timescales in the order of several months to years. Transport of the tracer material to the entrance area could therefore be expected to continue beyond the study period, which may result in a reasonably significant proportion of the originally deployed tracer material eventually migrating to the entrance area, particularly for the medium and coarse size fractions.

A conceptual description of the key sediment transport processes identified from the tracer study is presented in **Figure 30**. It should be noted that the size of the respective rip cell arrows in Figure 30 provide a general indication of the relative strength of the rip cells that were considered to influence the tracer results during the study period.

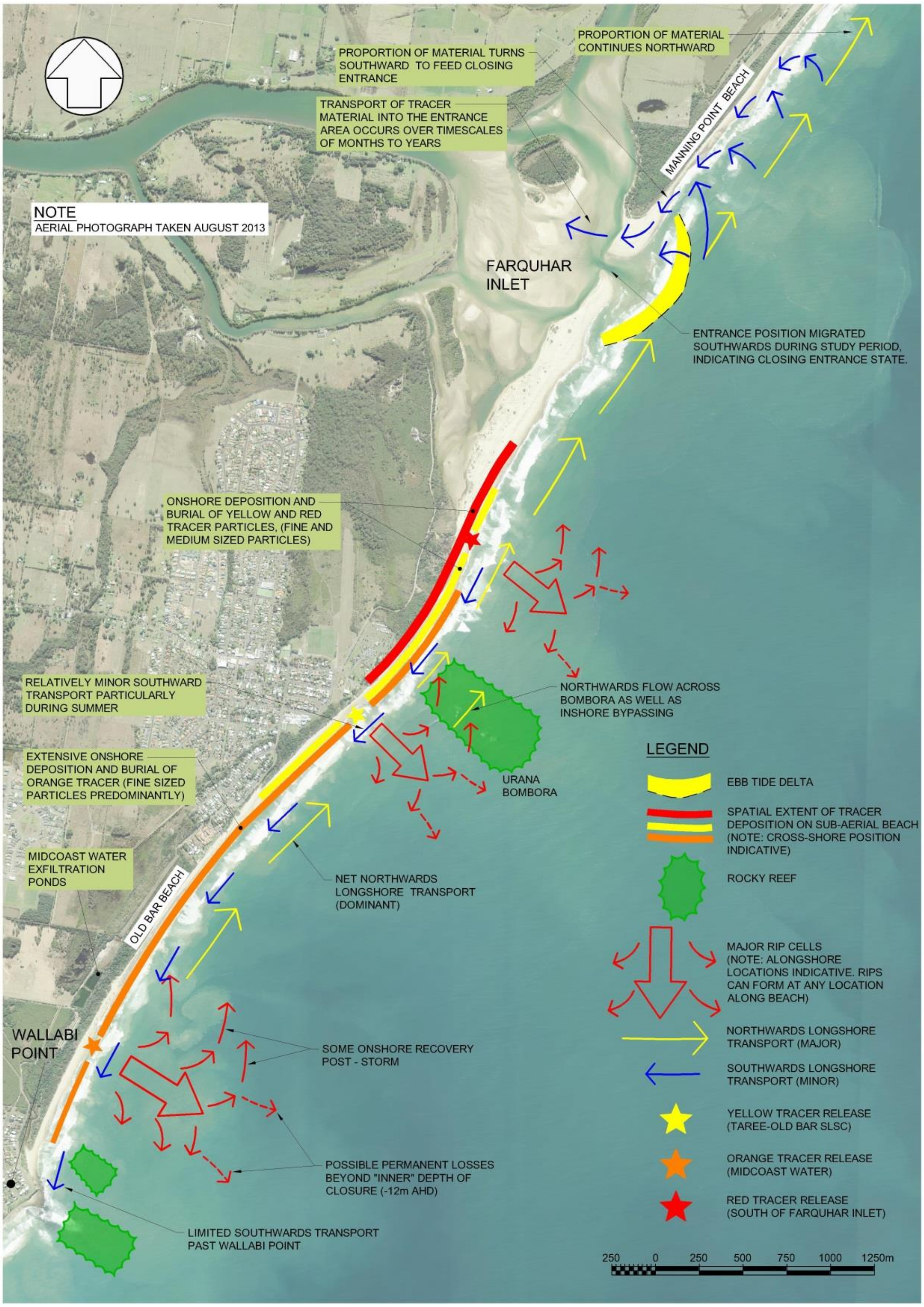


Figure 30: Conceptual description of sediment transport processes inferred from tracer results

8.2 Particle Size Results

Particle size analysis results for each tracer released indicate that under the conditions experienced during the study period, it was predominantly fine sediment that was transported alongshore and offshore from Old Bar Beach. Alongshore transport of the coarse tracer particles was less but wide transport of the coarse sized red tracer was evident in the Sampling Exercise 5 results, including the Farquhar Inlet entrance area.

Medium sized tracer particles were also transported relatively widely during the study period, albeit to a much lesser degree than the fine sized tracer. In particular, the red and orange tracers were observed to be transported up to several kilometres from the respective tracer release sites. The transport of medium sized tracer particles was typically confined to the intertidal beach, inshore zone and inner nearshore zone, with negligible transport further offshore. Medium sized yellow and red tracer was also recorded inside the Farquhar Inlet entrance area at the end of the study period.

Several samples, in particular multiple depth-averaged samples, indicated both medium and coarse sized yellow and red tracer particles in the immediate vicinity of the respective tracer release sites. This suggests that a proportion of the yellow and red sand tracers did not erode after initial placement despite apparent erosion during winter months, and/or returned during the more accretionary spring/summer period and became buried.

In comparison, the beach samples (surface and depth-averaged) and nearshore/offshore samples demonstrated predominantly fine sized orange tracer particles being present almost throughout the sampling region, possibly suggesting deposition of predominantly fine sediment and burial of fine sediment during more quiescent summer months. However, the proportion of medium and coarse sized tracer particles in the beach samples (i.e., relative to fine sized particles) increased towards the end of the study period, which indicates that the finer material was transported away from the sub-aerial beach during the study period at a faster rate than the coarser fractions.

These observations may have implications for any future beach nourishment programs implemented at Old Bar Beach. For example, if nourishment were to be undertaken in the vicinity of Taree-Old Bar SLSC or the MidCoast Water Exfiltration Ponds, in general it could be expected that the nourishment sand would be readily transported offshore and to the north during storm conditions, particularly for the finer sand fractions. However, consideration could be given to sourcing medium and coarse sized sand for the nourishment material to increase the longevity of nourished profiles, potentially from Farquhar Inlet (see **Section 7.4**).

8.3 Recommendations for Supplementary Data Collection

Long-term sampling and analysis inside Farquhar Inlet would assist to further assess the transport mechanism between Old Bar Beach and the entrance area. An improved understanding of this transport mechanism, including accurate estimates of tracer mass budgets in the short to medium term, would be useful for assessing the feasibility of any future beach nourishment activities that utilises material from Farquhar Inlet.

For example, as noted previously, transport of the tracer material to the entrance area is very likely to continue beyond the study period considered herein. As such, the extent to which sand eroded from Old Bar Beach is transported to the entrance area cannot be fully assessed from the results acquired to date. Indeed, it may eventuate that a reasonably significant proportion of the originally deployed tracer material will, over time, migrate to the entrance area, particularly for the medium and coarse size fractions. Such a finding would strongly support the notion of Farquhar Inlet as a source of material for any future nourishment activities.

More accurate estimates of the long-term mass budgets for tracer material in the entrance area could be yielded from any future sampling exercises which may include:

- sampling at discrete depths using coring methods to assess burial of the tracer and mixing depths;
- adopting a denser and more regular sampling region than was implemented during this study;
- widening the Sampling Exercise 5 sampling region, particularly in the southern reaches of the entrance where a number of relatively high tracer counts were recorded in September 2015, to more accurately assess the extent of tracer deposition inside the entrance;
- geotechnical investigations (e.g. direct cone penetrometer [DCP] testing) at several locations inside the entrance area to estimate in situ dry densities, which would eliminate the requirement for certain assumptions in the mass budget calculations that are a source of potential errors; and,
- applying more sophisticated averaging methods, such as Voronoi polygon maps, to more accurately account for the variable spatial distribution in tracer results.

It is therefore recommended that at least one further sampling and analysis exercise be undertaken within the entrance area.

Additional rounds of sampling and analysis in the wider sampling region would further improve the understanding of longer-term sediment transport processes at Old Bar Beach. In particular, it is recommended that any such sampling include coring on the beach and in nearshore areas to assess burial of tracer material across the entire beach profile. It is recommended that consideration be given to implementing a further round of sampling and analysis throughout the overall study area in the short to medium term, particularly following any significant storm events.

Sediment sampling at a number of locations outside the sampling region assessed in this study would also provide valuable information on the spatial extent of sediment transport from Old Bar Beach, e.g. sampling further offshore, northwards along Manning Point Beach, south of Wallabi Point, etc.

Inshore wave and current data in the study area would assist in interpreting the sediment tracing results, and should be considered as part of any future sampling exercises.

Finally, it is understood that a variety of coastal management options may be considered for Old Bar Beach, including seawalls, groynes, artificial headlands, offshore reefs and beach nourishment. If any of these major works are implemented, another sediment tracing project could be considered as part of the post-construction monitoring to assess the effectiveness of the works. The results presented herein would essentially form a robust baseline dataset which could be compared to post-construction results to undertake this assessment.

9 DISCUSSION ON IMPLICATIONS FOR COASTAL MANAGEMENT AT OLD BAR

9.1 Preamble

A sound understanding of coastal processes and associated sediment dynamics is essential to inform assessment of the various coastal management options available for Old Bar Beach. Based on the information provided herein, it is clear that the sediment transport processes at Old Bar Beach are highly complex, with a range of processes influencing beach morphodynamics.

Overall, it is considered that significant sand losses can occur at Old Bar Beach in response to both longshore and cross-shore processes. In particular, cross-shore losses to water depths at or beyond the “inner” depth of closure (-12 m AHD) were observed to occur in response to a storm event at the end of August 2014 with an estimated ARI of 4 years. This may represent a permanent loss of sand from the beach system.

It was expected that the Farquhar inlet would have a strong influence on sediment dynamic in the area but this was not clearly evident in the tracer results. It may be that these processes operate over longer timescales than those considered during the study period.

The complex nearshore bathymetry also appears to influence sediment transport processes, particularly in the vicinity of Urana Bombora. For example, the observed inshore bypassing of Urana Bombora (both southwards and northwards) may be related to wave diffraction in the lee of the bombora during storms.

Effective coastal management options would need to consider the range of spatial and temporal scales over which sediment transport processes operate. It is fair to conclude that no single structural solution would adequately address all of the sediment loss mechanisms occurring at Old Bar Beach. A variety of coastal management options, including groynes, artificial headlands, offshore reefs and beach nourishment, are discussed in general terms below with reference to the tracer results presented herein.

It should be noted that seawalls are not discussed herein; this option was investigated in detail for Old Bar Beach in Royal HaskoningDHV (2013). However, it should be noted that seawalls of suitable scale, construction material and crest/toe elevations remain a valid and proven coastal protection option for beaches where cross-shore losses are a dominant process, which is the case at Old Bar Beach as demonstrated by the tracer results.

9.2 Groynes / Artificial Headlands

The tracer results demonstrated that longshore transport occurs in a predominantly northwards direction, including sediment bypassing of Urana Bombora to the north along the inshore zone and possibly also as overtopping due to suspended sediment load in flows. This means that the bombora does not form an effective barrier to longshore sediment transport, thereby enabling a net loss of sand from the Old Bar Beach compartment which may become more significant in response to projected sea level rise.

Evidence of a strong net littoral drift would support the notion of constructing groynes or artificial headlands along Old Bar Beach. However, there is geological evidence suggests that negligible littoral transport enters the Old Bar Beach compartment from the south. Furthermore, the entire region consists of complex reefs with only a thin veneer of sand making up the beach and nearshore zone (Coffey and Partners, 1981), while geomorphic evidence suggests that net littoral drift from the south would be significantly limited, perhaps negligible.

As such, the predominance of northwards longshore transport inferred from the tracer results is likely to be associated with material eroded from the local embayment rather than evidence of any strong net littoral drift. Therefore, groynes are unlikely to be effective in combatting ongoing recession within the embayment. However, given that there is a net drift to the north at Old Bar Beach, it could be expected that a small degree of accretion would occur on the updrift (southern) side of groynes constructed within the embayment. For example, a series of groynes could be constructed adjacent to critical areas to selectively build up sand reserves in these areas.

However, it is important to note that groynes as a stand-alone coastal protection option would not address the cross-shore sediment losses that are a dominant process at Old Bar Beach, and recession would be expected to continue. The offshore transport of tracer material attributed to the August 2014 storm event demonstrated the significance of this process, and the likely role of rip currents in transporting sediment to water depths at or beyond the “inner” depth of closure. In addition, groynes may exacerbate the development of rip currents during storm events, which would enhance the offshore loss mechanism and lead to further increases in recession rates. There would also be impacts on Farquhar Inlet and Manning Point Beach because sediment supply to these areas would be reduced by these structures.

9.3 Offshore Reef

An offshore reef is essentially an underwater mound of material that reduces wave energy reaching the shore. The reduction in wave energy can facilitate sediment deposition in the sheltered area inshore of the reef leading to formation of a salient (a shoreline bulge).

The tracer results confirmed that cross-shore sand losses occur at Old Bar Beach, likely to be due to rip currents during storms. In general, these losses could be reduced at localised sections of the beach with offshore reef(s) of suitable scale, crest level and construction material. The northwards net longshore transport mechanism evident from the tracer results would also generally support the development of a salient in the lee of the structure.

In practice, an emergent breakwater would be much more effective than a submerged artificial reef in combatting the cross-shore and longshore sediment losses at Old Bar Beach. However, the construction of breakwater structures is very expensive (more so than revetments, for example) and may therefore be cost prohibitive for Old Bar Beach.

Furthermore, artificial reef and breakwater structures may exacerbate the development of rip currents during storms, which would enhance the offshore loss mechanism and lead to further increases in recession rates.

Moreover, offshore reefs and breakwaters are best suited to sites with relatively simple, straight coastlines where shoreline response is straightforward to predict (WRL, 2013). As demonstrated by this study, there are considerable complexities surrounding regional coastal processes at Old Bar Beach. This means that the ability to predict shoreline response to an artificial reef structure(s) at this location would be highly uncertain.

9.4 Beach Nourishment (Farquhar Inlet)

It may be possible to implement a sand back-passing system which transports sand onto Old Bar Beach via pipelines from Farquhar Inlet. This scheme would require confirmation that a significant proportion of sand eroded from Old Bar Beach is transported into the entrance area.

Transport of the red tracer into the entrance area appeared to increase towards the end of the study period, while yellow and orange tracer became evident inside the entrance area for the first time during Sampling Exercise 5. The Farquhar Inlet results presented herein confirm that sand eroded from Old Bar Beach migrates to the entrance area over timescales in the order of several months to years. For example, it is estimated that around 6% of the red tracer and 2% of the yellow tracer was present in the entrance area some 16 months following tracer deployment. It is likely that the proportion of tracer material that is transported to the entrance area will continue to increase over time, although this would need to be confirmed by further investigations to determine whether Farquhar Inlet is a significant sink for sediment eroded from Old Bar Beach.

Furthermore, the PSD analysis undertaken during this study indicated that the material inside the entrance area would be suitable for beach nourishment purposes at Old Bar Beach, particularly the medium and coarse sized fractions.

It should be noted that the required quantities of nourishment material would depend on a number of factors, including the target beach widths, length of shoreline nourished, predicted recession rates, and whether companion protection options are also implemented. The nourishment quantities would therefore be potentially significant, and may exceed what is actually available inside the entrance area.

10 CONCLUSIONS

A sediment tracing study was undertaken at Old Bar Beach to improve the understanding of sediment transport processes at this location.

Prevailing conditions during the study period (May 2014 to March 2015) were generally characterised by mild to average wave conditions except for a single large storm event in August 2014 which had an estimated ARI of 4 years. Based on a comparison of beach surveys undertaken in November 2013 and March 2015, it was inferred that dune profiles did not undergo significant change during the study period. The entrance to Farquhar Inlet migrated southwards throughout the study period which is indicative of a closing entrance state.

Analysis of the collected samples provided unequivocal and tangible data on actual sediment transport at Old Bar Beach during the study period. Key observations included:

- Predominantly northwards alongshore transport was consistently inferred from the results for each sampling exercise. This included inshore bypassing of Urana Bombora from the yellow, orange and red tracer release sites, which indicated that this feature was not a barrier to alongshore sediment transport in either direction over the study period.
- Northwards transport of material from each release site continued at least 2 km past the entrance to Farquhar Inlet (to the limit of sampling), which indicated that northwards sediment transport at least partially bypassed the inlet.
- Some alongshore transport appeared to occur to the south, most notably during summer and likely as a result of the more easterly wave direction during this period. Overall, it appeared that the southwards transport occurs at a slower rate than the dominant northwards transport.
- Significant offshore transport and deposition occurred for each tracer, particularly as a result of a significant storm event in August 2014. This was most notable from the orange release site and was probably related to the development of large rip cell(s).
- In the sampling exercises undertaken following the August 2014 storm event, tracer material was recorded in samples collected around and offshore of an estimated "inner" depth of closure at -12 m AHD. This observation provides the clearest evidence for the cause of recession at Old Bar Beach from the sediment tracing; that is, it is related to cross-shore processes which move sand well offshore to depths where it may never return (or it may take many years to return) to the sub-aerial beach.
- The net northwards transport of material past Urana Bombora may also be contributing to the observed high recession rates at Old Bar Beach if this transport is occurring at a higher rate than the alongshore supply of material entering the Old Bar Beach system past Wallabi Point from the south. However, there is no clear evidence from the sediment tracing that the observed recession, particularly at the northern end of Old Bar Beach, would be caused by this process.
- Some onshore recovery of sand eroded from the beach and transported offshore during the August 2014 storm event was inferred from the results of subsequent sampling exercises.

- The Farquhar Inlet results confirmed that sand eroded from the entire length of Old Bar Beach migrates to the entrance area over timescales in the order of several months to years. It is likely that the proportion of tracer material that is transported to the entrance area will continue to increase over time, although this would need to be confirmed by further investigations to determine whether Farquhar Inlet is a significant sink for sediment eroded from Old Bar Beach.

Particle size analysis results for each tracer released indicated that under the conditions experienced during the study period, it was predominantly fine sediment that was transported alongshore and offshore from Old Bar Beach. Medium sized tracer particles also dispersed relatively widely alongshore, albeit to a much lesser degree than the fine sized tracer and typically confined to the intertidal beach and inshore areas shallower than 5 m near the respective tracer release sites. Alongshore transport of the coarse tracer particles was less and was typically confined to the intertidal beach in the immediate vicinity of the tracer release sites. However, transport of the medium and coarse sized red and yellow tracer particles into the Farquhar Inlet entrance area was also evident in the Sampling Exercise 5 results.

These observations may have implications for any future beach nourishment implemented at Old Bar Beach. For example, if nourishment was to be undertaken in the vicinity of Taree-Old Bar SLSC or the MidCoast Water Exfiltration Ponds, in general it could be expected that the nourishment sand would be readily transported offshore and to the north during storm conditions, particularly for the finer sand fractions. However, consideration could be given to sourcing medium and coarse sized sand for the nourishment material to increase the longevity of nourished profiles, potentially from Farquhar Inlet.

The results of this study can be utilised to inform assessment of other coastal management options that may be considered for Old Bar Beach. For example:

- The predominance of northwards longshore transport inferred from the tracer results is likely to be associated with material eroded from the local embayment rather than evidence of any strong net littoral drift. Therefore, groynes are unlikely to be effective in combatting ongoing recession within the embayment. However, it could be expected that a small degree of accretion would occur on the updrift (southern) side of groynes, which could be constructed adjacent to critical areas to selectively build up sand reserves in these areas.
- The cross-shore sediment losses inferred from the tracer results could be reduced at localised sections of the beach with emergent breakwaters of suitable scale, crest level and construction material. However, the considerable complexities surrounding regional coastal processes at Old Bar Beach means that the ability to predict shoreline response to an artificial reef structure(s) at this location would be highly uncertain.
- Seawalls of suitable scale, construction material and crest/toe levels remain a valid and proven coastal protection option for beaches where cross-shore losses are a dominant process, which is the case at Old Bar Beach as demonstrated by the tracer results.

11 REFERENCES

ASR Ltd (2011), *Old Bar Beach Stabilisation Investigation: Feasibility Study*, ASR Ref: 130-2011, September 2011

Coffey and Partners (1981), *Geomorphological Assessment Wallabi Point to Crowdy Head, Taree*, prepared for Sinclair Knight and Partners

Gordon AD (2013), *Coastal Acclimatisation to Intermittently Open River Entrances (IORE)*, Coasts and Ports Conference, September 2013

Roy, P.S., Zhuang, W-Y, Birch, G.F., Cowell, P.J. and Congxian Li (1997), *Quaternary Geology of the Forster-Tuncurry Coast and Shelf, Southeast Australia*, Geological Survey Report: GS 1992/201, December 1997

Royal HaskoningDHV (2013), *Old Bar Beach Coastal Protection Structure Design Investigation*, prepared for Greater Taree City Council, November 2013

Royal HaskoningDHV (2014), *Risk Assessment to Define Appropriate Development Setbacks and Controls in Relation to Coastline Hazards at Old Bar*, prepared for Greater Taree City Council, April 2014

Shand, T.D., Goodwin, I.D., Mole, M.A., Carley, J.T., Browning, S., Coghlan, I.R., Harley, M.D. and Peirson, W.L. (2011), *NSW Coastal Inundation Hazard Study: Coastal Storms and Extreme Waves*, WRL Technical Report 2010/16, January 2011

Sinclair Knight & Partners [SKP] (1981), *Old Bar Coastal Erosion Study*, prepared for Department of Public Works, NSW, November 1981 (DRAFT)

Water Research Laboratory [WRL] (2010), *Peer Review of Black Head to Crowdy Head Coastline Hazard Definition Study and Management Options Study*, WRL Technical Report 2010/21, July 2010

Water Research Laboratory [WRL] (2012), *Old Bar Submerged Artificial Reef Review*, WRL2012001 JTC:MJB LR20120530, 30 May 2012

Water Research Laboratory [WRL] (2013), *A Review of Artificial Reefs for Coastal Protection in NSW*, WRL Technical Report 2012/08 (IN DRAFT), March 2013

WorleyParsons (2010a), *Black Head to Crowdy Head Coastline Hazard Definition Study Volume 1: Report*, prepared for Greater Taree City Council, September 2010

WorleyParsons (2010b), *Greater Taree Coastline Management Study, Black Head to Crowdy Head*, prepared for Greater Taree City Council, October 2010

WorleyParsons (2013), *A Coastal Zone Management Plan for Greater Taree*, prepared for Greater Taree City Council, March 2013

You Z-J, Lord DB and Watson PJ (2009), *Estimation of Relative Sea Level Rise from Fort Denison Tide Gauge Data*. Proceedings of the 19th Australasian Coastal and Ocean Engineering Conference, Wellington, New Zealand

Appendix A - Certificate of Analysis for samples taken 2 May 2014 for particle size distribution analysis

CERTIFICATE OF ANALYSIS

Work Order	: **EN1401548**	Page	: 1 of 5
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Newcastle
Contact	: MR PATRICK LAWLESS	Contact	: Peter Keyte
Address	: SUITE 505 100 Walker Street NORTH SYDNEY 2060	Address	: 5/585 Maitland Road Mayfield West NSW Australia 2304
E-mail	: pat.lawless@rhdhv.com	E-mail	: peter.keyte@als.com.au
Telephone	: +61 02 8854 5000	Telephone	: 61-2-4968-9433
Facsimile	: ----	Facsimile	: +61-2-4968 0349
Project	: GREATER TAREE CITY COUNCIL	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 05-MAY-2014
Sampler	: ----	Issue Date	: 22-MAY-2014
Site	: ----		
		No. of samples received	: 15
Quote number	: ----	No. of samples analysed	: 15

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Hamish Murray	Supervisor - Soils	Newcastle - Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	1H 02/05/14	1M 02/05/14	1L 02/05/14	2H 02/05/14	2M 02/05/14
			Client sampling date / time	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00
Compound	CAS Number	LOR	Unit	EN1401548-001	EN1401548-002	EN1401548-003	EN1401548-004	EN1401548-005
EA150: Particle Sizing								
+75µm	----	1	%	99	96	96	99	93
+150µm	----	1	%	90	38	90	79	91
+300µm	----	1	%	<1	3	5	31	30
+425µm	----	1	%	<1	2	<1	6	8
+600µm	----	1	%	<1	<1	<1	1	4
+1180µm	----	1	%	<1	<1	<1	<1	3
+2.36mm	----	1	%	<1	<1	<1	<1	2
+4.75mm	----	1	%	<1	<1	<1	<1	2
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	<1	4	4	<1	7
Sand (>75 µm)	----	1	%	99	96	96	99	91
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	2
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

			Client sample ID	2L 02/05/14	3H 02/05/14	3M 02/05/14	3L 02/05/14	4H 02/05/14
			Client sampling date / time	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00
Compound	CAS Number	LOR	Unit	EN1401548-006	EN1401548-007	EN1401548-008	EN1401548-009	EN1401548-010
EA150: Particle Sizing								
+75µm	----	1	%	97	100	99	99	100
+150µm	----	1	%	86	95	55	87	60
+300µm	----	1	%	75	11	2	2	14
+425µm	----	1	%	64	<1	<1	<1	<1
+600µm	----	1	%	57	<1	<1	<1	<1
+1180µm	----	1	%	45	<1	<1	<1	<1
+2.36mm	----	1	%	36	<1	<1	<1	<1
+4.75mm	----	1	%	23	<1	<1	<1	<1
+9.5mm	----	1	%	4	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	3	<1	<1	1	<1
Sand (>75 µm)	----	1	%	61	100	99	99	100
Gravel (>2mm)	----	1	%	36	<1	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)

			Client sample ID	4M 02/05/14	4L 02/05/14	5H 02/05/14	5M 02/05/14	5L 02/05/14
			Client sampling date / time	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00	02-MAY-2014 15:00
Compound	CAS Number	LOR	Unit	EN1401548-011	EN1401548-012	EN1401548-013	EN1401548-014	EN1401548-015
EA150: Particle Sizing								
+75µm	----	1	%	98	98	100	100	99
+150µm	----	1	%	96	88	98	47	91
+300µm	----	1	%	56	82	27	5	17
+425µm	----	1	%	29	72	4	<1	3
+600µm	----	1	%	10	56	<1	<1	<1
+1180µm	----	1	%	<1	36	<1	<1	<1
+2.36mm	----	1	%	<1	23	<1	<1	<1
+4.75mm	----	1	%	<1	16	<1	<1	<1
+9.5mm	----	1	%	<1	4	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	2	2	<1	<1	<1
Sand (>75 µm)	----	1	%	98	75	100	100	99
Gravel (>2mm)	----	1	%	<1	23	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1

Appendix B - Sampling and analysis of particle size distribution results for native beach material

Sampling and analysis of particle size distribution results for native beach material

Sample Locations

A total of 15 samples were collected at Old Bar Beach on 2 May 2014 for particle size distribution (PSD) analysis. Sampling was carried out at the following five locations (from north to south):

- Site 5 (Farquhar Inlet);
- Site 1 (Surf Club);
- Site 3 (littoral rainforest);
- Site 2 (Meridian Resort);
- Site 4 (Exfiltration Ponds).

Three samples were collected at each location at the following positions on the beach:

- H - High water swash (top of wetted line on the beach);
- M - Mean sea level (about 20 m further seaward of above);
- L - Low tide (about 10 m further seaward of above).

Results

PSD results for each sample are summarised in **Table B1**. This includes the determined material type, median grain size data (diameter, D_{50}), and soil classification results (i.e. proportions of sand, mud and gravel) for each sample. Soil classification results for each sample are plotted in **Figure B1**. Median grain size data is plotted in **Figure B2**, and is also overlaid onto an aerial photograph in **Figure B3**, which also indicates the sampling locations.

Table B1: Summary of Sample Analysis

Sample ID	Type	D_{50} (μm)	GRAVEL	SAND	MUD
5H	Sand	239.7	0.0%	100.0%	0.0%
5M	Sand	144.2	0.0%	100.0%	0.0%
5L	Sand	220.2	0.0%	99.0%	1.0%
1H	Sand	204.1	0.0%	99.0%	1.0%
1M	Sand	130.0	0.0%	96.2%	3.8%
1L	Sand	207.9	0.0%	96.2%	3.8%
3H	Sand	217.4	0.0%	100.0%	0.0%
3M	Sand	160.1	0.0%	99.0%	1.0%
3L	Sand	202.8	0.0%	99.0%	1.0%
2H	Sand	228.0	0.0%	99.0%	1.0%
2M	Slightly Gravelly Sand	239.0	2.2%	91.1%	6.7%
2L	Sandy Gravel	890.2	38.1%	59.0%	2.9%
4H	Sand	174.4	0.0%	100.0%	0.0%
4M	Sand	324.1	0.0%	98.1%	1.9%
4L	Gravelly Sand	735.0	26.1%	72.0%	1.9%

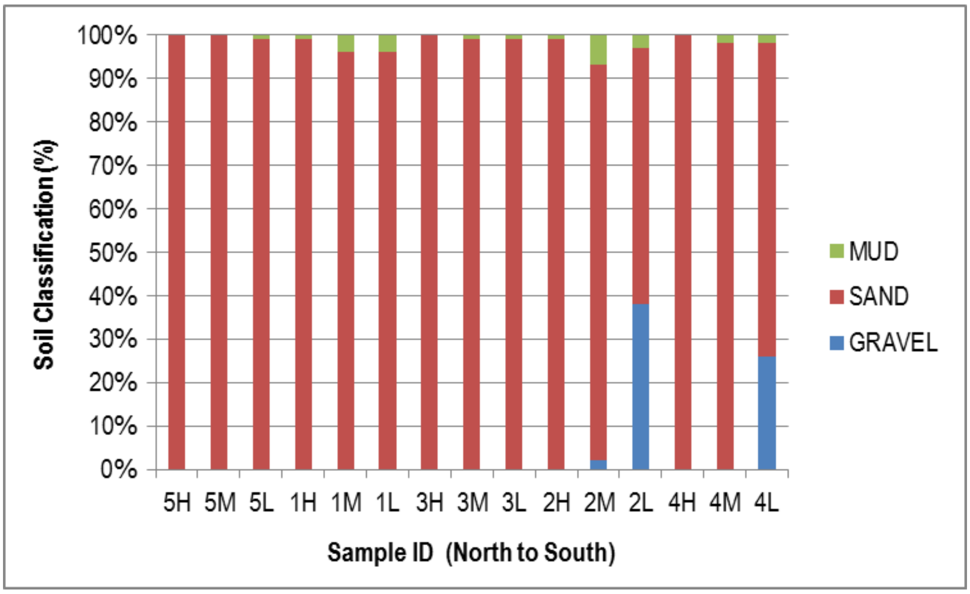


Figure B1: Soil classification results for each sample

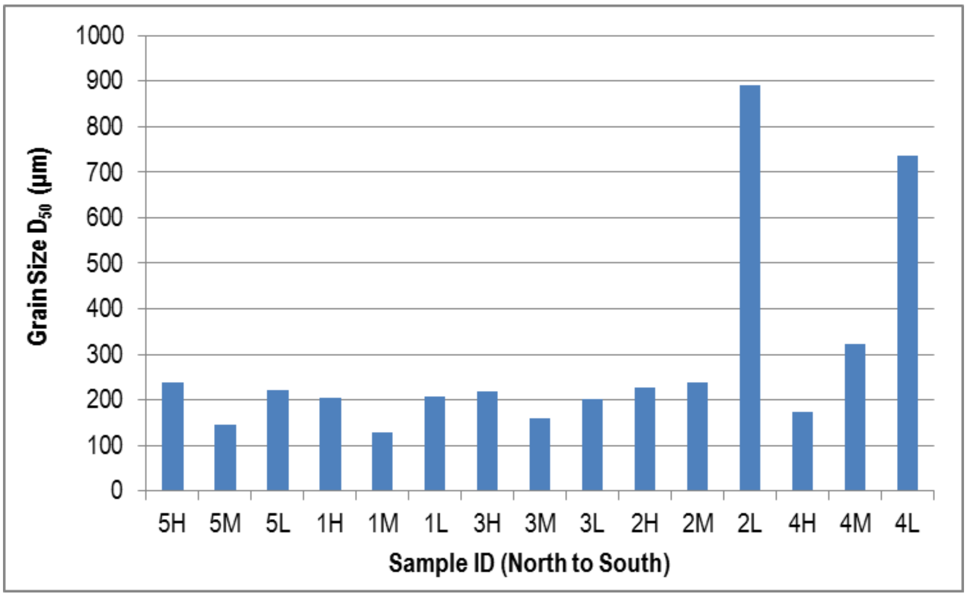


Figure B2: Median grain size results for each sample, D_{50} (µm)

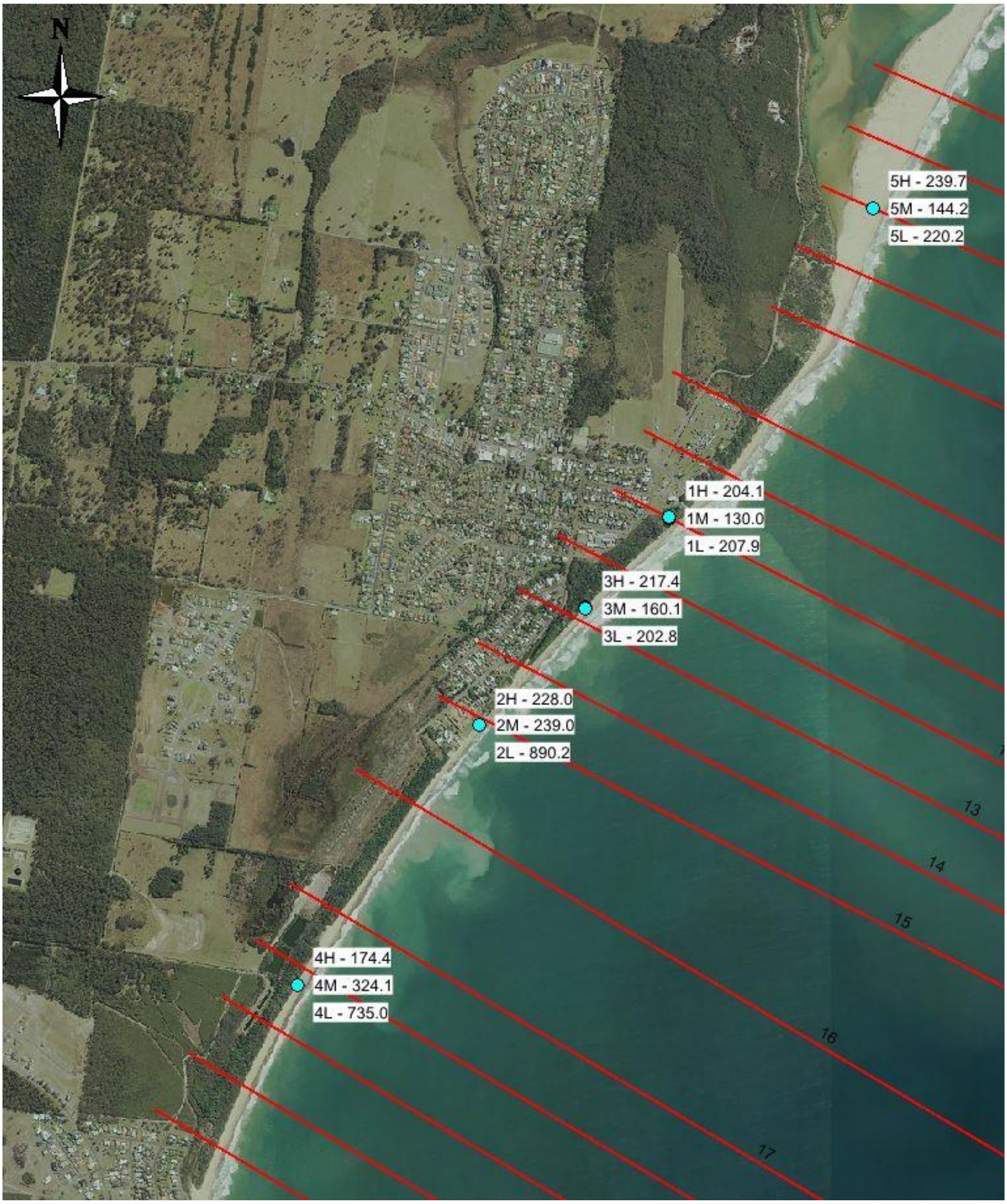


Figure B3: Aerial view of median grain size results for each sample, D_{50} (µm)

It is evident that the majority of samples can be classified as approximately 100% sand, with the exception of samples 2M, 2L and 4L (highlighted red in Table B1). The following is noted for these samples:

- Sample 2M contains the largest percentage of mud (6.7%), where the mud is spread out over the whole range of silt/clay classification. Sample 2M can be defined as slightly gravelly sand.
- Sample 2L contains the smallest percentage of sand of (59.0%) and largest percentage of gravel (38.1%) (890 µm D_{50}). Sample 2L can be defined as sandy gravel. Specifically, the majority of the gravel in Sample 2L was fine gravel, with very little coarse gravel present.
- Sample 4L is similar to Sample 2L but with more sand and less gravel. However, the majority of the sand is coarse sand. Sample 4L can be defined as gravelly sand with large grain size (735 µm D_{50}).

The spatial distribution of the results indicates the following:

- Sites 3 and 5 – majority sand throughout.
- Site 1 - majority sand throughout, with traces of mud in samples 1M and 1L (3.8% for each sample, highlighted in green in Table B1), perhaps indicating that beach sediments are slightly finer moving seaward.
- Site 2 – sediment becomes coarser moving seaward.
- Site 4 – sediment becomes slightly coarser moving seaward.

Summary

In general, the results presented herein indicate that the sediments at Old Bar Beach are predominantly sand. At the northern end of the beach, grain sizes are reasonably consistent in the order of 130 to 240 µm. Around the middle and southern portion of the beach, grain sizes at or above mean sea level are also sandy (170 to 320 µm), however much more gravelly material was recorded in samples collected from the lower beach face, characterised by grain sizes in the order of 700 to 900 µm.

Appendix C - Material Safety Data Sheet (MSDS) for Tracer Material

MATERIAL SAFETY DATA SHEET

1. Product/Manufacturer's Details:

SERIES NAME:	EcoTrace Fluorescent Tracer
APPLICATION:	Particle tracing
MANUFACTURER'S NAME:	c/o ETS Worldwide Ltd., The Coach House, Bannachra, Helensburgh, Argyll, G84 9EF
TELEPHONE:	01389 711001
CONTACT:	Dr. Jonathan Marsh

2. Composition/Information on Ingredients

COMPOSITION:	Solid solution of fluorescent dyes in thermoplastic polymer base
HAZARDOUS INGREDIENTS:	Does not contain any substances presenting a health hazard within the meaning of the Dangerous Substance Directive 67/548/EEC as amended by the Seventh Amendment 92/32/EEC

3. First Aid Measures

GENERAL:	In all cases of doubt or when symptoms persist, seek medical attention. Never give anything by mouth to an unconscious person.
INHALATION:	Remove to fresh air, keep patient warm and at rest; if breathing is irregular or stopped, administer artificial respiration. Give nothing by mouth. If unconscious, place in recovery position and seek medical advice.
EYE CONTACT:	Irrigate copiously with clean fresh water for at least 10 minutes holding the eyelids apart and seek medical advice
SKIN CONTACT:	Wash skin thoroughly with soap and water or use recognised skin cleaner. Do NOT use solvents or thinners
INGESTION:	If accidentally swallowed give two glasses of water to drink. Do NOT induce vomiting. If symptoms persist seek medical advice

4. Fire Fighting Measures

EXTINGUISHING MEDIA:	Foam, CO_2 powders, water fog
PRECAUTIONS:	Exposure to decomposition products may cause a health hazard (Section 9)

5. Accidental Release Measures

PERSONAL PRECAUTIONS:	Refer to protective measures listed in Section 7. Avoid dust formation. Take precautionary measures against static discharges
METHODS FOR CLEANING UP:	Contain spillage with suitable dust binding materials such as sand/sawdust and dispose in accordance with Section 12. Clean affected areas with water/biodegradable surfactant solution – avoid use of solvents Refer to protective measures listed in Section 7. Avoid dust formation. Take precautionary measures against static discharges
METHODS FOR CLEANING UP:	Contain spillage with suitable dust binding materials such as sand/sawdust and dispose in accordance with Section 12. Clean affected areas with water

6. Handling and Storage

HANDLING:	Avoid dust formation. Take precautionary measures against static discharges
STORAGE:	Store in a dry well ventilated place away from sources of heat and direct sunlight. Keep away from sources of ignition. Keep away from strong oxidising agents and alkaline and acidic materials. Containers, which are open, should be closed and kept upright to prevent leakage and control contamination. Keep in original packaging.

7. Exposure Controls/Personal Protection

ENGINEERING MEASURES: Provide local exhaust ventilation if required. See exposure limits

EXPOSURE LIMITS:	SHORT TERM EXPOSURE LIMITS	LONG TERM EXPOSURE LIMITS
Total inhalable dust:	10 mg/m^3	10 mg/m^3
Respirable dust:	5 mg/m^3	5 mg/m^3

RESPIRATORY PROTECTION:	Provide local extraction if required. See exposure limits. If exposure limits are likely to be exceeded then ensure that masks are used – EN 143 type P2 is recommended
HAND PROTECTION:	Wear gloves
EYE PROTECTION:	Wear goggles
GENERAL SAFETY & HYGIENE MEASURES:	The usual precautions for the handling of chemicals must be observed

8. Physical and Chemical Properties

FORM:	Coloured fine powder
SOFTENING POINT:	Not applicable – Thermoset product
DECOMPOSITION POINT:	Above 190°C
SOLUBILITY IN WATER:	None
pH VALUE:	6–7.5 (5% in water @ 25°C)
SPECIFIC GRAVITY	c. 1.0 up to 2.65 @ 20°C
FLASH POINT:	Not applicable
ODOUR:	Slight smell
VISCOSITY:	Not applicable
BOILING POINT:	Not applicable
VAPOUR DENSITY:	Not applicable
VAPOUR PRESSURE:	Not applicable
EXPLOSION HAZARD:	Dust explosion hazard
MIN EXPLOSIBLE CONC:	67–75 g/M^3
MIN IGNITION ENERGY:	7–10 mJ

9. Stability and Reactivity

CONDITIONS CONTRIBUTING TO INSTABILITY:	Product is stable under recommended storage and handling conditions. If exposed to elevated temperatures gas can be liberated – in these cases suitable control procedures should be implemented.
MATERIALS TO AVOID:	Keep product away from strong oxidising agents, strongly alkaline and strongly acidic materials
HAZARDOUS DECOMPOSITION PRODUCTS:	Fumes may contain oxides of sulphur, carbon and nitrogen.

10. Toxicological Information

ACUTE ORAL TOXICITY LD50:	More than 16 g/kg
ACUTE DERMAL TOXICITY LD50:	More than 23 g/kg
ACUTE DUST INHALATION LC50:	More than 4.4 mg/L (4 hours)*
EYE IRRITATION:	No significant irritation
HEAVY METAL CONTENT:	Typical Analysis Expressed in mg/kg Antimony <1, Arsenic <1, Barium <1, Cadmium <1, Chromium <1, Lead <1, Mercury <1, Selenium <2
FREE PRIMARY AROMATIC AMINE:	Less than 0.1% w/w typical analysis
NOTES:	The values for acute oral toxicity acute dermal toxicity and acute dust inhalation refer to tests conducted on representative samples. These tests resulted in NO DEATHS OF THE TEST ANIMALS.

11. Ecological Information

Tests have been carried out by CEFAS Weymouth and ETS Ltd. exposing Pacific Oysters to high concentrations of EcoTrace tracer particles. The results indicated <5% uptake of available tracer particles peaking at 2 hours after exposure followed by discharge in the faecal strands. EcoTrace particles were depurated when the oysters were placed in clean water over a 5 day period with trace levels remaining in the Oysters after depuration. Further details are available from ETS Ltd. The tracer has also been fed to *Daphnia* over a prolonged period by Alcontrol Laboratories who found no mortalities.

12. Disposal considerations

Waste and emptied containers should be disposed of in accordance with current regulations

13. Transport information

Considered as Non-Hazardous under Transport Regulations

14. Regulatory Information

LABELLING ACCORDING TO EU DIRECTIVES:	Not subject to labelling
NATIONAL LEGISLATION/ REGULATIONS:	This product is classified as NON-HAZARDOUS under the UK 'Chemicals (Hazard Information and Packaging/Regulations' CHIP Regulations

15. Other Information

The information in this MSDS is based on the present state of our knowledge and on current EU and National Laws. It is the responsibility of the user to ensure that their employees are aware of the content of this MSDS and also to ensure that any additional local rules and regulations are satisfied. The information contained herein is provided in accordance with the current legal requirement and should not be considered as a guarantee of the product's properties or performance. The information in this Safety Data Sheet is pursuant to:

a) The Chemicals (Hazard Information and Packaging) Regulation 1994
b) Article 27 of the Dangerous Substances Directive – 67/548/EEC as amended by the Seventh Amendment – 92/32/EEC (Official Journal No. L154. 5 June 1992 P1)
c) Article 10 of the Dangerous Preparation Directive – 88/379/EEC (Official Journal No. L187. 16 July 1988 P14)
d) The Safety Data Sheets Directive – 91/155/EEC as amended by Directive 93/112/EEC (Official Journal No. L314. 16 December 1993, P38)

Appendix D - Impacts of Tracer Material on Ecotoxicology and Human Consumption

Uptake & Elimination Tests of EcoTrace Fluorescent Tracer particles By Pacific Oysters

ETS carried out tests in conjunction with CEFAS (a UK Government laboratory) in order to establish baseline information on the effect of releasing EcoTrace fluorescent tracer particles in close proximity to shellfish areas including oyster beds. The tests involved exposing oysters to a very concentrated level of EcoTrace particles and measuring the rate of uptake and concentration held within the oyster over time. Further tests were then carried out to assess whether the oysters retained or eliminated the tracer when added to clean water (depuration). CEFAS undertook the uptake and elimination trials at the Weymouth laboratories using tracer supplied by ETS.

The tests clearly indicate that tracer is taken up by the oysters. Maximum concentrations of tracer in the oysters occurred at Time 2 hours after exposure. The concentration of tracer measured in the oysters at Time 2 hours, expressed as a percentage of the total tracer in the circulation tank at Time 0 hours, ranged between 14-58%. Furthermore, the tests indicated that after the peak uptake at Time 2 hours, the oysters begin to export the tracer particles in faecal waste, with concentrations decreasing to between 1-3% in the oysters after 24 and 48 hours. During this time the oysters remained in the circulation tank continually exposed to tracer. Further testing indicated that the tracer particles were depurated when the oysters were placed in clean water, with concentrations after five days of 0.1-0.2% of the total tracer present in the exposure circulation tank. The full report is available on request.

Effect of Non-Metallic Products on the Quality of Portable Water

In 2000 samples of ETS' tracer were tested in accordance with the methods specified in;

1. BS6920: 1996 Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

2. Methods of Test and the Water Regulations Advisory Scheme Information Note and Guidance Note No- 9-01-02 Issue 1, June 1995, Requirements for the testing of non-metallic products for use in contact with portable water.

3. Water Regulation Advisory Scheme Instruction No Admin 7, January 1998 update amendments.

It is concluded that ETS' tracer particles satisfied the criteria set out in BS6920: Part 1: 1996 'Specification' and thus does comply with the requirements of the Water Regulations Advisory Scheme Tests of Effect on Water Quality for use with cold water. The report is available upon request.

Appendix E - Fall velocity testing of the tracer material

Fall velocity testing of the tracer material

Given that the tracer particles were intended to represent natural non-cohesive sand, ETS carried out fall velocity tests on the yellow, red and orange tracer particles and sand collected from the beach during Sampling Exercise 4 that was also analysed for PSD (refer Section 7.4 of main report). The tests were carried out to compare the two different types of particles (sand tracer and natural sand) to ensure they behaved in a similar manner if eroded and resuspended into the water column.

The fall velocity tests involved timing the fall of a unique individual particle of known size over a 1 m (1000 mm) vertical distance in seawater at constant temperature. A total of 5 grains were tested per size band per colour/beach material. For these tests, the temperature was maintained at 20°C ±1°C (equivalent to ambient room temperature at time of test) and 35.1% salinity (as per ocean water). ETS used ambient room temperature since it is difficult to warm the entire 1 m water column consistently and continuously and avoid pockets of warmer and cooler water. In addition, ETS always conducts fall velocity tests at or around 20°C to allow comparison from one tracer/sediment to another for all project sites tested, and it is a standard temperature for tests in other laboratories. Also, a water temperature of 20°C is reasonably representative of ocean temperatures along the NSW coastline for most of the year.

For the test, the three colours of tracer particles (yellow, red and orange) and beach sediment were soaked and wetted in the same way for the same duration from a dry state. Individual particles were selected by microscope and sized using a microscope eyepiece graticule to ensure comparison between grain sizes. Sizing in this way only allows measurements in two dimensions (X and Y) and not Z, which leads to variability in the actual grain size, however the same approach is used for natural sand and tracer particles. Three size bands were compared, corresponding to the fine, medium and coarse sizes adopted for the study (refer Section 6.3 of main report) with the results detailed in **Table E1**. It should be noted that the sizes cover quite a wide range (125 µm), which means that the variation in settling velocities is also large, particularly compared with velocities reported in the literature which tend to isolate one size of particle or use a sphere to compare measured with mathematical calculations. By comparison, the purpose of these measurements was to ensure that the sand tracers and the natural sand were similar in laboratory conditions.

Table E1: Fall velocity results for Yellow, Red and Orange tracer particles and Old Bar beach sand (Round 4)

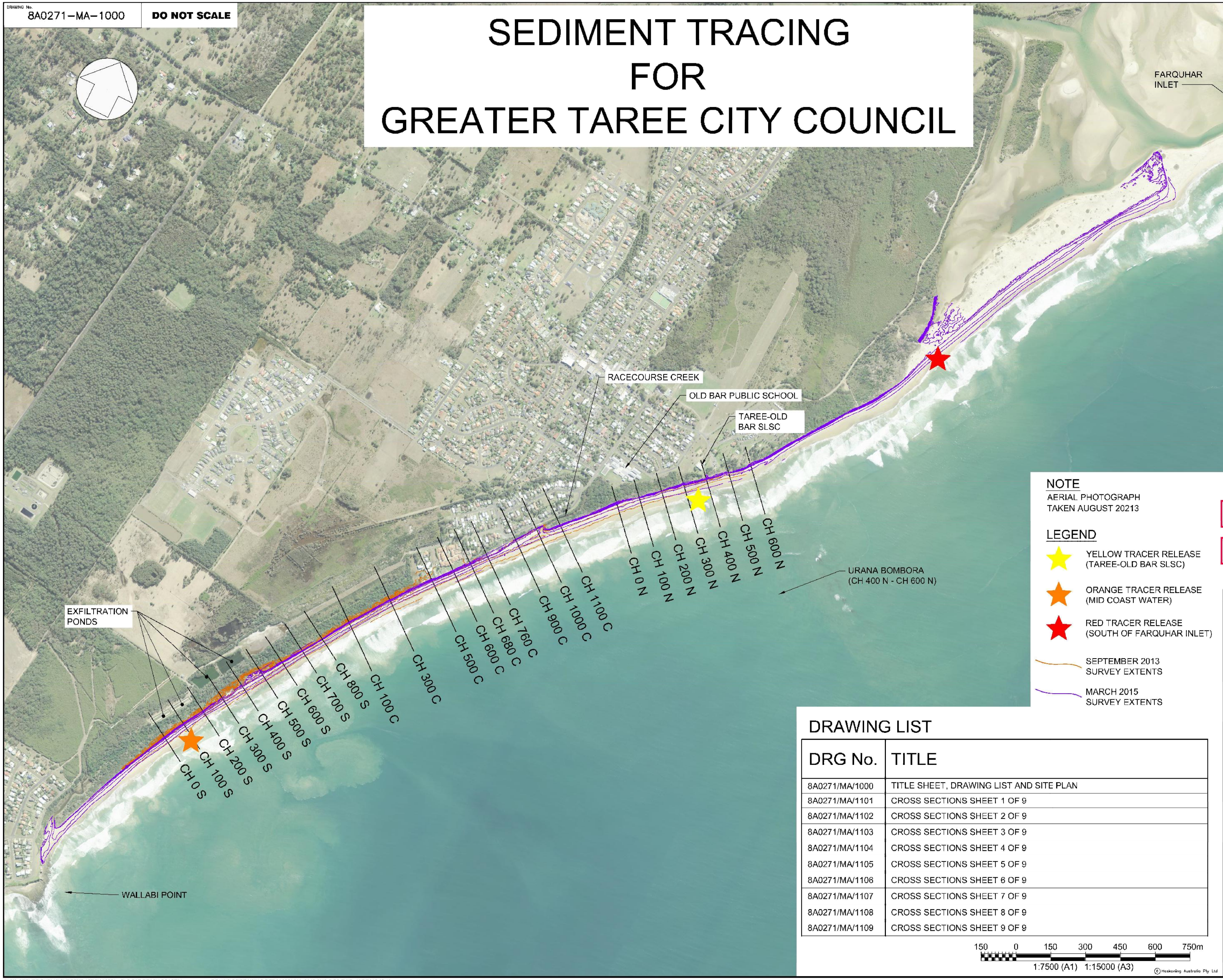
Grain size (mm)	Average fall velocity Yellow tracer (mm/s)	Average fall velocity Red tracer (mm/s)	Average fall velocity Orange tracer (mm/s)	Average fall velocity Old Bar beach sand (mm/s)
Fine 0.125 – 0.250	20.1 (23.6, 20.7, 22.3, 16.4, 17.6)	19.8 (16.8, 18.7. 19.1, 22.3, 21.9)	18.5 (15.4, 17.1, 20.4, 21.0, 18.8)	18.9 (16.3, 20.9, 15.7, 22.1, 19.7)
Medium 0.250–0.375	32.5 (33.9, 38.7, 27.7, 29.4, 32.6)	34.4 (25.8, 33.6, 40.1, 34.0, 38.7)	35.0 (27.3, 39.9, 32.7, 37.1, 38)	32.1 (35.6, 29.1, 26.1, 33.2, 36.7)
Coarse 0.375–0.500	56.9 (58.4, 61.2, 54.3, 52.8, 57.6)	56.6 (63.4, 52.1, 58.8. 58.1, 50.7)	53.7 (57.1, 50.4, 48.9, 52.1, 59.9)	54.1 (49.9, 62.3, 50.2, 47.7, 60.6)

For the given size ranges, allowing for the variability finding identical size grains, the fall velocities for the three size bands were very similar for the three sand tracers and beach sand and the minor differences are not considered to be significant.

Appendix F - Drawings: Comparison of November 2013 and March 2015 beach surveys

DRAWING No. 8A0271–MA–1000 | DO NOT SCALE

SEDIMENT TRACING FOR GREATER TAREE CITY COUNCIL



NOTE

AERIAL PHOTOGRAPH TAKEN AUGUST 20213

LEGEND

- YELLOW TRACER RELEASE (TAREE-OLD BAR SLSC)
- ORANGE TRACER RELEASE (MID COAST WATER)
- RED TRACER RELEASE (SOUTH OF FARQUHAR INLET)
- SEPTEMBER 2013 SURVEY EXTENTS
- MARCH 2015 SURVEY EXTENTS

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

DRAWING LIST

DRG No.	TITLE
8A0271/MA/1000	TITLE SHEET, DRAWING LIST AND SITE PLAN
8A0271/MA/1101	CROSS SECTIONS SHEET 1 OF 9
8A0271/MA/1102	CROSS SECTIONS SHEET 2 OF 9
8A0271/MA/1103	CROSS SECTIONS SHEET 3 OF 9
8A0271/MA/1104	CROSS SECTIONS SHEET 4 OF 9
8A0271/MA/1105	CROSS SECTIONS SHEET 5 OF 9
8A0271/MA/1106	CROSS SECTIONS SHEET 6 OF 9
8A0271/MA/1107	CROSS SECTIONS SHEET 7 OF 9
8A0271/MA/1108	CROSS SECTIONS SHEET 8 OF 9
8A0271/MA/1109	CROSS SECTIONS SHEET 9 OF 9

150 0 150 300 450 600 750m

1:7500 (A1) 1:15000 (A3)

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	28.08.15	NOTES ADDED	BAM	GPB	
A	28.08.15	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: TITLE SHEET DRAWING LIST AND SITE PLAN

HASKONING AUSTRALIA PTY LTD
SYDNEY
Royal HaskoningDHV
Enhancing Society Together
Suite 5, Level 5
100 Walker Street
North Sydney NSW 2060
+61 2 8854 5000 Telephone
+61 2 9929 0960 Fax
www.royalhaskoning.com Internet

DRAWN SGB | DATE 10/09/2015 | JOB No. 8A0271

AUTOCAD REF. 8A0271–MA_2015–AUG–FIGS

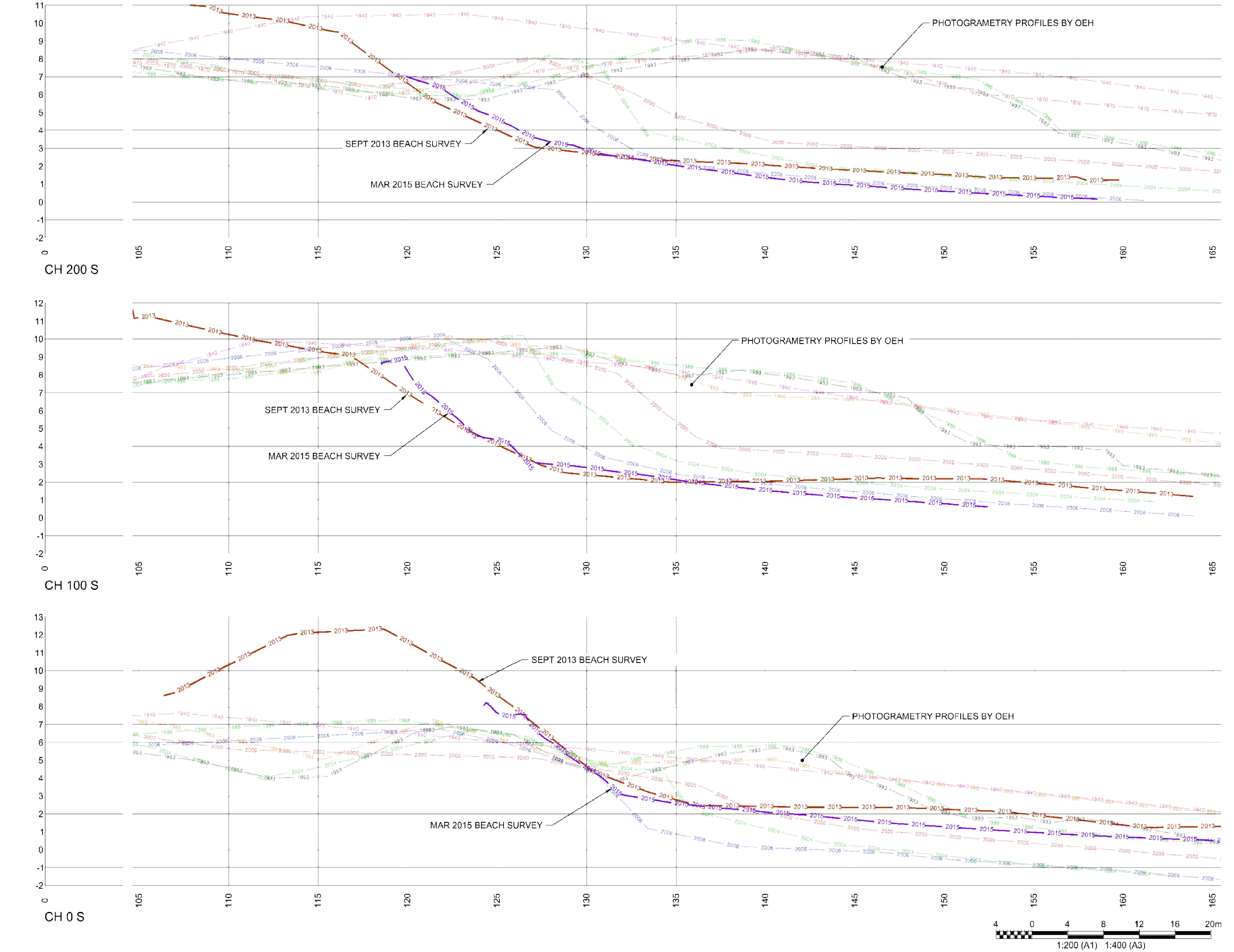
SCALE AT A1 1:7500

DRAWING No. 8A0271–MA–1000 | REVISION B

\\HKA-SERVER\PUBLIC\CURRENT JOBS\8A0271 - OLD BAR BEACH COASTAL PROTECTION STRUCTURE DESIGN\E TECHNICAL DATA\E11 WORKING DRAWINGS\DRAWING SET\8A0271-MA_2015-AUG-FIGS.DWG 10/2/2015 12:49 PM

DRAWING No. 8A0271/MA/1101

DO NOT SCALE



AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 1 OF 9

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

AUTOCAD REF. 8A0271-MA-SECTIONS

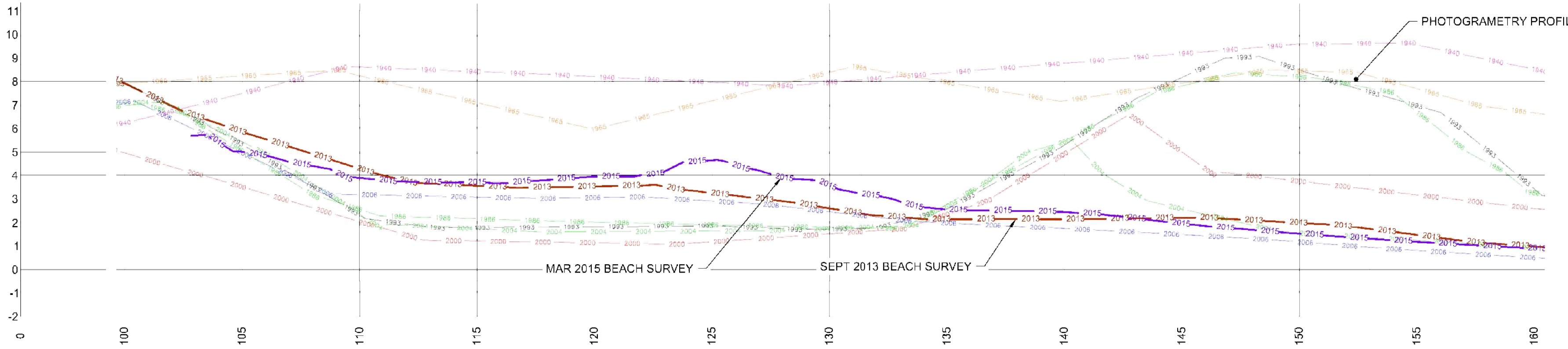
SCALE AT A1 AS SHOWN

DRAWING No. 8A0271/MA/1101 | REVISION A

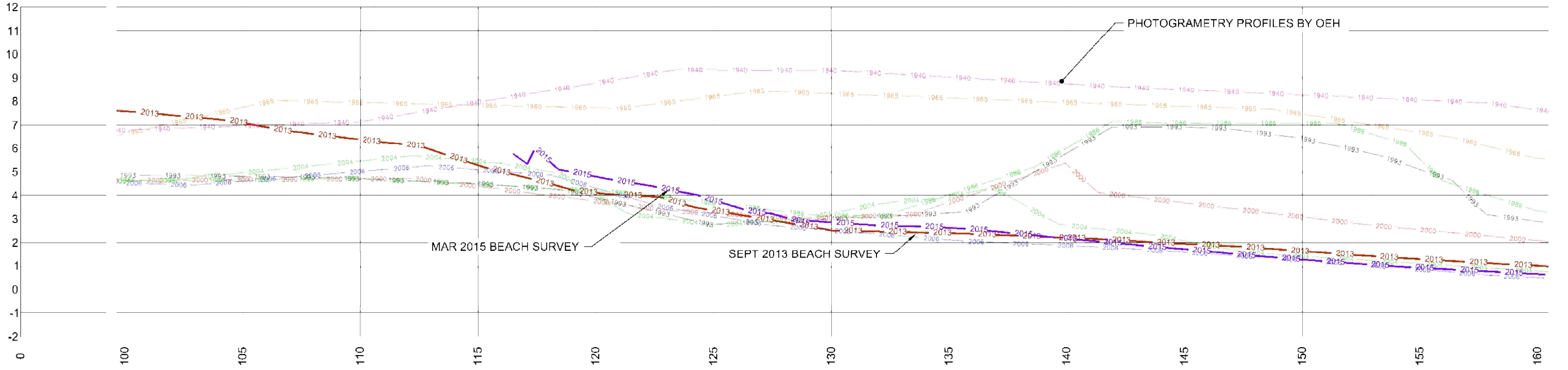
\\HKA-SERVER\PUBLIC\CURRENT JOBS\8A0271 - OLD BAR BEACH COASTAL PROTECTION STRUCTURE DESIGN\6. TECHNICAL DATA\611 WORKING DRAWINGS\DRAWING SET\8A0271-MA-SECTIONS.DWG 10/2/2015 12:22 PM

DRAWING No. 8A0271/MA/1102

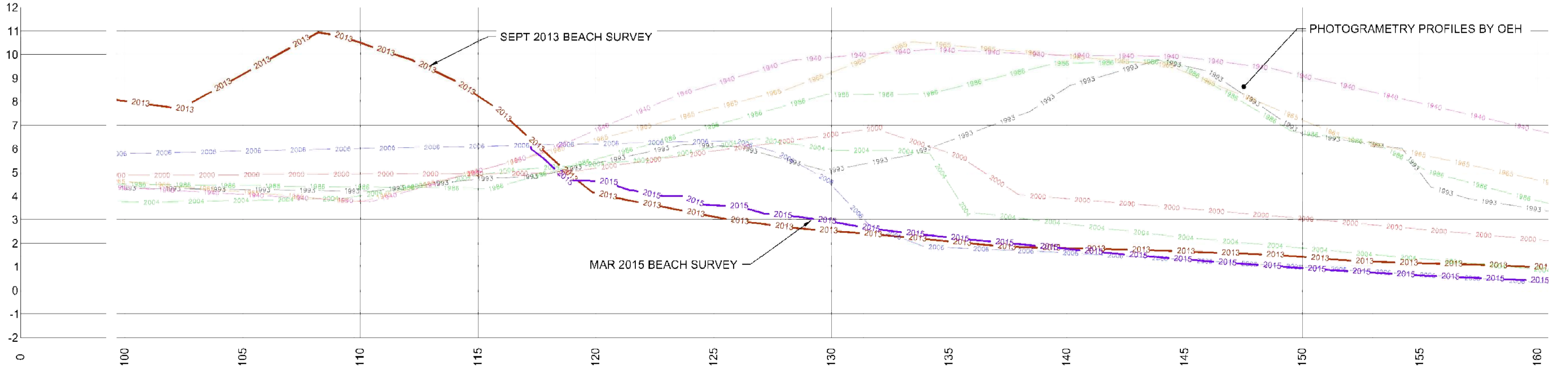
DO NOT SCALE



CH 500 S



CH 400 S



CH 300 S

4 0 4 8 12 16 20m

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 2 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY

Royal HaskoningDHV
Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

AUTOCAD REF. 8A0271-MA-SECTIONS

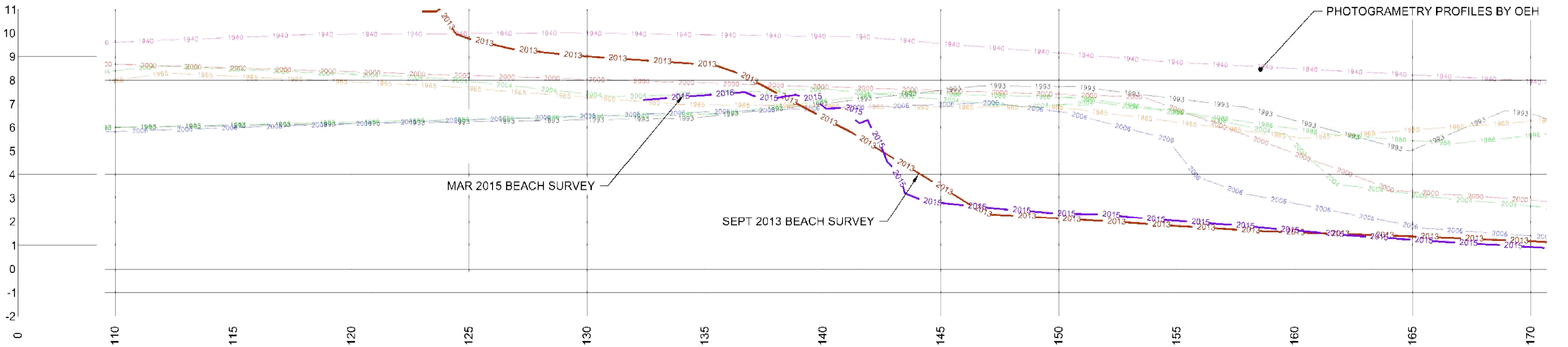
SCALE AT A1 AS SHOWN

DRAWING No. 8A0271/MA/1102 | REVISION A

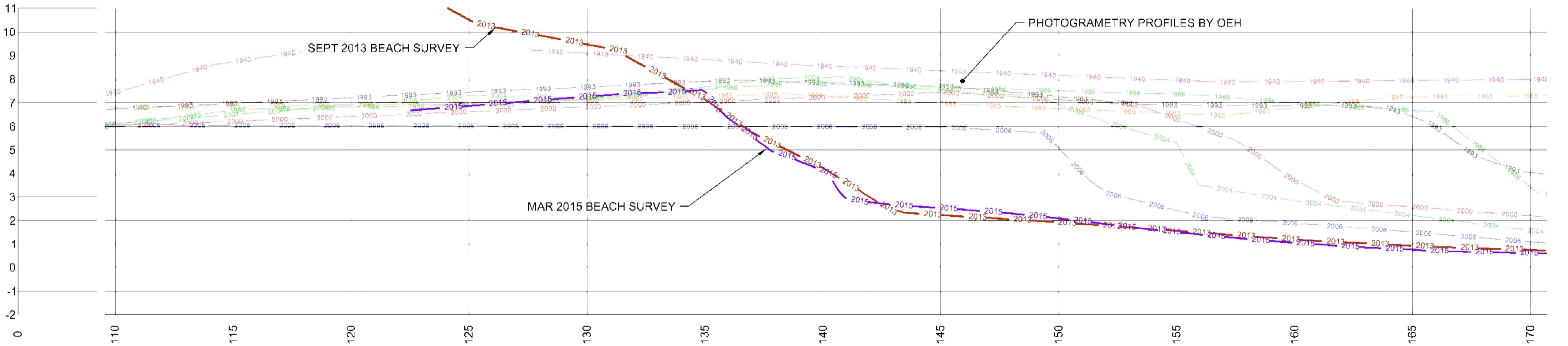
\\HKA-SERVER\PUBLIC\CURRENT JOBS\8A0271 - OLD BAR BEACH COASTAL PROTECTION STRUCTURE DESIGN\6 TECHNICAL DATA\E11 WORKING DRAWINGS\DRAWING SET\8A0271-MA-SECTIONS.DWG 10/2/2015 12:23 PM

DRAWING No. 8A0271/MA/1103

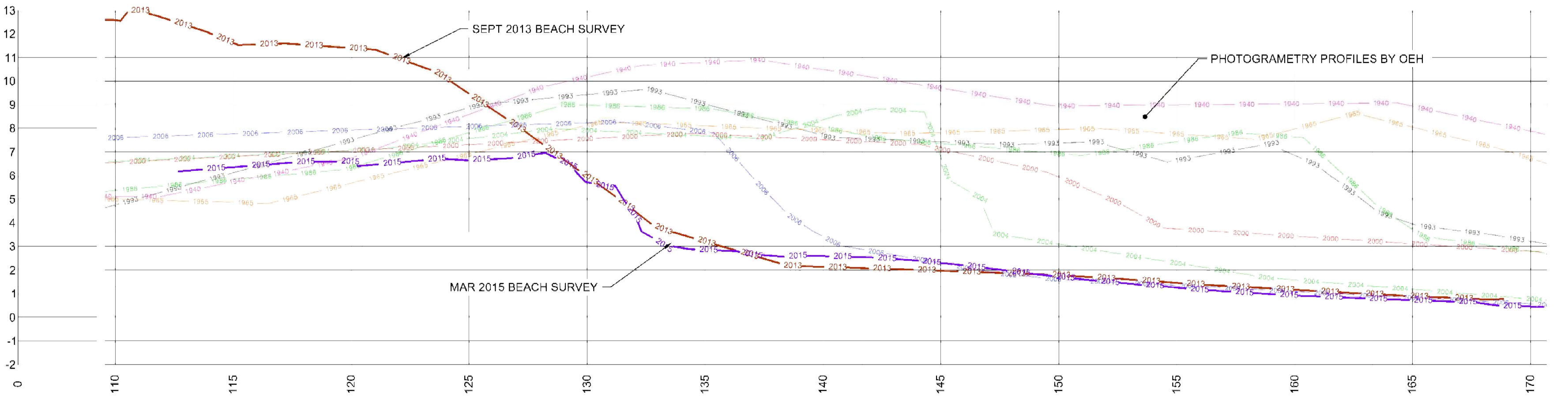
DO NOT SCALE



CH 800 S



CH 700 S



CH 600 S

4 0 4 8 12 16 20m

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 3 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

AUTOCAD REF. 8A0271-MA-SECTIONS

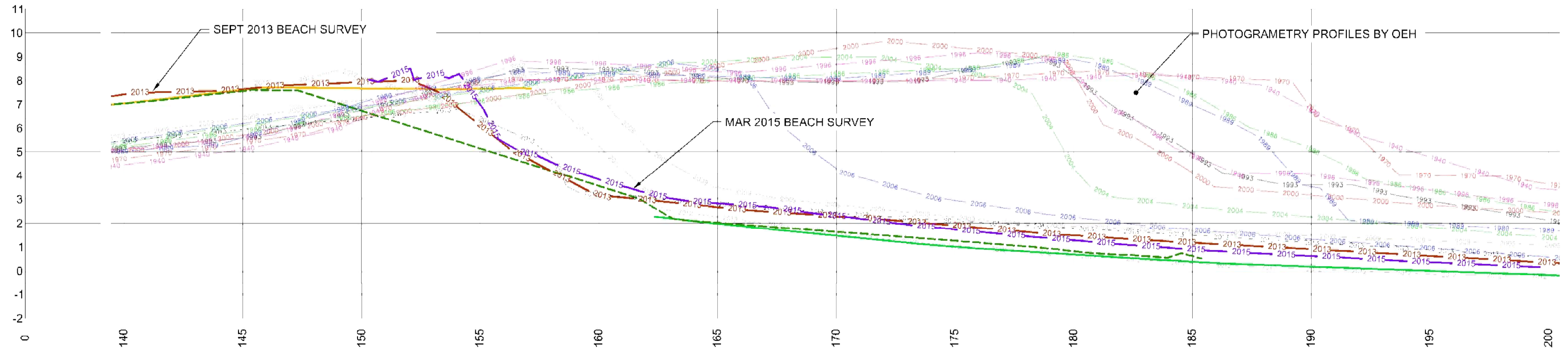
SCALE AT A1 AS SHOWN

DRAWING No. 8A0271/MA/1103 | REVISION A

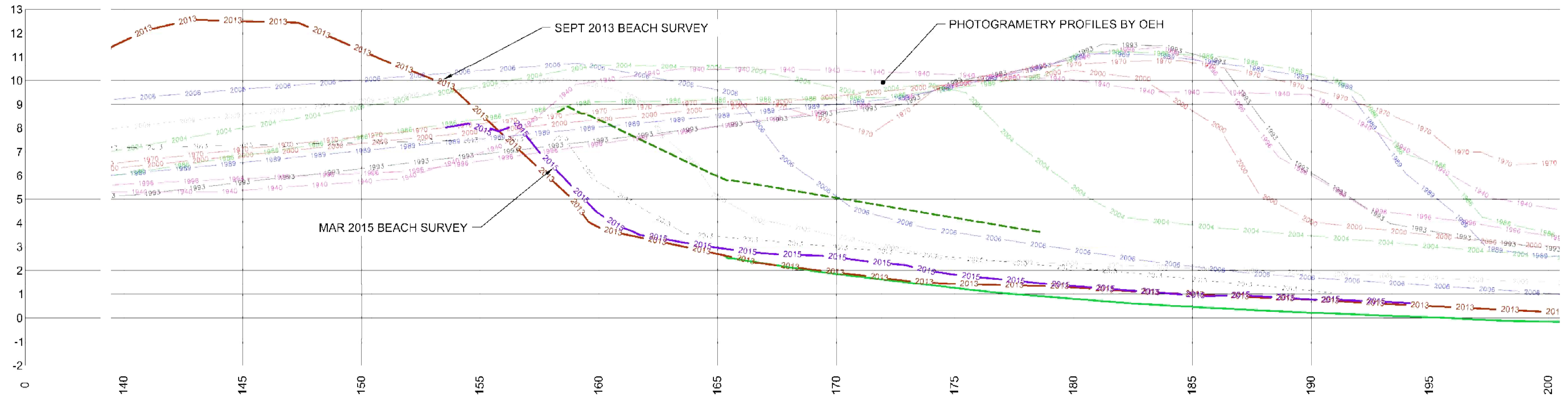
\\HKA-SERVER\PUBLIC\CURRENT JOBS\8A0271 - OLD BAR BEACH COASTAL PROTECTION STRUCTURE DESIGN\E TECHNICAL DATA\E11 WORKING DRAWINGS\DRAWING SET\8A0271-MA-SECTIONS.DWG 10/2/2015 12:23 PM

DRAWING No. 8A0271/MA/1104

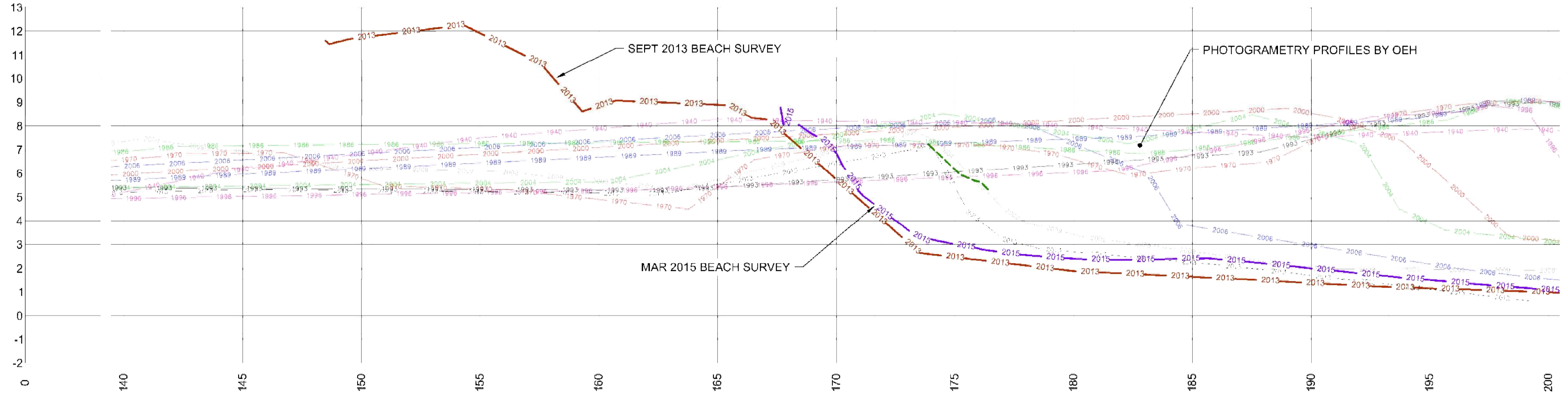
DO NOT SCALE



CH 500 C



CH 300 C



CH 100 C

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 4 OF 9

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

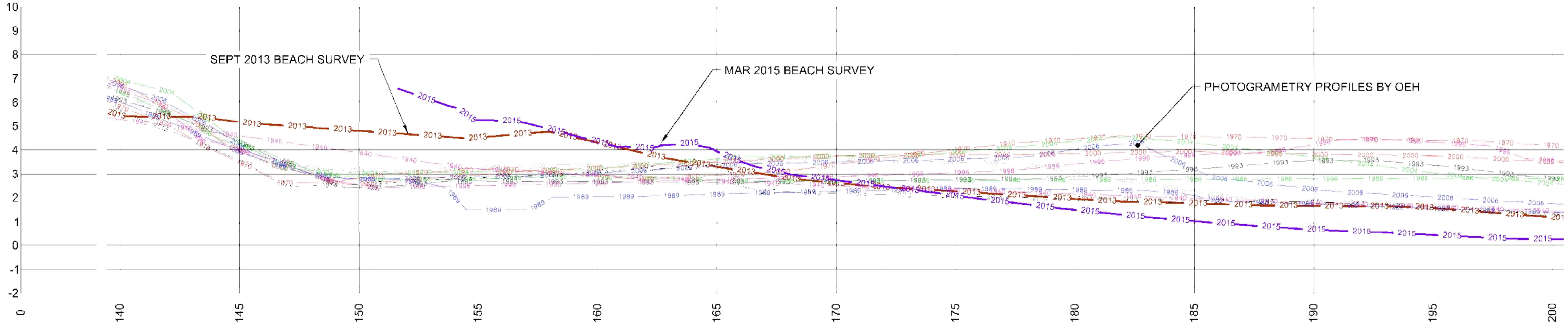
AUTOCAD REF. 8A0271-MA-SECTIONS

SCALE AT A1 AS SHOWN

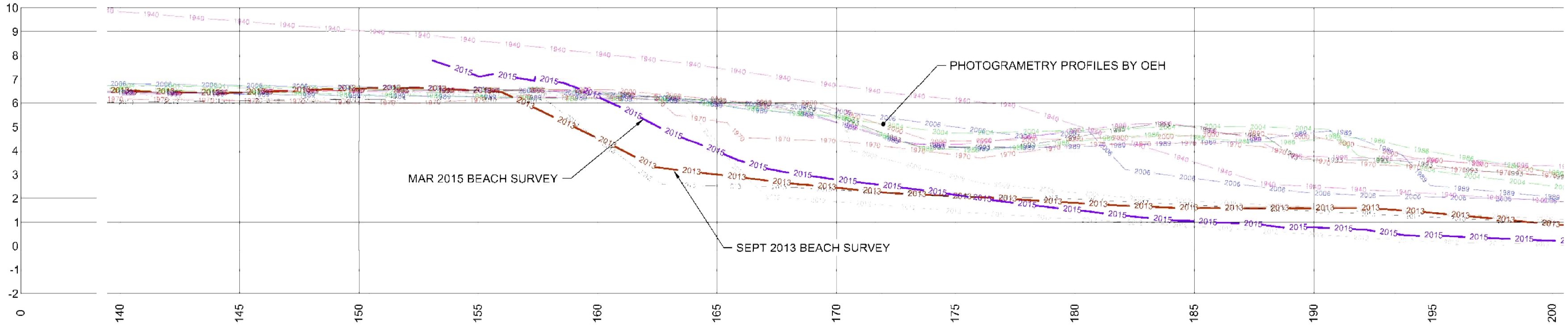
DRAWING No. 8A0271/MA/1104 | REVISION A

DRAWING No. 8A0271/MA/1105

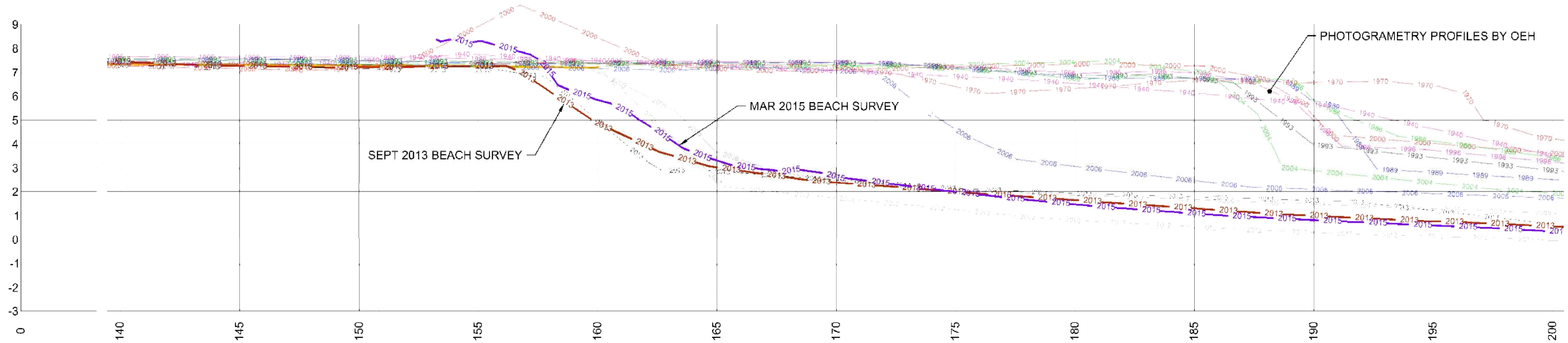
DO NOT SCALE



CH 760 C



CH 680 C



CH 600 C

4 0 4 8 12 16 20m

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 5 OF 9

HASKONING AUSTRALIA PTY LTD SYDNEY

Royal HaskoningDHV Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

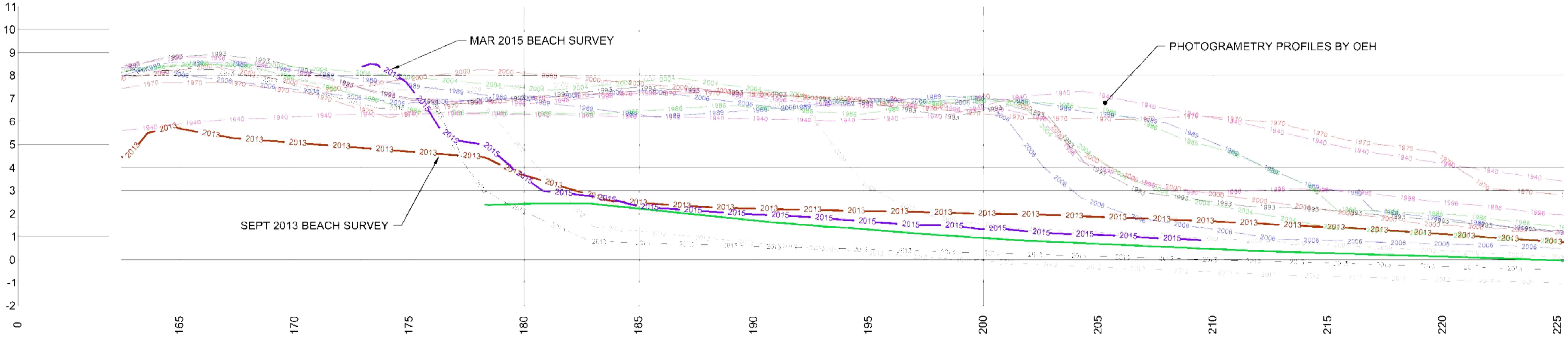
AUTOCAD REF. 8A0271-MA-SECTIONS

SCALE AT A1 AS SHOWN

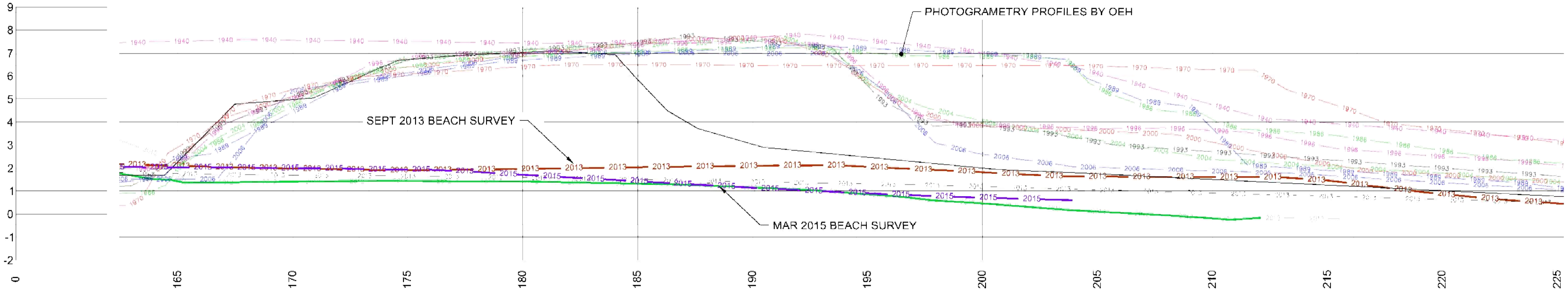
DRAWING No. 8A0271/MA/1105 | REVISION A

DRAWING No. 8A0271/MA/1106

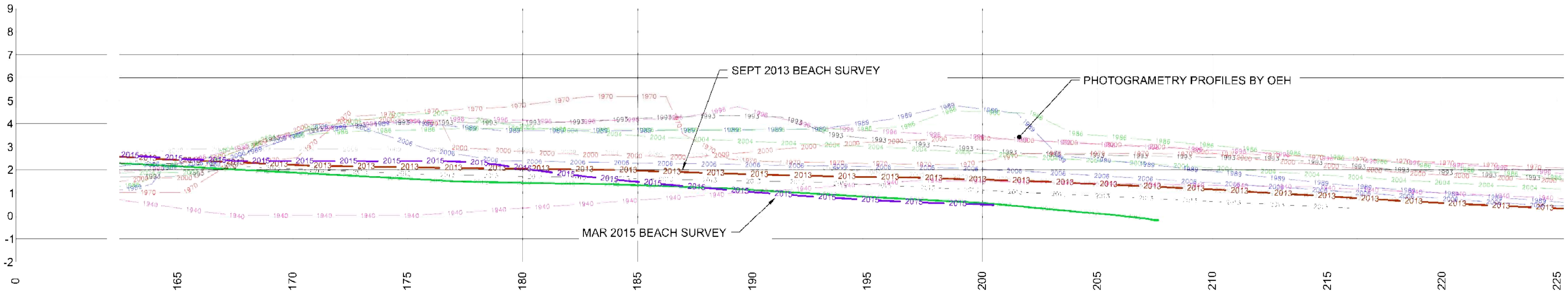
DO NOT SCALE



CH 1100 C



CH 1000 C



CH 900 C

4 0 4 8 12 16 20m

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 6 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY
Royal HaskoningDHV
Enhancing Society Together
Suite 5, Level 5
100 Walker Street
North Sydney NSW 2060
+61 2 8854 5000 Telephone
+61 2 9929 0960 Fax
www.royalhaskoning.com Internet

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

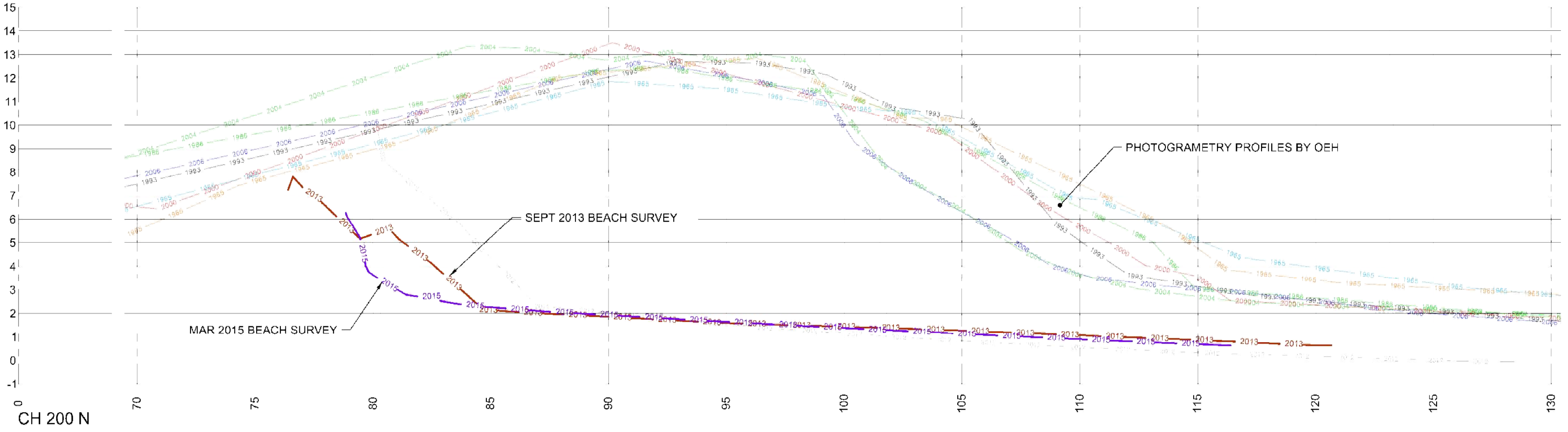
AUTOCAD REF. 8A0271-MA-SECTIONS

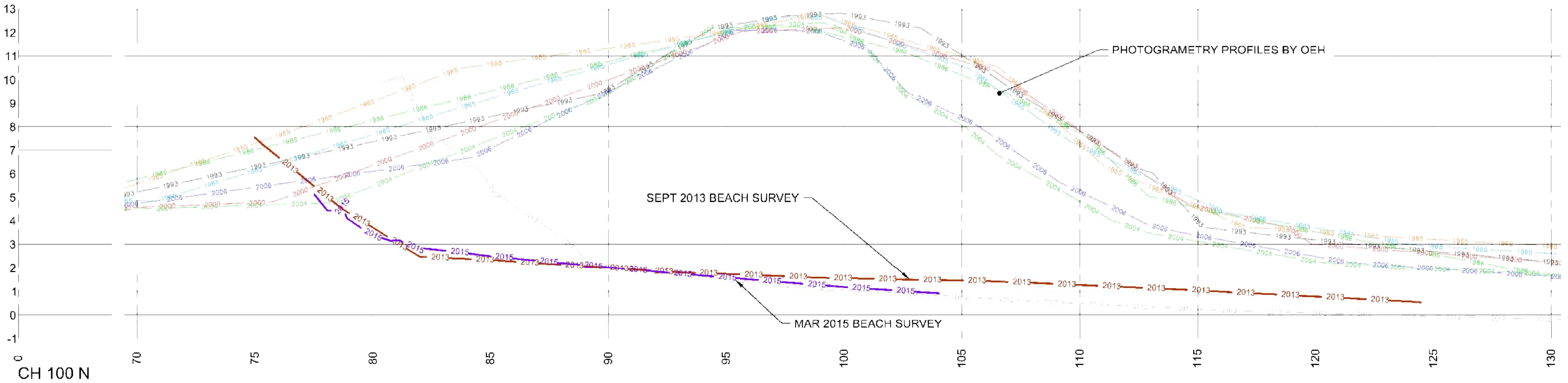
SCALE AT A1 AS SHOWN

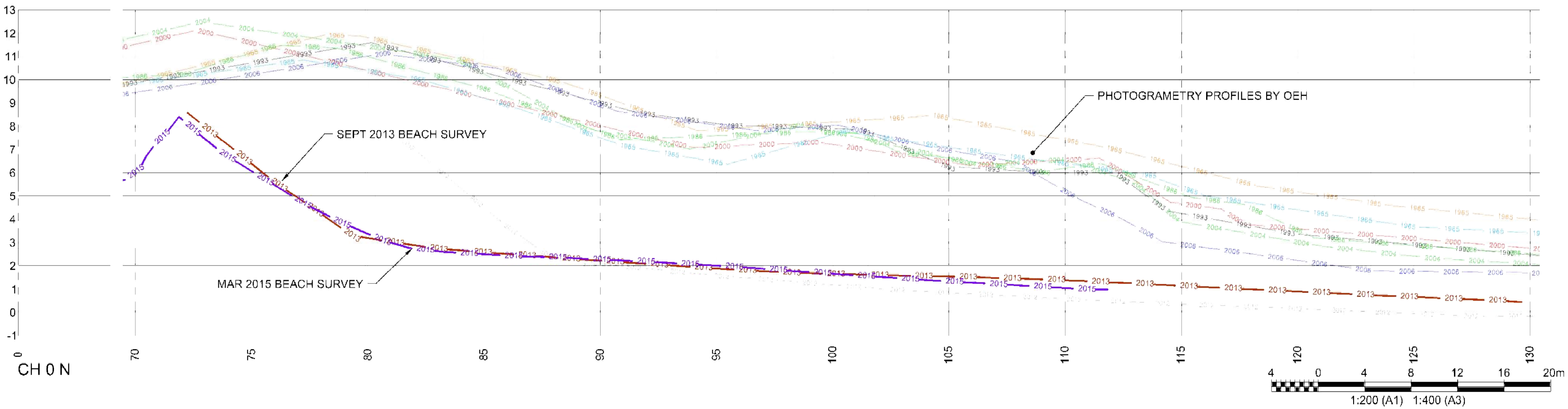
DRAWING No. 8A0271/MA/1106 | REVISION A

DRAWING No. 8A0271/MA/1107

DO NOT SCALE







AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT

Greater Taree City Council

PROJECT:

OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE:

CROSS SECTIONS SHEET 7 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY

Royal HaskoningDHV
Enhancing Society Together

Suite 5, Level 5
100 Walker Street
North Sydney NSW 2060
+61 2 8854 5000 Telephone
+61 2 9929 0960 Fax
www.royalhaskoning.com Internet

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

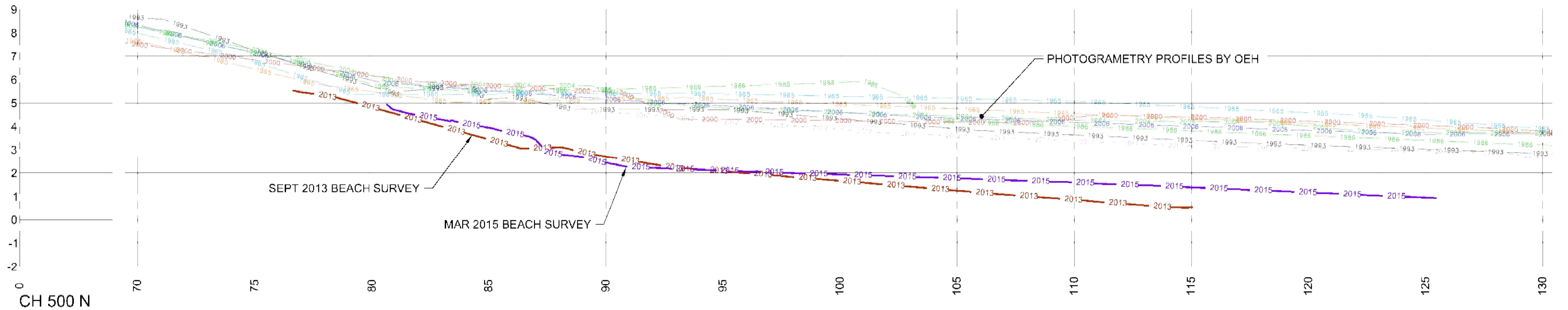
AUTOCAD REF. 8A0271-MA-SECTIONS

SCALE AT A1 AS SHOWN

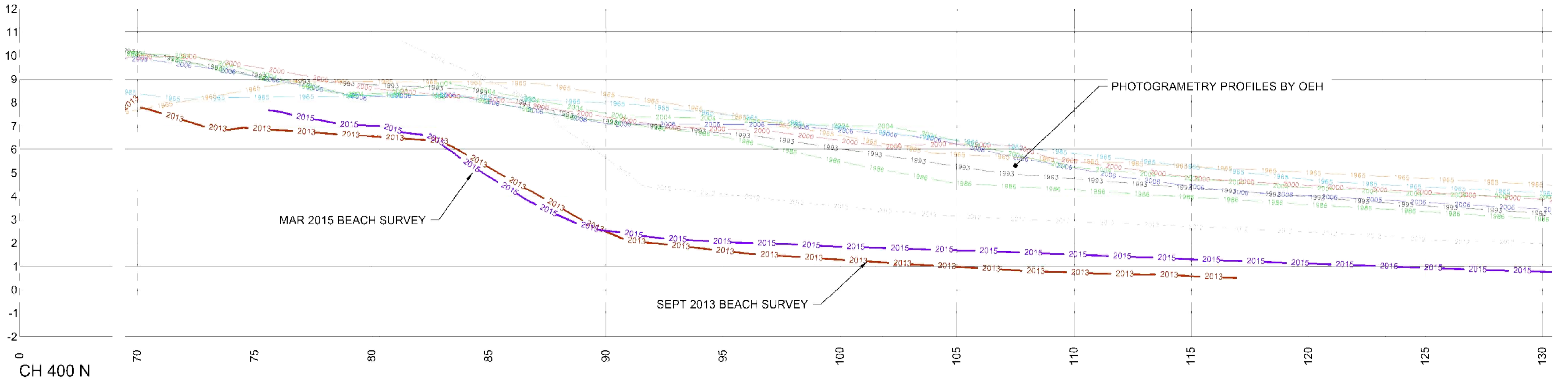
DRAWING No. 8A0271/MA/1107 | REVISION A

DRAWING No. 8A0271/MA/1108

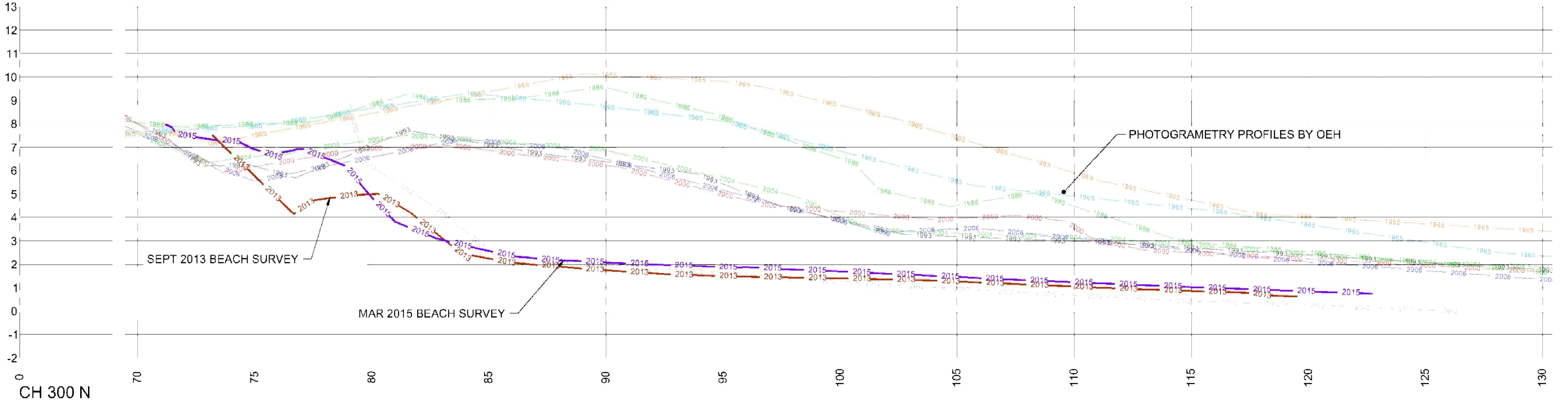
DO NOT SCALE



CH 500 N



CH 400 N



CH 300 N

4 0 4 8 12 16 20m

1:200 (A1) 1:400 (A3)

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 8 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY

Royal HaskoningDHV
Enhancing Society Together

DRAWN SGB DATE 02/10/2015 JOB No. 8A0271

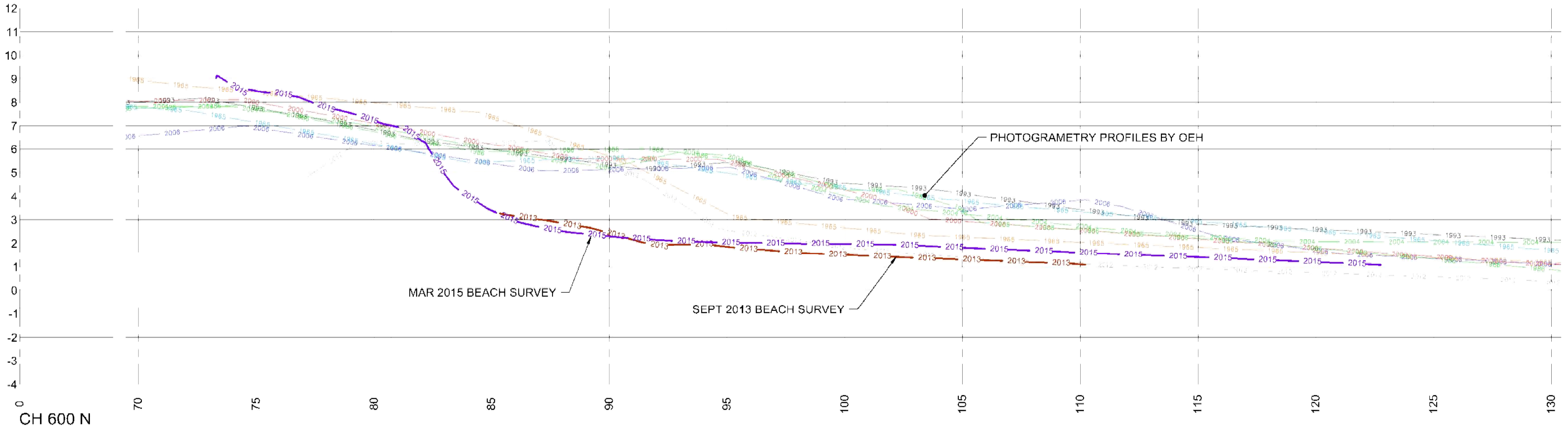
AUTOCAD REF. 8A0271-MA-SECTIONS

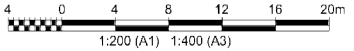
SCALE AT A1 AS SHOWN

DRAWING No. 8A0271/MA/1108 REVISION A

DRAWING No. 8A0271/MA/1109

DO NOT SCALE





AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY	CHK	APPD
B	04.12.13	PRELIMINARY DESIGN	SGB	GPB	GWB
A	07.11.13	PRELIMINARY ISSUE FOR CLIENT REVIEW	SGB	GPB	

REVISIONS

CLIENT: Greater Taree City Council

PROJECT: OLD BAR BEACH SEDIMENT TRACING

DRAWING TITLE: CROSS SECTIONS SHEET 9 OF 9

HASKONING AUSTRALIA PTY LTD
SYDNEY

Royal HaskoningDHV
Enhancing Society Together

DRAWN SGB | DATE 02/10/2015 | JOB No. 8A0271

AUTOCAD REF. 8A0271-MA-SECTIONS

SCALE AT A1 AS SHOWN

DRAWING No. 8A0271/MA/1109 | REVISION A

\\HKA-SERVER\PUBLIC\CURRENT JOBS\8A0271 - OLD BAR BEACH COASTAL PROTECTION STRUCTURE DESIGN\5 TECHNICAL DATA\E11 WORKING DRAWINGS\DRAWING SET\8A0271-MA-SECTIONS.DWG 10/2/2015 12:27 PM

Appendix G - Tracer Analysis Results

Royal HaskoningDHV

Tracer results are plotted in the figures contained in this appendix as tabulated below.

Figure Number	Title
G1	Yellow Tracer – Count per Square Metre
G2	Yellow Tracer – Particle Size
G3	Yellow Tracer – Depth Averaged Samples
G4	Red Tracer – Count per Square Metre
G5	Red Tracer – Particle Size
G6	Red Tracer – Depth Averaged Samples
G7	Orange Tracer – Count per Square Metre
G8	Orange Tracer – Particle Size
G9	Orange Tracer – Depth Averaged Samples

Tracer results for all samples collected during the study period are also tabulated in this appendix as follows:

Table Number	Title
G1	Total Tracer Counts – Sampling Exercise 1
G2	Tracer Particle Size Counts – Sampling Exercise 1
G3	Total Tracer Counts – Sampling Exercise 2
G4	Tracer Particle Size Counts – Sampling Exercise 2
G5	Total Tracer Counts – Sampling Exercise 3
G6	Tracer Particle Size Counts – Sampling Exercise 3
G7	Total Tracer Counts – Sampling Exercise 4
G8	Tracer Particle Size Counts – Sampling Exercise 4
G9	Total Tracer Counts – Sampling Exercise 5
G10	Tracer Particle Size Counts – Sampling Exercise 5

Sample coordinates are listed in Tables G1, G3, G5, G7 and G9 for the respective sampling exercises. The Sample ID also provides an indication of the spatial location of each sample, whereby:

- the first value corresponds with the transect number along which the sample was collected; and
- the second value corresponds with the cross-shore position along the transect, from 1 to 7 moving offshore, i.e.:
  - Sample 1: MHW;
  - Sample 2: MSL;
  - Sample 3: MLW;
  - Sample 4: -2 m AHD;
  - Sample 5: -4 m AHD;
  - Sample 6: -7 m AHD;
  - Sample 7: -11 m AHD.

For example, Sample ID 5_4 was collected at a bed level of around -2 m AHD along Transect 5.

Sample IDs beginning with 'F' were collected inside the entrance to Farquhar Inlet (Sampling Exercises 2, 3 and 4 only).

Depth-averaged beach samples collected during Sampling Exercise 4 are denoted with the subscript '_D'.

Table G1: Total Tracer Counts - Sampling Exercise 1

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)
3_1	152.6052	-31.9529	0	86
3_2	152.6054	-31.9597	0	97
3_3	152.6056	-31.9530	0	345
4_1	152.6023	-31.9568	0	283
4_2	152.6025	-31.9569	0	84
4_3	152.6027	-31.9570	0	126
5_1	152.6011	-31.9588	0	224
5_2	152.6014	-31.9587	71	283
5_3	152.6016	-31.9590	0	133
6_1	152.6000	-31.9608	0	84
6_2	152.6003	-31.9609	82	164
6_3	152.6005	-31.9609	552	331
7_1	152.5989	-31.9629	0	0
7_2	152.5991	-31.9630	0	86
7_3	152.5993	-31.9631	0	486
8_1	152.5979	-31.9650	0	0
8_2	152.5981	-31.9651	103	0
8_3	152.5983	-31.9652	722	0
9_1	152.5954	-31.9679	1297	0
9_2	152.5956	-31.9680	2163	108
9_3	152.5959	-31.9681	3973	0
10_1	152.5939	-31.9698	1182	0
10_2	152.5942	-31.9699	5555	0
10_3	152.5944	-31.9700	8474	0
11_1	152.5919	-31.9714	4181	0
11_2	152.5921	-31.9716	3192	0
11_3	152.5923	-31.9717	3668	118
12_1	152.5898	-31.9731	1535	0
12_2	152.5900	-31.9732	1118	0
12_3	152.5903	-31.9733	959	0
13_1	152.5878	-31.9747	0	0
13_2	152.5880	-31.9748	90	0
13_3	152.5883	-31.9749	0	0
14_1	152.5859	-31.9764	0	0
14_2	152.5861	-31.9765	0	0
14_3	152.5863	-31.9766	0	0
3_4	152.606	-31.9532	220	440
4_4	152.603	-31.9571	398	318
5_4	152.602	-31.9591	101	0
6_4	152.60143	-31.96116	334	0

Sample ID	Longitude	Latitude	Yellow Count (per m²)	Red Count (per m²)
7_4	152.60005	-31.96364	1087	0
8_4	152.599	-31.9655	1920	107
9_4	152.597	-31.9685	811	0
10_4	152.595	-31.9703	550	92
11_4	152.593	-31.972	0	0
12_4	152.591	-31.9735	0	0
13_4	152.589	-31.9751	180	0
14_4	152.587	-31.9769	0	0
3_5	152.60778	-31.953817	230	230
3_6	152.60967	-31.954548	0	107
3_7	152.61163	-31.955283	371	0
4_5	152.60568	-31.957667	0	0
4_6	152.60682	-31.95825	0	0
4_7	152.61048	-31.959467	0	111
5_7	152.6101	-31.961633	107	0
5_6	152.60542	-31.960467	0	108
5_5	152.60377	-31.959633	1773	118
6_5	152.60242	-31.961483	0	101
6_6	152.60377	-31.9624	0	0
6_7	152.60817	-31.963667	0	0
7_7	152.6061	-31.96545	0	0
7_6	152.60272	-31.964533	0	0
7_5	152.60085	-31.963517	618	0
8_5	152.5997	-31.96535	379	253
8_6	152.60203	-31.966533	238	0
8_7	152.60473	-31.9672	0	64
9_6	152.60055	-31.970167	0	0
9_5	152.59792	-31.968917	735	0
9_7	152.60217	-31.972533	86	0
10_5	152.59435	-31.973433	814	0
11_6	152.59693	-31.975083	0	0
10_7	152.59597	-31.9763	83	0
12_6	152.59525	-31.975467	0	0
12_5	152.5937	-31.973967	337	0
12_5A	152.59233	-31.974667	262	0
13_6	152.59337	-31.976167	0	0
13_7	152.59508	-31.977833	0	0
12_7	152.59842	-31.9788	0	0
14_7	152.59608	-31.979533	0	0
14_6	152.5915	-31.977883	0	0
13_5	152.59088	-31.97555	122	122
14_5	152.58928	-31.977217	97	0

Table G2: Tracer Particle Size Counts - Sampling Exercise 1

Sample ID	Yellow Tracer Count			Red Tracer Count		
	Small	Medium	Large	Small	Medium	Large
3_1	0	0	0	1	0	0
3_2	0	0	0	1	0	0
3_3	0	0	0	2	1	0
4_1	0	0	0	1	3	0
4_2	0	0	0	0	0	1
4_3	0	0	0	0	0	1
5_1	0	0	0	0	1	2
5_2	1	0	0	1	2	1
5_3	0	0	0	0	1	0
6_1	0	0	0	1	0	0
6_2	0	1	0	1	0	1
6_3	5	0	0	1	2	0
7_1	0	0	0	0	0	0
7_2	0	0	0	0	0	1
7_3	0	0	0	0	3	1
8_1	0	0	0	0	0	0
8_2	1	0	0	0	0	0
8_3	3	3	0	0	0	0
9_1	8	6	2	0	0	0
9_2	12	6	2	1	0	0
9_3	13	17	5	0	0	0
10_1	6	5	1	0	0	0
10_2	27	14	11	0	0	0
10_3	27	27	19	0	0	0
11_1	20	20	10	0	0	0
11_2	14	17	2	0	0	0
11_3	7	16	8	1	0	0
12_1	6	13	0	0	0	0
12_2	4	5	2	0	0	0
12_3	6	2	0	0	0	0
13_1	0	0	0	0	0	0
13_2	1	0	0	0	0	0
13_3	0	0	0	0	0	0
14_1	0	0	0	0	0	0
14_2	0	0	0	0	0	0
14_3	0	0	0	0	0	0
3_4	2	0	0	2	2	0
4_4	5	0	0	3	1	0
5_4	1	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count		
	Small	Medium	Large	Small	Medium	Large
6_4	1	2	0	0	0	0
7_4	1	5	4	0	0	0
8_4	8	7	3	0	1	0
9_4	4	2	1	0	0	0
10_4	5	1	0	1	0	0
11_4	0	0	0	0	0	0
12_4	0	0	0	0	0	0
13_4	2	0	0	0	0	0
14_4	0	0	0	0	0	0
3_5	2	0	0	2	0	0
3_6	0	0	0	1	0	0
3_7	6	0	0	0	0	0
4_5	0	0	0	0	0	0
4_6	0	0	0	0	0	0
4_7	0	0	0	1	0	0
5_7	1	0	0	0	0	0
5_6	0	0	0	1	0	0
5_5	10	5	0	1	0	0
6_5	0	0	0	0	1	0
6_6	0	0	0	0	0	0
6_7	0	0	0	0	0	0
7_7	0	0	0	0	0	0
7_6	0	0	0	0	0	0
7_5	2	3	0	0	0	0
8_5	2	1	0	2	0	0
8_6	2	0	0	0	0	0
8_7	0	0	0	1	0	0
9_6	0	0	0	0	0	0
9_5	8	0	0	0	0	0
9_7	1	0	0	0	0	0
10_5	5	2	0	0	0	0
11_6	0	0	0	0	0	0
10_7	1	0	0	0	0	0
12_6	0	0	0	0	0	0
12_5	2	1	0	0	0	0
12_5A	3	0	0	0	0	0
13_6	0	0	0	0	0	0
13_7	0	0	0	0	0	0
12_7	0	0	0	0	0	0
14_7	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count		
	Small	Medium	Large	Small	Medium	Large
14_6	0	0	0	0	0	0
13_5	1	0	0	1	0	0
14_5	1	0	0	0	0	0

Table G3: Total Tracer Counts - Sampling Exercise 2

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
3_1	152.6053	-31.9529	0	173	0
3_2	152.6054	-31.9530	0	0	0
3_3	152.6056	-31.9530	0	275	0
4_1	152.6024	-31.9568	0	253	0
4_2	152.6025	-31.9569	0	415	0
4_3	152.6027	-31.9570	0	431	0
5_1	152.6010	-31.9588	95	286	0
5_2	152.6014	-31.9587	0	94	0
5_3	152.6016	-31.9590	0	400	0
6_1	152.5999	-31.9608	0	542	0
6_2	152.6003	-31.9609	92	92	0
6_3	152.6005	-31.9609	0	891	0
7_1	152.5988	-31.9628	0	191	0
7_2	152.5991	-31.9630	0	258	0
7_3	152.5993	-31.9631	0	825	0
8_1	152.5978	-31.9649	0	113	0
8_2	152.5981	-31.9651	0	783	0
8_3	152.5983	-31.9652	242	242	0
9_1	152.5953	-31.9679	0	92	0
9_2	152.5956	-31.9680	116	116	0
9_3	152.5959	-31.9681	497	249	0
10_1	152.5939	-31.9697	0	92	0
10_2	152.5942	-31.9699	125	0	0
10_3	152.5944	-31.9700	773	129	0
11_1	152.5918	-31.9714	251	0	84
11_2	152.5921	-31.9716	449	0	0
11_3	152.5923	-31.9717	255	127	127
12_1	152.5898	-31.9730	93	0	0
12_2	152.5900	-31.9732	490	0	0
12_3	152.5903	-31.9733	250	0	125
13_1	152.5878	-31.9747	0	0	0
13_2	152.5880	-31.9748	0	0	0
13_3	152.5883	-31.9749	0	0	0
14_1	152.5858	-31.9764	0	0	85
14_2	152.5861	-31.9765	0	0	0
14_3	152.5863	-31.9766	0	0	0
15_1	152.5841	-31.9782	0	0	0
15_2	152.5843	-31.9783	0	0	0
15_3	152.5845	-31.9784	0	0	394

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
16_1	152.5812	-31.9812	0	0	95
16_2	152.5814	-31.9813	0	0	0
16_3	152.5816	-31.9814	0	0	0
17_1	152.5783	-31.9848	0	0	89
17_2	152.5785	-31.9849	0	0	0
17_3	152.5787	-31.9849	0	0	128
18_1	152.5769	-31.9867	0	0	87
18_2	152.5771	-31.9868	0	0	131
18_3	152.5774	-31.9869	0	0	126
19_1	152.5756	-31.9886	0	0	0
19_2	152.5758	-31.9887	0	0	0
19_3	152.5761	-31.9887	0	0	0
20_1	152.5742	-31.9906	0	0	0
20_2	152.5744	-31.9906	0	0	204
20_3	152.5746	-31.9907	0	0	0
21_1	152.5732	-31.9927	0	0	0
21_2	152.5733	-31.9927	0	0	0
21_3	152.5734	-31.9928	0	0	0
22_1	152.5716	-31.9972	0	0	0
22_2	152.5717	-31.9973	0	91	0
22_3	152.5718	-31.9973	0	0	0
23_1	152.5680	-32.0006	0	0	0
23_2	152.5681	-32.0007	0	0	0
23_3	152.5683	-32.0007	0	0	0
F1	152.6046	-31.9499	0	0	0
F2	152.6051	-31.9494	0	0	0
F3	152.6053	-31.9490	0	0	0
F4	152.6066	-31.9483	0	0	0
F5	152.6073	-31.9471	121	241	0
F6	152.6050	-31.9486	0	0	0
F7	152.6039	-31.9490	0	0	0
F8	152.6041	-31.9508	0	0	0
F9	152.6052	-31.9515	0	0	0
1_4	152.6160	-31.9421	0	0	133
1_5	152.6172	-31.9427	0	0	0
1_6	152.6193	-31.9433	0	330	0
1_7	152.6220	-31.9444	289	193	96
2_4	152.6128	-31.9457	0	0	0
2_5	152.6145	-31.9467	0	127	0
2_6	152.6158	-31.9470	105	105	0
2_7	152.6178	-31.9477	0	0	0

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
3_4	152.6076	-31.9537	0	147	0
3_5	152.6076	-31.9538	116	578	0
3_6	152.6097	-31.9545	0	0	87
3_7	152.6129	-31.9559	108	108	324
4_4	152.6046	-31.9570	0	132	0
4_5	152.6043	-31.9575	0	129	0
4_6	152.6067	-31.9584	606	243	121
4_7	152.6094	-31.9594	0	0	0
5_4	152.6028	-31.9592	109	871	0
5_5	152.6029	-31.9595	0	145	145
5_6	152.6054	-31.9603	442	265	708
5_7	152.6084	-31.9615	274	0	137
6_4	152.6013	-31.9609	410	547	0
6_5	152.6019	-31.9615	239	0	239
6_6	152.6042	-31.9624	133	133	266
6_7	152.6072	-31.9635	185	185	462
7_4	152.5999	-31.9630	258	775	0
7_5	152.6010	-31.9636	0	115	0
7_6	152.6034	-31.9645	66	0	328
7_7	152.6056	-31.9654	0	105	418
8_4	152.5986	-31.9649	644	515	0
8_5	152.6008	-31.9660	972	278	278
8_6	152.6023	-31.9666	0	195	391
8_7	152.6055	-31.9678	0	0	0
9_4	152.5974	-31.9682	572	114	0
9_5	152.5979	-31.9690	222	111	0
9_6	152.6007	-31.9702	106	317	212
9_7	152.6058	-31.9724	0	0	0
10_4	152.5934	-31.9729	192	192	287
10_5	152.5962	-31.9708	194	97	292
10_7	152.5959	-31.9765	119	119	0
11_6	152.5982	-31.9742	0	0	0
12_4	152.5916	-31.9741	101	0	0
12_5	152.5918	-31.9739	358	0	0
12_5A	152.5923	-31.9747	278	0	649
12_6	152.5940	-31.9749	0	0	0
12_7	152.5976	-31.9765	0	0	0
13_4	152.5903	-31.9752	285	0	0
13_5	152.5899	-31.9756	0	0	114
13_6	152.5913	-31.9762	96	0	574
13_7	152.5951	-31.9779	0	0	431

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
14_4	152.5879	-31.9766	0	0	103
14_5	152.5878	-31.9773	0	0	0
14_6	152.5893	-31.9779	0	0	163
14_7	152.5928	-31.9794	0	0	90
15_4	152.5859	-31.9787	107	0	107
15_5	152.5863	-31.9796	0	0	136
15_6	152.5873	-31.9797	0	0	192
15_7	152.5909	-31.9811	0	0	587
16_4	152.5829	-31.9817	0	0	0
16_5	152.5832	-31.9821	0	0	0
16_6	152.5844	-31.9827	0	0	0
16_7	152.5874	-31.9841	0	78	233
17_4	152.5799	-31.9856	0	0	137
17_5	152.5804	-31.9859	0	0	122
17_6	152.5816	-31.9864	0	0	97
17_7	152.5838	-31.9875	0	0	0
18_4	152.5789	-31.9877	0	0	0
18_5	152.5795	-31.9881	0	0	425
18_6	152.5809	-31.9888	0	0	154
18_7	152.5822	-31.9903	55	0	55
19_4	152.5776	-31.9897	0	0	79
19_5	152.5782	-31.9903	0	0	0
19_6	152.5789	-31.9907	0	0	101
19_7	152.5797	-31.9924	0	0	0
20_4	152.5760	-31.9915	0	0	108
20_5	152.5766	-31.9924	0	0	98
20_6	152.5773	-31.9931	0	0	323
21_4	152.5748	-31.9933	0	0	371
21_5	152.5746	-31.9944	0	0	0
21_6	152.5754	-31.9953	0	0	129
21_7	152.5757	-31.9968	0	0	101
22_4	152.5710	-32.0019	0	0	0
22_5	152.5712	-32.0028	0	0	0
22_6	152.5733	-32.0036	0	0	0
22_7	152.5753	-32.0050	0	0	0
23_4	152.5720	-32.0015	0	0	0
23_5	152.5726	-32.0021	0	0	0
23_6	152.5723	-32.0044	0	0	0
23_7	152.5733	-32.0064	0	0	0
24_4	152.6194	-31.9383	0	0	0
24_5	152.6198	-31.9385	326	163	0

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
24_6	152.6224	-31.9395	208	104	0
24_7	152.6252	-31.9405	0	0	0
25_4	152.6243	-31.9338	0	269	0
25_5	152.6258	-31.9346	0	247	0
25_6	152.6272	-31.9355	0	0	0
25_7	152.6273	-31.9364	0	152	152

Table G4: Tracer Particle Size Counts - Sampling Exercise 2

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
3_1	0	0	0	2	0	0	0	0	0
3_2	0	0	0	0	0	0	0	0	0
3_3	0	0	0	1	1	0	0	0	0
4_1	0	0	0	1	2	0	0	0	0
4_2	0	0	0	1	1	2	0	0	0
4_3	0	0	0	1	2	0	0	0	0
5_1	1	0	0	1	1	1	0	0	0
5_2	0	0	0	0	0	1	0	0	0
5_3	0	0	0	0	1	2	0	0	0
6_1	0	0	0	2	2	1	0	0	0
6_2	0	1	0	1	0	0	0	0	0
6_3	0	0	0	4	3	0	0	0	0
7_1	0	0	0	0	1	1	0	0	0
7_2	0	0	0	2	0	0	0	0	0
7_3	0	0	0	3	2	1	0	0	0
8_1	0	0	0	1	0	0	0	0	0
8_2	0	0	0	4	1	0	0	0	0
8_3	2	0	0	2	0	0	0	0	0
9_1	0	0	0	1	0	0	0	0	0
9_2	1	0	0	1	0	0	0	0	0
9_3	4	0	0	1	1	0	0	0	0
10_1	0	0	0	0	1	0	0	0	0
10_2	0	1	0	0	0	0	0	0	0
10_3	1	1	4	0	1	0	0	0	0
11_1	1	2	0	0	0	0	1	0	0
11_2	4	0	0	0	0	0	0	0	0
11_3	1	1	0	1	0	0	1	0	0
12_1	1	0	0	0	0	0	0	0	0
12_2	3	1	0	0	0	0	0	0	0
12_3	1	0	1	0	0	0	1	0	0
13_1	0	0	0	0	0	0	0	0	0
13_2	0	0	0	0	0	0	0	0	0
13_3	0	0	0	0	0	0	0	0	0
14_1	0	0	0	0	0	0	0	1	0
14_2	0	0	0	0	0	0	0	0	0
14_3	0	0	0	0	0	0	0	0	0
15_1	0	0	0	0	0	0	0	0	0
15_2	0	0	0	0	0	0	0	0	0
15_3	0	0	0	0	0	0	0	0	3

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
16_1	0	0	0	0	0	0	0	1	0
16_2	0	0	0	0	0	0	0	0	0
16_3	0	0	0	0	0	0	0	0	0
17_1	0	0	0	0	0	0	0	1	0
17_2	0	0	0	0	0	0	0	0	0
17_3	0	0	0	0	0	0	0	1	0
18_1	0	0	0	0	0	0	0	1	0
18_2	0	0	0	0	0	0	0	1	0
18_3	0	0	0	0	0	0	0	1	0
19_1	0	0	0	0	0	0	0	0	0
19_2	0	0	0	0	0	0	0	0	0
19_3	0	0	0	0	0	0	0	0	0
20_1	0	0	0	0	0	0	0	0	0
20_2	0	0	0	0	0	0	0	1	1
20_3	0	0	0	0	0	0	0	0	0
21_1	0	0	0	0	0	0	0	0	0
21_2	0	0	0	0	0	0	0	0	0
21_3	0	0	0	0	0	0	0	0	0
22_1	0	0	0	0	0	0	0	0	0
22_2	0	0	0	1	0	0	0	0	0
22_3	0	0	0	0	0	0	0	0	0
23_1	0	0	0	0	0	0	0	0	0
23_2	0	0	0	0	0	0	0	0	0
23_3	0	0	0	0	0	0	0	0	0
F1	0	0	0	0	0	0	0	0	0
F2	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0
F5	1	0	0	1	1	0	0	0	0
F6	0	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	0	0
F8	0	0	0	0	0	0	0	0	0
F9	0	0	0	0	0	0	0	0	0
1_4	0	0	0	0	0	0	1	0	0
1_5	0	0	0	0	0	0	0	0	0
1_6	0	0	0	1	2	0	0	0	0
1_7	3	0	0	1	1	0	1	0	0
2_4	0	0	0	0	0	0	0	0	0
2_5	0	0	0	1	0	0	0	0	0
2_6	1	0	0	1	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
2_7	0	0	0	0	0	0	0	0	0
3_4	0	0	0	1	0	0	0	0	0
3_5	1	0	0	2	3	0	0	0	0
3_6	0	0	0	0	0	0	1	0	0
3_7	1	0	0	1	0	0	3	0	0
4_4	0	0	0	1	0	0	0	0	0
4_5	0	0	0	0	0	1	0	0	0
4_6	5	0	0	1	1	0	1	0	0
4_7	0	0	0	0	0	0	0	0	0
5_4	1	0	0	6	2	0	0	0	0
5_5	0	0	0	0	1	0	1	0	0
5_6	5	0	0	3	0	0	7	1	0
5_7	4	0	0	0	0	0	2	0	0
6_4	3	0	0	3	1	0	0	0	0
6_5	2	0	0	0	0	0	2	0	0
6_6	2	0	0	2	0	0	4	0	0
6_7	2	0	0	2	0	0	5	0	0
7_4	1	1	0	4	1	1	0	0	0
7_5	0	0	0	0	1	0	0	0	0
7_6	1	0	0	0	0	0	5	0	0
7_7	0	0	0	1	0	0	4	0	0
8_4	4	1	0	4	0	0	0	0	0
8_5	7	0	0	2	0	0	2	0	0
8_6	0	0	0	2	0	0	4	0	0
8_7	0	0	0	0	0	0	0	0	0
9_4	4	1	0	1	0	0	0	0	0
9_5	2	0	0	0	1	0	0	0	0
9_6	1	0	0	2	1	0	2	0	0
9_7	0	0	0	0	0	0	0	0	0
10_4	2	0	0	2	0	0	3	0	0
10_5	0	2	0	1	0	0	3	0	0
10_7	1	0	0	1	0	0	0	0	0
11_6	0	0	0	0	0	0	0	0	0
12_4	1	0	0	0	0	0	0	0	0
12_5	2	1	0	0	0	0	0	0	0
12_5A	3	0	0	0	0	0	7	0	0
12_6	0	0	0	0	0	0	0	0	0
12_7	0	0	0	0	0	0	0	0	0
13_4	2	1	0	0	0	0	0	0	0
13_5	0	0	0	0	0	0	1	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
13_6	1	0	0	0	0	0	5	1	0
13_7	0	0	0	0	0	0	8	0	0
14_4	0	0	0	0	0	0	0	1	0
14_5	0	0	0	0	0	0	0	0	0
14_6	0	0	0	0	0	0	1	1	0
14_7	0	0	0	0	0	0	1	0	0
15_4	1	0	0	0	0	0	0	1	0
15_5	0	0	0	0	0	0	1	0	0
15_6	0	0	0	0	0	0	2	0	0
15_7	0	0	0	0	0	0	6	0	0
16_4	0	0	0	0	0	0	0	0	0
16_5	0	0	0	0	0	0	0	0	0
16_6	0	0	0	0	0	0	0	0	0
16_7	0	0	0	1	0	0	3	0	0
17_4	0	0	0	0	0	0	0	1	0
17_5	0	0	0	0	0	0	0	1	0
17_6	0	0	0	0	0	0	1	0	0
17_7	0	0	0	0	0	0	0	0	0
18_4	0	0	0	0	0	0	0	0	0
18_5	0	0	0	0	0	0	1	3	0
18_6	0	0	0	0	0	0	1	1	0
18_7	1	0	0	0	0	0	0	1	0
19_4	0	0	0	0	0	0	1	0	0
19_5	0	0	0	0	0	0	0	0	0
19_6	0	0	0	0	0	0	1	0	0
19_7	0	0	0	0	0	0	0	0	0
20_4	0	0	0	0	0	0	0	1	0
20_5	0	0	0	0	0	0	0	1	0
20_6	0	0	0	0	0	0	3	0	0
21_4	0	0	0	0	0	0	3	1	0
21_5	0	0	0	0	0	0	0	0	0
21_6	0	0	0	0	0	0	1	0	0
21_7	0	0	0	0	0	0	1	0	0
22_4	0	0	0	0	0	0	0	0	0
22_5	0	0	0	0	0	0	0	0	0
22_6	0	0	0	0	0	0	0	0	0
22_7	0	0	0	0	0	0	0	0	0
23_4	0	0	0	0	0	0	0	0	0
23_5	0	0	0	0	0	0	0	0	0
23_6	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
23_7	0	0	0	0	0	0	0	0	0
24_4	0	0	0	0	0	0	0	0	0
24_5	2	0	0	0	1	0	0	0	0
24_6	2	0	0	0	1	0	0	0	0
24_7	0	0	0	0	0	0	0	0	0
25_4	0	0	0	3	0	0	0	0	0
25_5	0	0	0	1	1	0	0	0	0
25_6	0	0	0	0	0	0	0	0	0
25_7	0	0	0	1	0	0	1	0	0

Table G5: Total Tracer Counts - Sampling Exercise 3

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
1_3	-31.9416	152.6149	0	0	0
1_4	-31.9421	152.6160	166	83	0
1_5	-31.9427	152.6172	163	0	0
1_6	-31.9433	152.6193	0	95	0
1_7	-31.9444	152.6220	59	0	59
1_8	-31.9452	152.6241	0	0	0
10_1	-31.9697	152.5939	0	101	0
10_3	-31.9700	152.5944	208	0	0
10_4	-31.9732	152.5938	78	157	391
10_5	-31.9708	152.5962	350	140	210
10_7	-31.9765	152.5959	155	0	78
11_1	-31.9714	152.5918	0	0	0
11_3	-31.9717	152.5923	111	0	222
11_6	-31.9742	152.5982	0	0	0
12_1	-31.9730	152.5898	0	0	0
12_3	-31.9733	152.5903	0	0	0
12_4	-31.9741	152.5916	0	151	527
12_5	-31.9739	152.5918	402	134	67
12_5A	-31.9747	152.5923	0	0	146
12_6	-31.9749	152.5940	161	81	404
12_7	-31.9765	152.5976	0	0	0
13_1	-31.9747	152.5878	0	0	0
13_3	-31.9749	152.5883	0	0	339
13_4	-31.9752	152.5903	77	0	77
13_5	-31.9756	152.5899	0	0	291
13_6	-31.9762	152.5913	58	0	116
13_7	-31.9779	152.5951	120	0	300
14_1	-31.9764	152.5858	0	0	190
14_3	-31.9766	152.5863	0	0	133
14_4	-31.9769	152.5882	0	0	0
14_5	-31.9773	152.5878	0	0	63
14_6	-31.9779	152.5893	130	0	389
14_7	-31.9794	152.5928	0	0	147
15_1	-31.9782	152.5841	99	0	99
15_3	-31.9784	152.5845	0	0	0
15_4	-31.9787	152.5859	0	0	82
15_5	-31.9796	152.5863	82	0	410
15_6	-31.9797	152.5873	0	0	0
15_7	-31.9811	152.5909	0	0	179

Sample ID	Longitude	Latitude	Yellow Count (per m²)	Red Count (per m²)	Orange Count (per m²)
15_8	-31.9825	152.5926	0	0	116
16_1	-31.9812	152.5812	0	0	299
16_3	-31.9814	152.5816	0	0	0
16_4	-31.9817	152.5829	0	0	294
16_5	-31.9821	152.5832	75	0	523
16_6	-31.9827	152.5844	0	0	71
16_7	-31.9841	152.5874	0	153	0
16_8	-31.9865	152.5922	0	0	0
17_1	-31.9848	152.5783	0	0	105
17_3	-31.9849	152.5787	0	0	0
17_4	-31.9856	152.5799	0	0	350
17_5	-31.9859	152.5804	0	0	248
17_6	-31.9864	152.5816	0	0	477
17_7	-31.9875	152.5838	0	0	56
17_8	-31.9885	152.5874	0	0	235
18_1	-31.9867	152.5769	0	0	98
18_3	-31.9869	152.5774	120	0	120
18_4	-31.9877	152.5789	0	0	171
18_5	-31.9881	152.5795	0	0	161
18_6	-31.9888	152.5809	0	0	0
18_7	-31.9903	152.5822	0	0	0
18_8	-31.9918	152.5839	0	0	0
19_1	-31.9886	152.5756	0	0	0
19_3	-31.9887	152.5761	0	0	0
19_4	-31.9897	152.5776	82	0	328
19_5	-31.9903	152.5782	279	0	70
19_6	-31.9907	152.5789	0	0	0
19_7	-31.9924	152.5797	0	0	0
2_1	-31.9453	152.6113	0	0	0
2_3	-31.9454	152.6116	0	0	0
2_4	-31.9462	152.6138	70	139	0
2_5	-31.9467	152.6145	0	0	0
2_6	-31.9470	152.6158	190	0	0
2_7	-31.9477	152.6178	0	0	0
2_8	-31.9487	152.6209	0	0	0
20_1	-31.9906	152.5742	0	0	97
20_3	-31.9907	152.5746	0	0	0
20_4	-31.9915	152.5760	0	78	388
20_5	-31.9924	152.5766	0	0	201
20_6	-31.9931	152.5773	0	0	0

Sample ID	Longitude	Latitude	Yellow Count (per m²)	Red Count (per m²)	Orange Count (per m²)
21_1	-31.9927	152.5732	0	0	0
21_3	-31.9928	152.5734	0	0	0
21_4	-31.9933	152.5748	0	0	140
21_5	-31.9944	152.5746	0	0	132
21_6	-31.9953	152.5754	0	0	64
21_7	-31.9968	152.5757	0	0	135
23_1	-32.0006	152.5680	0	0	0
23_3	-32.0007	152.5683	0	0	0
23_4	-32.0019	152.5710	0	0	0
23_5	-32.0021	152.5726	0	0	0
23_6	-32.0044	152.5723	0	0	0
23_7	-32.0064	152.5733	0	0	0
24_1	-31.9379	152.6178	0	101	0
24_3	-31.9380	152.6181	0	0	0
24_4	-31.9383	152.6194	0	0	0
24_5	-31.9385	152.6198	0	0	0
24_6	-31.9395	152.6224	0	184	92
24_7	-31.9405	152.6252	0	0	103
24_8	-31.9413	152.6274	0	0	0
25_1	-31.9342	152.6213	0	0	0
25_3	-31.9343	152.6215	0	0	0
25_4	-31.9338	152.6243	82	0	82
25_5	-31.9346	152.6258	0	0	0
25_6	-31.9355	152.6272	179	179	89
25_7	-31.9364	152.6273	0	0	0
25_8	-31.9369	152.6304	0	0	0
26_4	-31.9506	152.6092	0	83	0
26_5	-31.9512	152.6102	0	157	0
26_6	-31.9517	152.6113	0	0	0
26_7	-31.9535	152.6152	0	0	0
3_1	-31.9529	152.6053	0	0	0
3_3	-31.9530	152.6056	0	0	0
3_4	-31.9537	152.6076	0	82	0
3_5	-31.9538	152.6076	0	87	0
3_6	-31.9545	152.6097	74	149	74
3_7	-31.9559	152.6129	0	99	99
3_8	-31.9566	152.6150	0	74	74
3_9	-31.9578	152.6168	0	0	0
4_1	-31.9568	152.6024	0	479	120
4_3	-31.9570	152.6027	116	348	0

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
4_4	-31.9570	152.6046	257	171	0
4_5	-31.9575	152.6043	73	438	0
4_6	-31.9584	152.6067	293	73	73
4_7	-31.9594	152.6094	0	0	0
5_1	-31.9588	152.6010	112	225	0
5_3	-31.9590	152.6016	0	232	0
5_4	-31.9592	152.6028	76	304	76
5_5	-31.9595	152.6029	80	398	0
5_6	-31.9603	152.6054	131	65	65
5_7	-31.9615	152.6084	0	113	169
6_1	-31.9608	152.5999	0	107	0
6_3	-31.9609	152.6005	114	228	0
6_4	-31.9609	152.6013	81	162	81
6_5	-31.9615	152.6019	0	163	0
6_6	-31.9624	152.6042	62	124	124
6_7	-31.9635	152.6072	37	0	185
6_8	-31.9644	152.6091	179	0	179
7_1	-31.9628	152.5988	0	129	0
7_3	-31.9631	152.5993	211	527	0
7_4	-31.9630	152.5999	358	286	215
7_5	-31.9636	152.6010	432	432	173
7_6	-31.9645	152.6034	0	0	297
7_7	-31.9654	152.6056	0	0	101
7_8	-31.9667	152.6087	0	0	0
8_1	-31.9649	152.5978	0	0	0
8_3	-31.9652	152.5983	112	112	0
8_4	-31.9651	152.5992	327	82	82
8_5	-31.9660	152.6008	78	155	0
8_6	-31.9666	152.6023	119	0	59
8_7	-31.9678	152.6055	0	0	0
9_1	-31.9679	152.5953	89	89	0
9_3	-31.9681	152.5959	112	0	112
9_4	-31.9682	152.5974	478	0	0
9_5	-31.9690	152.5979	920	354	0
9_6	-31.9702	152.6007	0	222	0
9_7	-31.9724	152.6058	0	0	64
F1	-31.9510	152.6066	97	0	0
F10	-31.9494	152.6036	0	0	0
F11	-31.9517	152.6025	0	0	0
F2	-31.9501	152.6058	0	0	0

Sample ID	Longitude	Latitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
F3	-31.9469	152.6084	0	0	0
F4	-31.9443	152.6091	0	0	0
F5	-31.9476	152.6093	0	0	0
F6	-31.9513	152.6038	0	0	0
F7	-31.9461	152.6067	0	115	0
F8	-31.9467	152.6045	0	0	0
F9	-31.9493	152.6050	0	0	0

Table G6: Tracer Particle Size Counts - Sampling Exercise 3

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
1_1	0	0	0	0	0	0	0	0	0
1_3	0	0	0	0	0	0	0	0	0
1_4	2	0	0	0	1	0	0	0	0
1_5	2	0	0	0	0	0	0	0	0
1_6	0	0	0	1	0	0	0	0	0
1_7	1	0	0	0	0	0	1	0	0
1_8	0	0	0	0	0	0	0	0	0
10_1	0	0	0	0	1	0	0	0	0
10_3	1	1	0	0	0	0	0	0	0
10_4	1	0	0	1	1	0	4	1	0
10_5	5	0	0	2	0	0	2	1	0
10_7	2	0	0	0	0	0	1	0	0
11_1	0	0	0	0	0	0	0	0	0
11_3	1	0	0	0	0	0	1	1	0
11_6	0	0	0	0	0	0	0	0	0
12_1	0	0	0	0	0	0	0	0	0
12_3	0	0	0	0	0	0	0	0	0
12_4	0	0	0	2	0	0	5	2	0
12_5	5	1	0	1	1	0	0	1	0
12_5A	0	0	0	0	0	0	2	0	0
12_6	1	1	0	0	1	0	5	0	0
12_7	0	0	0	0	0	0	0	0	0
13_1	0	0	0	0	0	0	0	0	0
13_3	0	0	0	0	0	0	1	1	1
13_4	1	0	0	0	0	0	1	0	0
13_5	0	0	0	0	0	0	1	3	0
13_6	1	0	0	0	0	0	2	0	0
13_7	2	0	0	0	0	0	5	0	0
14_1	0	0	0	0	0	0	0	2	0
14_3	0	0	0	0	0	0	0	0	1
14_4	0	0	0	0	0	0	0	0	0
14_5	0	0	0	0	0	0	1	0	0
14_6	2	0	0	0	0	0	6	0	0
14_7	0	0	0	0	0	0	2	0	0
15_1	0	1	0	0	0	0	0	0	1
15_3	0	0	0	0	0	0	0	0	0
15_4	0	0	0	0	0	0	0	1	0
15_5	1	0	0	0	0	0	1	4	0
15_6	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15_7	0	0	0	0	0	0	3	0	0
15_8	0	0	0	0	0	0	2	0	0
16_1	0	0	0	0	0	0	0	2	1
16_3	0	0	0	0	0	0	0	0	0
16_4	0	0	0	0	0	0	4	0	0
16_5	1	0	0	0	0	0	5	1	1
16_6	0	0	0	0	0	0	0	1	0
16_7	0	0	0	2	0	0	0	0	0
16_8	0	0	0	0	0	0	0	0	0
17_1	0	0	0	0	0	0	0	1	0
17_3	0	0	0	0	0	0	0	0	0
17_4	0	0	0	0	0	0	2	2	0
17_5	0	0	0	0	0	0	1	1	1
17_6	0	0	0	0	0	0	6	1	0
17_7	0	0	0	0	0	0	1	0	0
17_8	0	0	0	0	0	0	3	0	0
18_1	0	0	0	0	0	0	0	0	1
18_3	0	1	0	0	0	0	0	1	0
18_4	0	0	0	0	0	0	0	1	1
18_5	0	0	0	0	0	0	0	1	1
18_6	0	0	0	0	0	0	0	0	0
18_7	0	0	0	0	0	0	0	0	0
18_8	0	0	0	0	0	0	0	0	0
19_1	0	0	0	0	0	0	0	0	0
19_3	0	0	0	0	0	0	0	0	0
19_4	1	0	0	0	0	0	0	3	1
19_5	4	0	0	0	0	0	1	0	0
19_6	0	0	0	0	0	0	0	0	0
19_7	0	0	0	0	0	0	0	0	0
2_1	0	0	0	0	0	0	0	0	0
2_3	0	0	0	0	0	0	0	0	0
2_4	1	0	0	1	1	0	0	0	0
2_5	0	0	0	0	0	0	0	0	0
2_6	1	1	0	0	0	0	0	0	0
2_7	0	0	0	0	0	0	0	0	0
2_8	0	0	0	0	0	0	0	0	0
20_1	0	0	0	0	0	0	0	1	0
20_3	0	0	0	0	0	0	0	0	0
20_4	0	0	0	0	1	0	3	2	0
20_5	0	0	0	0	0	0	3	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
20_6	0	0	0	0	0	0	0	0	0
21_1	0	0	0	0	0	0	0	0	0
21_3	0	0	0	0	0	0	0	0	0
21_4	0	0	0	0	0	0	2	0	0
21_5	0	0	0	0	0	0	2	0	0
21_6	0	0	0	0	0	0	1	0	0
21_7	0	0	0	0	0	0	1	1	0
23_1	0	0	0	0	0	0	0	0	0
23_3	0	0	0	0	0	0	0	0	0
23_4	0	0	0	0	0	0	0	0	0
23_5	0	0	0	0	0	0	0	0	0
23_6	0	0	0	0	0	0	0	0	0
23_7	0	0	0	0	0	0	0	0	0
24_1	0	0	0	0	1	0	0	0	0
24_3	0	0	0	0	0	0	0	0	0
24_4	0	0	0	0	0	0	0	0	0
24_5	0	0	0	0	0	0	0	0	0
24_6	0	0	0	0	2	0	1	0	0
24_7	0	0	0	0	0	0	1	0	0
24_8	0	0	0	0	0	0	0	0	0
25_1	0	0	0	0	0	0	0	0	0
25_3	0	0	0	0	0	0	0	0	0
25_4	1	0	0	0	0	0	1	0	0
25_5	0	0	0	0	0	0	0	0	0
25_6	2	0	0	2	0	0	1	0	0
25_7	0	0	0	0	0	0	0	0	0
25_8	0	0	0	0	0	0	0	0	0
26_4	0	0	0	1	0	0	0	0	0
26_5	0	0	0	1	1	0	0	0	0
26_6	0	0	0	0	0	0	0	0	0
26_7	0	0	0	0	0	0	0	0	0
3_1	0	0	0	0	0	0	0	0	0
3_3	0	0	0	0	0	0	0	0	0
3_4	0	0	0	0	1	0	0	0	0
3_5	0	0	0	1	0	0	0	0	0
3_6	1	0	0	1	0	1	1	0	0
3_7	0	0	0	1	0	0	1	0	0
3_8	0	0	0	1	0	0	1	0	0
3_9	0	0	0	0	0	0	0	0	0
4_1	0	0	0	0	4	0	1	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
4_3	0	0	0	1	1	1	0	0	0
4_4	3	0	0	1	1	0	0	0	0
4_5	1	0	0	0	6	0	0	0	0
4_6	3	1	0	0	1	0	1	0	0
4_7	0	0	0	0	0	0	0	0	0
5_1	0	1	0	0	2	0	0	0	0
5_3	0	0	0	2	0	0	0	0	0
5_4	1	0	0	2	2	0	1	0	0
5_5	1	0	0	4	1	0	0	0	0
5_6	2	0	0	1	0	0	1	0	0
5_7	0	0	0	2	0	0	3	0	0
6_1	0	0	0	0	0	1	0	0	0
6_3	0	1	0	0	0	2	0	0	0
6_4	1	0	0	2	0	0	1	0	0
6_5	0	0	0	2	0	0	0	0	0
6_6	1	0	0	2	0	0	2	0	0
6_7	1	0	0	0	0	0	5	0	0
6_8	3	0	0	0	0	0	3	0	0
7_1	0	0	0	0	1	0	0	0	0
7_3	0	2	0	0	2	3	0	0	0
7_4	5	0	0	4	0	0	2	1	0
7_5	1	4	0	2	3	0	2	0	0
7_6	0	0	0	0	0	0	4	0	0
7_7	0	0	0	0	0	0	1	1	0
7_8	0	0	0	0	0	0	0	0	0
8_1	0	0	0	0	0	0	0	0	0
8_3	1	0	0	0	1	0	0	0	0
8_4	2	1	1	0	0	1	1	0	0
8_5	0	1	0	0	1	1	0	0	0
8_6	1	1	0	0	0	0	1	0	0
8_7	0	0	0	0	0	0	0	0	0
9_1	1	0	0	0	0	1	0	0	0
9_3	1	0	0	0	0	0	1	0	0
9_4	5	1	0	0	0	0	0	0	0
9_5	7	6	0	4	1	0	0	0	0
9_6	0	0	0	3	0	0	0	0	0
9_7	0	0	0	0	0	0	1	0	0
F1	1	0	0	0	0	0	0	0	0
F10	0	0	0	0	0	0	0	0	0
F11	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
F2	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0
F5	0	0	0	0	0	0	0	0	0
F6	0	0	0	0	0	0	0	0	0
F7	0	0	0	1	0	0	0	0	0
F8	0	0	0	0	0	0	0	0	0
F9	0	0	0	0	0	0	0	0	0

Royal HaskoningDHV

Table G7: Total Tracer Counts - Sampling Exercise 4

Sample ID	Latitude	Longitude	Yellow Count (per m²)	Red Count (per m²)	Orange Count (per m²)
3_1	-31.9529	152.6052	0	0	0
3_2	-31.9597	152.6054	0	0	0
3_3	-31.9530	152.6056	0	0	0
3A_1	-31.9529	152.6052	0	0	0
3A_2	-31.9597	152.6054	0	0	0
3A_3	-31.9530	152.6056	0	0	0
4_1	-31.9568	152.6023	0	0	0
4_2	-31.9569	152.6025	0	0	0
4_3	-31.9570	152.6027	0	0	0
5_1	-31.9588	152.6011	0	0	141
5_2	-31.9587	152.6014	0	0	67
5_3	-31.9590	152.6016	0	0	0
5_1D	-31.9588	152.6011	0	0	0
5_2D	-31.9587	152.6014	0	0	0
5_3D	-31.9590	152.6016	0	0	0
5A_1	-31.9598	152.6004	0	0	0
5A_2	-31.9599	152.6006	0	0	0
5A_3	-31.9600	152.6008	0	0	0
5A_1D	-31.9598	152.6004	0	0	0
5A_2D	-31.9599	152.6006	0	0	0
5A_3D	-31.9600	152.6008	0	0	0
6_1	-31.9608	152.6000	0	0	0
6_2	-31.9609	152.6003	0	0	0
6_3	-31.9609	152.6005	0	0	0
6_1D	-31.9608	152.6000	0	0	153
6_2D	-31.9609	152.6003	0	0	0
6_3D	-31.9609	152.6005	0	0	0
6A_1	-31.9618	152.5993	0	0	0
6A_2	-31.9619	152.5995	0	0	0
6A_3	-31.9620	152.5997	0	0	0
6A_1D	-31.9618	152.5993	0	0	0
6A_2D	-31.9619	152.5995	0	0	0
6A_3D	-31.9620	152.5997	0	0	0
7_1	-31.9629	152.5989	0	0	63
7_2	-31.9630	152.5991	0	0	0
7_3	-31.9631	152.5993	0	0	0
7_1D	-31.9629	152.5989	0	0	0
7_2D	-31.9630	152.5991	0	0	0
7_3D	-31.9631	152.5993	0	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
7A_1	-31.9639	152.5982	0	0	0
7A_2	-31.9640	152.5985	0	0	0
7A_3	-31.9640	152.5987	0	0	0
7A_1D	-31.9639	152.5982	0	0	0
7A_2D	-31.9640	152.5985	0	0	0
7A_3D	-31.9640	152.5987	0	0	0
8_1	-31.9650	152.5979	0	0	0
8_2	-31.9651	152.5981	0	0	0
8_3	-31.9652	152.5983	0	0	0
8_1D	-31.9650	152.5979	0	0	69
8_2D	-31.9651	152.5981	0	0	98
8_3D	-31.9652	152.5983	0	88	0
8A_1	-31.9669	152.5962	0	0	0
8A_2	-31.9670	152.5963	0	0	0
8A_3	-31.9672	152.5965	0	0	0
8A_1D	-31.9669	152.5962	0	0	0
8A_2D	-31.9670	152.5963	0	0	0
8A_3D	-31.9672	152.5965	0	0	0
8B_1	-31.9658	152.5970	0	0	0
8B_2	-31.9659	152.5971	0	0	0
8B_3	-31.9660	152.5973	0	0	0
8B_1D	-31.9658	152.5970	0	0	0
8B_2D	-31.9659	152.5971	0	0	0
8B_3D	-31.9660	152.5973	0	0	0
9_1	-31.9679	152.5954	0	0	0
9_2	-31.9680	152.5956	0	0	0
9_3	-31.9681	152.5959	0	0	0
9_1D	-31.9679	152.5954	0	0	0
9_2D	-31.9680	152.5956	0	0	0
9_3D	-31.9681	152.5959	0	0	0
9A_1	-31.9690	152.5946	0	0	0
9A_2	-31.9691	152.5948	0	0	0
9A_3	-31.9692	152.5949	0	0	73
9A_1D	-31.9690	152.5946	0	0	0
9A_2D	-31.9691	152.5948	0	0	100
9A_3D	-31.9692	152.5949	0	0	0
10_1	-31.9698	152.5939	0	0	0
10_2	-31.9699	152.5942	0	0	0
10_3	-31.9700	152.5944	0	0	0
10_1D	-31.9698	152.5939	0	0	0
10_2D	-31.9699	152.5942	0	0	84

Sample ID	Latitude	Longitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
10_3D	-31.9700	152.5944	0	0	0
10A_1	-31.9713	152.5920	0	0	0
10A_2	-31.9714	152.5921	0	0	0
10A_3	-31.9716	152.5925	0	0	0
10A_1D	-31.9713	152.5920	0	0	0
10A_2D	-31.9714	152.5921	0	0	0
10A_3D	-31.9716	152.5925	0	0	0
11_1	-31.9714	152.5919	0	0	0
11_2	-31.9716	152.5921	0	0	0
11_3	-31.9717	152.5923	0	0	0
11_1D	-31.9714	152.5919	0	0	0
11_2D	-31.9716	152.5921	0	0	0
11_3D	-31.9717	152.5923	0	0	0
11A_1	-31.9723	152.5907	0	0	0
11A_2	-31.9724	152.5909	0	0	0
11A_3	-31.9727	152.5911	0	0	0
11A_1D	-31.9723	152.5907	0	0	0
11A_2D	-31.9724	152.5909	0	0	0
11A_3D	-31.9727	152.5911	0	89	0
12_1	-31.9731	152.5898	0	0	0
12_2	-31.9732	152.5900	0	0	0
12_3	-31.9733	152.5903	0	0	0
12_1D	-31.9731	152.5898	0	0	0
12_2D	-31.9732	152.5900	0	0	0
12_3D	-31.9733	152.5903	0	0	0
12A_1	-31.9739	152.5886	0	0	0
12A_2	-31.9741	152.5888	0	0	0
12A_3	-31.9743	152.5891	0	0	0
12A_1D	-31.9739	152.5886	0	0	0
12A_2D	-31.9741	152.5888	0	0	0
12A_3D	-31.9743	152.5891	0	0	0
13_1	-31.9747	152.5878	0	0	0
13_2	-31.9748	152.5880	75	0	0
13_3	-31.9749	152.5883	0	0	0
13_1D	-31.9747	152.5878	71	0	0
13_2D	-31.9748	152.5880	0	0	0
13_3D	-31.9749	152.5883	0	0	0
14_1	-31.9764	152.5859	0	0	0
14_2	-31.9765	152.5861	0	0	0
14_3	-31.9766	152.5863	0	0	0
15_1	-31.9782	152.5841	0	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m²)	Red Count (per m²)	Orange Count (per m²)
15_2	-31.9783	152.5843	0	0	0
15_3	-31.9784	152.5845	0	0	0
15A_1	-31.9800	152.5822	0	0	0
15A_2	-31.9802	152.5823	70	0	0
15A_3	-31.9803	152.5825	0	0	0
16_1	-31.9812	152.5812	0	0	0
16_2	-31.9813	152.5814	0	0	0
16_3	-31.9814	152.5816	0	0	0
16A_1	-31.9829	152.5798	0	0	0
16A_2	-31.9830	152.5800	0	0	0
16A_3	-31.9830	152.5801	0	0	0
17_1	-31.9848	152.5783	0	0	0
17_2	-31.9849	152.5785	0	0	0
17_3	-31.9849	152.5787	0	0	0
17_1D	-31.9848	152.5783	0	0	0
17_2D	-31.9849	152.5785	0	0	0
17_3D	-31.9849	152.5787	0	0	0
17A_1	-31.9858	152.5775	0	0	0
17A_2	-31.9859	152.5777	0	0	0
17A_3	-31.9861	152.5779	0	0	0
17A_1D	-31.9858	152.5775	0	0	0
17A_2D	-31.9859	152.5777	0	0	0
17A_3D	-31.9861	152.5779	0	0	0
18_1	-31.9867	152.5769	0	0	0
18_2	-31.9868	152.5771	0	0	0
18_3	-31.9869	152.5774	83	0	0
18_1D	-31.9867	152.5769	0	0	0
18_2D	-31.9868	152.5771	0	0	0
18_3D	-31.9869	152.5774	0	0	0
18A_1	-31.9876	152.5761	0	0	0
18A_2	-31.9877	152.5763	90	0	0
18A_3	-31.9878	152.5764	84	0	0
18A_1D	-31.9876	152.5761	0	0	0
18A_2D	-31.9877	152.5763	0	0	0
18A_3D	-31.9878	152.5764	0	0	0
19_1	-31.9886	152.5756	63	0	0
19_2	-31.9887	152.5758	0	0	0
19_3	-31.9887	152.5761	86	0	0
19_1D	-31.9886	152.5756	0	0	0
19_2D	-31.9887	152.5758	92	0	92
19_3D	-31.9887	152.5761	0	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
19A_1	-31.9895	152.5749	0	0	0
19A_2	-31.9896	152.5750	84	0	0
19A_3	-31.9897	152.5752	0	0	0
19A_1D	-31.9895	152.5749	0	0	0
19A_2D	-31.9896	152.5750	0	0	0
19A_3D	-31.9897	152.5752	0	0	0
20_1	-31.9906	152.5742	0	0	0
20_2	-31.9906	152.5744	0	0	0
20_3	-31.9907	152.5746	0	0	0
20_1D	-31.9906	152.5742	0	0	0
20_2D	-31.9906	152.5744	0	0	0
20_3D	-31.9907	152.5746	0	0	0
20A_1	-31.9917	152.5736	0	0	0
20A_2	-31.9917	152.5737	250	0	0
20A_3	-31.9918	152.5739	0	0	0
20A_1D	-31.9917	152.5736	0	0	0
20A_2D	-31.9917	152.5737	106	0	0
20A_3D	-31.9918	152.5739	0	0	0
21_1	-31.9927	152.5732	0	0	0
21_2	-31.9927	152.5733	0	0	0
21_3	-31.9928	152.5734	0	0	0
21_1D	-31.9927	152.5732	70	0	0
21_2D	-31.9927	152.5733	0	0	0
21_3D	-31.9928	152.5734	0	0	0
24_1	-31.9379	152.6178	0	0	0
24_3	-31.9380	152.6181	0	0	0
25_1	-31.9342	152.6213	0	0	0
25_3	-31.9343	152.6215	0	0	0
1_1	-31.9417	152.6145	0	0	0
1_3	-31.9416	152.6149	0	0	0
2_1	-31.9453	152.6113	0	0	0
2_3	-31.9454	152.6116	0	0	0
F1	-31.9520	152.6040	0	0	0
F2	-31.9508	152.6066	0	0	0
F3	-31.9514	152.6053	0	0	0
F4	-31.9501	152.6060	0	0	0
F5	-31.9477	152.6078	0	0	0
F6	-31.9487	152.6088	0	0	0
F7	-31.9479	152.6060	0	0	0
F8	-31.9478	152.6049	0	0	0
F9	-31.9491	152.6047	0	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
F10	-31.9991	152.6032	0	0	0
F11	-31.9512	152.6034	0	0	0
F12	-31.9516	152.6022	0	0	0
F13	-31.9527	152.6031	0	0	0
1_4	-31.9421	152.6160	0	0	0
2_4	-31.9458	152.6127	0	0	0
3_4	-31.9537	152.6076	0	0	0
4_4	-31.9570	152.6046	0	0	0
5_4	-31.9592	152.6028	0	0	0
6_4	-31.9609	152.6013	0	0	0
7_4	-31.9630	152.5999	0	0	0
8_4	-31.9652	152.5994	0	0	0
9_4	-31.9682	152.5974	0	0	0
10_4	-31.9732	152.5938	0	0	0
12_4	-31.9742	152.5920	0	0	0
13_4	-31.9753	152.5905	0	0	0
14_4	-31.9769	152.5882	0	0	0
15_4	-31.9790	152.5858	0	0	0
16_4	-31.9817	152.5829	0	0	0
17_4	-31.9856	152.5799	0	0	0
18_4	-31.9877	152.5789	0	0	0
19_4	-31.9897	152.5776	0	0	0
20_4	-31.9915	152.5760	0	0	0
21_4	-31.9933	152.5748	0	0	0
23_4	-32.0019	152.5710	0	0	0
24_4	-31.9383	152.6194	0	0	0
25_4	-31.9338	152.6243	0	0	0
26_4	-31.9506	152.6092	0	0	0
1_5	-31.9427	152.6172	0	0	0
2_5	-31.9467	152.6145	0	0	0
3_5	-31.9539	152.6079	0	0	0
4_5	-31.9575	152.6043	0	0	0
5_5	-31.9595	152.6029	0	0	0
6_5	-31.9615	152.6019	0	0	0
7_5	-31.9636	152.6010	47	0	0
8_5	-31.9660	152.6008	0	0	0
9_5	-31.9690	152.5979	0	0	0
10_5	-31.9708	152.5962	0	0	0
12_5	-31.9739	152.5918	0	0	0
13_5	-31.9756	152.5899	86	0	0
14_5	-31.9773	152.5878	73	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m^2)	Red Count (per m^2)	Orange Count (per m^2)
15_5	-31.9796	152.5863	0	0	0
16_5	-31.9821	152.5832	0	0	0
17_5	-31.9859	152.5804	0	0	0
18_5	-31.9881	152.5795	0	0	0
19_5	-31.9903	152.5782	0	0	0
20_5	-31.9924	152.5766	0	0	0
21_5	-31.9944	152.5746	0	0	0
23_5	-32.0021	152.5726	0	0	0
24_5	-31.9386	152.6208	0	0	0
25_5	-31.9346	152.6258	0	0	0
26_5	-31.9512	152.6102	0	0	0
1_6	-31.9433	152.6193	0	0	0
2_6	-31.9470	152.6158	0	0	0
3_6	-31.9545	152.6097	0	0	0
4_6	-31.9584	152.6067	0	0	0
5_6	-31.9603	152.6054	0	0	0
6_6	-31.9624	152.6042	63	0	0
7_6	-31.9645	152.6034	0	0	0
8_6	-31.9666	152.6023	0	0	0
9_6	-31.9702	152.6007	0	0	0
11_6	-31.9742	152.5982	0	0	0
12_6	-31.9749	152.5940	76	0	0
13_6	-31.9762	152.5913	79	0	0
14_6	-31.9779	152.5893	0	0	0
15_6	-31.9797	152.5873	0	0	0
16_6	-31.9827	152.5844	0	0	0
17_6	-31.9864	152.5816	0	0	0
18_6	-31.9888	152.5809	0	0	0
19_6	-31.9907	152.5789	0	0	0
20_6	-31.9931	152.5773	0	0	0
21_6	-31.9953	152.5754	0	0	0
23_6	-32.0044	152.5723	0	0	0
24_6	-31.9395	152.6224	0	0	0
25_6	-31.9355	152.6272	0	0	0
26_6	-31.9517	152.6113	0	0	0
1_7	-31.9444	152.6220	0	0	0
2_7	-31.9477	152.6178	0	0	0
3_7	-31.9559	152.6129	0	0	0
4_7	-31.9594	152.6094	0	0	0
5_7	-31.9615	152.6084	0	0	0
6_7	-31.9635	152.6072	0	0	0

Sample ID	Latitude	Longitude	Yellow Count (per m²)	Red Count (per m²)	Orange Count (per m²)
7_7	-31.9654	152.6056	0	0	0
8_7	-31.9665	152.6051	0	0	0
9_7	-31.9724	152.6058	0	0	0
10_7	-31.9765	152.5959	61	0	0
12_7	-31.9765	152.5976	0	0	0
13_7	-31.9779	152.5951	0	0	0
14_7	-31.9794	152.5928	0	0	0
15_7	-31.9811	152.5909	0	0	0
16_7	-31.9841	152.5874	0	0	0
17_7	-31.9875	152.5838	0	0	0
18_7	-31.9903	152.5822	0	0	0
19_7	-31.9924	152.5797	0	0	0
21_7	-31.9968	152.5757	0	0	0
23_7	-32.0064	152.5733	0	0	0
24_7	-31.9405	152.6252	0	0	0
25_7	-31.9364	152.6273	0	0	0
26_7	-31.9535	152.6152	0	0	0
1_8	-31.9452	152.6241	0	0	0
2_8	-31.9487	152.6209	0	0	0
3_8	-31.9566	152.6150	0	0	0
6_8	-31.9644	152.6091	0	0	0
7_8	-31.9667	152.6087	0	0	0
15_8	-31.9825	152.5926	0	0	0
16_8	-31.9865	152.5922	0	0	0
17_8	-31.9885	152.5874	0	0	0
18_8	-31.9918	152.5839	0	0	0
24_8	-31.9413	152.6274	0	0	0
25_8	-31.9369	152.6304	0	0	0
12_5A	-31.9747	152.5923	146	0	0

Table G8: Tracer Particle Size Counts - Sampling Exercise 4

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
3_1	0	0	0	72	0	0	0	0	0
3_2	0	0	0	0	71	0	0	0	0
3_3	0	0	0	0	0	0	0	0	0
3A_1	0	0	0	0	0	0	0	0	0
3A_2	0	0	0	0	0	0	0	0	0
3A_3	85	0	0	0	0	0	0	0	0
4_1	0	0	0	135	0	0	0	0	0
4_2	0	0	0	0	0	0	0	0	0
4_3	0	0	0	0	0	0	0	0	0
5_1	0	0	0	141	70	141	0	0	0
5_2	0	0	0	0	67	67	0	0	0
5_3	0	0	0	0	0	0	79	0	0
5_1D	0	0	0	0	0	0	0	0	0
5_2D	67	0	0	0	67	0	0	0	0
5_3D	0	0	0	0	0	0	0	0	0
5A_1	0	0	0	0	0	0	0	0	0
5A_2	73	0	0	0	73	0	0	0	0
5A_3	0	243	0	0	121	0	0	0	0
5A_1D	71	0	0	214	0	0	0	0	0
5A_2D	76	76	0	76	76	0	0	0	0
5A_3D	0	0	0	0	0	0	0	0	0
6_1	0	0	0	0	0	0	0	0	0
6_2	85	0	0	0	0	0	0	0	0
6_3	97	0	0	0	0	0	0	0	0
6_1D	0	0	0	0	76	153	0	0	0
6_2D	0	0	0	0	0	0	0	0	0
6_3D	0	0	0	90	90	0	0	0	0
6A_1	0	0	0	0	0	0	0	0	0
6A_2	70	0	0	70	0	0	0	0	0
6A_3	0	0	0	166	0	0	0	0	0
6A_1D	0	0	0	0	0	0	0	0	0
6A_2D	0	0	0	73	146	0	0	0	0
6A_3D	0	0	0	92	276	0	0	0	0
7_1	0	0	0	0	0	63	0	0	0
7_2	76	0	0	152	0	0	0	0	0
7_3	0	0	0	325	244	0	81	0	0
7_1D	0	0	0	0	181	0	0	0	0
7_2D	101	0	0	0	101	0	0	0	0
7_3D	93	0	0	93	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
7A_1	0	0	0	0	0	0	0	0	0
7A_2	0	0	0	93	93	0	0	0	0
7A_3	0	0	0	106	0	0	0	0	0
7A_1D	0	0	0	0	77	0	0	0	0
7A_2D	0	0	0	0	0	0	0	0	0
7A_3D	0	0	0	98	0	0	0	0	0
8_1	0	0	0	64	127	0	0	0	0
8_2	261	0	0	0	87	0	87	0	0
8_3	0	0	0	0	0	0	80	0	0
8_1D	0	0	0	0	0	69	0	0	0
8_2D	98	0	0	0	0	98	0	0	0
8_3D	0	0	88	0	177	0	0	0	0
8A_1	0	0	0	0	0	0	0	0	0
8A_2	90	0	0	0	0	0	90	0	0
8A_3	383	0	0	77	0	0	306	0	0
8A_1D	152	0	0	0	0	0	0	0	0
8A_2D	91	0	0	0	91	0	0	0	0
8A_3D	199	0	0	0	0	0	0	0	0
8B_1	0	0	0	0	0	0	0	0	0
8B_2	84	0	0	84	0	0	0	0	0
8B_3	88	0	0	175	88	0	0	0	0
8B_1D	0	0	0	0	0	0	0	0	0
8B_2D	0	0	0	0	0	0	0	0	0
8B_3D	184	184	0	0	0	0	0	0	0
9_1	65	0	0	65	0	0	0	0	0
9_2	0	0	0	0	0	0	88	0	0
9_3	254	0	0	85	0	0	0	0	0
9_1D	0	0	0	0	0	0	0	0	0
9_2D	90	0	0	0	0	0	90	0	0
9_3D	84	84	0	84	84	0	168	0	0
9A_1	64	0	0	64	0	0	0	0	0
9A_2	81	0	0	0	0	0	81	0	0
9A_3	0	0	0	0	0	73	0	0	0
9A_1D	0	0	0	0	0	0	0	0	0
9A_2D	0	0	0	100	0	100	0	0	0
9A_3D	156	78	0	0	0	0	0	0	0
10_1	62	62	0	0	0	0	0	0	0
10_2	0	0	0	81	0	0	81	0	0
10_3	0	84	0	0	84	0	0	0	0
10_1D	0	0	0	0	0	0	0	0	0
10_2D	169	0	0	0	84	84	84	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
10_3D	162	81	0	0	0	0	0	0	0
10A_1	0	0	0	0	67	0	0	0	0
10A_2	237	0	0	79	0	0	0	0	0
10A_3	0	89	0	0	0	0	179	0	0
10A_1D	0	0	0	0	0	0	66	0	0
10A_2D	0	0	0	0	92	0	0	0	0
10A_3D	84	0	0	84	0	0	0	0	0
11_1	0	0	0	0	0	0	0	0	0
11_2	85	0	0	0	0	0	0	0	0
11_3	171	0	0	0	0	0	86	0	0
11_1D	0	0	0	0	0	0	66	0	0
11_2D	0	155	0	0	0	0	0	0	0
11_3D	89	89	0	89	0	0	0	0	0
11A_1	0	0	0	0	0	0	0	0	0
11A_2	0	0	0	0	0	0	0	0	0
11A_3	0	0	0	0	0	0	0	0	0
11A_1D	0	65	0	0	0	0	0	0	0
11A_2D	0	86	0	0	0	0	86	0	0
11A_3D	0	176	89	0	0	0	0	0	0
12_1	0	0	0	0	0	0	0	0	0
12_2	167	0	0	83	0	0	0	0	0
12_3	76	76	0	0	0	0	0	0	0
12_1D	0	0	0	0	0	0	0	0	0
12_2D	0	0	0	0	0	0	0	0	0
12_3D	0	0	0	84	0	0	84	0	0
12A_1	0	0	0	0	0	0	0	0	0
12A_2	0	0	0	0	0	0	0	0	0
12A_3	0	0	0	0	0	0	0	0	0
12A_1D	0	0	0	0	0	0	0	0	0
12A_2D	0	0	0	83	0	0	0	0	0
12A_3D	0	0	0	0	0	0	87	0	0
13_1	0	0	0	0	0	0	0	0	0
13_2	0	0	0	75	0	0	75	75	0
13_3	79	0	0	0	0	0	0	0	0
13_1D	0	0	0	0	0	0	0	71	0
13_2D	0	0	0	0	0	0	0	0	0
13_3D	88	0	0	0	0	0	88	0	0
14_1	0	0	0	0	0	0	0	0	0
14_2	84	0	0	0	0	0	0	0	0
14_3	83	0	0	0	0	0	83	0	0
15_1	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15_2	0	0	0	0	0	0	0	0	0
15_3	0	0	0	0	0	0	87	0	0
15A_1	0	0	0	0	0	0	0	0	0
15A_2	0	70	0	0	0	0	0	70	0
15A_3	0	0	0	0	0	0	0	0	0
16_1	0	0	0	0	0	0	0	0	0
16_2	0	80	0	0	0	0	80	0	0
16_3	0	0	0	0	0	0	0	0	0
16A_1	0	0	0	0	0	0	0	0	0
16A_2	80	0	0	0	0	0	0	0	0
16A_3	0	0	0	0	0	0	0	0	0
17_1	0	0	0	0	0	0	0	0	0
17_2	74	0	0	0	0	0	148	0	0
17_3	0	0	0	0	0	0	0	0	0
17_1D	0	0	0	0	0	0	0	0	0
17_2D	0	0	0	0	0	0	89	0	0
17_3D	0	0	0	0	0	0	96	0	0
17A_1	0	0	0	0	0	0	0	0	0
17A_2	0	0	0	0	0	0	240	0	0
17A_3	0	0	0	0	0	0	0	0	0
17A_1D	0	0	0	0	0	0	0	0	0
17A_2D	0	0	0	0	0	0	0	0	0
17A_3D	0	0	0	0	0	0	0	0	0
18_1	0	0	0	0	0	0	0	0	0
18_2	0	0	0	0	0	0	88	0	0
18_3	0	0	0	0	0	0	83	83	0
18_1D	0	0	0	0	0	0	0	0	0
18_2D	0	0	0	0	0	0	90	0	0
18_3D	0	0	0	0	0	0	0	0	0
18A_1	0	0	0	0	0	0	0	0	0
18A_2	0	0	0	0	0	0	0	90	0
18A_3	0	0	0	0	0	0	168	84	0
18A_1D	0	0	0	0	0	0	71	0	0
18A_2D	0	0	0	0	0	0	0	0	0
18A_3D	0	0	0	0	0	0	0	0	0
19_1	0	0	0	0	0	0	0	63	0
19_2	0	0	0	0	0	0	102	0	0
19_3	86	0	0	0	0	0	0	86	0
19_1D	0	0	0	0	0	0	0	0	0
19_2D	0	0	0	0	0	92	0	92	0
19_3D	0	0	0	0	0	0	98	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
19A_1	0	0	0	0	0	0	0	0	0
19A_2	0	0	0	0	0	0	0	84	0
19A_3	0	0	0	0	0	0	0	0	0
19A_1D	0	0	0	0	0	0	0	0	0
19A_2D	0	0	0	0	0	0	95	0	0
19A_3D	0	0	0	0	0	0	187	0	0
20_1	0	0	0	0	0	0	0	0	0
20_2	0	0	0	0	0	0	0	0	0
20_3	93	0	0	0	0	0	0	0	0
20_1D	0	0	0	0	0	0	66	0	0
20_2D	0	0	0	0	0	0	98	0	0
20_3D	0	0	0	0	0	0	0	0	0
20A_1	0	0	0	0	0	0	0	0	0
20A_2	0	0	0	0	0	0	0	250	0
20A_3	0	0	0	0	0	0	330	0	0
20A_1D	0	0	0	0	0	0	0	0	0
20A_2D	0	0	0	0	0	0	106	0	106
20A_3D	0	0	0	0	0	0	102	0	0
21_1	0	0	0	0	0	0	0	0	0
21_2	0	0	0	0	0	0	156	0	0
21_3	0	0	0	0	0	0	0	0	0
21_1D	0	0	0	0	0	0	0	70	0
21_2D	0	0	0	0	0	0	85	0	0
21_3D	0	0	0	0	0	0	82	0	0
24_1	0	0	0	0	0	0	0	0	0
24_3	0	0	0	0	0	0	0	0	0
25_1	0	0	0	0	0	0	0	0	0
25_3	0	0	0	0	0	0	0	0	0
1_1	0	0	0	0	0	0	0	0	0
1_3	0	0	0	0	0	0	0	0	0
2_1	0	0	0	0	0	0	0	0	0
2_3	0	0	0	0	0	0	0	0	0
F1	0	0	0	0	0	0	0	0	0
F2	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	0	0	0
F4	0	0	0	71	0	0	0	0	0
F5	0	0	0	0	0	0	0	0	0
F6	66	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	0	0
F8	0	0	0	138	0	0	0	0	0
F9	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
F10	0	0	0	82	82	0	0	0	0
F11	0	0	0	99	0	0	0	0	0
F12	0	0	0	96	0	0	0	0	0
F13	0	0	0	0	137	0	0	0	0
1_4	0	0	0	64	0	0	0	0	0
2_4	0	0	0	81	81	0	0	0	0
3_4	66	0	0	133	0	0	0	0	0
4_4	63	0	0	63	127	0	0	0	0
5_4	80	0	0	160	0	0	0	0	0
6_4	0	0	0	69	0	0	69	0	0
7_4	68	0	0	0	0	0	136	0	0
8_4	0	0	0	0	0	0	202	0	0
9_4	0	0	0	125	0	0	0	0	0
10_4	160	0	0	320	0	0	80	0	0
12_4	0	0	0	0	0	0	223	0	0
13_4	0	0	0	0	0	0	0	0	0
14_4	0	0	0	0	0	0	235	0	0
15_4	146	0	0	73	0	0	0	0	0
16_4	0	0	0	69	0	0	0	0	0
17_4	77	0	0	0	0	0	77	0	0
18_4	0	0	0	0	0	0	230	0	0
19_4	70	0	0	0	0	0	282	0	0
20_4	73	0	0	0	0	0	363	0	0
21_4	81	0	0	0	0	0	487	0	0
23_4	0	0	0	0	0	0	143	0	0
24_4	76	0	0	0	0	0	153	0	0
25_4	0	0	0	0	0	0	0	0	0
26_4	0	0	0	0	0	0	0	0	0
1_5	0	0	0	137	0	0	0	0	0
2_5	0	71	0	71	71	0	71	0	0
3_5	76	76	0	0	0	0	0	0	0
4_5	0	69	0	138	69	0	69	0	0
5_5	61	61	0	182	121	0	61	0	0
6_5	66	0	0	133	66	0	66	0	0
7_5	0	0	0	95	0	0	47	47	0
8_5	0	0	0	0	0	0	0	0	0
9_5	0	0	0	0	0	0	0	0	0
10_5	220	147	0	147	73	0	73	0	0
12_5	67	67	0	0	67	0	67	0	0
13_5	86	0	0	0	0	0	86	86	0
14_5	73	0	0	0	0	0	364	73	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15_5	0	0	0	0	0	0	73	0	0
16_5	0	65	0	0	0	0	65	0	0
17_5	76	0	0	0	0	0	152	0	0
18_5	71	71	0	0	0	0	71	0	0
19_5	70	0	0	0	0	0	0	0	0
20_5	67	0	0	0	0	0	0	0	0
21_5	0	0	0	0	0	0	87	0	0
23_5	0	0	0	0	0	0	0	0	0
24_5	0	0	0	0	0	0	0	0	0
25_5	0	0	0	0	0	0	0	0	0
26_5	0	0	0	0	0	0	0	0	0
1_6	0	0	0	66	0	0	0	0	0
2_6	0	0	0	70	0	0	0	0	0
3_6	0	0	0	72	0	0	0	0	0
4_6	131	0	0	131	0	0	0	0	0
5_6	141	0	0	0	0	0	70	0	0
6_6	0	0	0	0	0	0	0	63	0
7_6	0	0	0	0	0	0	74	0	0
8_6	0	0	0	0	65	0	65	0	0
9_6	0	0	0	215	0	0	0	0	0
11_6	0	0	0	75	75	0	150	0	0
12_6	0	0	0	0	0	0	228	76	0
13_6	0	0	0	0	0	0	157	79	0
14_6	0	0	0	0	0	0	123	0	0
15_6	0	68	0	68	68	0	0	0	0
16_6	0	0	0	0	0	0	76	0	0
17_6	62	0	0	62	0	0	0	0	0
18_6	82	0	0	0	0	0	0	0	0
19_6	0	0	0	160	0	0	80	0	0
20_6	0	0	0	0	0	0	0	0	0
21_6	0	0	0	0	0	0	85	0	0
23_6	0	0	0	0	0	0	0	0	0
24_6	0	0	0	0	0	0	0	0	0
25_6	70	0	0	0	0	0	139	0	0
26_6	66	0	0	66	0	0	66	0	0
1_7	0	0	0	0	0	0	71	0	0
2_7	0	0	0	0	0	0	152	0	0
3_7	0	0	0	0	0	0	0	0	0
4_7	0	0	0	0	0	0	72	0	0
5_7	0	0	0	0	0	0	55	0	0
6_7	0	0	0	64	0	0	129	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
7_7	0	0	0	0	0	0	0	0	0
8_7	0	0	0	0	0	0	0	0	0
9_7	0	0	0	0	0	0	71	0	0
10_7	0	0	0	0	0	0	0	61	0
12_7	0	0	0	0	0	0	0	0	0
13_7	0	0	0	0	0	0	120	0	0
14_7	0	0	0	0	0	0	57	0	0
15_7	0	0	0	0	0	0	0	0	0
16_7	0	0	0	0	0	0	0	0	0
17_7	0	0	0	0	0	0	78	0	0
18_7	0	0	0	0	0	0	0	0	0
19_7	0	0	0	0	0	0	0	0	0
21_7	0	0	0	0	0	0	0	0	0
23_7	0	0	0	0	0	0	0	0	0
24_7	0	0	0	0	0	0	0	0	0
25_7	0	0	0	0	0	0	68	0	0
26_7	0	0	0	0	0	0	0	0	0
1_8	0	0	0	0	0	0	0	0	0
2_8	0	0	0	0	0	0	0	0	0
3_8	0	0	0	0	0	0	0	0	0
6_8	0	0	0	0	0	0	0	0	0
7_8	0	0	0	0	0	0	0	0	0
15_8	0	0	0	0	0	0	0	0	0
16_8	0	0	0	0	0	0	0	0	0
17_8	0	0	0	0	0	0	0	0	0
18_8	0	0	0	0	0	0	0	0	0
24_8	0	0	0	0	0	0	0	0	0
25_8	0	0	0	0	0	0	0	0	0
12_5A	0	73	0	0	0	0	0	73	73

Table G9: Total Tracer Counts - Sampling Exercise 5

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
6_3	-31.9609	152.6003	286	0	0
6_6	-31.9624	152.6042	278	139	139
5_4	-31.9592	152.6028	264	176	352
9_4	-31.9682	152.5974	257	343	0
9_5	-31.9690	152.5979	255	340	85
8A_2	-31.9670	152.5963	220	0	147
4_7	-31.9594	152.6094	220	132	616
8A_2D	-31.9670	152.5963	220	0	0
8_4	-31.9652	152.5994	213	0	0
F-22	-31.9535	152.6027	190	63	0
7A_2D	-31.9640	152.5985	180	0	0
7A_3	-31.9640	152.5987	177	177	0
9_2	-31.9679	152.5955	177	0	0
12_5	-31.9739	152.5918	175	0	175
25_5	-31.9346	152.6258	163	0	0
26_5	-31.9512	152.6102	153	229	153
12_4	-31.9742	152.5920	152	0	76
3_3	-31.9537	152.6049	151	151	0
11A_3	-31.9727	152.5911	132	0	66
6_3D	-31.9609	152.6003	131	131	0
9_3D	-31.9682	152.5958	129	129	64
9A_1D	-31.9690	152.5946	123	62	0
9A_3	-31.9692	152.5949	121	0	0
8A_3	-31.9672	152.5965	111	0	55
8B_3D	-31.9660	152.5973	110	0	220
7_2	-31.9629	152.5990	104	52	0
F-15	-31.9521	152.6017	101	0	0
26_4	-31.9506	152.6092	98	98	0
3_2	-31.9537	152.6046	86	86	0
12A_3	-31.9743	152.5891	83	0	250
7_2D	-31.9629	152.5990	80	160	80
4_3	-31.9570	152.6030	77	0	153
13_4	-31.9753	152.5905	76	0	152
14_6	-31.9779	152.5893	74	0	368
3A_2	-31.9551	152.6041	71	0	142
7_3D	-31.9630	152.5992	67	67	0
19A_2D	-31.9896	152.5750	66	0	66
F-14	-31.9516	152.6008	65	130	0
17A_3	-31.9861	152.5779	65	0	0
8_2D	-31.9650	152.5979	63	0	0

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
8A_3D	-31.9672	152.5965	63	0	0
11A_2	-31.9724	152.5909	62	0	0
10_2	-31.9698	152.5940	59	0	0
7A_3D	-31.9640	152.5987	59	0	59
5_2	-31.9588	152.6012	59	0	0
11_3	-31.9716	152.5925	58	0	0
10_3	-31.9702	152.5944	57	0	57
14_1	-31.9767	152.5861	56	0	0
6_5	-31.9615	152.6019	55	0	110
3_6	-31.9545	152.6097	55	0	0
5_3D	-31.9590	152.6014	55	0	0
F-19	-31.9531	152.6020	53	0	0
11A_2D	-31.9724	152.5909	50	50	0
18A_1D	-31.9876	152.5761	50	50	50
5_3	-31.9590	152.6014	50	0	0
12_2	-31.9732	152.5898	50	0	99
3_1	-31.9537	152.6043	48	48	0
F-16	-31.9514	152.6019	46	0	0
8A_1D	-31.9669	152.5962	37	0	0
3A_1	-31.9549	152.6039	0	49	0
3A_3	-31.9554	152.6043	0	0	0
4_1	-31.9567	152.6024	0	0	0
4_2	-31.9568	152.6027	0	0	71
5_1	-31.9587	152.6010	0	0	0
5_1D	-31.9587	152.6010	0	0	0
5_2D	-31.9588	152.6012	0	0	0
5A_1	-31.9598	152.6004	0	0	0
5A_2	-31.9599	152.6006	0	0	143
5A_3	-31.9600	152.6008	0	87	87
5A_1D	-31.9598	152.6004	0	0	0
5A_2D	-31.9599	152.6006	0	56	0
5A_3D	-31.9600	152.6008	0	55	55
6_1	-31.9607	152.5999	0	87	0
6_2	-31.9608	152.6001	0	122	61
6_1D	-31.9607	152.5999	0	0	0
6_2D	-31.9608	152.6001	0	241	0
6A_1	-31.9618	152.5993	0	0	0
6A_2	-31.9619	152.5995	0	0	138
6A_3	-31.9620	152.5997	0	0	72
6A_1D	-31.9618	152.5993	0	153	0
6A_2D	-31.9619	152.5995	0	137	0

Sample ID	Latitude	Longitude	Yellow Tracer (count per m²)	Red Tracer (count per m²)	Orange Tracer (count per m²)
6A_3D	-31.9620	152.5997	0	0	0
7_1	-31.9628	152.5988	0	0	0
7_3	-31.9630	152.5992	0	126	0
7_1D	-31.9628	152.5988	0	94	0
7A_1	-31.9639	152.5982	0	0	0
7A_2	-31.9640	152.5985	0	0	62
7A_1D	-31.9639	152.5982	0	126	0
8_1	-31.9649	152.5977	0	0	0
8_2	-31.9650	152.5979	0	50	0
8_3	-31.9651	152.5981	0	0	74
8_1D	-31.9649	152.5977	0	47	47
8_3D	-31.9651	152.5981	0	86	0
8A_1	-31.9669	152.5962	0	0	0
8B_1	-31.9658	152.5970	0	0	0
8B_2	-31.9659	152.5971	0	82	82
8B_3	-31.9660	152.5973	0	124	0
8B_1D	-31.9658	152.5970	0	0	0
8B_2D	-31.9659	152.5971	0	0	0
9_1	-31.9678	152.5953	0	0	0
9_3	-31.9682	152.5958	0	0	98
9_1D	-31.9678	152.5953	0	0	88
9_2D	-31.9679	152.5955	0	0	64
9A_1	-31.9690	152.5946	0	0	182
9A_2	-31.9691	152.5948	0	0	0
9A_2D	-31.9691	152.5948	0	0	0
9A_3D	-31.9692	152.5949	0	0	52
10_1	-31.9698	152.5939	0	53	0
10_1D	-31.9698	152.5939	0	0	0
10_2D	-31.9698	152.5940	0	0	0
10_3D	-31.9702	152.5944	0	60	60
10A_1	-31.9713	152.5920	0	70	70
10A_2	-31.9714	152.5921	0	0	0
10A_3	-31.9716	152.5925	0	0	0
10A_1D	-31.9713	152.5920	0	0	0
10A_2D	-31.9714	152.5921	0	0	50
10A_3D	-31.9716	152.5925	0	0	0
11_1	-31.9713	152.5920	0	0	0
11_2	-31.9714	152.5921	0	0	0
11_1D	-31.9713	152.5920	0	0	0
11_2D	-31.9714	152.5921	0	0	0
11_3D	-31.9716	152.5925	0	0	53

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
11A_1	-31.9723	152.5907	0	51	0
11A_1D	-31.9723	152.5907	0	45	90
11A_3D	-31.9727	152.5911	0	0	0
12_1	-31.9730	152.5897	0	0	0
12_3	-31.9734	152.5901	0	0	0
12_1D	-31.9730	152.5897	0	0	0
12_2D	-31.9732	152.5898	0	0	0
12_3D	-31.9734	152.5901	0	0	111
12A_1	-31.9739	152.5886	0	0	0
12A_2	-31.9741	152.5888	0	0	163
12A_1D	-31.9739	152.5886	0	0	0
12A_2D	-31.9741	152.5888	0	0	136
12A_3D	-31.9743	152.5891	0	51	0
13_1	-31.9747	152.5878	0	0	47
13_2	-31.9748	152.5879	0	0	173
13_3	-31.9750	152.5880	0	0	120
13_1D	-31.9747	152.5878	0	49	0
13_2D	-31.9748	152.5879	0	0	50
13_3D	-31.9750	152.5880	0	0	0
14_2	-31.9765	152.5859	0	0	67
14_3	-31.9763	152.5858	0	0	0
15_1	-31.9780	152.5843	0	0	0
15_2	-31.9781	152.5845	0	0	0
15_3	-31.9783	152.5846	0	0	0
15A_1	-31.9800	152.5822	0	0	0
15A_2	-31.9802	152.5823	0	0	77
15A_3	-31.9803	152.5825	0	0	0
16_1	-31.9810	152.5814	0	51	0
16_2	-31.9811	152.5815	0	0	0
16_3	-31.9812	152.5816	0	0	0
16A_1	-31.9829	152.5798	0	0	0
16A_2	-31.9830	152.5800	0	0	153
16A_3	-31.9830	152.5801	0	0	0
17_1	-31.9848	152.5783	0	0	0
17_2	-31.9849	152.5785	0	67	0
17_3	-31.9850	152.5786	0	0	229
17_1D	-31.9848	152.5783	0	0	0
17_2D	-31.9849	152.5785	0	59	0
17_3D	-31.9850	152.5786	0	0	67
17A_1	-31.9858	152.5775	0	0	0
17A_2	-31.9859	152.5777	0	0	83

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
17A_1D	-31.9858	152.5775	0	0	0
17A_2D	-31.9859	152.5777	0	0	94
17A_3D	-31.9861	152.5779	0	0	68
18_1	-31.9867	152.5769	0	0	47
18_2	-31.9868	152.5771	0	0	0
18_3	-31.9869	152.5773	0	0	106
18_1D	-31.9867	152.5769	0	0	0
18_2D	-31.9868	152.5771	0	0	0
18_3D	-31.9869	152.5773	0	0	133
18A_1	-31.9876	152.5761	0	0	0
18A_2	-31.9877	152.5763	0	0	115
18A_3	-31.9878	152.5764	0	0	71
18A_2D	-31.9877	152.5763	0	0	68
18A_3D	-31.9878	152.5764	0	0	79
19_1	-31.9886	152.5755	0	0	0
19_2	-31.9887	152.5756	0	0	178
19_3	-31.9888	152.5758	0	0	83
19_1D	-31.9886	152.5755	0	0	59
19_2D	-31.9887	152.5756	0	0	0
19_3D	-31.9888	152.5758	0	0	0
19A_1	-31.9895	152.5749	0	0	57
19A_2	-31.9896	152.5750	0	0	112
19A_3	-31.9897	152.5752	0	0	0
19A_1D	-31.9895	152.5749	0	0	0
19A_3D	-31.9897	152.5752	0	0	57
20_1	-31.9906	152.5742	0	0	0
20_2	-31.9906	152.5744	0	0	156
20_3	-31.9907	152.5745	0	0	302
20_1D	-31.9906	152.5742	0	0	93
20_2D	-31.9906	152.5744	0	0	0
20_3D	-31.9907	152.5745	0	0	0
20A_1	-31.9917	152.5736	0	0	0
20A_2	-31.9917	152.5737	0	0	59
20A_3	-31.9918	152.5739	0	0	0
20A_1D	-31.9917	152.5736	0	0	0
20A_2D	-31.9917	152.5737	0	0	134
20A_3D	-31.9918	152.5739	0	0	0
21_1	-31.9926	152.5731	0	0	0
21_2	-31.9927	152.5732	0	0	56
21_3	-31.9928	152.5734	0	0	0
21_1D	-31.9926	152.5731	0	0	0

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
21_2D	-31.9927	152.5732	0	0	0
21_3D	-31.9928	152.5734	0	0	79
25_1	-31.9342	152.6211	0	0	0
1_1	-31.9417	152.6145	0	0	0
2_1	-31.9452	152.6112	0	0	0
1_4	-31.9421	152.6160	0	71	71
2_4	-31.9458	152.6127	0	0	0
3_4	-31.9537	152.6076	0	66	0
4_4	-31.9570	152.6046	0	161	81
6_4	-31.9609	152.6013	0	57	57
7_4	-31.9630	152.5999	0	120	120
10_4	-31.9732	152.5938	0	180	0
14_4	-31.9769	152.5882	0	0	146
15_4	-31.9790	152.5858	0	0	152
16_4	-31.9817	152.5829	0	0	0
17_4	-31.9856	152.5799	0	0	141
18_4	-31.9877	152.5789	0	0	0
19_4	-31.9897	152.5776	0	0	0
20_4	-31.9915	152.5760	0	0	0
21_4	-31.9933	152.5748	0	0	0
23_4	-32.0019	152.5710	0	0	0
25_4	-31.9338	152.6243	0	58	0
1_5	-31.9427	152.6172	0	66	0
2_5	-31.9467	152.6145	0	0	0
3_5	-31.9539	152.6079	0	166	0
4_5	-31.9575	152.6043	0	170	0
5_5	-31.9595	152.6029	0	52	0
7_5	-31.9636	152.6010	0	0	0
8_5	-31.9660	152.6008	0	0	124
10_5	-31.9708	152.5962	0	0	54
13_5	-31.9756	152.5899	0	75	75
14_5	-31.9773	152.5878	0	0	162
15_5	-31.9796	152.5863	0	0	0
16_5	-31.9821	152.5832	0	0	74
17_5	-31.9859	152.5804	0	0	77
18_5	-31.9881	152.5795	0	0	0
19_5	-31.9903	152.5782	0	0	0
20_5	-31.9924	152.5766	0	0	0
21_5	-31.9944	152.5746	0	0	0
23_5	-32.0021	152.5726	0	0	0
1_6	-31.9433	152.6193	0	0	0

Sample ID	Latitude	Longitude	Yellow Tracer (count per m^2)	Red Tracer (count per m^2)	Orange Tracer (count per m^2)
2_6	-31.9470	152.6158	0	0	51
4_6	-31.9584	152.6067	0	0	248
5_6	-31.9603	152.6054	0	0	295
7_6	-31.9645	152.6034	0	0	0
8_6	-31.9666	152.6023	0	187	0
9_6	-31.9702	152.6007	0	0	70
11_6	-31.9742	152.5982	0	0	67
12_6	-31.9749	152.5940	0	0	0
13_6	-31.9762	152.5913	0	0	0
15_6	-31.9797	152.5873	0	0	113
16_6	-31.9827	152.5844	0	0	271
17_6	-31.9864	152.5816	0	0	0
18_6	-31.9888	152.5809	0	0	0
19_6	-31.9907	152.5789	0	0	0
20_6	-31.9931	152.5773	0	0	0
21_6	-31.9953	152.5754	0	0	0
23_6	-32.0044	152.5723	0	0	0
25_6	-31.9355	152.6272	0	0	0
26_6	-31.9517	152.6113	0	0	0
1_7	-31.9444	152.6220	0	0	47
2_7	-31.9477	152.6178	0	0	0
3_7	-31.9559	152.6129	0	0	164
5_7	-31.9615	152.6084	0	81	0
6_7	-31.9635	152.6072	0	0	162
7_7	-31.9654	152.6056	0	0	0
8_7	-31.9665	152.6051	0	0	73
9_7	-31.9724	152.6058	0	0	0
10_7	-31.9765	152.5959	0	0	57
12_7	-31.9765	152.5976	0	0	0
13_7	-31.9779	152.5951	0	0	0
14_7	-31.9794	152.5928	0	0	0
15_7	-31.9811	152.5909	0	0	0
16_7	-31.9841	152.5874	0	0	0
17_7	-31.9875	152.5838	0	0	0
18_7	-31.9903	152.5822	0	0	0
19_7	-31.9924	152.5797	0	0	0
21_7	-31.9968	152.5757	0	0	0
23_7	-32.0064	152.5733	0	0	0
25_7	-31.9364	152.6273	0	0	0
26_7	-31.9535	152.6152	0	0	59
1_8	-31.9452	152.6241	0	0	0

Sample ID	Latitude	Longitude	Yellow Tracer (count per m²)	Red Tracer (count per m²)	Orange Tracer (count per m²)
2_8	-31.9487	152.6209	0	0	0
3_8	-31.9566	152.6150	0	0	0
6_8	-31.9644	152.6091	0	0	0
7_8	-31.9667	152.6087	0	0	0
8_8	-31.9670	152.6047	0	0	0
15_8	-31.9825	152.5926	0	0	55
16_8	-31.9865	152.5922	0	0	0
17_8	-31.9885	152.5874	0	0	0
18_8	-31.9918	152.5839	0	0	38
25_8	-31.9369	152.6304	0	0	0
12_5A	-31.9747	152.5923	0	0	53
F-1	-31.9503	152.6070	0	0	0
F-2	-31.9518	152.6056	0	0	0
F-3	-31.9516	152.6042	0	42	0
F-4	-31.9488	152.6072	0	0	0
F-5	-31.9501	152.6059	0	0	0
F-6	-31.9513	152.6025	0	0	44
F-8	-31.9495	152.6050	0	0	0
F-9	-31.9475	152.6067	0	0	0
F-10	-31.9448	152.6064	0	51	0
F-11	-31.9468	152.6038	0	0	0
F-12	-31.9497	152.6019	0	0	0
F-13	-31.9504	152.6009	0	64	0
F-17	-31.9505	152.6021	0	0	0
F-18	-31.9521	152.6024	0	371	62
F-20	-31.9533	152.6009	0	124	0
F-21	-31.9542	152.6016	0	247	0

Table G10: Tracer Particle Size Counts - Sampling Exercise 5

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
3_1	48	0	0	0	48	0	0	0	0
3_2	0	86	0	0	0	86	0	0	0
3_3	76	76	0	0	0	151	0	0	0
3A_1	0	0	0	0	0	49	0	0	0
3A_2	71	0	0	0	0	0	142	0	0
3A_3	0	0	0	0	0	0	0	0	0
4_1	0	0	0	0	0	0	0	0	0
4_2	0	0	0	0	0	0	0	71	0
4_3	0	0	77	0	0	0	153	0	0
5_1	0	0	0	0	0	0	0	0	0
5_2	59	0	0	0	0	0	0	0	0
5_3	50	0	0	0	0	0	0	0	0
5_1D	0	0	0	0	0	0	0	0	0
5_2D	0	0	0	0	0	0	0	0	0
5_3D	55	0	0	0	0	0	0	0	0
5A_1	0	0	0	0	0	0	0	0	0
5A_2	0	0	0	0	0	0	0	143	0
5A_3	0	0	0	0	87	0	87	0	0
5A_1D	0	0	0	0	0	0	0	0	0
5A_2D	0	0	0	0	56	0	0	0	0
5A_3D	0	0	0	0	55	0	55	0	0
6_1	0	0	0	87	0	0	0	0	0
6_2	0	0	0	0	61	61	61	0	0
6_3	0	190	95	0	0	0	0	0	0
6_1D	0	0	0	0	0	0	0	0	0
6_2D	0	0	0	161	0	80	0	0	0
6_3D	131	0	0	0	131	0	0	0	0
6A_1	0	0	0	0	0	0	0	0	0
6A_2	0	0	0	0	0	0	69	69	0
6A_3	0	0	0	0	0	0	72	0	0
6A_1D	0	0	0	51	51	51	0	0	0
6A_2D	0	0	0	0	68	68	0	0	0
6A_3D	0	0	0	0	0	0	0	0	0
7_1	0	0	0	0	0	0	0	0	0
7_2	104	0	0	0	52	0	0	0	0
7_3	0	0	0	0	63	63	0	0	0
7_1D	0	0	0	47	47	0	0	0	0
7_2D	80	0	0	80	80	0	80	0	0
7_3D	0	0	67	0	67	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
7A_1	0	0	0	0	0	0	0	0	0
7A_2	0	0	0	0	0	0	0	62	0
7A_3	177	0	0	177	0	0	0	0	0
7A_1D	0	0	0	42	84	0	0	0	0
7A_2D	120	60	0	0	0	0	0	0	0
7A_3D	59	0	0	0	0	0	0	59	0
8_1	0	0	0	0	0	0	0	0	0
8_2	0	0	0	0	50	0	0	0	0
8_3	0	0	0	0	0	0	74	0	0
8_1D	0	0	0	0	47	0	47	0	0
8_2D	63	0	0	0	0	0	0	0	0
8_3D	0	0	0	0	0	86	0	0	0
8A_1	0	0	0	0	0	0	0	0	0
8A_2	220	0	0	0	0	0	0	147	0
8A_3	55	55	0	0	0	0	55	0	0
8A_1D	37	0	0	0	0	0	0	0	0
8A_2D	220	0	0	0	0	0	0	0	0
8A_3D	63	0	0	0	0	0	0	0	0
8B_1	0	0	0	0	0	0	0	0	0
8B_2	0	0	0	0	82	0	0	82	0
8B_3	0	0	0	124	0	0	0	0	0
8B_1D	0	0	0	0	0	0	0	0	0
8B_2D	0	0	0	0	0	0	0	0	0
8B_3D	0	110	0	0	0	0	220	0	0
9_1	0	0	0	0	0	0	0	0	0
9_2	177	0	0	0	0	0	0	0	0
9_3	0	0	0	0	0	0	98	0	0
9_1D	0	0	0	0	0	0	88	0	0
9_2D	0	0	0	0	0	0	64	0	0
9_3D	0	129	0	129	0	0	0	64	0
9A_1	0	0	0	0	0	0	182	0	0
9A_2	0	0	0	0	0	0	0	0	0
9A_3	121	0	0	0	0	0	0	0	0
9A_1D	62	62	0	62	0	0	0	0	0
9A_2D	0	0	0	0	0	0	0	0	0
9A_3D	0	0	0	0	0	0	52	0	0
10_1	0	0	0	53	0	0	0	0	0
10_2	59	0	0	0	0	0	0	0	0
10_3	0	57	0	0	0	0	0	57	0
10_1D	0	0	0	0	0	0	0	0	0
10_2D	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
10_3D	0	0	0	0	60	0	60	0	0
10A_1	0	0	0	0	70	0	0	70	0
10A_2	0	0	0	0	0	0	0	0	0
10A_3	0	0	0	0	0	0	0	0	0
10A_1D	0	0	0	0	0	0	0	0	0
10A_2D	0	0	0	0	0	0	0	50	0
10A_3D	0	0	0	0	0	0	0	0	0
11_1	0	0	0	0	0	0	0	0	0
11_2	0	0	0	0	0	0	0	0	0
11_3	0	0	58	0	0	0	0	0	0
11_1D	0	0	0	0	0	0	0	0	0
11_2D	0	0	0	0	0	0	0	0	0
11_3D	0	0	0	0	0	0	53	0	0
11A_1	0	0	0	0	0	51	0	0	0
11A_2	62	0	0	0	0	0	0	0	0
11A_3	0	66	66	0	0	0	66	0	0
11A_1D	0	0	0	45	0	0	90	0	0
11A_2D	50	0	0	50	0	0	0	0	0
11A_3D	0	0	0	0	0	0	0	0	0
12_1	0	0	0	0	0	0	0	0	0
12_2	0	50	0	0	0	0	50	50	0
12_3	0	0	0	0	0	0	0	0	0
12_1D	0	0	0	0	0	0	0	0	0
12_2D	0	0	0	0	0	0	0	0	0
12_3D	0	0	0	0	0	0	111	0	0
12A_1	0	0	0	0	0	0	0	0	0
12A_2	0	0	0	0	0	0	0	163	0
12A_3	0	83	0	0	0	0	83	167	0
12A_1D	0	0	0	0	0	0	0	0	0
12A_2D	0	0	0	0	0	0	0	136	0
12A_3D	0	0	0	0	51	0	0	0	0
13_1	0	0	0	0	0	0	47	0	0
13_2	0	0	0	0	0	0	87	87	0
13_3	0	0	0	0	0	0	0	120	0
13_1D	0	0	0	49	0	0	0	0	0
13_2D	0	0	0	0	0	0	0	0	50
13_3D	0	0	0	0	0	0	0	0	0
14_1	56	0	0	0	0	0	0	0	0
14_2	0	0	0	0	0	0	0	67	0
14_3	0	0	0	0	0	0	0	0	0
15_1	0	0	0	0	0	0	0	0	0

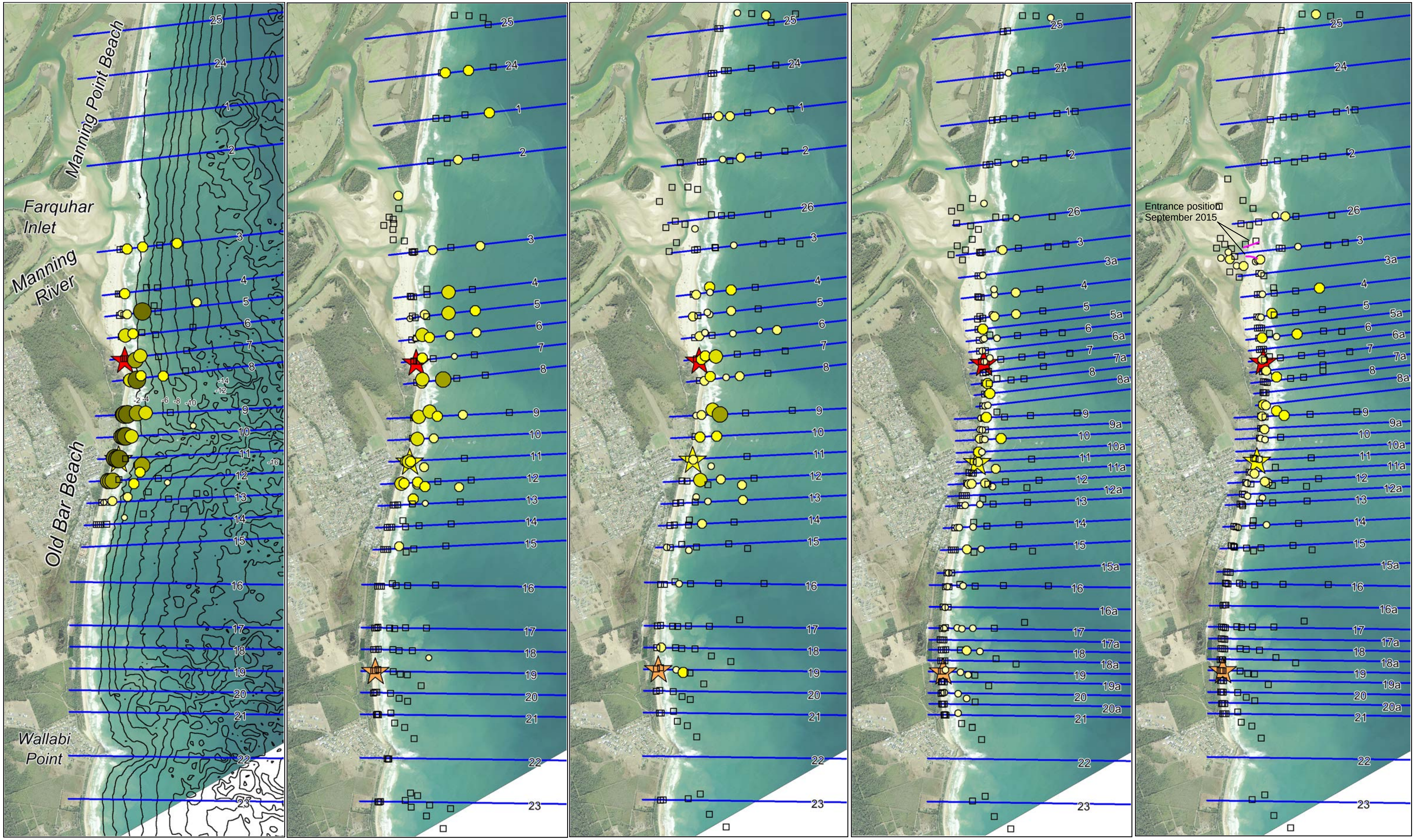
Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
15_2	0	0	0	0	0	0	0	0	0
15_3	0	0	0	0	0	0	0	0	0
15A_1	0	0	0	0	0	0	0	0	0
15A_2	0	0	0	0	0	0	0	77	0
15A_3	0	0	0	0	0	0	0	0	0
16_1	0	0	0	0	0	51	0	0	0
16_2	0	0	0	0	0	0	0	0	0
16_3	0	0	0	0	0	0	0	0	0
16A_1	0	0	0	0	0	0	0	0	0
16A_2	0	0	0	0	0	0	153	0	0
16A_3	0	0	0	0	0	0	0	0	0
17_1	0	0	0	0	0	0	0	0	0
17_2	0	0	0	67	0	0	0	0	0
17_3	0	0	0	0	0	0	76	76	76
17_1D	0	0	0	0	0	0	0	0	0
17_2D	0	0	0	0	59	0	0	0	0
17_3D	0	0	0	0	0	0	67	0	0
17A_1	0	0	0	0	0	0	0	0	0
17A_2	0	0	0	0	0	0	0	83	0
17A_3	0	65	0	0	0	0	0	0	0
17A_1D	0	0	0	0	0	0	0	0	0
17A_2D	0	0	0	0	0	0	94	0	0
17A_3D	0	0	0	0	0	0	0	68	0
18_1	0	0	0	0	0	0	0	47	0
18_2	0	0	0	0	0	0	0	0	0
18_3	0	0	0	0	0	0	0	53	53
18_1D	0	0	0	0	0	0	0	0	0
18_2D	0	0	0	0	0	0	0	0	0
18_3D	0	0	0	0	0	0	67	67	0
18A_1	0	0	0	0	0	0	0	0	0
18A_2	0	0	0	0	0	0	0	115	0
18A_3	0	0	0	0	0	0	71	0	0
18A_1D	50	0	0	0	50	0	0	50	0
18A_2D	0	0	0	0	0	0	0	68	0
18A_3D	0	0	0	0	0	0	0	79	0
19_1	0	0	0	0	0	0	0	0	0
19_2	0	0	0	0	0	0	0	178	0
19_3	0	0	0	0	0	0	0	83	0
19_1D	0	0	0	0	0	0	59	0	0
19_2D	0	0	0	0	0	0	0	0	0
19_3D	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
19A_1	0	0	0	0	0	0	57	0	0
19A_2	0	0	0	0	0	0	56	56	0
19A_3	0	0	0	0	0	0	0	0	0
19A_1D	0	0	0	0	0	0	0	0	0
19A_2D	66	0	0	0	0	0	66	0	0
19A_3D	0	0	0	0	0	0	0	57	0
20_1	0	0	0	0	0	0	0	0	0
20_2	0	0	0	0	0	0	78	0	78
20_3	0	0	0	0	0	0	202	101	0
20_1D	0	0	0	0	0	0	93	0	0
20_2D	0	0	0	0	0	0	0	0	0
20_3D	0	0	0	0	0	0	0	0	0
20A_1	0	0	0	0	0	0	0	0	0
20A_2	0	0	0	0	0	0	0	59	0
20A_3	0	0	0	0	0	0	0	0	0
20A_1D	0	0	0	0	0	0	0	0	0
20A_2D	0	0	0	0	0	0	67	67	0
20A_3D	0	0	0	0	0	0	0	0	0
21_1	0	0	0	0	0	0	0	0	0
21_2	0	0	0	0	0	0	56	0	0
21_3	0	0	0	0	0	0	0	0	0
21_1D	0	0	0	0	0	0	0	0	0
21_2D	0	0	0	0	0	0	0	0	0
21_3D	0	0	0	0	0	0	79	0	0
25_1	0	0	0	0	0	0	0	0	0
1_1	0	0	0	0	0	0	0	0	0
2_1	0	0	0	0	0	0	0	0	0
1_4	0	0	0	71	0	0	71	0	0
2_4	0	0	0	0	0	0	0	0	0
3_4	0	0	0	0	66	0	0	0	0
4_4	0	0	0	161	0	0	81	0	0
5_4	264	0	0	88	88	0	264	88	0
6_4	0	0	0	0	57	0	57	0	0
7_4	0	0	0	60	60	0	120	0	0
8_4	213	0	0	0	0	0	0	0	0
9_4	171	86	0	171	86	86	0	0	0
10_4	0	0	0	90	90	0	0	0	0
12_4	152	0	0	0	0	0	76	0	0
13_4	76	0	0	0	0	0	76	76	0
14_4	0	0	0	0	0	0	0	146	0
15_4	0	0	0	0	0	0	76	76	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
16_4	0	0	0	0	0	0	0	0	0
17_4	0	0	0	0	0	0	71	71	0
18_4	0	0	0	0	0	0	0	0	0
19_4	0	0	0	0	0	0	0	0	0
20_4	0	0	0	0	0	0	0	0	0
21_4	0	0	0	0	0	0	0	0	0
23_4	0	0	0	0	0	0	0	0	0
25_4	0	0	0	58	0	0	0	0	0
26_4	98	0	0	0	0	98	0	0	0
1_5	0	0	0	66	0	0	0	0	0
2_5	0	0	0	0	0	0	0	0	0
3_5	0	0	0	166	0	0	0	0	0
4_5	0	0	0	170	0	0	0	0	0
5_5	0	0	0	52	0	0	0	0	0
6_5	55	0	0	0	0	0	110	0	0
7_5	0	0	0	0	0	0	0	0	0
8_5	0	0	0	0	0	0	124	0	0
9_5	255	0	0	255	85	0	85	0	0
10_5	0	0	0	0	0	0	54	0	0
12_5	175	0	0	0	0	0	175	0	0
13_5	0	0	0	75	0	0	75	0	0
14_5	0	0	0	0	0	0	162	0	0
15_5	0	0	0	0	0	0	0	0	0
16_5	0	0	0	0	0	0	74	0	0
17_5	0	0	0	0	0	0	77	0	0
18_5	0	0	0	0	0	0	0	0	0
19_5	0	0	0	0	0	0	0	0	0
20_5	0	0	0	0	0	0	0	0	0
21_5	0	0	0	0	0	0	0	0	0
23_5	0	0	0	0	0	0	0	0	0
25_5	163	0	0	0	0	0	0	0	0
26_5	153	0	0	76	153	0	153	0	0
1_6	0	0	0	0	0	0	0	0	0
2_6	0	0	0	0	0	0	51	0	0
3_6	55	0	0	0	0	0	0	0	0
4_6	0	0	0	0	0	0	124	62	62
5_6	0	0	0	0	0	0	221	0	74
6_6	278	0	0	139	0	0	139	0	0
7_6	0	0	0	0	0	0	0	0	0
8_6	0	0	0	187	0	0	0	0	0
9_6	0	0	0	0	0	0	70	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
11_6	0	0	0	0	0	0	67	0	0
12_6	0	0	0	0	0	0	0	0	0
13_6	0	0	0	0	0	0	0	0	0
14_6	74	0	0	0	0	0	368	0	0
15_6	0	0	0	0	0	0	113	0	0
16_6	0	0	0	0	0	0	135	135	0
17_6	0	0	0	0	0	0	0	0	0
18_6	0	0	0	0	0	0	0	0	0
19_6	0	0	0	0	0	0	0	0	0
20_6	0	0	0	0	0	0	0	0	0
21_6	0	0	0	0	0	0	0	0	0
23_6	0	0	0	0	0	0	0	0	0
25_6	0	0	0	0	0	0	0	0	0
26_6	0	0	0	0	0	0	0	0	0
1_7	0	0	0	0	0	0	47	0	0
2_7	0	0	0	0	0	0	0	0	0
3_7	0	0	0	0	0	0	164	0	0
4_7	220	0	0	132	0	0	616	0	0
5_7	0	0	0	81	0	0	0	0	0
6_7	0	0	0	0	0	0	162	0	0
7_7	0	0	0	0	0	0	0	0	0
8_7	0	0	0	0	0	0	73	0	0
9_7	0	0	0	0	0	0	0	0	0
10_7	0	0	0	0	0	0	57	0	0
12_7	0	0	0	0	0	0	0	0	0
13_7	0	0	0	0	0	0	0	0	0
14_7	0	0	0	0	0	0	0	0	0
15_7	0	0	0	0	0	0	0	0	0
16_7	0	0	0	0	0	0	0	0	0
17_7	0	0	0	0	0	0	0	0	0
18_7	0	0	0	0	0	0	0	0	0
19_7	0	0	0	0	0	0	0	0	0
21_7	0	0	0	0	0	0	0	0	0
23_7	0	0	0	0	0	0	0	0	0
25_7	0	0	0	0	0	0	0	0	0
26_7	0	0	0	0	0	0	59	0	0
1_8	0	0	0	0	0	0	0	0	0
2_8	0	0	0	0	0	0	0	0	0
3_8	0	0	0	0	0	0	0	0	0
6_8	0	0	0	0	0	0	0	0	0
7_8	0	0	0	0	0	0	0	0	0

Sample ID	Yellow Tracer Count			Red Tracer Count			Orange Tracer Count		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
8_8	0	0	0	0	0	0	0	0	0
15_8	0	0	0	0	0	0	55	0	0
16_8	0	0	0	0	0	0	0	0	0
17_8	0	0	0	0	0	0	0	0	0
18_8	0	0	0	0	0	0	38	0	0
25_8	0	0	0	0	0	0	0	0	0
12_5A	0	0	0	0	0	0	53	0	0
F-1	0	0	0	0	0	0	0	0	0
F-2	0	0	0	0	0	0	0	0	0
F-3	0	0	0	0	0	42	0	0	0
F-4	0	0	0	0	0	0	0	0	0
F-5	0	0	0	0	0	0	0	0	0
F-6	0	0	0	0	0	0	0	44	0
F-8	0	0	0	0	0	0	0	0	0
F-9	0	0	0	0	0	0	0	0	0
F-10	0	0	0	51	0	0	0	0	0
F-11	0	0	0	0	0	0	0	0	0
F-12	0	0	0	0	0	0	0	0	0
F-13	0	0	0	0	0	64	0	0	0
F-14	65	0	0	65	65	0	0	0	0
F-15	50	50	0	0	0	0	0	0	0
F-16	46	0	0	0	0	0	0	0	0
F-17	0	0	0	0	0	0	0	0	0
F-18	0	0	0	185	124	62	62	0	0
F-19	53	0	0	0	0	0	0	0	0
F-20	0	0	0	0	62	62	0	0	0
F-21	0	0	0	62	185	0	0	0	0
F-22	190	0	0	0	63	0	0	0	0



SAMPLING EXERCISE 1 - JUL 2014 | **SAMPLING EXERCISE 2 - SEP 2014** | **SAMPLING EXERCISE 3 - NOV/DEC 2014** | **SAMPLING EXERCISE 4 - MAR 2015** | **SAMPLING EXERCISE 5 - SEP 2015**

PROJECT NO: 8A0406 PROJECT TITLE: Old Bar Sediment Tracing

0 0.5 1km
Approx. Scale

SCALE 1:40,000 PAGE SIZE A3

FIGURE G1 **YELLOW TRACER - COUNT PER SQUARE METRE**

CREATED BY B.MACKENZIE
REVISION A
DATE 05/02/2016

FILEPATH \\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo

CO-ORDINATE SYSTEM Projection: WGS84

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

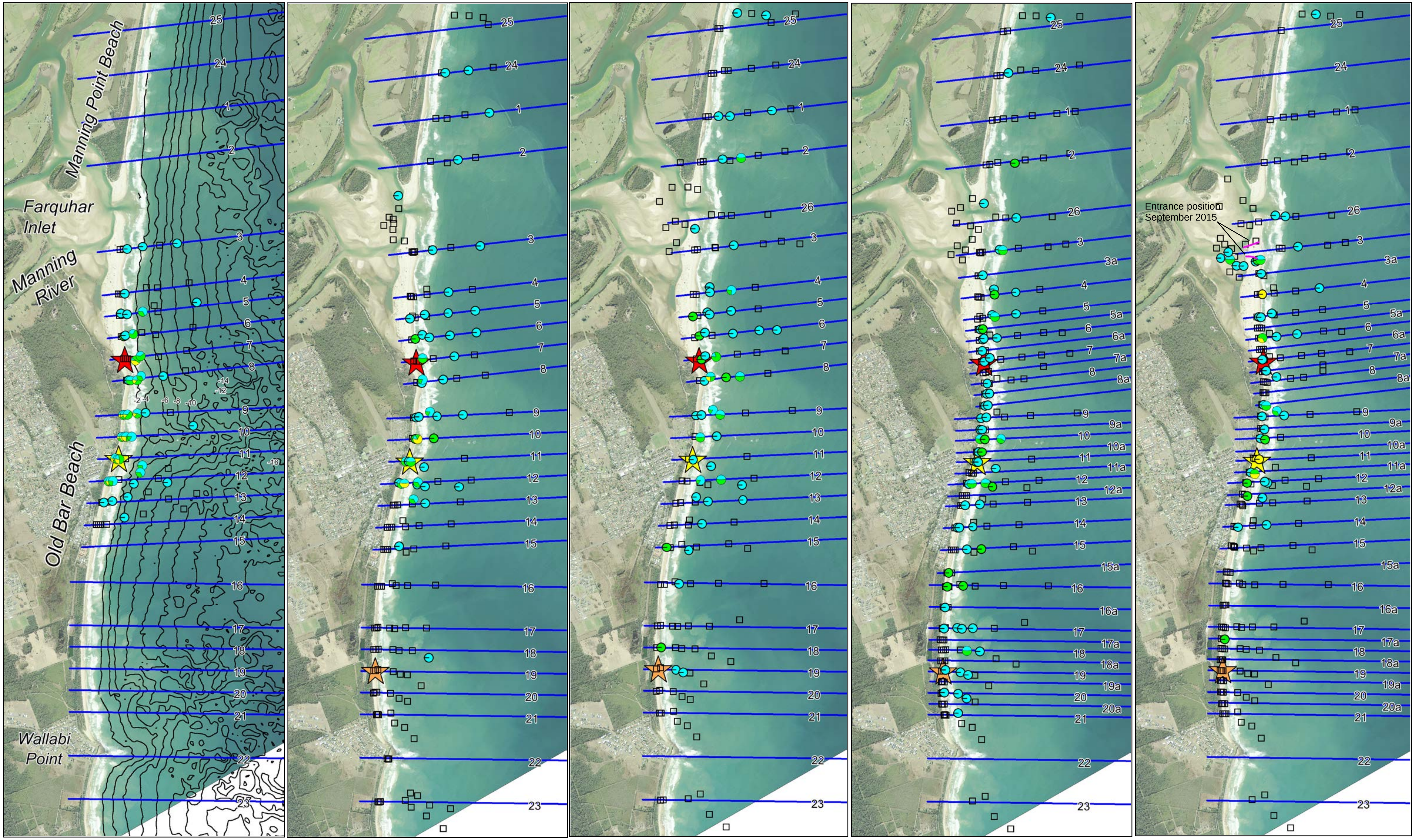
Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together



SAMPLING EXERCISE 1 - JUL 2014

SAMPLING EXERCISE 2 - SEP 2014

SAMPLING EXERCISE 3 - NOV/DEC 2014

SAMPLING EXERCISE 4 - MAR 2015

SAMPLING EXERCISE 5 - SEP 2015

PROJECT NO:	8A0406
PROJECT TITLE:	Old Bar Sediment Tracing
FIGURE G2	YELLOW TRACER - PARTICLE SIZE
FILEPATH	\\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo

0 0.5 1km
Approx. Scale

SCALE	1:40,000
PAGE SIZE	A3
CREATED BY	B.MACKENZIE
REVISION	A
DATE	05/02/2016
CO-ORDINATE SYSTEM	Projection: WGS84

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

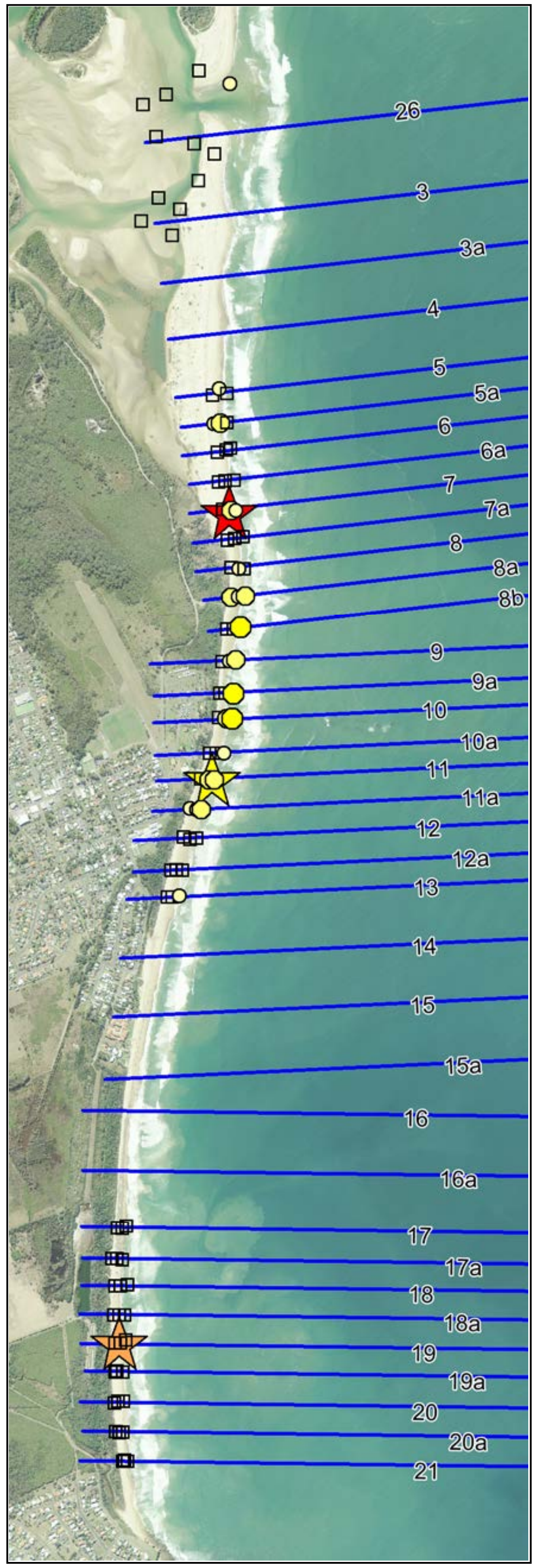
Particle Size:

- Fine
- Medium
- Coarse
- No Count

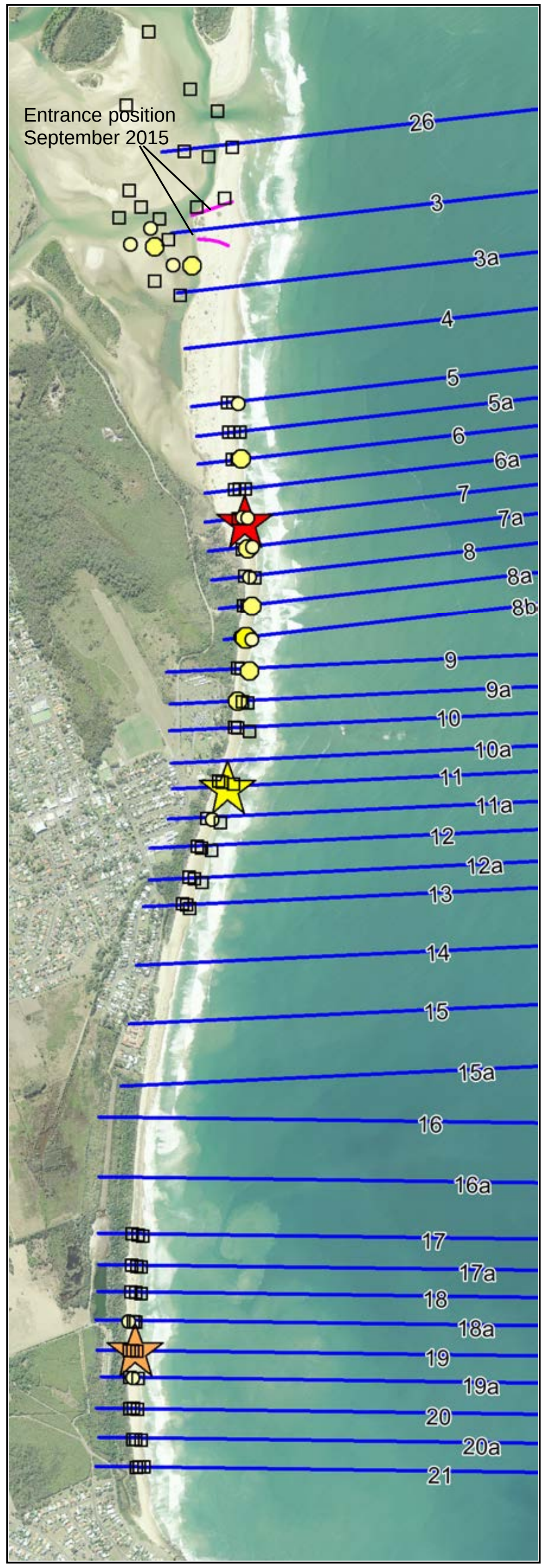
NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

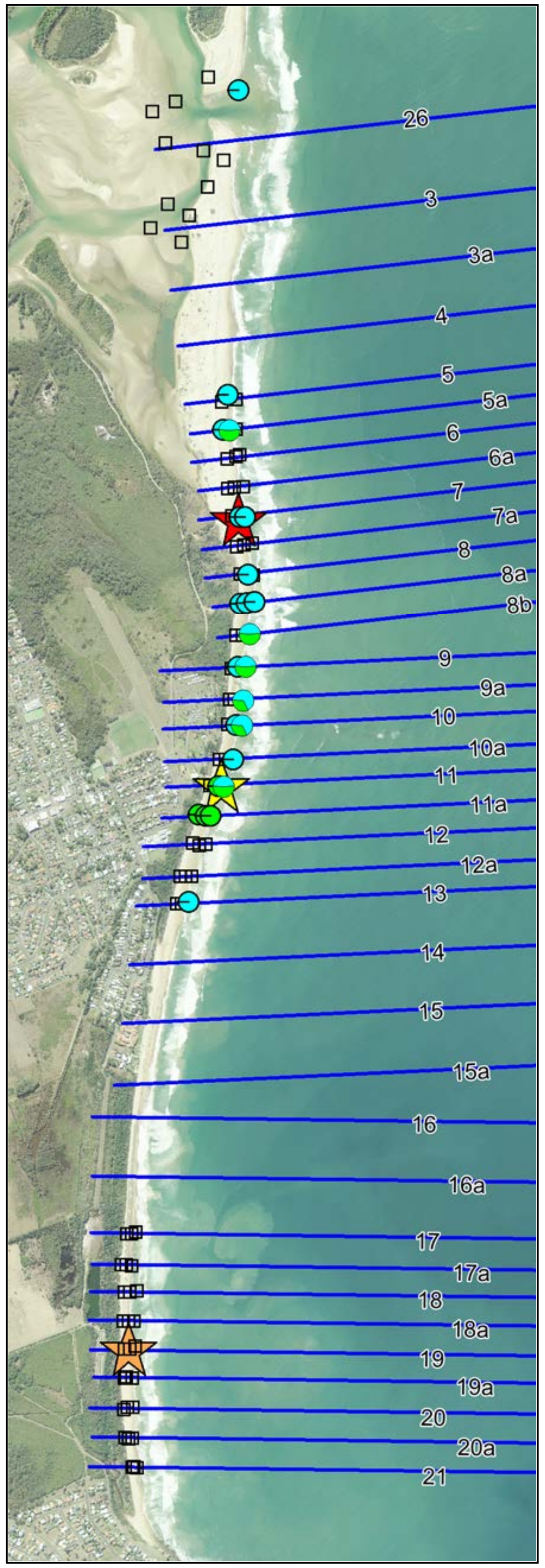
Royal HaskoningDHV
Enhancing Society Together



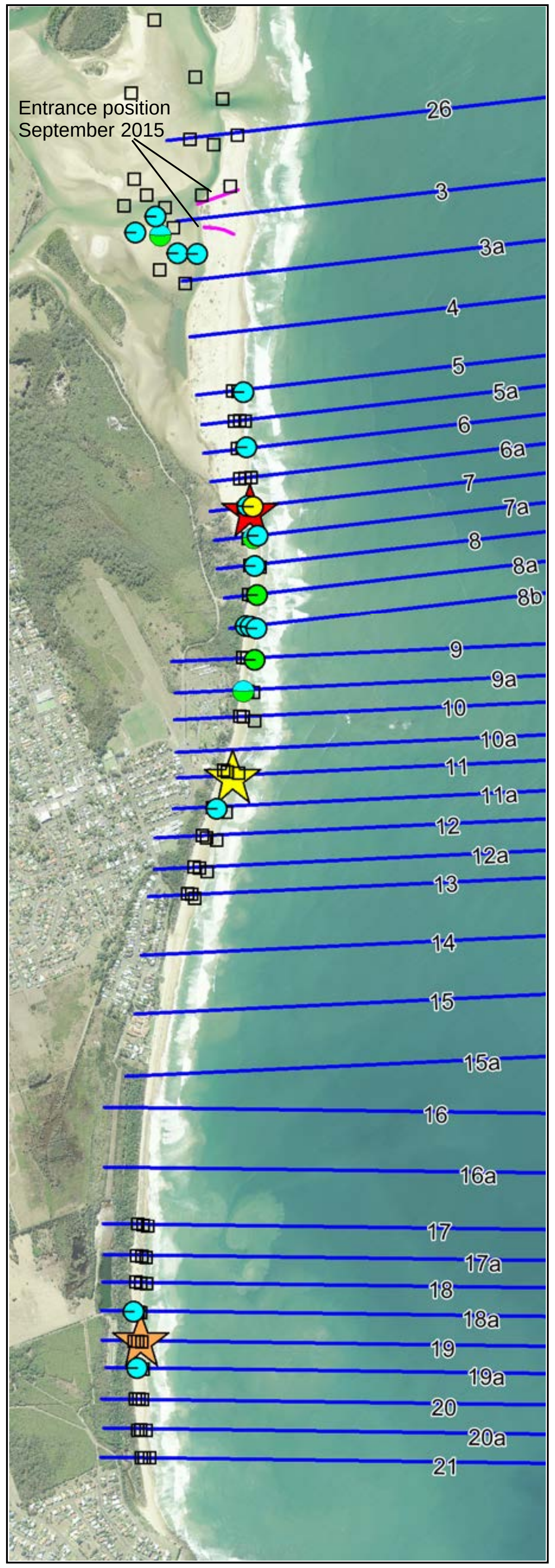
COUNT PER SQUARE METRE
SAMPLING EXERCISE 4 - MAR 2015



COUNT PER SQUARE METRE
SAMPLING EXERCISE 5 - SEP 2015



PARTICLE SIZE
SAMPLING EXERCISE 4 - MAR 2015



PARTICLE SIZE
SAMPLING EXERCISE 5 - SEP 2015

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

Particle Size:

- Fine
- Medium
- Coarse
- No Count

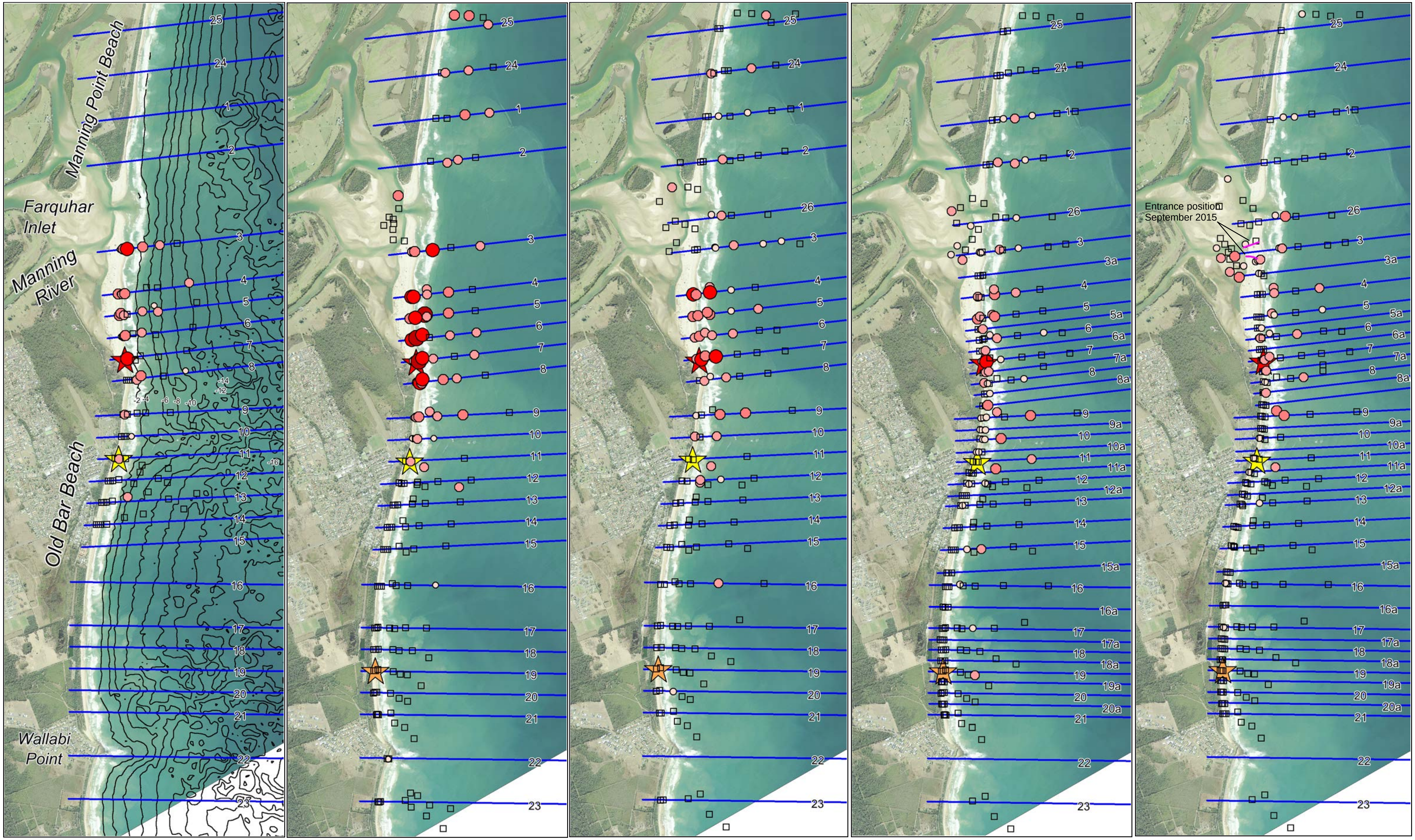
PROJECT NO:	8A0406	PROJECT TITLE:	Old Bar Sediment Tracing
SCALE	1:30,000	PAGE SIZE	A3
FIGURE G3	YELLOW TRACER - DEPTH AVERAGE		
CREATED BY	B.MACKENZIE		
REVISION	A		
DATE	05/02/2016		
FILEPATH	\\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo	CO-ORDINATE SYSTEM	Projection: WGS84

0 375 750m
Approx. Scale

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together



SAMPLING EXERCISE 1 - JUL 2014

SAMPLING EXERCISE 2 - SEP 2014

SAMPLING EXERCISE 3 - NOV/DEC 2014

SAMPLING EXERCISE 4 - MAR 2015

SAMPLING EXERCISE 5 - SEP 2015

PROJECT NO: 8A0406 PROJECT TITLE: Old Bar Sediment Tracing

0 0.5 1km
Approx. Scale

SCALE 1:40,000 PAGE SIZE A3

FIGURE G4 **RED TRACER - COUNT PER SQUARE METRE**

CREATED BY B.MACKENZIE
REVISION A
DATE 05/02/2016

FILEPATH \\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo

CO-ORDINATE SYSTEM Projection: WGS84

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

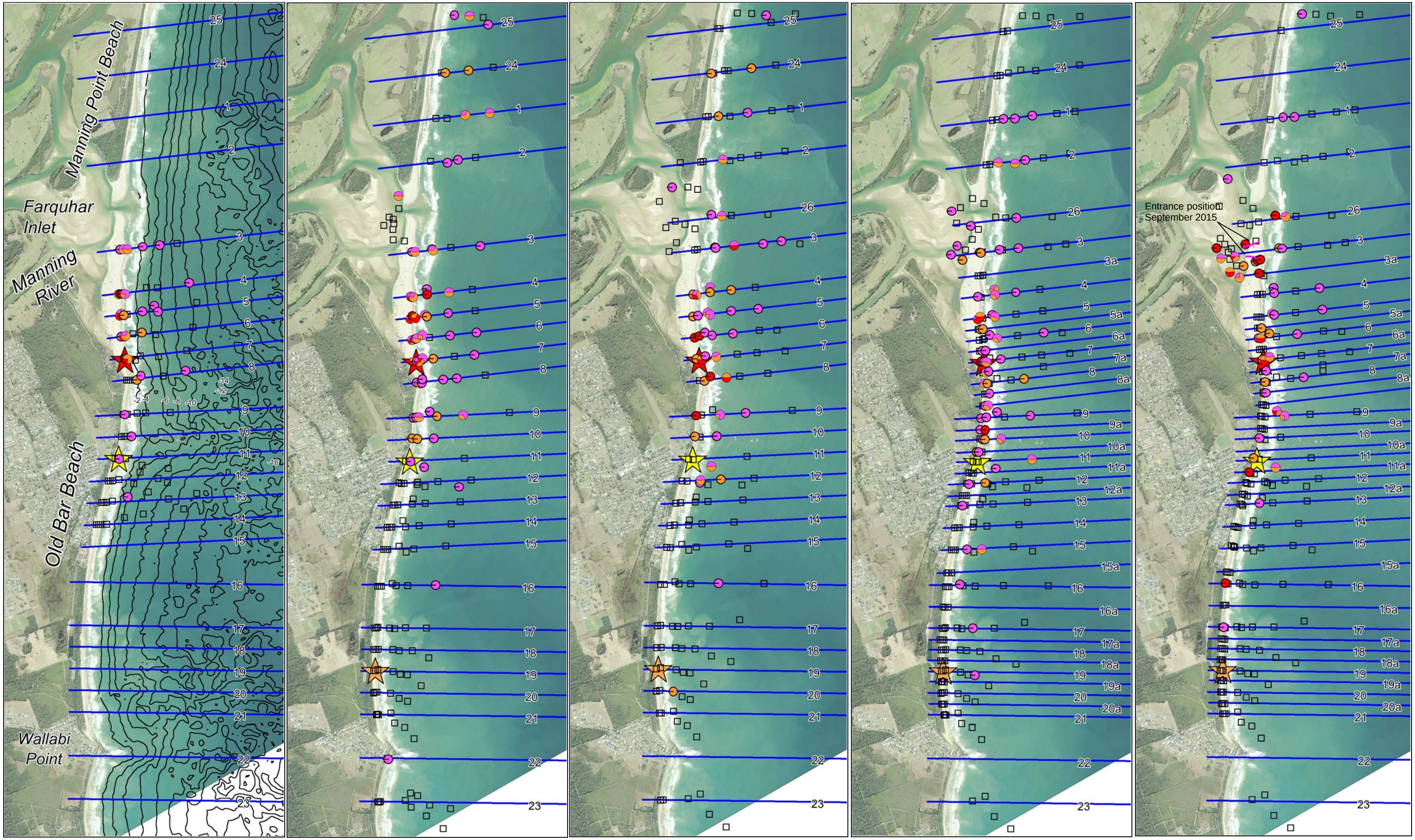
Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together



SAMPLING EXERCISE 1 - JUL 2014

SAMPLING EXERCISE 2 - SEP 2014

SAMPLING EXERCISE 3 - NOV/DEC 2014

SAMPLING EXERCISE 4 - MAR 2015

SAMPLING EXERCISE 5 - SEP 2015

PROJECT NO: 8A0406	PROJECT TITLE: Old Bar Sediment Tracing	SCALE 1:40,000	PAGE SIZE A3
FIGURE G5	RED TRACER - PARTICLE SIZE	CREATED BY B.MACKENZIE REVISION A DATE 05/02/2016	
FILEPATH \\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo		CO-ORDINATE SYSTEM Projection: WGS84	

0 0.5 1km
Approx. Scale

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

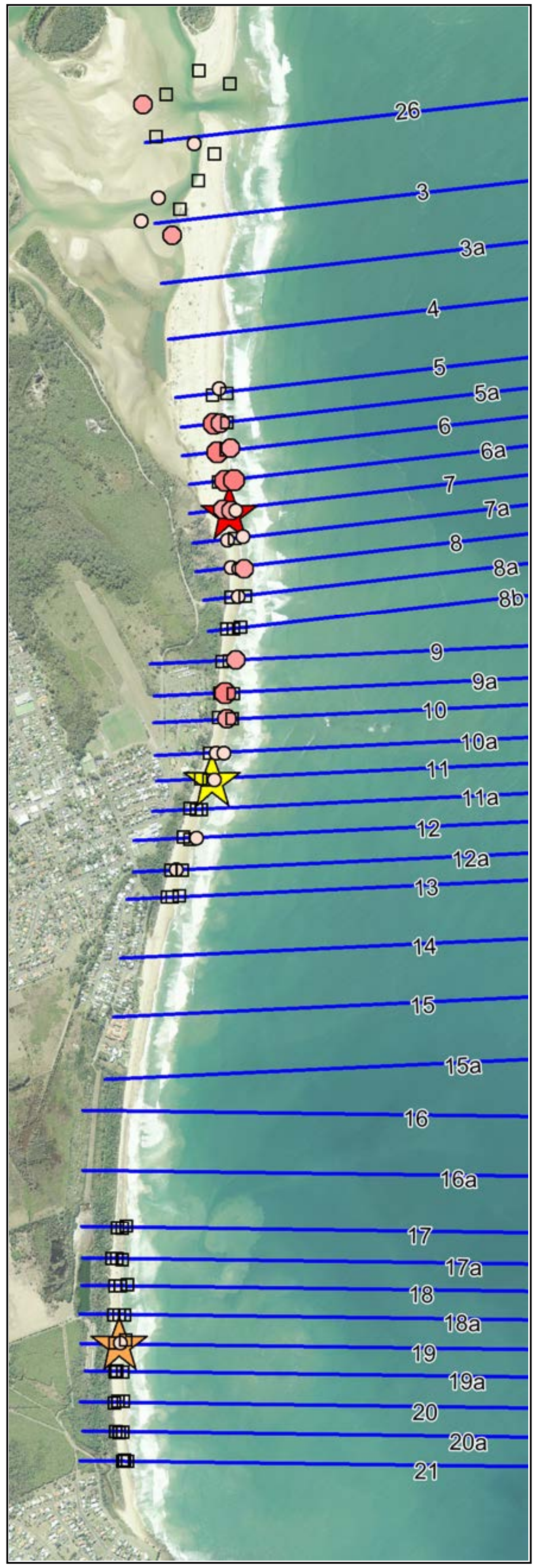
Particle Size:

- Fine
- Medium
- Coarse
- No Count

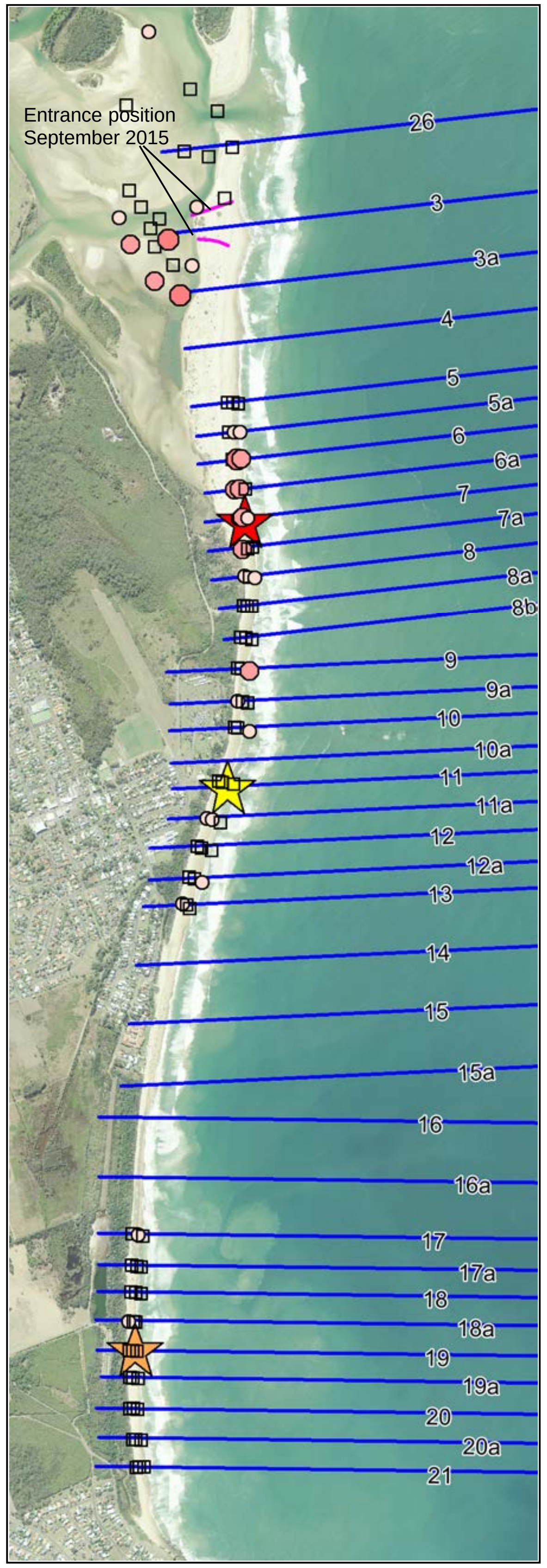
NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

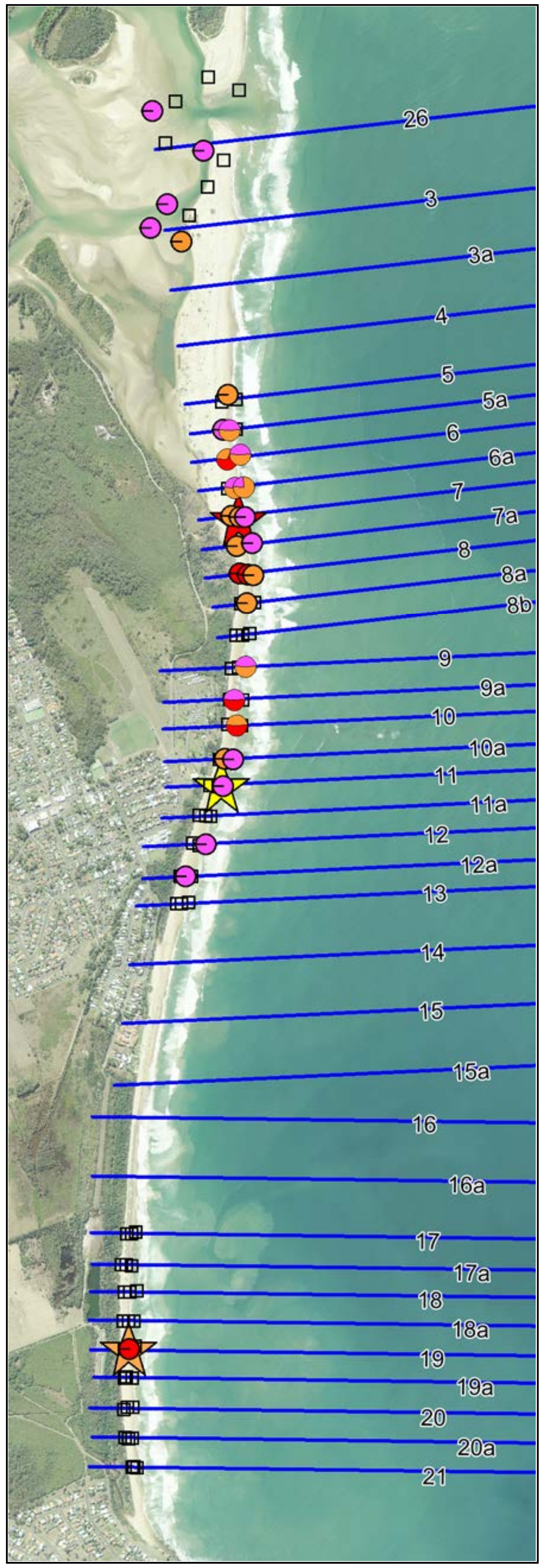
Royal HaskoningDHV
Enhancing Society Together



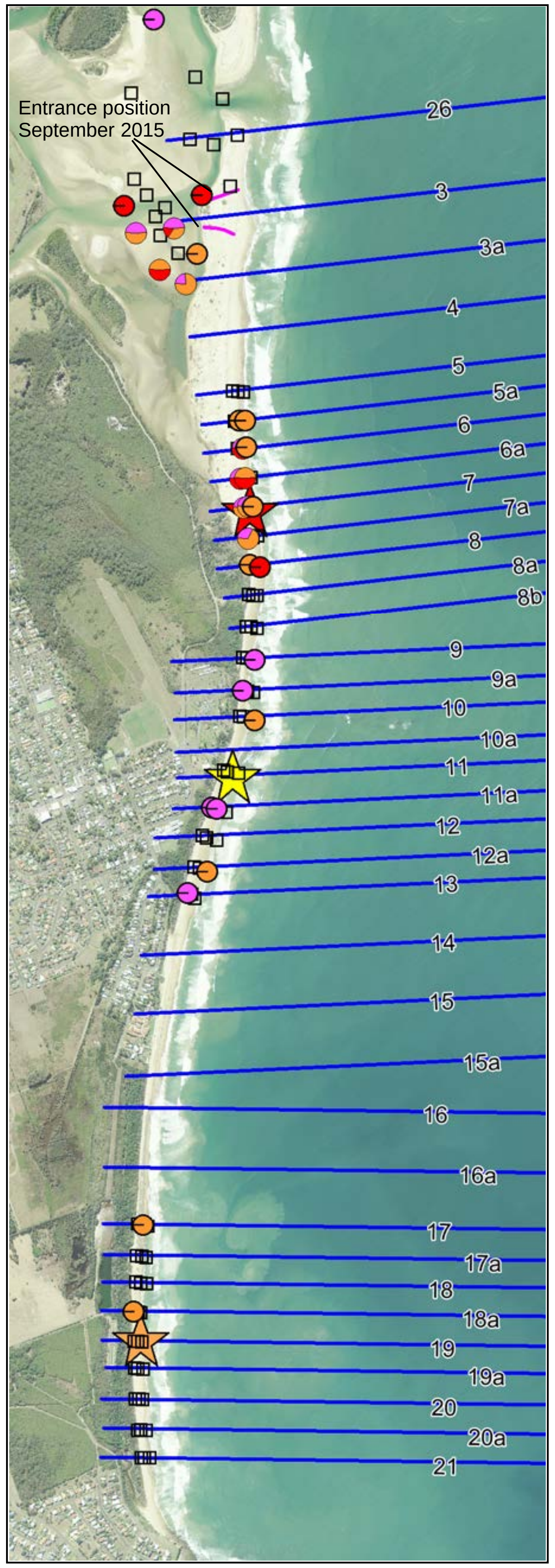
COUNT PER SQUARE METRE
SAMPLING EXERCISE 4 - MAR 2015



COUNT PER SQUARE METRE
SAMPLING EXERCISE 5 - SEP 2015



PARTICLE SIZE
SAMPLING EXERCISE 4 - MAR 2015



PARTICLE SIZE
SAMPLING EXERCISE 5 - SEP 2015

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

Particle Size:

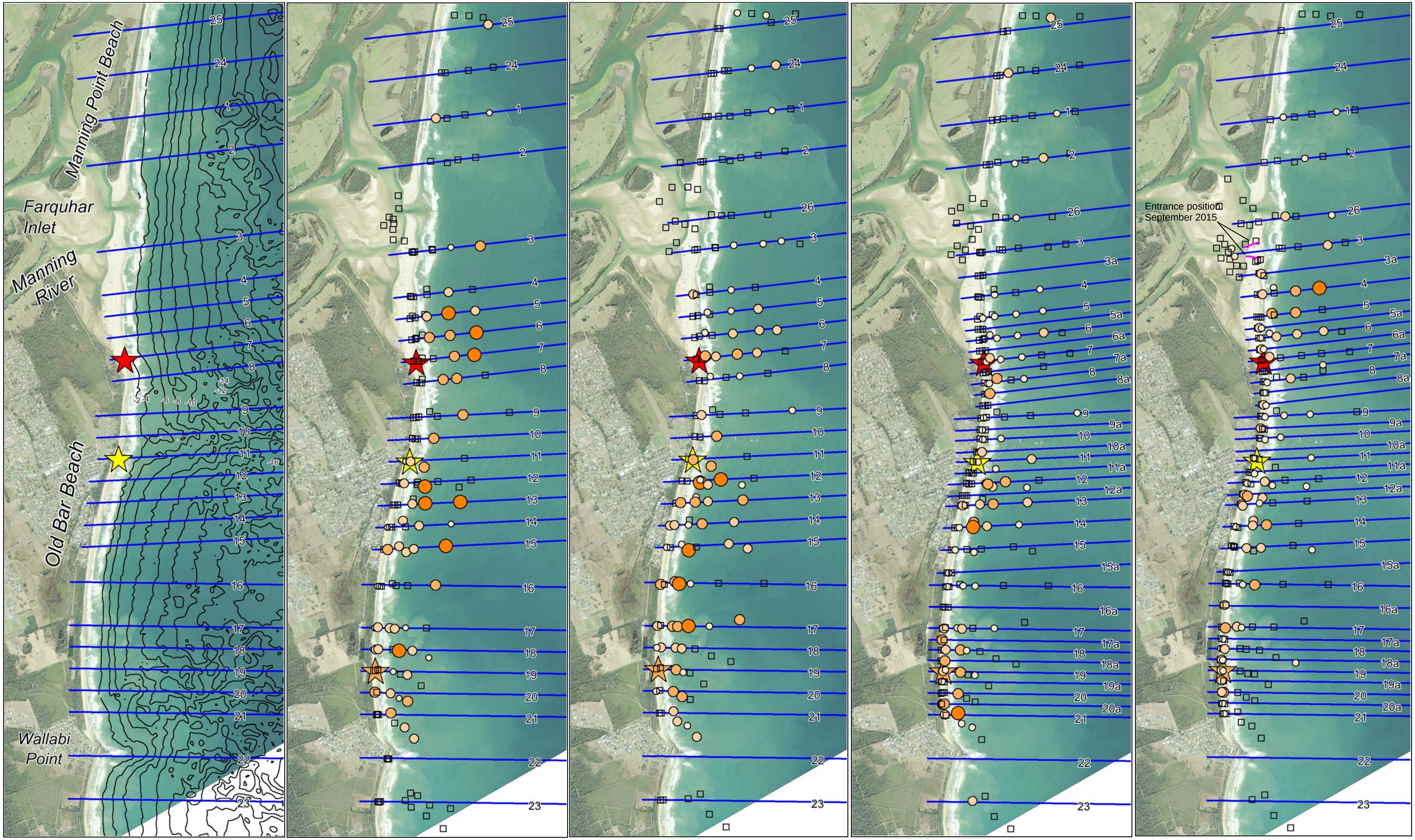
- Fine
- Medium
- Coarse
- No Count

PROJECT NO: 8A0406	PROJECT TITLE: Old Bar Sediment Tracing	0 375 750m Approx. Scale	
		SCALE 1:30,000	PAGE SIZE A3
FIGURE G6	RED TRACER - DEPTH AVERAGE	CREATED BY	B.MACKENZIE
		REVISION	A
		DATE	05/02/2016
FILEPATH	\\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo	CO-ORDINATE SYSTEM	Projection: WGS84

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together



SAMPLING EXERCISE 1 - JUL 2014 | SAMPLING EXERCISE 2 - SEP 2014 | SAMPLING EXERCISE 3 - NOV/DEC 2014 | SAMPLING EXERCISE 4 - MAR 2015 | SAMPLING EXERCISE 5 - SEP 2015

PROJECT NO: 8A0406 PROJECT TITLE: Old Bar Sediment Tracing

0 0.5 1km
Approx. Scale

SCALE 1:40,000 PAGE SIZE A3

FIGURE G7 **ORANGE TRACER - COUNT PER SQUARE METRE**

CREATED BY B.MACKENZIE
REVISION A
DATE 05/02/2016

FILEPATH \\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo

CO-ORDINATE SYSTEM Projection: WGS84

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

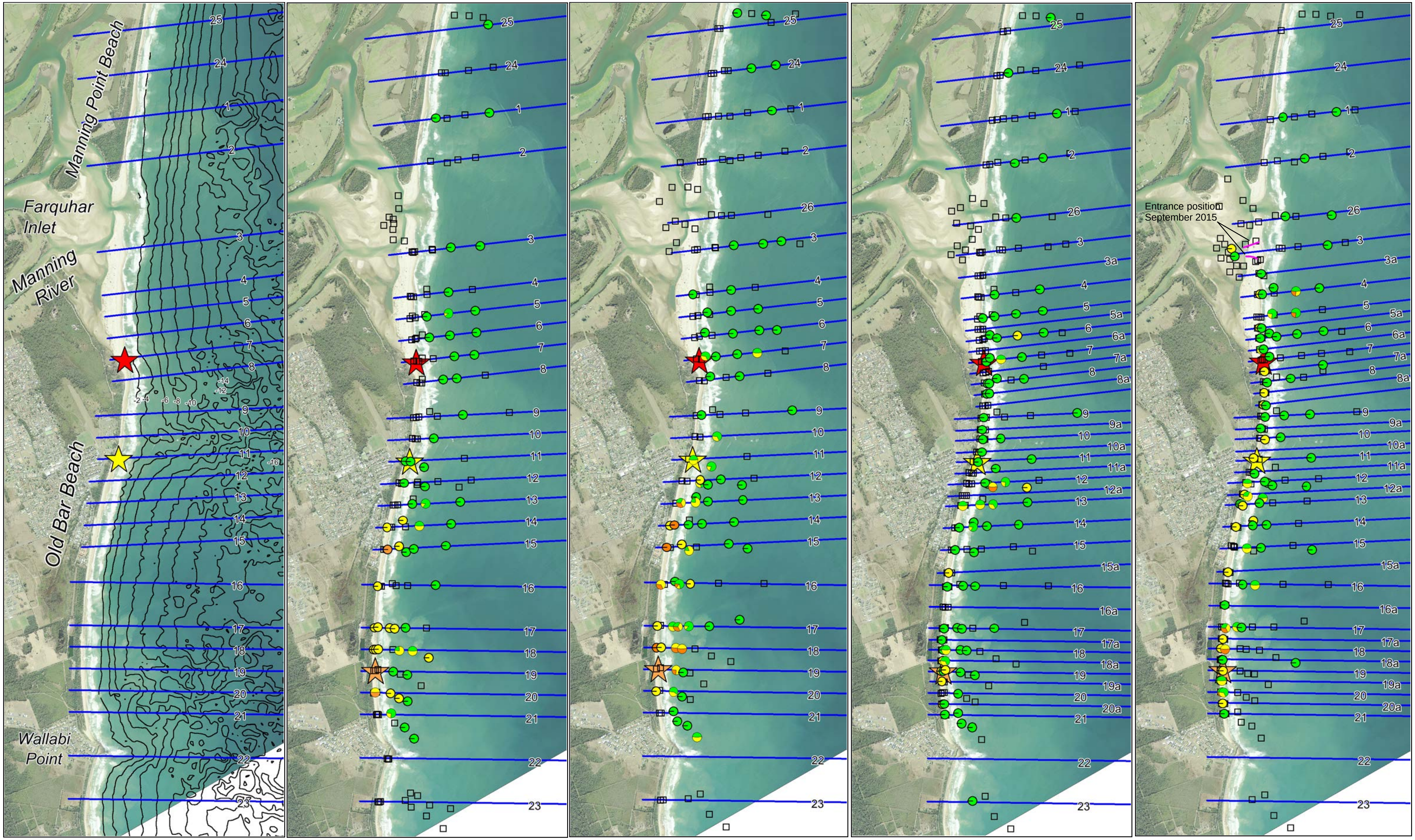
Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together



SAMPLING EXERCISE 1 - JUL 2014

SAMPLING EXERCISE 2 - SEP 2014

SAMPLING EXERCISE 3 - NOV/DEC 2014

SAMPLING EXERCISE 4 - MAR 2015

SAMPLING EXERCISE 5 - SEP 2015

PROJECT NO: 8A0406 PROJECT TITLE: Old Bar Sediment Tracing

0 0.5 1km
Approx. Scale

SCALE 1:40,000 PAGE SIZE A3

FIGURE G8 **ORANGE TRACER - PARTICLE SIZE**

CREATED BY B.MACKENZIE
REVISION A
DATE 05/02/2016

FILEPATH \\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo

CO-ORDINATE SYSTEM Projection: WGS84

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

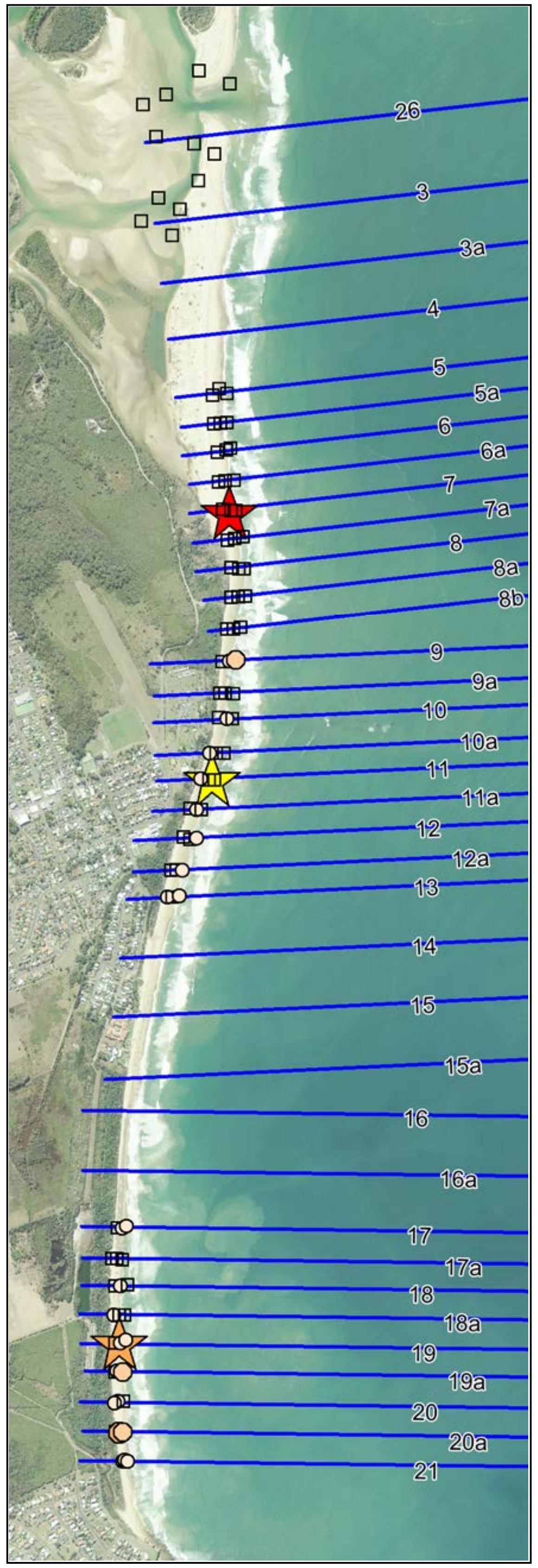
Particle Size:

- Fine
- Medium
- Coarse
- No Count

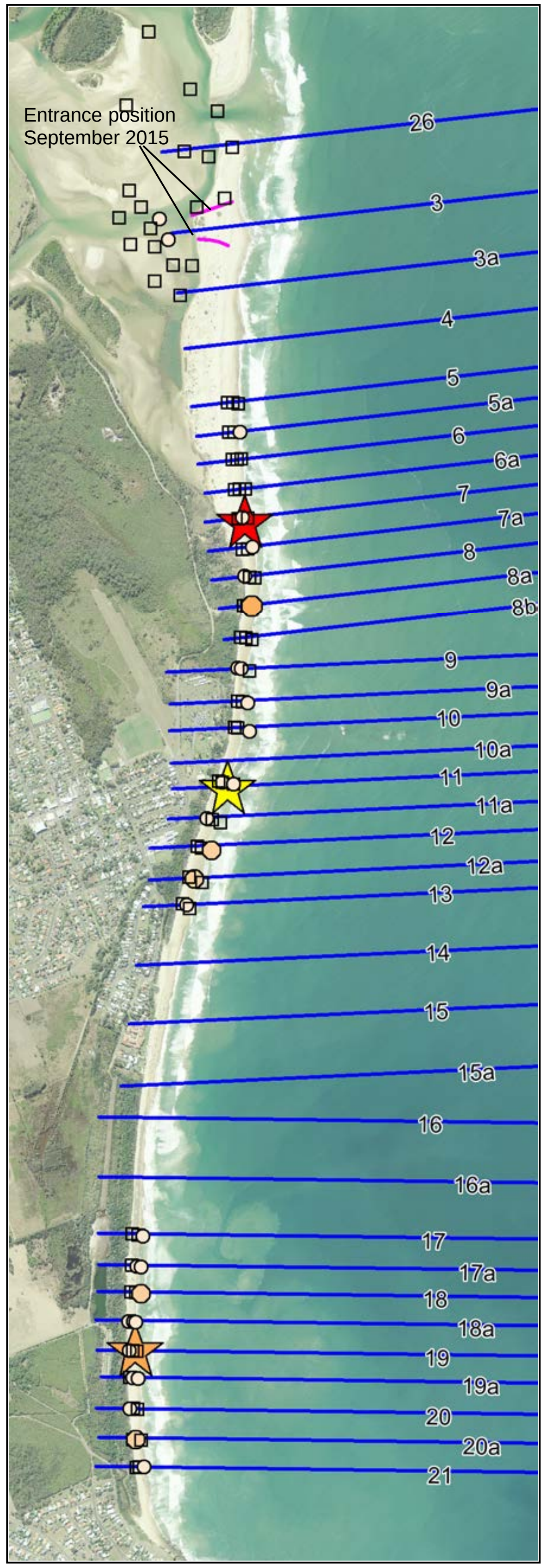
NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

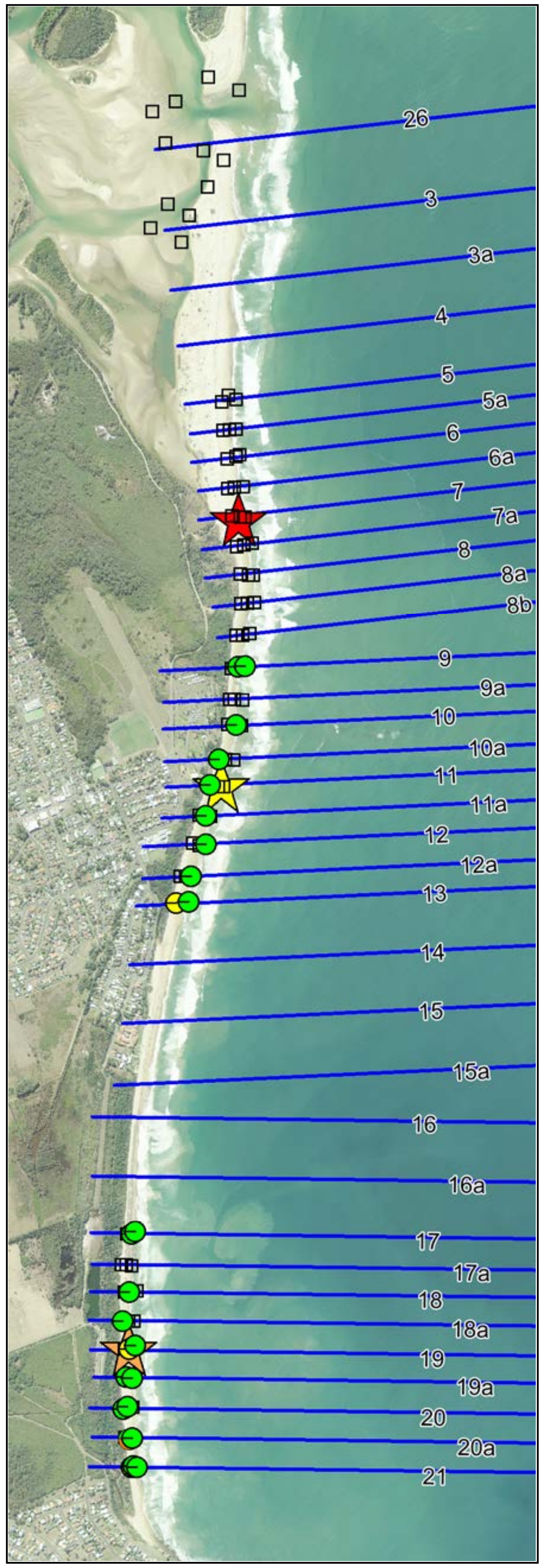
Royal HaskoningDHV
Enhancing Society Together



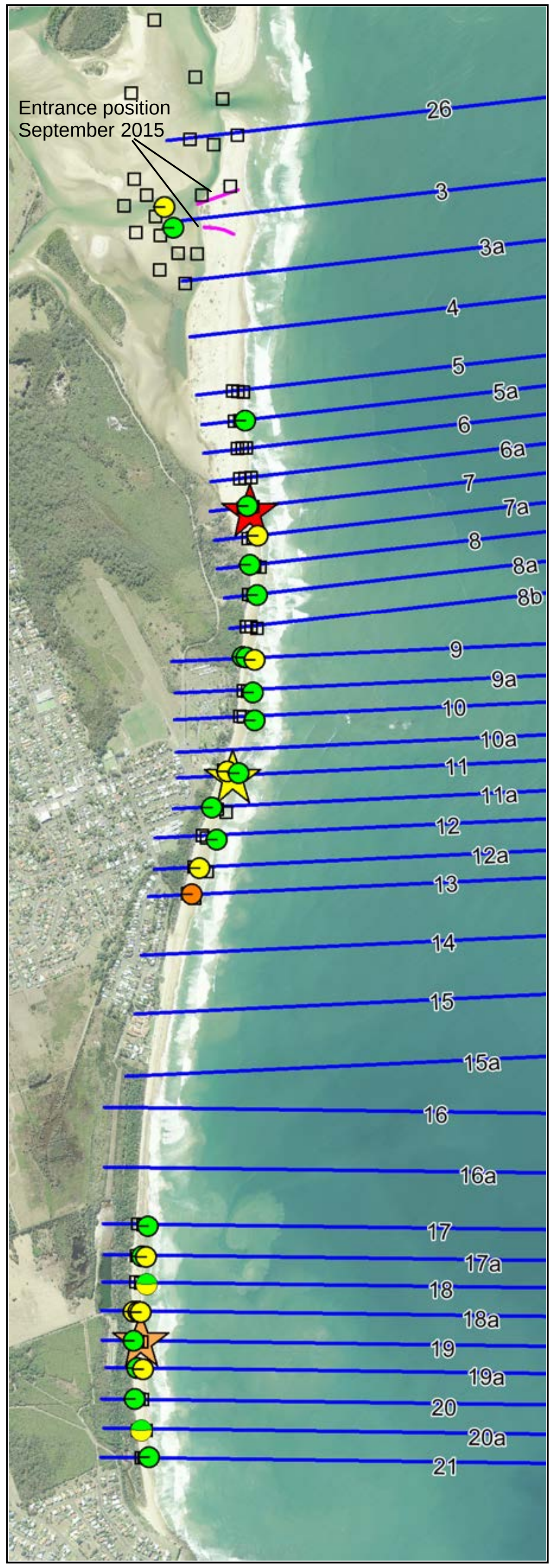
COUNT PER SQUARE METRE
SAMPLING EXERCISE 4 - MAR 2015



COUNT PER SQUARE METRE
SAMPLING EXERCISE 5 - SEP 2015



PARTICLE SIZE
SAMPLING EXERCISE 4 - MAR 2015



PARTICLE SIZE
SAMPLING EXERCISE 5 - SEP 2015

LEGEND

- Red Tracer Release
- Yellow Tracer Release
- Orange Tracer Release
- Transect

Count per square metre:

- 0
- 1 to 100
- 100 to 200
- 200 to 400
- 400 to 800
- 800 to 1,600
- >1,600

Particle Size:

- Fine
- Medium
- Coarse
- No Count

PROJECT NO:	8A0406	PROJECT TITLE:	Old Bar Sediment Tracing
FIGURE G9	ORANGE TRACER - DEPTH AVERAGE		
FILEPATH	\\HKA-SERVER\Public\CURRENT JOBS\8A0406 - Old Bar tracing\MapInfo	CO-ORDINATE SYSTEM	Projection: WGS84

0 375 750m
Approx. Scale

SCALE	1:30,000	PAGE SIZE	A3
CREATED BY	B.MACKENZIE		
REVISION	A		
DATE	05/02/2016		

NOTE

1. Aerial photograph taken August 2013
2. Hydrosurvey taken September to December 2009
3. Upward bearing at 330 degrees

Royal HaskoningDHV
Enhancing Society Together

Appendix H - Comparison of Particle Size Distribution Results for Farquhar Inlet and Old Bar Beach Samples

PSD analysis was undertaken for samples collected inside Farquhar Inlet and along Old Bar Beach. A total of 24 samples collected from Farquhar Inlet were analysed, comprising 11 from Sampling Exercise 3 (surface samples) and 13 from Sampling Exercise 4 (depth-averaged samples). Six (6) beach samples were analysed for comparison with the inlet samples.

The PSD analysis provided detailed data on the size fractions in the fine, medium and coarse size classes for sand, based on the Wentworth grain size classification. Sieve sizes ranged from 63 µm to 1 mm. The data are presented in:

- **Table H1** and **Figure H1** - Farquhar Inlet surface samples, Sampling Exercise 3;
- **Table H2** and **Figure H2** - Farquhar Inlet depth-averaged samples, Sampling Exercise 4;
- **Table H3** and **Figure H3** – Old Bar Beach surface samples, Sampling Exercise 4.

Table H1: PSD data (%retained on sieve by weight) and d_{50} values for Farquhar Inlet surface samples, Sampling Exercise 3

Sieve Size	Sample ID										
	3-F1	3-F2	3-F3	3-F4	3-F5	3-F6	3-F7	3-F8	3-F9	3-F10	3-F11
1mm	100	64	99	99	100	100	97	92	88	98	99
710µm	99	49	98	98	99	99	90	90	44	82	36
500µm	90	13	83	95	93	92	54	73	12	25	14
355µm	55	2	37	88	60	69	20	37	10	18	9
250µm	11	0	9	26	13	17	5	8	9	5	3
180µm	2	0	2	4	3	4	2	3	9	3	2
125µm	1	0	1	2	2	3	1	3	9	3	2
63µm	1	0	1	2	2	3	1	3	0	3	2
d_{50} (µm)	341	729	392	286	329	312	479	401	743	584	767

Table H2: PSD data (%retained on sieve by weight) and d_{50} values for Farquhar Inlet depth-averaged samples, Sampling Exercise 4

Sieve Size	Sample ID												
	4-F1	4-F2	4-F3	4-F4	4-F5	4-F6	4-F7	4-F8	4-F9	4-F10	4-F11	4-F12	4-F13
1mm	85	76	76	75	70	94	93	85	96	97	99	99	95
710µm	57	28	56	58	26	85	77	62	89	88	92	94	78
500µm	41	22	37	38	8	62	49	36	59	77	70	82	58
355µm	29	12	23	24	7	36	25	24	25	45	44	45	41
250µm	18	2	15	16	7	12	11	13	9	15	15	12	20
180µm	7	1	5	6	7	5	7	8	6	6	5	4	5
125µm	6	1	3	6	7	5	4	6	5	6	4	4	4
63µm	6	1	3	6	7	4	3	6	5	6	4	4	4
d_{50} (µm)	606	833	632	618	858	427	504	603	455	375	383	372	423

Table H3: PSD data (% passing by weight) and d_{50} values for Old Bar Beach surface samples, Sampling Exercise 4

Sieve Size	Sample ID					
	10_3	12_1	14_1	15_3	18_1	20_2
1mm	98	100	100	44	100	30
710µm	93	100	99	35	98	19
500µm	78	97	91	14	94	6
355µm	43	79	58	6	84	2
250µm	17	35	27	4	35	2
180µm	6	8	6	3	8	2
125µm	5	4	3	3	5	2
63µm	5	4	2	3	5	1
d_{50} (µm)	379	282	326	1259	278	1924

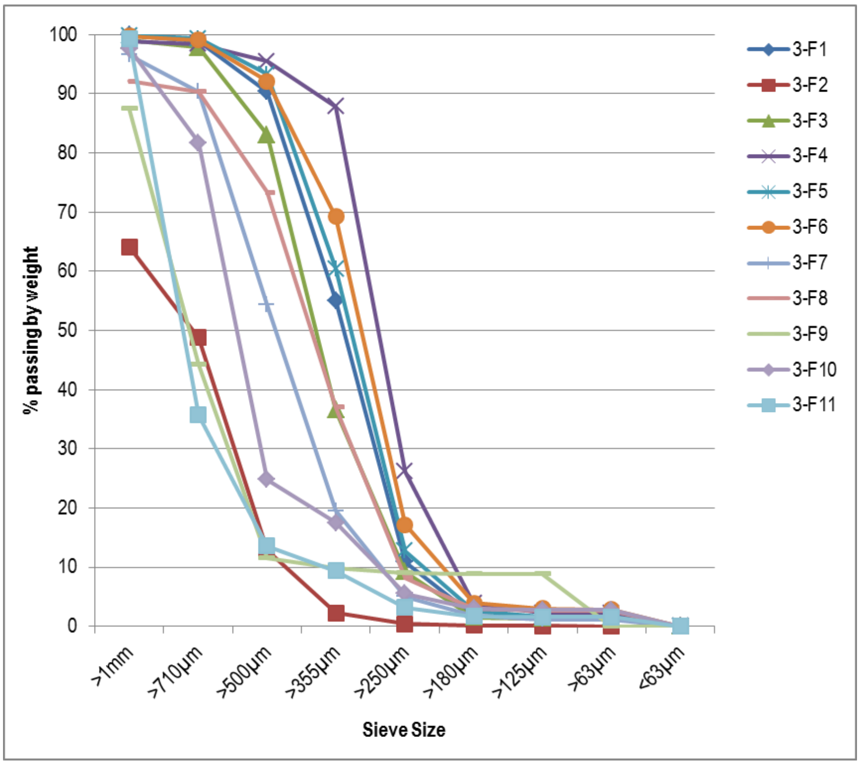


Figure H1: PSD data (%retained on sieve by weight) for Farquhar Inlet surface samples, Sampling Exercise 3

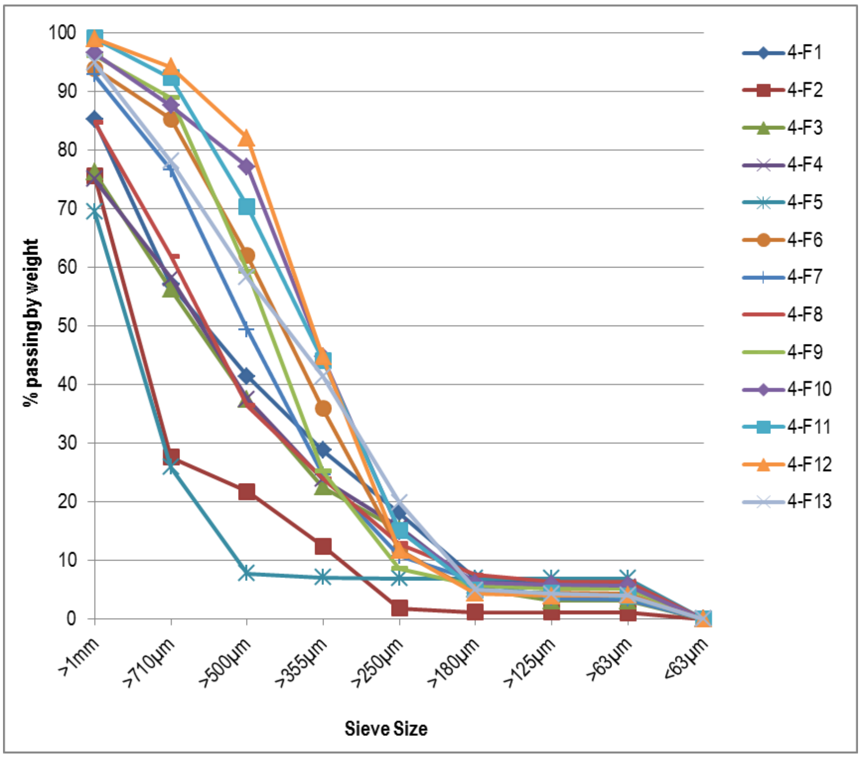


Figure H2: PSD data (%retained on sieve by weight) for Farquhar Inlet depth-averaged samples, Sampling Exercise 4

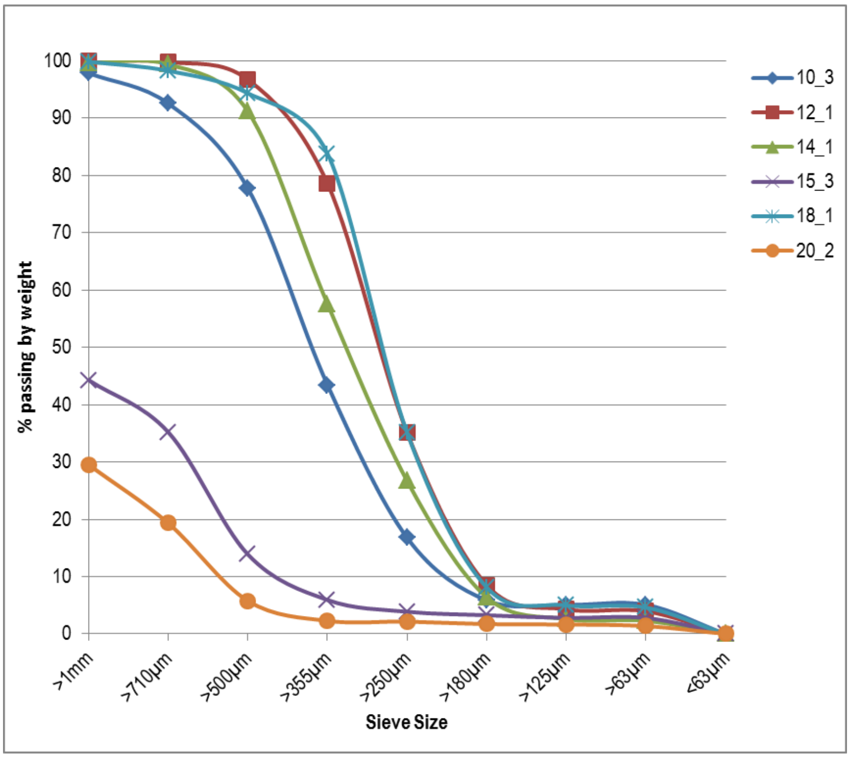


Figure H3: PSD data (%retained on sieve by weight) for Old Bar Beach surface samples, Sampling Exercise 4