Gorgon Gas Development and Jansz Feed Gas Pipeline

Coastal Stability Management and Monitoring Plan Supplement: Management Triggers

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Terminology, Definitions, and Abbreviations

Terms, definitions and abbreviations used in this document are listed below. These align with the terms, definitions and abbreviations defined in Schedule 2 of the Western Australian Gorgon Gas Development Ministerial Implementation Statement No. 800 (Statement No. 800) and the Commonwealth Gorgon Gas Development Ministerial Approvals (EPBC Reference: 2003/1294, 2008/4178).

BD	Base of Primary Dune; sampling site located at the base of the primary dune.
Beach Face	Sloping section of beach directly affected by wave action.
CBF	Crest of Beach Face; sampling site located at the change in slope at the transition between the Beach Face and Foredune Area.
Coast	The land adjacent to the sea upon which waves have an effect, extending from Mean Low Water to beyond the permanent dune vegetation line.
Construction	Construction includes any Proposal-related (or action-related) construction and commissioning activities within the Terrestrial and Marine Disturbance Footprints, excluding investigatory works such as, but not limited to, geotechnical, geophysical, biological and cultural heritage surveys, baseline monitoring surveys and technology trials.
Construction Period	The period from the date on which the Gorgon Joint Venture participants first commence construction of the Proposal until the date on which the Gorgon Joint Venture participants issue a notice of acceptance of work under the EPCM, or equivalent contract entered into in respect of the second LNG train of the Gas Treatment Plant.
Cth	Commonwealth of Australia
DEC	Former Western Australian Department of Environment and Conservation (now Department of Environment and Regulation and Parks and Wildlife)
DEWHA	Former Commonwealth Department of the Environment, Water, Heritage and the Arts (now Commonwealth Department of the Environment)
DoT	Western Australian Department of Transport (previously Department for Planning and Infrastructure)
DotE	Commonwealth Department of the Environment (previously the Commonwealth Department of the Environment, Water, Heritage and the Arts)
EPBC Reference: 2003/1294	Commonwealth Ministerial Approval (for the Gorgon Gas Development) as amended or replaced from time to time.
EPBC Reference: 2008/4178	Commonwealth Ministerial Approval (for the Revised Gorgon Gas Development) as amended or replaced from time to time.

EPCM	Engineering, Procurement and Construction Management
FA	Foredune Area; sampling site located between the beach face and the primary dune, which is populated by scattered vegetative hummocks and marine turtle body holes.
Gorgon Gas Development	The Gorgon Gas Development as approved under Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178 as amended or replaced from time to time.
GPS	Global Positioning System
LNG	Liquefied Natural Gas
m	Metre
MAD	Median Absolute Deviation
Management Triggers	Are quantitative, or where this is demonstrated to be not practicable, qualitative matters above or below whichever relevant additional management measures or investigations must be considered.
Marine Facilities	In relation to Condition 17.2 of Statement No. 800 and Condition 13.2 of EPBC Reference: 2003/1294 and 2008/4178, the Marine Facilities are the: • Materials Offloading Facility (MOF) • LNG Jetty.
Marine Turtles	Refers to Flatback, Green and Hawksbill Turtles nesting on Barrow Island.
MOF	Materials Offloading Facility
MTEP	Marine Turtle Expert Panel
Nesting Habitat Zones	Collective term for Optimal, Sub-optimal and Unsuitable Marine Turtle Nesting Habitat Zones
Operations (Gorgon Gas Development)	In relation to Statement No. 800 and EPBC Reference: 2003/1294 and 2008/4178, for the respective LNG trains, this is the period from the date on which the Gorgon Joint Venturers issue a notice of acceptance of work under the Engineering, Procurement and Construction Management (EPCM) contract, or equivalent contract entered into in respect of that LNG train of the Gas Treatment Plant; until the date on which the Gorgon Joint Venturers commence decommissioning of that LNG train.
Optimal Marine Turtle Nesting Habitat	Where characteristics of measured physical parameters within the study area are considered ideal for marine turtle nesting.
PD	Primary Dune; sampling site located on the primary dune beyond the permanent vegetation line.

Parks and Wildife	Western Australian Department of Parks and Wildlife (previously Department of Environment and Conservation)
Performance Standards	Are matters which are developed for assessing performance, not compliance, and are quantitative targets or where that is demonstrated to be not practicable, qualitative targets, against which progress towards achievement of the objectives of conditions can be measured.
Practicable	Practicable means reasonably practicable having regard to, among other things, local conditions and circumstances (including costs) and to the current state of technical knowledge. For the purposes of the conditions of EPBC Reference 2003/1294 and 2008/4178 which include the term "practicable", when considering whether the draft plan meets the requirements of these conditions, the Commonwealth Minister will determine what is 'practicable' having regard to local conditions and circumstances including but not limited to personnel safety, weather or geographical conditions, costs, environmental benefit and the current state of scientific and technical knowledge
Primary Dune	The largest and most mature seaward dune.
Project Attributable	Attributable to the construction and/or operation of the MOF or LNG Jetty
PSD	Particle Size Distribution
RTK GPS	Real Time Kinematic Global Positioning System
Significant Impact	An impact on a Matter of National Environmental Significance, relevant to EPBC Reference: 2003/1294 and 2008/1478 that is important, notable or of consequence having regard to its context or intensity.
Statement No. 800	Western Australian Ministerial Implementation Statement No. 800 (for the Gorgon Gas Development) as amended or replaced from time to time.
Sub-optimal Marine Turtle Nesting Habitat	Where characteristics of measured physical parameters within the study area are considered less than ideal but may still allow successful marine turtle nesting.
Transect	The path along which a surveyor moves, counts and records observations.
Unsuitable Marine Turtle Nesting Habitat	Where characteristics of measured physical parameters within the study area are unlikely to allow successful turtle nesting.

1.0 Introduction

The Gorgon Gas Development and Jansz Feed Gas Pipeline Coastal Stability Management and Monitoring Plan (Chevron Australia 2015) was developed as required by Condition 25 of Ministerial Implementation Statement No. 800 (Statement No. 800) for the Revised and Expanded Gorgon Gas Development, which was approved by the Director General of the Western Australian Department of Environment and Conservation on 10 September 2009. The Plan was also required under Condition 18 of the Commonwealth Approval for the Revised and Expanded Gorgon Gas Development (EPBC Reference: 2003/1294 and 2008/4178), and was approved by the Assistant Secretary, Environment Assessment Branch of the Commonwealth Department of Environment, Water, Heritage and the Arts on 14 September 2009.

The Coastal Stability Management and Monitoring Plan Supplement: Management Triggers (this Supplement) has been prepared to meet the requirements of Condition 25.4.iv of Statement No. 800 and Condition 18.4.iv of EPBC Reference: 2003/1294 and 2008/4178 that the Coastal Stability Management and Monitoring Plan addressed in a preliminary way but that required supplementing. This Supplement should be read in conjunction with the Coastal Stability Management and Monitoring Plan.

Revision 1 of this Supplement (this version) incorporates new, but interim, Marine Turtle Nesting Habitat Management Triggers related to detecting adverse changes to the beach structure and beach sediments that could have implications for marine turtles nesting on the beaches adjacent to the MOF. It is Chevron Australia's intention to revise this Plan in 2016 upon completion of sediment transport modelling studies; at this time the interim Management Triggers will be reviewed and amended as necessary.

The requirements of this Supplement, as stated in Condition 25.4.iv of Statement No. 800 and Condition 18.4.iv of EPBC Reference: 2003/1294 and 2008/4178 are listed in Table 1.1. Table 1.1 also references the specific sections of this Supplement where each requirement is addressed.

Table 1.1 Requirements of this Coastal Stability Management and Monitoring Plan Supplement: Management Triggers

Ministerial Document	Condition No.	Requirement	Section Reference in this Supplement
Statement No. 800	25.4.iv	The Plan must include:... iv. Management Triggers.	Section 2.0 *Note that the collection of additional information and other data analysis not included in Beach Structure and Beach Sediments Management Trigger analysis is discussed in Section 2.1.4. The management measures that may be implemented when a Management Trigger is exceeded are detailed in Section 3.0. State of environment information is presented in Section 5.0.*
EPBC Reference: 2003/1294 and 2008/4178	18.4.iv	The Plan must include:... iv. Management Triggers.	Section 2.0 *Note that the collection of additional information and other data analysis not included in Beach Structure and Beach Sediments Management Trigger analysis is discussed in Section 2.1.4. The management measures that may be implemented when a Management Trigger is exceeded are detailed in Section 3.0. State of environment information is presented in Section 5.0.*

Following approval, this Supplement will be considered to be approved as part of the Coastal Stability Management and Monitoring Plan, but will be maintained as a stand-alone document. Where relevant, amendments made to the Coastal Stability Management and Monitoring Plan will also be considered to be amendments to this Supplement. Any matters or requirements in the Supplement that are taken from the Coastal Stability Management and Monitoring Plan (rather than Statement No. 800 or EPBC Reference: 2003/1294 and 2008/4178) may be amended from time to time in accordance with amendments to the Coastal Stability Management and Monitoring Plan. Amendments to this Supplement may also be made directly in accordance with Section 8.3 of the Coastal Stability Management and Monitoring Plan. Note that if there is any difference or inconsistency between the Coastal Stability Management and Monitoring Plan and this Supplement in relation to either Condition 25.4.iv of Statement No. 800 or Condition 18.4.iv of EPBC Reference: 2003/1294 and 2008/4178, then this Supplement is to be preferred.

1.1 Objectives

The key objective of this Supplement is to identify the Management Triggers, which are values for beach structure, beach sediments and marine turtle nesting habitat that have been established to "trigger" additional management measures. The management measures that may be implemented when a Management Trigger is exceeded are also set out in this Supplement. The reporting actions required if monitoring shows that beach profiles and sand grain size change beyond the set Performance Standards are defined by Condition 25.6 of Statement No. 800 and Condition 18.6 of EPBC Reference: 2003/1294 and 2008/4178. The Performance Standards are defined in Section 6.3 of the Coastal Stability Management and Monitoring Plan. Section 5.3 of the Coastal Stability Management and Monitoring Plan sets out the potential mitigation measures which may be considered in the event that there is a change in beach profile and sand grain size beyond the Performance Standards.

1.2 Stakeholder Consultation

Under Condition 25.2 of Statement No. 800 and Condition 18.2 of EPBC Reference: 2003/1294 and 2008/4178, the Western Australian Department of the Environment and Conservation (DEC), the Western Australian Department for Transport (DoT), the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA) and the Marine Turtle Expert Panel (MTEP), are to be consulted during the preparation of the Coastal Stability Management and Monitoring Plan.

Revision 0 of this Supplement to the Coastal Stability Management and Monitoring Plan was prepared with input from:

- DEC: The DEC reviewed and provided comment on the Draft Supplement.
- DoT: The DoT was provided with the Draft Supplement for their review.
- MTEP: The MTEP was provided with a verbal briefing and discussed the Draft Supplement at an Expert Panel meeting on 8 December 2009.
- Dr M. Chaloupka, Ecological Modelling Services Pty Ltd, Independent Reviewer: Dr Chaloupka reviewed the Draft Supplement and his comments have been incorporated or otherwise resolved.

Revision 1 (this version) of the Supplement was prepared to incorporate new interim Management Triggers for marine turtle nesting habitat, with input from:

- MTEP: The MTEP was provided with a presentation and discussed the proposed revisions to the Supplement at an Expert Panel meeting on 27 August 2015. MTEP endorsed the scope of revision to this Supplement, the parameters used to define Nesting Habitat Zones, the

process for deriving interim Management Triggers for marine turtle nesting habitat, the parameters and criteria used to set triggers, and the revised Performance Standard (in the Coastal Stability Management and Monitoring Plan) related to potential implications for marine turtles nesting on beaches adjacent to the MOF. MTEP endorsed the proposed changes to the Plan via a letter to Chevron Australia and the State and Commonwealth Ministers for the Environment on 24 September 2015.

- Parks and Wildlife: The proposed content, scope and structure of changes to the Plan were presented to Parks and Wildlife on 11 September 2015 and subsequently endorsed.
- DoT: The proposed content, scope and structure of changes to the Plan were communicated to DoT who advised that they did not need to review the detail of proposed changes based on the scope of the revision.
- DotE: The proposed content, scope and structure of changes to the Plan were communicated to DotE and the revised Plan will be submitted to DotE for approval.

2.0 Management Triggers

Section 5.3 of the Coastal Stability Management and Monitoring Plan defers to this Supplement to define Management Triggers. Management Triggers defined in this Supplement are based on three features:

- Beach Structure
- Beach Sediments
- Marine Turtle Nesting Habitat

The beach structure and beach sediment triggers were originally proposed in Revision 0 of this Supplement, and incorporate considerations for both coastal stability and marine turtles.

The interim Marine Turtle Nesting Habitat Management Trigger (Section 2.2) has been developed to specifically address the second objective of the Plan. This trigger better integrates the individual parameters that could have implications for marine turtle nesting, by defining Nesting Habitat Zones; and recognises that the level and type of adverse changes that could have implications for marine turtles differ to the those that could have implications for the stability of the beach.

Management Triggers for beach structure and beach sediments are applicable to data collected at each biannual routine monitoring survey. Interim Management Triggers for Marine Turtle Nesting Habitat are only applicable to the post-dry season routine monitoring survey. Management Triggers for marine turtle nesting habitat are interim; Chevron Australia proposes to review the interim Management Triggers in 2016 following completion of environmental studies aimed at determining the likely range of post-construction beach structure under ambient metocean conditions.

The Coastal Stability Management and Monitoring Plan (Section 5.2.2.2) outlines monitoring requirements following storms that meet specific meteorological criteria; results of such ‘major event’ monitoring will not assessed against Management Triggers. However, major event monitoring may provide information useful to further understanding of beach profile dynamics and may be included in the ongoing review of all transects (Section 2.1.4.1).

2.1 Beach Structure and Beach Sediments

In this Supplement, baseline data for the period July 2008 to October 2009 have been used to visually demonstrate the ‘normal’ range of variation for the selected parameters, however baseline survey data from July 2008 up to the last survey before construction commenced (April

2010) were used to establish the 'normal' range of variation for the purposes of setting Beach Structure and Beach Sediments Management Triggers.

Table 2.1 Management Triggers for Beach Structure and Beach Sediments

Parameter (State)	Proposed Impacts Management Triggers/Criteria for Measuring Significant Adverse Impacts	Proposed Analysis	Management Trigger
Beach Structure - Beach Volume	Change in volume of beach at specific points of interest (cubic metres of sediment per metre of longshore beach width [m^3/5 m^2]) outside the 'normal' range of oscillation in beach volume	Shewhart control charts at selected points of interest along selected transects	Management Trigger based on mean and standard deviation of baseline data: Table 2.4
Beach Structure - Beach Slope	Change in beach slope at specific points of interest outside the 'normal' range of oscillation in beach slope		
Beach Sediment Characteristics	Change in sediment characteristics at specific depths at points of interest outside the 'normal' range of oscillation in sediment characteristics	Plot of particle size distribution	Change in sediment particle size from medium sand to either fine gravel or coarse silt at 0.6 m depth at the Foredune Area or 0.3 m depth at the Crest of Beach Face along selected transects

Other parameters proposed in the Coastal Stability Management and Monitoring Plan may be used for further information to investigate and assess whether there are significant adverse impacts on beach structure and beach sediments, should a Management Trigger be exceeded on Terminal Beach or Bivalve Beach (Table 2.2). Table 2.2 includes those parameters monitored and managed through the Long-term Marine Turtle Management Plan (Chevron Australia 2014). Implementing an investigation following exceedance of a Beach Structure or Beach Sediments Management Trigger is detailed in Section 3.0 of this Supplement.

Table 2.2 Parameters used for Further Information to Investigate and Measure Significant Adverse Impacts on Beach Structure and Sediments

Parameter (State)	Proposed Impacts Management Triggers/Criteria for Measuring Significant Adverse Impacts	Proposed Analysis and Use
Beach Envelope of Change	Beach profile outside 'normal' range of oscillation in beach morphology	Beach Profiles along selected transects indicating range of changes. This provides a visual summary of change along a beach profile. Profiles for selected transects are presented in Section 5.0 for information.
Beach Volume	Change in volume of beach at specific points of interest (cubic metres of sediment per metre of longshore beach width [m^3/5 m^2]) outside the 'normal' range of oscillation in beach volume	Range of slope and volume at points of interest along selected transects with controls applied from quality control charts (Brownlee 1957). To provide a summary of the range of variation in beach slope and volume.
Beach Slope	Change in beach slope at	

Parameter (State)	Proposed Impacts Management Triggers/Criteria for Measuring Significant Adverse Impacts	Proposed Analysis and Use
	specific points of interest outside the 'normal' range of oscillation in beach slope	
Beach Sediment Characteristics	Change in sediment characteristics at specific depths at points of interest outside the 'normal' range of oscillation in sediment characteristics	Particle size distribution, moisture content and density data.
Dune Vegetation	Change in the position of vegetation lines from baseline (pre-2008)	Overlay of vegetation lines on aerial photos.
Marine turtle nesting and incubation parameters*	Change in track density on east coast beaches adjacent to Town Point	The Long-term Marine Turtle Management Plan (Chevron Australia 2014), includes Management Triggers required to respond to changes detected in marine turtle demographic parameters. Information generated from monitoring of trends in demographic parameters and responses to triggers may be available for use as further information should the Management Triggers in this Supplement be exceeded, triggering the requirement for further investigation.
	Percentage of females that successfully lay a clutch of eggs on east coast beaches adjacent to Town Point	
	Percentage of eggs in clutches that successfully hatch on east coast beaches adjacent to Town Point	
	Change in percentage of eggs in clutches that produce hatchlings to surface on east coast beaches adjacent to Town Point	

** Parameters related to Marine Turtles are included for information only. These parameters will not form a part of monitoring under the Coastal Stability Management and Monitoring Plan or this Supplement.*

The remainder of this Section discusses the selection of primary monitoring transects (Section 2.1.1.1) and points of interest (Section 2.1.1.2) and presents Beach Structure and Beach Sediments Management Triggers assigned to each of the relevant parameters.

2.1.1 Data Included in Analysis for Management Triggers

2.1.1.1 Selection of Primary Monitoring Transects

Revision 0 of the Coastal Stability Management and Monitoring Plan established 49 transects for monitoring beach structure and beach sediments on Terminal Beach and Bivalve Beach (25 and 24 transects respectively) and two transects on each of the reference beaches (Inga Beach, Yacht Club Beach North and Yacht Club Beach South) (Coastal Stability Management and Monitoring Plan, Section 5.1; this Supplement, Appendix 1). Although monitoring of beach structure is now completed by remote sensing surveys to generate a digital elevation model (Coastal Stability Management and Monitoring Plan, Revision 1 Amendment 1, Table 5-1), Management Trigger analysis is focused on two primary monitoring transects on Terminal Beach (T11 and T22) and two primary monitoring transects on Bivalve Beach (B11 and B22) extracted from the digital elevation model. The two transects were selected from the six established transects on Terminal Beach (T11, T13, T16, T19, T21, and T22) and Bivalve Beach (B1, B11, B16, B21, B22, and B24) that included beach sediment characteristic sampling

(refer to Appendix 1). The two transects were chosen to facilitate comparison with reference beaches during any further analysis.

The transects located immediately adjacent to Town Point (T1 and B1; refer to Appendix 1) were not included in the Management Trigger analysis due to the presence of rock and the lack of a distinct Foredune Area. Therefore T11 and B11 were selected as being the closest to Town Point despite the restricted baseline data (January–April 2010), as these transects are amongst those most likely to be impacted as a consequence of the presence of the MOF and LNG Jetty should a significant adverse impact occur. Transects T22 and B22 were selected as they are located at comparable distances along the length of each beach to the reference beach transect locations (Appendix 1).

The investigation of significant change along the primary monitoring transects will be interpreted within the context of the suite of parameters collected from the other transects along Terminal Beach and Bivalve Beach, as well as from reference beaches. Implementation of an investigation following exceedance of a Management Trigger is detailed in Section 3.1.

2.1.1.2 Selection of Points of Interest

Figure 2.1 illustrates the typical (simplified) cross-section through the beaches on the east coast of Barrow Island, and includes the position of key points of interest along the cross-section, namely the:

- Primary Dune (PD)
- Base of the Primary Dune (BD)
- Foredune Area (FA)
- Crest of Beach Face (CBF).

When considering overall beach volume along a transect, it is recognised that changes in volume within the Primary Dune could potentially overshadow changes elsewhere along the transect, which could result in a failure to identify changes, for example, to the Crest of Beach Face or Foredune Area. Analysis of beach structure and beach sediment characteristics along the selected transects will therefore focus on the Foredune Area and the Crest of Beach Face for comparison against Beach Structure and Beach Sediments Management Triggers. Sampling points were established and located using Real Time Kinematic Global Positioning System (RTK GPS) to ensure continuity of future sampling regardless of changes to beach profile (i.e. the sampling locations will not change based on the beach formation present at the time of monitoring).

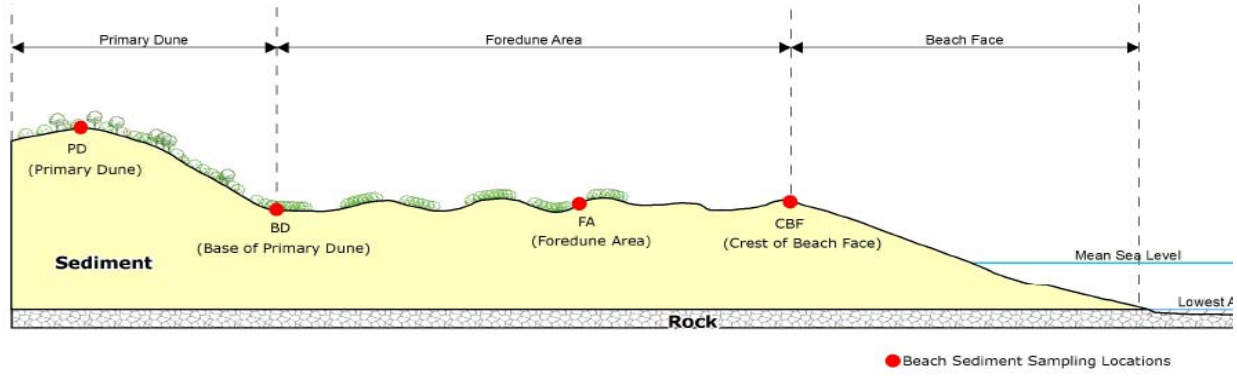


Figure 2.1 Coastal Dune System Beach Transect and Beach Sediment Sampling Locations

Table 2.3 describes the analysis for each point of interest selected for beach volume and beach slope analysis.

Table 2.3 Selection of Information used for Analysis of Beach Volume and Beach Slope

Point of Interest	Reason for Selection	Analysis for Management Trigger
Primary Dune	Not considered further: limited direct relevance to marine turtles	
Base of Primary Dune		
Foredune Area	Marine turtle nesting area	Control Chart using Management Triggers: average of three consecutive, 5 × 1 m segments of beach on the selected transects (Figure 2.2). An average value[1] of three segments was selected as the Foredune Area tends to be wide and the GPS location is in the centre of the Foredune Area.
Crest of Beach Face	Beach access and egress point for female turtles and hatchlings	Control Chart using Management Triggers: single 5 × 1 m segment of beach on the selected transects (Figure 2.2). The Crest of Beach Face tends to be narrower and have a greater slope than the Foredune Area.

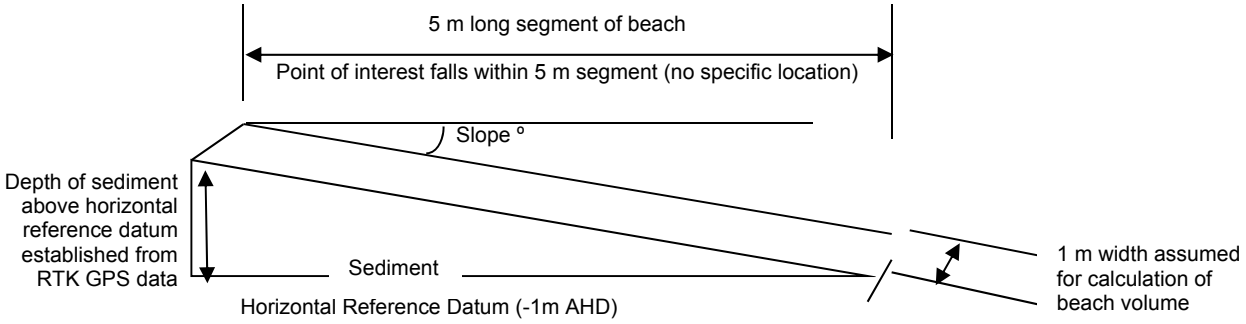


Figure 2.2 Beach Segments Used for Calculation of Beach Volume and Beach Slope (not to scale)

Data from the Primary Dune and the Base of the Primary Dune, along with the remainder of the transect, may be used for investigation should a Management Trigger be exceeded (Section 3.0).

Beach sediment characteristics have the potential to affect nesting success and hatching success (Coastal Stability Management and Monitoring Plan, Section 3.54.3). Selection of points of interest for sediment particle size therefore corresponds to depths relevant to marine turtles. In the Foredune Area which is used for marine turtle nesting, this is at approximately 60 cm below the surface, corresponding with the average depth of a Flatback Turtle (*Natator depressus)* nest, which is approximately 64 cm (Pendoley Environmental 2007). The Crest of Beach Face is where marine turtles access and leave the beach during nesting season and where hatchlings leave the beach after emergence. Selection of points of interest for sediment particle size at the surface provides an indication of whether the beach sediment characteristics vary (Section 2.1.3). Baseline information for surface sediment particle size data were limited

[1] Average values of the Foredune Area were used to reduce the potential for a marked change in profile affecting the dataset (i.e. show steeper slope or flatter slope than was common across the beach). The Crest of Beach Face was in several cases too narrow to allow averages to be used.

and data that were available indicated greater variability, therefore surface sediment particle size at the Crest of Beach Face was not selected for Management Trigger analysis.

2.1.2 Selection of Appropriate Management Triggers: Beach Volume and Beach Slope

Statistical process control charts are used to display the variability in measurements over time, as well as the closeness of individual data points (or groups) to 'expected' values. The approach is consistent with that proposed by Chaloupka (2009), who provided background on the use of Shewhart control charts to graphically measure changes in the mean or variability over time when applied to demographic parameters for the Barrow Island Flatback Turtle population (Chevron Australia 2014).

Control charts establish:

- a centreline (in this case the mean of the baseline information), with a slope of zero
- Upper and Lower Control Limits (Management Triggers) using 1, 2 and 3-sigma (σ) (± 1, 2, or 3 standard deviations) approach (Figure 2.3).

Baseline data may be collected over a series of survey periods on parameters such as beach volume and beach slope. By calculating the mean and standard deviations for baseline data, it is possible to identify if data from future surveys falls within or beyond one, two or three standard deviations.

Shewhart statistical process control charts are used as a quality control tool to monitor processes, with the application of a number of Management Triggers to detect non-random situations (NIST/SEMATECH 2006). By plotting through time some measure of a stochastic process with reference to its 'expected' value (based on the baseline data set in this case), control charts can help managers diagnose when a parameter of interest may show deviations beyond those 'expected' given the natural temporal variability measured across impact and reference beaches. Control charts can thus provide an 'early warning signal' of a system that may be going 'out of control' after just a single time of sampling after an impact and thus management measures can be implemented much earlier. The application of Management Triggers for statistical process control charts to assess changes in beach structure and beach sediment characteristics on east coast Barrow Island beaches may potentially enable detection of one-off events, seasonal, annual and longer-term smaller scale trends (Table 2.4). However, while control charts are a means of diagnosing what could be contributing to the detected change; they do not provide a means of attributing causality.

It is important to note that the Management Triggers presented in Table 2.4 are based on industrial applications with normally distributed data and strict process controls. Chaloupka (2009) highlighted problems with applying rules designed for industrial systems to natural environments where fluctuations were poorly understood. Consequently, Management Triggers based on industrial process controls may not be relevant to beach profile dynamics, i.e. where understanding of the natural variability of the oscillation in beach volume and slope parameters on Barrow Island is limited. Accordingly, the Management Triggers presented in Table 2.4 will need to be regularly reviewed and updated accordingly (Section 4.0). In cases of non-parametric data distribution, the use of alternative approaches, such as median absolute deviation (MAD) limits, may also need to be considered (M. Chaloupka, pers. comm. December 2009).

Table 2.4 Beach Structure and Beach Sediments Management Triggers (based on Industrial Process Controls) Applied to Beach Volume and Beach Slope with Relevance to Monitoring Periods

Management Trigger (based on NIST/SEMATECH 2006)	Monitoring Time Horizon	Event that Application of the Management Trigger Would Capture
A single point falls outside the mean ±3 Sigma (σ) limit *(Management Trigger 1: Figure 2.3)*	3 months	Investigation of a significant short-term change on the relevant beaches (e.g. may indicate changes recorded as a result of a cyclone)
Two out of three successive points fall outside of the mean ±2σ limit *(Management Trigger 2: Figure 2.3)*	9 months (>1 season)	Investigation of change to beach structure that exceeds 1 season
Four out of five successive points fall outside of the mean ±1σ limit *(Management Trigger 3: Figure 2.3)*	15 months (>1 year)	Investigation of change outside of 'normal' range over the course of a year
Eight consecutive points on the same side of the mean *(Management Trigger 4: Figure 2.3)*	24 months (>2 years)	Investigation of a longer-term ongoing beach change, i.e. accretion or erosion (indicating a long-term shift to the mean)

** See note, Figure 2.3.*

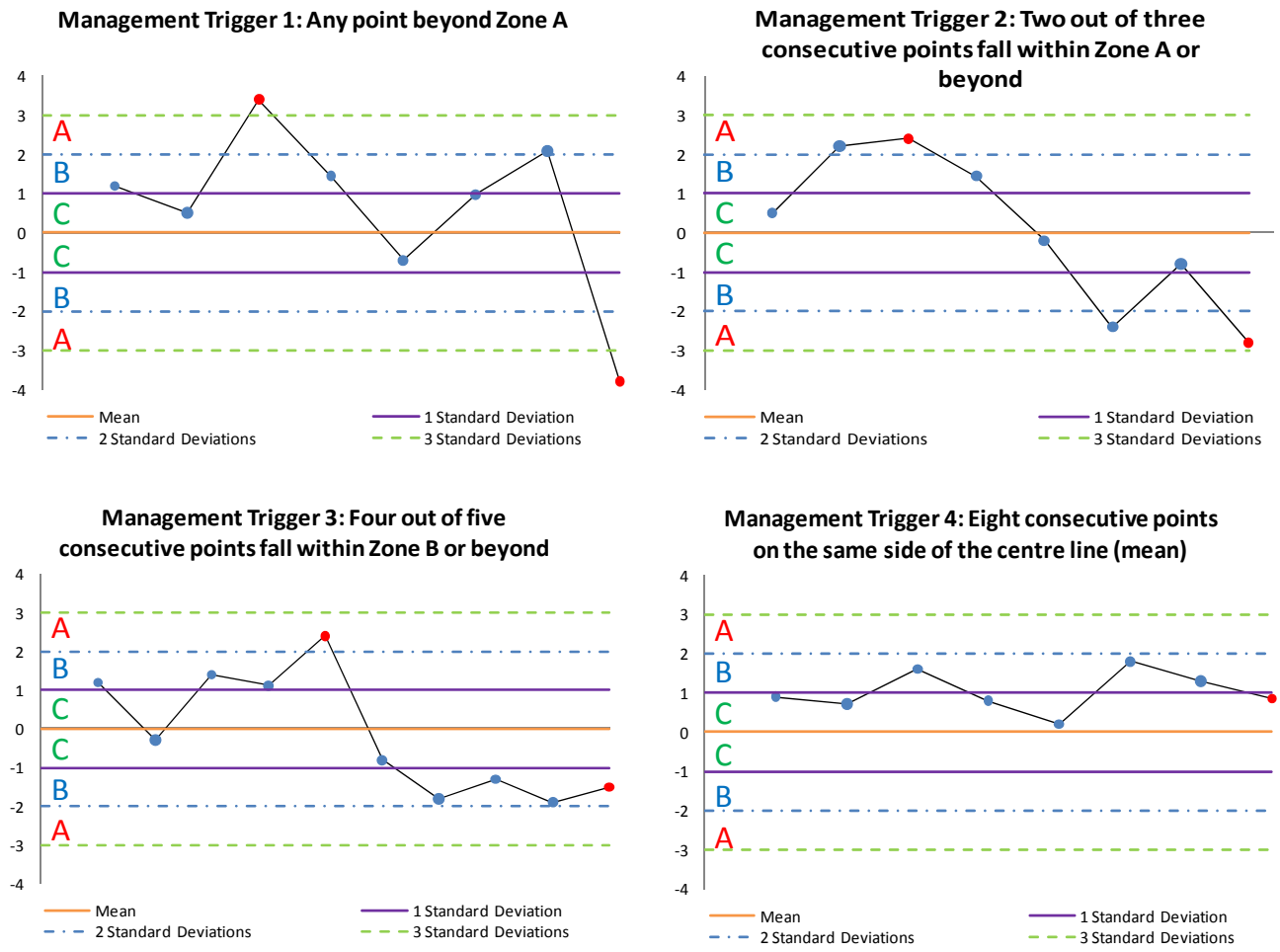


Figure 2.3 Diagrammatic Representation of the Beach Structure and Beach Sediments Management Triggers for Beach Volume and Beach Slope and Indication of when an "Alert" would be Triggered (red dots)

Source: Based on Wikipedia Contributors 2009.*

** Note that Wikipedia acknowledges that Management Trigger 4 is disputed, NIST/SEMTECH 2006 use 8 consecutive points on the same side of the centre line, as per Table 2.4.*

2.1.3 Selection of Appropriate Management Triggers: Beach Sediment Characteristics

Beach sediment characteristics (particle size, moisture and density) were determined at selected points of interest (Section 2.1.1.2) along each of six established transects on each of Terminal Beach (T11, T13, T16, T19, T21, and T22) and Bivalve Beach (B1, B11, B16, B21, B22, and B24), and both transects on each reference beach (refer to Appendix 1). Baseline data indicated that sediments were medium sands at the Foredune Area (at 60 cm depth below existing surface level) and the Crest of Beach Face (at 30 cm depth below existing surface level), with minimal variation between beaches and over time (Section 5.0).

If sediment particle size deviates from medium sand to either fine gravel or coarse silt at either of the selected points of interest on the selected primary monitoring transects at Terminal Beach and Bivalve Beach, at relevant depths, it will constitute an exceedance of the Management Trigger.

2.1.4 Further Analysis Not Included in Management Trigger Analysis

2.1.4.1 Ongoing Review

2.1.4.1.1 Range of Beach Volume and Beach Slope: Selected Transects

The range of beach volume and beach slope for each of the six transects and points of interest on each of Terminal Beach (T11, T13, T16, T19, T21, and T22) and Bivalve Beach (B1, B11, B16, B21, B22, and B24) (Section 2.1.1) are presented as an indication of the variation of these parameters during the baseline period July 2008 to October 2009 (Section 5.0). A Management Trigger was not established for the range of beach volume or beach slope; rather, range may be used as additional information, should investigation be undertaken as part of an Alert Measure (Section 3.0).

The range of average Foredune Area volume and slope and the range of Crest of Beach Face volume and slope along the selected transects were established from baseline data. Inner and outer control limits were determined based on the number of sampling occasions included in baseline data (n=6). Control chart limits were standard values based on assumed standard deviations in normally distributed populations (Brownlee 1957).

Some transects were sampled four times (i.e. quarterly, commencing in January 2009); however, using values for n=6 provided a more stringent control than applying the lower control chart limits for n=4. Inner and outer control limits will be revised if additional data are included in the baseline. These limits are established for information only and are not associated with any Management Triggers.

2.1.4.1.2 Sediment Characteristics: Selected Transects

Sediment particle size at selected depths at points of interest are included as a Management Trigger (Table 2.1). Sediment moisture content and sediment density have been excluded from consideration as Management Triggers, as they may be more influenced by environmental parameters (e.g. moisture content influenced by tidal state and rainfall events).

2.1.4.1.3 Beach Envelope of Change: All Transects

Beach Envelope of Change figures depict vertical change along the length of the transect over time. Beach profiles for the primary monitoring transects are presented in Section 5.1.

No specific Management Triggers have been established for Beach Envelope of Change as beach volume and beach slope data were derived from the beach transects and specific Management Triggers have been assigned to these parameters. Nevertheless, Beach Envelopes of Change may be used as additional information, should investigation be undertaken as part of an Alert Measure (Section 3.1). Review of Beach Envelopes of Change for all transects will also be undertaken as part of the ongoing monitoring of all transects.

2.1.4.1.4 Dune Vegetation: All Beaches

Dune vegetation lines were plotted on historic aerial photography and presented in the Coastal Stability Management and Monitoring Plan. Dune vegetation lines from recent aerial photography may be used as additional information where relevant, should investigation be undertaken as part of an Alert Measure (Section 3.1).

2.2 Marine Turtle Nesting Habitat - Interim

Interim Management Triggers for Marine Turtle Nesting Habitat are based on remote sensing data captured between October 2009 (baseline) to October 2014 and are set for the area of Nesting Habitat Zones, quantified annually according to physical criteria measured through the post-dry season routine monitoring survey (Section 5.2 of the Coastal Stability Management and Monitoring Plan). The Nesting Habitat Zones are used as indicators of change that may have implications for nesting marine turtles, based on observed changes to turtle behaviour from baseline to October 2014 caused by changes to beach structure (Section 5.3).

2.2.1 Data Included in Analysis for Interim Management Triggers

2.2.1.1 Selection of Study Area and Physical Parameters Defining the Marine Turtle Nesting Habitat

A fixed study area for each beach has been defined, according to physical parameters (refer to Section 5.2 and Section 5.3), as follows:

- Landward extents – defined by natural features such as the base of Primary Dune or established vegetation line, whichever is most seaward; northern and southern extents of beaches are bounded by natural landform features such as rocky headlands or creek discharge lines
- Seaward extent – defined by a fixed line through the intertidal zone roughly parallel to the bathymetry/topography of the beach, wide enough to account for potential changes to the beach through alongshore redistribution of sand.

Within the study area boundaries described above, data captured for the routine post-dry monitoring survey are analysed according to the physical criteria defined in Table 2.5 to quantify (map) and divide the study area into Nesting Habitat Zones:

- Optimal – Where characteristics of measured physical parameters within the study area are considered ideal for marine turtle nesting
- Sub-optimal – Where characteristics of measured physical parameters within the study area are considered less than ideal but may still allow successful marine turtle nesting
- Unsuitable - Where characteristics of measured physical parameters within the study area are unlikely to allow successful turtle nesting

The physical parameters and criteria that define the Nesting Habitat Zones (Table 2.5) were developed in consultation with MTEP from 2014-2015, and endorsed for use by MTEP in August 2015. Nesting Habitat Zones are categorised according to the lowest criteria they meet for any individual physical parameter; i.e. an area can only be categorised as Optimal if it meets all criteria for the Optimal category.

Table 2.5 Marine Turtle Nesting Habitat Zones and the Physical Parameters and Criteria that Define them

Physical Parameter	Marine Turtle Nesting Habitat Zones and Defining Criteria		
	Unsuitable	**Sub-optimal**	**Optimal**
Landward Boundary	Landward of the established vegetation line or base of primary dune	Seaward of the established vegetation line or base of primary dune.	
Seaward Boundary	Seaward of the Mean High Water Springs tide line	Landward of the Mean High Water Springs tide line	
Rock	Full restriction of access to the nesting area due to sub-aerial rock	Possible restriction of access to the nesting area due to intertidal rock	No restriction of access to the nesting area due to rock
Sediment Composition	Median grain size of either gravel or fines	Median grain size of either very coarse sand, fine or very fine sand	Median grain size of medium or coarse sand
Sand Depth	< 0.6m sand depth		>0.6m sand depth
Other	Presence of infrastructure OR Discontinuous Optimal / Sub-optimal nesting areas within otherwise Unsuitable area	Discontinuous Optimal nesting areas within otherwise Sub-optimal area	

2.2.1.2 Selection of Appropriate Interim Management Triggers for Marine Turtle Nesting Habitat

The process for determining interim Marine Turtle Nesting Habitat Management Triggers was developed in consultation with, and endorsed by, MTEP in August 2015. Examination (by the MTEP) of changes in nesting habitat area in each zone from baseline (October 2009) to October 2014, and the observed responses of marine turtles to those changes, suggested that a further reduction in Optimal nesting habitat has the highest potential for implications to marine turtles nesting on the beaches; therefore it is currently the most appropriate parameter to set an Interim Management Trigger for.

Despite the observed changes to beach structure to October 2014 resulting in a reduced area of available nesting habitat, the changes have, to date, not resulted in a detectable impact to marine turtle biological indicators as:

- nesting success measures at Terminal and Bivalve Beaches are not significantly different between October 2014 and baseline (Pendoley Environmental, 2015a)
- hatchling and emergence success rates remain high across Terminal and Bivalve Beaches and statistically similar, or higher, during the construction period compared to baseline (Pendoley Environmental, 2015b)
- population parameters show a continued high nester abundance and survival probability for the Barrow Island rookery (Chaloupka, 2015)

Given the absence of measurable effects to turtle biological indicators, MTEP considered that a further annual change of a magnitude already experienced (annually) is unlikely to cause a decline in turtle biological parameters and is therefore not reasonable cause for immediate

action. The magnitude of the trigger and subsequent management measures are set accordingly.

The interim Management Triggers are applied to Bivalve and Terminal Beaches separately and only to data collected from the post-dry season routine monitoring survey.

Table 2.6 Interim Marine Turtle Nesting Habitat Management Triggers Applied to Optimal Marine Turtle Nesting Habitat at Terminal and Bivalve Beaches for the post-dry Routine Monitoring Survey

Parameter	Interim Management Trigger	Management Measure
Annual change in Optimal Marine Turtle Nesting Habitat between post-dry season routine monitoring surveys	Level 1 – Change in excess of the average annual change + 1 standard deviation, from October 2009 to October 2014	Alert
	Level 1 – Change in excess of the average annual change + 2 standard deviations, from October 2009 to October 2014	Review

3.0 Exceeding a Management Trigger: Implementing Management Measures

Exceedance of a Management Trigger may result in consideration of appropriate responses, including measures that aim to investigate and establish the significance of any Project Attributable adverse impacts to the beaches adjacent to the MOF and LNG Jetty and the implications for marine turtle nesting.

3.1 Beach Structure and Beach Sediments

Management measures for exceedances of Beach Structure and Beach Sediments are summarised in Figure 3.1, which presents alignment of the management measures with notification commitments and reporting requirements (Section 8.2 of the Coastal Stability Management and Monitoring Plan), and may include:

Alert: Review of existing data and other relevant information to assess whether the Management Trigger exceedance is Project Attributable and has resulted in a significant adverse impact to the beaches adjacent to the MOF and LNG Jetty. This management measure may include:

- examination of Beach Envelopes of Change and other monitored parameters
- review of metocean data
- comparison of changes in beach volume, beach slope and sediment particle size along other monitored transects on Terminal Beach and Bivalve Beach in the first instance
- followed by comparison with changes in beach volume, beach slope and sediment particle size on monitored transects on reference beaches.

The Alert Measure is completed when Chevron Australia can determine, based on results of preliminary investigations, whether beach profiles and sand grain size have changed beyond the Performance Standards established in the Coastal Stability Management and Monitoring Plan (Coastal Stability Management and Monitoring Plan, Table 6.1). The Alert Measure does not preclude further management action being implemented.

Review: Undertake further assessment with the aim of diagnosing the cause of the change, which may involve reviews of the risks associated with exceeding the Performance Standard. This may include:

- further field surveys of beach structure and sediment characteristics to assist with trend diagnosis
- a review of trends in parameters related to marine turtle nesting, hatching and emergence success (Table 2.2) on beaches adjacent to Town Point in relation to the identified trends in beach volume, beach slope or beach sediment characteristics
- advice from MTEP as appropriate (this does not preclude consultation with other stakeholders)
- a risk assessment.

The Review Measure does not preclude further management action being implemented.

Action: Following the Review Measure, Chevron Australia may consider a range of potential beach management options, including a robust evaluation of the environmental benefits and environmental costs of each option. Actions may include “do nothing” or “continue monitoring” as considered appropriate. Potential management options are identified in Section 5.4 of the Coastal Stability Management and Monitoring Plan.

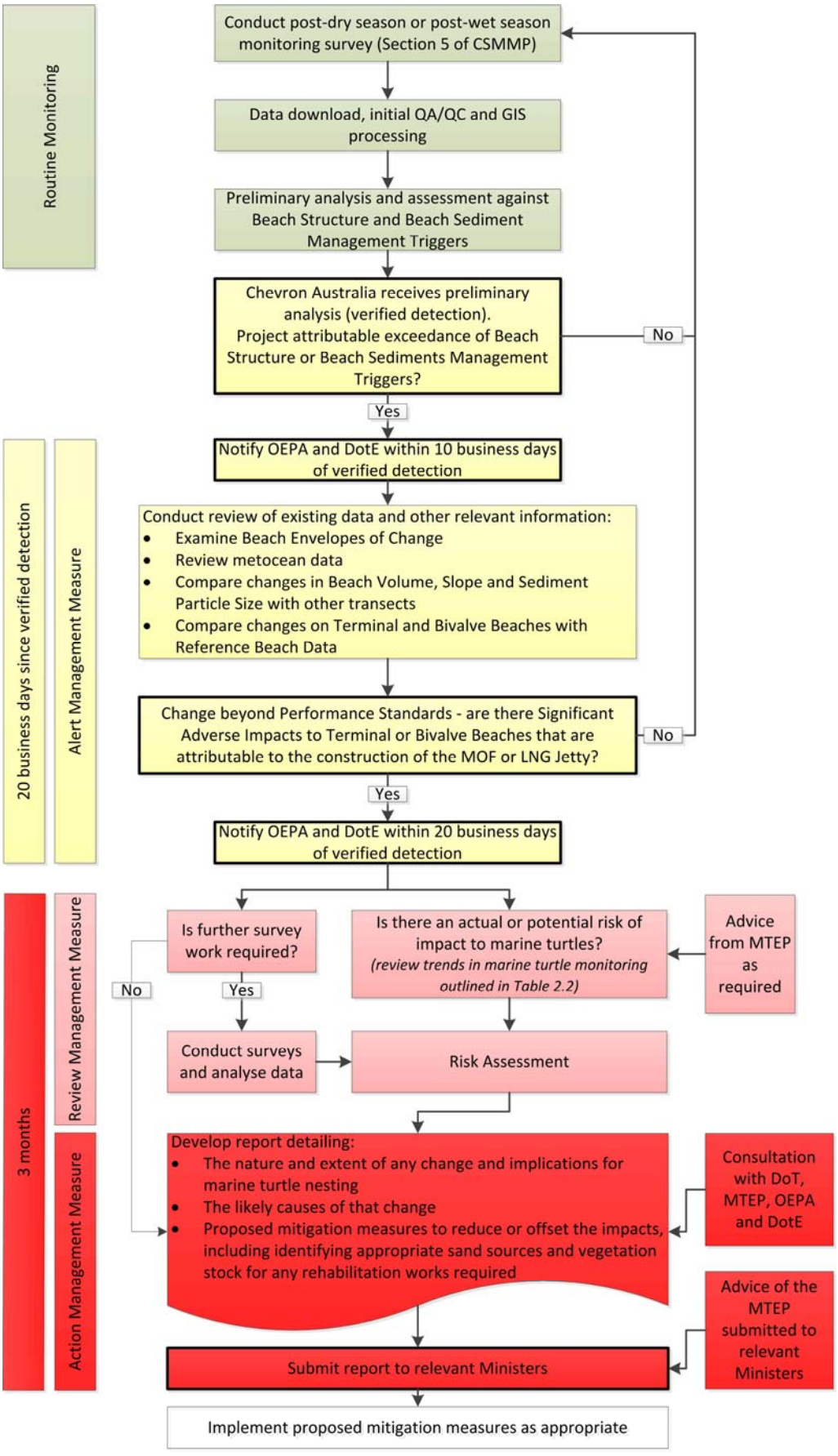


Figure 3.1 Management Measures, Notification and Reporting Associated with Exceedance of Beach Structure and Beach Sediments Management Triggers

3.2 Marine Turtle Nesting Habitat – Interim

Management measures for exceedances of interim Marine Turtle Nesting Habitat Management Triggers are summarised in Figure 3.1, which presents alignment of the management measures with notification commitments and reporting requirements (Section 8.2 of the Coastal Stability Management and Monitoring Plan, and may include:

Alert: Upon exceedance of a Level 1 interim Management Trigger (Section 2.2), review of existing data and other relevant information to assess whether the interim Management Trigger exceedance is project attributable and determine the cause of the change. This management measure may include:

- a review of metocean data contributing to the change
- a comparison of changes at Terminal and Bivalve Beaches compared to Reference Beaches

The Alert Measure does not preclude further management action being implemented.

Review: Upon exceedance of a Level 2 interim Management Trigger, undertake further monitoring and / or analysis of turtle biological parameters to determine whether the measured changes to nesting habitat are resulting in implications to marine turtles nesting on Bivalve and Terminal Beaches. This management measure may include:

- Additional monitoring of turtle biological parameters undertaken in the upcoming nesting season
- a review of trends in biological parameters related to marine turtle nesting on beaches adjacent to Town Point in relation to the identified changes in nesting habitat
- advice from MTEP as appropriate (this does not preclude consultation with other stakeholders)
- a risk assessment.

The Review Measure is completed when Chevron Australia reports the findings to DotE and OEPA (Section 8.2 of the Coastal Stability Management and Monitoring Plan), however the Review Measure does not preclude further management action being implemented.

Action: Management action is unlikely to be required during implementation of interim Marine Turtle Nesting Habitat Triggers, given the long life-cycle of marine turtles and in the absence of detectable impacts to turtle biological parameters from changes to the beaches as at October 2014. However, on advice from MTEP, Chevron Australia may consider a range of potential beach management options in the event of changes significantly beyond a Level 2 interim Management Trigger that may have immediate implications for marine turtles nesting on Bivalve and Terminal Beaches. Options for actions would be subject to a robust evaluation of the environmental benefits and environmental costs of each option. Potential management options are identified in Section 5.4 of the Coastal Stability Management and Monitoring Plan.

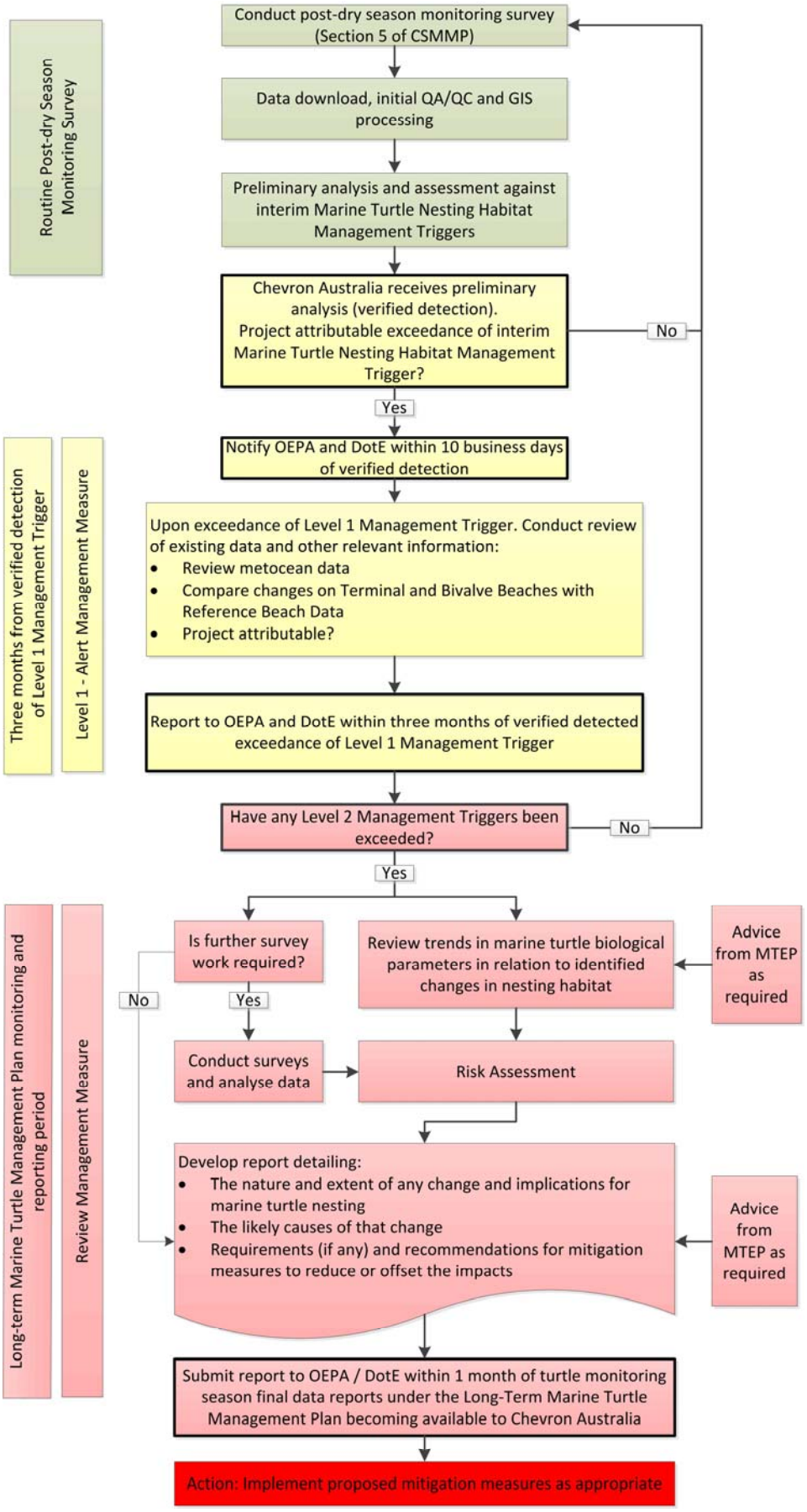


Figure 3.2 Management Measures, Notification and Reporting Associated with Exceedance of Interim Marine Turtle Nesting Habitat Management Triggers

4.0 Revision of this Supplement

Revision 1 of this Supplement incorporates new, but interim, Marine Turtle Nesting Habitat Management Triggers related to detecting adverse changes to the beach structure and beach sediments that could have implications for marine turtles nesting on the beaches adjacent to the MOF.

Review of this Supplement may be undertaken in accordance with Section 8.3 of the Coastal Stability Management and Monitoring Plan. Chevron Australia continues to undertake work to better understand the coastal processes on the east coast of Barrow Island, the influence of the completed Marine Facilities on beach structure, and potential implications to marine turtles and other sensitive receptors. With the benefit of this increased understanding and five years of post-construction monitoring, at this stage Chevron Australia intends to revise the Management Triggers and associated management measures in 2016.

5.0 State of Environment Information

5.1 Beach Structure and Beach Sediments Parameters – Baseline State

Data presented in this Section includes the baseline monitoring program over the period July 2008–October 2009, for the selected primary monitoring transects and points of interest, with relevant controls established for Management Triggers.

5.1.1 Terminal Beach

5.1.1.1 Beach Envelope of Change

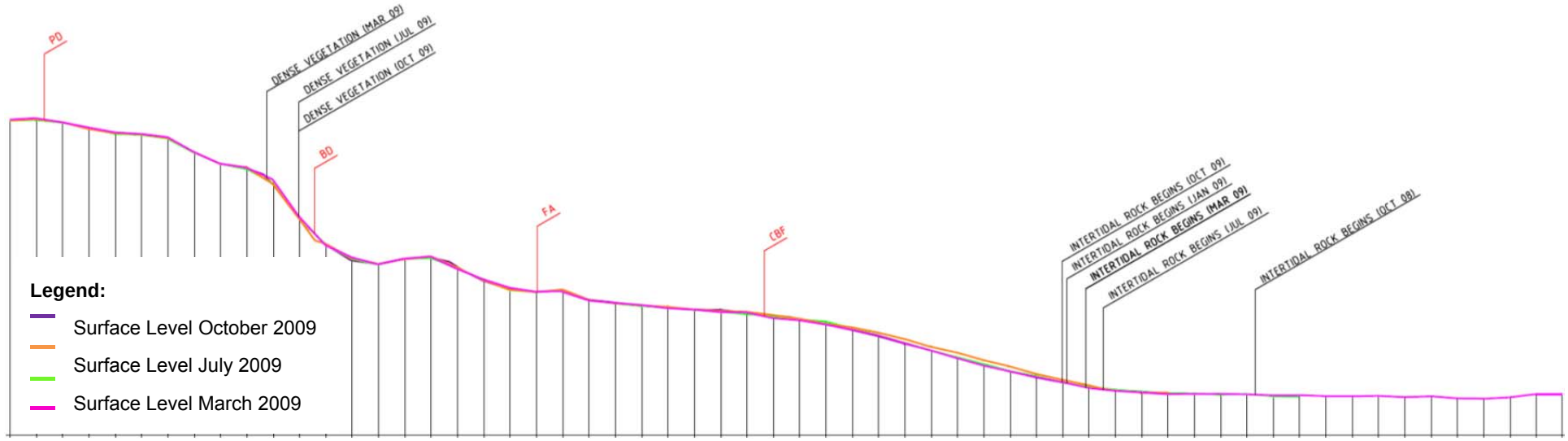


Figure 5.1 Terminal Beach Transect 11 Beach Envelope of Change, January 2009 – October 2009

Notes: PD: Primary Dune; BD: Base of Primary Dune; FA: Foredune Area; CBF: Crest of Beach Face.

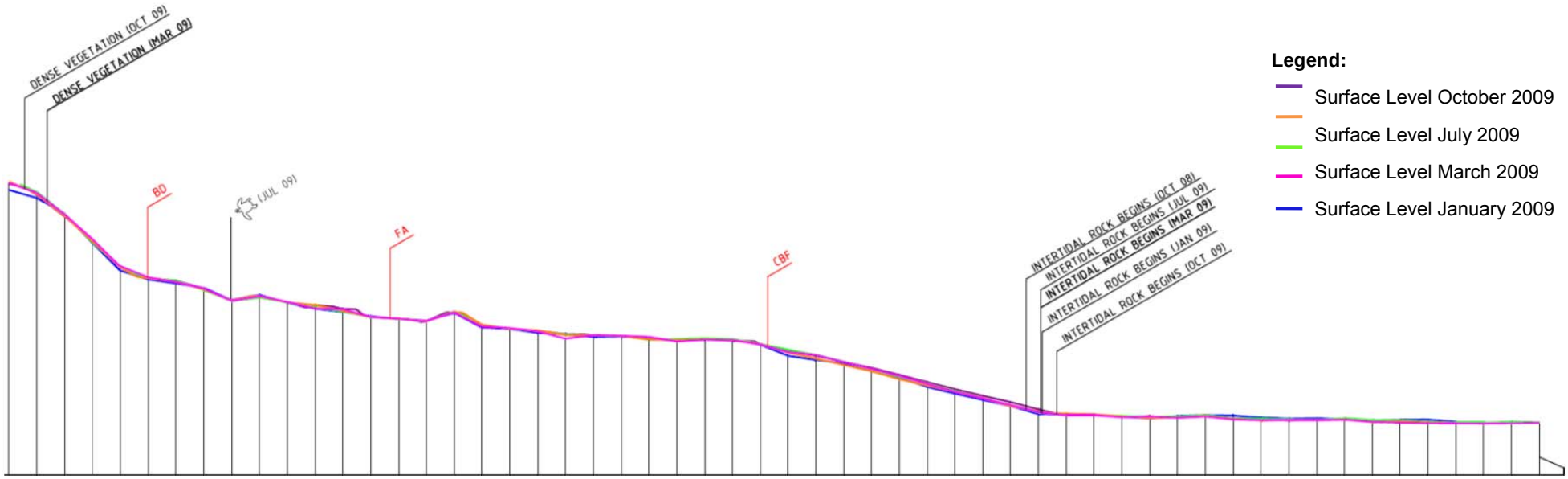


Figure 5.2 Terminal Beach Transect 22 Beach Envelope of Change, October 2008 – October 2009

Notes: denotes a marine turtle body pit. BD: Base of Primary Dune; FA: Foredune Area; CBF: Crest of Beach Face.

5.1.1.2 Beach Slope

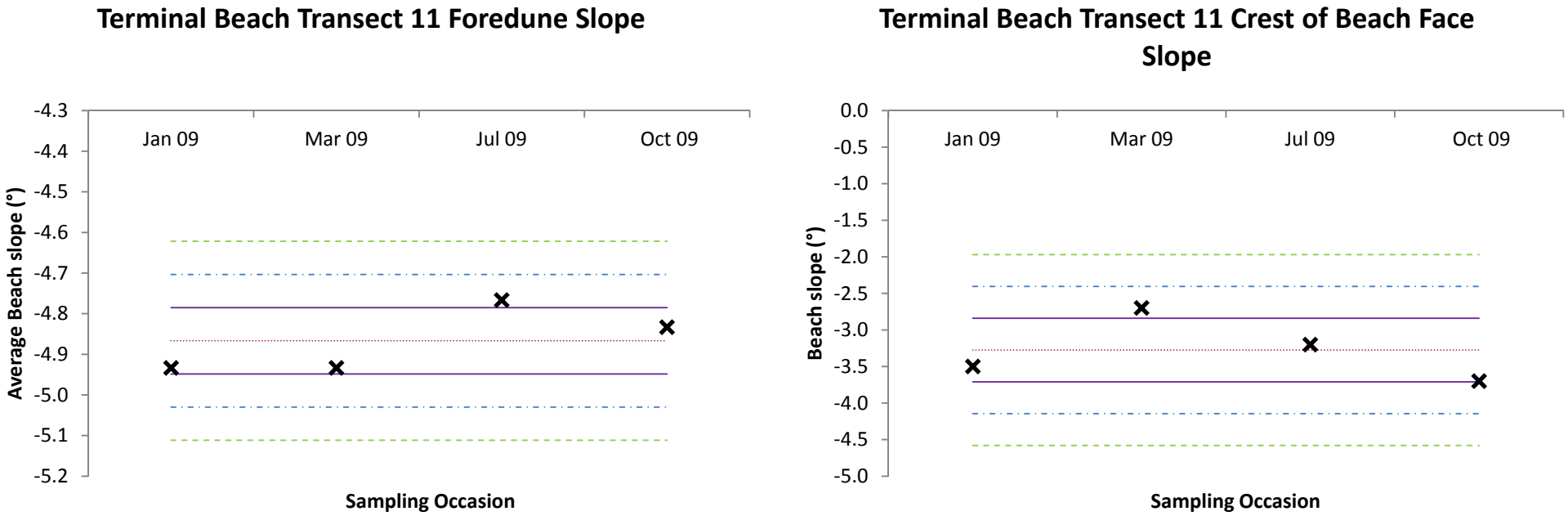


Figure 5.3 Indicative Control Charts based on Baseline Data (January 2009 – October 2009) for Terminal Beach Transect 11 Beach Slope at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - · - · - = ± 2 SD, – – – – = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

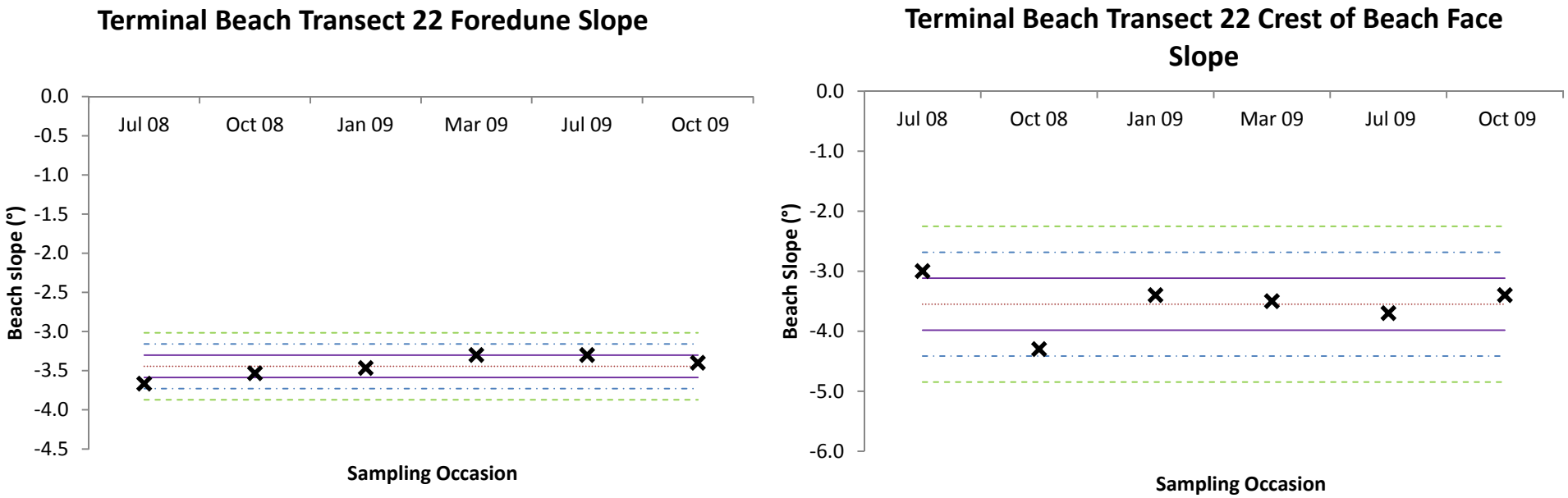


Figure 5.4 Indicative Control Charts based on Baseline Data (July 2008 – October 2009) for Terminal Beach Transect 22 Beach Slope at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, —— = ± 1 SD, -·-·- = ± 2 SD, - - - = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: July 2008 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

5.1.1.3 Range in Beach Slope

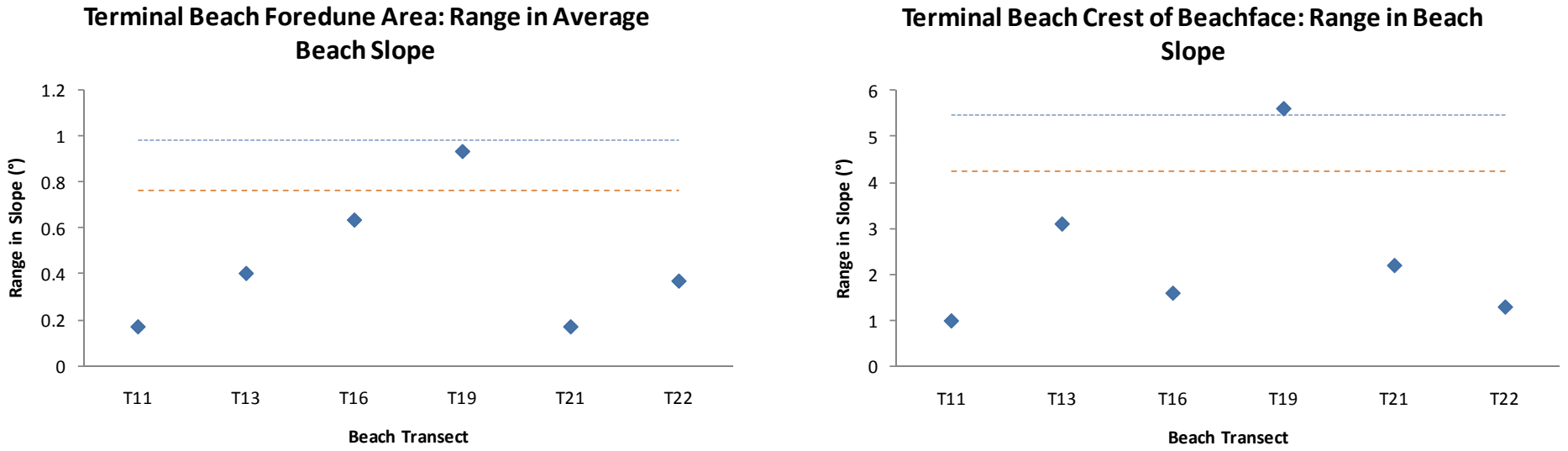


Figure 5.5 Indicative Control Charts for Range of Beach Slope at the Foredune Area and Crest of Beach Face for Terminal Beach

Notes: ◆= range, - - - - - - - = Inner control line, ····· = Outer control line.
Sample size = n=6 sampling occasions.

5.1.1.4 Beach Volume

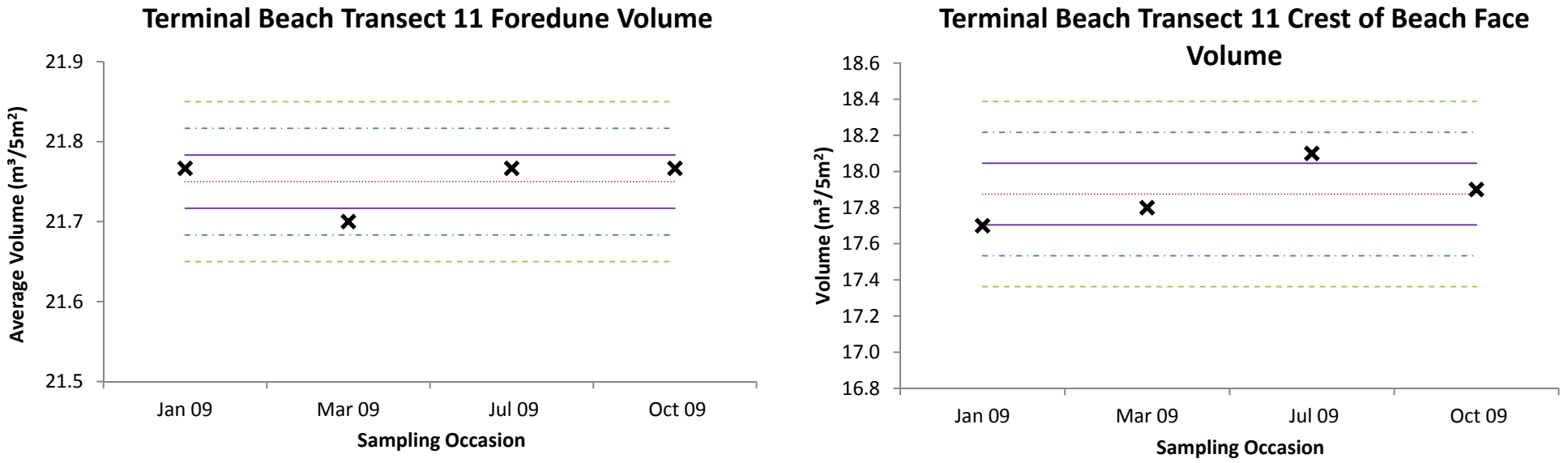


Figure 5.6 Indicative Control Charts based on Baseline Data (January 2009 – October 2009) for Terminal Beach Transect 11 Beach Volume at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - - - = ± 2 SD, — — — = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

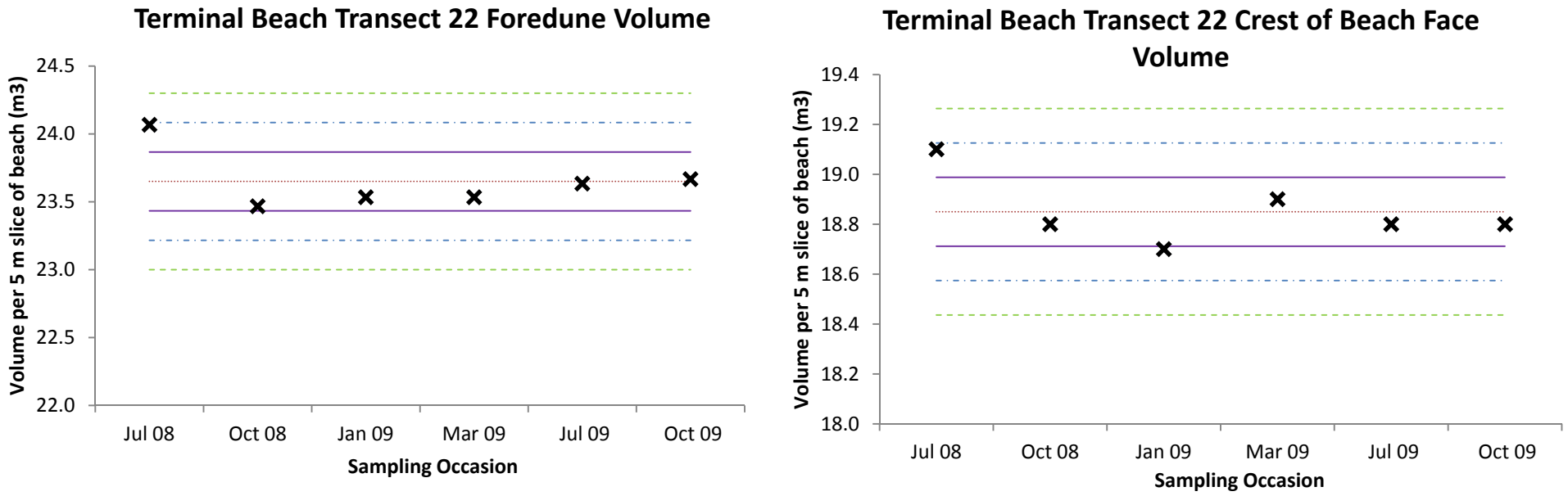


Figure 5.7 Indicative Control Charts based on Baseline Data (July 2008 – October 2009) for Terminal Beach Transect 22 Beach Volume at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - · - · - = ± 2 SD, – – – – = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: July 2008 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

5.1.1.5 Range in Beach Volume

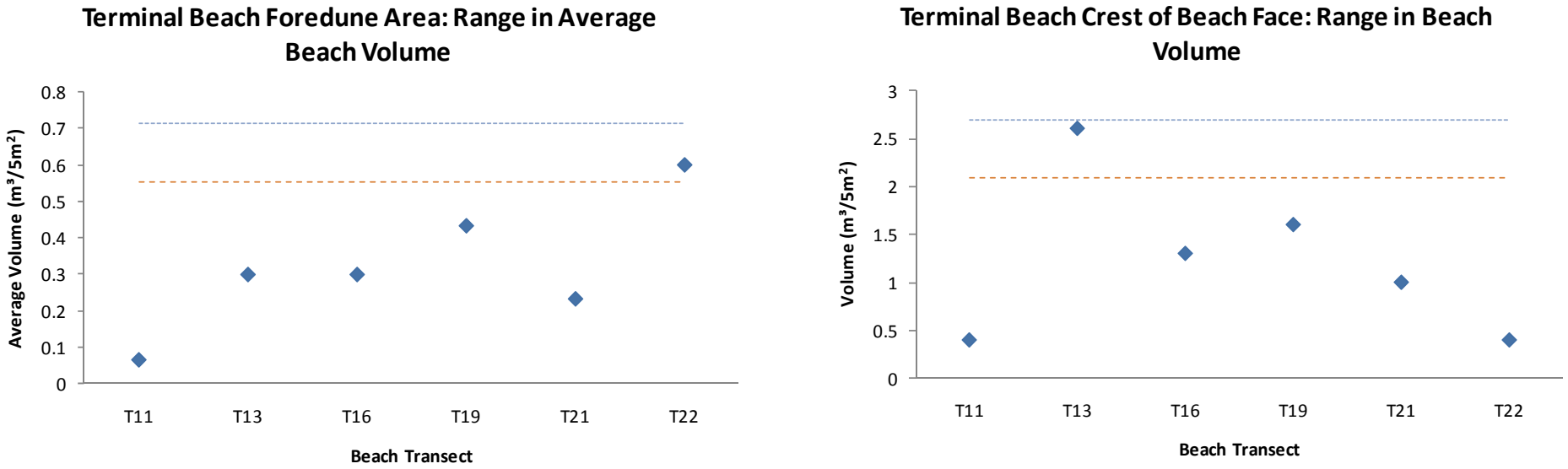


Figure 5.8 Indicative Control Charts for Range of Beach Volume at the Foredune Area and Crest of Beach Face for Terminal Beach

Notes: ♦= range, - - - - - = Inner control line, ····· = Outer control line.
Sample size = n=6 sampling occasions.

5.1.1.6 Beach Sediment

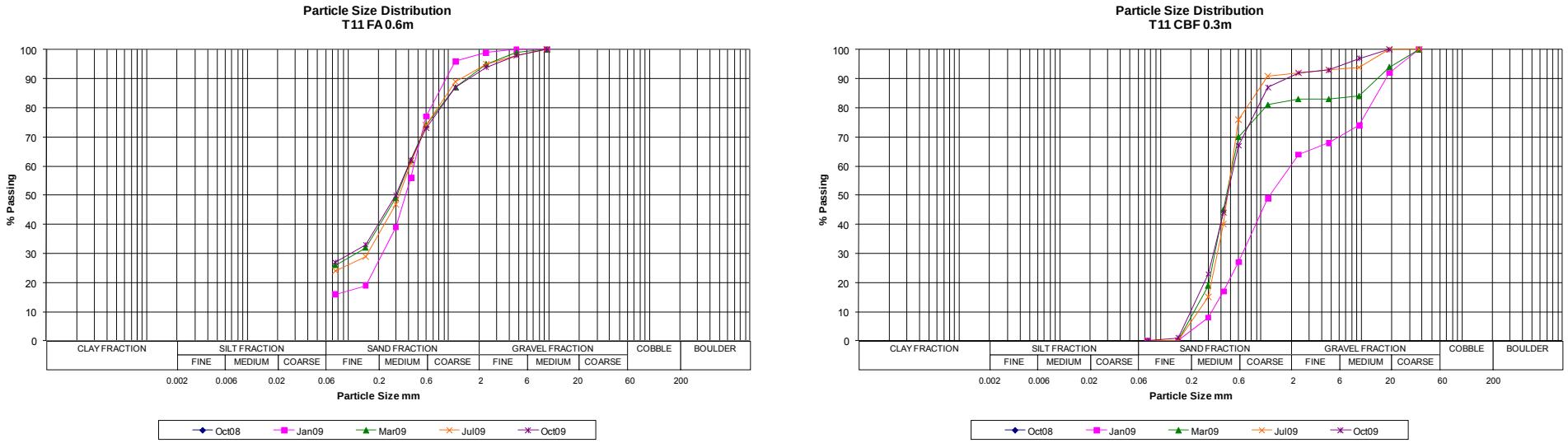


Figure 5.9 Terminal Beach Transect 11 Particle Size Distribution Charts: Foredune Area at 0.6 m Depth and Crest of Beach Face at 0.3 m Depth, October 2008 – October 2009

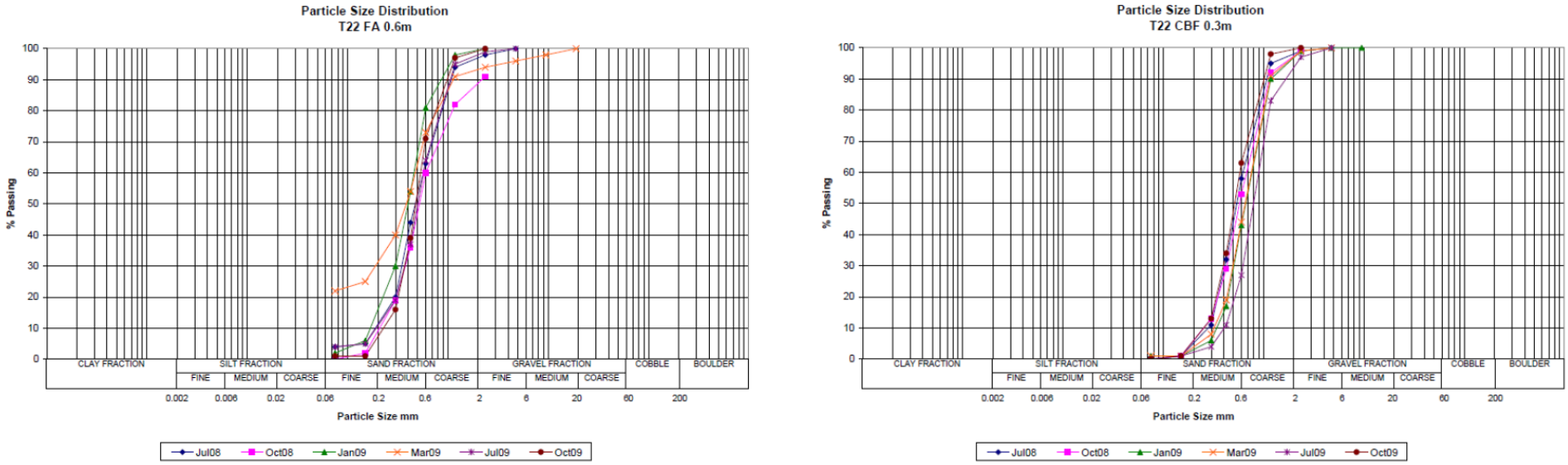


Figure 5.10 Terminal Beach Transect 22 Particle Size Distribution Charts: Foredune Area at 0.6 m Depth and Crest of Beach Face at 0.3 m Depth, July 2008 – October 2009

5.1.2 Bivalve Beach

5.1.2.1 Beach Envelope of Change

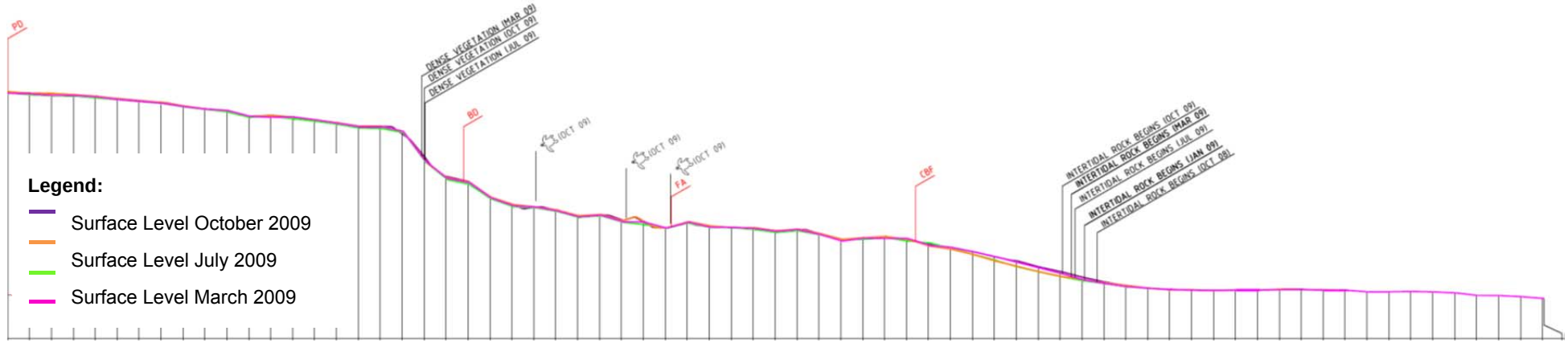


Figure 5.11 Bivalve Beach Transect 11 Beach Envelope of Change, January 2009 – October 2009

Notes: denotes a marine turtle body pit. PD: Primary Dune; BD: Base of Primary Dune; FA: Foredune Area; CBF: Crest of Beach Face.

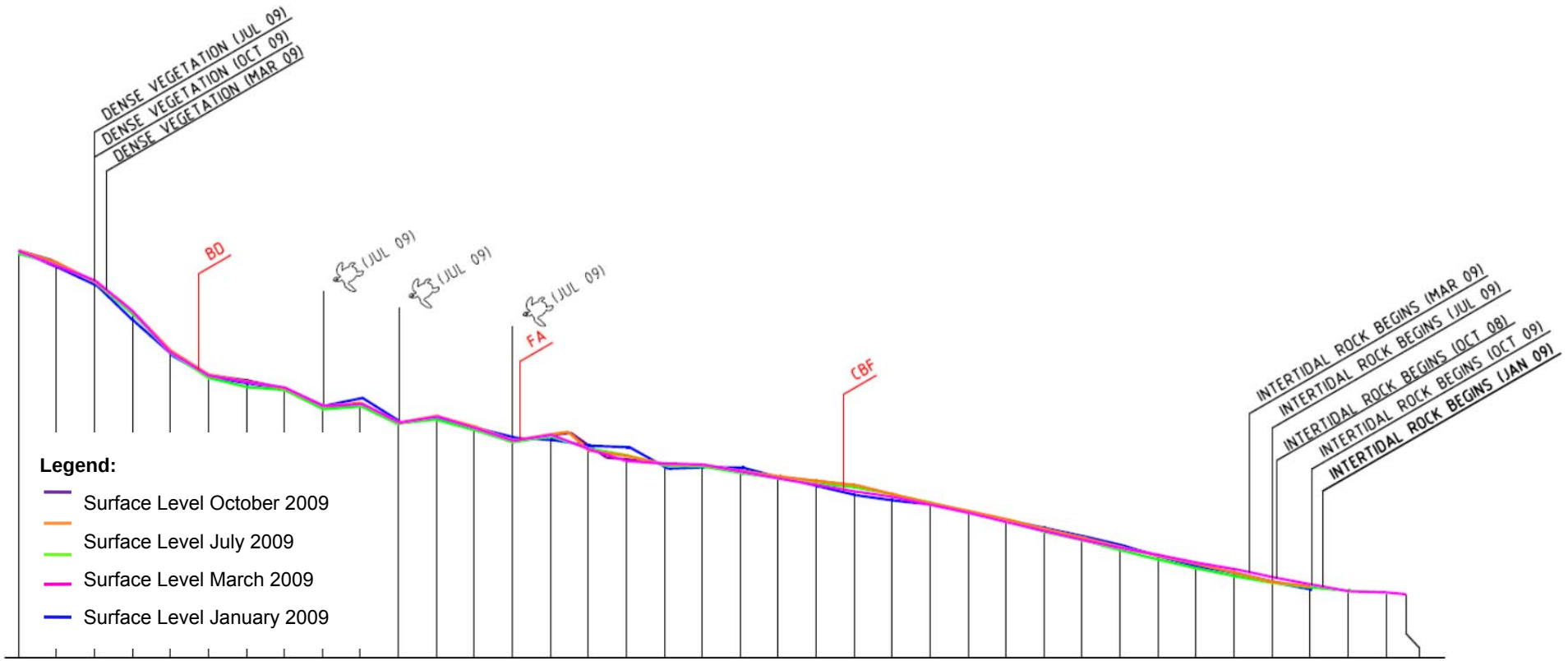


Figure 5.12 Bivalve Beach Transect 22 Beach Envelope of Change, October 2008 – October 2009

Notes: denotes a marine turtle body pit. BD: Base of Primary Dune; FA: Foredune Area; CBF: Crest of Beach Face.

5.1.2.2 Beach Slope

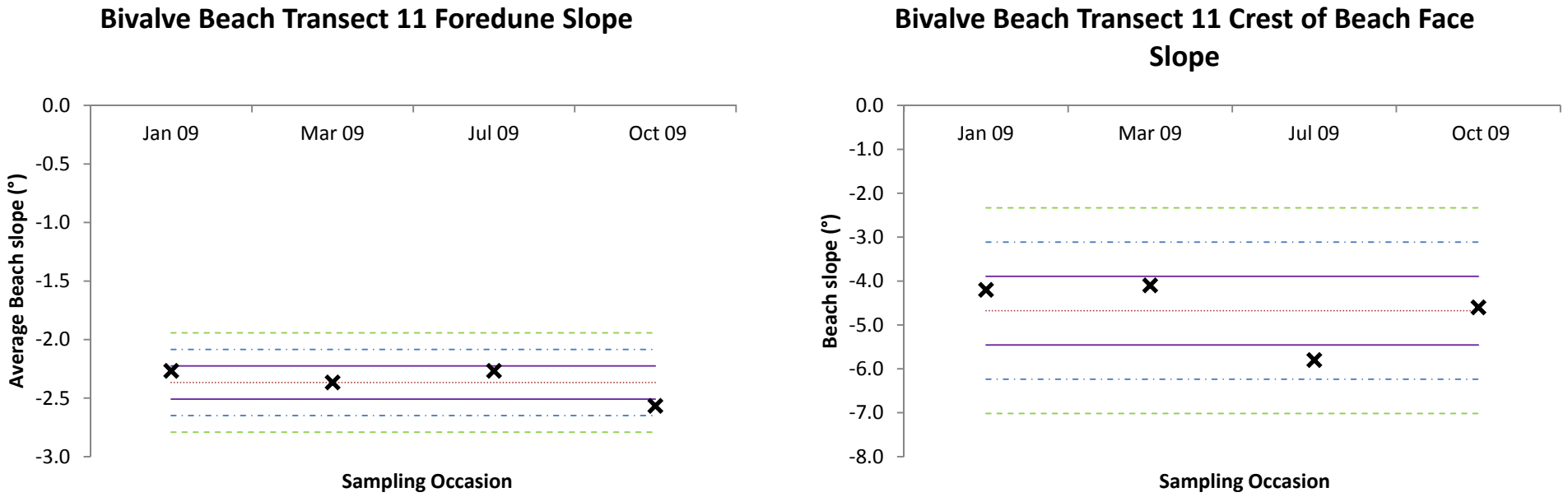


Figure 5.13 Indicative Control Charts based on Baseline Data (January 2009 – October 2009) for Bivalve Beach Transect 11 Beach Slope at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - · - · - = ± 2 SD, – – – – = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

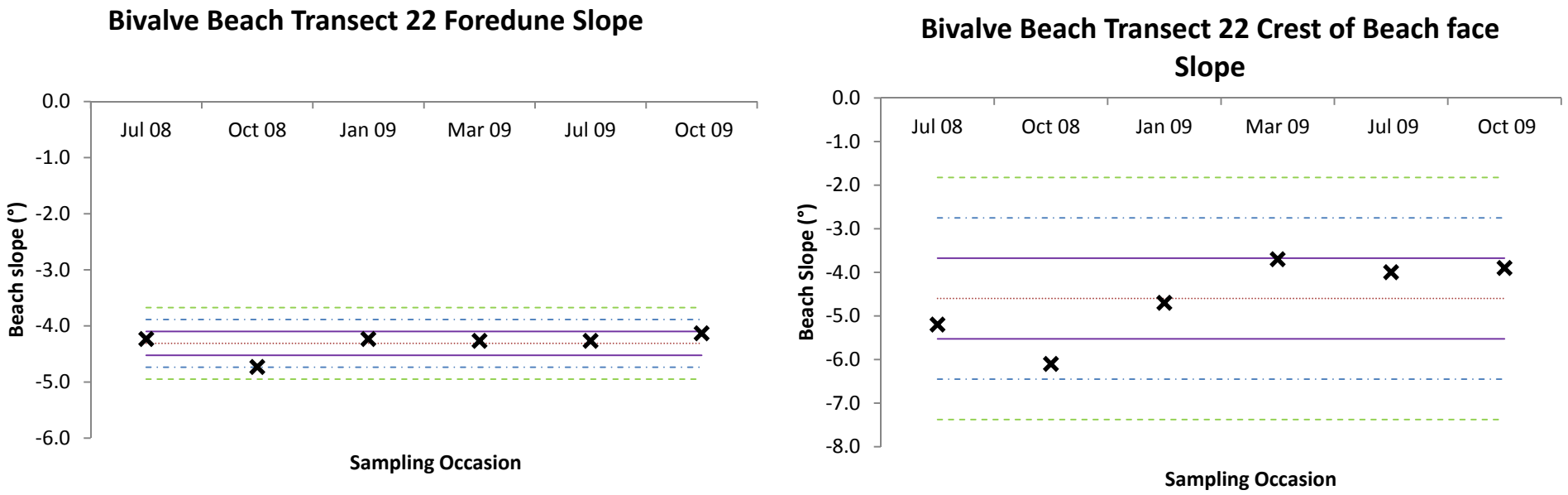


Figure 5.14 Indicative Control Charts based on Baseline Data (July 2008 – October 2009) for Bivalve Beach Transect 22 Beach Slope at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, -·-·- = ± 2 SD, - - - - = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

5.1.2.3 Range in Beach Slope

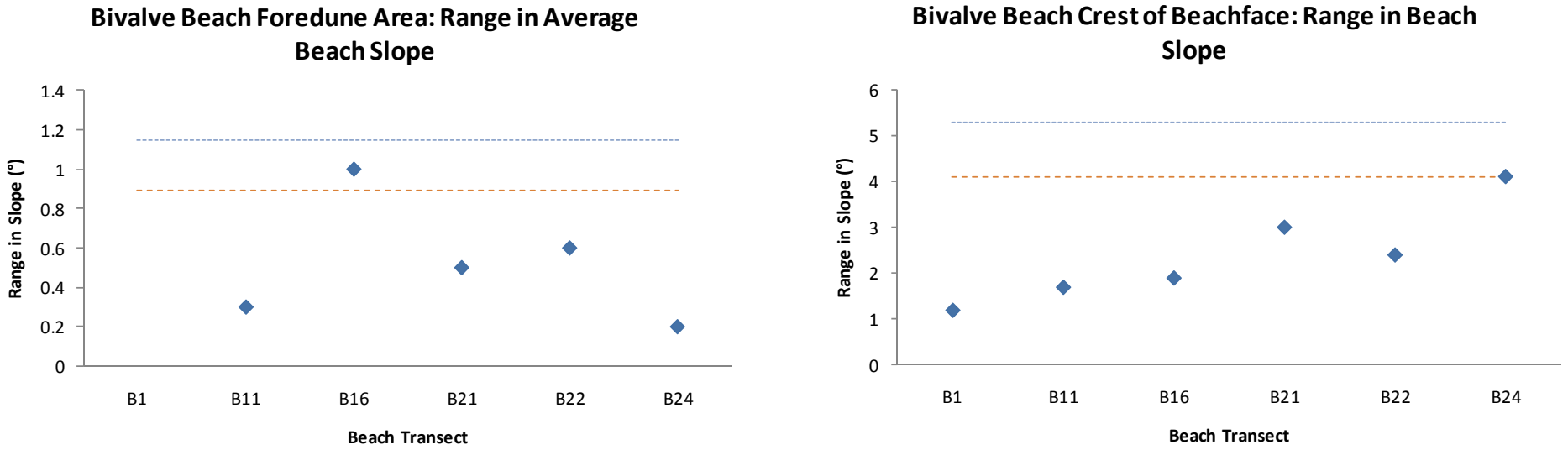


Figure 5.15 Indicative Control Charts for Range of Beach Slope at the Foredune Area and Crest of Beach Face for Bivalve Beach

Notes: ◆= range, - - - - - - - = Inner control line, ---------- = Outer control line.
Sample size = n=6 sampling occasions.

5.1.2.4 Beach Volume

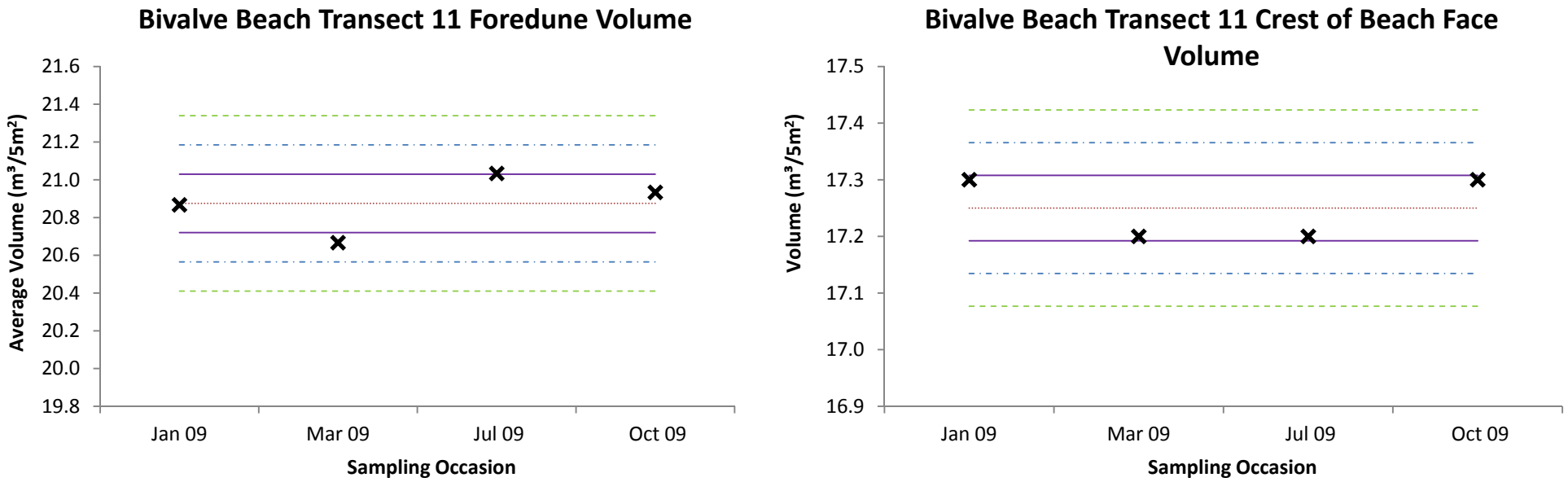


Figure 5.16 Indicative Control Charts based on Baseline Data (January 2009 – October 2009) for Bivalve Beach Transect 11 Beach Volume at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - - - = ± 2 SD, — — — = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

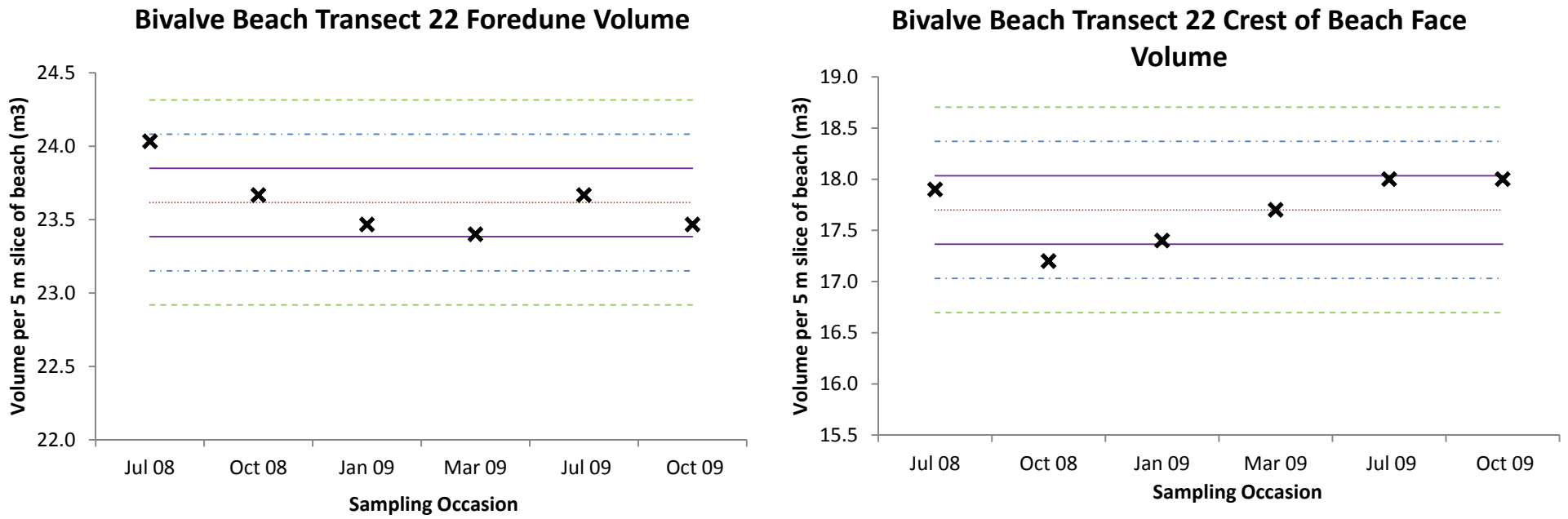


Figure 5.17 Indicative Control Charts based on Baseline Data (July 2008 – October 2009) for Bivalve Beach Transect 22 Beach Volume at the Foredune Area and Crest of Beach Face

Note: X= recorded values from baseline monitoring period. ····· = baseline mean, ——— = ± 1 SD, - - - = ± 2 SD, — — — = ± 3 SD. Mean and standard deviation values were calculated using baseline data (recorded values: January 2009 to October 2009); these will be updated with further baseline information prior to commencement of construction activities associated with the MOF and LNG Jetty. Once construction has commenced, the mean and standard deviation values will remain 'fixed', with ongoing review and refinement of the Management Triggers (refer Section 4.0).

5.1.2.5 Range in Beach Volume

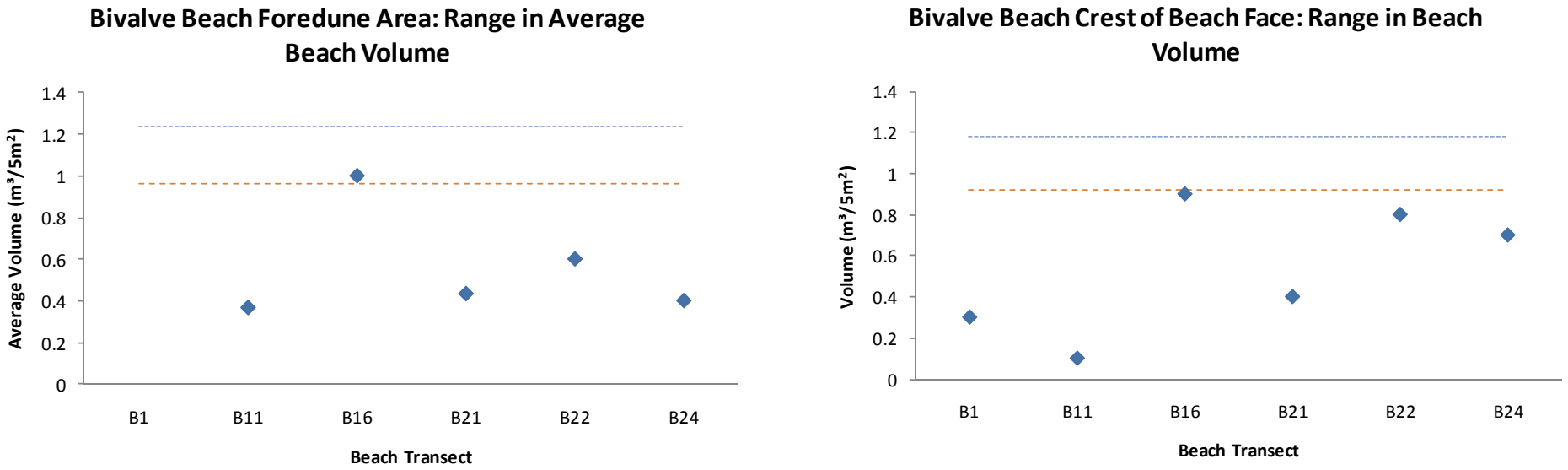


Figure 5.18 Indicative Control Charts for Range of Beach Volume at the Foredune Area and Crest of Beach Face for Bivalve Beach

Notes: ♦= range, - - - - - = Inner control line, ····· = Outer control line.
Sample size = n=6 sampling occasions.

5.1.2.6 Beach Sediment

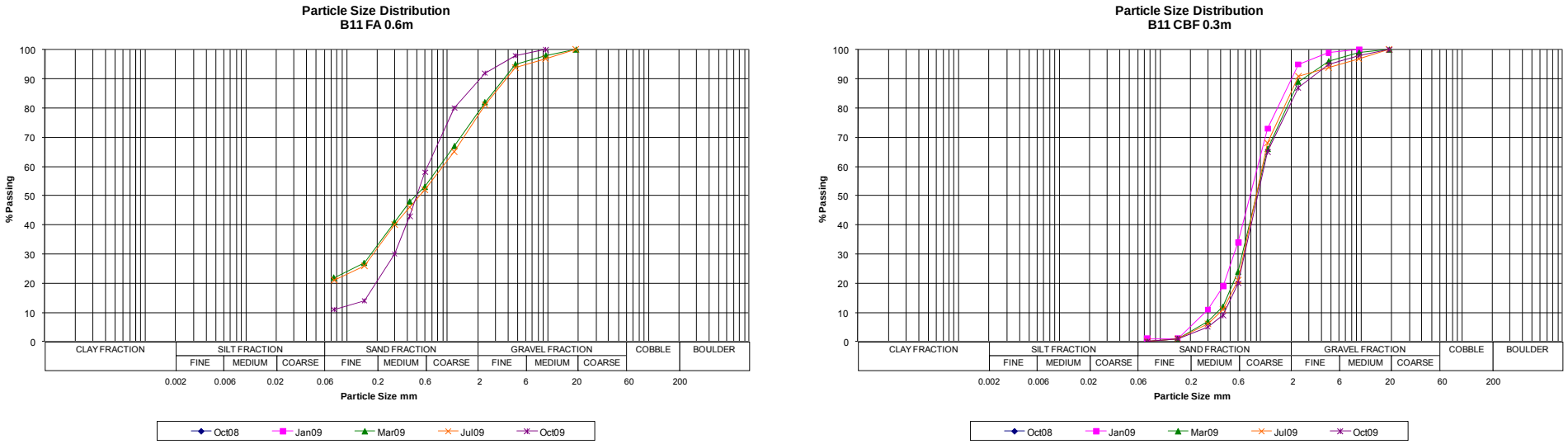


Figure 5.19 Bivalve Beach Transect 11 Particle Size Distribution Charts: Foredune Area at 0.6 m Depth and Crest of Beach Face at 0.3 m Depth, October 2008 – October 2009

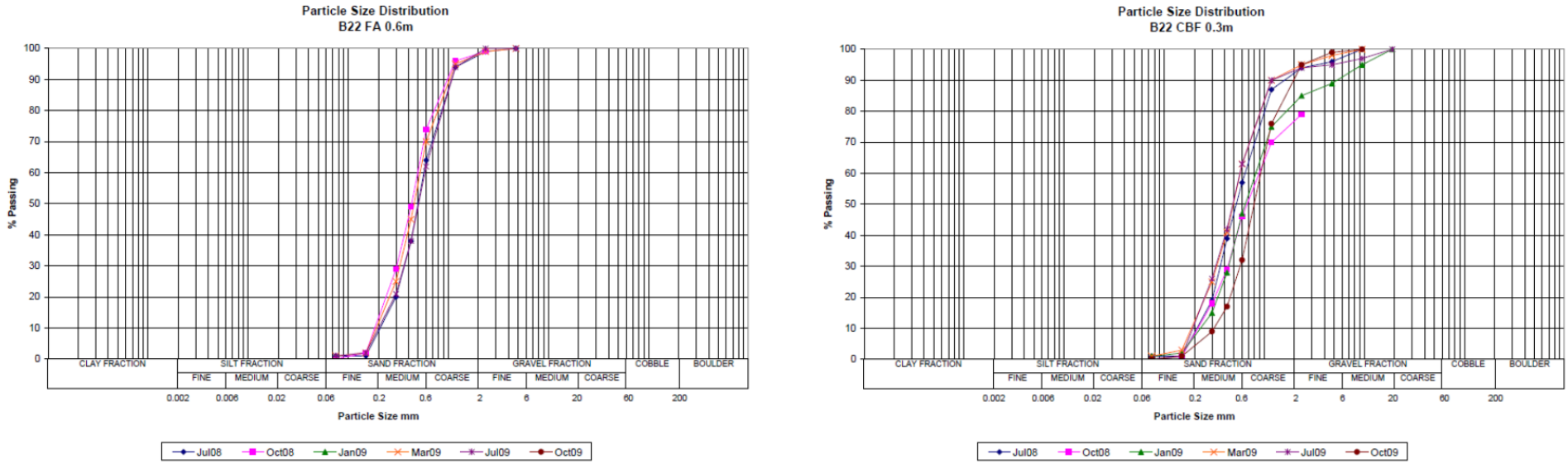


Figure 5.20 Bivalve Beach Transect 22 Particle Size Distribution Charts: Foredune Area at 0.6 m Depth and Crest of Beach Face at 0.3 m Depth, July 2008 – October 2009

5.2 Marine Turtle Nesting Habitat – Baseline State

Data presented in this Section is the baseline state of Marine Turtle Nesting Habitat in October 2009, as determined by the mapping process defined in Section 2.2.1.1.

5.2.1 Terminal Beach

In October 2009, the Terminal Beach study area was represented by the following areas of Marine Turtle Nesting Habitat:

- Optimal – 2.25 ha
- Sub-optimal – 0.11 ha
- Unsuitable – 3.74 ha

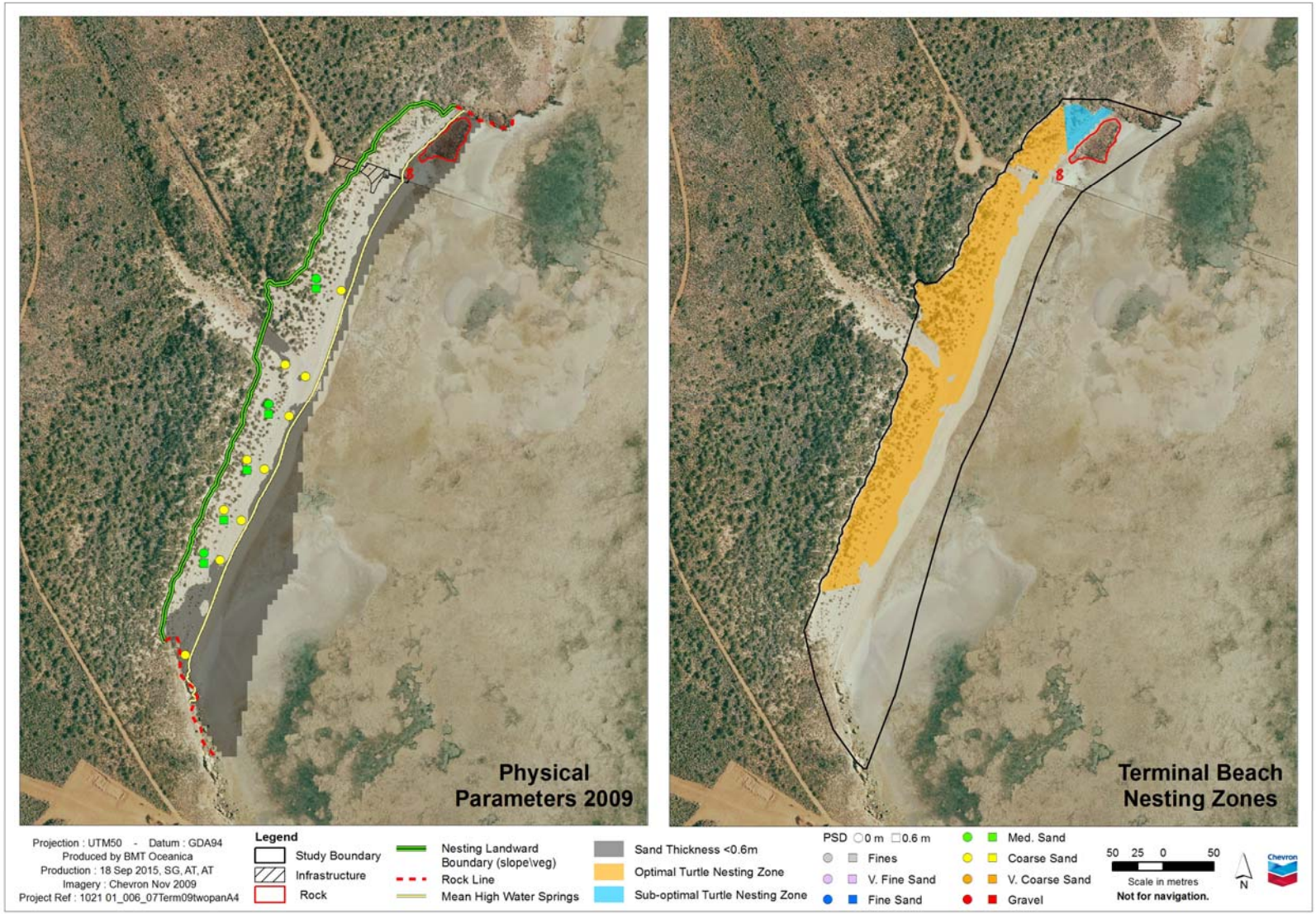
Optimal habitat accounted for the vast proportion of beach above the Mean High Water Springs Line and over 36% of the entire study area (Figure 5.21).

5.2.2 Bivalve Beach

In October 2009, the Bivalve Beach study area was represented by the following areas of Marine Turtle Nesting Habitat:

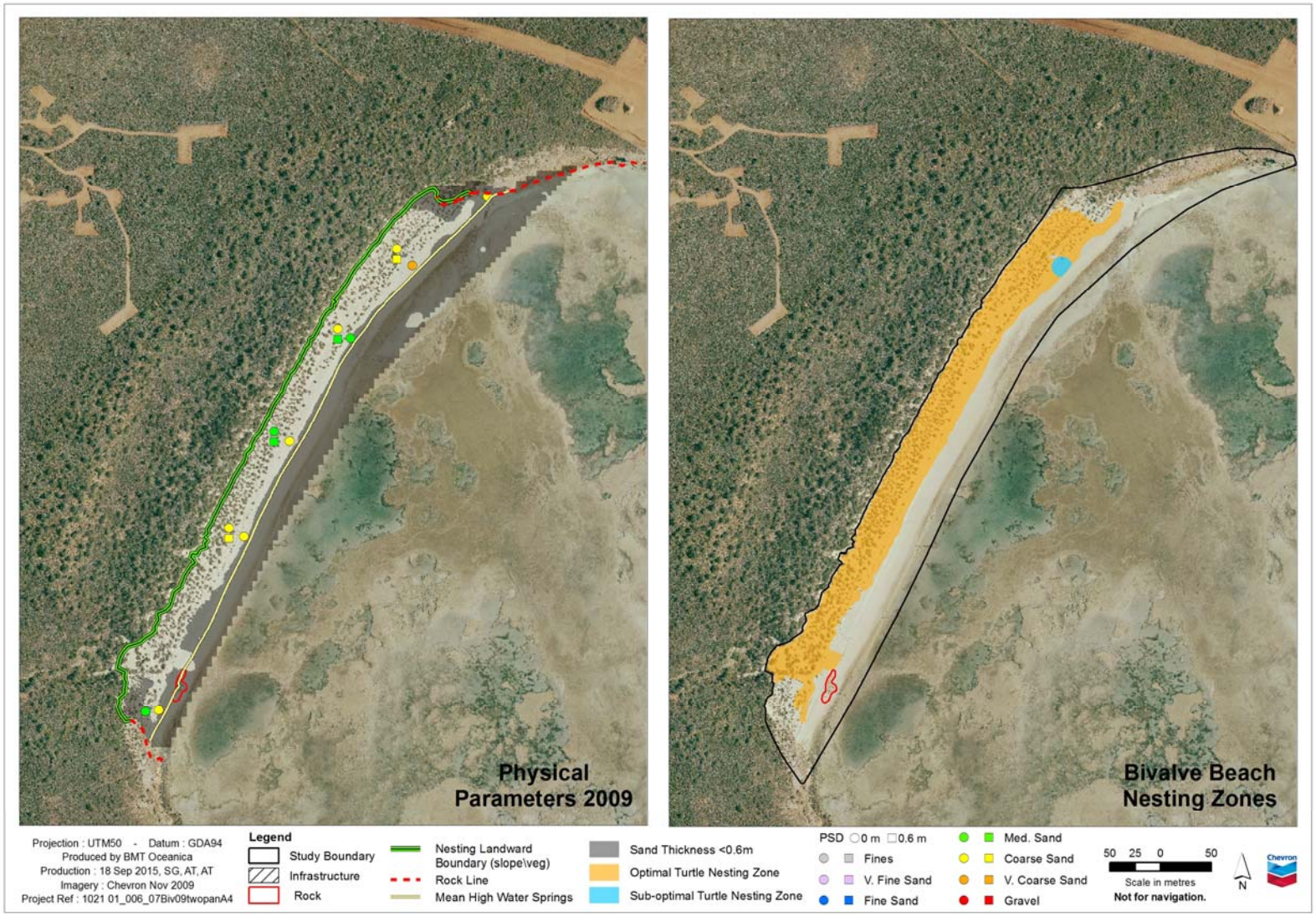
- Optimal – 2.1 ha
- Sub-optimal – 0.03 ha
- Unsuitable – 3.37 ha

As with Terminal Beach, Optimal habitat accounted for the vast proportion of beach above the Mean High Water Springs Line and over 38% of the entire study area (Figure 5.22).



**Note – Space within the Study Area not mapped as either Optimal or Sub-optimal is categorised as Unsuitable*

Figure 5.21 Marine Turtle Nesting Habitat Zones at Terminal Beach and the Physical Parameters that Define them, October 2009



**Note – Space within the Study Area not mapped as either Optimal or Sub-optimal is categorised as Unsuitable*

Figure 5.22 Marine Turtle Nesting Habitat Zones at Bivalve Beach and the Physical Parameters that Define them, October 2009

5.3 Marine Turtle Nesting Habitat – October 2014 State

Data presented in this Section is the October 2014 State of Marine Turtle Nesting Habitat, as determined by the mapping process defined in Section 2.2.1.1. Changes in the area for each zone were largely driven by the exposure of intertidal and sub-aerial (above the high tide line) rock due to alongshore sediment redistribution towards the MOF (Section 3.3.2 of the Coastal Stability Management and Monitoring Plan). The changes to the beaches are mostly in the active beach face zone, with minimal changes in the back beach, foredune area and further landward.

Despite the observed changes to beach structure to October 2014 resulting in a reduced area of available nesting habitat, the changes have, to date, not resulted in a detectable impact to marine turtle biological indicators as:

- nesting success measures at Terminal and Bivalve Beaches are not significantly different between October 2014 and baseline (Pendoley Environmental, 2015a)
- hatchling and emergence success rates remain high across Terminal and Bivalve Beaches and statistically similar, or higher, during the construction period compared to baseline (Pendoley Environmental, 2015b)
- population parameters show a continued high nester abundance and survival probability for the Barrow Island rookery (Chaloupka, 2015)

5.3.1 Terminal Beach

In October 2014, the Terminal Beach study area was represented by the following areas of Marine Turtle Nesting Habitat (Figure 5.23):

- Optimal – 0.90 ha
- Sub-optimal – 0.89 ha
- Unsuitable – 4.31 ha

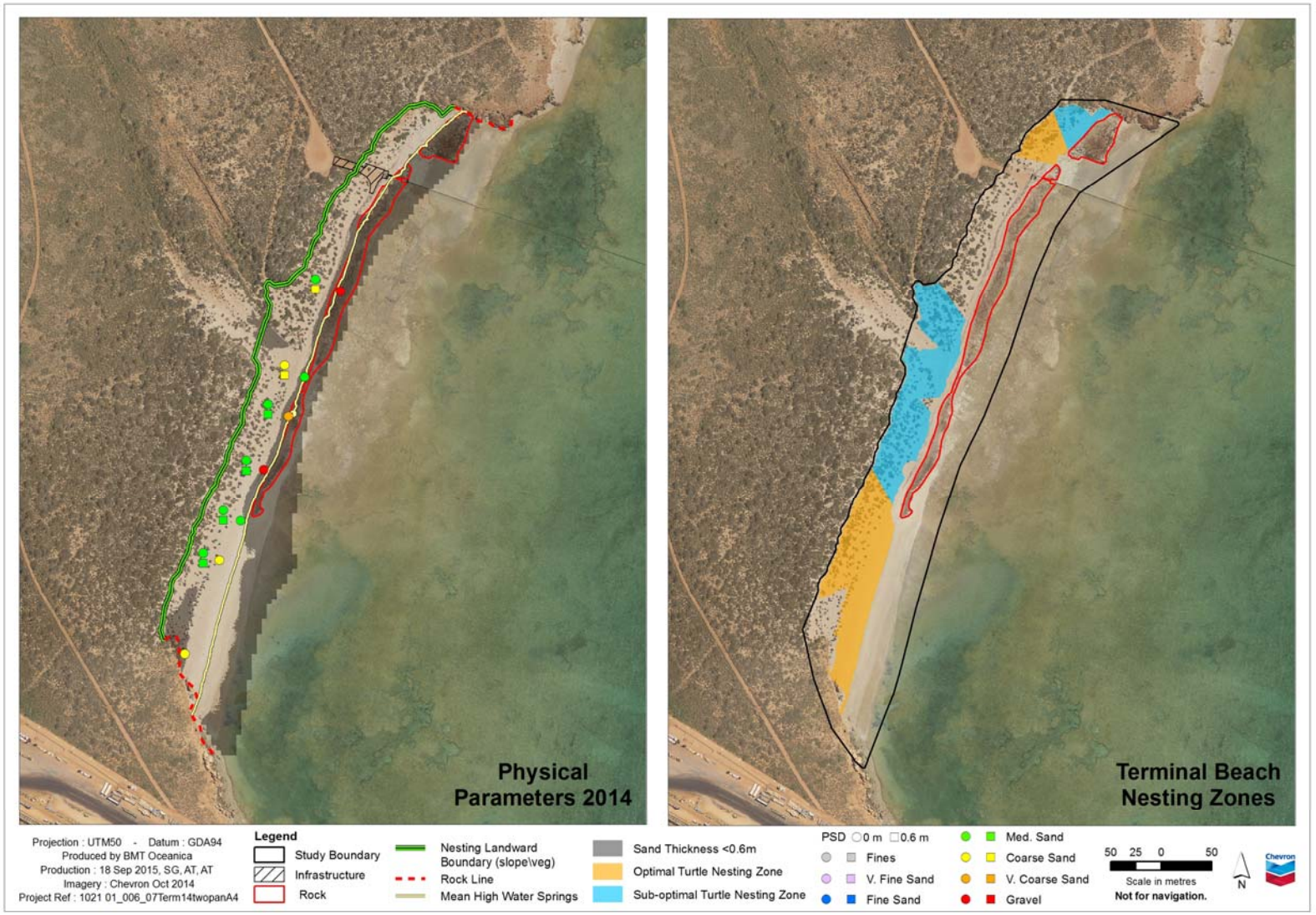
Optimal habitat accounted for over 14.7% of the study area, with Sub-optimal habitat at 14.6% and Unsuitable habitat at 70.7%.

5.3.2 Bivalve Beach

In October 2014, the Bivalve Beach study area was represented by the following areas of Marine Turtle Nesting Habitat (Figure 5.24):

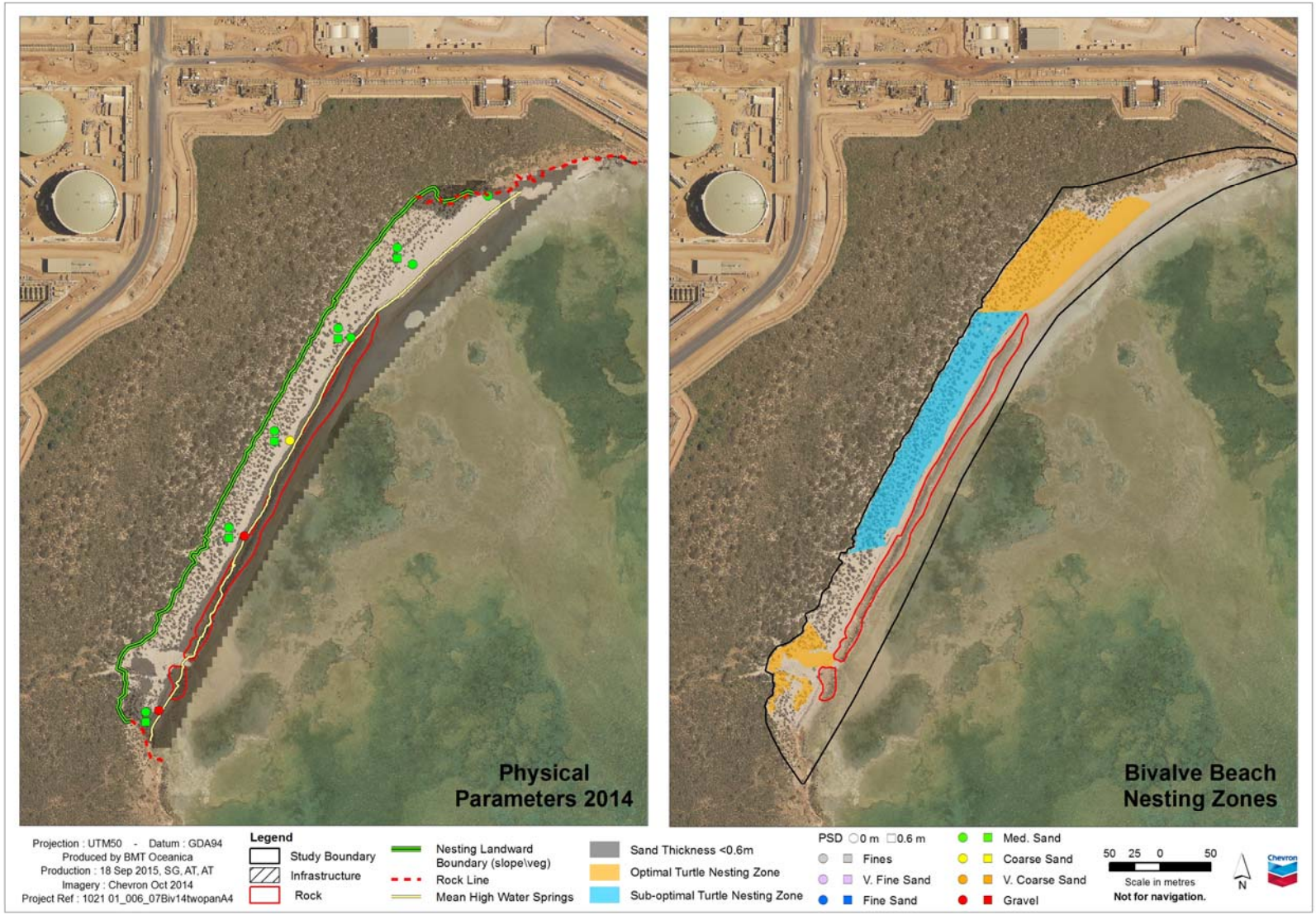
- Optimal – 0.96 ha
- Sub-optimal – 0.85 ha
- Unsuitable – 3.69 ha

Optimal habitat accounted for over 17.5% of the study area, with Sub-optimal habitat at 15.4% and Unsuitable habitat at 67%.



**Note – Space within the Study Area not mapped as either Optimal or Sub-optimal is categorised as Unsuitable*

Figure 5.23 Marine Turtle Nesting Habitat Areas at Terminal Beach and the Physical Parameters that Define them, October 2014



**Note – Space within the Study Area not mapped as either Optimal or Sub-optimal is categorised as Unsuitable*

Figure 5.24 Marine Turtle Nesting Habitat Areas at Bivalve Beach and the Physical Parameters that Define them, October 2014

6.0 References

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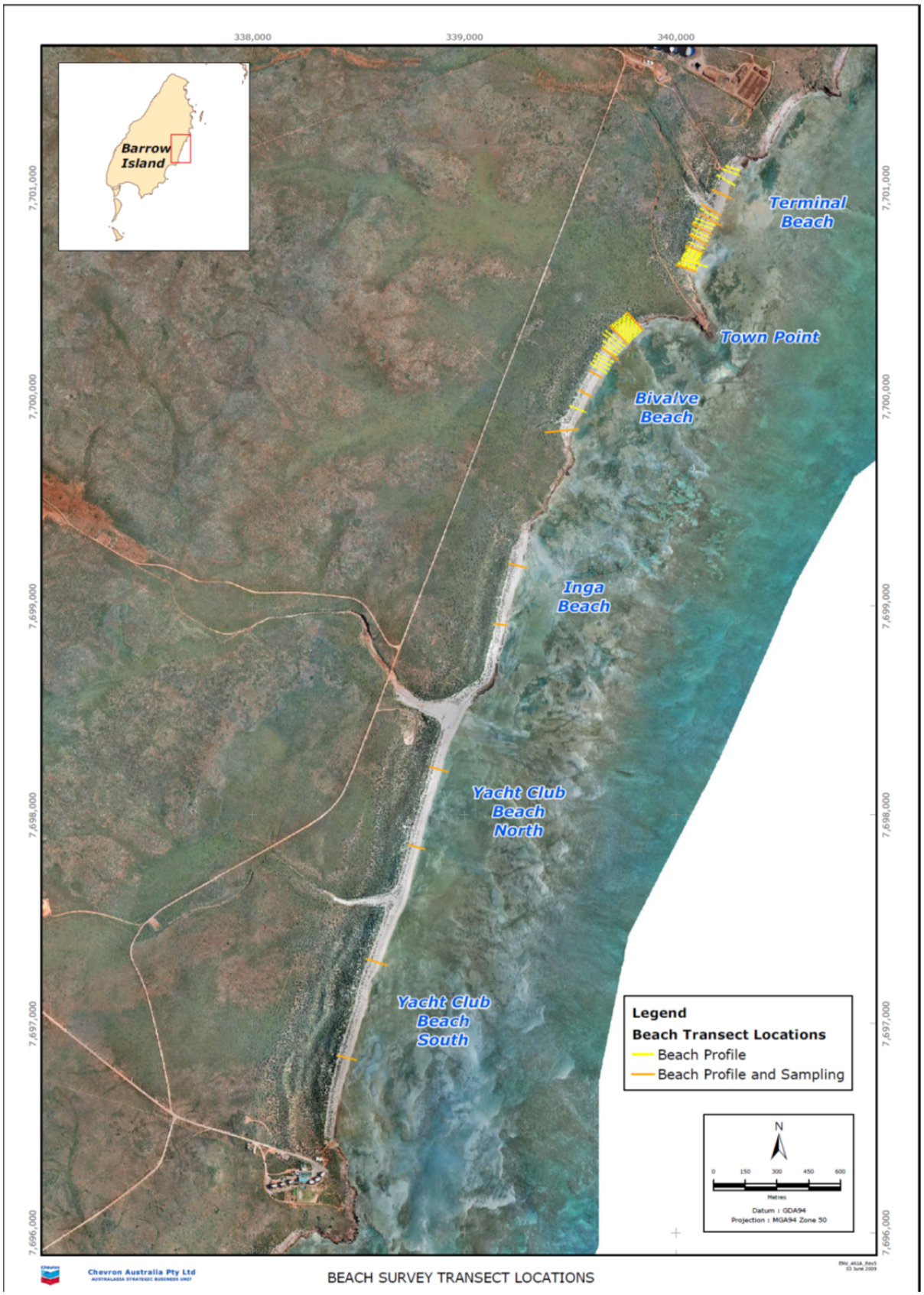
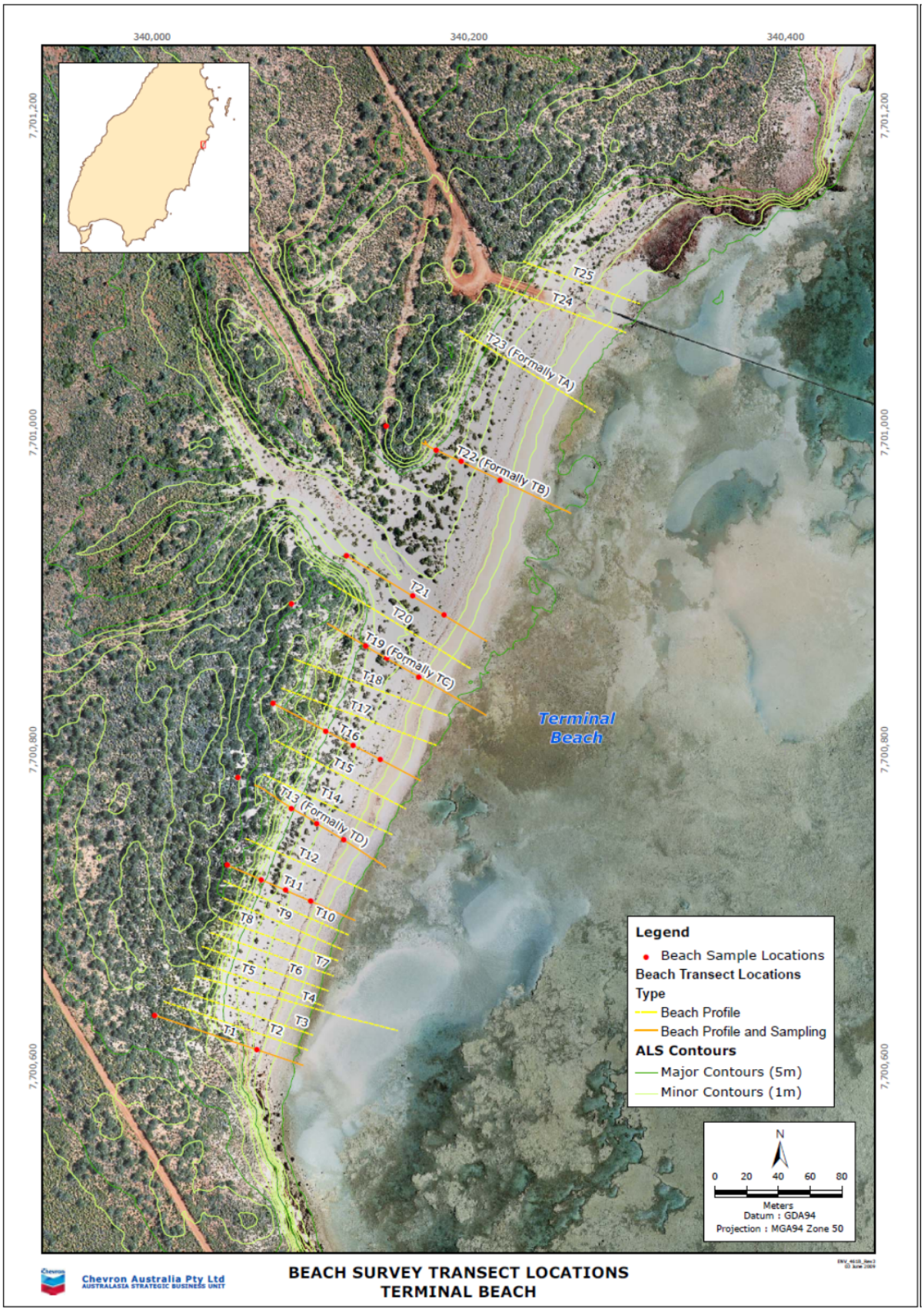
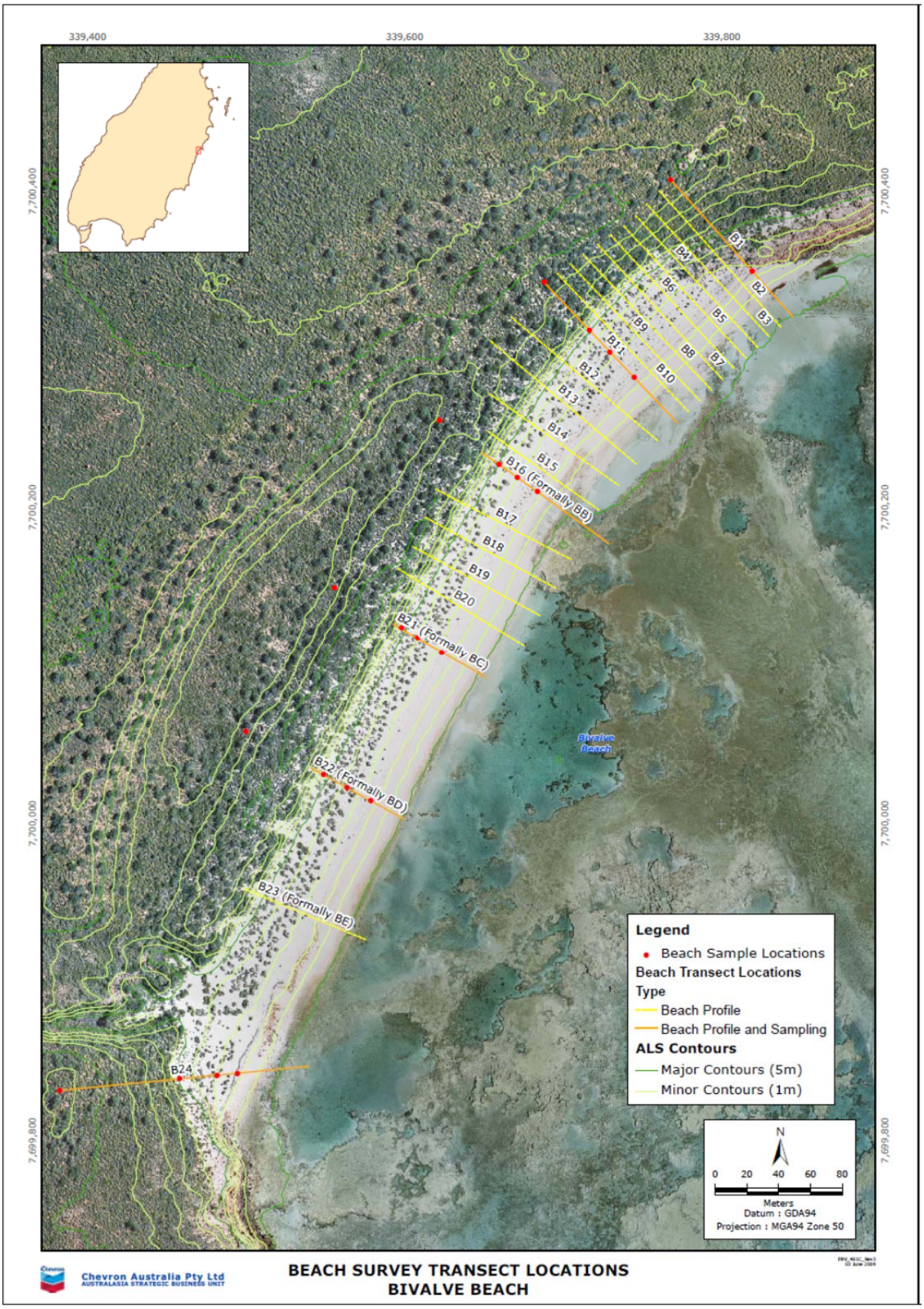
Appendix 1 Location of Beach Monitoring Transects



Beach Survey Transect Locations



Terminal Beach Survey Transect Locations



Bivalve Beach Survey Transect Locations