REPORT

Duranbah Beach Surf Quality Investigation

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Project related

TWEEDSAND BYPASSING

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1 Introduction

1.1 Overview

Tweed Sand Bypassing (TSB), formerly referred to as TRESBP, is a joint scheme between the New South Wales (NSW) and Queensland (QLD) Governments, which was set up to establish and maintain a navigable entrance to the Tweed River and restore and maintain coastal sand supply to the southern Gold Coast beaches. The project is coordinated by NSW Department of Industry – Lands (Lands) on behalf of the two States.

Duranbah Beach is the most northern beach in NSW and falls within the TSB project area, it has national and international recognition as a consistent, high quality surf break. Over the last 17 years, sand supply to Duranbah Beach has been impacted by the operation of the TSB project, as the principle fixed outlet for sand delivery to QLD is located at Snapper Rock East (SRE), refer Figure 1. This has resulted in Duranbah Beach being referred to as a “skipped” beach in terms of the sand supply that would have occurred prior to the establishment of the TSB.

The importance and need for managing Duranbah Beach, is formally recognised in the TRESBP Environmental Management Plans Operations Sub-Plan B.15, which provides for a periodic sand delivery strategy to Duranbah Beach as well as for the management of surf quality and beach amenity.

This report sets out a study that aims to identify the morphological conditions that dictate high surf quality at Duranbah Beach and how these conditions are related to TSB dredging, sand pumping and placement operations. It includes options for future TSB operational strategies that could be managed with the aim of optimising surfing amenity at Duranbah Beach.

This report was prepared by Royal HaskoningDHV (RHDHV) on behalf of Lands. It has been prepared with the understanding that this is primarily a document for internal use by the TSB organisation. It has been assumed that the reader has a level of knowledge of coastal dynamics, the TSB operations and the TSB Project Area.

Figure 1 Location of existing pipeline network (source: Lands, 2018)

1.2 Project objectives and scope

The objectives of this study are to:

- Identify and evaluate the surf zone dynamics and develop an understanding of the key coastal processes that impact surf quality at Duranbah Beach.
- Quantify and record the patterns of sand bank formation in the nearshore and offshore zones that create the highest quality surf amenity at Duranbah Beach.

These objectives are to be met through the six tasks outlined below. These tasks have been undertaken by utilising available project data to:

1. Develop an understanding of the key coastal processes that impact surf quality and beach management issues at Duranbah Beach.
2. Quantify and record the historical and current patterns of sand bank formation in both the nearshore and offshore zones that create the highest quality surf amenity at Duranbah Beach.
3. Identify and evaluate the impact of the Tweed River entrance bar and how this influences surf quality.
4. Explore how previous sand placement strategies (pumping and dredging strategies) at Duranbah Beach associated with TSB operations have historically impacted surf quality at Duranbah Beach.
5. Identify and map an idealised nearshore profile which seeks to maximise surfing amenity and can be used to provide a baseline against which changes in bathymetry due to sand delivery can be compared.
6. Propose how sand placement strategies at Duranbah Beach could be managed with the aim of optimising surf quality.

1.3 Report structure

The report includes:

- Background information on Duranbah Beach as well as surfing amenity and surf quality is provided in Section 2.
- Available surf quality data for Duranbah Beach is examined in Section 3.
- A description of the existing coastal processes at Duranbah Beach along with an overview of the surfing zones at Duranbah Beach and a process to identify period of historically high-quality surf is provided in Section 4.
- Section 5 documents the common morphological modes of the Tweed River Bar and the bars influence on surf quality.
- Historical sand placement at Duranbah Beach and its influence on surf amenity is explored in Section 6 including a discussion of the idealised beach profile and bar morphology and a sand placement strategies that aim of enhancing surf amenity at Duranbah Beach.
- A summary and discussion of the findings as well as limitations can be found in Section 6.

2 Background Information

2.1 Duranbah Beach

Duranbah Beach is located between the Tweed River and the NSW/QLD state boarder. The 350m long beach is orientated due east and is bound by the northern Tweed River training wall to the south and Point Danger headland to the north. The beach is backed by a low vegetated dune, extending for about 200m along the beach, being the widest at the centre of the beach and narrowing toward either end.

Point Danger is a remnant basaltic flow from the Tweed Volcano. It overlays much older, well-bedded argillite of the Neranleigh-Fernvale beds (NF beds) and dates to 240-290 million years ago. Originally Point Danger rounded off into the ocean until it was quarried from mid-1890 -1910 to supply rocks for the original Tweed River training walls, Figure 2.

Figure 2 Quarrying of Point Danger basalt in order to build the original Tweed River training walls, circa 1890 -1910 (Guthrie, 2011)

The Tweed River training walls were extended seaward of Point Danger in the mid-1960's giving Duranbah Beach its current geomorphic configuration. It is important to recognise that the location of the present-day entrance to the Tweed River is a relatively recent event in geological terms and there is uncertainty whether the reworking of marine sediments within the estuary may still have been an ongoing process, even without human interventions (Jacobs, 2017).

Between these two hard structures (training wall and headland), Duranbah Beach is a variable width sandy beach about 350m in length. A vegetated dune extends most of the length of the back beach as well as road and park reserve on the northern and southern ends of the dune as seen in Figure 3. The width of the sandy beach and nearshore sand bank morphology is governed by the northward movement of coastal sand along Letitia Spit (located on the southern side of the river) and across the Tweed River entrance to Duranbah Beach (Lawson, 2015). There is an estimated net northerly longshore sand transport within the region in the order of 500,000m³ per year. The annual net longshore transport has been estimated to vary from about 250,000 to 1,000,000m³ per year (Hyder, 1997).

The beach is composed of fine sand and exposed to high wave energy, with median significant wave heights in the order of 1.3m, this combination producing a low gradient beach up to 100m wide. An attached bar is usually cut by rips against the rocks at either end of the beach, with several transient rips often active around the centre of the beach as seen in Figure 3

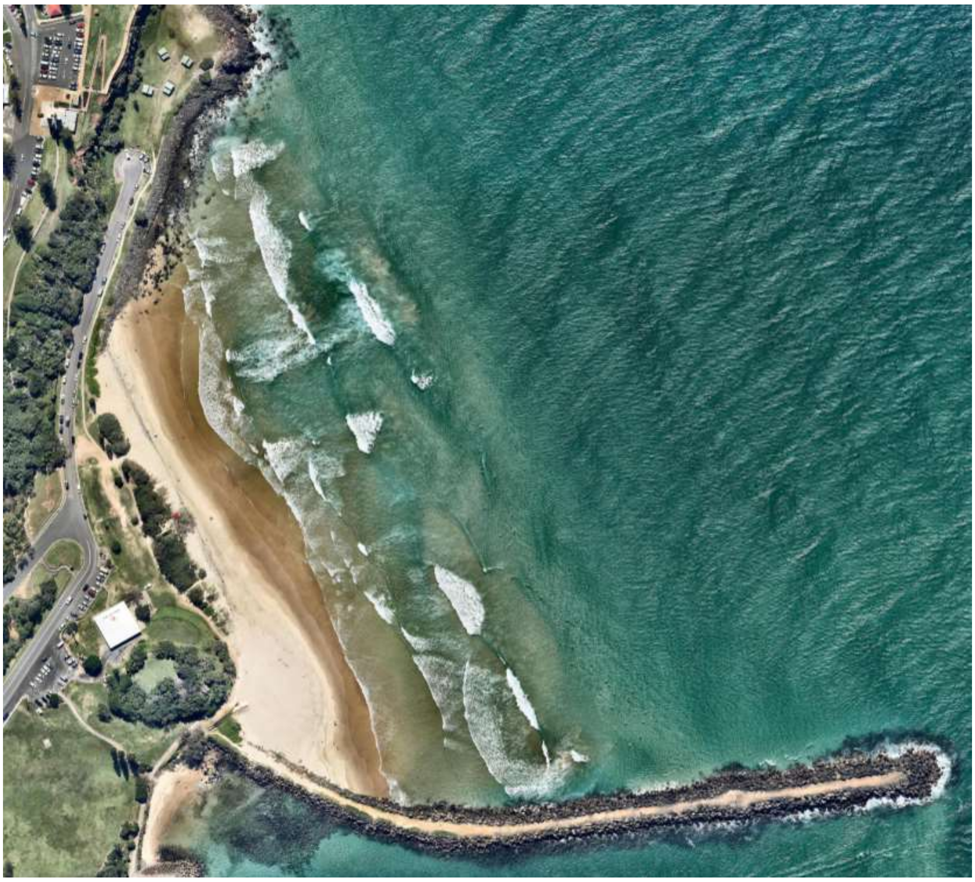


Figure 3 Duranbah Beach (source: Nearmaps, 09/04/2015)

Duranbah Beach surfing conditions have been subject to the influence of coastal engineering works since the early 1900s when the Tweed River was initially trained. Prior to 1900, the beach formed part of a dynamic river entrance. The initial construction of the training wall stabilised Duranbah Beach. Following the extension of the Tweed River training walls between 1962 and1965 by 400m, there was a reduction in littoral sand supply northward past the training walls. By the early 1990s enough sand had accreted south of the training walls, along Letitia Spit, for sand to naturally bypass the Tweed River entrance and offshore of Duranbah Beach. At the same time an ebb-tide delta formed across the entrance to the Tweed River becoming the main transport pathway for northward moving sediment. Numerous dredging campaigns were undertaken to ensure safe navigation of the Tweed River entrance. The dredging campaigns also involved nearshore nourishment of the QLD beaches to the north. In 2001 mechanical sand bypassing to QLD was re-established through the operation of the TSB project which involved the construction of a permanent fixed jetty-based sand pumping and delivery system.

The operation of the TSB has affected Duranbah Beach by influencing the amount of northward moving sediment able to form offshore sand banks and be available for onshore transport to build the beach and dune. As a result, nourishment of Duranbah Beach has been required periodically, to ensure a useable beach berm width, maintain inner nearshore shoals and manage surf quality in-line with the provisions of the TSB project. The local surfing community are well aware of the 'engineered' nature of Duranbah Beach and have accepted the operations of the TSB as the 'norm'. They closely monitor changes to the nearshore morphology and TSB sand placement operations.

Surfing conditions at Duranbah Beach fluctuate seasonally and from day to day, depending on several factors, the majority of which cannot be controlled or influenced by TSB operations. However, the underlying elements which dictate the mechanics of Duranbah Beach and place it as a valuable, consistent surf break is the influence of the Tweed River Bar (TRB) and nearshore morphology, both of which can be affected by TSB operations. Under ideal conditions, the focusing of wave energy across the TRB and development of the inner nearshore shoals are the mechanism responsible for the formation of Duranbah's characteristic "A-frame" peaks.

2.2 Surfing amenity

Surf breaks are the product of complex interactions of nearshore bathymetry, wave characteristics (height, period and direction), tide, local wind conditions, and if present, interactions with shoreline structures (ASBPA, 2011). When conditions are favourable at a given location, surf quality can generally be considered as being high or of good quality. However, surf quality can be subjective as it is often dependent on the individual surfer's skill level, preferences and mode of wave riding (standing, prone, kneeling, bodysurfing etc.). In addition, other external factors can affect a surfer's perception of amenity such as crowding, atmosphere in the line-up or ease of access to breaks.

The following section provides a primer on the key physical parameters and process used to describe surf amenity.

2.2.1 Peel angle

The peel angle of a wave is defined as the angle between the trail of the broken wave ('white water') and the crest of the unbroken wave as it propagates shoreward. It is used to describe the minimum speed required for a surfer to traverse the unbroken 'face' of the wave. Figure 4 provides an example of the estimation of peel angles using aerial photography.

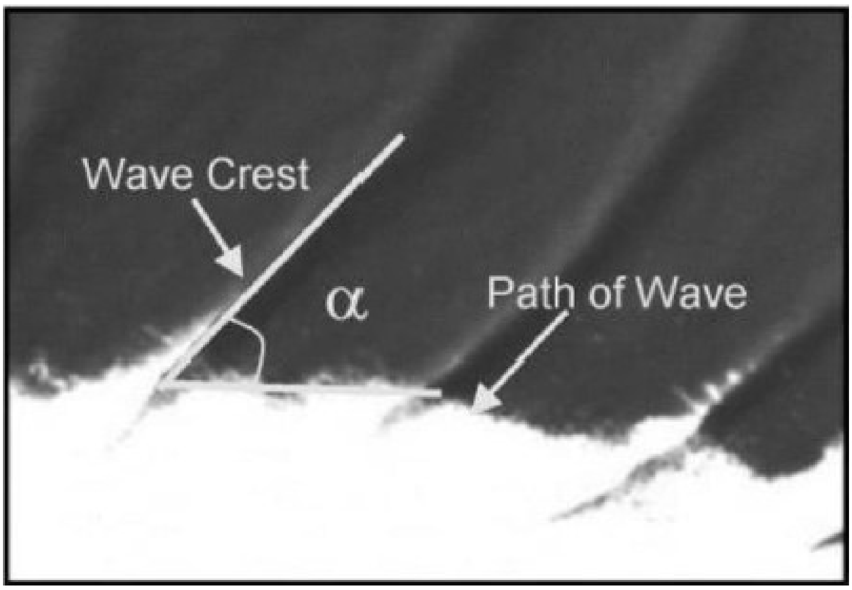
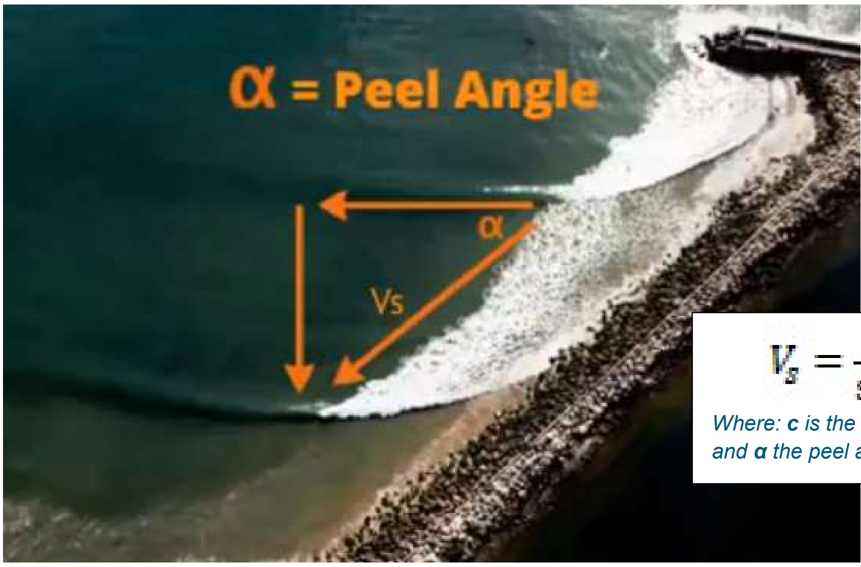


Figure 4 Estimation of wave peel angle using aerial photography (Mead, 2001).

The peel angle governs the down-the-line velocity (speed) of the surfer as the wave breaks progressively along the wave crest. A small peel angle is associated with a fast down-the-line velocity and larger peel angles with slower down-the-line velocities. The down-the-line velocity experienced by the surfer is also a function of wave celerity, as seen in Figure 5 (Henriquez, 2004). The speed an individual can reach under their own power also depends on the skill level of the surfer, the wave height and breaker intensity (available power), the mode of wave riding and the surfer's equipment.

The peel angle ranges between 0˚ and 90˚. Larger peel angles suit beginners (70°-90°). Smaller peel angles (30°-50°) are more challenging and are suited to more advanced surfers. Peel angles less than about 25˚ are described as 'close-outs' in surfing terms and mean a large section of the wave crest breaks simultaneously and thus cannot be surfed (Mead and Black, 2001). Even top professional surfers are unable to generate the speed required to stay clear of the breaking white water for these peel angles.



$$V_s = \frac{c}{\sin \alpha}$$

*Where: **c** is the wave celerity; and **α** the peel angle.*

Figure 5 Peel angle and surfer velocity representation, photo Tom Cozad, (source: https://www.youtube.com/watch?time_continue=284&v=A_ExZbTwFps:)

2.2.2 Breaking intensity (BI)

When waves propagate towards the shore or over a shallow bathymetric feature (e.g. reef, sandbar), shoaling occurs up to the point when the ratio of the wave height to the wavelength increases, steepening the wave until it becomes unstable and breaks. Depth-limited breaking will occur when orbital velocities, increasing towards the beach exceed the wave phase speed which decreases in the landward direction. The breaking wave height, Hb is defined as the height between the wave trough and the wave crest prior to the point of the crest overtopping (breaking). Wave breaking can be classified into four main types; spilling, plunging, collapsing and surging (Table 1).

Waves suitable for surfing generally break in the range between spilling and plunging types. When these waves are combined with an appropriate peel angle, surfing amenity is enhanced. Mead (2001) concluded that several factors including wave height, wave period, wind strength and direction can also affect the wave steepness and thus breaker intensity. However, the biggest influence on the shape of breaking waves is induced from changes in the bathymetry.

Galvin (1968) and Battjes (1974) implemented the so-called breaker type index and Iribarren Number (or surf similarity parameter), respectively, which allows the classification of the breaker type as a function of wave steepness and seabed slope (limits are presented in Table 1).

$$\xi_b = \frac{\beta}{\sqrt{H_b / L_\infty}}$$

Where: β is the bottom slope; Hb the wave height at breakpoint; and $L\infty$ the deep-water wavelength.

Table 1 Description of four main breaker types

<table>
<tr><th colspan="2">Breaker Types (after SPM, 1977 and Galvin, 1968)</th></tr>
<tr>
<td>

Spilling Breaker

- Bubbles and turbulent water spill down front face of wave
- The upper 25% of the front face may become vertical before breaking

Iribarren Number:

$\xi_b < 0.4$

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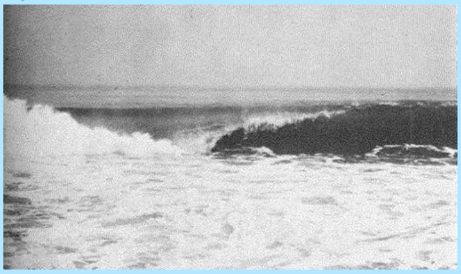
Plunging Breaker



- Crest curls over a large air pocket
- Smooth splash-up usually follows

Iribarren Number range:

$0.4 < \xi_b < 2.0$

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Surging Breaker

- Wave slides up beach with little or no bubble production
- Water surface remains almost plane except where ripples may be produced on the beach face during runback

Iribarren Number:

$\xi_b > 2.0$

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<td>

Collapsing Breaker

- Breaking occurs over lower half of wave
- Minimal air pocket
- Usually no splash-up with bubbles and foam present

Iribarren Number:

$\xi_b > 2.0$

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2.2.3 Ride length (R_L)

The length of a surfer's ride is another factor in the perceived amenity of a surfing wave. The ride length is simply defined as the time elapsed during each ride. As a rule of thumb, the longer the ride length, the greater the amenity. However, this is a subjective correlation as amenity is generally dependant on the relationship of the ride length with breaker intensity and peel angle, as an example; a short ride length with a low peel angle and high breaker intensity may be to one surfer as amenable as a long ride length with high peel angle and low breaker intensity to another surfer.

The distance covered by the surfer over the ride length does not have a linear relationship with surfer velocity (V_s). This is due to a wave having a number of 'sections' of varying lengths. These sections are due to peaks in wave crest height along the incoming wave orthogonal[1]. The peaks can be caused by; interaction of swells with different periods and directions, wave super-position and from undulating bathymetry causing the orthogonal to have different wave height (and steepness) along its length. A new wave section begins when there is a change in breaking wave height (H_b), peel angle (α), or breaking intensity (BI), and is said to have a section length, S_L.

Each of these sections requires the surfer to make alterations in their speed (V_s) in order to traverse the unbroken wave face. Skilled surfers anticipate these changes and manage V_s by performing different manoeuvres on the wave face as well as atop the breaking portion of the wave. Some surfers see amenity in waves with several sections on which numerous manoeuvres may be performed and some view superior 'wave quality' as uniformity of the (desired) peel angle along the ride length.

The inherent subjectivity of surf amenity should be noted when investigating the wave quality parameters described above. Due to its more exposed location and orientation, Duranbah Beach is generally exposed to more swell than the Gold Coast beaches to the north. The consistency of waves means Duranbah Beach is heavily utilised for surfing. Duranbah Beach is recognised for its high breaking intensity, low peel angles and short, intense rides suited to high-performance surfing.

[1] The wave orthogonal is defined as the unbroken line of the wave crest as it propagates forward

3 Available data

3.1 Metocean data

Historical data from the Coolangatta Airport weather station and Tweed directional waverider buoy have been utilised for analysis in this study. Their location, operation and long-term statistics have been detailed further as part of the metocean analysis undertaken in Section 3.2.

3.2 Bathymetric data

The TSB and City of Gold Coast (the City) undertake semi-seasonal hydrographic and beach surveys of Duranbah Beach and surrounding areas. The surveys are undertaken by a variety of methods with varying spatial resolution; marine LiDAR, Multibeam Echosounder (MBES), Single Beam Echosounder (SBES) and RTK GPS. These surveys differ in their extent and resolution however, the TSB and the City have an extensive record of Tweed River entrance and Duranbah Beach nearshore morphology with good temporal resolution.

As part of this analysis, raw soundings of concurrent beach and entrance survey data were interpolated onto a 2m x 2m resolution mesh, covering the spatial extent of each given dataset. **Appendix B** shows these interpolated datasets placed on a timeline with previously interpolated datasets of the TBR and Duranbah Beach to determine trends in bar morphology.

Beach profile data is also regularly taken perpendicular to the shoreline from the upper dune (~+5mRL) to nearshore sub-aerial sandbar (~-3mRL). The three main transects (DBM 1 to 3) where data has been consistently collected are equidistantly spaced along the length of Duranbah Beach (Figure 32).

3.3 Coastal monitoring

During the period from 2010 to 2015 two organisations have managed coastal monitoring cameras from the Point Danger Headland; Coastalcoms and Water Research Laboratory (WRL). The cameras take an elevated view of Duranbah Beach from differing angles. Select images and videos have been used to identify surf quality, surfer numbers and wave breaking patterns for select periods at Duranbah Beach.

In addition to these fixed position cameras, TB and the City undertake regular coast and project-wide aerial photography via fixed wing and helicopter. These images, Google Earth and Nearmaps have been used to cross-reference surf and geomorphic conditions at Duranbah Beach for this study.

3.4 TSB operational data

TSB supplied historical sand pumping data along with records of dredging. This information includes the timing, volumes and placement location for historical sand placements from both pumping and dredging sand transfers.

3.5 Surf quality data

The historical recording of surf quality or surf amenity data on a local beach scale is virtually non-existent, particularly regarding surf quality and transient sandbar morphology. Surf reports and ratings tend to be on a regional scale and at this level are concerned predominantly with wind speed and direction as well as wave parameters (height, direction and period) and to a lesser extent tidal fluctuation. As such, tracking good or excellent surfing conditions at a beach scale in a manner that avoids the subjectivity of these records is challenging.

Coastalwatch (coastalwatch.com.au) have been providing regionally-based surf reports of the Gold Coast since 1998. The chief forecaster John Charlton is a life-long surfer who has been providing daily surf reports of the region for over 35 years. John is a trusted advisor of surf conditions amongst Gold Coast surfers. Coastalwatch has provided over 13 years of these daily surf reports, which in some instances details the most suited beach for the daily surf conditions but also offers a surf quality rating between one to ten (one = poor, ten = highest quality). Table 2 shows the percentage occurrence of surf quality ratings from 3-8.

Table 2 Coastalwatch surf quality rating and percentile of occurrence of each rating.

Surf quality rating (1-10)	Percentage of ratings less than
3	19%
4	40%
5	68%
6	84%
7	95%
8	99%

4 Duranbah Beach coastal processes and surf amenity

4.1 Duranbah Beach metocean conditions

In order to quantify surf quality at Duranbah, it is essential to investigate the physical parameters governing surf amenity. This subsection summaries the meteorological and oceanographic conditions (wind, waves, water levels and currents) at the study site as they relate to surfing and wave quality. The following report section describes the geomorphological parameters affecting wave quality (bathymetric conditions and variability). It is the interplay of these parameters (metocean and geomorphological) that govern the wave quality and subsequent surfing amenity.

4.1.1 Wind

Wind measurements were sourced from the Bureau of Meteorology (BoM) nearby Coolangatta Airport weather station (station number: 40717) for the 18 year period from October 1987 to October 2005. The proximity of the station to the study site can be seen in Figure 7. While the airport site is afforded some sheltering from the south and east due to Point Danger and Fingal it has been deemed a suitable proxy for this study.

Ten-minute wind speed and direction recordings were averaged over three-hour intervals for the collection period. A wind rose for the entire collection period can be seen in Figure 6 (left). The wind data was then filtered to ascertain wind speed and directions that occur only in daylight hours (civil dawn to civil dusk) under the assumption that surfing will predominantly be practised between these times, Figure 6 (right).

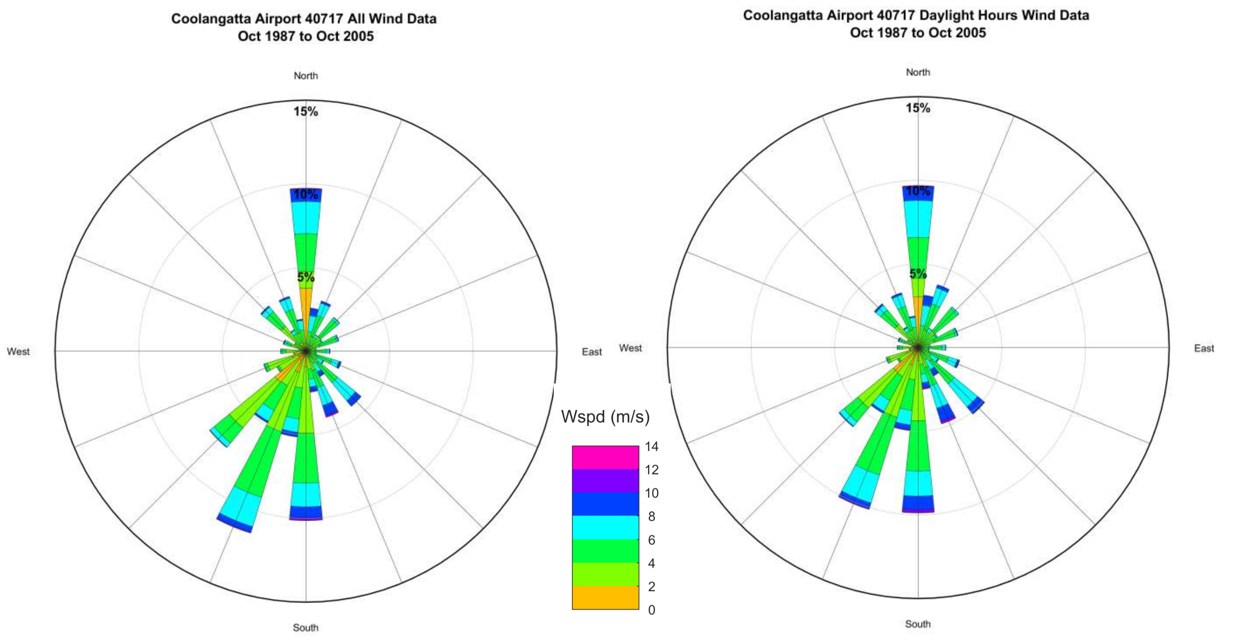


Figure 6 Wind rose of all three hourly averaged wind speed and direction (left) Similar wind rose for daylight hours (right). BoM weather station, 40717: Coolangatta Airport Oct. 1987 to October 2005.

The daytime winds show a slightly higher occurrence of directionality from the easterly quadrant (onshore directed at Duranbah Beach). Winds from these directions (from the sea blowing to the land) are typical less-favoured by surfers, especially if they exceed 5-10kts in magnitude.

4.1.2 Waves

The QLD Department of Environment and Science (DSITI) and the TSB jointly operate the Tweed Heads waverider buoy. The buoy was installed January 1995 in 22m of water; it is located approximately 2km south of Duranbah Beach, as seen in Figure 7.

The proximity of the buoy to the study site and its deployment depth is suitable in describing the wave conditions just offshore of the beach. The long-term statistics and wave roses for the Tweed wave buoy can be seen in Figure 8 and Table 3. In general, at the 22m depth contour (wave buoy location), waves come from just south of east, with less frequent events coming from the north. The largest wave events appear to come from north of east.

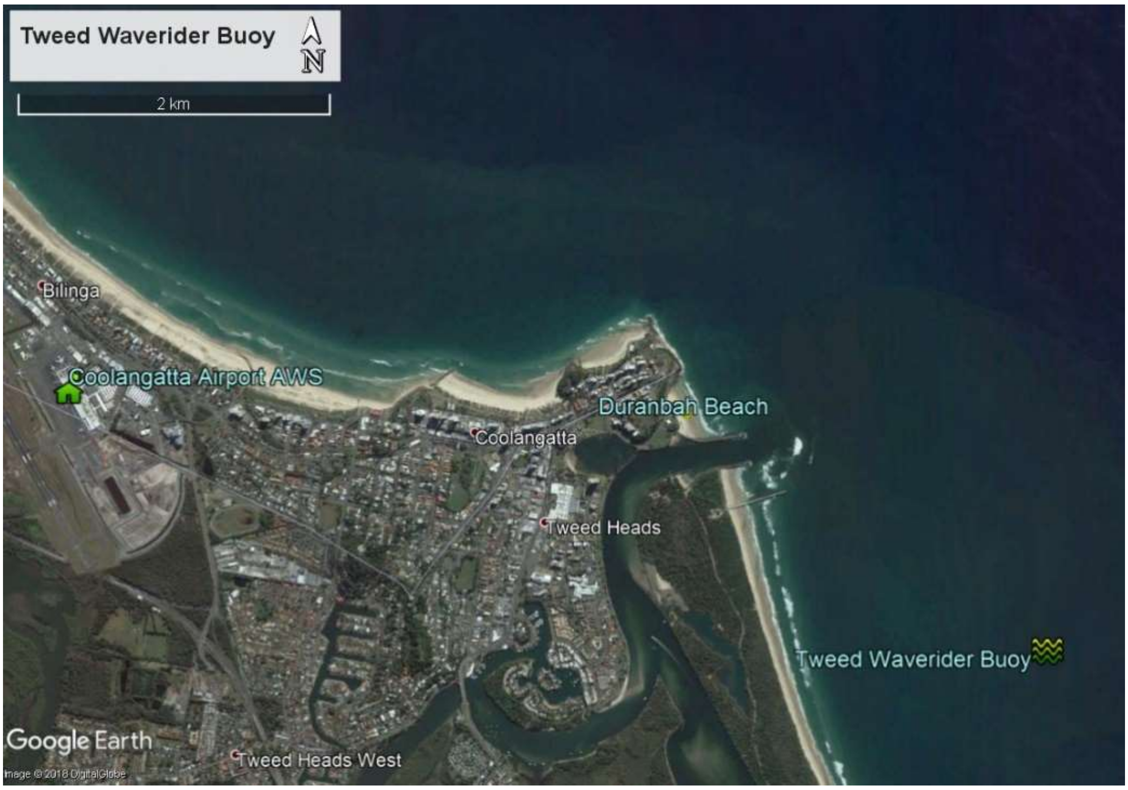


Figure 7 Tweed waverider buoy, Coolangatta Airport (Automated Weather Station and Duranbah Beach location.

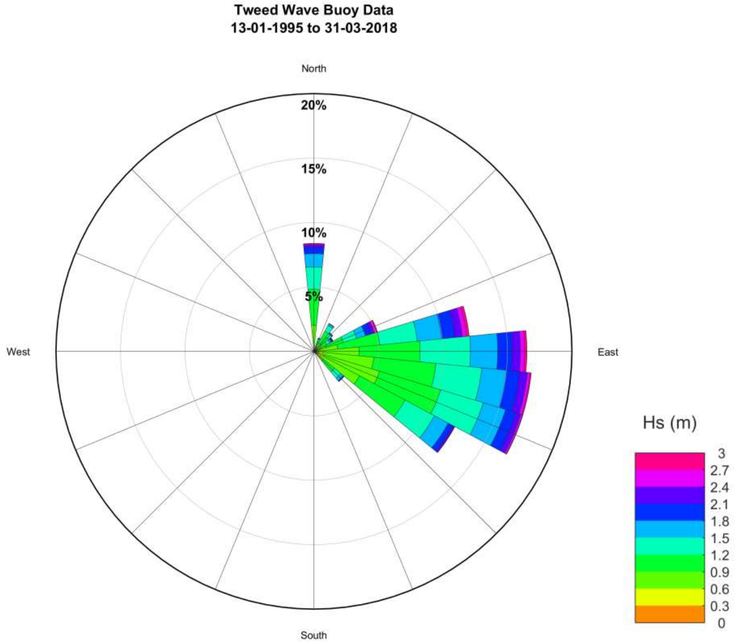


Figure 8 Long term (24 years) wave rose for the Tweed Waverider Buoy

Table 3 Long term (24 years) and seasonal statistics for the Tweed Waverider Buoy

Parameter	Statistic	Long term average (24 years)	Winter	Autumn	Summer	Spring
Hs (m)	Average	1.24	1.17	1.37	1.29	1.11
	20th percentile	0.84	0.77	0.93	0.89	0.81
	90th percentile	1.86	1.82	2.05	1.91	1.58
	Max	7.52	5.57	7.52	6.71	3.72
Tp (s)	Average	9.19	9.90	9.51	8.70	8.65
	20th percentile	7.02	7.65	7.61	6.62	6.20
	90th percentile	12.19	12.97	12.18	11.52	11.98
	% of time sea (Tp<8s)	32%	23%	25%	39%	42%
	% of rime swell (Tp>8s)	68%	77%	75%	61%	58%
Peak Wave Direction (°N)	Weighted average	86.2	86.5	83.3	87.7	91.3
	Average	90.5	94.6	90.7	89.3	87.3
	STD	32.8	34.8	30.3	28.6	36.8

The extension of the Tweed River training walls effectively redirected the longshore current (and sediment transport pathway) along the shoreline to travel seaward of the Tweed River entrance. The subsequent introduction of the TSB to regulate the amount of northward-moving sediment that travels around the entrance plays an important role in the size, shape and location of the ebb-tide sand bar offshore of the Tweed River. The dimension and location of the bar govern the amount of wave refraction, diffraction and subsequent super-position of wave orthogonals that occur in its lee. The gradients in wave radiation stress caused by this feature are the predominant drivers of localised nearshore currents at Duranbah Beach.

4.1.3 Currents

The current regime in the nearshore area of Duranbah Beach is an interplay of several physical processes; the angle of the incoming wave energy, the ebb and flood of the adjacent Tweed River, gradients in wave radiation stresses due to undulating bathymetric features breaking waves in non-uniformity, transient and stationary rip cell formation in the nearshore. In general, there is a regional net northward current due to the average wave direction offshore (Table 3) that occurs in shallow depths, inshore of wave breaking and follows the orientation of the coastline. Localised tidal currents caused by the ebb of the Tweed River have been shown to have an intermittent southerly trend. In addition, the East Australian Current (EAC) is located offshore and has a net southerly direction.

There have been several data collection exercises (RHDHV, 2017 and RHDHV, 2018) in the nearshore zone of Duranbah collecting directional current data. These campaigns have focussed on single point locations offshore of the wave-breaking zone as the data has been used for sediment transport studies. The collection of surf-zone current data is rarely undertaken due to the logistical problems in the collection process as well as the high temporal and spatial variability of the current field. It is believed that these transient, short duration current patterns have a greater impact on nearshore sandbank formation and wave quality than the longer, phase-averaged beach-wide current fields.

4.1.4 Sediment transport regime

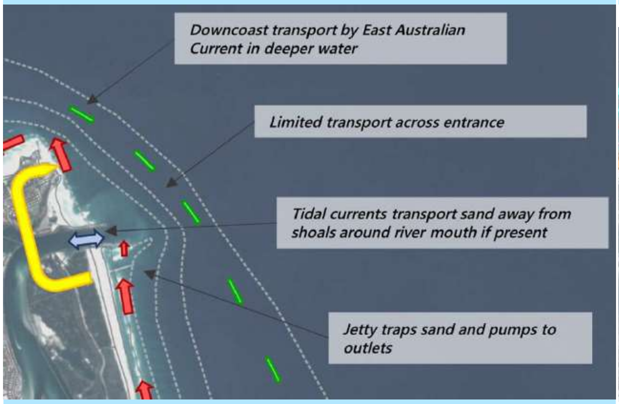
Numerous studies investigating the current regime and sediment transport regime have been undertaken in the Duranbah Beach area. The most recent review at the time of this study was carried out by Jacobs (2017). The study produced a quantified conceptual sand transport model of the TSB beaches for the four (4) most relevant metocean scenarios; modal SE swell, SE storm event, typical NE wave and NE storm event. These conceptual models can be seen in Table 4.

Two additional sand tracing studies using actual measurements of sand transport processes have been undertaken in the vicinity of Duranbah Beach. In one study the sand tracer was released offshore of from the hopper during a TSB dredging campaign. The findings of this study are summaries in Figure 9. The second study focused on TSB sand pumping operations, with the sand tracer released from the Snapper Rocks East (SRE) outlet during a typical sand pumping exercise. The findings of this study are summaries in Figure 10 (RHDHV, 2018).

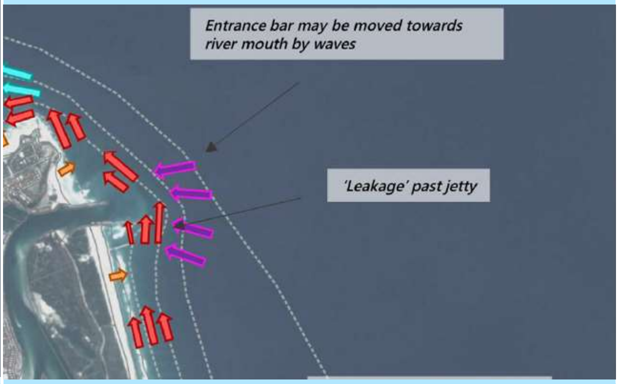
Table 4 Tweed Quantified Conceptual Sediment Transport Model (source: Jacobs, 2017)

Conceptual Sediment Transport Model

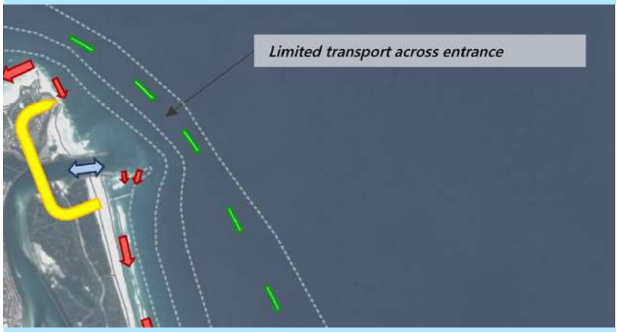
Modal SE Swell



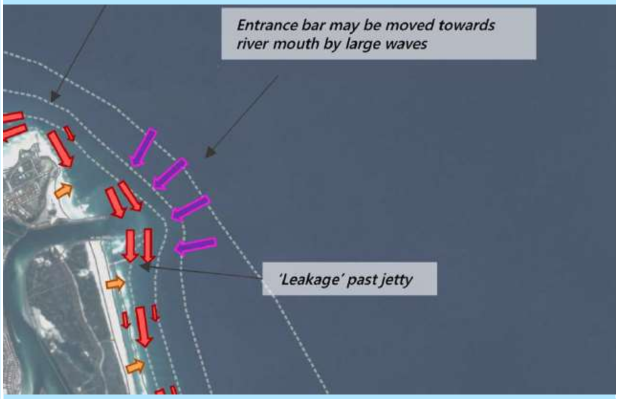
SE Storm Event



Typical NE Wave



NE Storm Event



LEGEND

Transport by tides and floods	Littoral transport
Transport by East Australian Current	Cross-embayment transport
TSB sand bypassing operations	Cross Shore transport

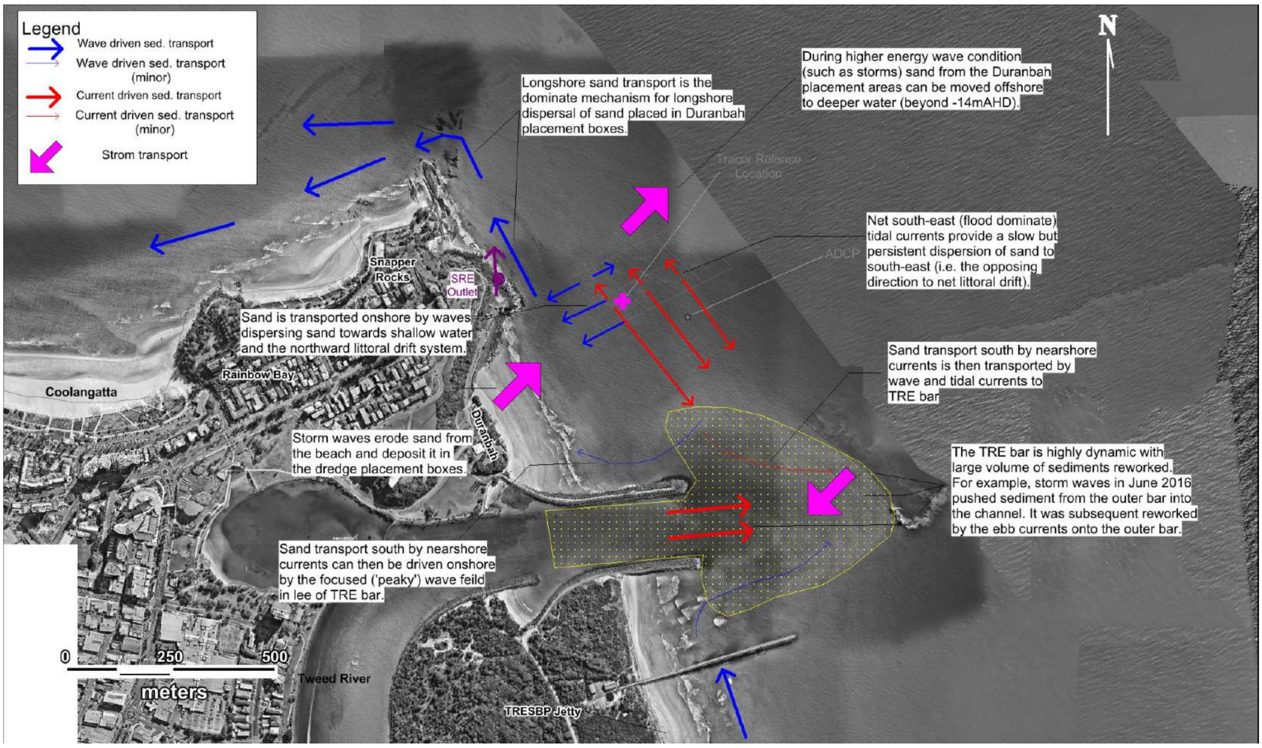


Figure 9 Conceptual description of sand transport processes inferred for the dredge material sad tracing study findings (source: RHDHV, 2017).

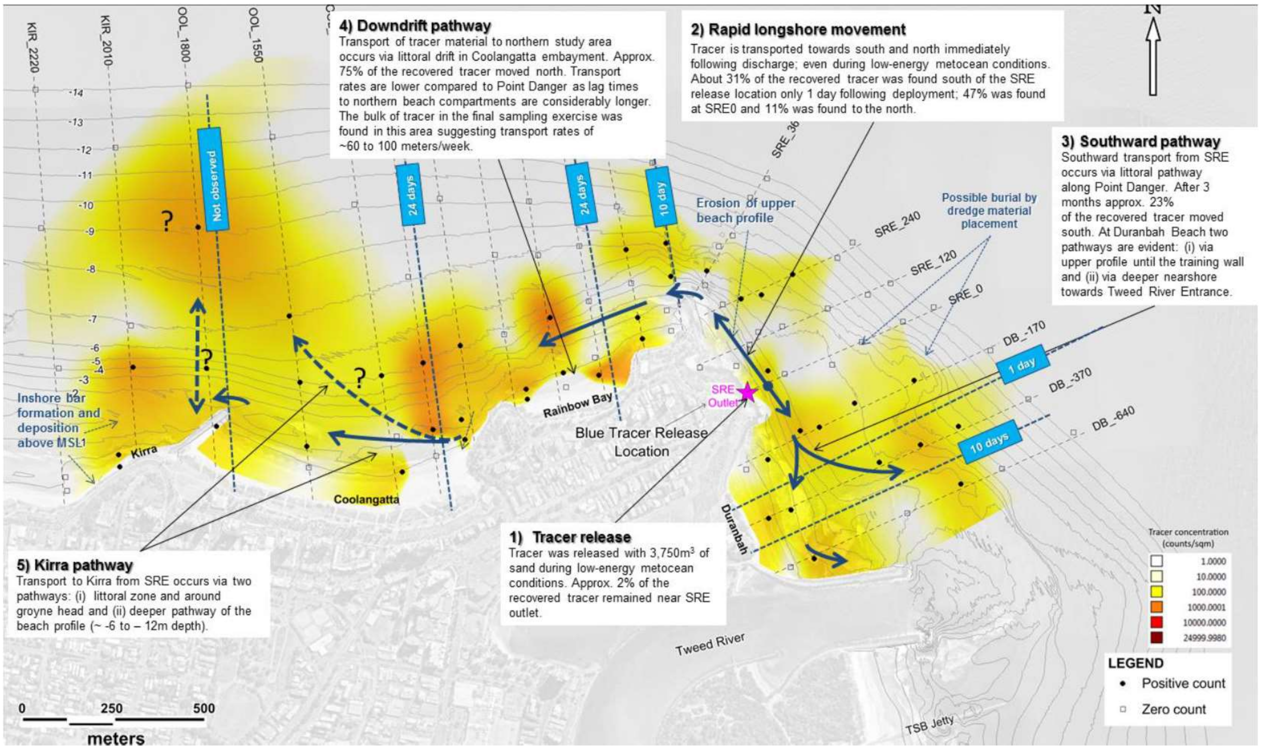


Figure 10 Conceptual description of main sand transport mechanisms and pathways following release from Snapper Rocks East outlet based on finding of Snapper Rock East sand tracing study (source: RHDHV, 2018).

4.2 Surfing zones at Duranbah Beach

In terms of surfing, there are three main zones along Duranbah Beach; northern training wall (the Wall), the Middle and Lovers Left, see Figure 11. A description of each of these zones, including the coastal processes, wave breaking mechanics and bathymetric conditions is provided in the following sub-sections.

Figure 11 Aerial image of Duranbah Beach designating the boundaries of the three surfing zones of Duranbah Beach (image: Google Earth, 5 May 2016).

4.2.1 Northern training wall (The Wall)

The Wall is located at the southern end of Duranbah Beach. The spot typically breaks adjacent to the northern training wall. On some occasions the wave can start out near the end of the training wall. The wave is predominantly a medium length right hand break, or right-hander. A right-hand wave breaks to the right when viewed by the surfer facing the beach. There is a permanent rip that runs out to sea from the shoreline along the wall. Along the northern edge of this rip a sand spit extends out to sea where incoming waves peel along its length. Depending on the angle of the incoming wave crest and section length, sometimes a shorter left-hand wave breaks into the rip against the training wall (Figure 12 right). However, the right-hander is the most surfed wave along this zone of the beach.

Figure 12 High quality surfing conditions at The Wall (pictures: Andrew Shield)

The sand spit of which the waves break along at the Wall is one of the most consistent geomorphic features of Duranbah Beach due to the permanence of the rip at this location. As most of the other rips along the centre and at the northern end of Duranbah Beach are transient or semi-permanent in nature, a high proportion of the water that is trapped along the southern part of the beach by incoming waves makes its way back out to sea through this rip, as seen in Figure 13.

Figure 13 Geomorphic features of the 'Wall' at the southern end of Duranbah Beach. (image: Google Earth, 15 May 2016).

Incoming waves are refracted into the training wall as they enter the southern end of Duranbah Beach. Once the waves encounter the shallower water of the sand spit as well as the seaward flowing rip current, they shoal and break along the length of the sand spit. The wave terminates with a close-out at the end section or dissipate into a transient rip in the centre of the beach.

4.2.2 The Middle

Sometimes referred to as 'the middle section', 'middle peak' or 'middle bank', this wave breaking zone consists of between one to three 'A-frame' peaks (waves that peak up and break in both a left and right direction). As the name states, this section of Duranbah is located in the centre of the beach, just north of the Wall and just south of Lover's Left (**Sec 4.2.3).** Example images showing high quality surfing conditions at the Middle are provided in Figure 14.

Figure 14 High quality surfing conditions on the peaks in the Middle section of Duranbah Beach (pictures: Andrew Shield)

The Tweed River ebb-tide delta (or entratnce bar) plays an imprtant role in both breaking wave height and surf quality. The depth, size and location (plan form) of the entrance bar is a combination of preceding wave energy and direction, tidal and fluvial outflow of the Tweed River as well as the operations of the TSB. The shallowest parts of the entrance usually sit at depths of around five to seven metres. The bar is generally a scallop shape with a steep gradient on its shoreward face within the river entrance and a gentler seaward slope of around 1 in 50. Waves that are not large enough to break on the bar, refract, diffract and shoal as the incoming wave crest encounters the change in the bathymetry. The shape of the bar refracts wave fronts around both of its outer edges, causing these transformed wave fronts to cross over one another in the lee of the bar and prior to reaching the beach, Figure 15. This interaction in wave fronts is known as constructive interference as the meeting of the wave fronts results in an addition of the wave heights at the intersection point, a schematic of which can be seen in Figure 16.

Consequently, during periods of medium to low wave heights along the rest of the Gold Coast, this section of Duranbah experiences larger waves as a secondary effect of the interference. These “peakier” waves are more amenable to high performance surfing with short but intense waves. The number and location of the resulting peaks as well as the breaking intensity and subsequent peel angles is a function of the shape, depth and location of the entrance bar to the wave breaking zone as well as incoming wave height, period and direction.

Figure 15 ‘Confused’ wave crests in the lee of the Tweed River entrance bar. Two distinct peaks can be seen to be breaking along the ‘Middle’ section with several surfers centred on the breaking point of each (source: Google Earth 30 April 2009)

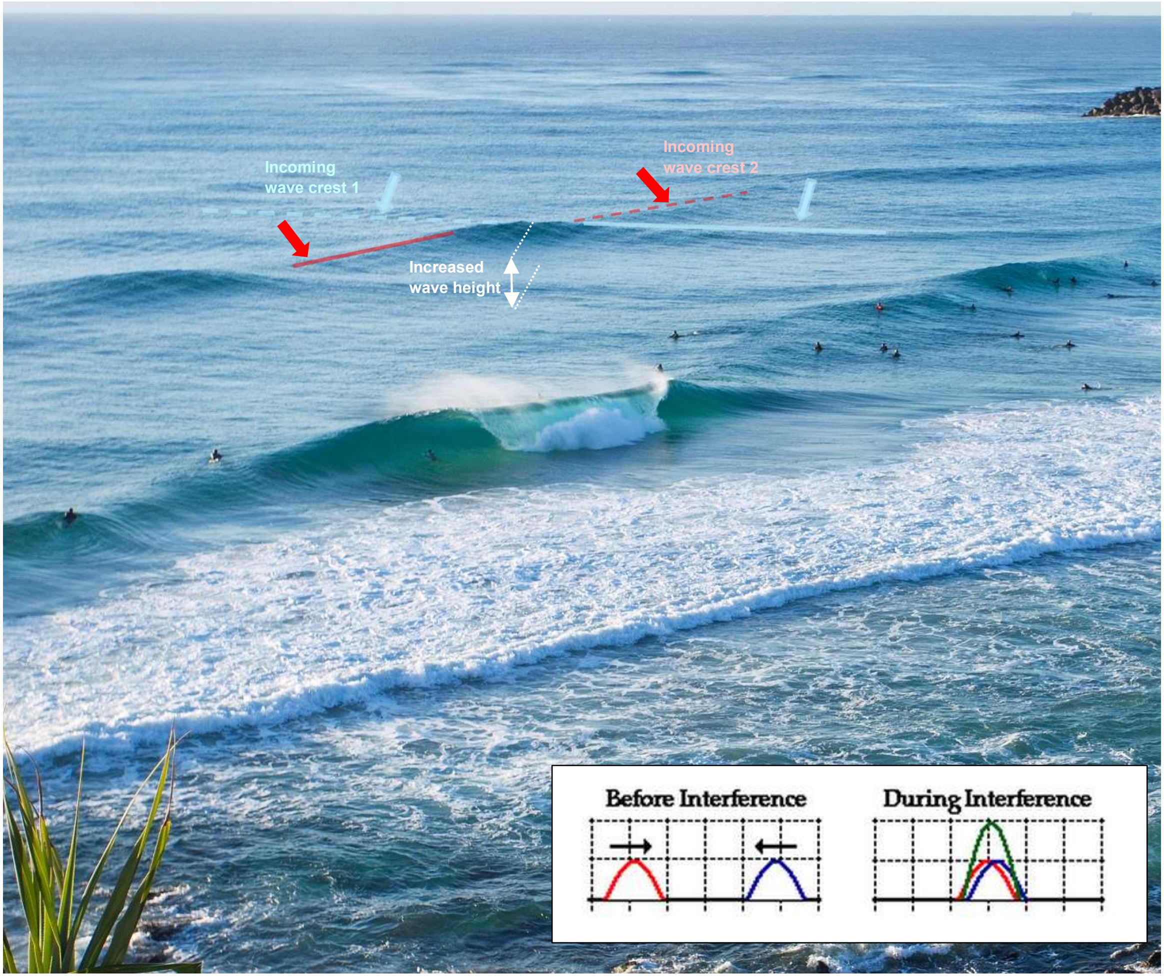


Figure 16 Example of constructive interference of wave crests or superposition as a result of an offshore entrance bar. (Source: Shield, 2018).

The consistency of the breaking will also cause localised changes in the surf zone current field resulting in changes to the bed morphology due to the formation of semi-permanent rip currents. These rips are generally transient in nature. However, if similar metocean conditions persist for extended periods, transverse bar and beach sand bank formations can form which can also affect the permanence of surf conditions/quality, modifying the breaking location of the transformed wave crests. This is generally a secondary driver to surf quality along this section of the beach compared to the influence of the entrance bar.

4.2.3 Lovers Left

The area in the northern most corner of Duranbah Beach is referred to as Lovers or Lovers Left. As the name suggests, this is predominantly a left-hand break. Lovers Left requires an east north-east (ENE) to north (N) swell to refract and peel along the thin spit of sand at the base of the southern Point Danger Headland, Figure 17.

Figure 17 Geomorphic features of Lovers Left at the northern end of Duranbah Beach and wave refraction pattern under an ENE – N swell direction. (image: Google Earth, 18 July 2016).

Due to the less frequent occurrence of north-east swells of rideable height in combination with offshore or light, Lovers Left is known as an inconsistent surf spot. Even though it is generally classified as a pointbreak, Lovers Left is sometimes referred to by surfers as any left-hand ride that occurs at the northern end of the beach, Figure 18. Wave are generally short in nature and have a high breaker intensity.

Figure 18 High quality surfing conditions at the Lovers Left section of Duranbah Beach (pictures: Andrew Shield). Note the bottom picture is located further south (towards the middle of Duranbah Beach) than the top.

4.3 Identification of surf quality

To identify high quality surf at Duranbah Beach, analysis was undertaken on the Coastalwatch dataset. A search was used to find days when the terms '*Duranbah', 'Dbah'* or '*D'bah'* were mentioned in the surf report. An additional filter identified when the surf quality rating was given as higher than a score of seven (top 1% of surf quality ratings). Of the 7,022 individual surf reports, 4,099 (58 per cent) mentioned Duranbah as the most suited beach for the daily conditions. This reaffirms the beach's consistency surf status. Of these 4,099 mentions, 127 individual records had a surf quality rating higher than seven, this analysis is visualised in Figure 19.

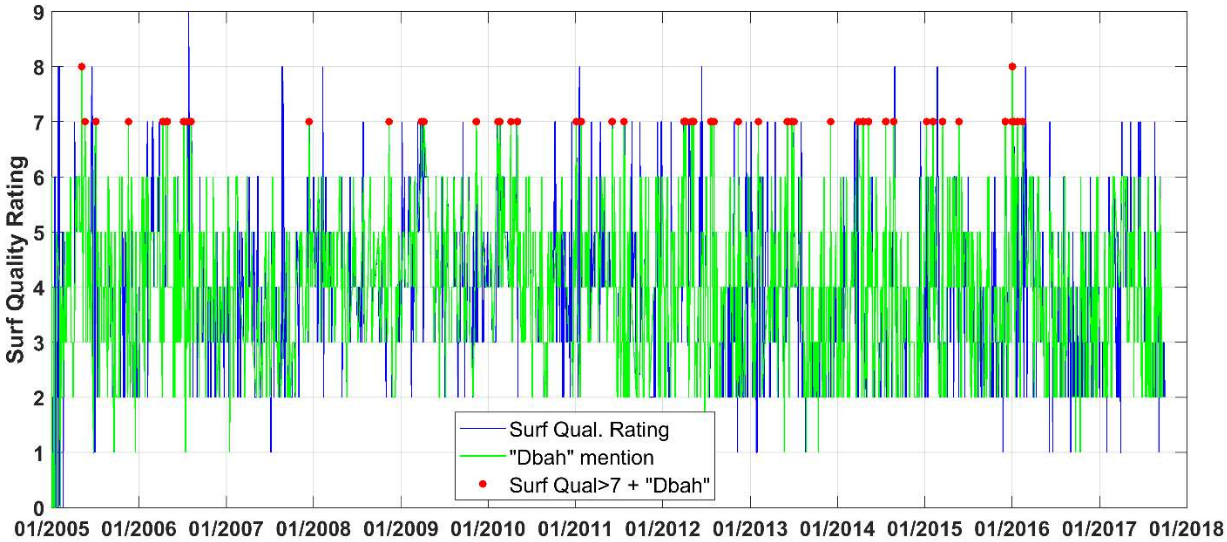


Figure 19 Analysis of Coastalwatch surf report data undertaken by John Charlton from 2005 – 2018. Blue line represents surf quality rating (1-10). Green line represents surf reports that mention 'Duranbah'. Red dots signify surf quality rating greater than 6 and mentioning Duranbah.

Figure 20 shows the individual reports (red dots) being grouped into clusters meeting the search criteria. These clusters have been used to identify periods when surf quality has been recognised as being high at Duranbah Beach (top 1% of ratings). Six high quality clusters were identified and can be seen circled in Figure 20 and detailed in Table 5.

These clusters were then cross-checked with internet searches for "Duranbah" attained through the *Google Analytics* online tools to determine if there has been public searches, check-ins or video up/download activity undertaken. This cross-check of search history or activity can be seen represented by the black line in Figure 20.

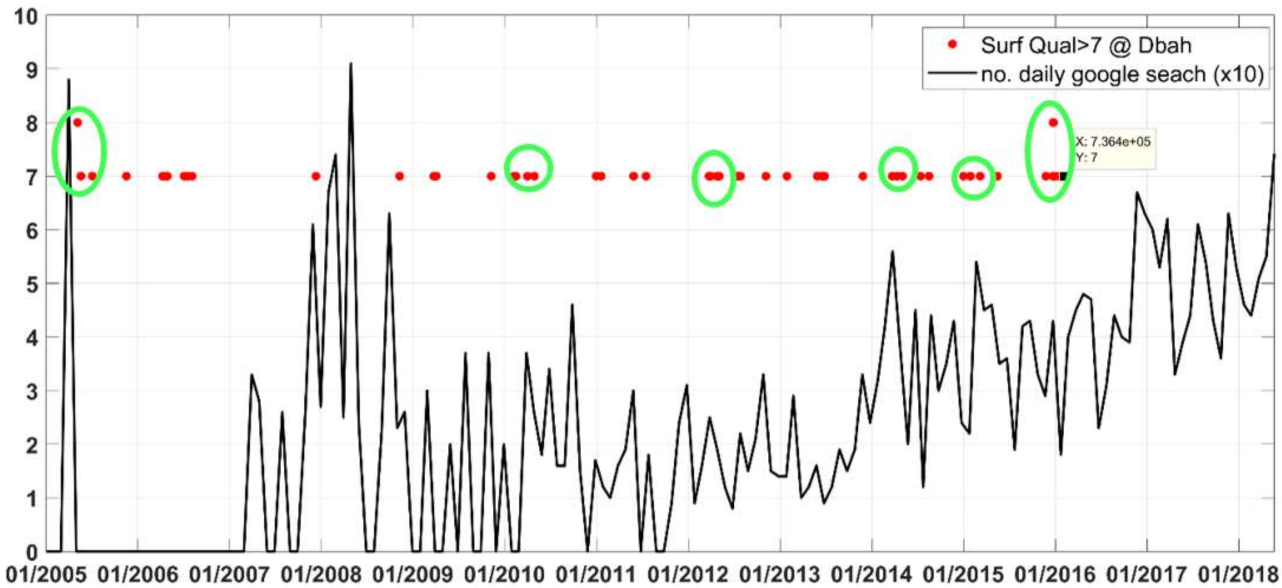


Figure 20 Identified high surf quality events at Duranbah (red dots) plotted against Google™ Analytics of "Duranbah" searches.

Table 5 Start and end dates of high-quality surf clusters

Cluster	Start	End
1	6/05/2005	4/07/2005
2	10/02/2010	5/04/2010
3	29/03/2012	9/05/2012
4	30/03/2014	10/05/2014
5	8/01/2015	16/03/2015
6	3/12/2015	14/02/2016

Figure 20 shows that some of the clusters were associated with spike in Google search activity. Internet searches also shows an overall upward trend through time. This trend is most likely associated with the increase in internet use in general and with the advent of social media (Facebook, Twitter and Instagram) increasing peoples overall online activity. In order to unequivocally determine high-quality surfing periods at Duranbah, manual confirmation of these selected periods was required.

During the period from 2010 to 2015 two organisations have managed coastal monitoring cameras from the Point Danger Headland; Coastalcomms and Water Research Laboratory (WRL). The cameras take an elevated view of Duranbah Beach from differing angles. For each of the individual selected dates within each of the cluster periods, manual analysis of images and video footage has been undertaken to verify surf amenity and rate surf quality at each of the breaks of Duranbah Beach. This analysis has been provided in **Appendix A.**

Of the 18 selected dates within each cluster, that only four of these dates had all three breaks (the Wall, the Middle, Lovers) with a rating based on image analysis of greater than 5, as seen in Figure 21. From this analysis and the definition of surf amenity at each of these locations, due to the nature of the metocean and geomorphic conditions that provide amenity at each break, it would be very rare for all three locations to be providing quality conditions at the same time. In general Lovers Left requires a N to ENE swell to provide the appropriate refraction around Point Danger for high surf quality (in conjunction with a light or offshore breeze). Whereas both the Wall and Middle require the more dominant E to SE swells (in conjunction with a light or offshore breeze). As such, for the purposes of this study, it is more cogent to focus on conditions at the Wall and (even more so) in the Middle in order to ascertain the influence the TSB project may have on surf quality at Duranbah Beach. Please note it can be seen that there was no video/imagery data for 2012 and as such this surf quality data cannot be verified and as such have been skipped.

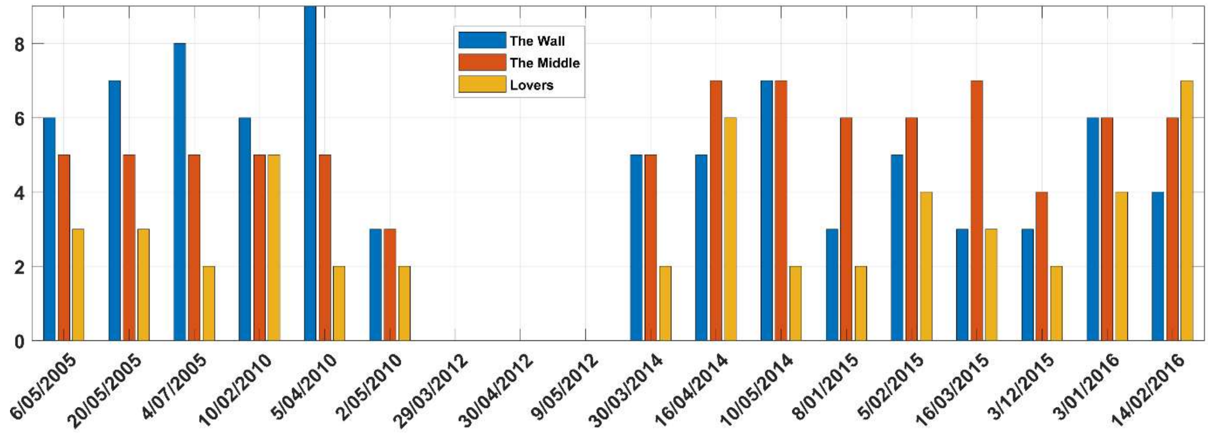


Figure 21 Surf quality rating (1 = poor, 10 = excellent) at each of the breaks of Duranbah Beach over the high surf quality clusters identified in Coastalwatch surf reports.

Following the selection process above, the following two dates have been selected as having highest surf amenity at the Wall and the Middle:

- 5 April 2010 (rating or nine for the Wall and five for the Middle)
- 10 May 2014 (ratings of six for both the Wall and the Middle)

In addition to these dates, another date has been selected based on one of the most popular video clips taken of Duranbah Beach posted by the surfing forecast website surfline.com, Figure 22. The video clip was posted on 21 February 2010 which coincides with the running of the Quiksilver Pro World Championship Tour (WCT) event held yearly at Snapper Rocks (27 February – 10 March, 2010) and has received over 32,000 views. The video features the world's best surfers practising prior to the commencement of the WCT event. Most of the surfing is seen to occur in the Middle and the Wall. The content for the video was collected over 2 or 3 sessions at Duranbah Beach in the week prior to the posting on the web (13 - 20 February 2010). Both the surfing and the conditions are seen to be 'world-class' in the video. Based on the quality of the waves in the footage and its online popularity (as opposed to videos created in similar time periods prior to the Quiksilver event in following years) the week commencing 13 February 2010 has also been identified as having high surf amenity for further analysis.

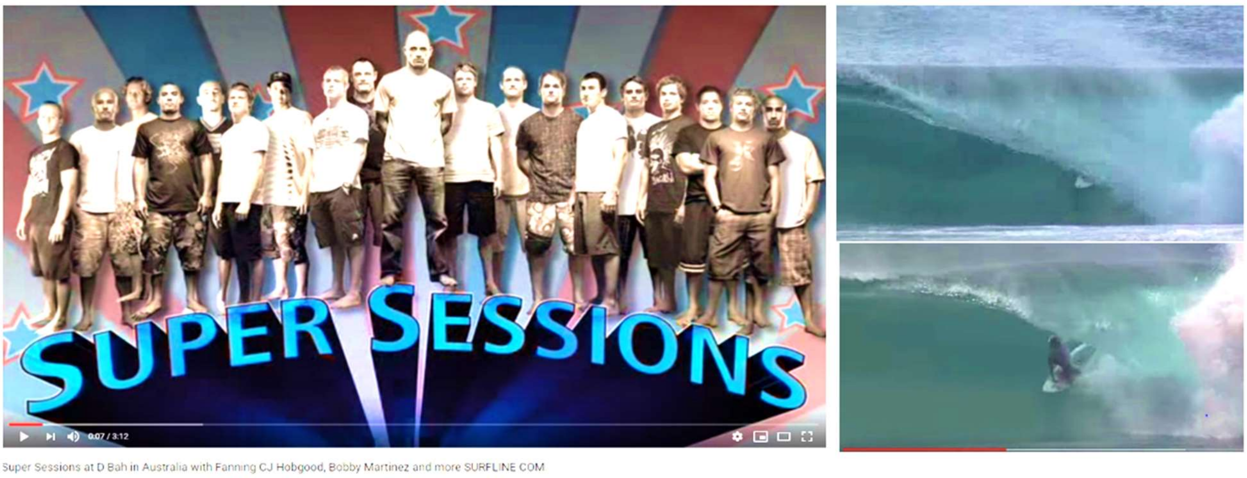


Figure 22 Screenshots from the Surfline video: Supper Session, uploaded Feb 21, 2010 (source: https://www.youtube.com/watch?v=s_pjYvwsuYo)

5 Influence of the Tweed River Bar

5.1 Preamble

As introduced above, the Tweed River Bar (TRB) plays an important role in the quality of waves along Duranbah Beach. The TRB is an ebb-tide delta or an accumulation of sand on the seaward side of an inlet formed by the ebb tidal current. These are most common in front of mixed energy inlets where tidal energy interacts with waves and longshore drift. The length (degree of protrusion) of an ebb tidal delta reflects the relative strengths of tidal flow and longshore current. The asymmetry of the delta is determined by the direction of longshore transport. The current TRB has developed following the extension of the Tweed River training walls and varies its size, depth and offshore location depending on the interplay with tidal, fluvial and wave forces.

The dominant east (E) to east south-east (ESE) wave directions create wave orthogonals that refract, diffract and shoal over the TRB scallop-shaped bar resulting in a confused wave field in the lee. The extent of the 'confusion' creates wave superposition, increasing wave heights and for the most part improves surf quality at Duranbah Beach. Changes in wave direction, wave height and period will cause wave interaction with the TRB to differ, altering the interference patterns and can at times reducing surf amenity. Interaction of the wave field in the lee of the bar and inshore (approximately 2m depth) sandbanks, gutters and rips also play a major role in surf quality. To further examine the effects of the array of possible influences; TRB morphologies, incoming wave conditions and nearshore morphology have on surf quality, a large matrix of phase-resolving wave modelling scenarios would be required.

In this study, the impact of the TBR on surf quality was quantified by utilising the bathymetry data collected by TSB. The analysis aimed to provide a correlation between the bar morphology and recognised high surf quality conditions. As discussed, there are a multitude of combinations of bar morphologies that may occur under differing metocean conditions. However, the identification of recurring morphological patterns provide insight into permutations that are conducive to high surf quality under ambient wave conditions.

Almost 30 TRB bathymetries showing the bar morphology were analysed dating from 2010 to 2017, these can be seen in **Appendix B**. The analysis showed that for the combined entrance and beach surveys, there appears to be five key morphological states. A definition of each of these states and occurrences is provided below.

5.2 Key morphological states

5.2.1 South breach

A complete bar state is one that is a generalised scallop shape with uniform bathymetry and general symmetry (i.e. no lean). A south breach state on the TRB has been defined as one that has a breach or opening of the shallower bathymetric contours (RL -5.0m and shallower) facing south. An example of the south breach bar state can be seen in Figure 23. The bar asymmetry is also slightly directed to the south. In general, this is a rare occurrence and usually follows extended periods of low wave energy and/or N-ENE wave conditions. Build-up of sediment within the Tweed River can also influence the ebb jet to be directed south, contributing to the morphological state.

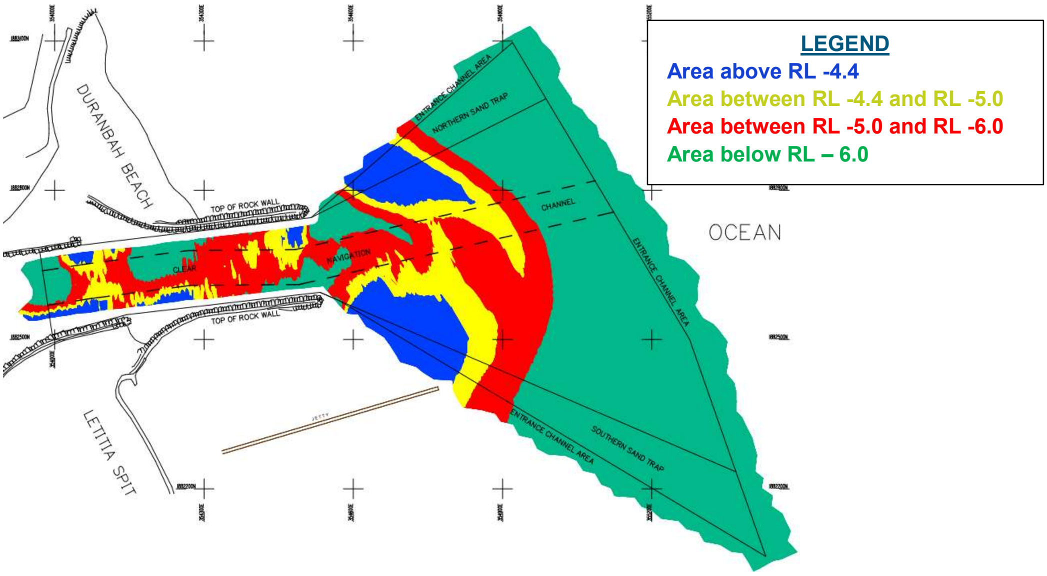


Figure 23 Tweed River Entrance Survey, June 2016 showing a south breach state of the TRB. (Source: Lands)

5.2.2 Centre breach

An example of the centre breach bar state can be seen in Figure 24. The centre breach state on the TRB is described as one that has a breach or opening of the shallower bathymetric contours (RL -5.0m and shallower) directly offshore of the river entrance. The bar is seen to be close to symmetrical.

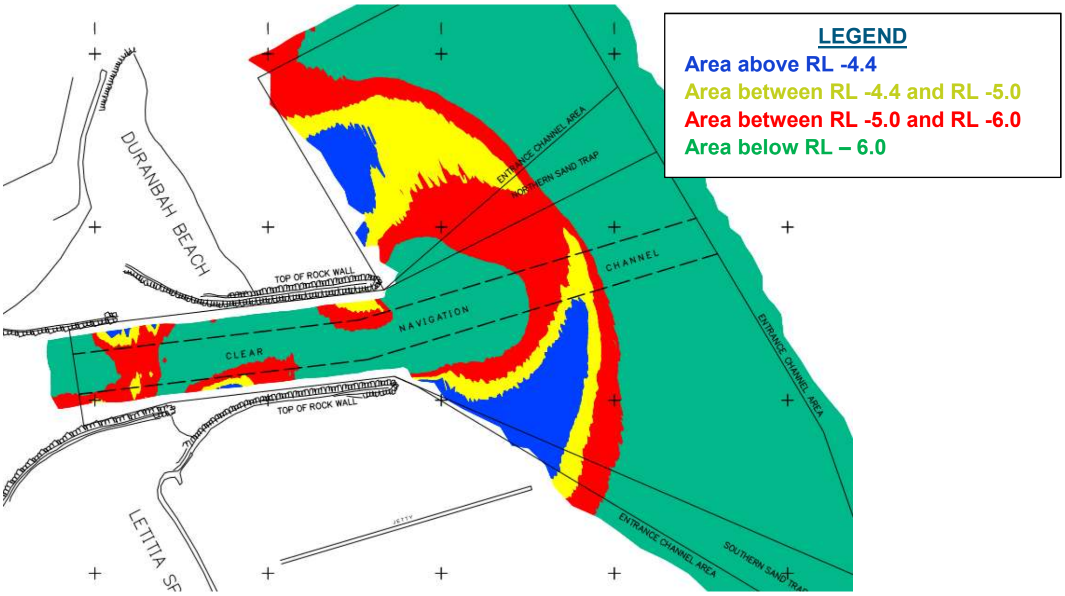


Figure 24 Tweed River Entrance Survey, November, 2017 showing a Centre breach state of the TRB. (Source: Lands)

5.2.3 North breach

An example of the north breach bar state can be seen in Figure 25. The north breach state on the TRB is described as one that has a breach or opening of the shallower bathymetric contours (RL -5.0m and shallower) facing north. The bar asymmetry (or lean) of the scallop is to the north whilst greatest volumes sit on the south arm of the bar offshore of Letica Spit to the south. Of the morphologies mapped in

Appendix B, this is seen to be the most common morphological state with the bar differing in size, volume and extent based on the interaction of the ebb-jet with the northerly longshore current.

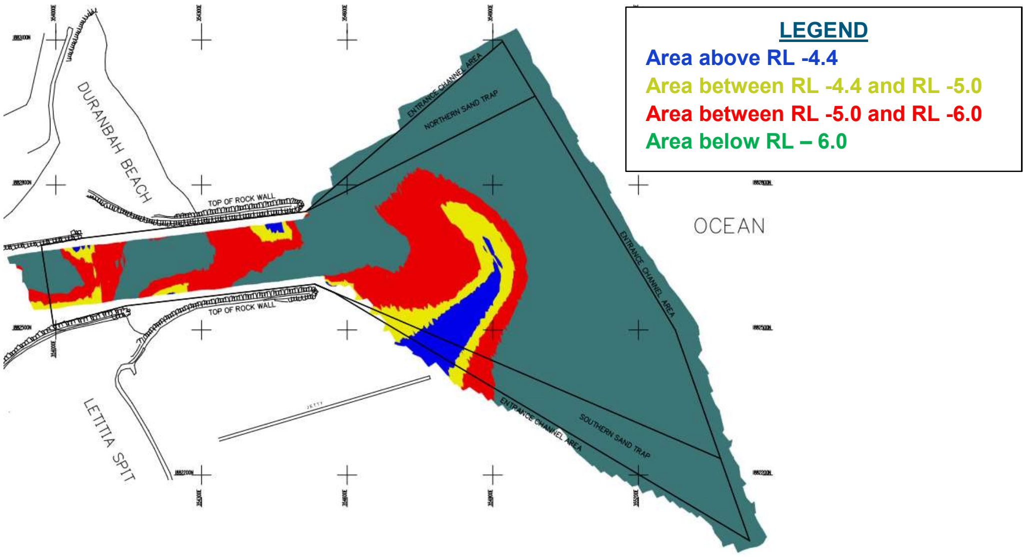


Figure 25 Tweed River Entrance Survey, April 2010 showing a North breach state of the TRB. (Source: Lands)

5.2.4 Shallow bar

An example of a shallow bar state can be seen in Figure 26. Contours shallower than RL -4.4m are generally connected (not breached) over the entirety of the TRB. Bar asymmetry may vary. In general, this is the bar state to which the TSB project wishes to avoid as, if this is reached, protocols will be triggered to initiate a sand pumping or dredging response in order to maintain safe passage for vessels across the TRB.

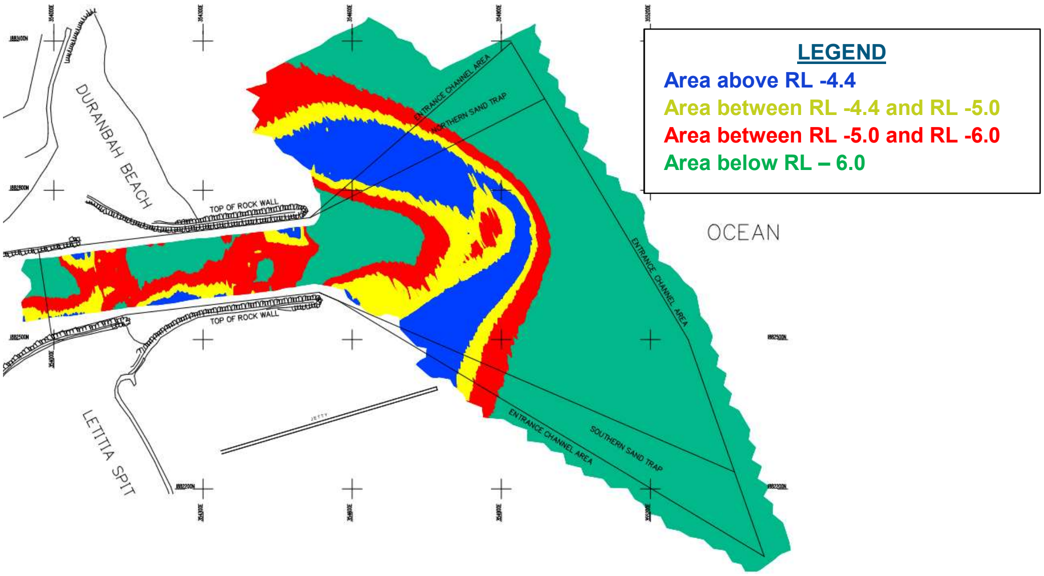


Figure 26 Tweed River Entrance Survey, April 2016 showing a Shallow TRB. (Source: Lands)

5.2.5 Deepened bar

An example of a deepened bar state can be seen in Figure 27. Contours shallower than RL -4.4m are generally rare over the entirety of the TRB. Bar asymmetry may vary, and breaches may be seen at several locations along the RL-5.0m contour. In general, the deepened state of the TRB generally has less influence over the incoming wave field under small to mean wave conditions (heights/periods).

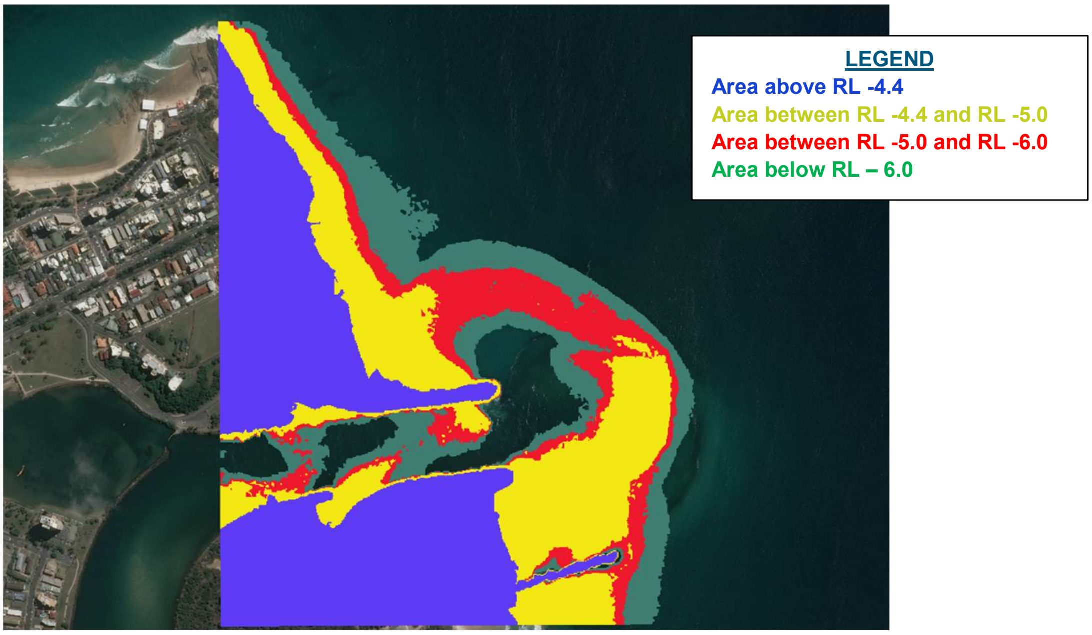
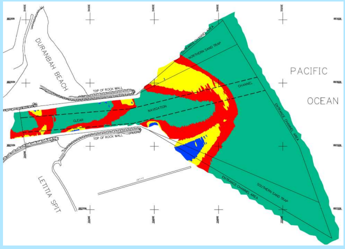
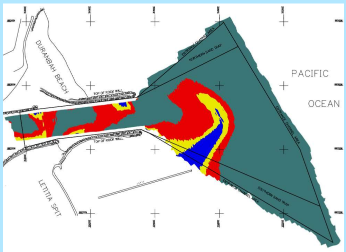
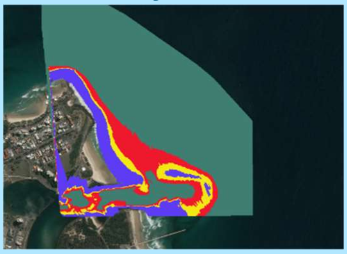
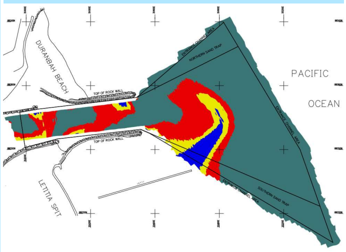


Figure 27 Tweed River Entrance Survey, November 2010 showing a Deepened TRB.

5.3 Correlation between bar morphology and surf amenity

Following the above identification of recurring TRB morphologies, a correlation has been attempted between the high surf quality days identified in Section 4.3 and available bathymetric data provided in **Appendix B**. The results of this analysis can be seen in Table 6. Both the 5 April 2010 and early February 2010 high surf quality periods have been classified using the same bathymetric surveys as the two closest *prior* and *after* surveys fall in January and April.

Table 6 Correlation of high surf quality occurrences with available survey data

	05 April 2010	10 May 2014	February 2010
Surf Quality Rating	The Wall = 9 The Middle = 8	The Wall = 7 The Middle = 6	The Wall = 7 The Middle = 7
Surf Conditions	• Hs~1.5-2m. • light winds until 15:00 • long right-hand bank against the wall • 1 predominant peak in the middle	• Hs~1m. • transient peaks • breaking very close to shore • light winds until 15:00	• varying
Closest Survey (prior)	**January 2010** 	**April 2014** 	**January 2010** 
Closest Survey (after)	**April 2010** 	**July 2014** 	**April 2010** 
Morphological Description	Both *prior* and *after* surveys depict a deepened bar state with a north breach. A shallow sand spit is extending from the beach to the bar on the southern side of the Tweed River (Leticia Spit) this arm is directed north towards the entrance. Although most sediment is located on the southern side of the TRB, the general shape shows an asymmetry of the generalise scallop-shape slanted to the north.	The *prior* survey shows a centre or slightly south breach and a deep TRB. A shallow sand spit is extending from the beach to the bar on the southern side of the Tweed River (Leticia Spit). The *after* survey shows a breach directly offshore and north of the northern Tweed River training wall. The former centre/south breach appears to have partially filled in and a slug of shallower sediment (>RL -4.4m) appears to have moved along the northern arm of the TRB. It is expected that the morphology at the time of the high surf quality period (10/05) would been somewhere in between the two surveys provided above; the shallow sand slug would have extended from the beach to the	Both *prior* and *after* surveys depict a deepened bar state with a north breach. A shallow sand spit is extending from the beach to the bar on the southern side of the Tweed River (Leticia Spit) this arm is directed north towards the entrance. Although most sediment is located on the southern side of the TRB, the general shape shows an asymmetry of the generalise scallop-shape slanted to the north.

		breach on the southern side of the Tweed River (Leticia Spit)	

6 Sand placement and idealised profile

6.1 TSB Operations

Since its inception, the TSB project has played a major role in the management of Duranbah Beach, Letitia Spit, the downdrift beaches of Coolangatta and Kirra. The initial over-nourishment of the Coolangatta embayment to remedy years of limited sand supply has reduced significantly and, in recent years, the system is approaching a regime in which sand pumping and dredging is more in-line with the natural sediment transport processes along this coastline. Sand volumes in the Snapper Rocks and Rainbow Bay area are now close to or less than what they were before pumping began (TSBa, 2013). For the coastal system as well as the TSB operations to have reached the current regime, numerous dredging, pumping and beach nourishment activities and strategies have been undertaken in the eighteen years of operation. However, the gradual reduction in pumping and major dredging activities means that Duranbah Beach sand pumping strategies and offshore dredging are reaching a more predictable and constant state of flux. With this consistency means that near and offshore beach profiles and subsequent surf quality has become to an extent, more predictable.

The extent, location and duration of previous sand placement strategies within the adjacent project beaches from Letitia Spit to Kirra have varied concurrently to the natural variation of the metocean conditions. In simple terms, sand is:

Pumping from the jet pumps and sand cones under the Bypass Jetty at Letitia Spit and placement via:

- The discharge outlet at the Snapper Rocks East (SRE) accounts for 70 per cent of the total sand transferred by TSB
- The discharge outlet at Kirra accounts for 2.5 per cent of the total sand transferred by TSB
- The discharge via temporary outlets at Duranbah Beach accounts for 6.5 per cent of the total sand transferred by TSB
- The outlets at Greenmount and Snapper Rocks West (SRW) account for less than 1 per cent of the total sand transferred by TSB combined
- Removal by dredging from the Tweed River Bar and placement across all approved placement boxes accounts for 20 per cent of sand transfer by TSB.
- Removal by dredging from the Tweed River Bar and placement in Duranbah (DBAH) placement boxes accounts for 2 per cent of sand transfer by TSB.

6.1.1 Pumping

To a lesser extent, lower volumes of sand are discharged via the pumping system to the discharge outlets of Snapper Rocks West (SRW), Greenmount and Kirra. From 2001 to 2010, the quantity of sand delivered by pumping and dredge to Duranbah Beach was equivalent to about 10% of the total sand quantity bypassed by the system at that time (Acworth, 2010). Since then, annual rates vary between 10,000-65,000m^3. Individually pumped placements have been generally limited to less than about 30,000m^3 per month, because of past evidence that larger placement volumes may have short term impacts on surfing amenity, as noted in the below:

"Discharge onto Duranbah Beach commenced on 17th April 2001. This discharge was onto the southern end of the upper beach, which had been recently eroded. After a discharge of 5,000 cubic metres a 3.0m high shallow cone had formed. The details were similar to East Snapper except that wave action had very little effect. Subsequent discharges produced a linked series of cones along the northern side of the northern entrance training wall. After placing 67,000 cubic metres in April/May 2001, "closing out" conditions limited surfboard riding. However, quality surfing conditions returned reasonably quickly. (Dyson et al. 2002)

In 2010, TSB in conjunction with Lands put in place a strategy to deliver sand to Duranbah Beach based on an annual target quantity for pumping of up to approximately 50,000 m^3 based on the program in Table 7.

Table 7 Duranbah Beach sand delivery strategy (Lawson, 2010)

Nominal Placement Date	Indicative Quantity	Placement Locations	Purpose
March/April	30,000m^3	Various outlet points along beach from seaward edge of dune	Build up sand reserves on the upper beach and dunes to provide a storm buffer of approximately 25m width in the centre of the beach leading into the winter months
November	20,000 m^3	From training wall into inter-tidal zone	Provide quantity of sand for natural reworking along beach and offshore to help maintain recreational beach width and surfing banks

The use of a temporary sand pumping outlet (Figure 28) was setup to provide flexibility for varying discharge locations to address changes in the sand nourishment needs over the year and provides an effective mechanism for achieving the objectives of the sand delivery under a primarily twice-a-year placement program. It has been found that different discharge locations were better suited to achieve certain outcomes. The most pertinent of these to providing surf amenity has been the discharge from the training wall into the intertidal zone tends to more readily restore beach width with and build up the nearshore shoal along the training wall to form the surfing bank described in Section 4.2.1.

Data on the efficacy of the training wall placement technique and its effect on surf quality has not been found. The resilience of this feature, regardless of artificial placement is noted in (RHDHV, 2018); 'The mechanism for the southward movement of sand [sic] due to the effects of the semi-permanent rip that exits Duranbah Beach by flowing along the northern training wall'.

Figure 28 Sand pumping at Duranbah Beach; (left) off the northern training wall (source: Joli). (right) via temporary pipeline to the northern end of Duranbah Beach (source: Coastalwatch)

The results of the varying pipe outlet locations can be summarised as follows, per (Lawson, 2010):

- Discharge from the training wall into the intertidal zone tends to more readily restore beach width with sand reworking along the shoreline as well as nearshore shoal build up along the training wall to form or enhance a 'surfing bank' (The Wall),
- Discharge from the southwest corner of the beach provides immediate replenishment of localised erosion of the foredune/upper beach profile without the need for supplementary dozing for shaping of the beach profile.
- Discharge from 3 to 4 back-beach locations achieves replenishment of the foredune sand store with little or no dozing required to reform the desired beach/foredune profile, if pumping is carried out using relatively high-density sand slurry.

Lawson (2010) also noted that, 'ongoing surf quality monitoring and consultation with the local surfing community has not identified any significant long-term adverse impact on Duranbah's surf quality'.

6.1.2 Dredging

Dredging of the TRB occurs following excessive sediment build up on the bar that can lead to dangerous conditions for vessels attempting to cross the entrance bar. As with pumping operations, the requirement for large scale dredging operations has reduced since the project's instigation, dredge totals from 1995 to 2016 can be seen in Table 8.

Table 8 TSB dredging overview (Source: TSB, 2018)

Campaign	Volume (m^3)
Stage 1 (26 Apr 1995 to 26 May 1998)	3,047,549
Stage 2 Pre-commissioning Dredging (1 Apr 2000 to 29 Apr 2001)	532,517
Stage 2 Operations Dredging Campaign 1 (11 May 2001 to 6 Nov 2001)	289,972
Stage 2 Operations Dredging Campaign 2 (20 May 2002 to 20 Oct 2002)	240,129
Stage 2 Operations Dredging Campaign 3 (7 Feb 2003 to 28 Sep 2003	230,892
Stage 2 Operations Dredging Campaign 4 (7 July 2004 to 30 Sep 2004)	169,926
Stage 2 Operations Dredging Campaign 5 (22 May 2005 to 30 Sep 2005)	199,059
Stage 2 Operations Dredging Campaign 6 (23 May 2006 to 28 Sep 2006)	200,298
Stage 2 Operations Dredging Campaign 7 (17 May 2008 to 24 Sep 2008)	198,979
Stage 2 Operations Dredging Campaign 8 (1 Dec 2011)	200
Stage 2 Operations Dredging Campaign 9 (1 Apr 2016 to 31 May 2016)	41,938
TOTAL	**5,151,460**

The dredged sand is placed in a variety of nearshore sand placement areas (Figure 29)[2] determined by the TSB operators.

[2] *Note: This includes 22,870 m^3 of sand delivered to Palm Beach from June 2005 to September 2005.*

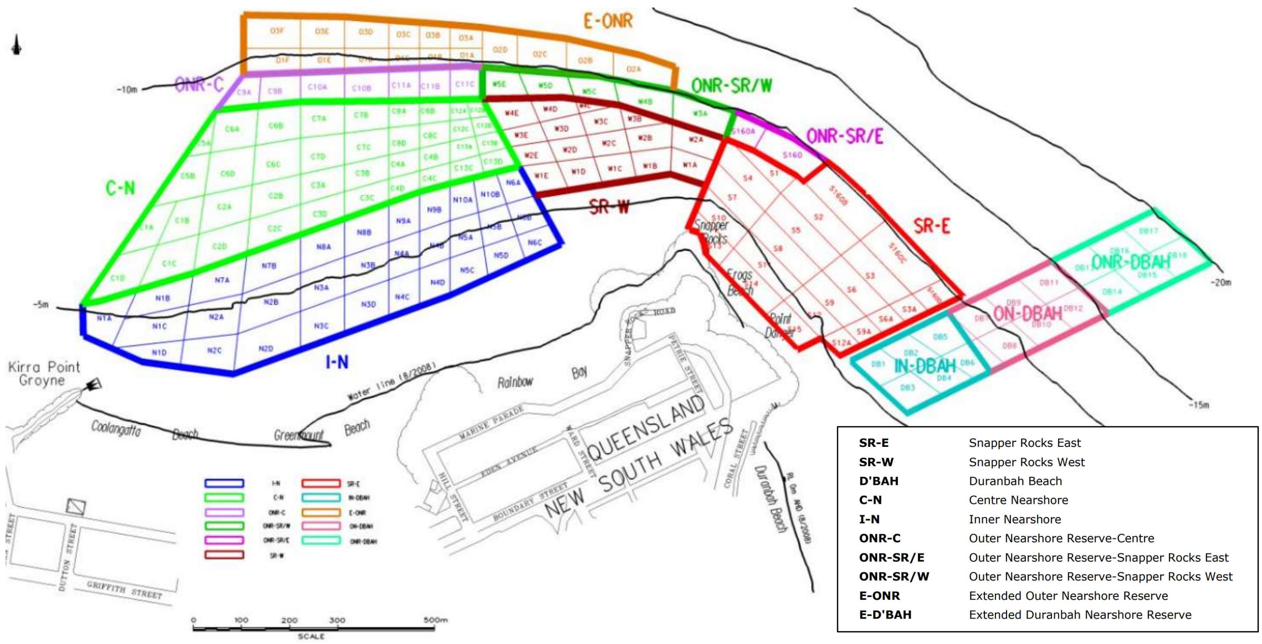


Figure 29 Dredge nearshore sand placement areas (Source: TSB, 2011).

A relatively large dredge placement of about 127,000 m^3 of sand was trialled in the northern Duranbah nearshore area between June to September 2008 as a response to consultation with the community, specifically the surfing community. The placement was hoped to strategically store sand in deeper nearshore reserves with the aim of delaying the longshore transport of sand northwards around Snapper Rocks. The dredging, pumping and placement strategies have had fluctuating effects on the shoreline and dune toe position, the upper dune volumes and offshore location of depth contours.

6.1.3 Effect on surf amenity

Ongoing surf quality monitoring and consultation with the local surfing community has shown that implementation of the TSB operations at Duranbah Beach (even within the period of largest fluctuation and sand relocation) has not identified any significant long-term adverse impact on Duranbah surf quality (Lawson, 2010). A supplementary correlation of these activities with the recently attained surf quality data from Coastalwatch has also been undertaken and can be seen in Figure 30.

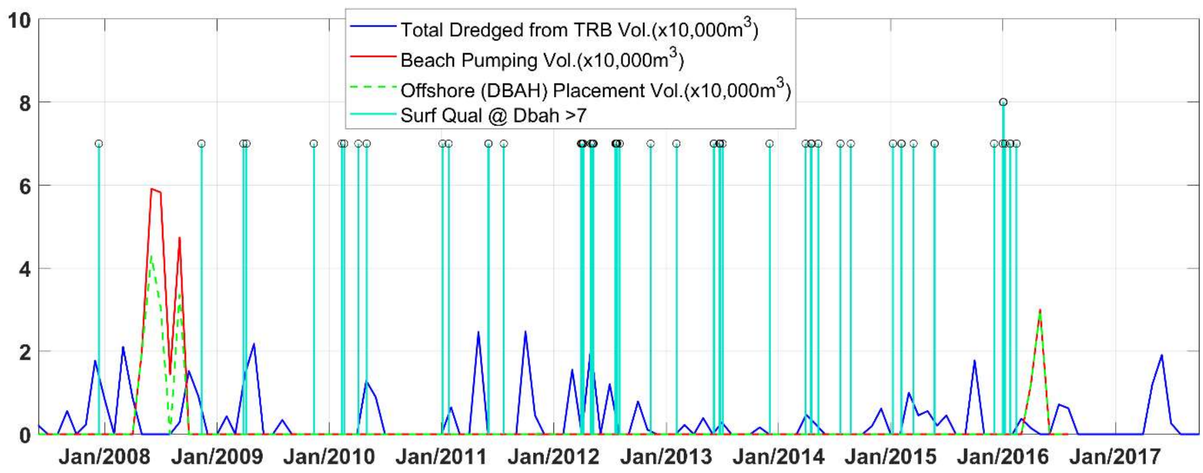


Figure 30 Surf quality rating higher than 7 as reported by Coastalwatch for Duranbah Beach and TSB pumping and Duranbah placement volumes

From this analysis, the only discernible correlation between identified high quality surf and TSB sand placement operations has been the implementation of offshore dredge deposition following periods of low surf amenity. This can be seen specifically in the offshore placement activities occurring mid-2008 and mid-2016. Prior to these nearshore nourishment campaigns, there was seen to be approximately six months when no high surf quality events occurred. It is expected that these placement campaigns within the Duranbah deposition area may have been in response to a large storm event, unsafe TRB conditions or stakeholder engagement as a response to low surf amenity.

Reiterating the findings of (Lawson, 2010), Figure 30 shows no discernible correlation between Duranbah Beach pumping activities and resulting surf quality at this location. It also reinforces the hypothesis that the key driver for wave quality, especially in the Middle, is derived from the entrance bar. If the two major dredging campaigns were in response to a period of shallow bar morphology, this is another supporting factor for the association of shallow bar morphology and lack of recognised high surf quality.

6.2 Idealised profile

The findings above and that of Lawson (2010) show that essentially the width of the sub aerial beach and dune profile appears to have minimal effect on surf quality at Duranbah Beach. Lawson's investigation tracked the shoreward location of the dune toe throughout major nearshore nourishment campaigns prior to 2010, as seen in Figure 31 whilst ongoing community consultation reportedly showed no impact on surf quality during this period.

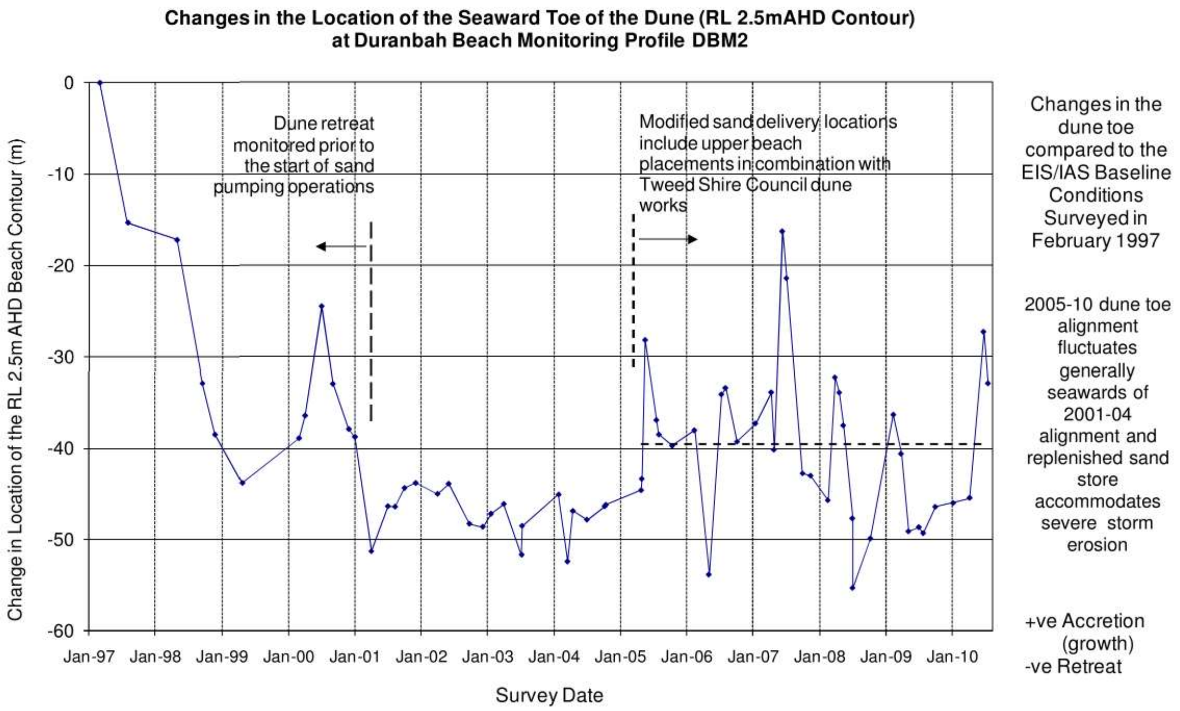


Figure 31 Change in location of dune toe at central Duranbah Beach monitoring profile DBM2 (source: Lawson, 2010)

Impacts of the sand pumping strategy directly from the northern Tweed River training wall (Lawson, 2010) have not been reported. It is understood though, that this persistent rip/sandspit feature is quick to re-establish itself following periods of low surf amenity.

6.2.1 Coastal profile analysis

Based on the range of mean wave heights and periods, wave breaking (and surfing) is expected to be most prevalent between the 1m and 3m depth contours (below mean sea level). In order to support the claims of the nearshore profile having little effect on surf quality, tracking of the offshore location of these depth contours has been investigated in respect to identified high surf quality events. Figure 32 shows the variation in three beach profiles extracted across Duranbah Beach from 2000-2016. The image shows the range in offshore location of the dune toe (+2.5m), shoreline (0m) and approximate breaker location (-2m) contours. The range for each of these can be seen to be in the order of ±25m, ±50m and ±100m respectively for the offshore distance of the dune toe, shoreline and breaker locations.

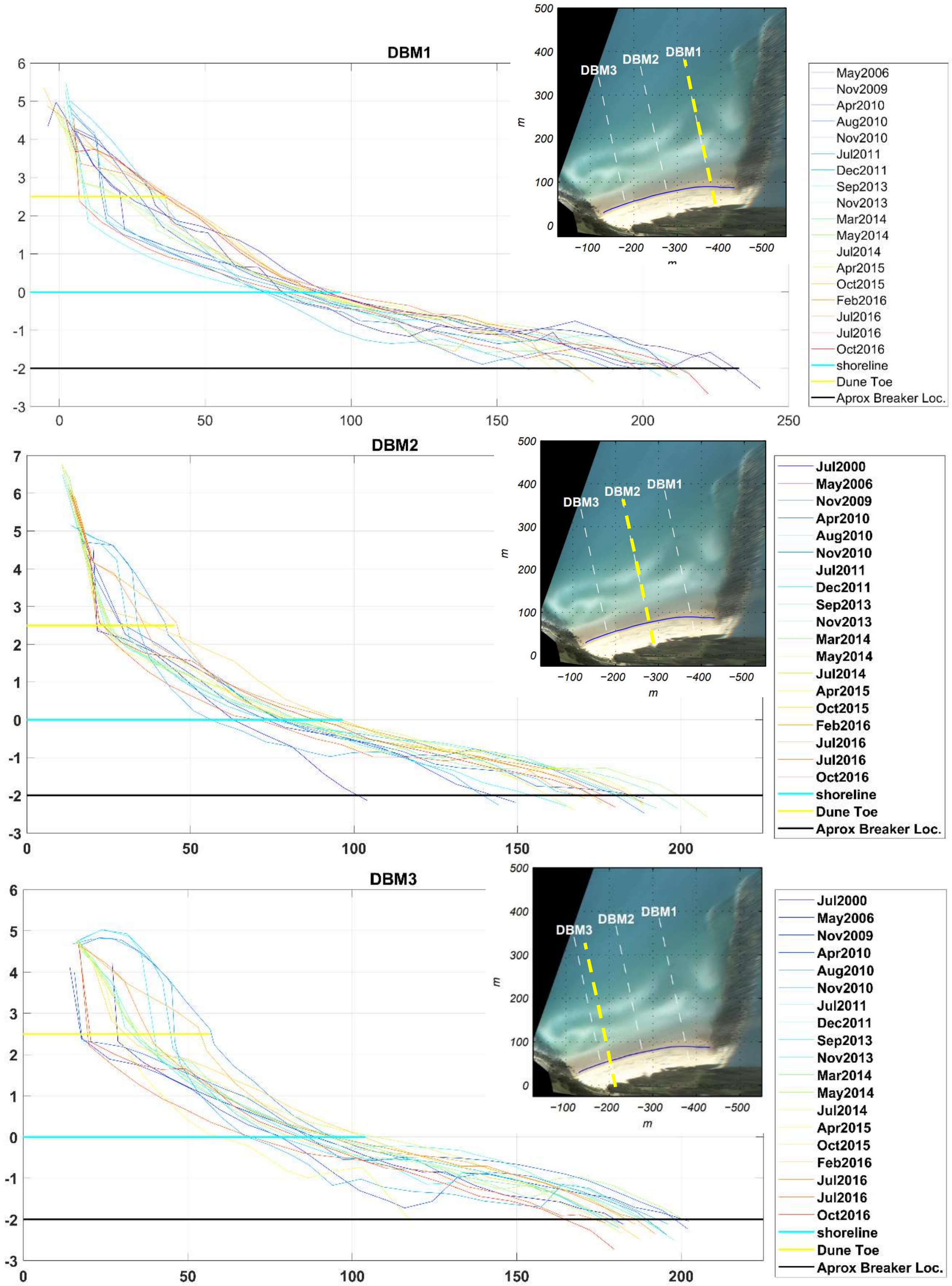


Figure 32 Beach transect profiles at locations DBM1, DBM2, DBM3 from 2000 to 2016.

The range in offshore position, particularly the -2m breaker location, and surf quality rating can be seen in Figure 33 for each transect. The three selected high-quality surf episodes of February 2010, May 2010 and May 2014 all appear to be at a point where there is a convergence of the DBM1, DBM2, and DBM3 breaker contour (-2m) at approximately 175 to 200m offshore of the dune crest for each. The convergence of each of these contours at the same offshore distance shows that the beach width is generally uniform along its length i.e. offshore contours are generally the same distance offshore (and parallel with) the upper beach and dune crest (+5m) contour.

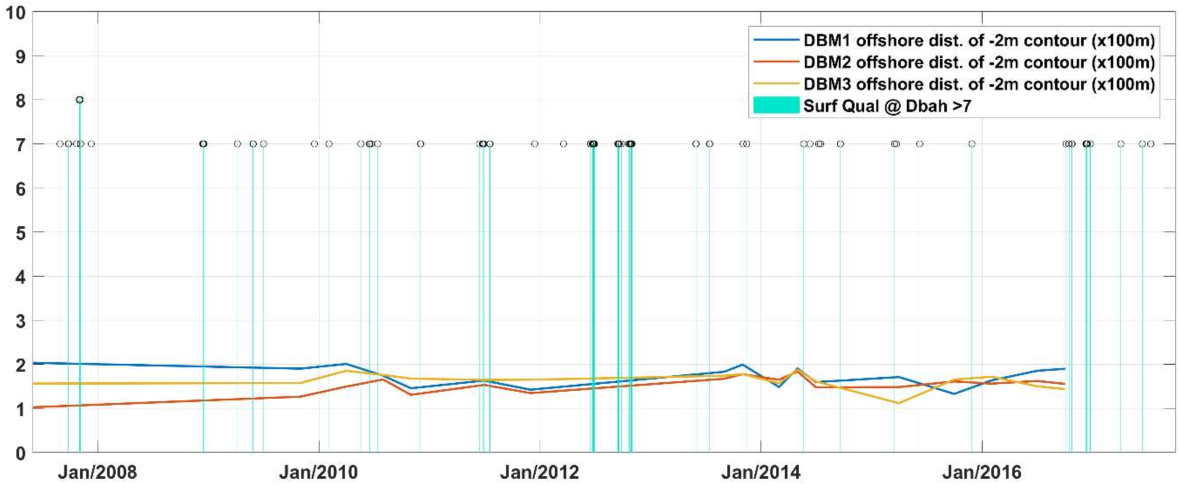


Figure 33 Offshore location (from dune crest) of beach transects DBM1, DBM2, DBM3 and recognised High Surf Quality events at Duranbah Beach

In determining an idealised profile for operational guidance into the future, it can be seen from the preceding subsections, that the most important factor in surf quality is the morphological state of the TRB. As a result, the management of the coastal profile (i.e. the subaerial and subaqueous beach) at Duranbah Beach should be driven by beach management objectives rather than surfing amenity objectives. The profile should be at a position where there is enough beach and dune width for beach amenity and capacity to buffer erosion in storm conditions.

6.2.2 Idealised profile for beach management

The mean profile from 2000 to 2016 for each transect has been calculated from the historical survey data to construct a ‘quasi-equilibrium’ idealised beach profile, Figure 34. The mean beach height was calculated at 5m intervals from the dune crest (+5m) to the transect termination (~-3m) over the 19 historic profiles. Each average profile was then processed using a smoothing function and the upper dune height set to 5m, this is the height (and distance onshore) that initial placement activities have placed the upper dune to act as a buffer during storm periods.

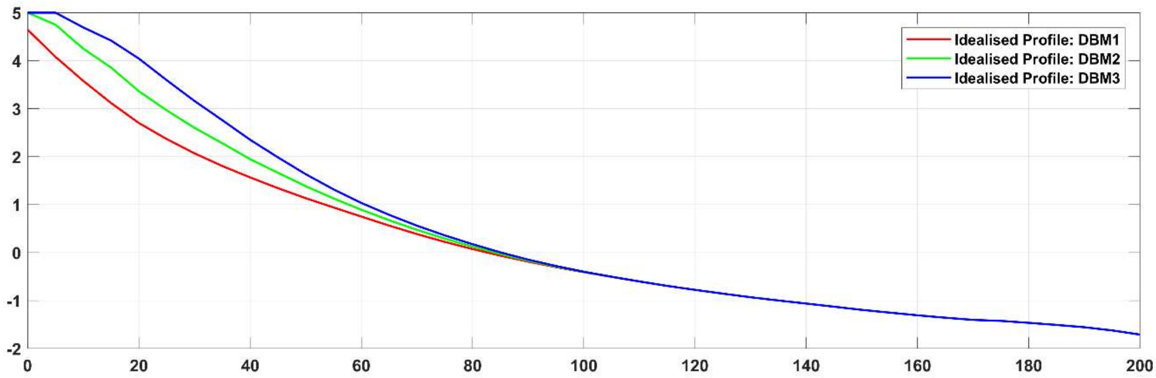


Figure 34 Idealised profiles for Duranbah Beach transects DBM 1 to 3 based on historical surveys.

6.3 Sand placement strategy

Lands in conjunction with the state governments of both Queensland and NSW, the City as well as the co-operation of local stakeholder groups have formulated a strategic pumping, dredging and placement strategy based upon the almost 20 years of operation, monitoring and analysis of the TSB project. The strategy is an interchange between maintaining a navigable entrance to the Tweed River, providing sand to the southern Queensland beaches and to a lesser extent mitigate adversely impacts on surfing amenity to the beaches in the project area. The following using the findings of this study to supplement the current strategy and incorporate strategic pumping, dredging and sand placements to maintain and/or prolong the morphological conditions that promote high quality surf amenity at Duranbah Beach.

The collected data has shown a linkage between the Tweed River Bar (TRB) being in a north breach bar condition that has been observed to promote high-quality surfing conditions at Duranbah Bach. From the available survey data, it appears that this is the predominant morphological condition that the TRB tends to experience. However, the influence of large storm events or northerly wave events will alter the typical littoral drift conditions and cause disruptions to the sand supply around the TRB.

The two sand tracing studies (RHDHV, 2017 and RHDHV, 2018) and Conceptual Sediment Transport Model (Jacobs, 2017) discuss these processes further. However, it is surmised that northerly travelling sand will travel past the end of the TSB Jetty atLetitia Spit. The jetty catches most of the northerly moving sand in its jets before it gets pumped via the TSB to the beaches to the north. The excess sand follows the TRB north until it reaches a deeper breach in the bar facing north (or just north of east) this is maintained by the ebb-jet of the Tweed River.

Disruptions to this flow by changes to the incoming wave conditions and weaker tidal flow can reverse the flow of sediment or, during storm periods, increase the supply to the TRB. These pulses of wave energy or changes to the mean conditions, create slugs of sediment or additional breaches in the TRB. The TRB formation becomes disjointed or overly shallow, affecting TRB navigation as well as surf amenity on Duranbah Beach.

Close monitoring of the TRB morphology and forecasting of wave events can assist operators in maintaining the ideal morphological shape of the TRB by over/under-pumping of sand through the TSB. It is difficult to predict morphological response to storm events, as such dredging will always be necessary in order to maintain navigation through the TRB. However, when dredging is to take place, the following should be considered by TSB:

1. Dredging should occur in a fashion that promotes a north breach condition, this include both Tweed River and Bar dredging activities.
2. Placement of sediment in the Duranbah placement boxes should be limited to times when:
    a. There is insufficient volume in these areas **as well as** on Duranbah Beach. Over-nourishment of the offshore profile during a period when there is enough storm buffer in the nearshore profile may cause over-nourishment of the Duranbah compartment and result in unfavourable entrance bar morphology.
    b. Sufficient northerly littoral transport is anticipated to occur.
3. Intermittent pumping from the northern Tweed River training wall is to occur if there has been an extended period of sand deficiency adjacent to the wall or in imbalance in beach volume at the northern end of the beach as opposed to the south.

Pumping of sand on to Duranbah Beach is of secondary importance to surf amenity with only a minor effect observed. Therefore, pumping should be directed at beach management objectives and be in response/preparation to large storms in order to maintain enough beach and dune width for amenity and to act as a buffer against beach erosion. The pumping strategy should be to re-establish/maintain the idealised profiles of DBM1 to 3, detailed in Section 6.1. Tweed Shire Council (TSC) have developed an artificial nourishment program that has been aimed at preserving surf quality and beach amenity, it is recommended that this continues and is monitored accordingly to ensure these objectives are met. This strategy has built on the prior work of WBM's Dune Management Plan prepared for TSC.

There is merit in further investigating the effect of sand pumping on the quality of amenity at the Wall from intermittent pumping from the northern Tweed River training wall. The observed consistency of this formation (over a range of nearshore morphologies) from the bathymetric and video/photo data however shows the resilience of this formation in providing surf amenity at this location.

A sand placement strategy specific to provide high surf quality at Lovers Left may be inhibitive for a few reasons:

- The relatively small occurrence of ideal metocean conditions required for surf amenity at this location (combination of N-ENE swell, W-WSW wind) means sand placement in anticipation of this event may be difficult.
- The relatively short seaward protrusion of Point Danger (in comparison to the northern Tweed River training wall). Wave breaking contours (-2m) at the seaward end of Point Danger are for most parts of the year at the same seaward extent as the same contours at the southern end of The Middle. This means that low peel angles (or close-outs) are prevalent and amenity at Lover's is dependent on offshore wave interference patterns or a sufficiently eroded southern Duranbah Beach extending the protrusion of the headland.

As such, the strategy above has been provided with the objective of creating geomorphic conditions conducive to quality surf predominantly at the Middle. The Middle can provide up to 3 different surfing peaks affording amenity to a greater number of surfers.

7 Summary and recommendations

7.1 Summary

The study utilised a wide range of available metocean, bathymetric/topographic, coastal monitoring and surf quality data to identify and evaluate the surf zone dynamics and develop an understanding of the key coastal processes that impact surf quality at Duranbah Beach. Trends in nearshore and offshore morphology, including the Tweed River Bar (TRB) have been categorised and identification of profiles that create the highest quality surf at Duranbah has been undertaken.

The three main surf zones at Duranbah Beach; the wall, the Middle and Lovers Left have differing geomorphology that create high surf quality:

- The wall is classified as a point break formed by a persistent sandspit that runs adjacent to a semi-permanent rip feature flowing seaward against the south-side of the northern Tweed River training wall.
- The Middle consists of between one to three ‘A-frame’ peaks as a result of the wave interference patterns the Tweed River Bar.
- Lovers Left is a left-hand break by a sandspit running at the base of the Point Danger headland. Lovers Left requires combination of north to east north-east swell with west to west south-west wind to break in its true form.

The TRB was seen to be the dominant the morphological features affecting surf quality at Duranbah Beach. The bar was seen to have five modal configurations; north, south and centre breach in shallow and deepened bar states. Historic surf quality reports as well photo/video analysis identified the highest surf quality to coincide with a north breach configuration of the TRB.

An investigation into TSB operations; dredging, placement and pumping of sand at Duranbah Beach reaffirmed the previous hypothesis of the importance of the TRB on surf quality. Little correlation could be made between beach width, nearshore sand placement and surf amenity and as such a sand placement and pumping strategy was proposed that:

- Promoted/prolonged a north breach TRB state
- Meets beach management objectives in response/preparation to large storms in order to maintain a beach and dune width for amenity and to act as a buffer against beach erosion.

Idealised nearshore profiles were suggested based upon historic averages of transect data at Duranbah Beach. The idealised profile includes a 5m high back-beach dune as a means of extra capacity for a storm buffer.

7.2 Limitations

The analysis herein was undertaken using scientifically-robust methods based on available surf quality, metocean and bathymetric datasets. The report provides an overview of the morphological conditions that create surf amenity at Duranbah Beach as they relate to the operation of the TSB. As mentioned previously, surf amenity and surf quality are extremely subjective and as such methods have been incorporated to limit where possible subjective-bias and partiality from the surf quality rating system.

One of the key data sources in the selection of high surf quality was the daily surf report data undertaken by Coastalwatch surf reporter John Charlton. This data was screened to include only the highest ratings (>7) at Duranbah Beach. It should be noted however, that in general these surf reports are a Gold Coast region-wide surf report and as such are not specific to Duranbah Beach. High surf quality ratings could mean that several locations were also experiencing high surf quality on any day. This means that ratings would be based more on metocean (wind, wave and tidal) conditions than they would be on specific morphological conditions that enhance surf amenity at Duranbah Beach. However, when Duranbah Beach had low surf quality i.e. waves that close-out due to uncharacteristic TRB and nearshore morphological conditions it is assumed that this beach would have been omitted from the surf report.

The study also relied upon assumptions of TRB morphology between successive surveys for dates selected as having high surf quality due to the temporal resolution of the survey data. Although these assumptions have been based on findings and models from previous studies, the assumptions should still be stated for completeness.

In general, the study met the objectives to develop an understanding of the key coastal processes that impact surf quality at Duranbah Beach. It has also provided insights into the nearshore profiles and TRB formations that create the highest quality surfing conditions at Duranbah Beach.

7.3 Recommendations

Although considerable knowledge is available from previous scientific and engineering studies and data analyses, it is recognised that a full understanding of the processes influencing surf quality at Duranbah Beach does not exist. This is due to the highly complex and variable nature of the physical processes involved and the substantial influence on the sand bypassing operations of the TSB. To aid knowledge development planning, the following recommendations are aimed to filling the critical knowledge gaps:

- Undertake a phase-resolving wave modelling exercise to analyse wave breaking patterns at Duranbah Beach for the most common TRB morphologies and nearshore profiles under ambient wave conditions. This exercise would assist in quantifying surf quality at Duranbah Beach. This model should be validated for historic instances of high surf quality due to the amount of video and imagery data available. It is expected that the results of this study would attract interest from the surfing community and would be seen a positive method of engaging and consulting with local stakeholders to reach a mutual project objective.
- Stakeholder (or professional) involvement to track detailed surf quality as it relates to both nearshore and Tweed River Bar morphology. The continuation of daily surf reports in the character of the Coastalwatch reports should remain, however it would be useful to include descriptions of the nearshore bar formations (number, location of peaks) and surf quality at each surfing zone.
- Extend the surf quality tracking to additional beaches within the study area;Letitia Spit, Snapper, Rainbow, Greenmount, Kirra. A similar study to this one should also be undertaken for these beaches (building on the work already undertaken in the Gold Coast Surf Management Plan) to identify morphologies conducive to surf amenity at each of the locations. This will aid to formalise (and quantify) surf amenity and surf quality throughout the study area to inform TSB operations.
- Monitoring of TRB morphology should continue as frequently as seasonally. Should this be cost prohibitive, it is recommended that new technologies such as remote sensing (e.g. drones and/or Satellite Derived Bathymetry) be undertaken during suitable conditions: clear water (good visibility), light winds and small waves on a monthly or seasonal basis. Photogrammetry of drone data (or elevated ARGUS cameras) should also be investigated as a method to conceptualise current TRB morphology. This data is not required to be as detailed or accurate as hydrographic

survey and could be view as supplementary in some cases. However, it will be used to describe the general planform of the TRB as it relates to one of the six morphologies identified in Section 5 to be used for qualitative analysis in conjunction with the surf reporting.

Further evidence and linkages between surf quality at Duranbah Beach, nearshore profiles and TRB morphology will strengthen the understanding of the current TSB operations and their impact on amenity at Duranbah Beach.

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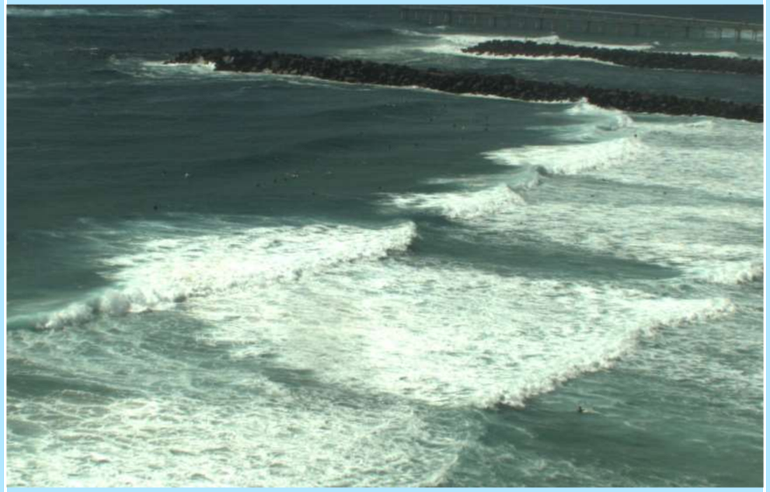
Appendix A: Video / image analysis of Duranbah Beach surf quality

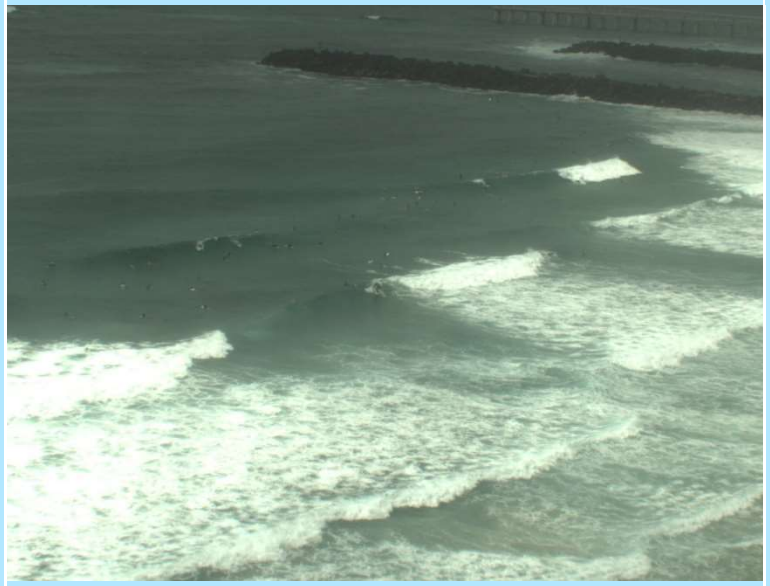
Date	Cluster	Number of Surfers (approx.)	Conditions Description	Wall Rating	Wall Image	Middle Rating	Middle Image	Lovers' Rating	Lovers' Image
06-May-2005	1	40 (9am)	• Hs~1.5m • light winds until 12:00 • 1 predominant peak in the middle • Lovers' 200m wide of headland	6	 WRL: 07:00	5	 WRL: 08:00	3	 WRL: 08:00
20-May-2005	1	30 (9am)	• Hs~1m, very sth • light winds all day • 2 predominant peaks in the middle • Lovers' 300m wide of headland	7	 WRL: 07:00	5	 WRL: 12:00	3	 WRL: 12:00
04-Jul-2005	1	50	• Hs1m, very sth • light winds all day • 2-3 transient peaks in the middle • Lovers' no defined peak	8	 WRL: 06:00	5		2	 WRL: 13:00

10-Feb-2010	2	50-60 (9AM)	• Hs~1-1.5m. • light winds until 16:00 • 2 predominant peaks in the middle	7	 Coastalwatch	5	 WRL: 10:00	5	 WRL: 09:00
05-Apr-2010	2	30-40 (09:00)	• Hs~1.5-2m. • light winds until 15:00 • long right-hand bank against the wall • 1 predominant peak in the middle	9	 Coastalwatch	8	 WRL: 09:00	3	 WRL: 09:00
02-May-2010	2	20-30 (09:00)	• Hs~1m. • light winds until 15:00 • small inside right against wall – high peel angle (fat) • no predominant peak in the middle, very straight	6	 WRL: 09:00	3	 WRL: 13:00	2	 WRL: 09:00
29-Mar-2012	3	NA	NA	NA	NA	NA	NA	NA	NA

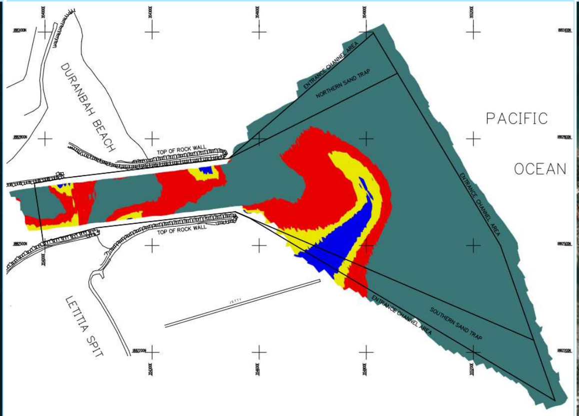
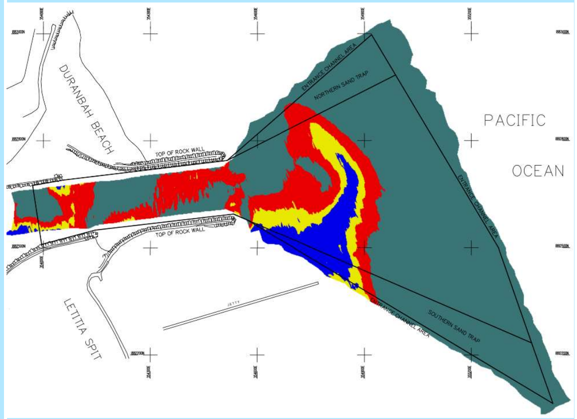
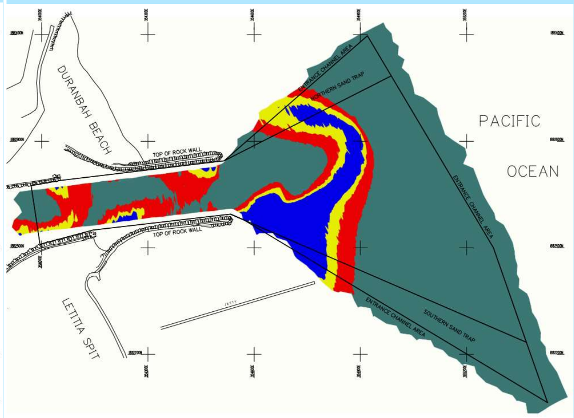
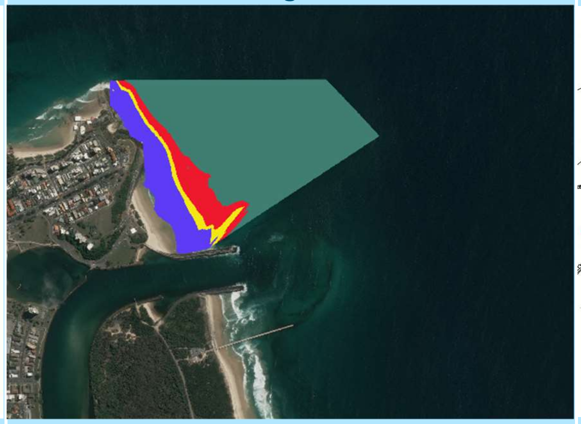
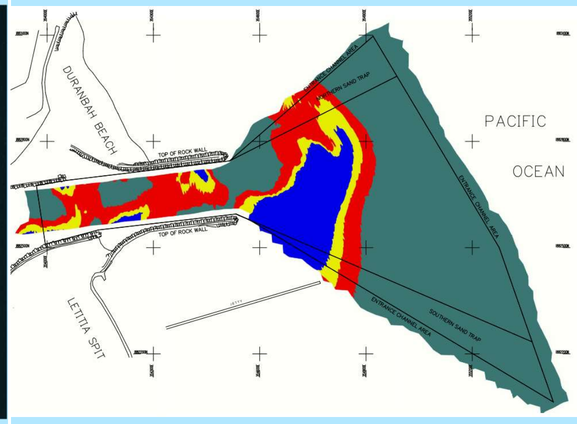
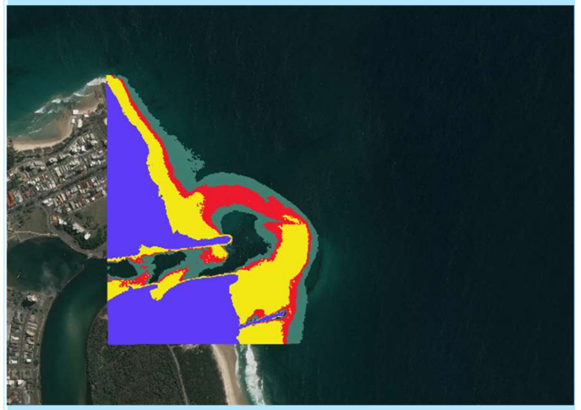
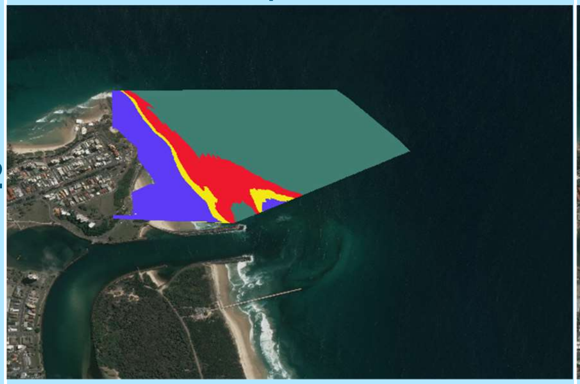
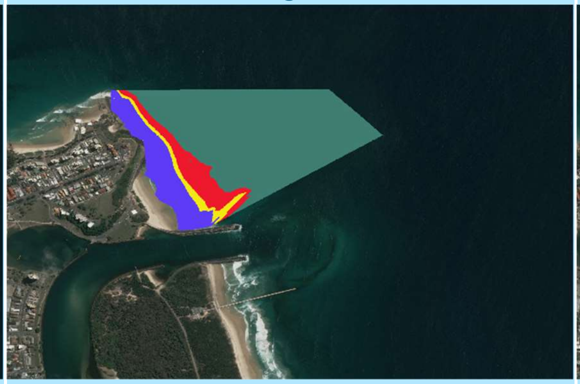
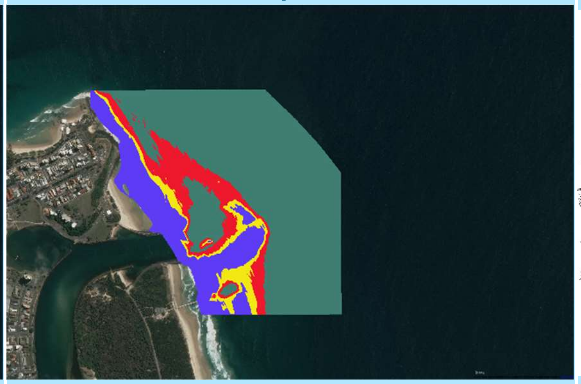
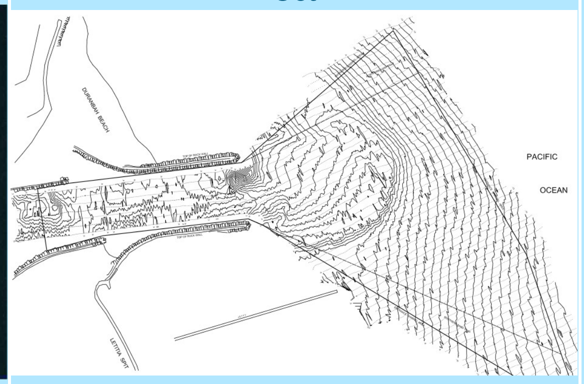
30-Apr-2012	3	NA	NA	NA	NA	NA	NA	NA	NA
09-May-2012	3	NA	NA	NA	NA	NA	NA	NA	NA
30-Mar-2014	4	60-70 (08:00)	• Hs~1m. • light winds until 15:00 • transient peaks • permanent rip next to Pt. Danger	5	 WRL: 11::30	5	 WRL: 10:30	2	 WRL: 09:00
16-Apr-2014	4	60-70 (09:00)	• Hs~1m. • light winds until 15:00	6	 Coastalwatch	7	 WRL: 12:00	6	 Coastalwatch

10-May-2014	4	80-90 (09:00)	• Hs~1m. • transient peaks • breaking very close to shore • light winds until 15:00	6	 WRL: 10:30	7	 WRL: 10:30	2	 WRL: 13:30
8-Jan-2015	5	20-30 (09:00)	• Hs~1m. • transient peaks	3	 WRL: 13:30	6	 WRL: 12:00	2	 WRL: 11:30
05-Feb-2015	5	20-30 (09:00)	• Hs~1-1.5m. • transient peaks	5	 WRL: 11:30	6	 WRL: 08:30	4	

										WRL: 11:30
16-Mar-2015	5	20 (09:00)	• Hs~1.5-2m. • Large transient peaks • Some waves breaking on delta • waves breaking against nth wall	3	 Coastalwatch	7	 WRL: 17:00	3	 WRL: 15:00
3-Dec-2015	6	20-30(09:00)	• Hs~1m. • windy by 10:00 • very straight • transient peaks	3	 Coastalwatch	4	 WRL: 11:00	2	 WRL: 13:00

03-Jan-2016	6	50-60 (09:00)	• Hs~1m. • transient peaks	6	 Coastalwatch	6	 WRL: 9:30	4	 WRL: 9:30
14-Feb-2016	6	30 – 40 (09:00)	• Hs~1m. • 2 predominant peaks • Predominant south swell • Windy by 13:00	4	 Coastalwatch	6	 WRL: 11:00	7	 Coastalwatch

Appendix B: Tweed River Bar morphology: 2010-2017

Year	Available Entrance Morphology				
	Area above RL -4.4	Area between RL -4.4 & RL -5.0	Area between RL -5.0 & RL -6.0	Area below RL -6.0	
	Jan 25	April	May 18	Aug 06	
2010					+
	Jan	Jul	Aug 21	Oct	Nov 10
2011					
	Apr 21	Aug 20	Sep 20	Oct	
2012					
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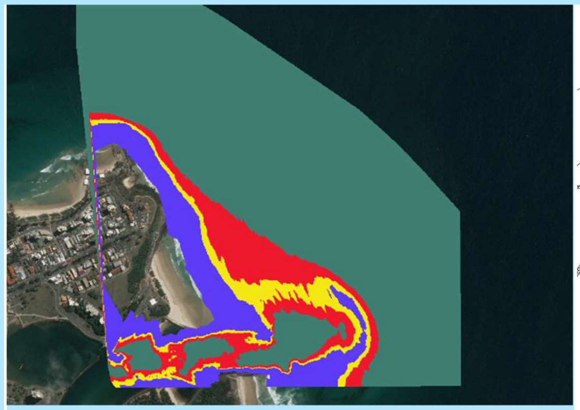

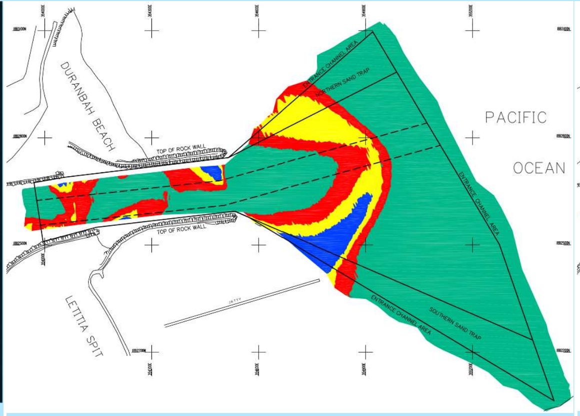

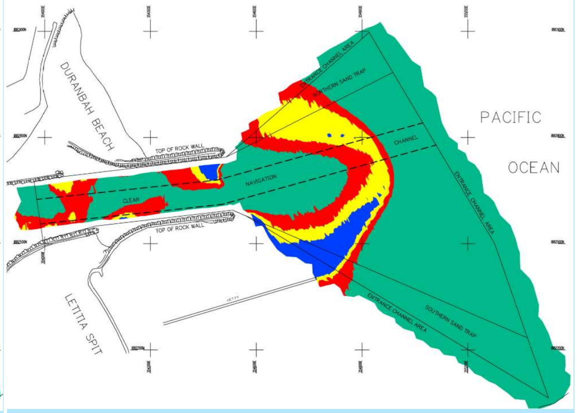

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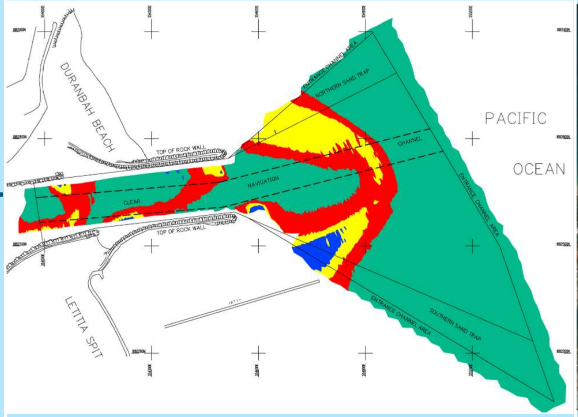

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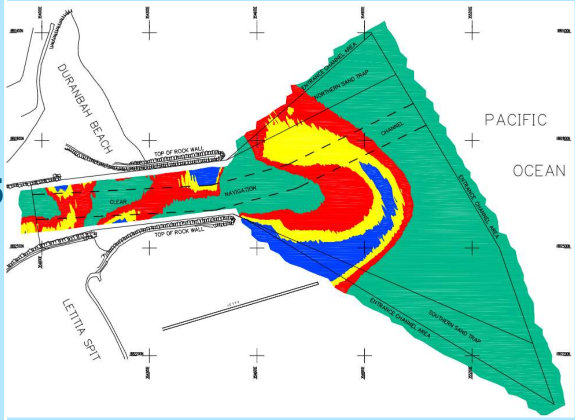

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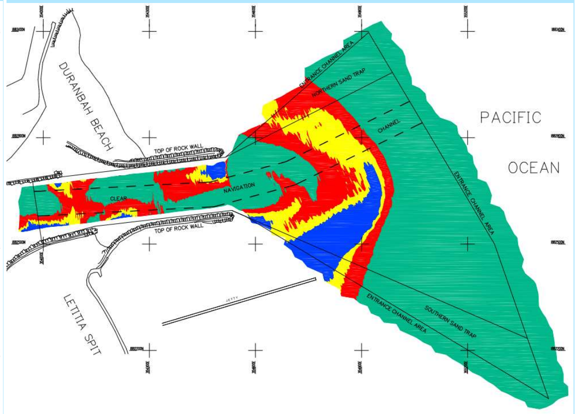

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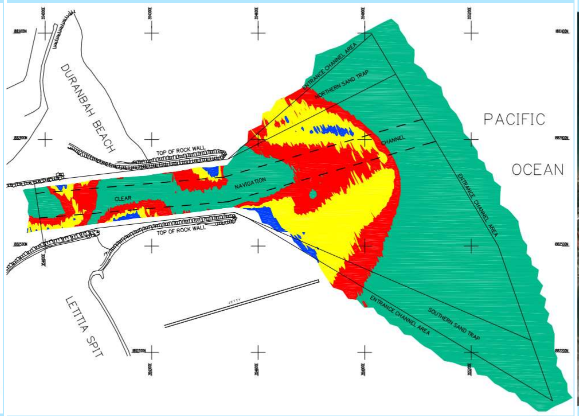

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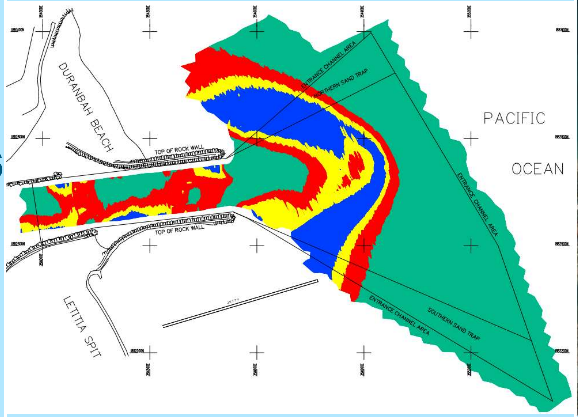

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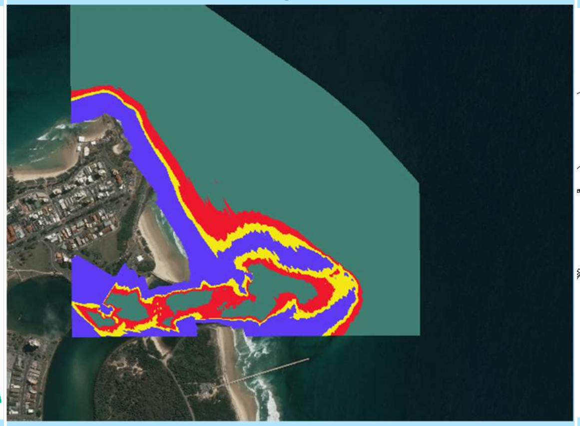

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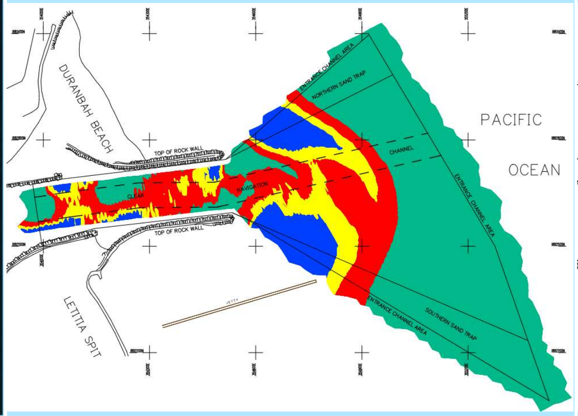

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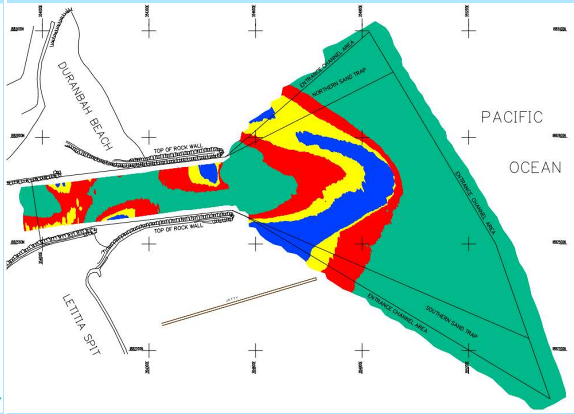

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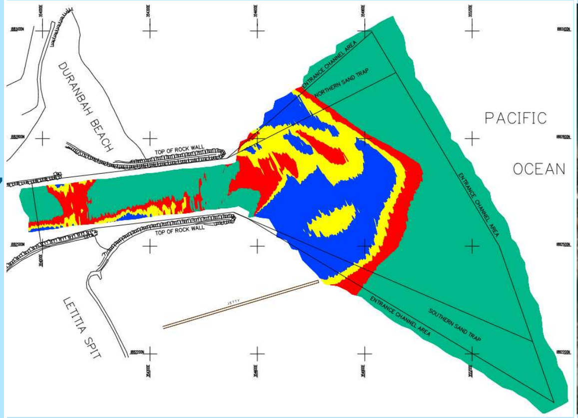
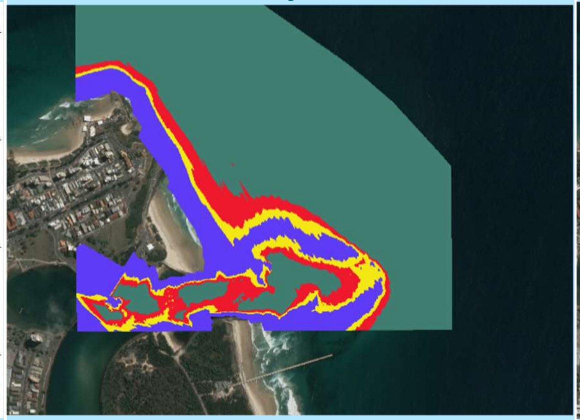
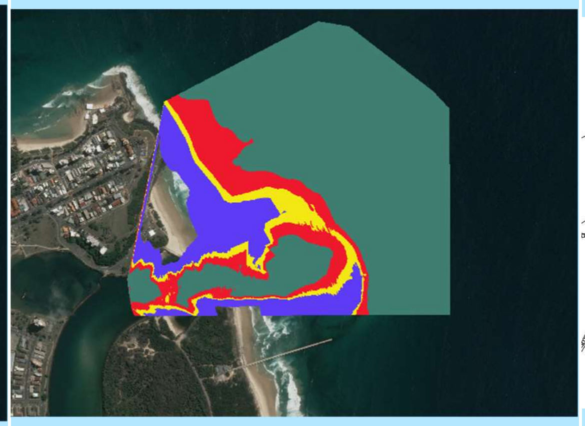
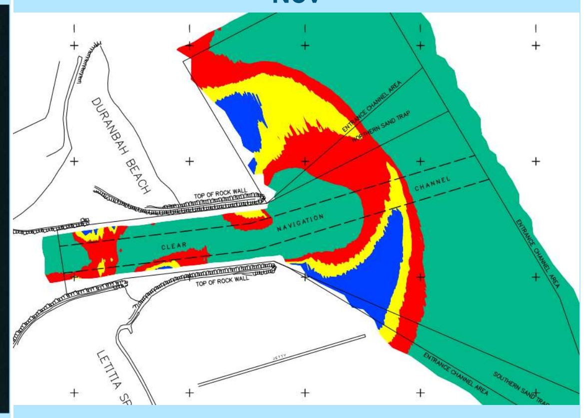
<tr><td>2017</td><td>
</td><td></td><td></td><td></td><td>
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