An Evaluation of the Viability of Re-establishing Tidal Exchange in Hoopers Inlet by Mechanical Excavation

A report prepared for the Otago Regional Council

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Executive summary

1. Hoopers Inlet is a wave-dominated inlet susceptible to closure, most probably during periods of low wave activity during which sand is deposited by wave action in the inlet mouth. It has closed at least five times over the last five decades. It last closed in August 2012 and remains closed.

2. Prolonged closure is associated with low water quality during periods of low runoff and road inundation during periods of high runoff.

3. Closure does not appear to be associated with variation in local winds or rainfall, although aeolian sedimentation may contribute to channel infilling, and low rainfall and lagoon levels reduce the likelihood of natural reopening. Closure and spit accretion and progradation probably resulted from the shoreward transport and deposition of sand usually contained in the inshore bar system.

4. The likelihood of natural reopening of the inlet is difficult to predict, but there is the reasonable prospect the inlet will remain closed for months, years or even indefinitely. The establishment of marram grass on the spit has the potential to establish a foredune and reduce the likelihood of natural reopening.

5. The opening to the inlet has been reestablished mechanically on at least two occasions. The success of such operations cannot be guaranteed, however. Future operations, should they be deemed necessary, should be timed to coincide with:

   - High lagoon levels.
   - Spring tides.
   - Late winter conditions when atmospheric pressures tend to be lower, ocean levels higher and beach erosion more likely.

6. For Hoopers Inlet to be successfully reopened a strong ebb flow must be established during the initial hours and days following cutting of the pilot channel. The pilot channel should be dug to approximately mean sea level, or preferably lower. Current water levels in the lagoon are well below mean sea level – indicating there is little prospect of success given current conditions. At least 2,300 m^3 of sand will need to be removed to excavate a channel 8-10 m wide, between the current lagoon and the beach, to a channel depth equal to about mean sea level.

Contents

1.0 Introduction

Hoopers Inlet (45°86’ S, 170°66’ E) is a barrier (bar-built) tidal inlet and lagoon system situated on the south-east coast of Otago Peninsula, 14 km northeast of Dunedin (Figure 1). Measuring 3.71 km^2 in area, c. 1800 m wide and 3000 m long, the lagoon is shallow with water depths of 1–2 m at high tide (Enright, 2006). The Hoopers Inlet catchment is 3,305 ha in area with three small streams discharging directly into the lagoon. A late-Holocene coastal barrier measuring approximately 1.4 km long by 1 km wide separates the lagoon from the open coast. The geomorphology of this barrier is comprised of dune landforms — foredune ridges and parabolic dune forms.

Figure 1. Location of Hoopers Inlet , Otago Peninsula,

The tidal signal in Hoopers Inlet is semi-diurnal with a strong spring-neap tidal cycle (Albrecht and Vennel, 2006). The tidal range at the highest spring tides is approximately 2.6 m. Alternative spring high tides are typically 30 cm greater than the intermediate spring tide. The prevailing winds are from the southwest and the northeast with a strong summer-winter contrast.

Hoopers inlet is usually open to the ocean. A single channel measuring approximately 1500 m long by 350 m wide (at high tide) connects the lagoon to the ocean at the western end of the Holocene barrier. The low tide channel is much narrower. Prior to the present closure the channel was only 35 m wide near the mouth. Periodically this narrow channel is choked with sediment and a sand spit builds across the inlet, so preventing tidal exchange. The most recent closure occurred in August 2012. Remedial works to reopen the channel mouth were attempted shortly after the inlet closed, but failed to maintain an opening. Sand deposited by waves quickly refilled the channel opening. The inlet has remained closed since this time and there is little immediate prospect of it opening naturally.

Closure of the entrance to Hoopers Inlet may be a natural process, but it has a number of adverse environmental outcomes for the local community. Roads bordering the inlet, which were constructed atop the then saltwater wetlands, were inundated following closure. Water quality has declined over the summer of 2012/13 with the continued use of the inlet by birds and the progressive decrease in water level and volume.

This report (i) examines the conditions preceding inlet closure and (ii) outlines the circumstances in which mechanical intervention is most likely to be successful.

2.0 Tidal Inlets

2.1 General morphology and processes of tidal inlets

A tidal inlet is defined as an opening in the shoreline through which water penetrates the land, thereby providing a connection between the ocean and bays, lagoons, estuaries, and tidal creek systems (Davis and Fitzgerald, 2004). The main channel of a tidal inlet is maintained by the continual flow of water back and forth between the lagoon and the sea resulting from the rise and fall of the tides, also known as 'tidal currents' (Davis and Fitzgerald, 2004). During the rising tide, the water level of the ocean rises at a faster rate than inside the inlet causing water to flow into the inlet (the flood current) while during a falling tide, the water level of the ocean drops ahead of the water level of the lagoon causing water to flow out of the inlet to the sea (ebb currents). In general, the volume of water entering the inlet during the rising tide equals the volume of water leaving the inlet during the falling tide. This volume is referred to as the tidal prism.

The morphology of tidal inlets is governed by the strength of the tidal currents, variable quantities of freshwater inflow from the lagoon side of the inlet, and different levels of wave activity acting along the ocean margin of the inlet (Komar, 1996). As such they display a range of morphologies depending on the relative dominance of these three processes.

The primary components of most tidal inlets include: an inlet throat, which is normally the narrowest and deepest part of the inlet and through which tidal currents attain their maximum velocities; a flood-tidal delta consisting of sand deposited by deceleration of flood-tide currents landward of the inlet throat; and an ebb-tide delta consisting of sand deposited by deceleration of ebb-tide currents seaward of the inlet throat (Davis and Fitzgerald, 2004) (Figure 2). The morphology of these deltas reflects the movement of sediment in and out of the inlet, and hence varies in different oceanographic settings (Komer, 1996). Microtidal (tidal range = 0–2 m) areas tend to have smaller ebb-tidal deltas and larger flood-tidal deltas. Mesotidal (= 2–4 m) areas show the opposite trend.

The observed morphology of the flood and ebb delta can be used to infer the relative importance of the tidal currents, freshwater inflow and wave activity on the inlet dynamics. Ebb-tidal deltas tend not to develop on oceanic coasts exposed to large waves. On such coasts the oceanic waves rather than tidal currents dominate sediment movement. The interaction of waves and currents tend to produce higher sediment concentrations during flood tides, than during ebb tides, transporting sediment into the lagoon and forming extensive flood tide deltas (Nummedal et al., 1977). In contrast inlets dominated by tidal currents have large ebb-tide deltas and a general absence of the inner shoals characteristic of a flood-tide delta. The study site shows characteristics of both wave and tide dominated inlets, but in general sediment movement at the mouth of Hoopers Inlet is dominated by wave activity.

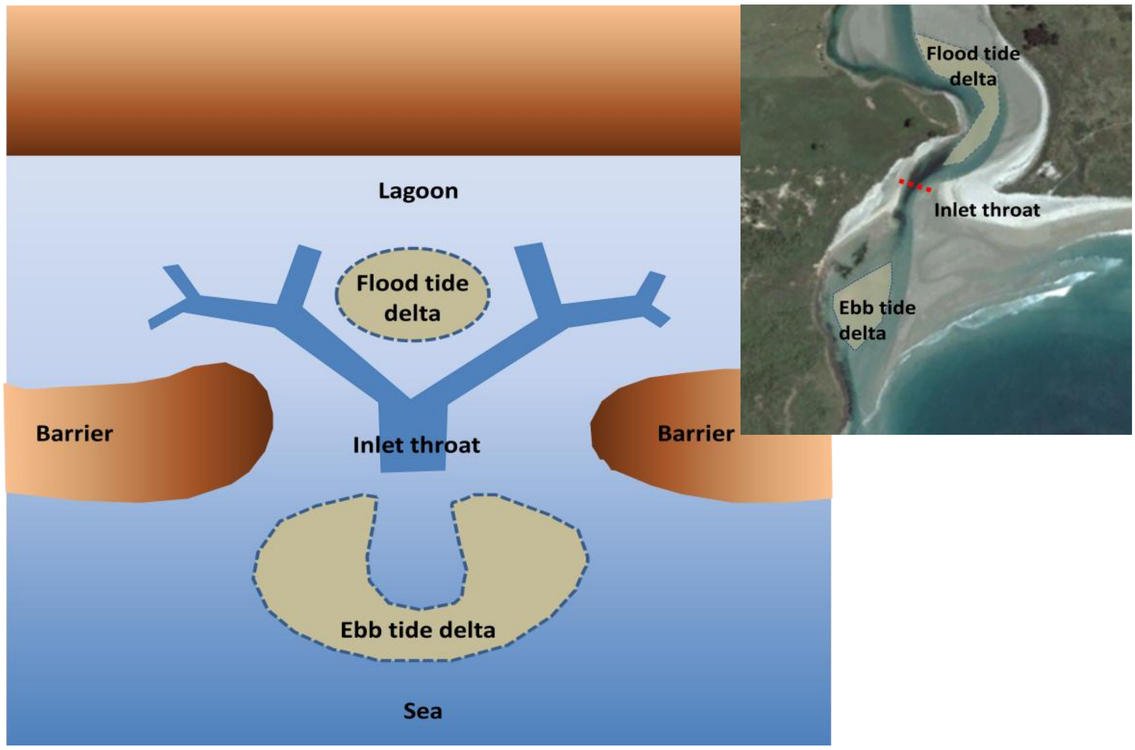

Figure 2. Common morphological features of tidal inlets. The inset identifies these features at Hoopers Inlet (in 2004) prior to closure.

2.2 Processes leading to inlet closures

Tidal inlets remain open primarily due to the scouring effect of tidal currents (Davis and Fitzgerald, 2004; Battalio et al., 2006), while waves and wind continuously deposit sand near the inlet throat. Under usual conditions the strength of the tidal currents are sufficient to remove this sand, maintaining an open inlet. Any change in the ability of the tidal currents to remove this sand allows sand to accumulate, a sand bar to form (or spit to extend, as in the current case), which may lead to periodic closure of the inlet.

A change in the ability of the tidal currents to remove sand deposited in the inlet can occur from either a decrease in the strength of the tidal current, or from an increase in the volume of sand deposited. For example, a decline in the water level of the lagoon decreases the strength of the ebb current, thus reducing the scouring potential of the tidal current. Hoopers Inlet is shallow and the volume of water contained at high tide must have declined as a result of late-Holocene and historic sedimentation (infilling). To some extent a eustatic rise in sea-level of around 20 cm over the last 150 years must have offset this process. Alternatively, an increase in the incidence of swell waves, which are more likely to add sand to the beach above mean sea level, may result in an increase in wave-deposited sand. Tidal currents are now no longer sufficient to remove this sand. Other factors leading to a decrease in tidal strength or increase in sand deposition include periods of reduced wave energy, or an increase in alongshore sand transport, respectively.

Several studies have examined the processes leading to the closure of specific inlets. Typically they have found that closure occurs when these factors, an increase in sand deposition coupled with reduced current strength, coincide. For example, Wilsons Inlet, a small seasonally closed inlet along the southwestern coast of Western Australia, closes because of both increases in onshore sediment transport rates and decreased stream flow during summer months (Ranasinghe and Pattiaratchi, 2003). Mangawhai Harbour, Northland, New Zealand, became un-navigable following the development of a dual-inlet system during a series of storms that breached the spit in 1978. While neither inlet closed completely, sand accumulated rapidly in the northern inlet once tidal current speeds declined.

2.3 Processes leading to inlet opening

For a tidal inlet to form the barrier must first be breached allowing water flow between the water bodies on each side (Kraus et al., 2002). Breaches occur naturally, or they can be purposely dug or dredged. Breaches are often transitory features, but if conditions are suitable a breach can develop into a more stable, semi-permanent tidal inlet.

Natural opening

The natural breaching of a barrier occurs in two ways; 1) a breach may open if waves break on the shore and wash over the spit, in the process scouring a trough between the open ocean and the body of water protected by the barrier; or 2) seepage through narrow barriers allows large volumes of sand to be transported quickly as slurry (Pierce, 1970) (Figure 3). Breaching by overwash occurs only when water reaches the top of the barrier spit, and can occur from both the seaward side of the barrier, typically during times of high waves and sustained elevated water levels. It may also occur from the landward side, typically when water levels are raised in the lagoon by groundwater and river inflow, runoff, or direct precipitation (Kraus et al., 2002; Kraus et al, 2008). Breaching by seepage occurs typically from the lagoon side of the barrier, and in comparison to overwash breaching, it is not necessary for water to have reached the top of the spit (Kraus et al., 2002; Kraus et al, 2008).

The likelihood of a barrier being breached depends on the morphology of the barrier and the elevation of the water level in the lagoon. Breaching potential from the seaward side is minimised if the barrier is high and wide; in which case barrier elevation and volume above mean sea level are key factors for resisting inundation and erosive wave attack during times of higher water levels (Kraus et al., 2008). Breaching from the lagoon side depends principally on the width of the barrier, and on the water elevation difference between the ocean and lagoon (Kraus et al., 2008).

The breaching process normally occurs during storms after waves have destroyed the foredune or eroded the upper beach and storm waves have overwashed the barrier. Even though this process may produce a shallow overwash channel, spits or barriers are seldom cut from their seaward side (Davis and Fitzgerald, 2004). In most instances the breaching of a barrier is the result of the storm surge increasing the height of waters in the back-barrier bay or lagoon. Overwash events of lesser magnitude may have the opposite effect, depositing more sand on the spit or barrier and within the former tidal channels. If the level of the ocean tide falls, the elevated waters of the lagoon may flow across the barrier towards the ocean, gradually incising the barrier and cutting a channel. If subsequent tidal exchange between the ocean and the bay is able to maintain the channel a tidal inlet is established. The breaching process is enhanced when offshore winds accompany the falling tide and if an overwash channel is present to facilitate drainage across the barrier.

In summary, the ideal conditions for natural reopening of an inlet are erosion of the seaward face of the spit or barrier (to cause a narrowing of the barrier); high water levels within the lagoon (due to overwash during storm events and/or freshwater input); spring high and low tides; and the presence of an incipient channel across the barrier.

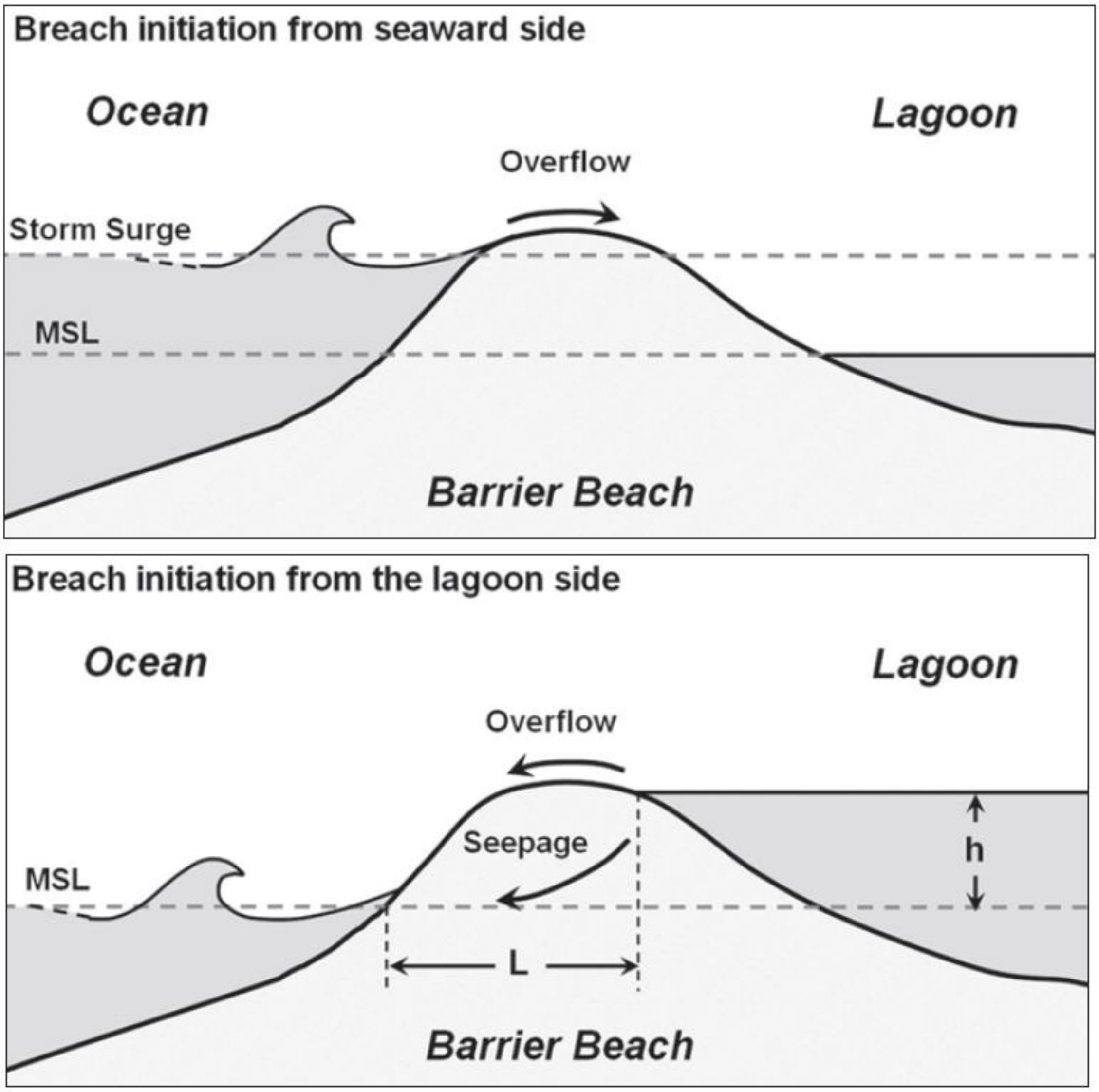

Figure 3. Processes of inlet breaching (adapted from Kraus et al., 2008)

Mechanical opening

In many communities, if the water levels become high, lagoons are manually breached to prevent flooding of adjacent properties and infrastructure, and to improve water quality (Kraus et al., 2008). A breach is usually opened by excavating a narrow channel across the sand spit separating the sea and the lagoon. If the water bodies are at different levels the pilot channel will quickly deepen and widen as water moves through the barrier from high water to low (Kraus et al., 2002; Wamsley and Kraus, 2005). Ideally the breach will reach an equilibrium morphology, where the amount of water entering the inlet equals that leaving — thus forming a stable tidal inlet.

Mechanically opened tidal inlets often close naturally by wave driven longshore sediment transport (Goodwin and Williams, 1991). Waves may also move the sand ejected from the pilot channel onshore, contributing to re-closure of the inlet (Kraus et al., 2008). In general the growth and stability of a breach depends on the maintenance of a sufficiently strong flow of water as driven by the head difference between the water in the ocean and the water in the lagoon, and any flow from tides and wind (Kraus and Wamsley, 2003). Small lagoons, for example, close naturally when breached because the tidal currents are not sufficient to remove the sand deposited in the opening by waves.

The timing of the cut will influence the nature of the post-breach flow in the inlet. In some cases the desired management goal has been to form a flood delta; the pilot channel was opened as the tide was rising. In most cases, however, the goal is to create a semi-permanent tidal inlet, and in these cases the pilot channel is usually opened at close to low tide, in order to maximize the duration of seaward flow (Kraus et al., 2008). An initial strong ebb flow minimizes the possibility of beach and littoral sediment entering the channel.

The experiences of Mr Nash and Mr Clearwater during recent excavations were valuable to understanding the present case. They agree that high inlet levels are a necessary precondition to successful reopening and that the current low lagoon levels would likely prevent a successful intervention. The successful 1995 and 1997 operations involved the excavation of an 8 m wide channel across the base of the spit in two stages — removal of the dry surface sand followed by rapid excavation of a trench to the mid-tide level. Two excavators were employed. Mr Nash and Mr Clearwater suggest the base of any future excavation should be at mean sea level; but it would be better to cut lower, if possible, to ensure maximum ebb flow speeds (forced by the difference between high lagoon levels and low tidal levels) and scour across the subsequent flood part of the tidal cycle. The 1995 and 1997 excavations were located close to the base of the spit; after which the channel migrated back toward the south until it encountered the Sandymount headland.

3.0 Methods

3.1 Dates of closure

It was difficult to confirm the precise dates of closure, but it was possible to gain a reasonable estimate of the number and timing of closures from aerial photographs, published sources and people who have had a long association with Hoopers Inlet, two of whom have attempted to open the inlet in recent years. Mr Lyall Nash, Mr Steve Clearwater and Mr Sam Neill have confirmed the inlet closed in the mid 1970's and 1980's, as well as the mid 1990's (1995 and 1997). Post-war aerial photographs show the inlet also closed in 1952. Mr Nash, who re-opened the inlet in 1995 and 1997, suggests the inlet is most likely to close during periods of northerly wind and wave conditions and periods of relatively calm wave conditions.

3.2 Spit & inlet morphology

The most recent closure of Hoopers Inlet is documented in a series of aerial images taken between December 2004 and December 2012. Photos were sourced from Google Earth, geo-rectified and analysed in ArcGIS (10). The area covered by the sand spit was mapped in each image. The shape and area of the sand spit and the location of the channel was compared with the 2004 image to illustrate changes in inlet morphology from a typical open state to a closed state. Due to differences in tides at the time of photography only the supra-tidal area of the spit (that part of the spit above high water) could be mapped. Nevertheless, this was sufficient to allow gross changes in the extent of the sand spit to be identified.

The morphology of the sand spit that closed Hoopers inlet in 2012 was described using aerial photography and ground-based topographic surveys.

The height and width of the current sand spit was surveyed on the 15th of March, 2013 to determine the relative height of lagoon and tidal levels and the volume of sand that would need to be excavated to enable reopening of the inlet. Four shore normal profiles were surveyed across the sand spit from the open coast to the landward edge of the channel using a Leica total station (Figure 4). One of the profiles (P3) was surveyed at the approximate location of the inlet throat in 2004. The elevation of high tide and the width and position of the channel were recorded along with other environmental variables including the width of the intertidal terrace and the inland extent of over-wash events.

Local mean sea level (msl) was calculated (to within 0.2 m) by subtracting the predicted high tide elevation from the observed and surveyed high tide strandline and adjusting for barometric pressure. On March 15th 2012 the predicted high tide at Hoopers Inlet was 0.78 m above msl. The barometric pressure was 1019 HPa. Winds were negligible at the time of surveying. The heights of the highest spring tides were determined from tide tables and superimposed on the profiles. These calculations indicate the spit is over-washed when significant waves coincide with the highest spring high tides. Observations of shells, marram grass (*Ammophila arenaria)* rhizome and stranded seaweed show this process has occurred at least once since inlet closure.

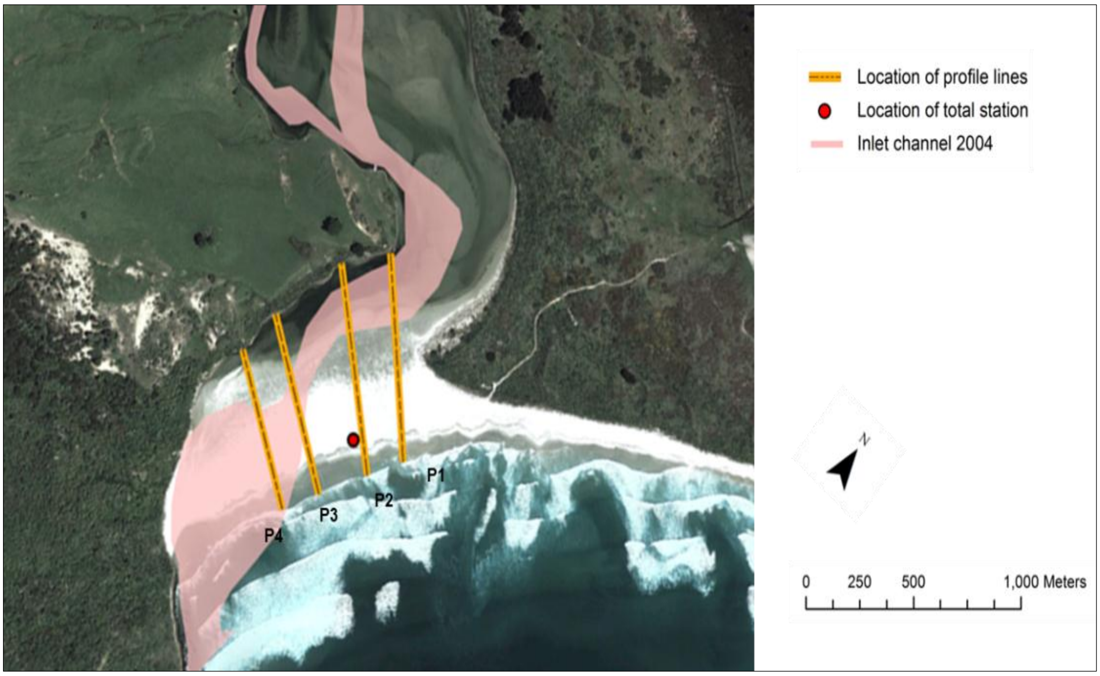

Figure 4. Location of the surveyed shore normal profiles surveyed in March relative to the existing spit and the tidal inlet in 2004.

3.3 Pre-closure conditions

The conditions that lead to closure are of obvious interest. What are these conditions and how often do they occur? Long-term wind records from Taiaroa Head (1952 – 2013) and Musselburgh (1985 – 2013) were analysed, with a particular focus on variation in total wind energy, and variation in winds from the northeast and southwest. Such winds have the potential to produce local waves that might favor or hinder north to south transport of sand in the inshore zone. That said, the waves propagating into the Allans Beach embayment, recorded in the available imagery, are predominantly swell waves from the southeast. The beach is relatively sheltered from locally generated waves approaching from the northeast by Cape Saunders. It proved unrealistic to identify the marine conditions that preceded the recent closures given the absence of wave data. Long-term rainfall records from the above stations were also examined, with the goal of identifying anomalously low rainfall prior to closure.

The sequence of satellite images prior to the most recent closure was examined for significant changes in the morphology of the beach-inshore bar system. The images were taken at different stages of the tide and wave conditions, so the data set was not ideal, but key differences in pre- and post-closure morphologies were indicated. These are discussed below.

4.0 Assessment of the pre-closure conditions

The closure of Hoopers Inlet occurred through the south-west extension of the existing spit, comprising supratidal (above high water), intertidal and subtidal (inshore) elements (Figure 5). There was little change in the location and size of the dry portion of the spit between 2004 and 2009, however, the sequence of satellite images since 2004 shows sand was accumulating in the intertidal and inshore environments. The growth of the spit occurred principally between 2009 and 2010. Between July 2009 and November 2010 the spit extended south at an average rate of 19m month^{-1} compared to an average rate of only 10m month^{-1} between November 2010 and September 2011.

The inlet closed around August 2012 and the spit has subsequently widened by progradation (accumulation of sand so that the line of high water is displaced toward the sea).

Closure and progradation probably resulted from the shoreward transport and deposition of sand usually contained in the inshore bar system. The satellite images show the outer edge of the bar system, which usually comprises a transverse bar and beach morphology with skewed rip channels (after Wright and Short, 1984). A comparison of the 2005 and 2012 images (Figure 6) indicates the outer edge of this bar system is closer to shore in 2012, implying shoreward transport of sand.

It seems likely that marine sedimentation, that is, changing patterns of beach-inshore sand accumulation, is the primary driver of inlet closure at Hoopers Inlet. Wind records from Taiaroa Head and Musselburgh, from 1952 and 1985 respectively, and rain data from 1985, was examined for any evidence of anomalous conditions preceding the 1995, 1997 and 2012 closure events. None were evident. The drought over the 2012/13 summer no doubt contributed to the low water levels within the impounded Inlet and so reduced the likelihood of a natural re-opening, but did not contribute to closure.

Coastal wave data for the study area is unfortunately not available. It is likely that instances of closure are preceded by a particular phase of waves from the north or an increased frequency of northerly waves over a longer period. Whether this process occurs in conjunction with variations in rainfall, aeolian sedimentation across the dry beach, and neap tidal stage is difficult to resolve. It does appear that the inlet is predisposed to close and to close for long periods. The last two closures, in the mid 1990s, were reversed only after intervention. Without such intervention long-term closure may be inevitable.

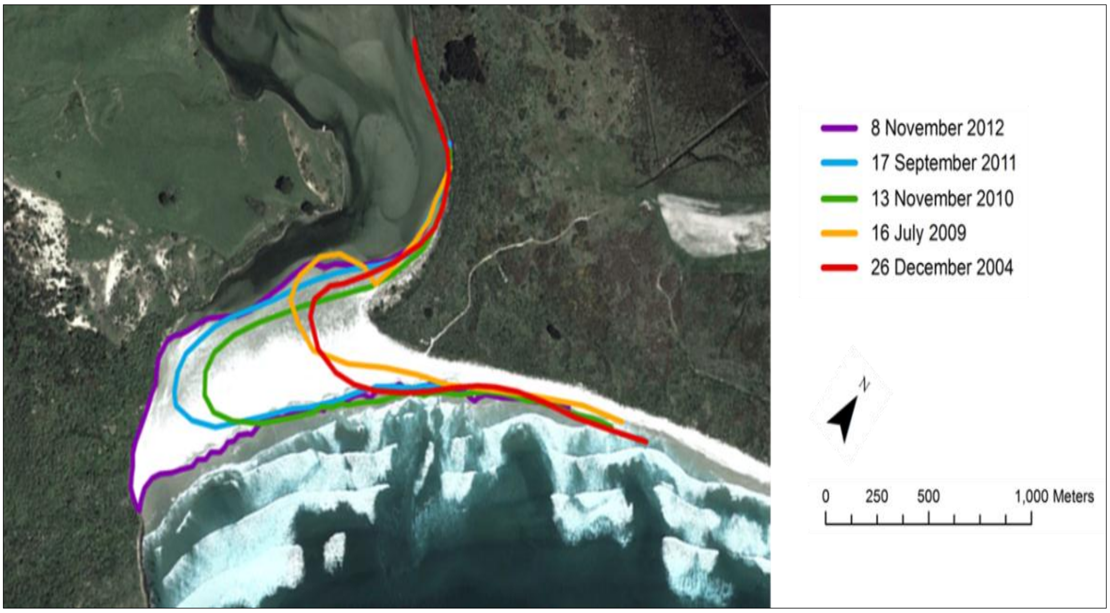

Figure 5. Development of the sand spit between December 2004 and November 2012

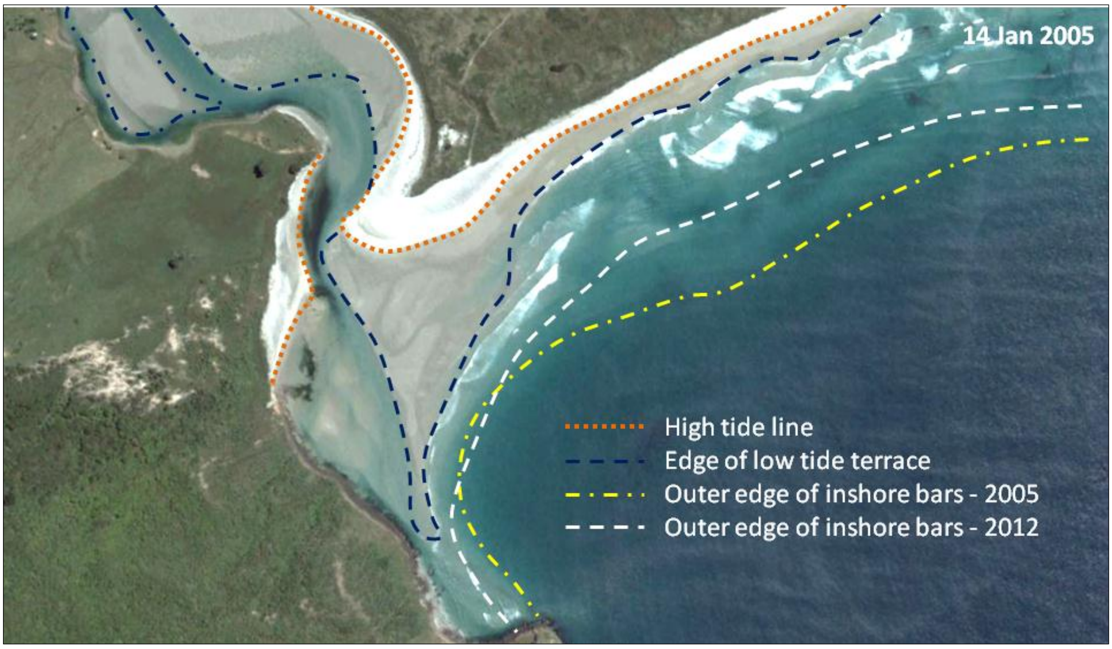

Figure 6. Morphological features of the pre-closure inlet and comparison of 2005 and 2012 inshore bar limits.

5.0 Current morphology of spit

The supratidal sand spit covers an area of 28,8131 m^2, an increase of 250% from its 2004 extent. There is little variation in the width of the spit alongshore — which ranges from 290 m – 350 m wide. The spit is narrowest towards the middle of the spit, corresponding roughly to the position of the tidal inlet in 2004. Similarly, there is little change in the height of the spit alongshore. It decreases alongshore from a height of 1.2 m above mean sea level at the eastern end of the spit to 0.9 m above mean sea level at the western end.

The onshore morphology is broadly similar along the length of the spit (Figure 7). Sand has accumulated along the seaward portion of the spit forming a broad ridge. Much of this sand would have been deposited by waves. The western end of the spit is lower than the level of the highest spring tides and we observed several strandlines indicating that waves have penetrated inland over much of this beach ridge in recent months. Northeast winds transport sand along the beach but until recently there have been few features on the surface of the spit able to capture this sand. In March, however, we observed several small marram plants growing on the spit. These have established over the last six months from wind-blown seed and wave-deposited rhizome during overwash events. As they grow — if they are not destroyed by repeat overwash events — they will trap sand and force accretion. The chances of a natural re-opening of the inlet would diminish if marram was to become established and an incipient foredune develop. Konlechner and Hilton (2011) have documented this process within Hoopers Inlet. A 1.5 m high incipient foredune formed within 3 years of marram rhizome stranding.

The inland margins of the current spit consist of a low flat terrace (Figure 7). The sand forming this terrace is relatively damp and is readily distinguished from the sand forming the higher sections of the spit by its (dark grey) color. This feature is easily identified on the 2011 aerial photograph. This terrace was the intertidal terrace when the inlet was still open.

Strand lines at the back of the spit indicate that water covered this terrace fairly recently. The spit probably acted as a dam allowing water to accumulate to higher than usual levels (which led to inundation of Allans Beach Road). At present, the water level in the inlet channel is low — 37 cm below mean sea level. Given the abnormally dry 2012/13 summer it is likely this level is close to the minimum levels of Hoopers inlet and we can expect the inlet level to rise during winter.

At present the channel ranges from maximum depths of 0.8 m to 1.5 m, and from widths of 33 m to 70 m. The former inlet channel has become shallower and narrower at its western end, as a result of both overwash processes and aeolian sedimentation. We observed sand being blown across the spit and across the former intertidal terrace and into the channel in both north-east and south-west winds. It is likely that while the inlet remains closed sand will continue to accumulate in the channel.

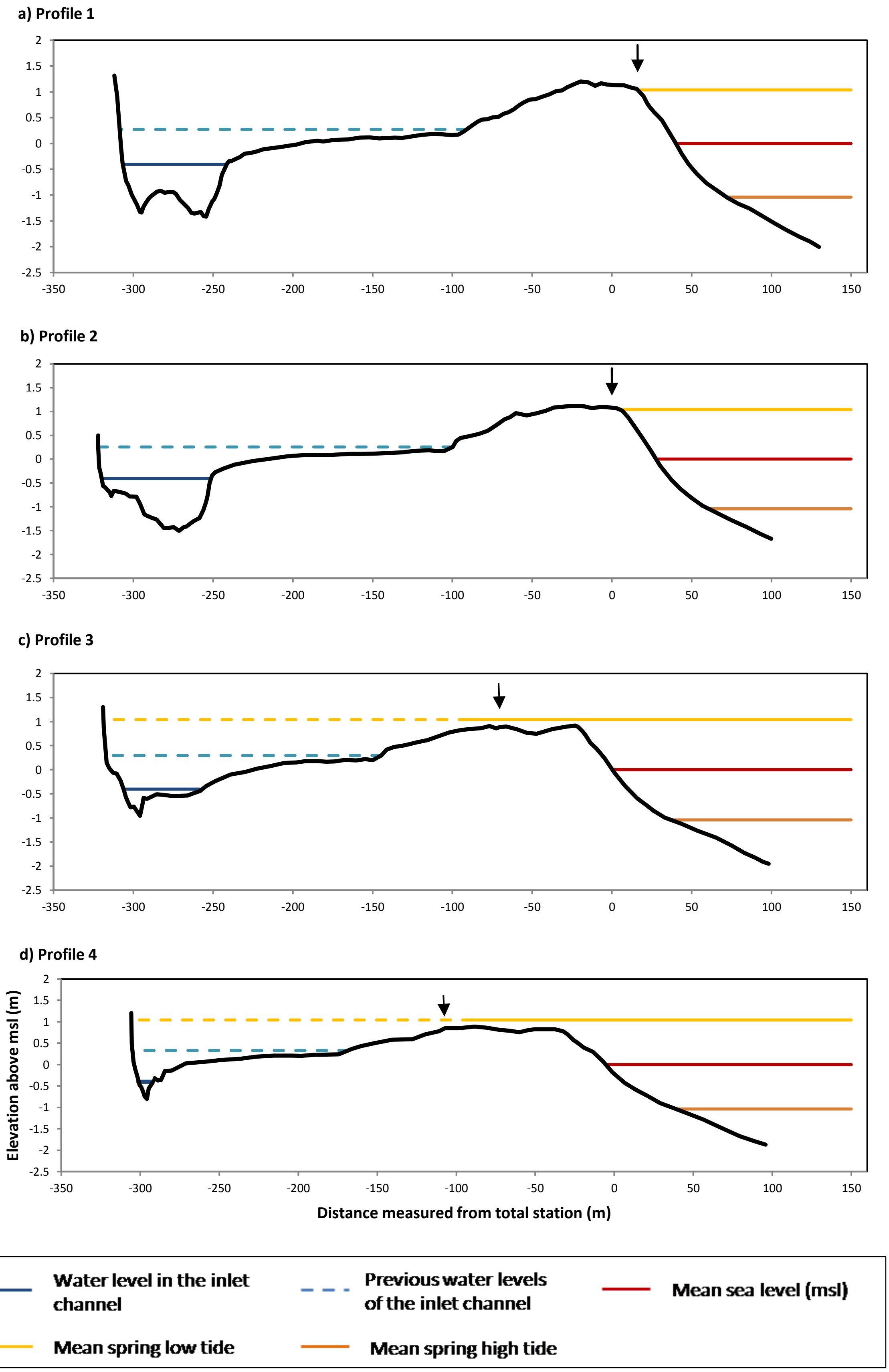

Figure 7. Elevation of the sand spit and water in the inlet channel relative to msl, the elevation of the highest spring tides and lowest spring tides.

Presently a number of small marram plants are growing across the surface of the sand spit. If left to establish, these plants will contribute to the stability of the sand spit and encourage accretion. At present, these plants are small (20-40 cm high), but they will begin to capture sand and form small dunes within a few months. Heyligers (2006) found that when plants similarly colonized sand-spits in Victoria, Australia, they greatly lessoned the potential for reopening.

6.0 Recommendations

6.1 Potential for the inlet to re-open naturally

Hoopers Inlet is unlikely to re-open naturally until at least mid to late winter when inputs of freshwater have raised the lagoon level. The abnormally hot and dry 2012/2013 summer has allowed a large volume of sand to accumulate at the mouth of inlet while simultaneously lowering the water levels of the lagoon to extremely low levels. Any wave overwash appears to be depositing sand on the spit and in the channel, so there is little prospect of a breach from the seaward side before winter.

The beach adjacent to Hoopers Inlet does display a strong seasonal cut-and-fill cycle (pers. obs.). Large volumes are sand are removed from the beach during winter storms, and are returned during the calmer summer months. It is likely winter storms will erode the seaward margin of the spit, decreasing the width of the bar and (possibly) forming overwash channels. Provided increased precipitation has raised water elevations in the lagoon, these conditions may lead to the development of a natural breach. However, there is an equal likelihood the inlet will remain closed.

6.2 Mechanical reopening of the Hoopers inlet

Timing is critical if mechanical opening is to be successful. Any attempt should be delayed until mid to late winter when:

- Lagoon levels are much higher than at present.
- High lagoon levels correspond with spring tides.
- Atmospheric pressures tend to be lower and ocean levels higher.
- Wave activity is likely to be higher and the face of the spit eroded and the spit somewhat reduced in width.
- Waves are more likely to be higher and steeper and have an erosional effect.

The placement of the pilot channel has implications for the volumes of sand to be excavated. The channel should be dug in the vicinity of Profile 2, where the adjacent channel is deepest and where the potential for establishing a strong ebb flow is greatest. Successful attempts to re-open Hoopers Inlet have occurred in this vicinity in the past.

For Hoopers Inlet to be successfully reopened a strong ebb flow must be established during the initial hours and days following cutting of the pilot channel. In part this will depend on the width of the channel cut. A channel that is too wide will not generate the tidal currents required to prevent sand from accumulating, while one that is too narrow is vulnerable to infilling from along-shore marine and aeolian sedimentation. The inlet throat was 35 m wide when Hoopers Inlet was last open, but these dimensions were in equilibrium when the water level in the lagoon was higher. The successful 1990's operations involved the excavation of an 8m wide channel across the base of the spit.

The pilot channel should be dug to approximately mean sea level, or preferably lower. Current water levels in the lagoon are well below mean sea level.

To excavate a channel 8-10 m wide, between the current lagoon and the beach, to mean sea level, at least 2,319 m^3 of sand will need to be removed. This is approximately the volume of the main pool at Dunedin's Moana Swimming Pool.

The channel should be cut during the spring tide phase of the tidal cycle and the channel cut during a falling tide (so that the difference between lagoon and ocean levels is at a maximum). Cutting the channel on a falling tide minimises the amount of sand deposited by the flood tidal current. It would also be beneficial to time the excavation for a period of low ocean waves, to reduce the deposition of sand in the channel.

Careful consideration will need to be given as too where the sand removed from the pilot channel is placed. If sand is placed too close to the inlet aeolian sedimentation and waves are likely to redeposit the sand into the channel.

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