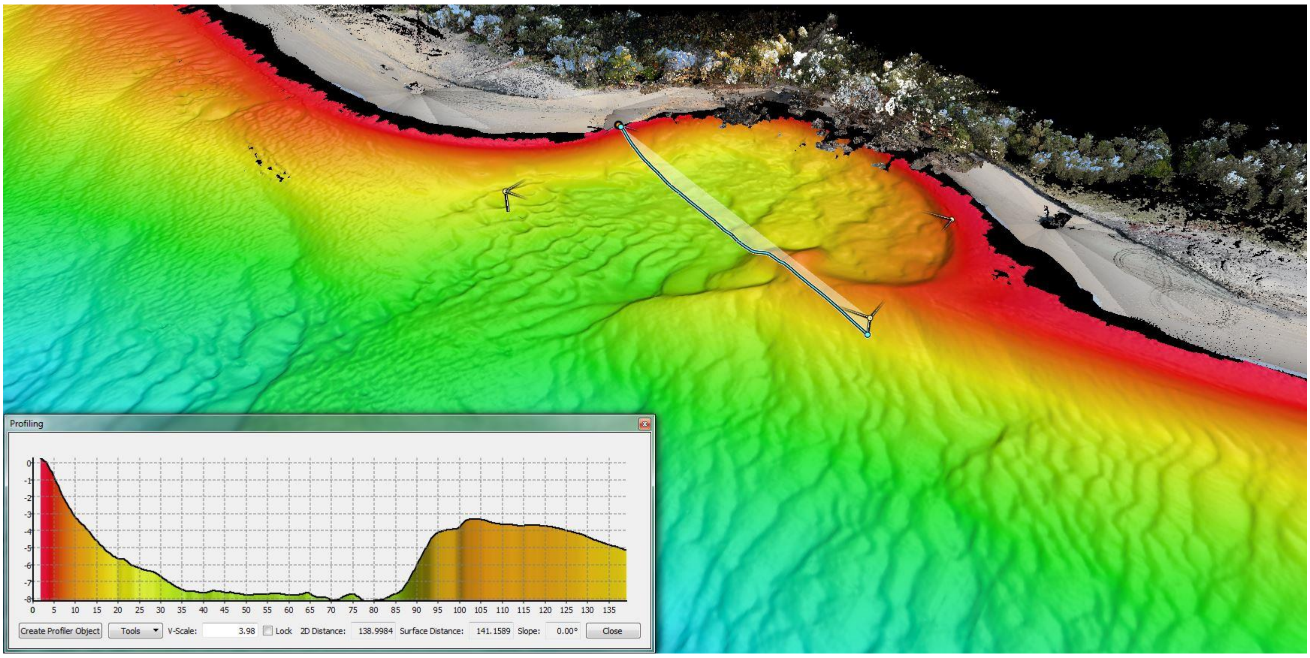
EDG consulting

Risks associated with nearshore instability
Inskip Point, Qld



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Prepared for:

Queensland Parks and Wildlife Service
Level 6, HQ South Tower
520 Wickham St
Fortitude Valley QLD 4006

Prepared by:

EDG Consulting Pty Ltd
91 Commercial Road
Teneriffe QLD 4005
t: +61 416 132 343
e: admin.edg@edgconsult.com.au

Author:

Ian Shipway – Principal

Reviewer:

Greg Hackney - Principal

Notes:

Final version following draft.

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1 Introduction

On 26 September 2015, a nearshore landslide occurred within the north facing beachfront at Inskip Point, Qld, eventually regressing to a camping ground and engulfing a four-wheel drive vehicle, a caravan and a camper trailer. The nearshore landslide ("September 2015 instability event") occurred late in the evening and was in the form of a retrogressive which gradually increased in size over a period of several hours, eventually forming an arc shaped scarp over 200 m wide. At the request of Queensland Parks and Wildlife Service (QPWS), a Principal from EDG Consulting Pty Ltd (EDG) visited the site of the event on the afternoon of 27 September 2015. Following that site visit, a brief report was prepared providing a preliminary assessment of the mechanisms of instability and advice with respect to short term risk management measures.

Subsequently, QPWS commissioned EDG to conduct a study of instability events on the Inskip Point Peninsula and provide longer term risk management strategies. This report presents the results of that study, which was conducted in accordance of our proposal of 12 October 2015 (document reference: B01006-1AD).

1.1 Study Aims

The main aims of the instability risk study were to:

- Develop knowledge of the history of past instability events on the Inskip Point peninsula.
- Gain an understanding of the mechanism of instability, including triggers and the geographical constraints which may affect the morphology and location of future events.
- Provide the information required to assess and analyse the risks presented by future instability.
- Devise practical risk management options which QPWS could implement to reduce risks.

1.2 Study Scope

The study was based on data that was readily available, with a focus on providing risk management outcomes within a few weeks of the study initiation. The main elements of work conducted for the study comprised:

1. Desk study and research into past events based on QPWS records and other readily available data. Information was sought with respect to:
   a. The location, date and time of past events and under what conditions the events occurred, relative to tides, seismic activity and other natural cycles.
   b. Mechanisms of failure for similar events in Australia and elsewhere. This involved a literature review and conversations with those currently conducting research.
   c. The geology and geotechnical conditions of the peninsula.
2. A one-day field visit to view the surface geomorphology and geological conditions, and the sites of historic instability events where they could be identified.
3. A high resolution multibeam sonar and vessel mounted/terrestrial laser survey of the northern side of the full east-west extent of the peninsula. The intent of the survey was to measure the geometry – bathymetry of the nearshore zone, both at the location of the recent event and along the beachfront generally. The survey was conducted by Port of Brisbane Pty Ltd using the vessel Navigator for hydrographic and land survey up to about the high water mark, and land based laser survey for the upper parts of the beach. Appendix 1 presents detailed results of the survey and information on the methods used.
4. A preliminary risk assessment in accordance with the methodology of the Australian Geomechanics Society (AGS, 2007).

2 Physical Setting of the Study Area

2.1 Location

Inskip Point is a sand peninsula, north of Rainbow beach which forms the southern edge of the channel leading to the Great Sandy Strait (Figure 1.1).

Figure 1.1 Location of Inskip Point (Map Data: Google, Digital Globe, CNES/Astrium 2015)

The area of the study was limited to the east-west oriented area of the beach as shown on Figure 1.2.

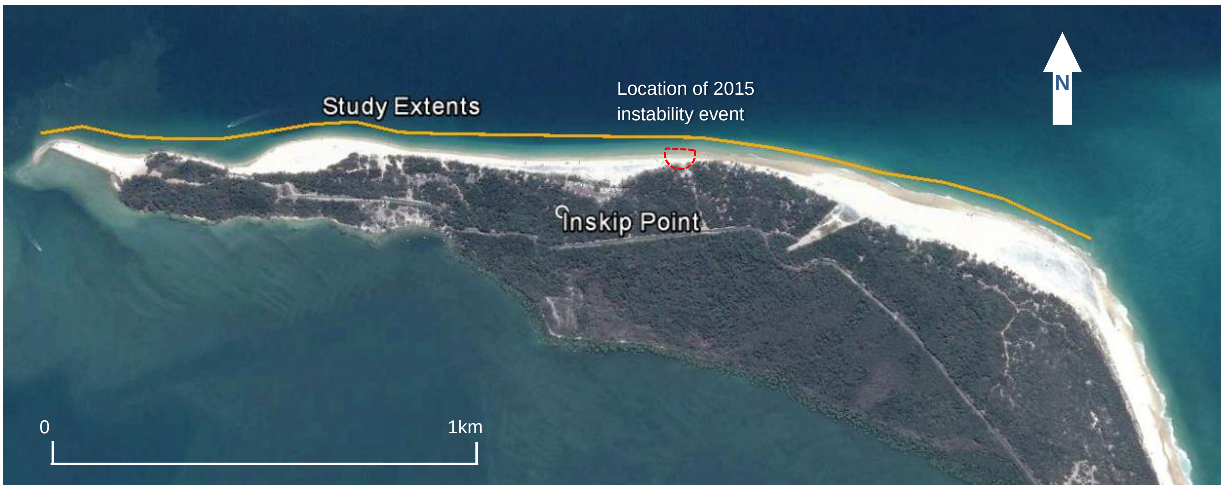

Figure 1.2 Extent of the study area – yellow line, relative to the zone of recent instability – red outline (Map Data: Google, CNES/Astrium 2015)

2.2 Surface Conditions

To the west of the location of the September 2015 instability event the beach slopes down from the tree line to the 0 m contour line (i.e. at 0m elevation relative to Australian Height Datum which is around or bit below the low water line) at about 3° to 4°. Towards the east, the beach increases in width from about 60 m to over 100 m over a distance of several hundred metres, and the slope down to the low water line flattens to about 1.5°. Figure 1.2 shows that to the west of the September 2015 instability event the tree line is irregular in shape, with broad scallops into the vegetation resulting in a widening of the beach. Drawing 1 is based on a topographic plot of the land based laser survey and bathymetry with a contour interval of 0.25m. The laser survey captures the trees as a series of closely spaced contours and so makes the tree line clear. This illustrates the varying widths of the beach, as defined by the position of the tree line, and shows the varying slope to different parts of the beach including the generally gentler grade down to the water-line east of the September 2015 instability event.

Within some of the broader scallops in the vegetation at the back of the beach, scarps are evident within the sand up to about 0.7m high, coinciding with zones of fallen trees (Figure 2.1). As these scarps are evident at elevations above the usual high water level of about 2m, we interpret them as the back scarps of previous instability events rather than the consequence of storm surge, as they are arc shaped and do not extend over the entire back beach area. In subsequent sections we present correlation with observed scarps and the locations of past instability events.

Figure 2.1 A small scarp at the rear of the vegetation line which is interpreted as the rear ward extent of past instability

Inland from the beach are variably shaped low dunes with vegetation cover ranging from low scrub to sparse trees varying in size up to about 600 mm in trunk diameter, but with most between about 50 mm to 300 mm. During our site visit we noted that there appeared to be more, larger diameter trees to the west of the 2015 instability event than to the east. Camp sites are situated within the trees and accessed by a series of unsealed roads. Drawing 1 shows the usage of the area, dividing it into the three named camping zones (Natone, Beagle, Sarawak) and an area designated as "Day Use" only.

2.2.1 The September 2015 instability event

Figure 2.2 is a publically available aerial photograph which shows the general shape of the September 2015 instability event. We made the following observations on our site visit of 27 September 2015, about 18 hours after the initiation of instability:

- The affected zone was in the form of an arc up to about 200 m wide.
- There was a sub vertical scarp at the back of the arc varying in height from 0.5 m to 1.5 m.
- Parts of the back scarp were being stabilised (i.e. held near vertical) by the roots of trees (Figure 2.3).
- A shallowly sloping (less than 10°) beach of about 5 m width had started to form below the back scarp.

- Out beyond the newly forming beach the sand dropped away at a much steeper angle, with dark blue water within the zone of instability suggesting a depth of 5 m or more quite close to the edge of the beach.
- Several trees up to about 8 m high had fallen into the zone of instability as their roots were undercut by the encroaching event.
- At this time the back scarp of the zone of instability did not appear to be retrogressing significantly.

We returned to the site at about 7:30 AM on Monday 28 September 2015 and noted that:

- The back scarp of the zone of instability had regressed only 2 m to 3 m metres from the position observed on Saturday evening and been reduced in slope in some parts to form a beach.
- Rapid and turbulent tidal flows and eddies were evident along the edge of the channel, where the adjacent beach falls to the sea floor.

Figure 2.2 Oblique aerial image of the 26 September 2015 instability event. Image source: ABC.Net.Au

Figure 2.3 View across the rear of the instability event looking west on the afternoon of 27 September 2013

During the visit on the morning of 28 September 2015 we were informed by staff on a Coast Guard vessel that the depth of water in the instability zone was a maximum of 9 m, shelving back to about 7 m closer to the beach.

In our follow up visit on 26 October 2015 to assess surface conditions along the whole peninsula we observed regression of the back scarp of about 3 m and some broadening of the beach below the scarp as shown on Figure 2.4.

Figure 2.4 Similar view from 26 September 2015 at around high tide (top) and 26 October 2015 at about low tide (bottom) illustrating several metres of further regression of the back scarp.

In our preliminary report following our initial site visit we concluded the following with respect to the mode of instability:

- The process triggering instability relates to over steepening of an off shore slope probably by erosion from rapid, turbulent tidal flows.

- The large tidal difference may have exacerbated the steepening by both creating more rapid, eroding flows and rapid draw-down effects near low tide higher up the beach than usual.
- Although the precise mechanics of instability are not clear, the outcome is rapid lateral movement of a large body of sand forming the nearshore zone and beach, with the scarp that initially formed rapidly retrogressing in-shore as the sand debris moved seaward.

2.3 Nearshore Bathymetry

Appendix I presents detailed results of the Hydrographic Survey carried out by Port of Brisbane. The bathymetric contours are illustrated on Drawing 1 with a false colour image derived from the sonar. Based on this data we interpret three distinct nearshore profiles along different parts of the beach, the main bathymetric features of which are illustrated in the three cross sections (Sections 1, 2 and 3) presented as Figure 2.5. Drawing 1 shows the locations represented by the cross sections.

One distinctive feature of the profiles is the relatively steep near-shore slope (slope angle typically 22° to 24°) which falls from around 0 m elevation down to about -7 m elevation. That steep slope is evident in the main portion of the beach as represented by Section 2, but is absent from the eastern and western extents of the beach (Sections 2 and 3). The steep submarine slope forms the southern side of the tidal channel, the orientation of which, is shown clearly by the darker blue water adjacent to the central part of the Peninsula in Figures 1.1 and 1.2.

Further offshore from the steepened section the sea floor profile drops at a gentler overall slope of about 9° but with numerous variably oriented sand ridges which we infer to be artefacts of the relatively rapid tidal currents which are frequently observed in the channel.

Drawing 2 shows detailed bathymetry of the September 2015 instability event which was conducted between 14 and 15 October 2015. At that time, the large bowl shaped depression in what is usually the in-shore zone had a maximum depth of about 6 m. A clear plume of sand can be seen as a raised mound over 50 m wide, extending for over 200 m off shore from the general location of the 0 m elevation contour line.

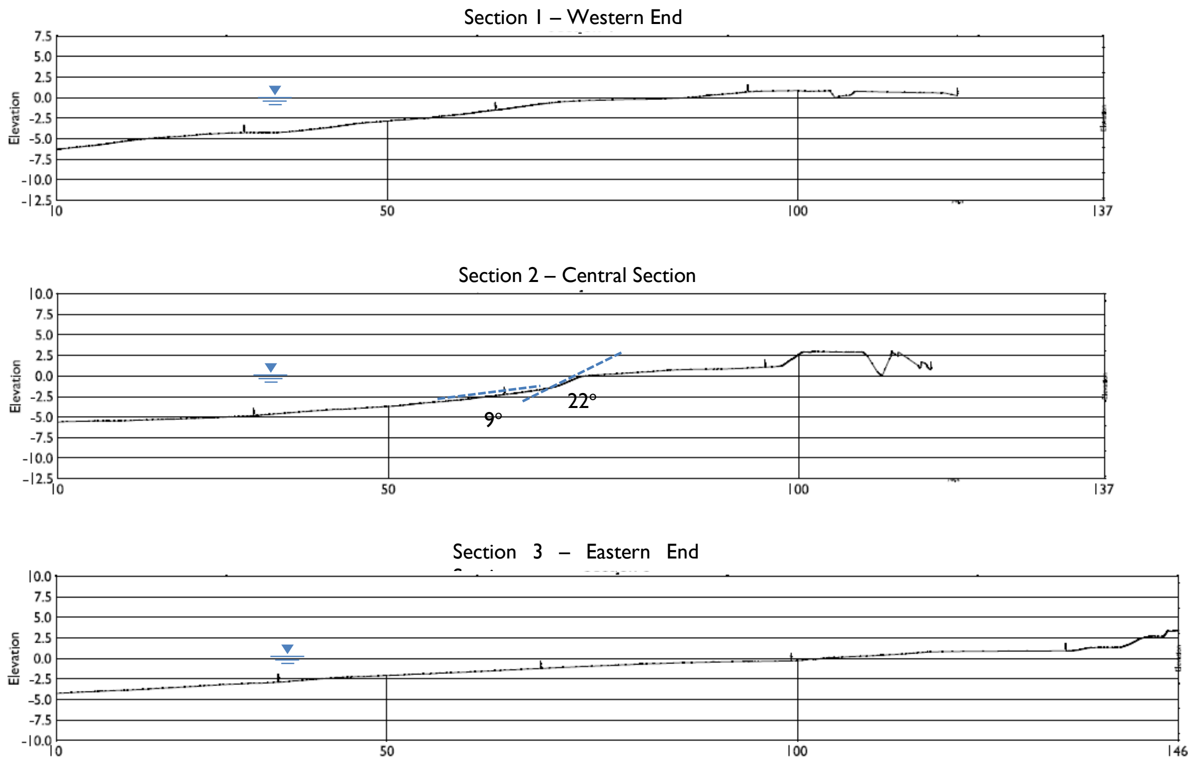

Figure 2.5 Cross Sections through three sections of the beach and near-shore zone. Section 1 represents the western most zone near the tip of the peninsula; Section 2, the main east-west extent of the beach; and Section 3 eastern end where the beach is oriented more towards the north-west.

2.4 Geology and Geotechnical Conditions

The 1:100,000 scale Wide Bay map sheet shows that the area of Inskip Point is underlain by Holocene aged Beach Ridges of the Coastal Plain (Qhcb). Ward (1987) provides a more detailed description suggesting that the beach sand extends to at least 15 m depth and notes the presence of "coffee rock" (humus cemented sand) further south at Rainbow beach. Although no subsurface investigation of geology has been conducted for this study, we made surface observations for the full length of the beach and the back dune camping area. The materials observed on the beach are judged to comprise predominantly fine to medium grained sand with no significant silt, which is consistent with the published geological description and geological environment. Similar materials with some minor silt and organic material content were observed within the back dune camping areas. We observed no "coffee rock" or other rock strength materials exposed on or behind the beach.

The high water mark is a long way up the beach because of its relatively flat slope, so we consider it reasonable to judge that sand was deposited more by water current and tidal influences than wind. Based on our experience, we consider that the sand is likely to be at least medium dense, or dense rather than loose, however the overall deposit could include some loose pockets.

3 Brief History of Instability

The primary reasons for collecting information on past instability events were to:

- Establish an approximate geographic spread for the events.
- Gain an understanding of the size, shape and extents of past events.
- Investigate possible correlations for events with natural phenomena and cycles such as tides based on date/time data.
- Assess similarities in events with respect to their morphology and retrogressive nature.

3.1 Information Sources

The main source for information on historical instability events was records available from QPWS. Their records mainly comprised brief diary entries and photographs. Dates were sometimes recorded but in some cases had to be interpreted from the metadata of digital image files. For some events where two cameras were used to capture images, the date and time metadata conflicted significantly, casting some doubt on when the images were captured. We used our judgement and any other available reports found on the internet to make assessments of date and time.

We also conducted a brief internet search to locate information and imagery of other instability events. Although reference is made to a number of events similar to that of September 2015, there are few reliable references with respect to date, time and precise location. On-line video of previous events, although often ambiguous with respect to date and time, has been useful to allow observation of similar events retrogressing up the beach, and make comparison to the September 2015 event.

A more detailed research exercise over publically available sources as well as through local press records may reveal significantly more detailed records.

3.2 Summary of previous instability events

Table 1 presents a summary of the identified events, with associated date and time data, and references. Further links and notes are presented in Section 8. The instability events have been identified by year and a numeric counter. Drawing 1 shows their approximate location based information supplied by QPWS and our observations of scarps near the existing tree line. No events have been observed to occur east of the Lead Lights, the location of which is shown on Drawing 1.

Table 1 Summary of historic instability events at Inskip Point

Event No.	Month-Year	Day	Time	General Location	Source	Notes
1873-1	Jan 1873	17	PM		Internet	Brisbane Courier - Occurred in evening
1901-1	Jun 1901				Internet	Speculative - Report from Brisbane Courier 3/7/1901
1938-1	Nov 1938	?			Internet	Speculative - Cairns Post article
1993-1	1993			Barge Loading Area	Internet	Speculative - Based on a photograph
2006-1	May 2006	-		West of Beagle	QPWS	Day unknown - About 11:00 AM and Active based on shadow
2010-1	Sep 2010	27		Sarawak	QPWS	Photographs taken 27/9/2010 15:15. Looks like end of active phase
2011-1	Jun 2011	26	10:00	Sarawak	QPWS	Earliest Photographs taken 26/6/2011 13:22 Time from Fraser Coast Chronicle
2011-2	Aug 2011	27		West of Beagle	QPWS	Photographs taken 28/8/2011 10:08

Event No.	Month-Year	Day	Time	General Location	Source	Notes
2012-1	Jun 2012	16		West of Sarawak	QPWS	Photographs stamped 16/6/2012 12:05PM Based on consecutive date stamps - 2 events in 2012
2012-2	Jun 2012	30		-	QPWS	Video stamped 30/6/2012 - Active event
2013-1	Aug 2013	-		Near barge loading area	Youtube	Link posted on 12/8/2013 - May be film of an earlier event
2013-2	Dec 2013	5		Sarawak – Near 2011-1	QPWS	Photographs taken 5/12/2013 19:28 Date stamp confirmed on 2 cameras
2015-1	Jan 2015	23		West end of Beagle	QPWS	Minor event - No photographs or information
2015-2	Sep 2015	26	10:30		QPWS	Good data

There were other events referred to in public sources which included ambiguous date, time and location information, which we omitted from the list.

3.3 Brief description of past instability

Figure 3.1 shows photographs of four events which occurred between 2010 and 2013.

a. 2010-1

b. 2011-1

c. 2012-1

d. 2013-2

Figure 3.1 Photographs showing the head scarp of four separate instability events at Inskip Point either within the early stages of retrogression (a,b) or a within day following (c,d)

The photographs demonstrate that the general surface expression of the various events is similar, with the head scarp forming an arc shaped near vertical face which retrogresses up the beach. Once retrogression is complete, a beach forms below the scarp and increases in width on the fall of the tide following.

Other similarities between events based on site observations/video of the 2015-2 event and historic events are:

- Events move up the beach in a slow, episodic rate with blocks of sand of about 0.5 m to 1.0 m thickness successively calving off different parts of the scarp.
- Events take no longer than about 3 hours before they cease retrogressing.
- The dark colour of the water immediately below the scarp suggests quite deep water (i.e. greater than 4 m to 5 m depth).
- Foam on the surface of the water is common in the general vicinity of the failing face.
- Once the active mechanism driving the instability event ceases, a less steep beach slowly forms below the head scarp and further regression of the scarp occurs only due to local erosion.
- Instability events do not "re-start" once halted.

The significant aspect which does differ between events is the extent of their regression up the beach, with some events moving into the tree line and others halting well short. The locations for past events shown on Drawing 3 mainly takes into consideration those events which have moved further up the beach, whereas some such as 2015-1 barely affected the beach beyond the low water line.

4 Assessment of the Mode of Instability

Data from the 2015-2 event, general site observations and the historic record show clear common characteristics for instability events at Inskip Point which have been noted in previous sections. The arc shaped form, general proportions of depth to width and retrogressive movement of material suggest that movement is effected by a flow or sliding mechanism. The mechanism which we consider best fits the observed characteristics is that of a "retrogressive breach flow slide" which has been described by Beinssen *et al* (2014) and Van den berg *et al* (2002). Figure 4.1 illustrates the mechanism in cross section.

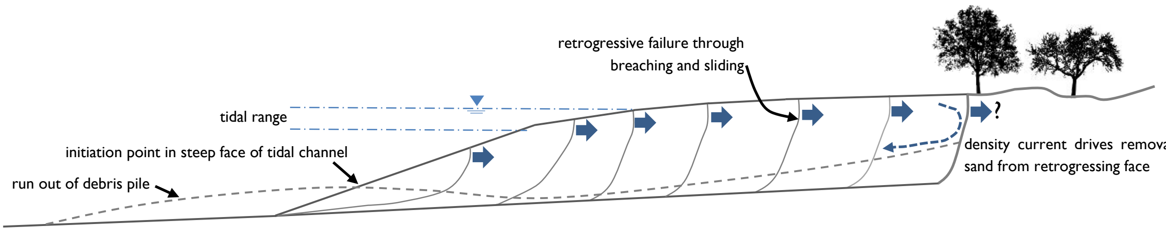

Figure 4.1 Diagrammatic cross section through breach flow slides at Inskip Point. Not to scale and with minor vertical exaggeration to demonstrate mechanisms.

Based on the references above, we consider that breach flow slides at Inskip Point develop in the following general manner:

- A triggering mechanism develops a localised overly steep face in dense sand which shears as a response to exceeding its angle of repose.
- Shearing generates negative pore pressures in the soil skeleton which allows a temporarily meta-stable sub-vertical face to develop.
- As the pore pressure progressively equalises at the face, sand is released grain by grain and falls from the wall.
- As the grains fall they develop a density current (a "fluid" with a higher density than seawater due to the presence of the sand grains, which flows downwards) which carry grains away from the face and beyond the immediate toe of the failure surface, allowing the face to remain steep.
- Where very steep slopes are developed by the process, a secondary mechanism involves sliding of blocks of sand from the scarp which has been observed in many instances of instability at Inskip Point.
- Retrogression continues until the density current lacks the strength to continue taking sand away from the over-steep face. This may be because either the sand supply is for some reason limited, or possibly because the system is "swamped" with an excessive amount of sand that it cannot carry and the sand falls out of suspension at the base of the face.

We also considered an alternative mechanism of a purely liquefaction based mass movement event. However, in a liquefaction flow slide a large proportion of the relatively loose mass moves in a single episode rather than a dense body of sand moving progressively, as is observed at Inskip Point.

Apart from the required geotechnical conditions comprising the presence of a dense body of fine to medium grained sand, the two other requirements for the development of a breach flow slide are:

- Sub-marine slopes steeper than 3 horizontal to 1 vertical (about 18°) over a height of 5 m or more – the bathymetry study shows that those along the main part of the beach at Inskip Point are 22° to 24°, as shown on Section 2 of Figure 2.5.
- An initiating mechanism must occur to disturb the lower parts of the sub-marine slope and create a locally over steepened section such that the breach mechanism becomes active.

Although we consider that the slope gradient and geotechnical requirements for the development of breach flow slides are generally met at Inskip Point, the precise initiating mechanism remains uncertain.

4.1 Initiating Mechanisms

Beinssen (2014) notes that the "trigger" event can be any event which changes the equilibrium soil stress state, occurring from either natural causes or human agency. Such events could include vibrations from pile driving, seismic accelerations from earthquakes, localised erosion from tidal currents or eddies formed due to tidal flow, erosion from ships propellers, or possibly even the effects of waves where they differ from the usual energy level.

To assess the validity of specific initiating mechanisms at Inskip Point we correlated instability events with several natural cycles.

4.1.1 Earthquake Inventory

Seismic accelerations generated by earthquakes can and do cause liquefaction (a reduction in soil strength due to increased pore water pressure between soil particles) at many scales. Liquefaction occurs during the period of seismic shaking and for a short time afterwards (i.e. minutes or hours), after which the induced pore pressures dissipate and the soil regains strength. Therefore, if seismic activity was the initiating mechanism at Inskip Point, earthquakes of sufficient magnitude and proximity would need to occur immediately prior to the instability events.

Reference to Geoscience Australia (2015) provides data on all earthquakes which have occurred in Qld. Correlating the times of earthquakes and instability events shows that there have been no earthquakes on the same day or even in the same week as events as shown on Table 4.1. In many cases, the closest earthquake in time occurred months before and was several hundred kilometres distant. The closest earthquake in time to the recent instability event was ten days before.

Table 4.1 Listing of earthquakes in Queensland which occurred closest in time to instability events

Event No.	Month-Year	Day	Nearest Earthquake					Location Notes	Distance (km)
			Mag	Date	Time	Lat	Long		
2006-1	May 2006	No Data	4.1	28/12/2005	19:05	-28.191	147.894	West of St George QLD.	577
2010-1	Sep 2010	27	2.5	15/08/2010	18:56	-26.701	152.283	East of Kingaroy	126
2011-1	Jun 2011	26	3.4	26/05/2011	22:29	-26.801	147.232	SE of Charleville	592
2011-2	Aug 2011	27	2.5	2/08/2011	11:20	-24.200	150.919	NE of Biloela	280
2012-1	Jun 2012	16	3.3	16/02/2012	20:49	-27.054	147.98	SW of Roma	525
2012-2	Jun 2012	30	3.3	16/02/2012	20:49	-27.054	147.98	SW of Roma	525
2013-1	Aug 2013	No Data	3.2	1/06/2013	15:59	-23.645	148.848	Near Blackwater	489
2013-2	Dec 2013	5	2.8	1/12/2013	20:51	-17.090	145.55	SW of Cairns	1239
2015-1	Jan 2015	23	3.3	5/09/2014	0:07	-16.949	143.895	NW of Chillagoe	1365
2015-2	Sep 2015	26	3.3	17/09/2015	9:37	-25.346	154.521	E of Fraser Island	156

4.1.2 Tidal Flow and Turbulence

In our visit to Inskip Point on 27 and 28 September 2015 we observed very distinct tidal flows, turbulence and eddies in the water immediately off shore over the submarine slope at around low tide. Others we have spoken to report seeing similar distinct tidal flows and turbulence in the past. We made these observations during a period of spring tides with a large tide range and have sought to assess whether erosion from these water movements could have triggered the instability events. We correlated the times when events initiated against:

- The diurnal tidal cycle.
- The cycle of neap and spring tides.

An example of a clear correlation would be if the events all occurred at about low tide within a period of spring tides, where the low tide had dropped down to below 0.5m elevation.

Unfortunately, information on the time of occurrence is available for only five instability events, and of these there are three for which a reasonably accurate start time can be established.

Drawing 4 shows a plot of the tidal fluctuation against time with information on the initiation of the five instability events where time data is available. On the plot, the event is signified by an orange circle where an accurate time for its initiation is known (events 2011-1 and 2015-2). Where only a time interval is known, the event start point is represented as an orange line representing that time interval. Although two of the events (2011-1 and 2015-2) appear to have initiated near the low tide, the others cannot be reliably correlated with a tidal period.

In our opinion, the data set is also insufficient to demonstrate a relationship or otherwise with high tidal range (i.e., spring tides). Although some events have occurred during such periods, others such as 2010-1 and 2011-1 appear not to have. Beinssen (*pers. com*) has collected data on over 50 inferred breach flow slide events at Amity Point and we understand even with this large data set has not been able to demonstrate a clear relationship between instability and either tidal flow or tidal range. We require significantly more accurate data on the timing of events at Inskip Point to draw firm conclusions on tidal correlation.

4.1.3 Discussion and Interim Conclusions on Initiation

Other mechanisms which could plausibly initiate nearshore instability mainly relate to human activities such as the actions of boat propellers which would occur at irregular times and places and so we lack the data on which to base any correlation.

We consider that the data on seismic activity provided above is adequate to rule out earthquakes as a trigger.

Consequently, our working hypotheses for initiating events is that they are caused, at least in part, by the rapid tidal flows and resulting eddies which are observed regularly off the peninsula. There may be some other factors related to tides or the physical condition of some pockets of sand which forms part of the mechanism. Further careful collection and correlation of data would be needed to prove or disprove this hypothesis.

4.2 Extents of Landward Regression

One aspect which does vary significantly between different breach flow slides is their termination point up the beach, with some stopping well short of the tree line and others encroaching. As noted previously, the events will stop when the density current is unable to continue to transport sand away and it builds up at the base of the developed face. At this stage the available literature suggests no definitive method to assess where a specific event may terminate.

We do not consider that the trees have a significant effect as they are generally undermined completely. In our opinion, breach flow slides at Inskip Point may stop because the volume of sand from above the water table being added is more than the density currents can remove, although this is not proven.

Consequently, our view is that until further information can be collected and understood, it would be prudent to base predictions of landward regression on the past extents of instability.

5 Hazard, Susceptibility and Risk Assessment

5.1 Hazards and Susceptibility

The hazard at Inskip Point comprises breach flow slides which retrogress up the beach forming sub-vertical scarps over an arc shaped area up to about 200 m wide. The geotechnical conditions immediately offshore are judged to be suitable for the initiation of such instability along the full length of the study area. Geometrically, breach flow slides have been found to initiate only in nearshore slopes steeper than 18° and over 5 m high. Consequently, we have divided the nearshore zone adjacent to Inskip Point into three categories of breach flow slide susceptibility based on these requirements and on the historical incidence of instability as shown in Table 5.1.

Table 5.1 Definition of flow slide susceptibility categories for Inskip Point

Susceptibility	Geotechnical Conditions Suitable?	Geometric Conditions Suitable?	History of Flow Slides?
Low	Yes	No	No
Medium	Yes	No	Yes
High	Yes	Yes	Yes

The Medium Susceptibility zone relates to areas where instability has occurred in the past, but where the prerequisite geometric conditions do not appear to be present at this point in time. If the nearshore slopes steepen due to the effects of tides, currents or other mechanisms, susceptibility to flow slides may increase.

Drawing 3 shows the peninsula divided into Low, Medium and High flow slide susceptibility zones based on the above classification.

5.2 Risk Assessment

The methods adopted for the risk assessment generally follow the principles published by the Australian Geomechanics Society in 2007 (AGS (2007) and Walker *et al* (2007)). We have provided general discussion of both risk to life and risk to property. We have conducted a preliminary quantitative risk assessment for one significant element at risk, but have addressed the risks to others only descriptively.

5.2.1 Description of the Risks in Qualitative Terms

The framework for the evaluation of risk provided in AGS (2007) is consistent with international practice and considers risk for each identified hazard as:

Risk = Likelihood x Consequences

Consequences are considered through the vulnerability of the specific elements at risk, be they people, property or less tangible assets. It is often useful to describe risks in simple terms within this framework.

How Often Will Flow Slides Occur?

The instability hazard which affects Inskip Point has an uncertain initiating mechanism, but based on QPWS records, breach flow slides have occurred with a frequency of a bit over one per year since 2006. On this basis, it is reasonable for those administering the area to expect an event every year while understanding that there could easily be none in a given year, but more than one the next.

When will they occur?

With our current understanding there is no evidence to suggest that events will occur at any specific time of year, season, or day more often than another, so they could occur during the day or night without warning. Observations suggest that flow slides cease retrogressing up the beach after 2 to 3 hours. None, either at Inskip or the many observed at Amity Point, have been known to restart once they have stopped (Beinssen *pers com*).

How fast do they move and how far will they extend?

Research at Amity Point shows that flow slides move at a rate of up to about 0.8 m laterally per minute (Beinssen, 2014). This seems to be generally consistent with observations of the rate of movement at Inskip Point. Although not all breach flow slides retrogress into the tree line and camping area, many do, possibly about half of those noted by QPWS. Flow slides at Inskip Point do not seem to have affected ground above about 2.5 m elevation.

Based on our understanding of the factors affecting susceptibility, flow slides are most likely to occur within the beachside fringe of the Sarawak camping area, the western end of the Beagle Camping Area, and the Day Use area to the west.

What are the elements at Risk and how vulnerable are they?

As the flow slides have a steep scarp at their rear and sides, and seem to be over 5 m deep, they can engulf anything founded/placed on the sand above in their path, as occurred in event 2015-2. This implies that vehicles and camping equipment would be at risk if in the path of a flow slide wherever they are on the beach. Those that were inside vehicles which fell from the scarp could be quite vulnerable.

The vulnerability of people, and consequently their risk profile, can be considered in several groups:

- Campers who are mainly outside during the day, but inside a tent or caravan at night.
- People who are in vehicles on the beach.
- People who are on the beach on foot during the day or night.
- People who sleep on the beach.

Campers are likely to be vulnerable if engulfed by a flow slide while within a caravan or tent, particularly if they were asleep. In many cases they may receive warning of the instability event and be able to leave as occurred with the recent event. During the day it is likely that they would be alerted to the event or observe it themselves.

Drivers on the beach would generally see a retrogressing scarp during the day, but may not at night. Drivers may not see a newly forming scarp as it retrogresses up from the water-line, but this situation where it was present but not easily visible, would be only in play for a few minutes of the flow slides.

People on the beach would generally be able to evade the hazard if they were awake. If engulfed it is likely that they would be able to swim out, assuming that they have that ability. If people were to be asleep on the beach in a sleeping bag, they could possibly be trapped.

Other elements which QPWS might consider to be at risk are:

- Property such as the toilet blocks, park fittings and roads which could be affected, and ensuing environmental damage from their loss.
- Reputation and community opinion.

5.2.2 Quantitative Risk Assessment

To provide a guide to the levels of risk to life posed to people by the flow slides we have conducted a preliminary, quantitative risk assessment to campers, as they are the people who have the potential for a longer stay at Inskip Point than most. We consider the risk assessment to be approximate. It could be refined with further research and information. The terminology used is from AGS (2007). In this case the assessment is based on "the person most at risk" who we have nominated as a person who spends all of their holidays and public holidays within the fringe of the tree line at Inskip Point.

Table 5.2 presents information on each of the terms in the risk calculation which are multiplied together to provide the risk to life for the person most at risk.

Table 5.2 Tabulated calculations of risk to life with notes

Risk $R_{(LoL)}$	**Probability** $P_{(H)}$	**Probability of Spatial Impact** $P_{(S:H)}$	**Probability Temporal Spatial** $P_{(T:S)}$	**Vulnerability** $V_{(D:T)}$
1×10^{-4}	1	0.4	8.6×10^{-4}	0.3
Notes:	Annual probability of a slide initiating, based on the count of events since May 2006	The probability that a flow slide will reach the elements at risk in the camping area	Based on: 1. Person present 31 days in a year 2. Instability may occur over only 62% of the beachside camping area 3. The rear of the breach flow slide is 50m wide	The person is able to avoid the flow slide through observation or warning 70% of the time

5.3 Risk Evaluation

Walker (2007) suggests a Tolerable Risk criteria level for an existing slope of 10^{-4} / annum for the "person most at risk". This level of risk is generally commensurate with that quoted as criteria by other government authorities in Australia and overseas for evaluating risks to the public.

The definition for a Tolerable Risk from AGS (2007) is: "Tolerable Risks are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable."

We note that the calculated level for risk to life to campers is at about the tolerable risk level. It would generally be prudent for those administering an area subject to such a level of risk to implement measures to reduce risk. Note that the risk calculation is approximate only and is based on some conservative judgements of probability for different factors affecting the risk. Risks to other individuals may differ from those modelled for the theoretical "person most at risk". A more accurate assessment could be conducted but it would require more data on the distribution of people at the site, realistic tenancy times and a better understanding of the likelihood of camping at different parts of the camping area.

The decision as to whether risk management options should be implemented in a specific instance should consider more than just the risk level. If cost effective measures which could provide a risk reduction are available, then they generally should be implemented where practical.

6 Risk Management Options

We have developed a number of risk management options which are outlined in Table 6.1. These will require careful consideration, and some may need further work prior to implementation to assess whether they would be effective and practical.

Table 6.1 Summary of risk management options

Category	Potential Measures	Management Option Details
Avoid the risk	Ensure that there is no camping on the beach and restrict camping to zones outside that which is most likely to be affected by flow slides.	In the first instance a buffer zone to camping would need to be established within the High Susceptibility zone on the basis of precedent with a suitable margin for safety. Consideration should be given to land use in the Medium Susceptibility zone.
	Prevent driving on the beach or limit driving on the beach to daylight hours only.	Risk could be avoided by not driving on the beach. Risk can be significantly reduced by not driving on the beach at night.
	Consider moving camping to other areas of Rainbow Beach further to the south which are subject to lower risk levels.	The practicality of this will depend whether other land is available. Any land opened to camping would also need to be assessed for the potential for flow sides or other risks.
Reduce the probability of unexpected instability	No practical measures currently identified with our current level of knowledge.	More research and understanding of initiation mechanisms would be required to be able to assess methods meaningfully. This will require collection of data on the timing and conditions of future events
Reduce the consequences of instability	Construct deep rock walls such as those at Amity Point or other structural barriers to intercept the flow slides.	Flow slides can be stopped by walls which extend below the base of the slide. To be useful, walls would need to be over 10 m deep, properly engineered and well maintained. We doubt that this would be practical or cost effective at Inskip Point.
	Conduct research and construct a wide sand bund to cut off the slides.	It is possible that a bund of sand over 2 m high could be effective at preventing flow slides from retrogressing further. Such a bund may have an environmental and social impact, be expensive to construct and would require significant research to ensure that it would be effective.
Manage the risk with monitoring or warning signs	Periodic monitoring of the geometry of the nearshore sand deposits with sonar.	Monitoring of the sea floor will allow continued assessment of where steeper slopes are forming that could lead to further breach flow slides. Advice would need to be sought from others on a suitable frequency of survey to ensure that changes could be detected. This is particularly important for the Medium Susceptibility zone.
	Install informative warning signs.	The warning signs should impart information to assist people to understand the causes and the associated risks that flow sides present to people and property. They should also explain the risks associated with driving or sleeping on the beach, or camping closest to the water.
	Install warning systems such as sirens.	Sirens and other warning systems have been suggested as an emergency response measure to alert people to an instability event. Advice should be sought from appropriate specialists on the practicality of such systems. It is not clear how people would respond appropriately to a warning signal without training on what was expected of them. False alarms may be common depending on who had responsibility for triggering the alarm.

To assist in the assessment of whether a restriction on camping for some parts of the peninsula would be practical, we have prepared a preliminary boundary to the buffer zone based on the location of past instability events with a safety margin to take into account the required offset from a potential scarp. Figure 6.1 shows the geotechnical basis for establishing the buffer zone. There are practical requirements such as the positioning of roads and other infrastructure which will also govern the precise location of the buffer zone. We worked with staff from QPWS on site to establish the practical position of the proposed buffer zone taking into account both geotechnical and practical considerations. Drawing 5 shows the proposed buffer zone boundary beyond which camping would need to be restricted in order to reduce risk to campers.

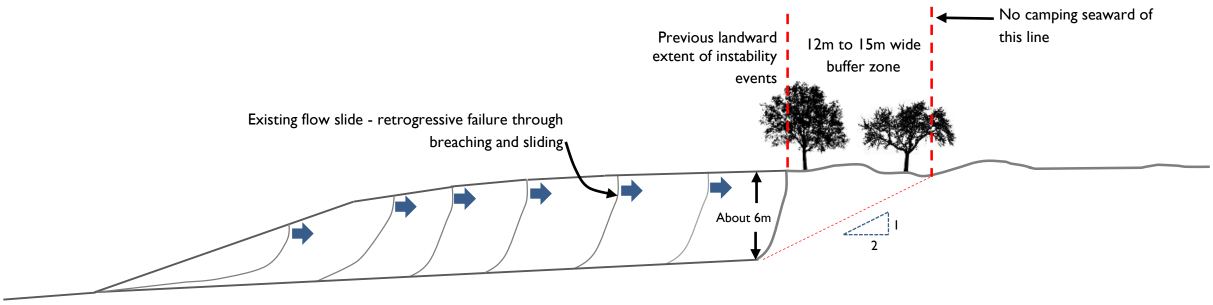

Figure 6.1 Diagrammatic cross section showing the geotechnical derivation of the buffer zone based on previous encroachment of the flow slides.

7 Further Work

The current study has been of short duration with a focus on developing some practical risk management options from a limited amount of data. QPWS could consider further study with universities, researchers and/or consultants to confirm some of the judgements made in this assessment or test other potential risk management strategies.

To this point we have not conducted any subsurface investigation of ground conditions by either drilling or geophysical methods. Either or both would be useful to assist in confirming the assumed ground model.

We also consider that consultation with marine engineers who are more able to interpret nearshore ocean processes may be helpful in gaining a better understanding of the failure mechanisms and developing a better model for the prediction of flow slide occurrence.

Further understanding of the flow slides could be gained if better records of each event could be made. Information that could be useful includes:

- Precise times for the initiation of events and when they cease retrogressing and details on how these times were derived, whether by observation or inference.
- GPS tracks around the perimeter of each event.
- Video and photographs with accurate time and date information.
- Observations of the general sea conditions (tides, turbulence etc) evident when the event began.

As noted previously, a more detailed literature search through library and press records could be beneficial in establishing the history of instability at Inskip Point including data on its extents and frequency of occurrence.

Sea level rise as a consequence of climate change could have an effect on the frequency and extent of instability events. Although our current understanding is limited, it seems logical to conclude that increasing sea level will lead to greater landward transgression of flow slides. Buffer zones may need to be reviewed in the coming years if evidence suggests that instability is encroaching further inland.

Please do not hesitate to contact the undersigned if you have questions or require further information on the contents of this report.

For and on behalf of EDG Consulting Pty Ltd

Ian Shipway
Principal

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Table 8.1 presents informal internet based references to past instability events at Inskip Point.

Table 8.1 Links to historic instability events

Event No.	Month-Year	General Location	Source	Links
1873-1	Jan 1873		Internet	http://indicatorloops.com/inskip.htm
1901-1	Jun 1901		Internet	http://indicatorloops.com/inskip.htm
1938-1	Nov 1938		Internet	http://indicatorloops.com/inskip.htm
1993-1	1993	Barge Loading Area	Internet	http://indicatorloops.com/inskip.htm
2006-1	May 2006	West of Beagle	QPWS	Labelled 2005 but probably 2006-1: https://www.youtube.com/watch?v=ILptlF7P6LI
2011-1	Jun 2011	Sarawak	QPWS	http://www.frasercoastchronicle.com.au/news/beach-slipping-away-inskip-point/888597/ https://www.youtube.com/watch?v=I9ieYvYdvdw https://www.youtube.com/watch?v=VpafAxjGq_Y
2013-1	Aug 2013	Near the barge loading area?	Youtube	https://www.youtube.com/watch?v=2oEiBveXbBA https://www.youtube.com/watch?v=8FfhLpWNx_s

Ground conditions and the natural environment often present the highest potential risks to project construction and operation. Helping our clients manage their geotechnical risk is fundamental to EDG. We have prepared these notes to assist our clients to understand the information we provide and help in managing risk.

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All site conditions cannot be identified

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The document presents an interpretation

Geotechnical information is an interpretation of conditions evident based on a limited number of facts established during a site investigation[1]. Engineering logs are an interpretation of observations of samples and test results at discrete locations in the subsurface profile. A geotechnical model is an interpretation of site conditions, developed using information from discrete locations on the site and an understanding of geological processes. Interpreted conditions at and between investigation locations may be different to those inferred on the engineering logs and geotechnical model. The client must consider how variations in conditions could affect the project and seek advice to reduce risk if it is unacceptable.

Conditions can change

The geotechnical information provided is based on the conditions observed at the time of the investigation. Such conditions may be time dependent and subject to external influences. Many things could influence the site conditions, including geological processes, variation in groundwater or surface water levels, other natural cycles and influence from human activities (on this site or nearby sites). Specific advice should be sought if conditions on site change from those observed at the time the report was prepared.

The contents are not final

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If in doubt seek additional assistance

Where there is uncertainty about your site, project or the geotechnical conditions evident, contact EDG for additional assistance.

1. Guidelines for the Provision of Geotechnical Information in Construction Contracts, Institution of Engineers, Australia, 1987.

Drawings

Appendix I

Combined High Resolution Multibeam Sonar and Vessel Mounted/Terrestrial Laser Survey Data