Appendix 13.5

Coastal Erosion Report Addendum: Assessment of December 2015 Slope Instabilities, Arup (2016)

13.5 Coastal Erosion Report

Indaver

Resource Recovery Centre, Ringaskiddy, Co. Cork

Coastal erosion report addendum: Assessment of the December 2015 slope instabilities

WM/REP/0002

Issue | 19 April 2016

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Contents

Page

1 Introduction 1

2 Summary of winter 2015 events 3

3 Site walkover and assessment 3

3.1 Site observations 3
3.2 Site assessment 5

4 Topographical survey assessment 9

4.1 Topographic survey 2016 9
4.2 Comparison of surveys 10

5 Erosion assessment 13

5.1 Methodology 13
5.2 Data from March 2016 survey added 13
5.3 Impact on the predicted maximum retreat rate 14

6 Conclusions and recommendations 16

6.1 Conclusions 16
6.2 Recommendations 17

Appendices

No table of contents entries found.

1 Introduction

Coastal erosion report for the EIS

Arup has previously undertaken an assessment of coastal erosion for the proposed Indaver development site at Ringaskiddy as described in the coastal study which was carried out in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery Centre, EIS 2016*). The assessment consisted of the following:

- Assessment of the retreat rate based on historical information and topographic surveys dating from 2008 to 2014
- Numerical wave modelling and beach sediment transport analysis
- Assessment of expected coastal retreat

In addition to these items Arup carried out an appraisal of the potential impacts of expected coastal retreat on the proposed Ringaskiddy Resource Recovery Centre and recommended proactive mitigation measures to minimise the risk of potential impacts on the development.

The report recommended that a conservative maximum retreat of 0.5m/year should be adopted for the site. Based on this rate of retreat it was determined that the waste to energy facility section of the proposed development has been located far enough away from the coastline to ensure that it will not be impacted by the predicted retreat rates over the design life of the development. Also, the proposed development will not increase the current rate of retreat.

In addition, while it was concluded that coastal protection measures were not required for the waste-to-energy facility, coastal protection measures were included in the planning application as a precautionary measure so as to reduce the rate of erosion of the glacial till face due to wave action. The coastal protection measures proposed comprised a beach monitoring programme and the placement of sacrificial material at the toe of the cliffs in the form of shingle.

Background to this Addendum

December 2015 was the wettest month on record in many areas of Ireland, particularly in the Southwest where rainfall amounts were approximately 3 times the average. By the end of December, many areas were entirely saturated and even normal rainfall events resulted in very significant flooding.

Storm Frank, the 6th major winter storm of 2015 brought high winds and significant rainfall between the 29 December 2015 and the 2 January 2016. Significant flooding resulted across much of the country. County Cork was badly affected with major flood events on many rivers such as the Blackwater, Bandon, Glashaboy, Owenacurra and many others. Between 29 December 2015 and 30 December 2015 immediately following the extreme rainfall associated with Storm Frank there were several localised slope failures at Gobby Beach on the eastern extent of the proposed Indaver site. Following these events Arup carried out an

assessment of the size and causes of the failures and reviewed them in relation to the outcomes of the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*).

The assessment includes the following:

- Site walkover
- Topographic survey
- Review of new survey against previous surveys
- Erosion assessment

This report details the findings of the assessment of the effects of the recent events on the proposed Indaver site and adjoining Gobby beach and makes any recommendations as to how these findings might be considered along with the findings of the previous coastal erosion study.

2 Summary of winter 2015 events

In late December 2015 and early January 2016 Ireland was exposed to extreme storm conditions, comprising heavy rainfall, high seas and high winds. This storm, known as Storm Frank, combined with a series of large storm events over the preceding months led to extensive damage and flooding to both inland and coastal areas throughout Ireland. Winds varied in direction from south to southwest to westerly direction. In county Cork approximately 60mm of rain fell between Tuesday 29 December and Wednesday 30 December. This combined with high tides and a substantial storm surge led to flooding at a number of locations throughout the county. There were reports of wave overtopping and flooding in Kinsale and Garretstown, as well as extensive flooding due to rising water levels in Passage West and Cork City. However, there are no reports of flooding or erosion due to wave action or overtopping in Cork Harbour.

December 2015 was the wettest month on record in many areas of Ireland, particularly in the southwest where rainfall amounts were approximately 3 times the average.

Met Éireann's December 2015 Weather Summary notes the following:

> *'All stations reported well above Long-Term Average (LTA) rainfall with most stations across the country reporting double or triple their normal rainfall for December. Wettest conditions (compared to LTA) were in county Cork where nearly all stations reported over 300% of LTA. Roche's Point reported the highest percentage of LTA with 342% (340.6 mm of rain) it's highest for December since 1955.'*

It is further noted that the highest rainfall total for the month of December was recorded at Cork Airport where some 402.2mm of rainfall fell, approximately 3 times the long term average. 324mm of rainfall, 312% of the LTA rainfall was also recorded at Fermoy, Moore Park.

Figure 2 below provides the depth duration curve for 1 in 200 year rainfall event at Cork Airport. It is extrapolated from 25 days to 31 days as Met Éireann's Depth Duration Frequency (DDF) data only extends to 25 days. It can be seen that the monthly calendar rainfall total for December of 402mm has a return period of more than 1 in 200 years.

Clearly, December's rainfall was exceptional. By the end of December, many areas were entirely saturated and even normal rainfall events resulted in very significant flooding. Groundwater levels were therefore also extremely elevated.

Storm Frank, the 6th major winter storm of 2015, brought high winds and significant rainfall between the 29 December 2015 and the 2 January 2016. Prior to 28 December 2015, approximately 312mm of rainfall had already fallen in the month at Cork Airport, with 248mm having fallen at Moore Park, Fermoy for the month to that date. A further 16mm of rain fell at both locations on the 28 December in the run-up to Storm Frank.

The largest rainfall amounts fell in a 21 hour window between about noon on the 29 Dec 2015 and 7am on the morning of the 30 Dec 2015 with 61mm being recorded at Cork Airport, 46mm at Moore Park, Fermoy.

In the days following the heavy rainfall associated with Storm Frank two section of the cliffs adjacent to the proposed Indaver development site at Ringaskiddy suffered a slip failure. The slope failures were contained to the southern area of the bay along an area with a substantial height of cliff. The north eastern part of the site adjacent to the car park was largely unaffected save for some shingle being moved from the beach to the adjacent lands.

In January 2016 Indaver commissioned a drone survey of the coast adjacent to the proposed development site. Figure 1 and Figure 3 below show two areas where significant slope failures occurred. The first area shown in Figure 1 (circled in blue) is approx. 20m long and cliff height is roughly 2 to 3m. This area is located approximately 50m south of the car park. The second area shown in Figure 3 (circled in blue) is a further 20m south and is approximately 40m in length and cliff height is roughly 7 to 9m.



Figure 1: Drone photography showing first area of slope failure and minimal damage to the beach north of this location

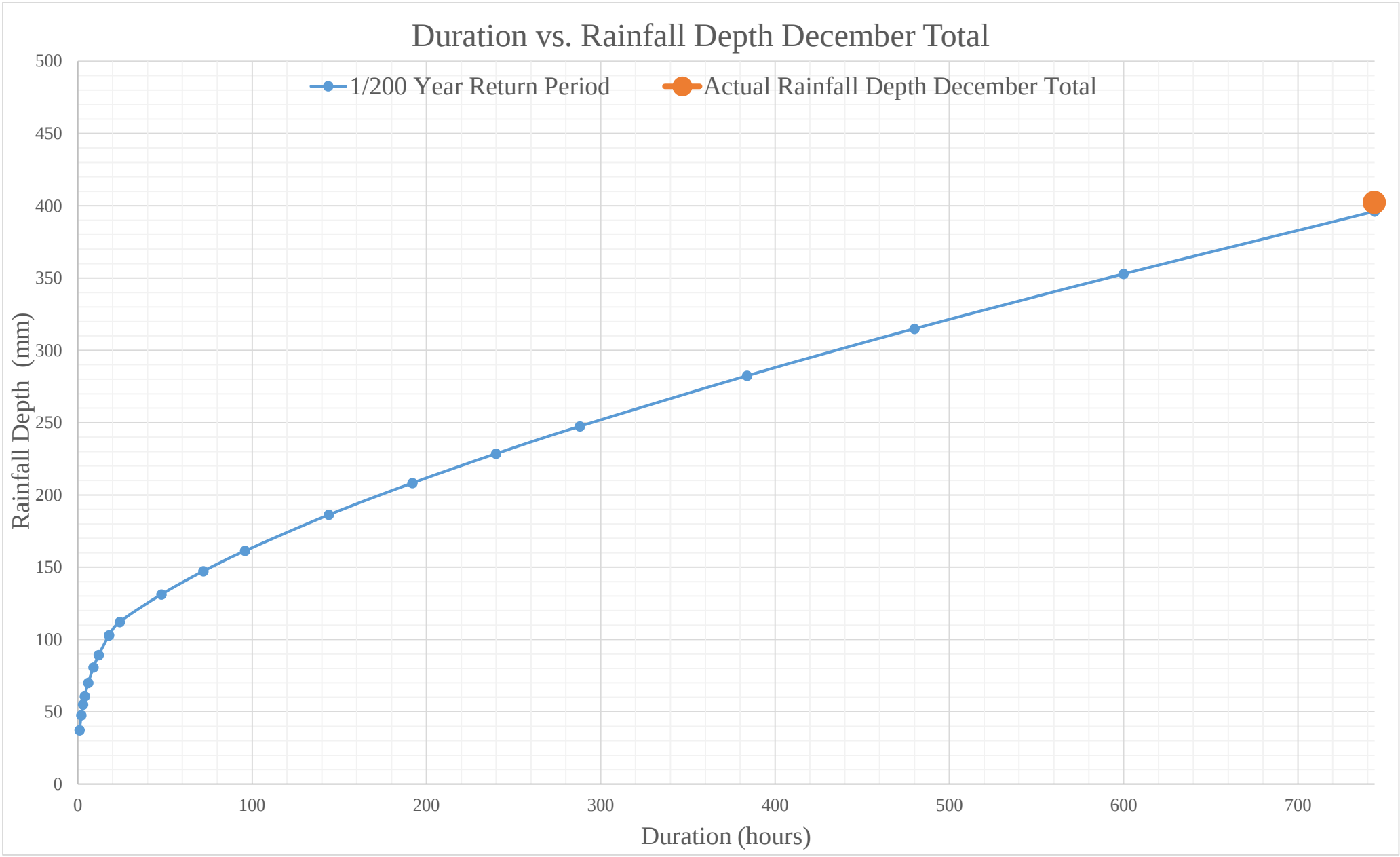


Figure 2: Depth duration graph for 1 in 200 year rainfall event



Figure 3: Drone photography showing slope failure to the southern section

Figure 4, Figure 5 and Figure 6 below show the affected area to the south of the beach as recorded in June 2009, September 2015 and December 2015. From the imagery it is clear that there has been localised slope failure between 2009 and 2016. Minor erosion occurred between June 2009 and June 2015 and a large slope failure occurred between September 2015 and December 2015. The nature and timeline of the failure will be discussed further in the following sections.



Figure 4: Cliff adjacent to proposed development site, June 2009



Figure 5: Cliff adjacent to proposed development site, September 2015



Figure 6: Cliff adjacent to proposed development site, December 2016 following failure

3 Site walkover and assessment

3.1 Site observations

Following the storm events and associated slope failure over December and January 2016 Arup carried out a site walkover. The site walkover was attended by a number of staff with expertise in the following areas: coastal engineering (Julie Ascoop), geotechnical engineering (Sean Mason) and environmental engineering (Fiona Patterson). The site walkover was undertaken on 1 March 2016 prior to low tide. Please refer to Appendix A for photographs taken during the site visit.

Figure 6 and Figure 7 below show the two areas of slope failure as described previously.



Figure 7: First area of slope failure approximately 50m south of car park



Figure 8: Second area of slope failure further 20m south

During the site walkover the following were the main items observed:

- A number of slope failures

  There were two slope failures observed along the Indaver site, as shown in Figure 7 and Figure 8.

  The first one approximately 50m south of the car park was rather small. The embankment is only approximately 2m high here and the failure looks to have adjusted the over-steep embankment to a more stable slope.

  The second slope failure was quite large and V-shaped back landward. A significant amount of material was slumped down in this failure.

- Water running out of the slope of the cliffs through the failures (there had been no recent rain in the days prior to site walkover). (Refer to Figure 9)

  In both failures water could be seen running out of the embankment. In the larger failure a small stream (of fresh water) ran out through the V-shaped failure into the sea.

- Sand lenses in the slope failures (Refer to Figure 10)

  In the large failure sand lenses were observed in the cliff slope.

- No evidence of coastal erosion at the bottom of the cliffs

  There was no evidence of any significant coastal erosion at the bottom of the cliffs. They did not have a 'notched' shape at the bottom and overall the beach shingle was high up on the beach covering the toe of the cliff. (Refer to Figure 11)



Figure 9: Water running out of the slope failure



Figure 10: Sand lens in the slope failure



Figure 11: Currently no evidence of ‘notching’ at the bottom of these cliffs

3.2 Site assessment

Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*, identifies both geotechnical and coastal causes for the cliff erosion.

As shown in the photographs in Appendix A and as previously recorded in the 2015 coastal study (Refer to), the soil cliffs are primarily a ‘boulder clay’ deposit, i.e. soils created, deposited and compacted by ice action. They generally comprise of sands, gravels and cobbles, with occasional boulders, embedded within a silty clay matrix, (hence the term ‘boulder clays’).

At this location there are local ‘fluvio-glacial’ deposits of sands and gravels within the boulder clay. These more granular deposits (lenses) are considerably more permeable than the surrounding boulder clays, and transmit water through

the ground, and out through the face of the cliffs where exposed. Therefore the surface water (rainfall) both (a) flows over the ground surface and down the cliff face, and (b) infiltrates into the ground and flows through these permeable lenses and channels out through the cliff face.



Figure 12: Surface water (which has infiltrated the ground and flows through the permeable lenses) flowing out through cliff face

Over time this infiltration of surface water leads to softening of the surrounding boulder clays, and erodes the sands and gravels from the face of the cliffs (as witnessed by pock-marks and erosional features across the cliff face). In periods of excessive rainfall the infiltrated surface water volume and pressure significantly increases, and correspondingly reduces the frictional strength of the boulder clay and sand/gravel deposits. This can result in the weight of sections of the cliffs exceeding the sliding resistance of the soil along planes of weakness, leading to slope failure.

The continued flow of water out through the face of the failed slopes and the saturated and softened condition of the slipped boulder clay soils, confirms this failure mechanism.

The impact of sea erosion on the recently slipped slopes appears to be minimal. In general the sea action in storm conditions erodes the face of the slopes within the tidal range, leading to the creation of cliffs (steepened slopes) and ongoing slip failures (see Figure 13 below). These over-steepened slopes are unstable in the long-term, but remain steep due to the erosion mechanism which effectively removes ‘slices’ of cliffs over time.

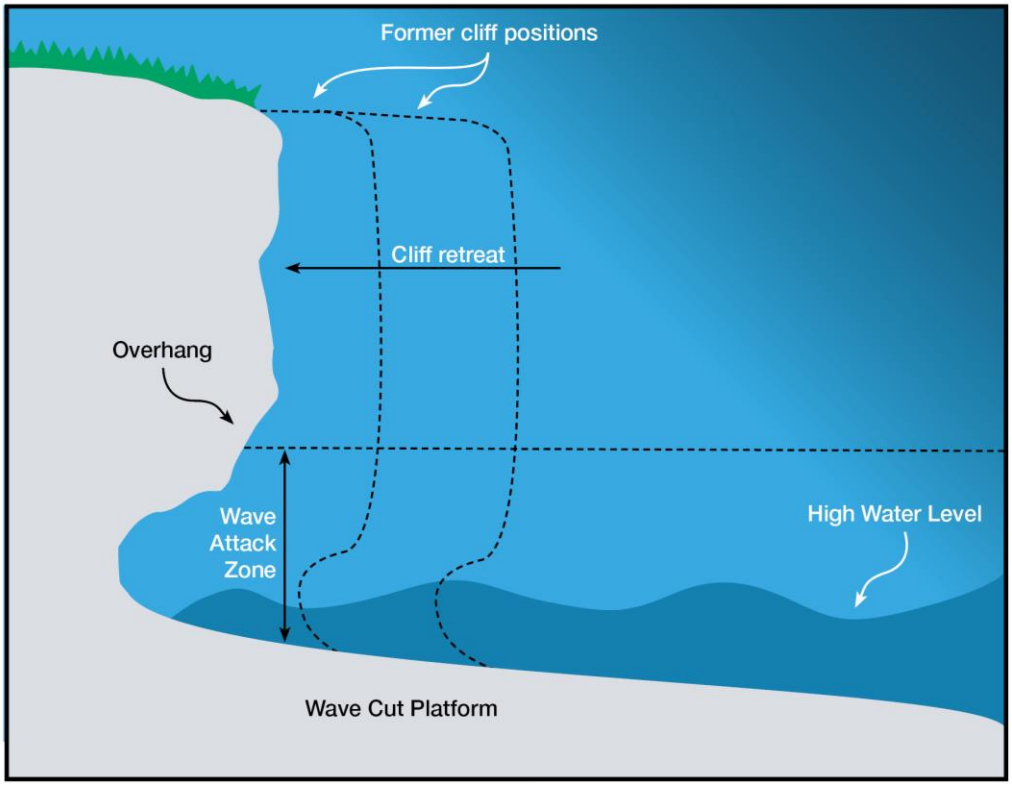


Figure 13: Typical steepened cliffs eroded by wave action

The photographs show that where tallest and steepest, the cliffs are predominately boulder clay soils with some minor local gravelly lenses. Where the recent slips have occurred there are significant deposits of sands. The presence of these sand deposits (lenses), and the 'flatter' or more circular slip surfaces observed, with significant flow of water through the face of the slips, clearly indicates failure due to infiltration of surface water (See Figure 14 and Figure 15 below). A circular geotechnical failure like that causes a larger retreat in the cliff than the 'slices' of cliff eroded by wave action.

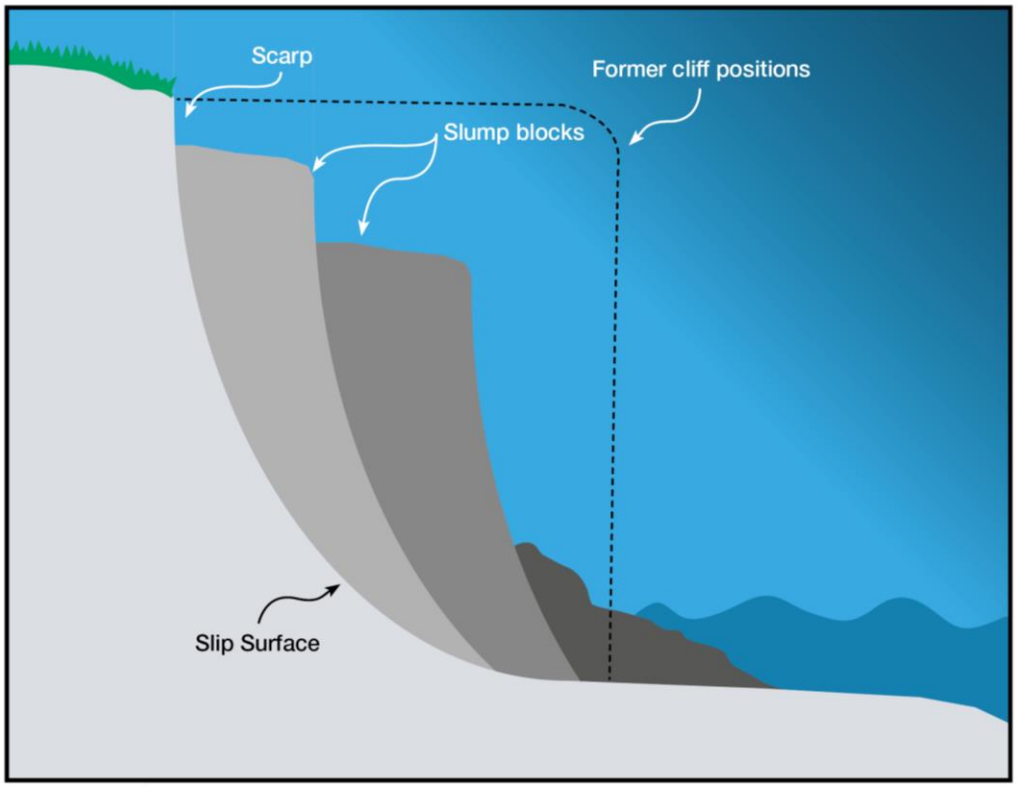


Figure 14: Typical slope failure showing circular slip surface

The evidence observed on site shows that the recent slope failures are due to the effects of the excessive rainfall over the month of December. While sea erosion is a contributing factor to erosion along this section of coast, the recent slips were triggered by water pressure and flow within the cliff material causing instability and slip failure.


Figure 15: Area of collapse showing flatter slope

4 Topographical survey assessment

4.1 Topographic survey 2016

In February 2016 a topographic survey of the site was undertaken by Laser Surveys. The survey extended from Paddy's Point in the north to a point approximately one kilometre to the south at Golden Rock.

The scope of the survey included:

- The sandy beach covering a vertical range from Mean Low Water Springs (MLWS) and Mean High Water Springs (MHWS);
- Area of the beach from MHWS including the cliff/ embankment/ higher land area behind the beach.
- Existing beach cliff/ embankment with levels from the north to the south of the survey area;
- The 0m contour
- Rock outcrops;
- Location and approximate extent of any collapsed sections of cliff;
- Cross-sections at ten specific locations showing accurately the top and toe of the cliff as well as the geometry of the slope of the cliff

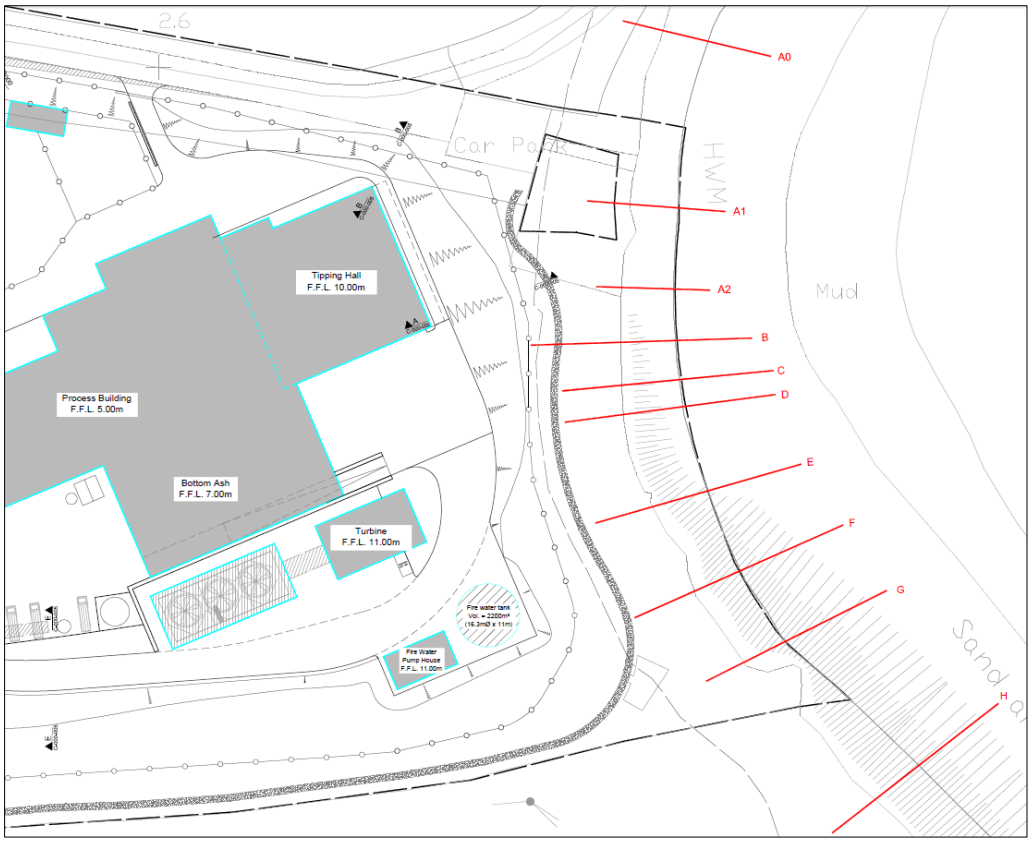


Figure 16: Specified sections for topographic survey

The survey was carried out during a period of spring tides in order to ensure maximum coverage. The survey was undertaken using a Trimble Precise Robotic Total Station and Trimble GPS, which enabled the surveyor to develop a detailed surface model of the surveyed area using laser scan data. In particular, this provided more detailed survey information in relation to the cliff face in comparison with previous surveys i.e. 2008, 2010 and 2014. For example, in previous surveys where only GPS was used, levels were only recorded at the top and bottom of the cliffs. In the 2016 survey the laser scan data provides a detailed profile of the cliff face.

If similar surveying methods are used in the future, i.e. more detailed survey information user laser scanning, it will be possible to analyse the movement of beach material within the study area based on a comparison of beach volumes. This would likely form part of any future beach monitoring programme and would inform when and where additional sacrificial material would be required.

The following final deliverables were provided by Laser Surveys:

- All recorded survey data and interpolated contour lines in AutoCAD format referenced to both OD Malin and Chart Datum.
- Cross-sections at specified locations showing accurately the top, toe and geometry of the slope of the cliff, in AutoCAD format to both OD Malin and Chart Datum.
- A brief technical report detailing survey method, benchmarks and estimation of volume of beach material

4.2 Comparison of surveys

Periodic topographic surveys have been carried out in the area in 2008, 2010 and 2014. In order to assess whether this recent event is in keeping with previous erosion estimates it is necessary to compare previous surveys with the most recent topographic survey.

Figure 17 shows sections A1 to G as well as the top and bottom of the cliff as derived from the 2008 and 2016 surveys. This figure shows the approximate locations of the two slope failures mentioned previously. The smaller slope failure located south of the car park is located roughly between sections B and D and the larger slope failure is located roughly between sections F and G.

From Figure 17 it can be seen that the bottom of the cliff line has remained relatively stable in comparison with the top of the cliff line. At the location of the larger slope failure in the south, the bottom of the cliff line has actually advanced since 2008. This is likely due to the presence of the slumped material from the upper cliff. The relative stability of the bottom of the cliff indicates that the toe of the cliff has not been affected to a large degree in recent years by erosion due to wave action.

Refer to Appendix B for detailed plan and section drawings showing comparisons between the various surveys.

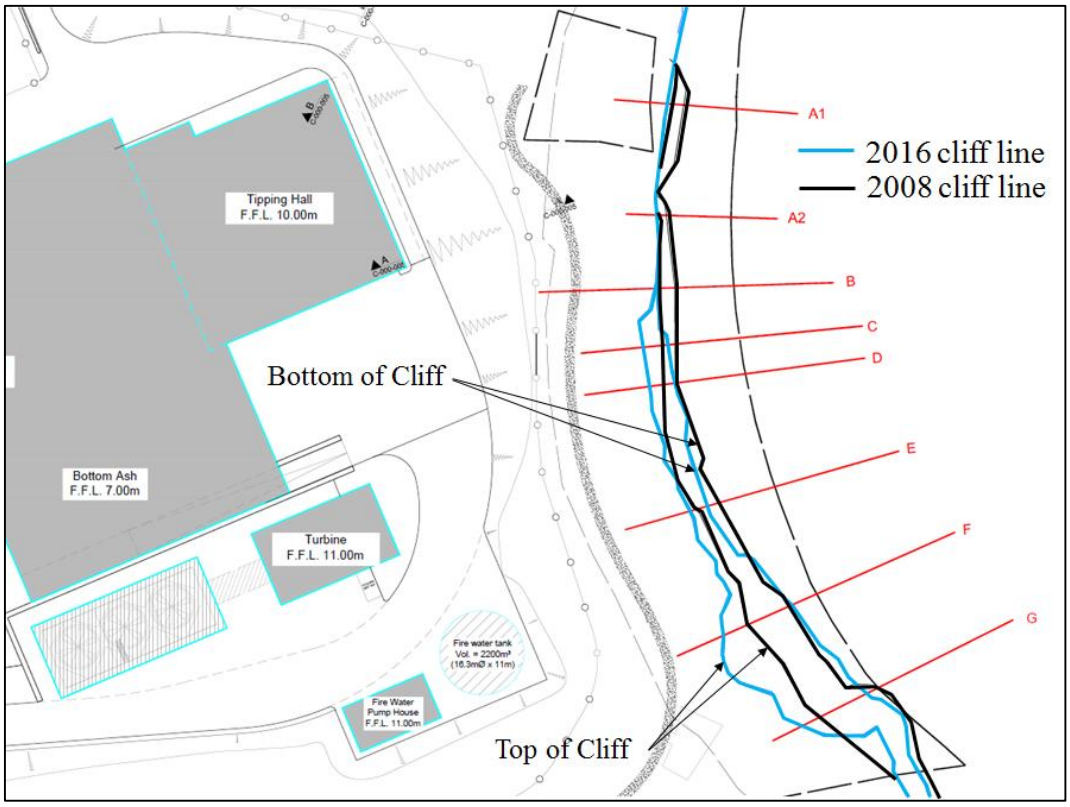


Figure 17: Sections A1 to G showing top and bottom (toe) of the cliff from 2008 and 2016 surveys

When comparing the topographic surveys from 2008 to 2016 it becomes obvious that the location of the largest slope failure was between sections F and G with a smaller collapse located between sections B and D. Figure 18 below shows an extract from the section drawings for sections F and G. The largest retreat of the top of the cliff between the 2008 and 2016 surveys was localised between sections F and G, with a value in the range of 7-9m.

From analysis of the sections in Figure 18 the following conclusions can be made:

- The upper section of the cliff has slipped with the debris accumulating at the toe of the cliffs
- Between 2008 and 2014 there has been little erosion in this area
- The toe of the cliff has remained stable i.e. has not been eroded significantly
- Beach levels have remained stable in recent years indicating that the foreshore/ beach has not been eroded during recent events

At the localised slope failures the fact that the toe of the cliffs and the foreshore/ beach levels have been largely unchanged between 2008 and 2016 would indicate that erosion by wave action has not been a significant issue recently. This confirms the findings of the site walkover i.e. while sea erosion is a contributing factor to erosion along this section of coast, the recent erosion events were due to water pressure and flow within the cliff material causing instability and slip failure rather than erosion due to wave action alone.

The effects of the recent erosion event on estimation of erosion rates for the area will be discussed in Section 5.

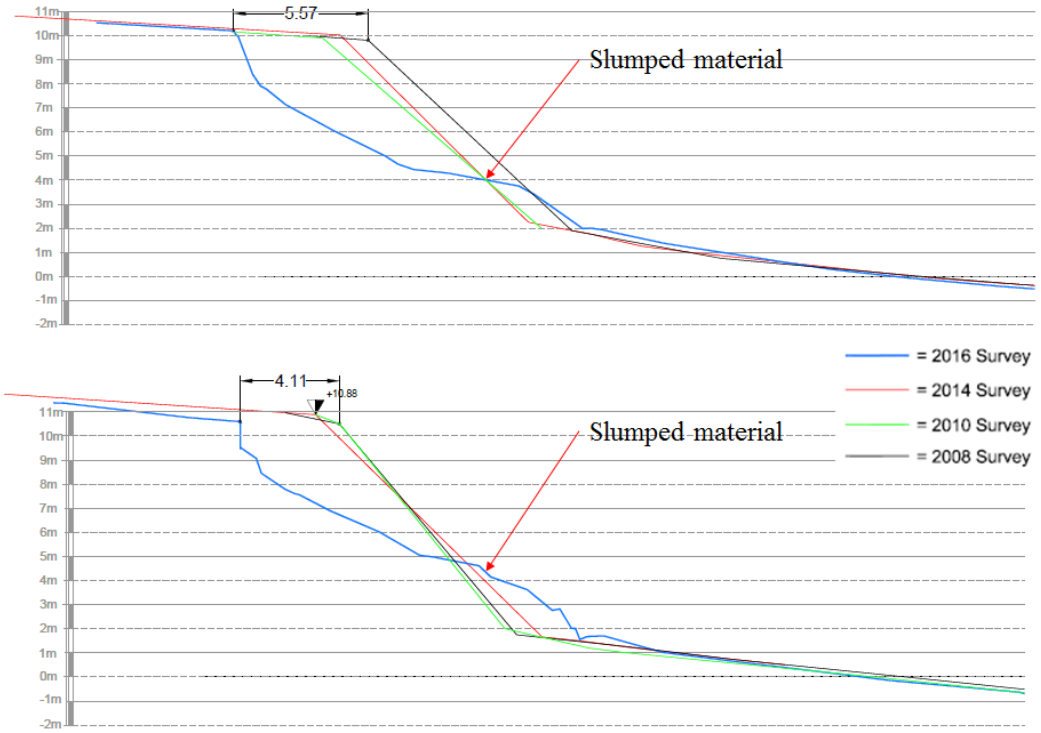


Figure 18: Sections F and G showing survey information from 2008 to 2016

Note that the previous surveys (2008 to 2014) show a straight line from the top of cliff to the toe due to the fact that survey data was only gathered at the top and toe of the cliff i.e. these lines do not accurately represent the profile of the cliffs in those years.

5 Erosion assessment

5.1 Methodology

This section addresses how the recent cliff collapses affect the previous estimate of erosion rate for the area of coast adjacent to the proposed development site. The topographic surveys were compared in order to derive the measured retreat over the full monitoring period, i.e. 2008 to 2016, at eight specific locations (A1 to G). These measurements were then used to estimate an erosion rate for the site. The measured retreat for the periods between topographic surveys can be found in Table 1. As in previous assessments, results for sections A1 and A2 are excluded because no significant retreat was historically recorded at these locations and accretion takes place in some years..

As mentioned in the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), the period of available reliable data is too short to be conclusive about the erosion trend in the area. This is due to the fact that erosion appears to be related to the more energetic or episodic wave storm events rather than being a constant process. This has been confirmed by recent erosion events. The previous coastal study therefore takes a conservative approach in establishing the erosion rate.

5.2 Data from March 2016 survey added

The table below shows the measured retreat in sections B-G at the top of the cliff/embankment.

Table 1: Measured retreat rate based on topographic surveys and inferred erosion rates

Sections	Retreat (m)					
	2008-2010	Retreat per year 2008-2010	2008-2014	Retreat per year 2008-2014	2008-2016	Retreat per year 2008-2016
B	0.91	0.46	0.91	0.15	1.20	0.15
C	0.90	0.45	1.73	0.29	3.69	0.46
D	1.14	0.57	1.82	0.30	2.67	0.33
E	1.36	0.68	1.81	0.30	1.34	0.17
F	1.10	0.55	1.10	0.18	5.57	0.70
G	1.00	0.50	1.98	0.33	4.11	0.51
Average	1.07	0.53	1.56	0.26	3.10	0.39

From the table, it is evident that the greatest retreat recorded by the most recent topographic survey has occurred between sections F and G where a localised geotechnical slide can clearly be seen, while there has also been significant erosion at sections C and D.

It can be observed that erosion rates inferred are below the maximum estimated retreat of 0.5m per year, except in the area where the localised geotechnical slide has occurred. However, the average erosion rate along the length of the study area which was effected by the recent slope failures (sections B to G) over the eight year period is 0.39m per year which is well below the previously predicted maximum erosion retreat of 0.5m per year.

This estimate is conservative for a number of reasons as follows;

- Sections A1 and A2 have not been included; if they were included in the estimate the average rate would reduce to approximately 0.30m per year
- This method of estimation does not take account of the stability of the toe of the cliffs and the beach/ foreshore levels; if beach and toe levels remain stable there will be no increase in nearshore wave conditions and hence no increase in erosion due to wave action
- The presence of local rock outcrops (visible and underlying) have not been included in this estimation; their presence will limit erosion of beach levels and hence limit the potential increase in nearshore wave heights and associated increase in erosion due to wave action
- Change in erosion patterns and potential accretion is not considered
- Erosion rates are based on analysis of the top of the cliff line only where the effects of erosion will be the most pronounced i.e. due to the pattern of erosion in the area the most significant retreat will occur at the top of the cliff rather than the bottom.

This conservative approach together with the allowances made in the wave and erosion modelling means that there is an adequate allowance for any changes that may occur due to climate change.

5.3 Impact on the predicted maximum retreat rate

The erosion rates appear to be consistent with the maximum retreat of 0.5m/ year based on historical evidence. A localised geotechnical failure has been identified following an extreme rainfall event. This geotechnical slide is not solely due to coastal processes and as outlined in section 3.2, the large slope failure has been mainly caused by geotechnical instability that caused larger circular slips rather than the notching at the toe of the cliff caused by normal coastal erosion. The geotechnical failure mechanism takes ‘bigger steps’ than the normal ‘notch, steepen and slump’ mechanism.

Sudden localised failures are not representative of an erosion rate for the coastal stretch as they result following extreme and infrequent events and are of limited extent.

The likelihood of another slope instability caused by water infiltration into sand lenses will actually be reduced by the proposed development due to the provision of on-site surface water drainage and the resulting reduction in infiltration of surface water in the area surrounding the site.

Taking into account the retreat recorded between 2008 to 2010 and 2008 to 2014 the most recent event is evidently an episodic and localised event i.e. a large amount of erosion has occurred over a short period of time.

Due to the episodic nature of the events, any erosion estimate needs to take into account retreat along the whole length of the study area as opposed to a localised location where the highest rate of erosion is recorded.

This study confirms that the maximum erosion rate estimate derived in the previous coastal study carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), remains at 0.5m per year. Again this is a conservative estimate for a number of reasons as mentioned.

While the estimated rate of 0.5m per year may be exceeded at a localised point in any given year it is unlikely that the maximum erosion rate over the length of the study area for the full monitoring period will exceed this estimate.

As described in the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), applying this predicted rate of erosion, and with no mitigation in place, gives an expected maximum retreat of 50m in 100 years' time, 15m in 30 years' time and 20m in 40 years' time.

Using this approach it is observed that a retreat of 50 m in 100 years would encroach beyond the security fence of the proposed development. The study found that there would be no impact on the proposed development after 30 years. The study found that there could be a risk of an impact on a small section of the proposed development after 40 years however this would be confined only to the amenity walkway and a small section of a diverted gas pipeline outside of the security fence line. The Resource Recovery Centre section of the proposed development will not be impacted by coastal erosion for the entire duration of the planning permission.

The placement of the proposed sacrificial material at the toe of the cliffs will help to dissipate the wave energy at the site and protect the toe and lower area of the cliffs from direct wave action and hence reduce the rate of erosion. This additional proactive measure will provide confidence that the estimated maximum rate of erosion (0.5m per year) is not exceeded while the sacrificial material is present.

With the application of the sacrificial material, there will continue to be no impact on the entire proposed development after 30 years. With the application of the sacrificial material, the diverted gas pipeline will not be impacted after 40 years. However, there is still a risk of an impact on the amenity walkway after 40 years. The waste-to-energy section of the proposed development will not be impacted by coastal erosion for the entire duration of the planning permission.

It is worth noting that the L2545 road to Haulbowline will be impacted in less than 30 years even with the application of sacrificial material. Therefore the road will be effected by erosion before any element of the proposed development.

6 Conclusions and recommendations

6.1 Conclusions

Following significant rainfall events in December 2015 and January 2016 a number of localised slope failures occurred adjacent to the proposed Indaver development site at Ringaskiddy. The slope failures were located south of the car park off the L2545 road and formed a small failure approximately 50m south of the car park and a larger failure approximately a further 20m south.

Arup carried out a site walkover with a team of experts from different disciplines following these events. Arup inspected the coast adjacent to the proposed development including the localised slope failures. The conclusions drawn from the site walkover were as follows:

- Surface water is being transmitted through the cliff face where granular deposits are present in the boulder clay leading to softening of the surrounding boulder clays, and erosion of the sands and gravels from the face of the cliffs (as witnessed by pock-marks and erosional features across the cliff face)
- Excessive rainfall has caused infiltrated surface water volume and pressure to increase and correspondingly reduces the frictional strength of the boulder clay and sand/gravel deposits resulting in slope failure
- The continued flow of water out through the face of the failed slopes and the saturated and softened condition of the slipped boulder clay soils, confirms this failure mechanism
- The ‘flatter’ or circular failure mechanism indicates that the slope failure is due to infiltration of surface water rather than by wave action

Laser Surveys carried out a topographic survey of the beach area adjacent to the proposed development and the surrounding area and the results were used to further assess the recent erosion events. The survey showed two clear areas where slope failures had occurred. From the comparison of all available topographic surveys and in particular in relation to the worst effected sections of the cliff (sections F and G) the following conclusions were derived:

- The upper section of the cliff had slipped and slumped at the toe of the cliffs
- Between 2008 and 2015 there had been little erosion in this area (refer to section 2)
- The toe of the cliff had remained stable i.e. has not been eroded significantly
- Beach levels have remained stable in recent years indicating that the foreshore/ beach has not been eroded during recent events

These conclusions indicate that the recent localised slope failures were not due to coastal erosion by wave action alone. While sea erosion is a contributing factor to erosion along this section of coast, the recent slips were due to water pressure and flow within the cliff material causing instability and slip failure.

An estimation of erosion rates for the study area was undertaken based on recorded retreat over the entire period of eight years (2008 to 2016). This analysis showed that a conservative estimate of the recorded erosion rate is 0.39m per year for the sections experiencing erosion and 0.30m per year for the whole study area. This is below the maximum retreat rate of 0.5m per year given in the Coastal Erosion study, which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*).

The Resource Recovery Centre in the proposed development has been located far enough away from the edge of the cliff to ensure that the waste to energy facility will not be impacted by the predicted retreat rates over the design life of the development.

6.2 Recommendations

Based on the conclusions of this study Arup recommend the following:

- An erosion rate of 0.5m per year is adopted for the coast adjacent to the proposed development in keeping with the rate recommended in the Coastal erosion report
- The study area is continually monitored as part of a the beach monitoring plan as recommended in the Coastal Erosion report

Appendix A

Site walkover photographs

A1



Figure 1: Slope failure at Gobby Beach facing south



Figure 2: Smaller slope failure to the north of the site approx. 50m south of car park



Figure 3: Saturated slumped material at smaller slope failure



Figure 4: Saturated slumped material at smaller slope failure



Figure 5: Larger slope failure approx. 20m to the south



Figure 6: Sand lenses surrounded by clays and gravels in slope face



Figure 7: Larger slope failure showing water running through the slope



Figure 8: Larger slope failure showing water running through the slope



Figure 9: Slumped and saturated material and vegetation at the southern extent of the larger slope failure



Figure 10: Slope face further south from large slope failure showing boulder clay and further slope failure



Figure 11: Minor notching due to wave action south of the larger slope failure



Figure 12: Slope failure further south from larger slope failure



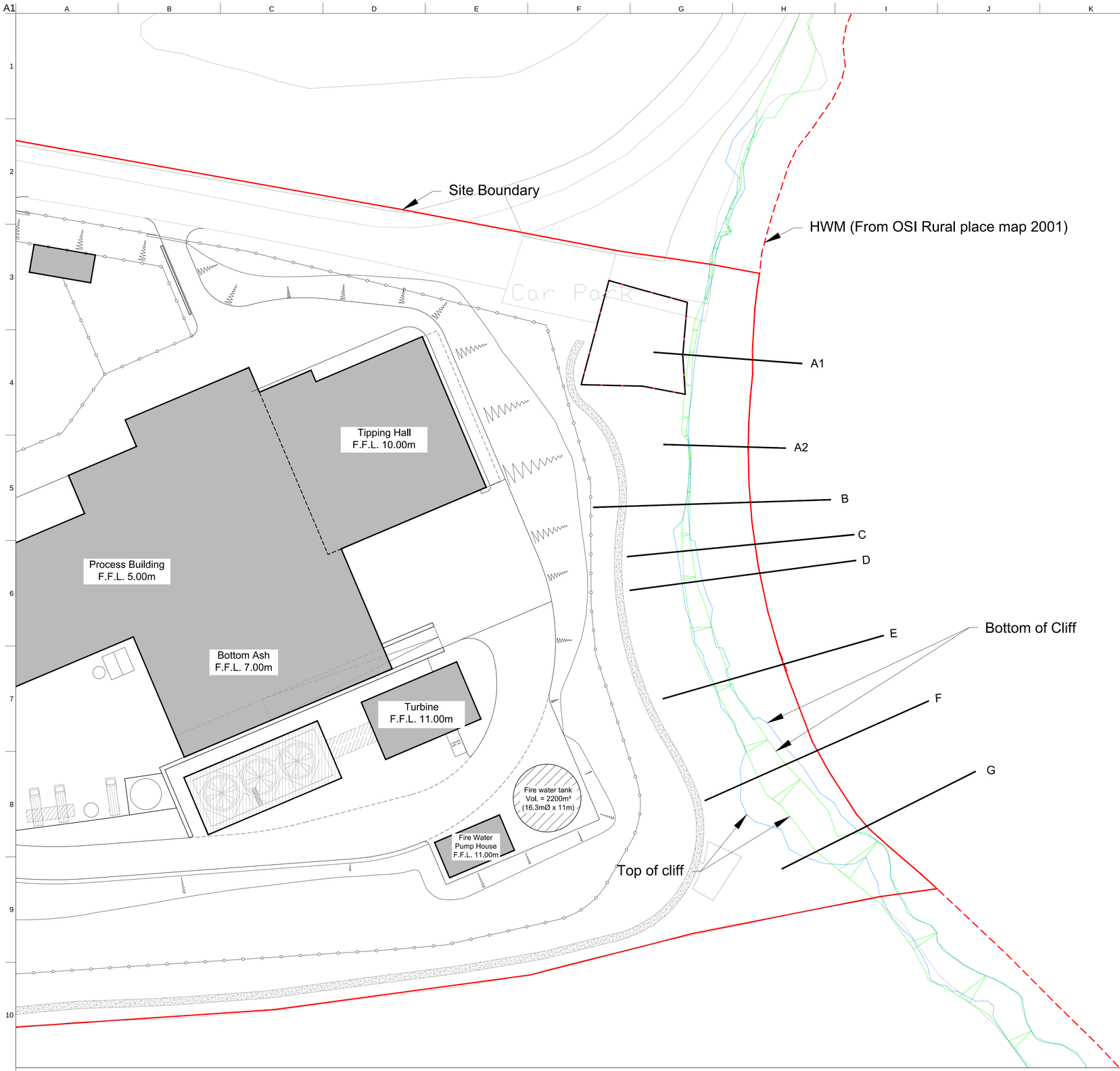
Figure 13: Beach adjacent to Indaver site boundary showing good beach levels



Figure 14: Gobby beach looking north from the top of the slope

Appendix B

Survey comparison drawings



NORTH.

Notes:

1. Information shown on this drawing is to be considered indicative only.
2. All dimensions are shown in metres unless noted otherwise.
3. All levels are shown in metres above ordnance datum.
4. All levels shown are based on most recent Bathymetric and Topographical Survey.
5. Material type and dimensions are assumed based on visual inspection and site investigation works.

Legend:

- Site boundary
- High water mark
- Top/ bottom of cliff 2014
- Top/ bottom of cliff 2016

Issue	Date	By	Chkd	Appd
I01	31/03/2016	JR	SL	SL
Issued for Information				

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Job Title: Ringaskiddy Resource Recovery Centre

Coastal Study
Comparative Plan

Scale at A1: 1:500
Discipline: Civil
Job No: 238129-00
Drawing Status: For Information
Drawing No: C-000-064
Issue: I01

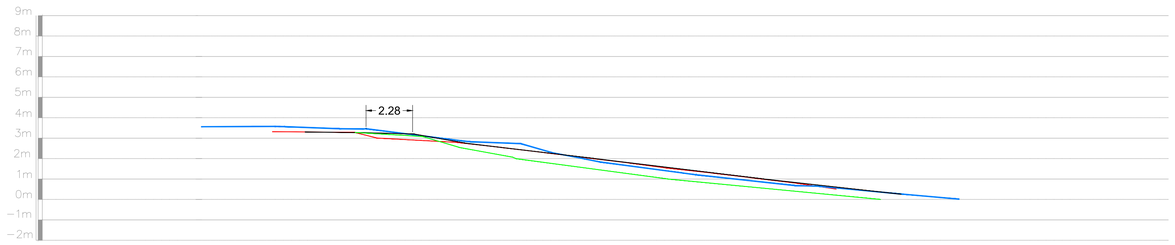
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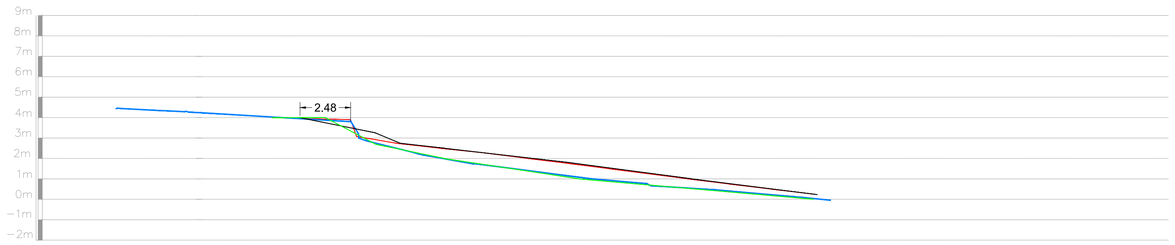
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A1

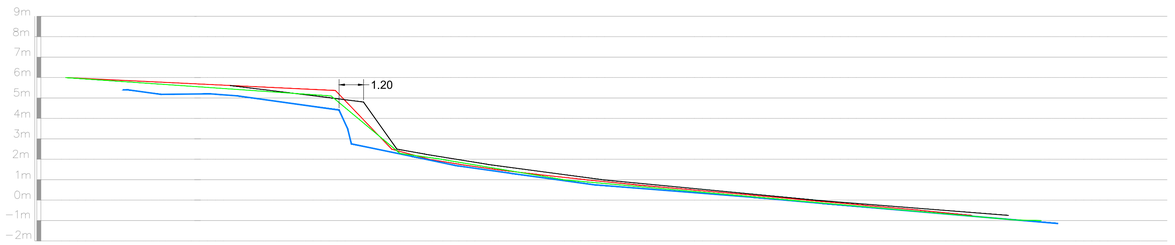
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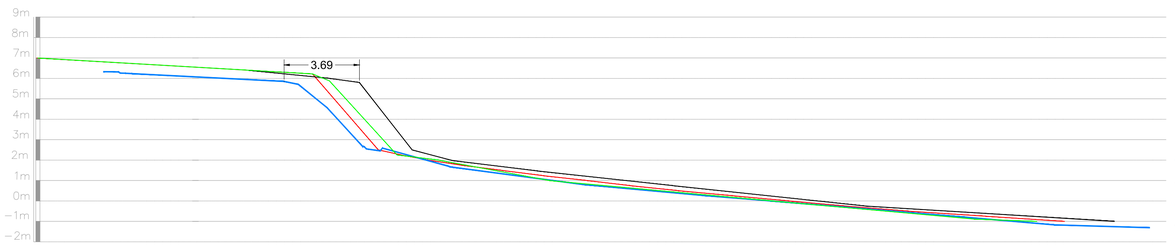
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B



C



Notes:

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3. All levels are shown in metres above ordnance datum.
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5. Material type and dimensions are assumed based on visual inspection and site investigation works.

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Coastal Study
Comparative Sections

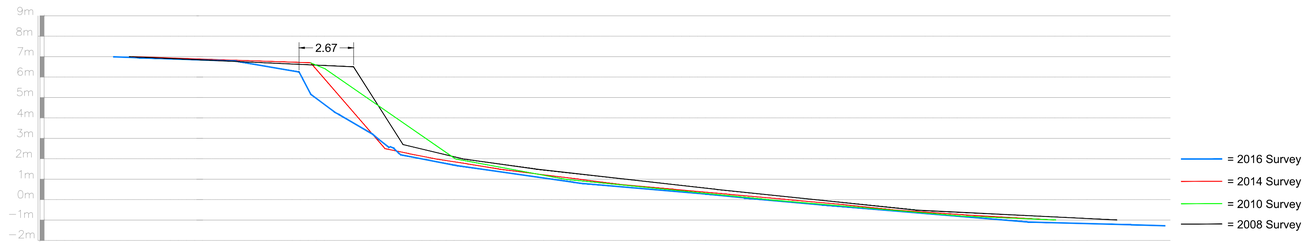
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Discipline: Civil
Job No: 238129-00
Drawing Status: For Information
Drawing No: C-000-065
Issue: I01

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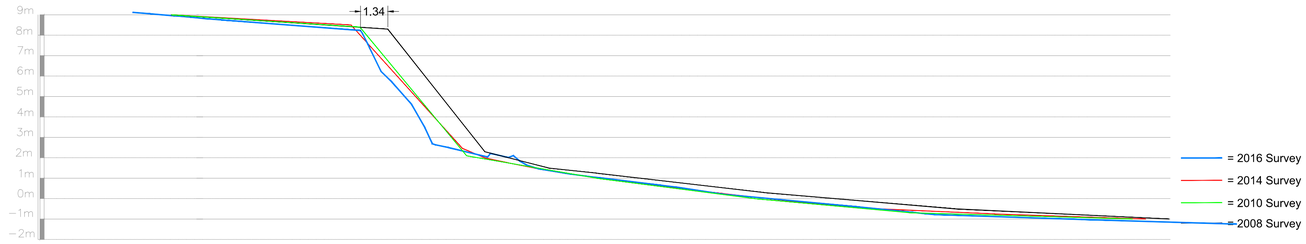
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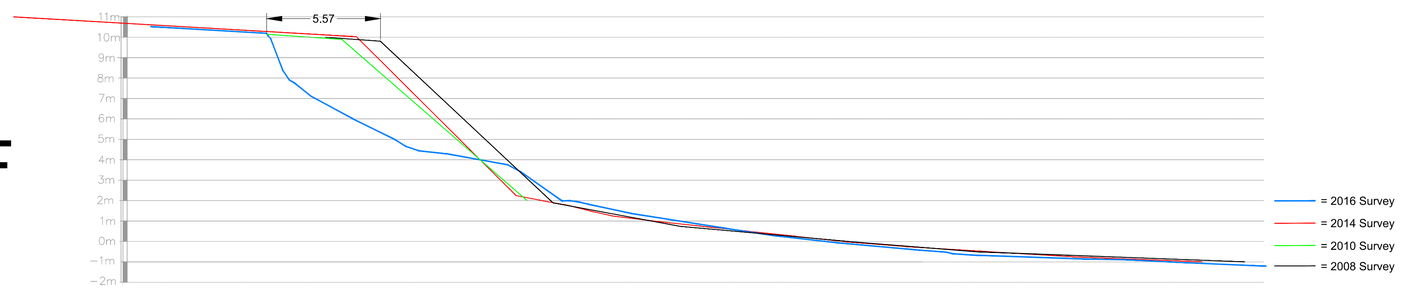
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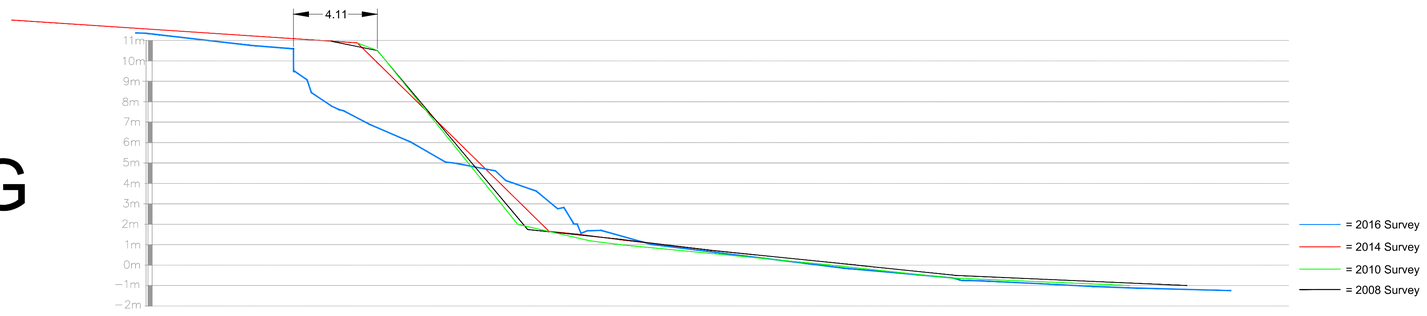
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F



G



Notes:

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Job Title: Ringaskiddy Resource Recovery Centre

Coastal Study
Comparative Sections

Scale at A1: 1:150
Discipline: Civil
Job No: 238129-00
Drawing Status: For Information
Drawing No: C-000-066
Issue: I01

Do not scale

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Indaver

Resource Recovery Centre, Ringaskiddy, Co. Cork

Coastal erosion report addendum: Assessment of the December 2015 slope instabilities

WM/REP/0002

Issue | 19 April 2016

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 238129-00

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Contents

Page

1 Introduction 1

2 Summary of winter 2015 events 3

3 Site walkover and assessment 3

3.1 Site observations 3
3.2 Site assessment 5

4 Topographical survey assessment 9

4.1 Topographic survey 2016 9
4.2 Comparison of surveys 10

5 Erosion assessment 13

5.1 Methodology 13
5.2 Data from March 2016 survey added 13
5.3 Impact on the predicted maximum retreat rate 14

6 Conclusions and recommendations 16

6.1 Conclusions 16
6.2 Recommendations 17

Appendices

No table of contents entries found.

1 Introduction

Coastal erosion report for the EIS

Arup has previously undertaken an assessment of coastal erosion for the proposed Indaver development site at Ringaskiddy as described in the coastal study which was carried out in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery Centre, EIS 2016*). The assessment consisted of the following:

- Assessment of the retreat rate based on historical information and topographic surveys dating from 2008 to 2014
- Numerical wave modelling and beach sediment transport analysis
- Assessment of expected coastal retreat

In addition to these items Arup carried out an appraisal of the potential impacts of expected coastal retreat on the proposed Ringaskiddy Resource Recovery Centre and recommended proactive mitigation measures to minimise the risk of potential impacts on the development.

The report recommended that a conservative maximum retreat of 0.5m/year should be adopted for the site. Based on this rate of retreat it was determined that the waste to energy facility section of the proposed development has been located far enough away from the coastline to ensure that it will not be impacted by the predicted retreat rates over the design life of the development. Also, the proposed development will not increase the current rate of retreat.

In addition, while it was concluded that coastal protection measures were not required for the waste-to-energy facility, coastal protection measures were included in the planning application as a precautionary measure so as to reduce the rate of erosion of the glacial till face due to wave action. The coastal protection measures proposed comprised a beach monitoring programme and the placement of sacrificial material at the toe of the cliffs in the form of shingle.

Background to this Addendum

December 2015 was the wettest month on record in many areas of Ireland, particularly in the Southwest where rainfall amounts were approximately 3 times the average. By the end of December, many areas were entirely saturated and even normal rainfall events resulted in very significant flooding.

Storm Frank, the 6th major winter storm of 2015 brought high winds and significant rainfall between the 29 December 2015 and the 2 January 2016. Significant flooding resulted across much of the country. County Cork was badly affected with major flood events on many rivers such as the Blackwater, Bandon, Glashaboy, Owenacurra and many others. Between 29 December 2015 and 30 December 2015 immediately following the extreme rainfall associated with Storm Frank there were several localised slope failures at Gobby Beach on the eastern extent of the proposed Indaver site. Following these events Arup carried out an

assessment of the size and causes of the failures and reviewed them in relation to the outcomes of the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*).

The assessment includes the following:

- Site walkover
- Topographic survey
- Review of new survey against previous surveys
- Erosion assessment

This report details the findings of the assessment of the effects of the recent events on the proposed Indaver site and adjoining Gobby beach and makes any recommendations as to how these findings might be considered along with the findings of the previous coastal erosion study.

2 Summary of winter 2015 events

In late December 2015 and early January 2016 Ireland was exposed to extreme storm conditions, comprising heavy rainfall, high seas and high winds. This storm, known as Storm Frank, combined with a series of large storm events over the preceding months led to extensive damage and flooding to both inland and coastal areas throughout Ireland. Winds varied in direction from south to southwest to westerly direction. In county Cork approximately 60mm of rain fell between Tuesday 29 December and Wednesday 30 December. This combined with high tides and a substantial storm surge led to flooding at a number of locations throughout the county. There were reports of wave overtopping and flooding in Kinsale and Garretstown, as well as extensive flooding due to rising water levels in Passage West and Cork City. However, there are no reports of flooding or erosion due to wave action or overtopping in Cork Harbour.

December 2015 was the wettest month on record in many areas of Ireland, particularly in the southwest where rainfall amounts were approximately 3 times the average.

Met Éireann's December 2015 Weather Summary notes the following:

> *'All stations reported well above Long-Term Average (LTA) rainfall with most stations across the country reporting double or triple their normal rainfall for December. Wettest conditions (compared to LTA) were in county Cork where nearly all stations reported over 300% of LTA. Roche's Point reported the highest percentage of LTA with 342% (340.6 mm of rain) it's highest for December since 1955.'*

It is further noted that the highest rainfall total for the month of December was recorded at Cork Airport where some 402.2mm of rainfall fell, approximately 3 times the long term average. 324mm of rainfall, 312% of the LTA rainfall was also recorded at Fermoy, Moore Park.

Figure 2 below provides the depth duration curve for 1 in 200 year rainfall event at Cork Airport. It is extrapolated from 25 days to 31 days as Met Éireann's Depth Duration Frequency (DDF) data only extends to 25 days. It can be seen that the monthly calendar rainfall total for December of 402mm has a return period of more than 1 in 200 years.

Clearly, December's rainfall was exceptional. By the end of December, many areas were entirely saturated and even normal rainfall events resulted in very significant flooding. Groundwater levels were therefore also extremely elevated.

Storm Frank, the 6th major winter storm of 2015, brought high winds and significant rainfall between the 29 December 2015 and the 2 January 2016. Prior to 28 December 2015, approximately 312mm of rainfall had already fallen in the month at Cork Airport, with 248mm having fallen at Moore Park, Fermoy for the month to that date. A further 16mm of rain fell at both locations on the 28 December in the run-up to Storm Frank.

The largest rainfall amounts fell in a 21 hour window between about noon on the 29 Dec 2015 and 7am on the morning of the 30 Dec 2015 with 61mm being recorded at Cork Airport, 46mm at Moore Park, Fermoy.

In the days following the heavy rainfall associated with Storm Frank two section of the cliffs adjacent to the proposed Indaver development site at Ringaskiddy suffered a slip failure. The slope failures were contained to the southern area of the bay along an area with a substantial height of cliff. The north eastern part of the site adjacent to the car park was largely unaffected save for some shingle being moved from the beach to the adjacent lands.

In January 2016 Indaver commissioned a drone survey of the coast adjacent to the proposed development site. Figure 1 and Figure 3 below show two areas where significant slope failures occurred. The first area shown in Figure 1 (circled in blue) is approx. 20m long and cliff height is roughly 2 to 3m. This area is located approximately 50m south of the car park. The second area shown in Figure 3 (circled in blue) is a further 20m south and is approximately 40m in length and cliff height is roughly 7 to 9m.



Figure 1: Drone photography showing first area of slope failure and minimal damage to the beach north of this location

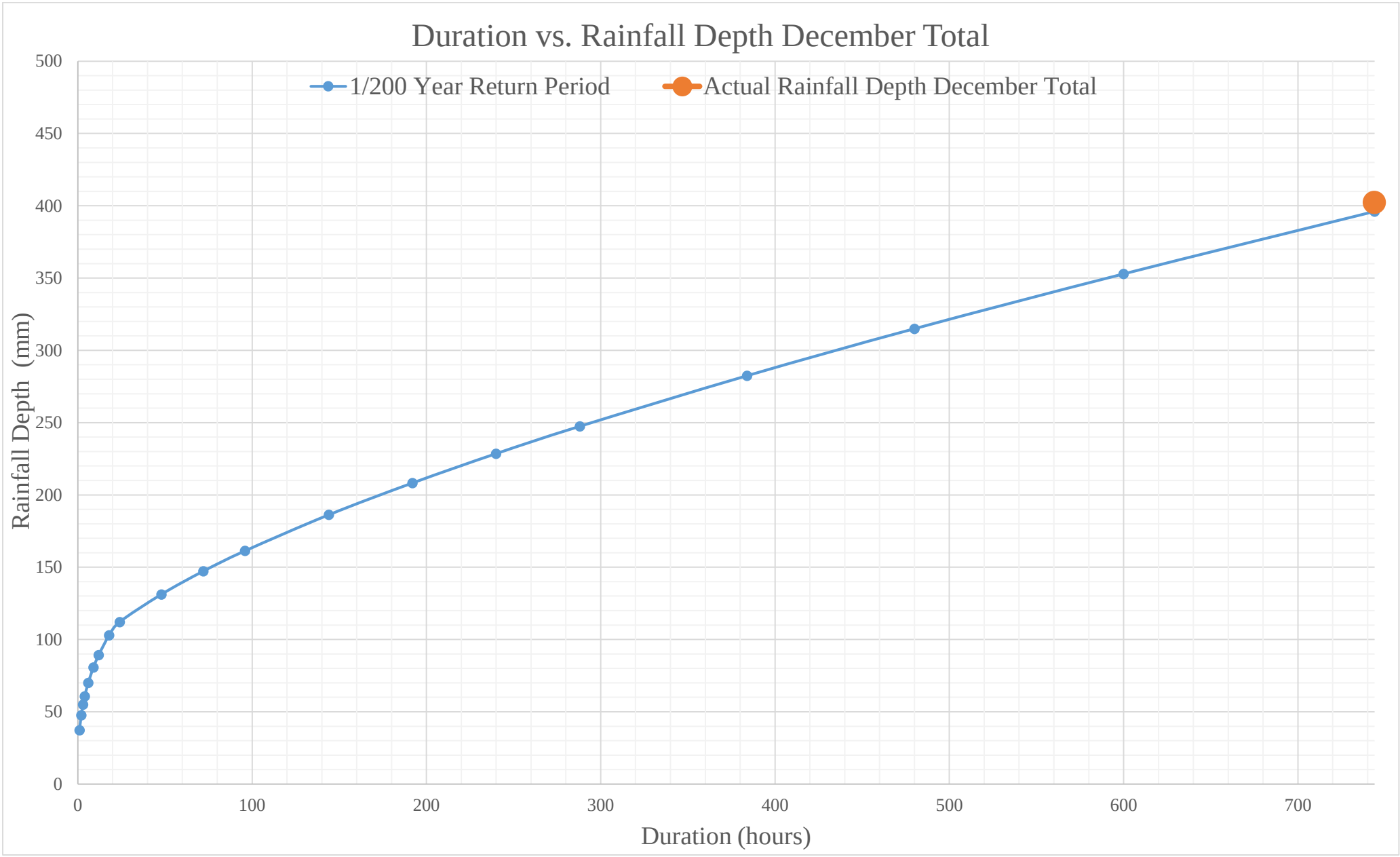


Figure 2: Depth duration graph for 1 in 200 year rainfall event



Figure 3: Drone photography showing slope failure to the southern section

Figure 4, Figure 5 and Figure 6 below show the affected area to the south of the beach as recorded in June 2009, September 2015 and December 2015. From the imagery it is clear that there has been localised slope failure between 2009 and 2016. Minor erosion occurred between June 2009 and June 2015 and a large slope failure occurred between September 2015 and December 2015. The nature and timeline of the failure will be discussed further in the following sections.



Figure 4: Cliff adjacent to proposed development site, June 2009



Figure 5: Cliff adjacent to proposed development site, September 2015



Figure 6: Cliff adjacent to proposed development site, December 2016 following failure

3 Site walkover and assessment

3.1 Site observations

Following the storm events and associated slope failure over December and January 2016 Arup carried out a site walkover. The site walkover was attended by a number of staff with expertise in the following areas: coastal engineering (Julie Ascoop), geotechnical engineering (Sean Mason) and environmental engineering (Fiona Patterson). The site walkover was undertaken on 1 March 2016 prior to low tide. Please refer to Appendix A for photographs taken during the site visit.

Figure 6 and Figure 7 below show the two areas of slope failure as described previously.



Figure 7: First area of slope failure approximately 50m south of car park



Figure 8: Second area of slope failure further 20m south

During the site walkover the following were the main items observed:

- A number of slope failures

  There were two slope failures observed along the Indaver site, as shown in Figure 7 and Figure 8.

  The first one approximately 50m south of the car park was rather small. The embankment is only approximately 2m high here and the failure looks to have adjusted the over-steep embankment to a more stable slope.

  The second slope failure was quite large and V-shaped back landward. A significant amount of material was slumped down in this failure.

- Water running out of the slope of the cliffs through the failures (there had been no recent rain in the days prior to site walkover). (Refer to Figure 9)

  In both failures water could be seen running out of the embankment. In the larger failure a small stream (of fresh water) ran out through the V-shaped failure into the sea.

- Sand lenses in the slope failures (Refer to Figure 10)

  In the large failure sand lenses were observed in the cliff slope.

- No evidence of coastal erosion at the bottom of the cliffs

  There was no evidence of any significant coastal erosion at the bottom of the cliffs. They did not have a 'notched' shape at the bottom and overall the beach shingle was high up on the beach covering the toe of the cliff. (Refer to Figure 11)



Figure 9: Water running out of the slope failure



Figure 10: Sand lens in the slope failure



Figure 11: Currently no evidence of ‘notching’ at the bottom of these cliffs

3.2 Site assessment

Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*, identifies both geotechnical and coastal causes for the cliff erosion.

As shown in the photographs in Appendix A and as previously recorded in the 2015 coastal study (Refer to), the soil cliffs are primarily a ‘boulder clay’ deposit, i.e. soils created, deposited and compacted by ice action. They generally comprise of sands, gravels and cobbles, with occasional boulders, embedded within a silty clay matrix, (hence the term ‘boulder clays’).

At this location there are local ‘fluvio-glacial’ deposits of sands and gravels within the boulder clay. These more granular deposits (lenses) are considerably more permeable than the surrounding boulder clays, and transmit water through

the ground, and out through the face of the cliffs where exposed. Therefore the surface water (rainfall) both (a) flows over the ground surface and down the cliff face, and (b) infiltrates into the ground and flows through these permeable lenses and channels out through the cliff face.



Figure 12: Surface water (which has infiltrated the ground and flows through the permeable lenses) flowing out through cliff face

Over time this infiltration of surface water leads to softening of the surrounding boulder clays, and erodes the sands and gravels from the face of the cliffs (as witnessed by pock-marks and erosional features across the cliff face). In periods of excessive rainfall the infiltrated surface water volume and pressure significantly increases, and correspondingly reduces the frictional strength of the boulder clay and sand/gravel deposits. This can result in the weight of sections of the cliffs exceeding the sliding resistance of the soil along planes of weakness, leading to slope failure.

The continued flow of water out through the face of the failed slopes and the saturated and softened condition of the slipped boulder clay soils, confirms this failure mechanism.

The impact of sea erosion on the recently slipped slopes appears to be minimal. In general the sea action in storm conditions erodes the face of the slopes within the tidal range, leading to the creation of cliffs (steepened slopes) and ongoing slip failures (see Figure 13 below). These over-steepened slopes are unstable in the long-term, but remain steep due to the erosion mechanism which effectively removes ‘slices’ of cliffs over time.

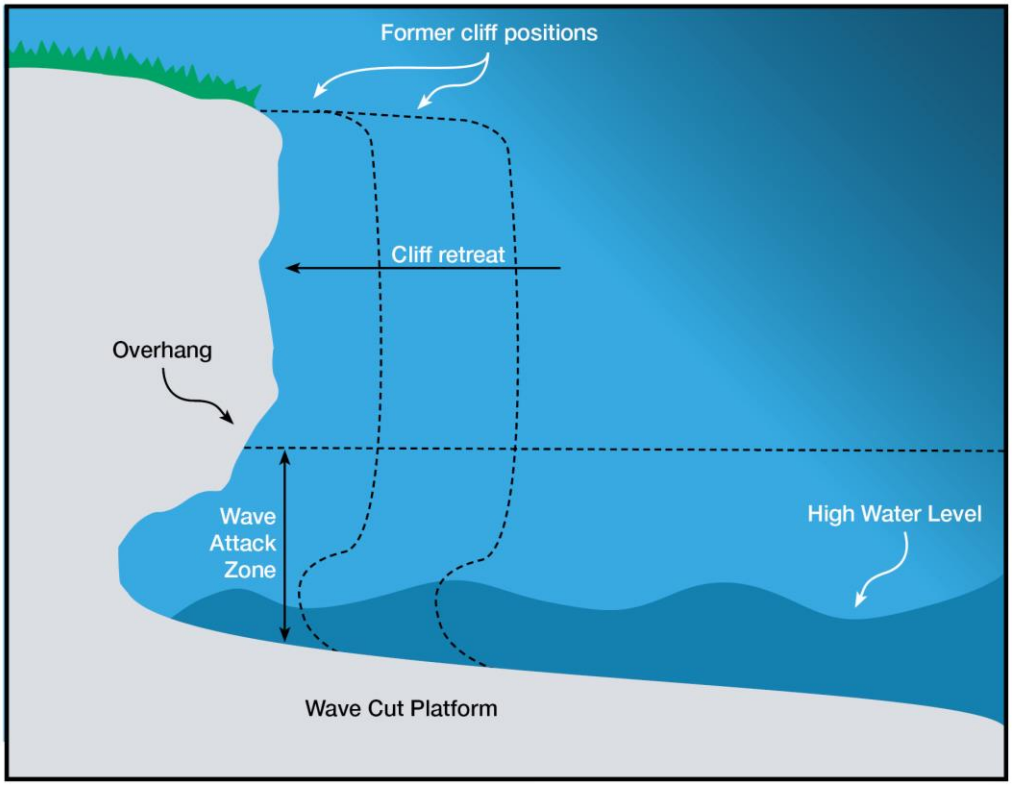


Figure 13: Typical steepened cliffs eroded by wave action

The photographs show that where tallest and steepest, the cliffs are predominately boulder clay soils with some minor local gravelly lenses. Where the recent slips have occurred there are significant deposits of sands. The presence of these sand deposits (lenses), and the 'flatter' or more circular slip surfaces observed, with significant flow of water through the face of the slips, clearly indicates failure due to infiltration of surface water (See Figure 14 and Figure 15 below). A circular geotechnical failure like that causes a larger retreat in the cliff than the 'slices' of cliff eroded by wave action.

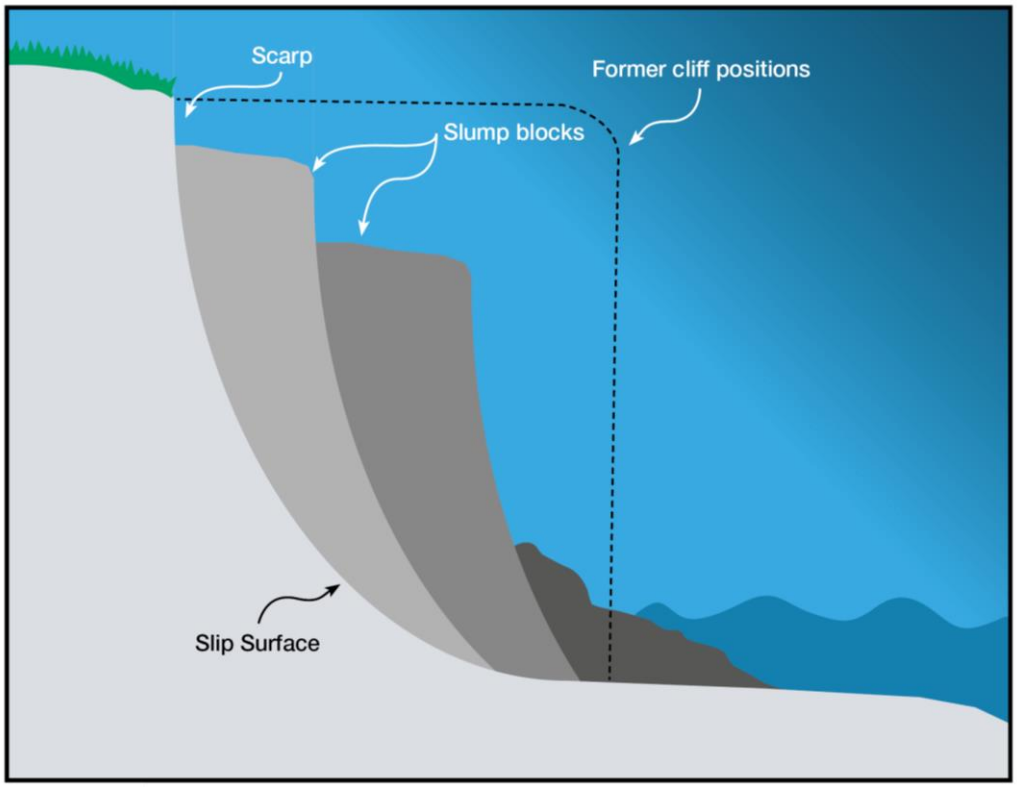


Figure 14: Typical slope failure showing circular slip surface

The evidence observed on site shows that the recent slope failures are due to the effects of the excessive rainfall over the month of December. While sea erosion is a contributing factor to erosion along this section of coast, the recent slips were triggered by water pressure and flow within the cliff material causing instability and slip failure.


Figure 15: Area of collapse showing flatter slope

4 Topographical survey assessment

4.1 Topographic survey 2016

In February 2016 a topographic survey of the site was undertaken by Laser Surveys. The survey extended from Paddy's Point in the north to a point approximately one kilometre to the south at Golden Rock.

The scope of the survey included:

- The sandy beach covering a vertical range from Mean Low Water Springs (MLWS) and Mean High Water Springs (MHWS);
- Area of the beach from MHWS including the cliff/ embankment/ higher land area behind the beach.
- Existing beach cliff/ embankment with levels from the north to the south of the survey area;
- The 0m contour
- Rock outcrops;
- Location and approximate extent of any collapsed sections of cliff;
- Cross-sections at ten specific locations showing accurately the top and toe of the cliff as well as the geometry of the slope of the cliff

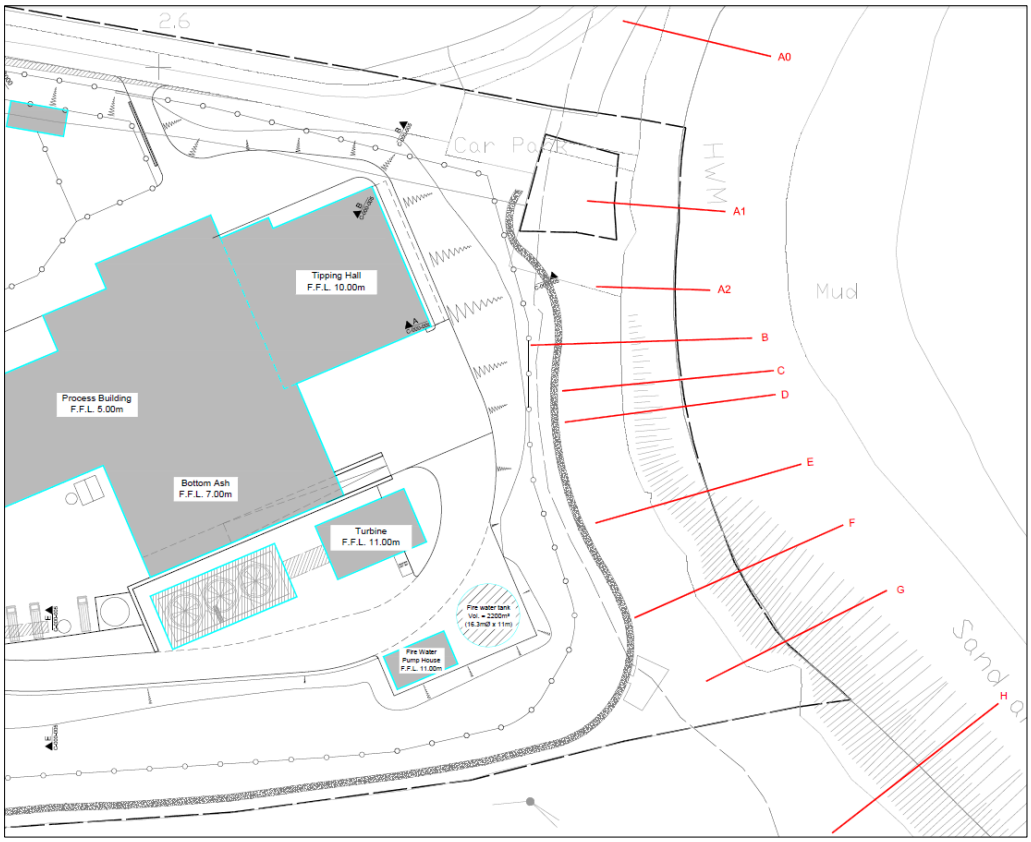


Figure 16: Specified sections for topographic survey

The survey was carried out during a period of spring tides in order to ensure maximum coverage. The survey was undertaken using a Trimble Precise Robotic Total Station and Trimble GPS, which enabled the surveyor to develop a detailed surface model of the surveyed area using laser scan data. In particular, this provided more detailed survey information in relation to the cliff face in comparison with previous surveys i.e. 2008, 2010 and 2014. For example, in previous surveys where only GPS was used, levels were only recorded at the top and bottom of the cliffs. In the 2016 survey the laser scan data provides a detailed profile of the cliff face.

If similar surveying methods are used in the future, i.e. more detailed survey information user laser scanning, it will be possible to analyse the movement of beach material within the study area based on a comparison of beach volumes. This would likely form part of any future beach monitoring programme and would inform when and where additional sacrificial material would be required.

The following final deliverables were provided by Laser Surveys:

- All recorded survey data and interpolated contour lines in AutoCAD format referenced to both OD Malin and Chart Datum.
- Cross-sections at specified locations showing accurately the top, toe and geometry of the slope of the cliff, in AutoCAD format to both OD Malin and Chart Datum.
- A brief technical report detailing survey method, benchmarks and estimation of volume of beach material

4.2 Comparison of surveys

Periodic topographic surveys have been carried out in the area in 2008, 2010 and 2014. In order to assess whether this recent event is in keeping with previous erosion estimates it is necessary to compare previous surveys with the most recent topographic survey.

Figure 17 shows sections A1 to G as well as the top and bottom of the cliff as derived from the 2008 and 2016 surveys. This figure shows the approximate locations of the two slope failures mentioned previously. The smaller slope failure located south of the car park is located roughly between sections B and D and the larger slope failure is located roughly between sections F and G.

From Figure 17 it can be seen that the bottom of the cliff line has remained relatively stable in comparison with the top of the cliff line. At the location of the larger slope failure in the south, the bottom of the cliff line has actually advanced since 2008. This is likely due to the presence of the slumped material from the upper cliff. The relative stability of the bottom of the cliff indicates that the toe of the cliff has not been affected to a large degree in recent years by erosion due to wave action.

Refer to Appendix B for detailed plan and section drawings showing comparisons between the various surveys.

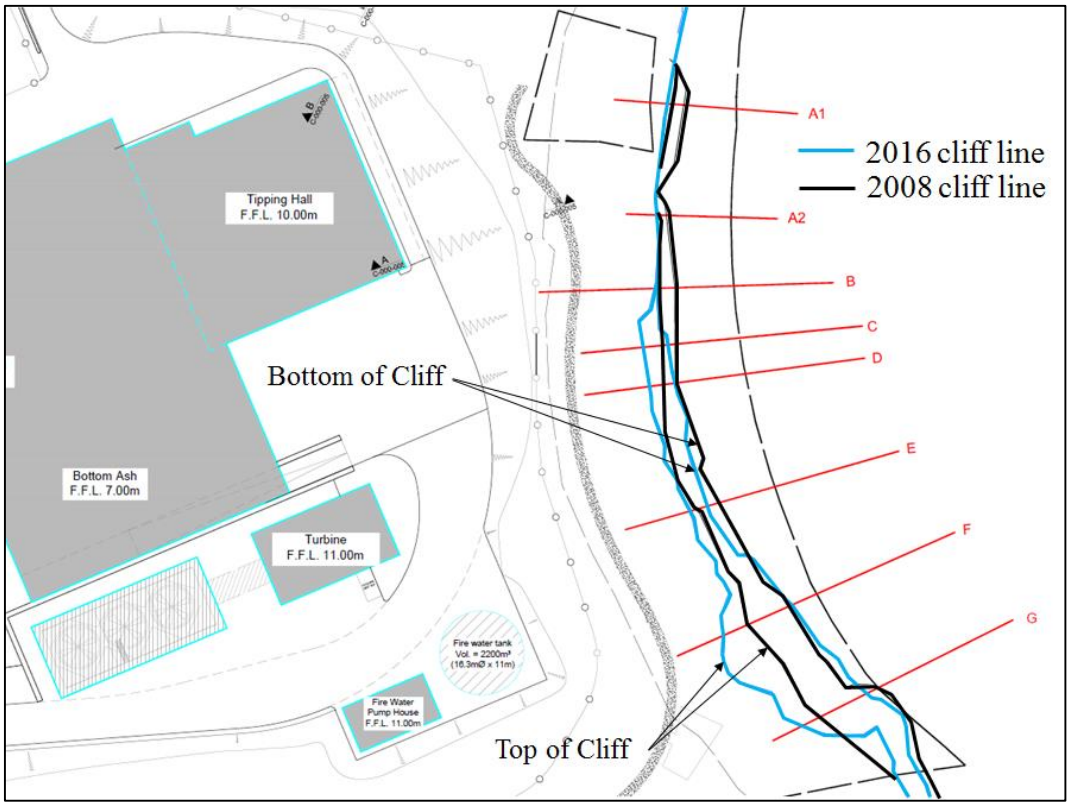


Figure 17: Sections A1 to G showing top and bottom (toe) of the cliff from 2008 and 2016 surveys

When comparing the topographic surveys from 2008 to 2016 it becomes obvious that the location of the largest slope failure was between sections F and G with a smaller collapse located between sections B and D. Figure 18 below shows an extract from the section drawings for sections F and G. The largest retreat of the top of the cliff between the 2008 and 2016 surveys was localised between sections F and G, with a value in the range of 7-9m.

From analysis of the sections in Figure 18 the following conclusions can be made:

- The upper section of the cliff has slipped with the debris accumulating at the toe of the cliffs
- Between 2008 and 2014 there has been little erosion in this area
- The toe of the cliff has remained stable i.e. has not been eroded significantly
- Beach levels have remained stable in recent years indicating that the foreshore/ beach has not been eroded during recent events

At the localised slope failures the fact that the toe of the cliffs and the foreshore/ beach levels have been largely unchanged between 2008 and 2016 would indicate that erosion by wave action has not been a significant issue recently. This confirms the findings of the site walkover i.e. while sea erosion is a contributing factor to erosion along this section of coast, the recent erosion events were due to water pressure and flow within the cliff material causing instability and slip failure rather than erosion due to wave action alone.

The effects of the recent erosion event on estimation of erosion rates for the area will be discussed in Section 5.

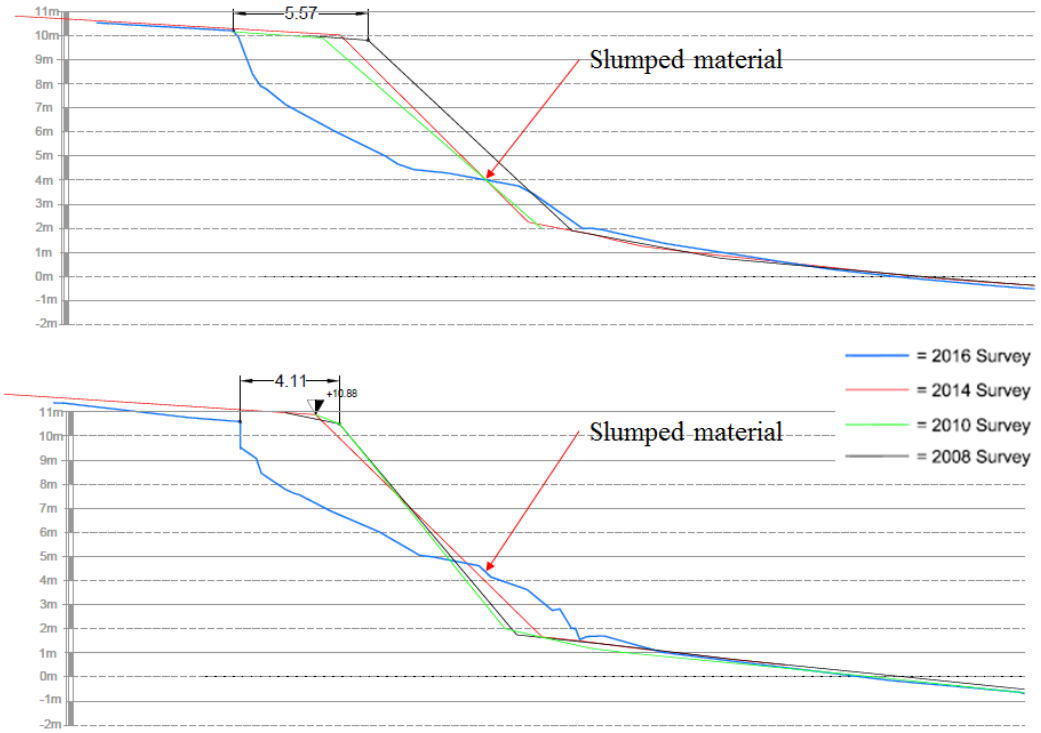


Figure 18: Sections F and G showing survey information from 2008 to 2016

Note that the previous surveys (2008 to 2014) show a straight line from the top of cliff to the toe due to the fact that survey data was only gathered at the top and toe of the cliff i.e. these lines do not accurately represent the profile of the cliffs in those years.

5 Erosion assessment

5.1 Methodology

This section addresses how the recent cliff collapses affect the previous estimate of erosion rate for the area of coast adjacent to the proposed development site. The topographic surveys were compared in order to derive the measured retreat over the full monitoring period, i.e. 2008 to 2016, at eight specific locations (A1 to G). These measurements were then used to estimate an erosion rate for the site. The measured retreat for the periods between topographic surveys can be found in Table 1. As in previous assessments, results for sections A1 and A2 are excluded because no significant retreat was historically recorded at these locations and accretion takes place in some years..

As mentioned in the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), the period of available reliable data is too short to be conclusive about the erosion trend in the area. This is due to the fact that erosion appears to be related to the more energetic or episodic wave storm events rather than being a constant process. This has been confirmed by recent erosion events. The previous coastal study therefore takes a conservative approach in establishing the erosion rate.

5.2 Data from March 2016 survey added

The table below shows the measured retreat in sections B-G at the top of the cliff/embankment.

Table 1: Measured retreat rate based on topographic surveys and inferred erosion rates

Sections	Retreat (m)					
	2008-2010	Retreat per year 2008-2010	2008-2014	Retreat per year 2008-2014	2008-2016	Retreat per year 2008-2016
B	0.91	0.46	0.91	0.15	1.20	0.15
C	0.90	0.45	1.73	0.29	3.69	0.46
D	1.14	0.57	1.82	0.30	2.67	0.33
E	1.36	0.68	1.81	0.30	1.34	0.17
F	1.10	0.55	1.10	0.18	5.57	0.70
G	1.00	0.50	1.98	0.33	4.11	0.51
Average	1.07	0.53	1.56	0.26	3.10	0.39

From the table, it is evident that the greatest retreat recorded by the most recent topographic survey has occurred between sections F and G where a localised geotechnical slide can clearly be seen, while there has also been significant erosion at sections C and D.

It can be observed that erosion rates inferred are below the maximum estimated retreat of 0.5m per year, except in the area where the localised geotechnical slide has occurred. However, the average erosion rate along the length of the study area which was effected by the recent slope failures (sections B to G) over the eight year period is 0.39m per year which is well below the previously predicted maximum erosion retreat of 0.5m per year.

This estimate is conservative for a number of reasons as follows;

- Sections A1 and A2 have not been included; if they were included in the estimate the average rate would reduce to approximately 0.30m per year
- This method of estimation does not take account of the stability of the toe of the cliffs and the beach/ foreshore levels; if beach and toe levels remain stable there will be no increase in nearshore wave conditions and hence no increase in erosion due to wave action
- The presence of local rock outcrops (visible and underlying) have not been included in this estimation; their presence will limit erosion of beach levels and hence limit the potential increase in nearshore wave heights and associated increase in erosion due to wave action
- Change in erosion patterns and potential accretion is not considered
- Erosion rates are based on analysis of the top of the cliff line only where the effects of erosion will be the most pronounced i.e. due to the pattern of erosion in the area the most significant retreat will occur at the top of the cliff rather than the bottom.

This conservative approach together with the allowances made in the wave and erosion modelling means that there is an adequate allowance for any changes that may occur due to climate change.

5.3 Impact on the predicted maximum retreat rate

The erosion rates appear to be consistent with the maximum retreat of 0.5m/ year based on historical evidence. A localised geotechnical failure has been identified following an extreme rainfall event. This geotechnical slide is not solely due to coastal processes and as outlined in section 3.2, the large slope failure has been mainly caused by geotechnical instability that caused larger circular slips rather than the notching at the toe of the cliff caused by normal coastal erosion. The geotechnical failure mechanism takes ‘bigger steps’ than the normal ‘notch, steepen and slump’ mechanism.

Sudden localised failures are not representative of an erosion rate for the coastal stretch as they result following extreme and infrequent events and are of limited extent.

The likelihood of another slope instability caused by water infiltration into sand lenses will actually be reduced by the proposed development due to the provision of on-site surface water drainage and the resulting reduction in infiltration of surface water in the area surrounding the site.

Taking into account the retreat recorded between 2008 to 2010 and 2008 to 2014 the most recent event is evidently an episodic and localised event i.e. a large amount of erosion has occurred over a short period of time.

Due to the episodic nature of the events, any erosion estimate needs to take into account retreat along the whole length of the study area as opposed to a localised location where the highest rate of erosion is recorded.

This study confirms that the maximum erosion rate estimate derived in the previous coastal study carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), remains at 0.5m per year. Again this is a conservative estimate for a number of reasons as mentioned.

While the estimated rate of 0.5m per year may be exceeded at a localised point in any given year it is unlikely that the maximum erosion rate over the length of the study area for the full monitoring period will exceed this estimate.

As described in the previous coastal study which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*), applying this predicted rate of erosion, and with no mitigation in place, gives an expected maximum retreat of 50m in 100 years' time, 15m in 30 years' time and 20m in 40 years' time.

Using this approach it is observed that a retreat of 50 m in 100 years would encroach beyond the security fence of the proposed development. The study found that there would be no impact on the proposed development after 30 years. The study found that there could be a risk of an impact on a small section of the proposed development after 40 years however this would be confined only to the amenity walkway and a small section of a diverted gas pipeline outside of the security fence line. The Resource Recovery Centre section of the proposed development will not be impacted by coastal erosion for the entire duration of the planning permission.

The placement of the proposed sacrificial material at the toe of the cliffs will help to dissipate the wave energy at the site and protect the toe and lower area of the cliffs from direct wave action and hence reduce the rate of erosion. This additional proactive measure will provide confidence that the estimated maximum rate of erosion (0.5m per year) is not exceeded while the sacrificial material is present.

With the application of the sacrificial material, there will continue to be no impact on the entire proposed development after 30 years. With the application of the sacrificial material, the diverted gas pipeline will not be impacted after 40 years. However, there is still a risk of an impact on the amenity walkway after 40 years. The waste-to-energy section of the proposed development will not be impacted by coastal erosion for the entire duration of the planning permission.

It is worth noting that the L2545 road to Haulbowline will be impacted in less than 30 years even with the application of sacrificial material. Therefore the road will be effected by erosion before any element of the proposed development.

6 Conclusions and recommendations

6.1 Conclusions

Following significant rainfall events in December 2015 and January 2016 a number of localised slope failures occurred adjacent to the proposed Indaver development site at Ringaskiddy. The slope failures were located south of the car park off the L2545 road and formed a small failure approximately 50m south of the car park and a larger failure approximately a further 20m south.

Arup carried out a site walkover with a team of experts from different disciplines following these events. Arup inspected the coast adjacent to the proposed development including the localised slope failures. The conclusions drawn from the site walkover were as follows:

- Surface water is being transmitted through the cliff face where granular deposits are present in the boulder clay leading to softening of the surrounding boulder clays, and erosion of the sands and gravels from the face of the cliffs (as witnessed by pock-marks and erosional features across the cliff face)
- Excessive rainfall has caused infiltrated surface water volume and pressure to increase and correspondingly reduces the frictional strength of the boulder clay and sand/gravel deposits resulting in slope failure
- The continued flow of water out through the face of the failed slopes and the saturated and softened condition of the slipped boulder clay soils, confirms this failure mechanism
- The ‘flatter’ or circular failure mechanism indicates that the slope failure is due to infiltration of surface water rather than by wave action

Laser Surveys carried out a topographic survey of the beach area adjacent to the proposed development and the surrounding area and the results were used to further assess the recent erosion events. The survey showed two clear areas where slope failures had occurred. From the comparison of all available topographic surveys and in particular in relation to the worst effected sections of the cliff (sections F and G) the following conclusions were derived:

- The upper section of the cliff had slipped and slumped at the toe of the cliffs
- Between 2008 and 2015 there had been little erosion in this area (refer to section 2)
- The toe of the cliff had remained stable i.e. has not been eroded significantly
- Beach levels have remained stable in recent years indicating that the foreshore/ beach has not been eroded during recent events

These conclusions indicate that the recent localised slope failures were not due to coastal erosion by wave action alone. While sea erosion is a contributing factor to erosion along this section of coast, the recent slips were due to water pressure and flow within the cliff material causing instability and slip failure.

An estimation of erosion rates for the study area was undertaken based on recorded retreat over the entire period of eight years (2008 to 2016). This analysis showed that a conservative estimate of the recorded erosion rate is 0.39m per year for the sections experiencing erosion and 0.30m per year for the whole study area. This is below the maximum retreat rate of 0.5m per year given in the Coastal Erosion study, which was carried out by Arup in 2015 (Refer to Appendix 13.3 *Coastal Study 2015 by Arup* of *Ringaskiddy Resource Recovery EIS 2016*).

The Resource Recovery Centre in the proposed development has been located far enough away from the edge of the cliff to ensure that the waste to energy facility will not be impacted by the predicted retreat rates over the design life of the development.

6.2 Recommendations

Based on the conclusions of this study Arup recommend the following:

- An erosion rate of 0.5m per year is adopted for the coast adjacent to the proposed development in keeping with the rate recommended in the Coastal erosion report
- The study area is continually monitored as part of a the beach monitoring plan as recommended in the Coastal Erosion report

Appendix A

Site walkover photographs

A1



Figure 1: Slope failure at Gobby Beach facing south



Figure 2: Smaller slope failure to the north of the site approx. 50m south of car park



Figure 3: Saturated slumped material at smaller slope failure



Figure 4: Saturated slumped material at smaller slope failure



Figure 5: Larger slope failure approx. 20m to the south



Figure 6: Sand lenses surrounded by clays and gravels in slope face



Figure 7: Larger slope failure showing water running through the slope



Figure 8: Larger slope failure showing water running through the slope



Figure 9: Slumped and saturated material and vegetation at the southern extent of the larger slope failure



Figure 10: Slope face further south from large slope failure showing boulder clay and further slope failure



Figure 11: Minor notching due to wave action south of the larger slope failure



Figure 12: Slope failure further south from larger slope failure



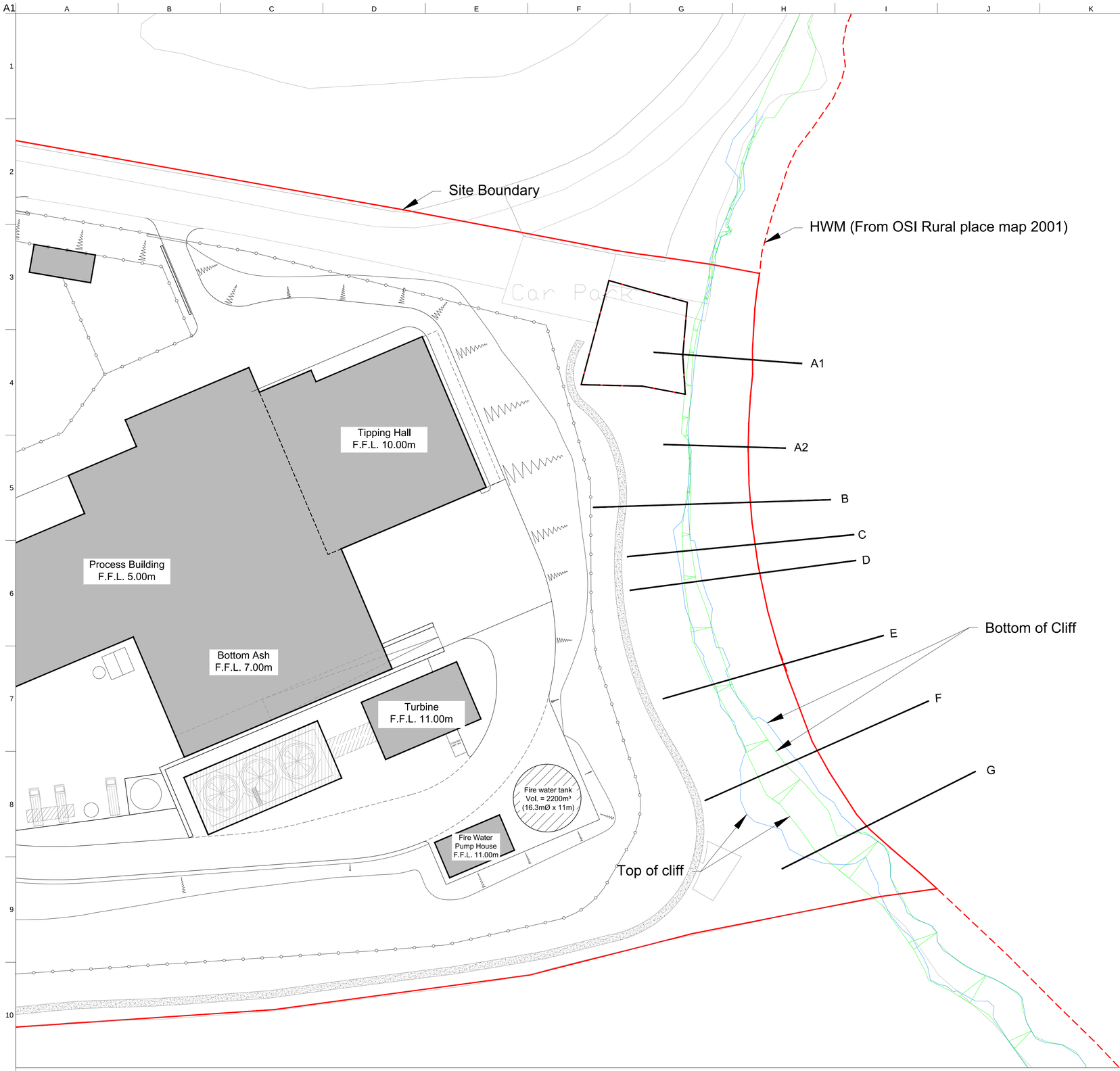
Figure 13: Beach adjacent to Indaver site boundary showing good beach levels



Figure 14: Gobby beach looking north from the top of the slope

Appendix B

Survey comparison drawings



NORTH.

Notes:

1. Information shown on this drawing is to be considered indicative only.
2. All dimensions are shown in metres unless noted otherwise.
3. All levels are shown in metres above ordnance datum.
4. All levels shown are based on most recent Bathymetric and Topographical Survey.
5. Material type and dimensions are assumed based on visual inspection and site investigation works.

Legend:

- Site boundary
- High water mark
- Top/ bottom of cliff 2014
- Top/ bottom of cliff 2016

Issue	Date	By	Chkd	Appd
I01	31/03/2016	JR	SL	SL
Issued for Information				

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Client: INDAVER

Job Title: Ringaskiddy Resource Recovery Centre

Coastal Study
Comparative Plan

Scale at A1: 1:500
Discipline: Civil
Job No: 238129-00
Drawing Status: For Information
Drawing No: C-000-064
Issue: I01

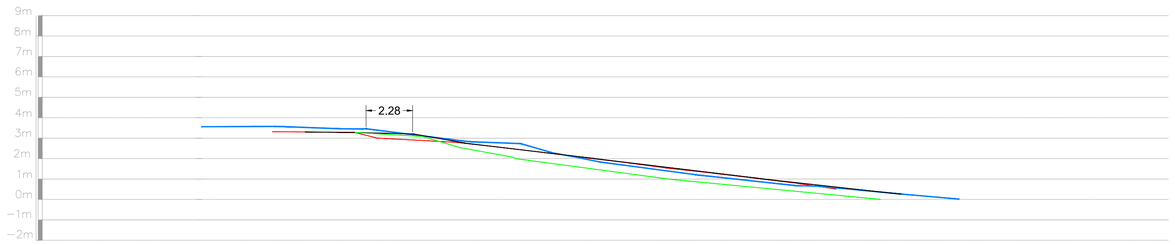
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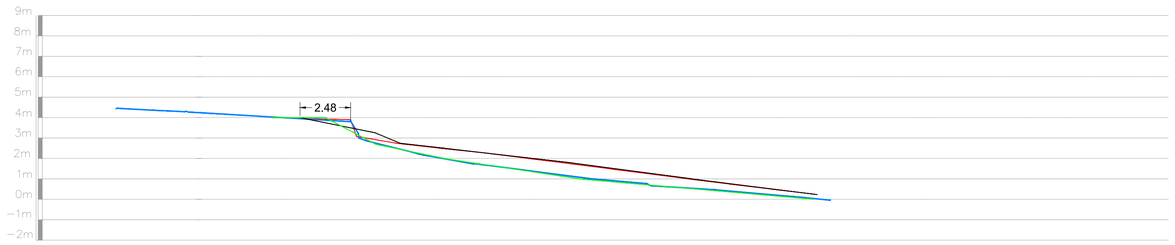
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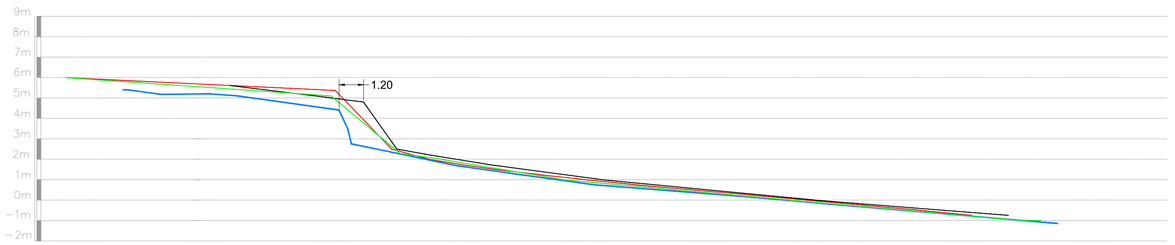
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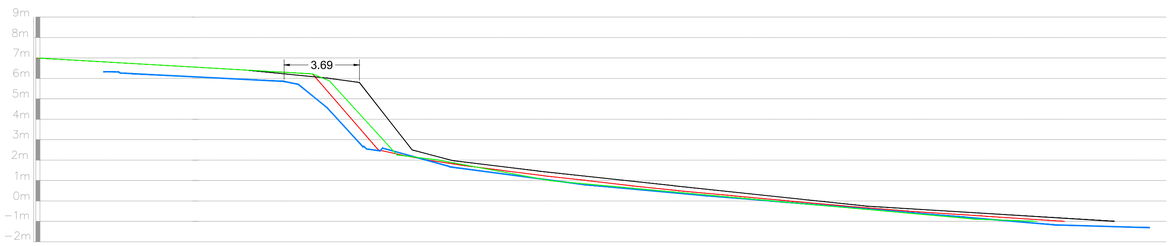
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B



C



Notes:

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5. Material type and dimensions are assumed based on visual inspection and site investigation works.

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Coastal Study
Comparative Sections

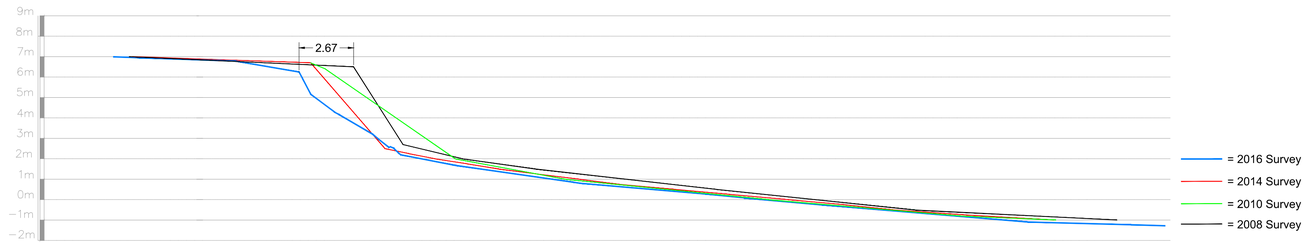
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Job No: 238129-00
Drawing Status: For Information
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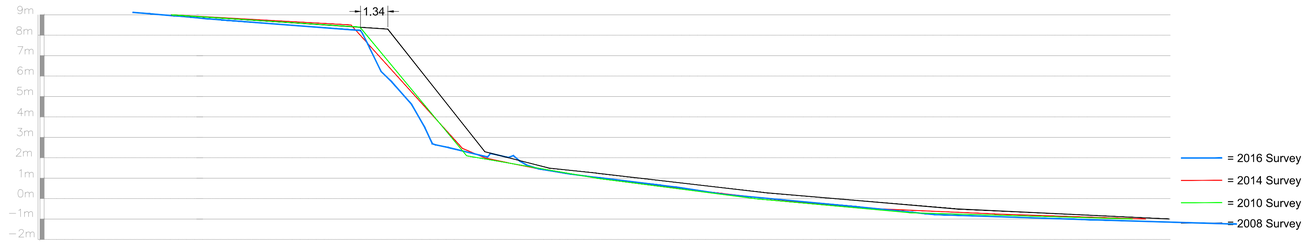
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A1

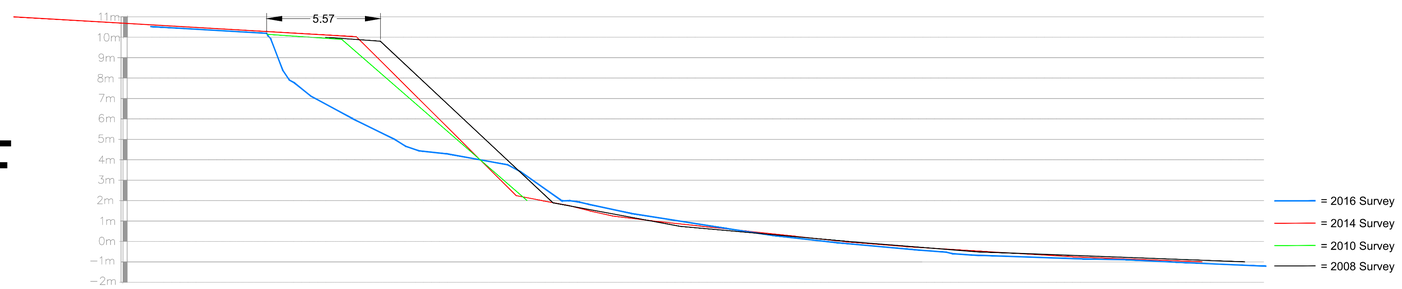
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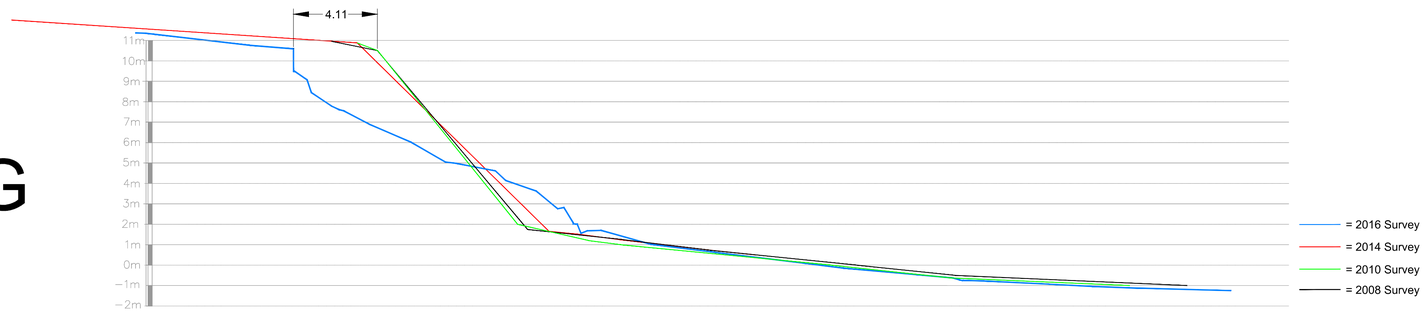
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F



G



Notes:

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Issue: I01

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