HOW DOES COASTAL MANAGEMENT IMPACT CLIFF RECESSION IN THE SWANAGE BAY?

Word Count: 5694

Contents:

How do Coastal Management Strategies affect Cliff recession in the Swanage Bay?

1.0 Introduction:

For my investigation, I will be focusing on the Swanage Bay and answering my enquiry question of: ***'How do Coastal management strategies affect Cliff recession in the Swanage Bay?'*** I will be studying how the cliffs change in the bay and I will be focusing on the area to the North of the pier in Swanage, otherwise known as 'Banjo Pier'. I will be considering how the cliffs characteristics have changed, as well as measuring the beach widths and heights at different areas along the coast, to see what impacts the coastal management strategies have on the coast.

1.1 Hypothesis:

- **The coastal defences have been successful at reducing cliff recession in Swanage Bay.**

1.2 Key Questions:

- **How have the cliffs changed along the bay?**
- **What are the subaerial impacts on the cliffs?**
- **Why have the Coastal Management strategies been in some parts of the bay but not others?**
- **How is cliff erosion being managed and are the strategies successful?**

1.3 Location

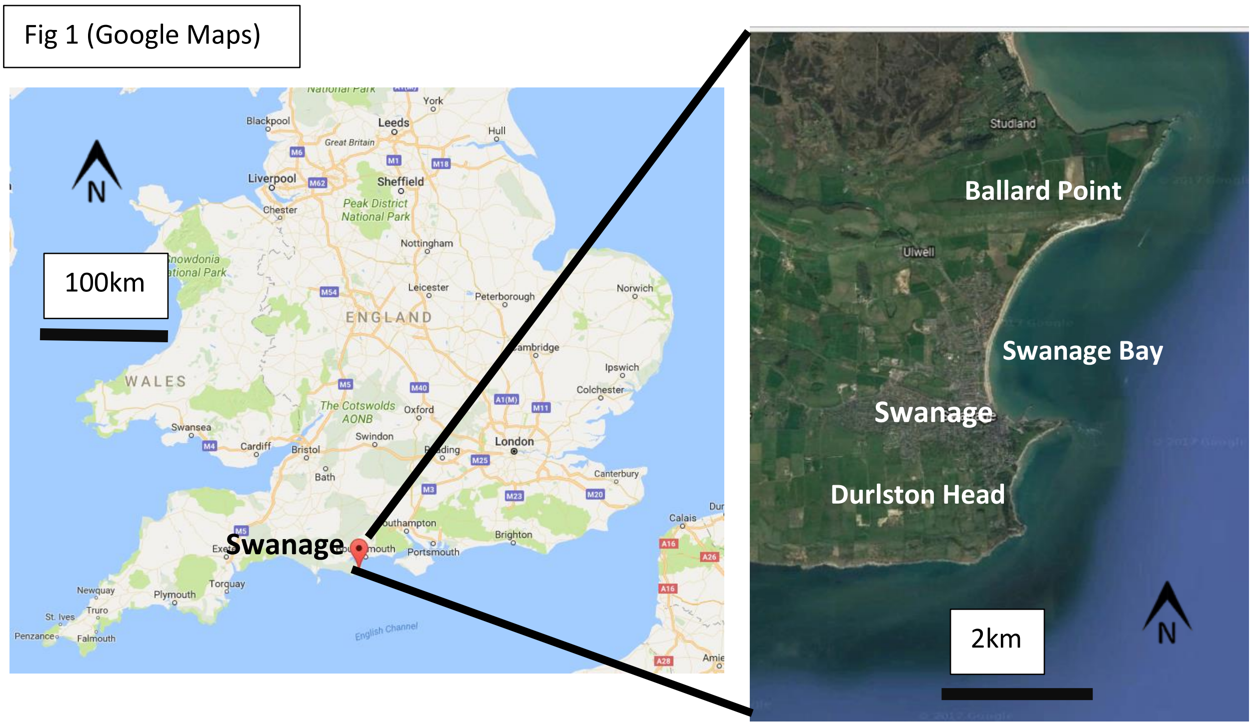
Where is the Swanage Bay?

Swanage is a small coastal town, located along the South Coast in the South East of Dorset, as can be seen from fig 1. It has a population of 9,601 and is near the large town of Bournemouth.

What are the physical characteristics of the Swanage Bay?

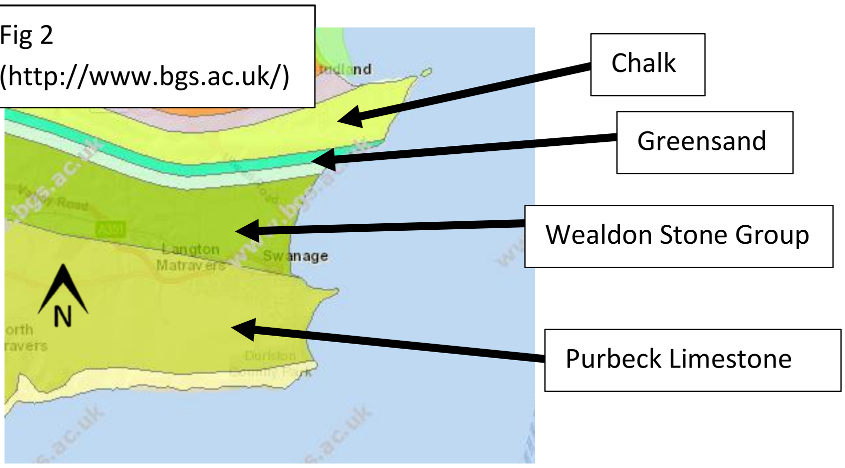
The Swanage Bay is situated on a section of discordant coastline, which means there are variations in rock type (see fig 2). As we can see, there are four main types of rock: Chalk, Wealden Stone and Purbeck Limestone. Purbeck limestone (at Durlston Head) is the hardest rock and very resistant to

Fig 1 (Google Maps)



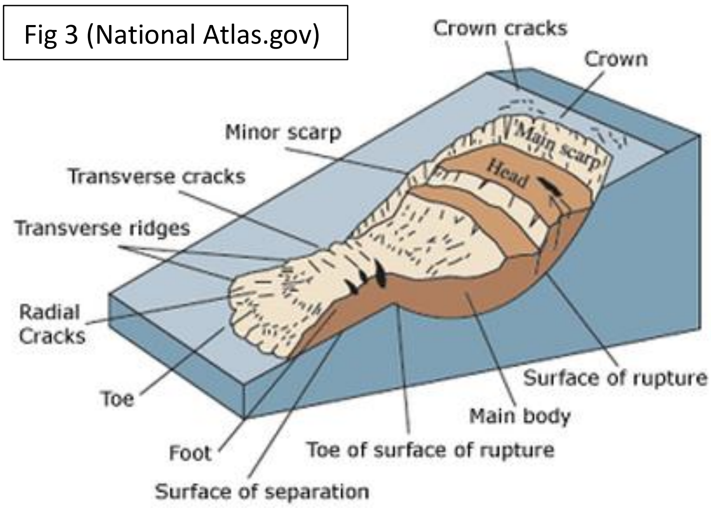
erosion, whilst the Wealden stone group (in Swanage Bay) is soft and highly susceptible to erosion. The Chalk (at Ballard Point) is a hard rock but is easier to erode than the limestone, as it is more vulnerable to weathering processes. Greensand (found between the chalk and Wealdon stone) is relatively resistant but still vulnerable to erosion. The varying strengths in rock resistance mean that the cliffs are going to be stronger or weaker in certain parts of the bay.

Fig 2 (http://www.bgs.ac.uk/)



Depending on the geology, subaerial processes can have an impact on the cliff erosion. Limestone and chalk are subject to chemical erosion they both are made up of calcium carbonate which reacts with carbonic acid (present in rain). This weakens the rock and can cause cliff collapse. Mechanical and biological weathering are also key parts in weakening the cliff and causing cliff collapse as the freeze-thaw cause chunks of rock to break off as water in cracks freezes and expands, whilst plant roots will often widen gaps in the rocks as they grow. Although the plants may weaken the chalk and limestone cliffs, they tend to strengthen the soft rock cliffs as they provide more structure and support with their roots. However, the soft Wealdon stone is very exposed to mass movement. This can be caused by marine action and the weather when it is rainy and wet. The sea can undercut the cliffs, which results in them slumping as they don't have enough support

Fig 3 (National Atlas.gov)

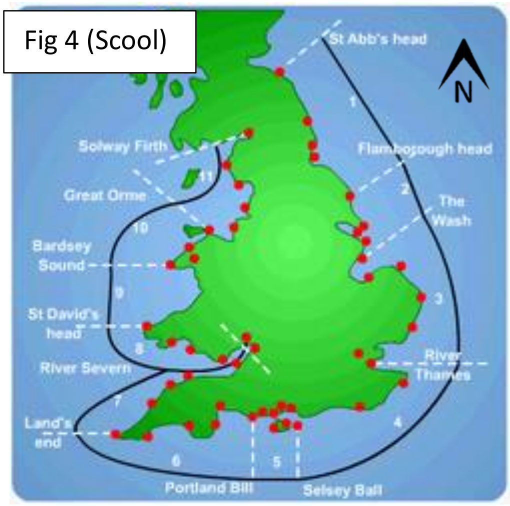


beneath. The structure of the rock can also affect the stability of a cliff as horizontally bedded rock tends to be more stable than vertically bedded rock. The chalk at Ballard Point is horizontally bedded making it even steadier whilst the Wealdon stone is easy to erode and subject to mass movement. The Wealdon stone often slumps as the material isn't strong and will be easily affected by wet weather. Gravity will also drag the material down. This can be seen in figure 3.

The weather of Swanage has had a significant impact on cliff recession and slumping recently, with the storms it has received in the past. In 2016, Storm Angus hit the town and damaged the sea wall as parts of it were strewn across the esplanade. According to the BBC parts of the A35 and local roads were flooded. This would have been due to the copious amounts of rainfall, which results in the sea having a more powerful swell (more erosive) and leaves the cliffs all saturated with water meaning that they are likely to slump.

1.4 Theory:

Fig 4 (Scool)



Swanage is found in sediment cell 5 (see fig 4). This cell is subdivided into many smaller sections. Figure 5 shows us the sediment transport in the Swanage Bay. As we can see from this diagram, Swanage gets a lot of it as sediment from cliff erosion and longshore drift. The general direction of longshore drift is going north. This is useful as it shows where the sediment normally goes when there aren't coastal management strategies in place. This information is highly important for me to answer my question as it shows what the general movement of sediment in the bay and why some areas are receding quicker than others.

There are three SMP's (shoreline management plans) in place in Swanage (fig 6). These are: No active intervention, hold the line with groynes and beach recharge and do minimum to hold the line. At point A, we can see that no active intervention is the strategy in place. This means there are defences for that part of the bay as either the land is not deemed valuable enough or it is deliberate with the chalk cliffs being a hotspot for fossils as they attract certain tourists. As result of there being no protection there is approximately 0.3m eroded per year. At point B, the SMP is hold the line, which means there are defences in place to prevent erosion such as a sea wall, groynes, and beach nourishment. The sea wall is concrete and is a physical barrier to erosion. The groynes (wooden) on the other hand, prevent longshore drift from happening, which causes there to be sediment build up and a larger beach which can absorb most of the seas energy, however it leaves other areas along the coast deprived of sediment. The beach nourishment is not a visible structure like the others, but is there to replenish the beach with sediment, creating more beach for tourism, whist having the effect of protection from erosion. The groynes and beach replenishment was last done in 2005 and cost £2.2 million. This management plan is used to protect this area due to its high land value. If there wasn't protection here, the beach could have been retreating by 0.6m per year and the local income would be affected drastically. At point C, the strategy in place is to do a minimum to hold the line. This is because although the land value is high, it is not vulnerable from the sea as it is sheltered by Durlston Head as seen in fig 1. The main defence that that part of the bay has is its sea wall. This can also be seen from fig 6, with it saying that without the minimum defence it would recede by only 0.2m per year. As we can see from these SMP's, there use is all down to the land value of the area and what they are protecting, with assessments and cost analysis all taken into consideration.

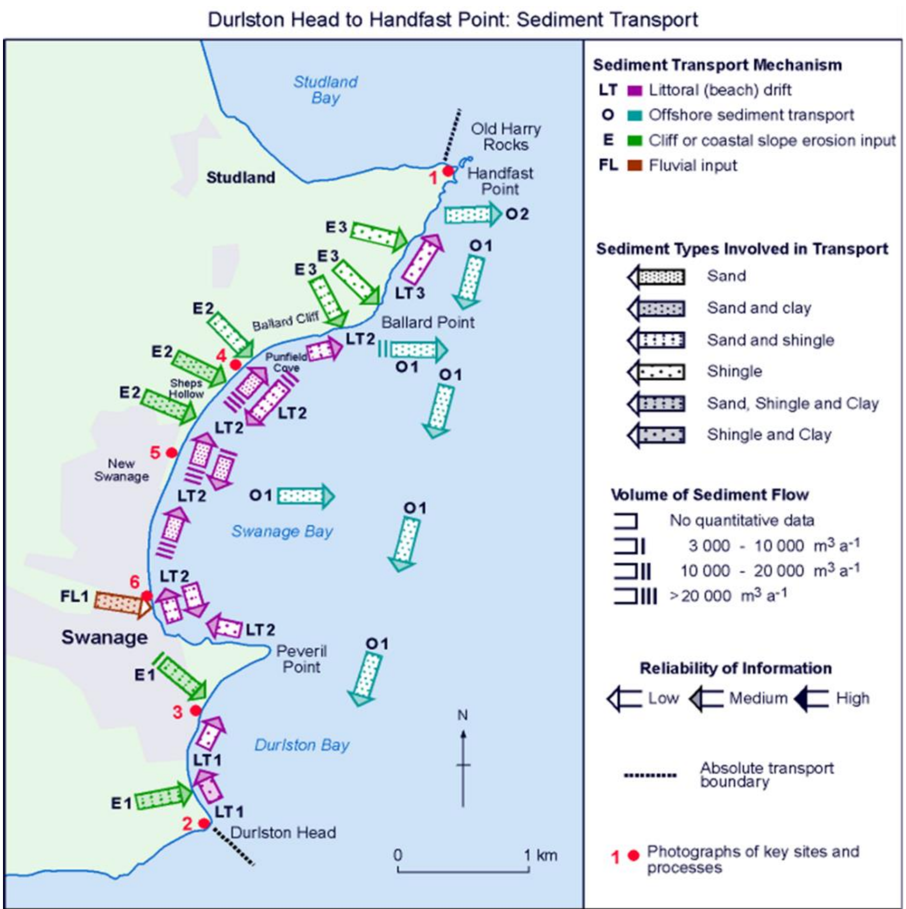
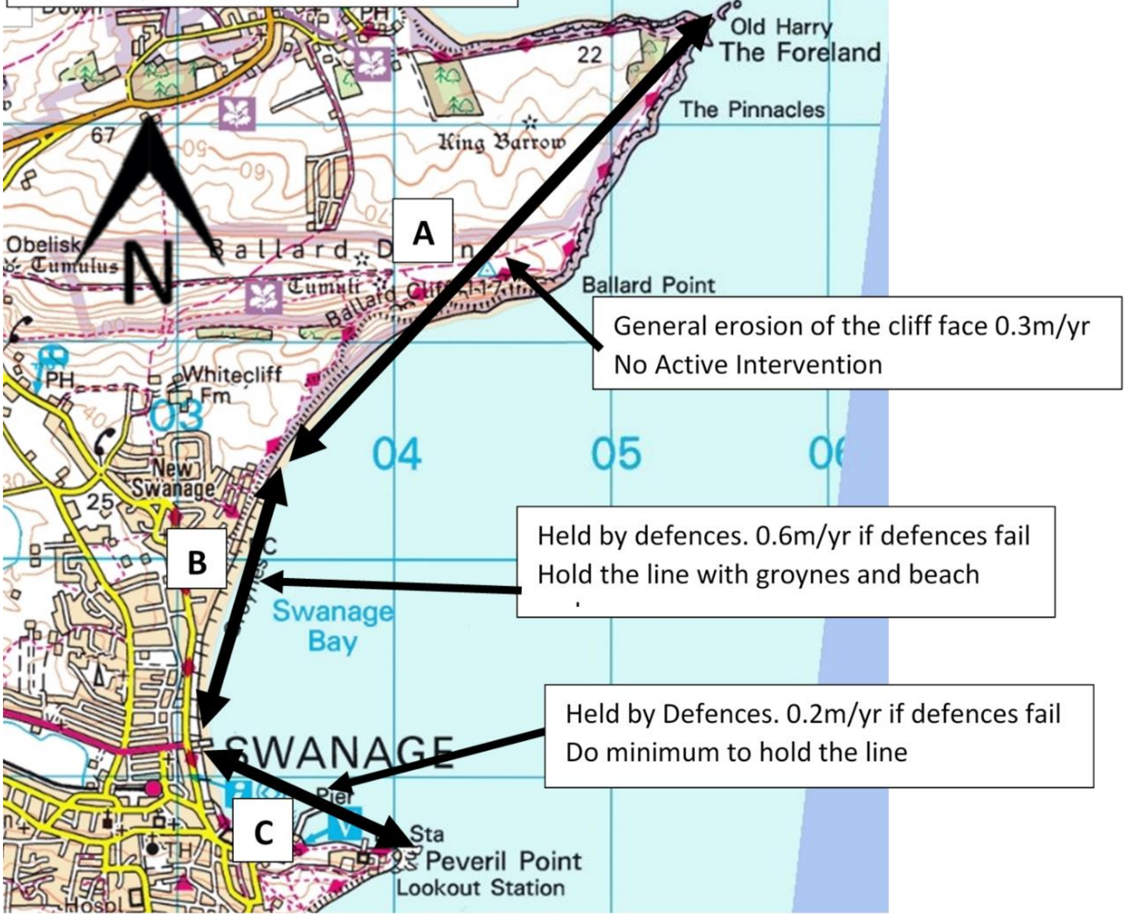


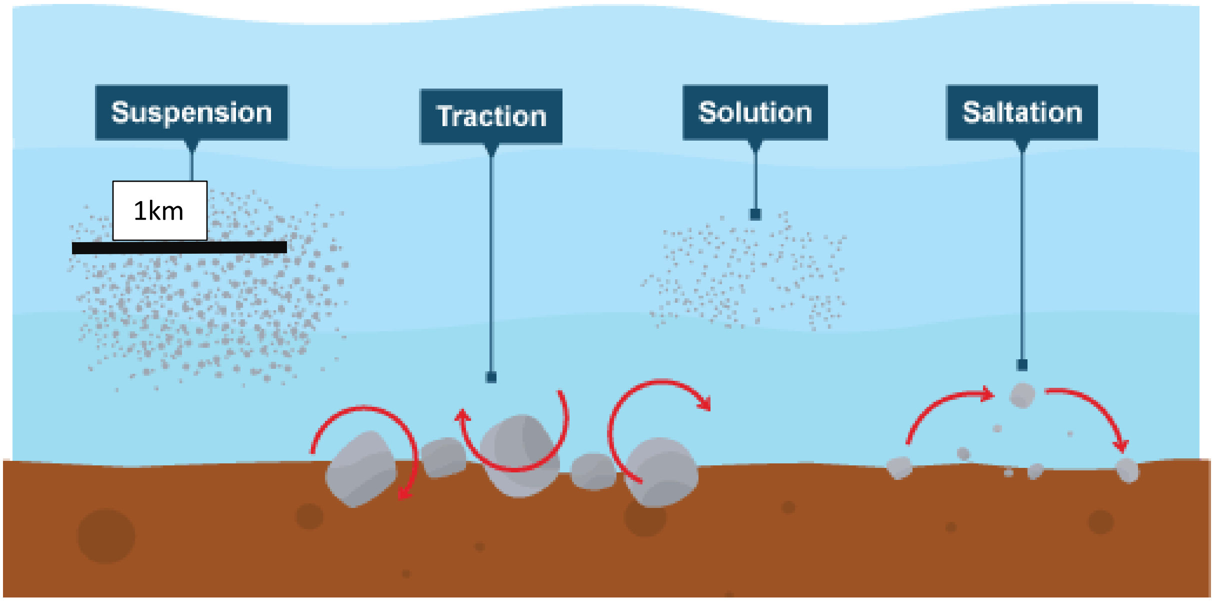
Fig 5 (http://www.scopac.org.uk/scopac_sedimentdb/swan/index.htm)

Fig 6 (Bing Maps) & (Leeson House FFC)



Longshore drift is the movement of material along a shoreline at an angle. It is a key part of my enquiry to answer my question of *'How does coastal management strategies impact cliff recession in the*

Fig 7 (http://www.bbc.co.uk/staticarchive/3dd94aeb36707b509ca7dd1f641a43a0180c82e5.png)



Swanage Bay?' with the idea that the coastal defences are starving the northern part of the bay from material. However, we need to first look at how the material is transported.

There are four ways of sediment transportation and these are: traction (when the larger material is rolled along the sea floor), saltation (where small material is picked up by water and deposited further along the direction of flow), suspension (when the fine, light material is carried in the water) and solution (when minerals have been dissolved and carried by the water). These processes can all be seen in the diagram in figure 7. The groynes stop this processes from happening.

LiDAR data shows us the differences in the coastal landscape in different years. This makes it very useful as we can see the differences that the coastal defences have had on the bay since they have been revamped.

2.0 Methodology:

2.1 Methodology Table:

Methodology Table					
Hypothesis: *'The coastal defences have been successful at reducing cliff recession in Swanage Bay.'*					
Date: *'19/06/2017 – 23/06/2017'*					
Data Collection	**Equipment (pg. 15)**	**Method**	**Justification**	**Limitations**	**Risk Assessment**
Cliff Instability Susceptibility Assessment (CISA) – This is a numbered test where you scale the section your looking at from 1-5 with 1 being the worst. This data was collected during the daytime, at the beginning of summer. This is data.	For this method, I didn't need any equipment apart from, a pen and a piece of paper to record my results on.	For this test, measurements taken at every single one of the 18 groynes. For the measurements beyond the groynes (north of them), five further tests were completed. These were spread roughly 200m apart (see fig 9). I would look at fig 8, and use my own observations to record my results. It is important to make sure it was the same person taking the results to ensure it was a fair test. The sections marked with an arrow on fig 8 are where the data was recorded. The assessment works by grading the section from 1-5 and if it met a certain requirement, I would then put that number down and move onto my next point.	This data will help assess how the cliffs have changed from where there are coastal defences and where there aren't any. It will also allow me to answer my key questions of: 'How have the cliffs changed along the bay?', 'What are the subaerial impacts on the cliffs?', 'Why have the Coastal Management strategies been in some parts of the bay but not others?' and 'How is cliff erosion being managed and are the strategies successful?'. This data will hopefully provide me with a good overview about the cliffs in the Swanage Bay.	There were limitations as some of the tests that the assessment requires were unable to be completed due to either safety reasons or lack of equipment to record the data. For example, in fig 8, we can see that I was not able to do effective fetch as it was not possible for me to measure the fetch.	For this test, as there wasn't any equipment required it meant there were no hazards regarding that, however I did have to keep a safe distance away from cliffs as they were unstable in some areas, as well as proceeding with care and caution when getting over the groynes due to their height.

Methodology Table

Hypothesis: *'The coastal defences have been successful at reducing cliff recession in Swanage Bay.'*

Date: *'19/06/2017 – 23/06/2017'*

Data Collection	Equipment (pg. 15)	Method	Justification	Limitations	Risk Assessment
Beach Profile – This is a practical test which involved using equipment to measure the beach profile (its width and its change in gradient). Data was taken at the start of Summer, during the day.	For this test, we needed: a clinometer, 2 ranging poles, a tape measure and a pen and paper to record the results on.	We took measurements from all the groynes along the Swanage Bay and then three points beyond the groynes as marked on the map in fig 9. We started off by putting a ranging pole at the top (where the beach met the cliffs or seawall) and bottom (where the sea and the beach met) part of the beach from where we were taking our measurement from. Then at the points we use the tape measure to record the distance between two ranging poles and would then use the clinometer to measure the gradient of the slope. To use clinometer, we measured from one of the intersects of the red and white ranging pole to the same point on the other ranging pole. From this, we could see the change in slope and could record the angle that the clinometer gave us.	This data is going to help see how much the longshore drift has been affected by the coastal defences and give us a view on where there is more and less beach in the Swanage Bay. It will help me answer the key questions: 'How have the cliffs changed along the bay?', 'Why have the Coastal Management strategies been in some parts of the bay but not others?' and 'How is cliff erosion being managed and are the strategies successful?'.	The limitations for this test, were that the tide was different at every groyne due to separate times of the day as we were only there for a certain amount of time. There was also the constraints of tourists and locals being in the way as they were on the beach.	We had to be careful with the ranging poles as they have pointed ends which if handled incorrectly could harm someone. There is also the factor of when putting the ranging pole into the ground of being careful of not stabbing your foot or someone else's due to its pointed end. The tape measure also has a sharp metal part at the end of it to keep it fixed in place when in use, so that needed to be handled with care so that we didn't cut ourselves. We also had to be careful going over the groynes because of their height and the equipment. We would the equipment over the groyne first (safely on the floor) and then go over ourselves. We also had to be careful around unstable parts of the cliff beyond the groynes.

Methodology Table

Hypothesis: *'The coastal defences have been successful at reducing cliff recession in Swanage Bay.'*

Date: *'19/06/2017 – 23/06/2017'*

Data Collection	Equipment (pg. 15)	Method	Justification	Limitations	Risk Assessment
Difference in sand height of Groyne/cm - This data was taken at the start of Summer, during the day. This test is to show the change in height from one side of the groyne to the other side of it.	For this, we needed a metre ruler, a pen and some paper to record the results.	For this data, we looked at only where the groynes were (fig 9) and measured the heights of groyne that were above sand on either side. We achieved this by using a metre ruler and measuring the height of the middle of the groyne on both side and then a subtraction of the South side on the North side. This was then repeated at all the groynes. The sampling method for was systematic as all 18 groynes were measured.	The point of this data is to prove that longshore drift is being prevented by the coastal defences as well as to show that the groynes do have an impact on the cliff recession in the Swanage Bay.	The limitations of this test were that the measurements weren't all done at the same time and that there were the occasional obstacles on the beach such as people and posts in the way.	The risk assessment, for this is that we needed to be careful crossing over the groynes due to the difference in height on either side and the metre ruler needed to be held in a safe manner to prevent harming ourselves or somebody else.
Questionnaire – This was a where I asked people some questions about the cliff management strategies. I did this during the day and around the final groynes to the North of the Swanage Bay.	For this, all I needed was a pen and paper to record quotes and answers from the people I asked.	This was completed around the final groynes to the North of the Swanage Bay, from groyne 12 – 18. What I would do is ask someone passing by the question – 'Do you like the cliff management strategies?' and record if the answer was a 'yes' or a 'no'. Then I would take further notes on their opinions. I asked about 20 people. I made sure not to ask any sensitive questions as I did not what to upset the locals.	The point of this questionnaire was to find out the local's opinions on how some parts were being managed. It is also to see whether the implementation of cliff management strategies impacted the locals in anyway. It will help me answer all my key questions.	The limitations were that not everyone was willing to answer my question. Only certain people would continue up the beach to where I was due to its isolation, so it was mainly dog walkers I spoke to. There is also personal bias on people you would ask, so the results can be skewed by that.	The risk of this would be too careful around the people, making I did not offend them.

Methodology Table

Hypothesis: *'The coastal defences have been successful at reducing cliff recession in Swanage Bay.'*

Date: *'19/06/2017 – 23/06/2017'*

Data Collection	Equipment (pg. 15)	Method	Justification	Limitations	Risk Assessment
Percentage coverage of vegetation of cliff face – This data was collected during the daytime and at the beginning of summer. This is data is to judge the amount of material of the cliff side whether it is vegetation, bare or something else.	For this test, all I needed was a quadrat, a pen and some paper.	This assessment was completed at all the same points as the CISA was, so at all the groynes and at the 5 points beyond the groynes, as shown in fig 9. This would work by me standing at each of the points and holing up the quadrat straight out in front of me. Then I would make a judgement on how much of the area was covered in vegetation, bare ground and anything else from sight. The vegetation would signify that the cliff was stable, whilst the bare ground would show that the cliff was unstable and had suffered recent slumping. I would continue this process at each of the points.	This test is to show that stability of the cliff at different areas of the Swanage Bay. It will help me answer all my key questions as it shows which part of the bay have the most stable cliffs and what affect the coastal management strategies have.	The problems with this test was that there was only so far that I could go until I came across problems in the town, as there were the added complications of buildings and roads.	The risk with this test was that I had to be careful going over the groynes due to the height difference on either side.
Photo Analysis – These where photos of the area that I am investigating and where done during day at the beginning of summer. They are to show the visual	All I needed for this was my camera.	For this I went to every point as shown in fig 9 and took pictures of the cliffs. I also took photos of the cliffs to the north that were hard to access.	These photos will be pivotal in helping me answer my question. They will show a visual representation of the cliffs and the difference of what coastal defence strategies have on it.	The limitations of this were few, but there was just the problem access to certain parts of the bay.	I had to make sure that I was careful getting over the groynes due to the change in height on either side.

Methodology Table					
Hypothesis: *'The coastal defences have been successful at reducing cliff recession in Swanage Bay.'*					
Date: *'19/06/2017 – 23/06/2017'*					
Data Collection	**Equipment (pg. 15)**	**Method**	**Justification**	**Limitations**	**Risk Assessment**
difference along the bay.					
Secondary Data					
LiDAR – This stands for light detection and ranging. It is a remote sensing that examines the Earth's surface. It is done annually.		This data was achieved by a helicopter or an airplane firing a laser at the surface of the target area. The lasers reflect on the ground, which means the distance from the ground to the airplane can be worked out by the time it takes to reflect. From this, the change in surface height can be worked out.	This data is very helpful as it allows us to compare the data that we get to the past. It shows the difference from when the coastal defences were depleted and refurbished. It is good data that will help me answer my question.		
Historical Maps – These are maps that can be used to compare to current maps.		For this, I went on to https://wtp2.appspot.com/ and compared the historic maps to the present maps.	This data will be useful as it will show the changes from the past and how much the bay has changed.		

Fig 8 CISA – Geo Factsheet 359 coastal fieldwork 1: Physical

Parameters	VERY BAD 1	BAD 2	NORMAL 3	GOOD 4	VERY GOOD 5
Geomechanical			**Joints**		
→ No. of joints	Crushed rock	>3	2 + random fractures	1 + random fractures	Occasional random fractures
→ Spacing	<0.06m	0.06–0.2m	0.3–0.6m	0.7–2.0m	>2m
Aperture	>1m	0.01–1m	0.002–0.01m	0.0005–0.002m	<0.0005 or closed
→ Water condition	Spring water	Wet	Very damp	Damp	Dry
Weathering	Extremely weathered	Very weathered	Weathered	Slightly weathered	Not weathered
Morphological			**Cliffs**		
Cliff height	>30m	30–15m	14–5m	4–2m	<2m
→ Cliff slope	Overhanging	Steep: 75°–90°	Strong: 50°–74°	Moderate: 30°–49°	Gentle: <30°
→ Sea caves	Widespread	Widespread at the sea level	Widespread above the sea level	Slight	Absent
Natural breakwater	Absent	Very small	Small	Wide	Very wide
→ Mass movement: material and evidence	Widespread	Widespread around the sea level	Only material at the foot of the cliff	Slight	Absent
→ Abrasive action	Very intense	Intense	Moderate	Poor	Absent
Meteo-marine			**Sea waves**		
Effective fetch	>250km	250–200km	201–150km	151–100km	<100km
Exposure to storm wave fronts	80°–90°	60°–79°	40°–59°	10°–39°	<10°
Anthropogenic			**Engineering structures**		
→ Reinforcement	Absent	Poor	Localized	Widespread	Very widespread

CISA Value	<15	15–30	31–45	46–60	61–70
Class no.	1	2	3	4	5
Classification	Completely unstable	Unstable	Partially stable	Stable	Completely stable

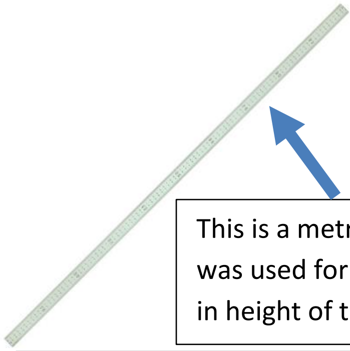
→ Parameters used in this investigation

Fig 9 – Google Maps

2.2 Equipment:

This is a ranging pole. This is used to measure the beach profile

This is a tape measure. It was used for the beach profile.



This is a metre ruler, which was used for the difference in height of the groynes.

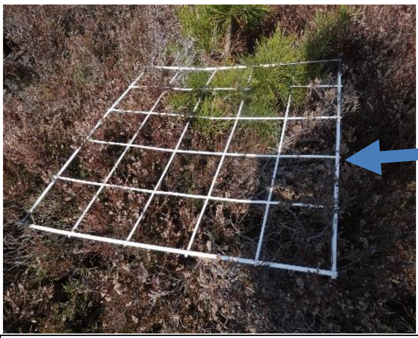
These Photos are my own photos.

(https://static.rapidonline.com/catalogue images/Module/M072235P02WL.jpg)

This is the camera I used

This is clinometer. It is used to measure the angle of the beach.

(http://www.chescientific.com/edu/company/Griffin%20Education/480f4f74-3dc7-4c2d-97dc-394d0cb62d58YSD-600-010U.jpg)



This is a quadrat. It is used to work out the coverage of

(http://3.bp.blogspot.com/-9RJb2eQGqwI/UZnhT2mNGRI/AAAAAAAAA7o/An5F6iz5ysE/s)1600/DSC02602.JPG)

3.0 Data Representation: 3.1 Primary Data

Cliff Instability Susceptibility Assessment:

Fig 10

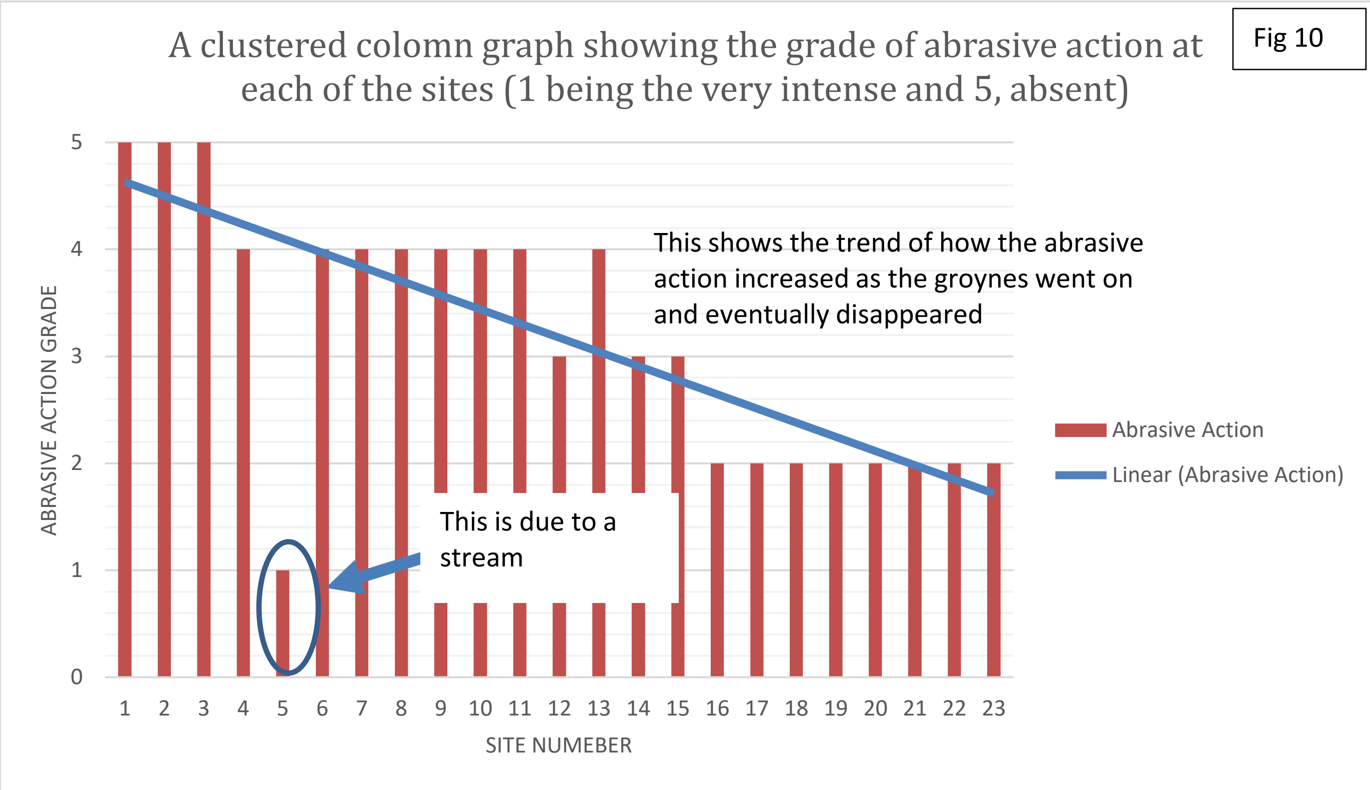
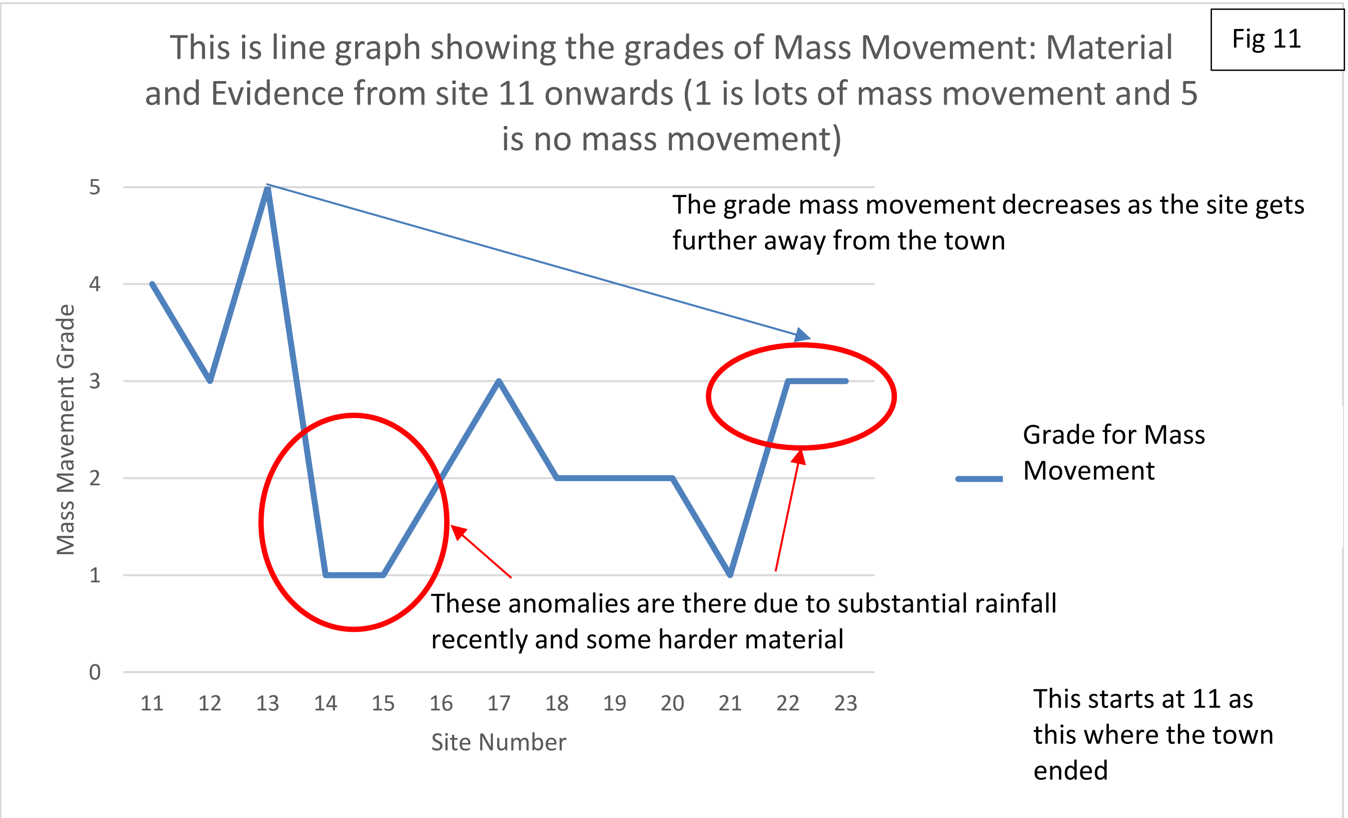


Fig 11



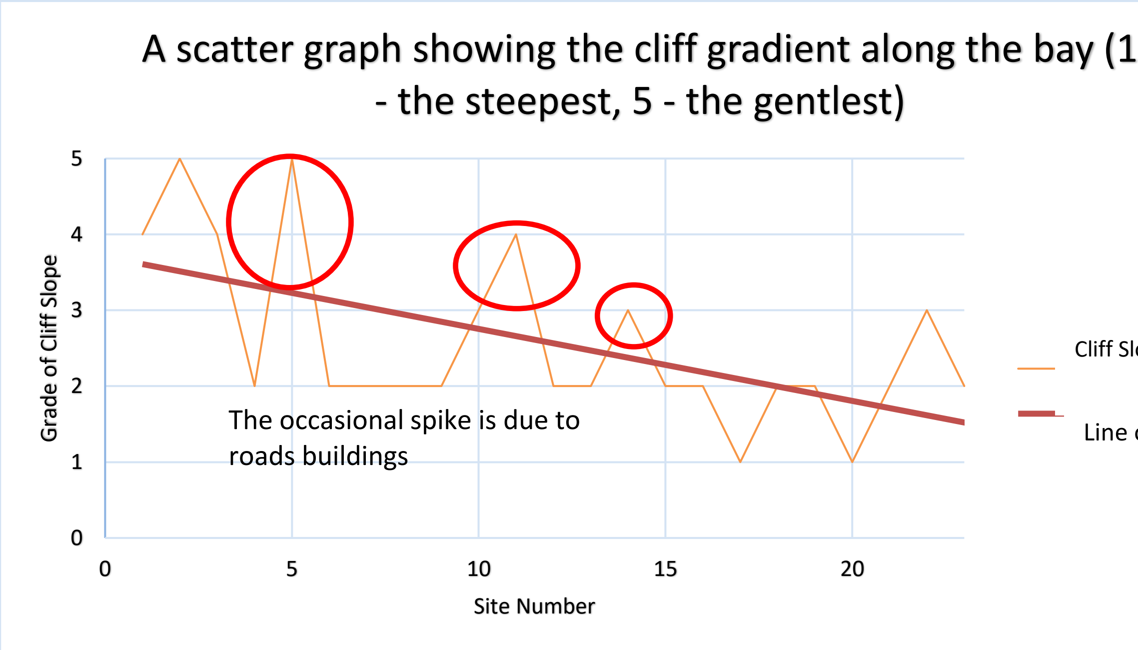


Fig 12

Beach Profile:

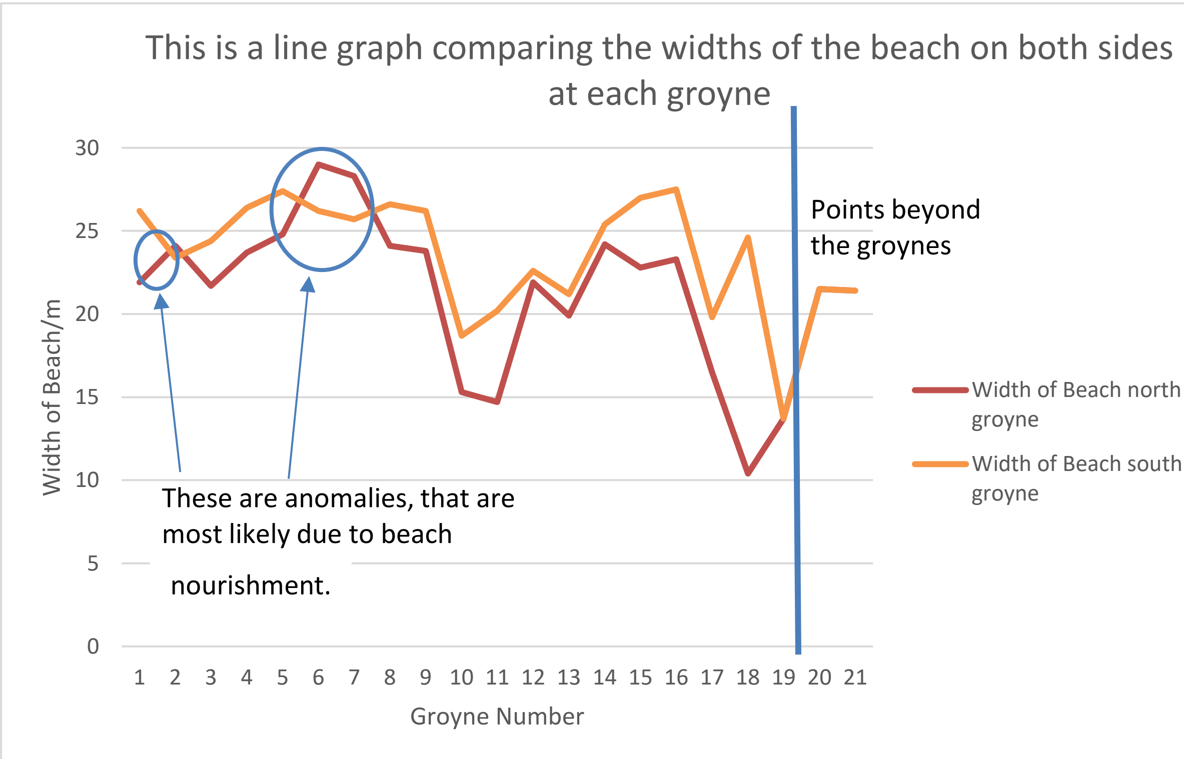
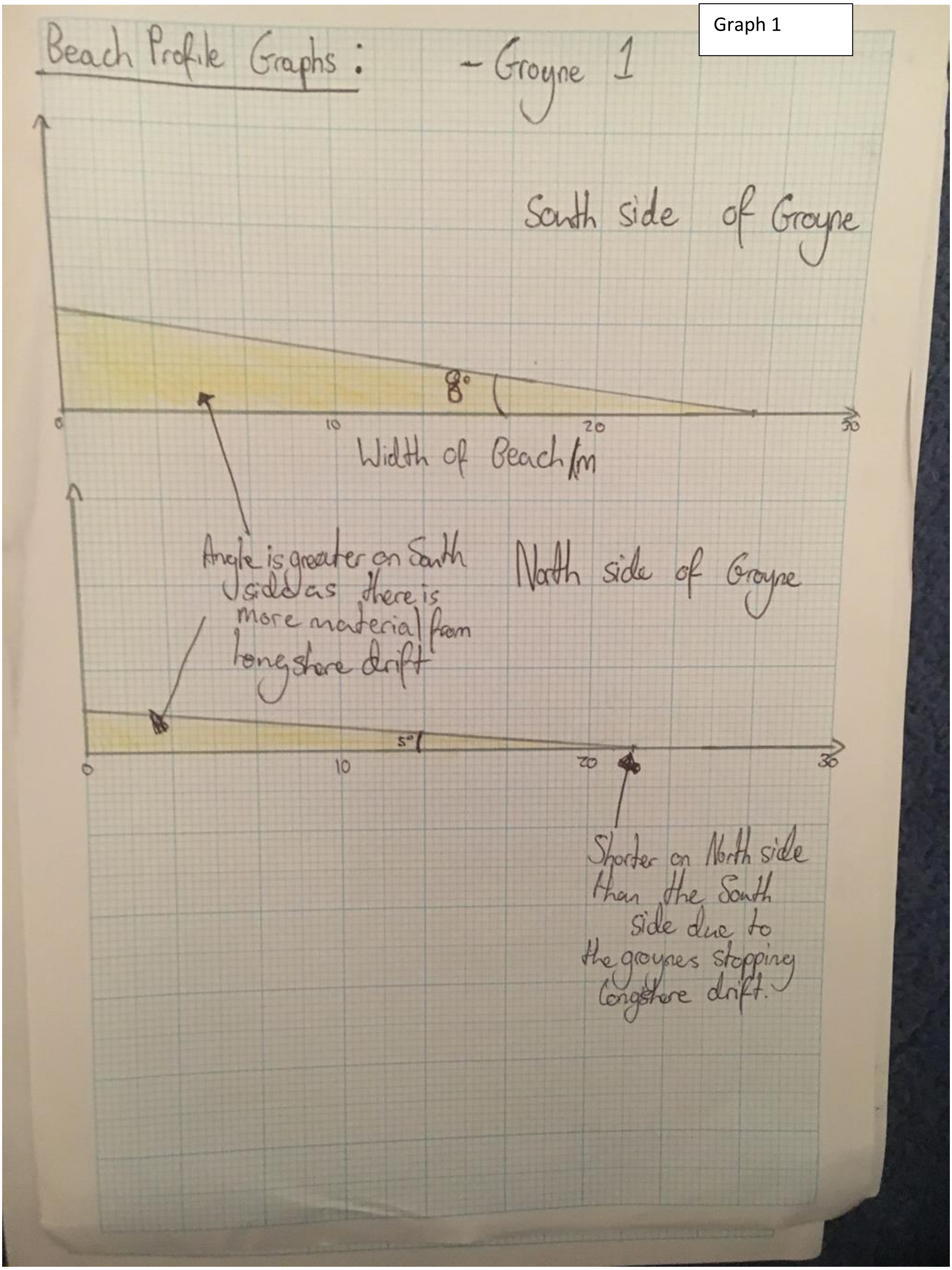


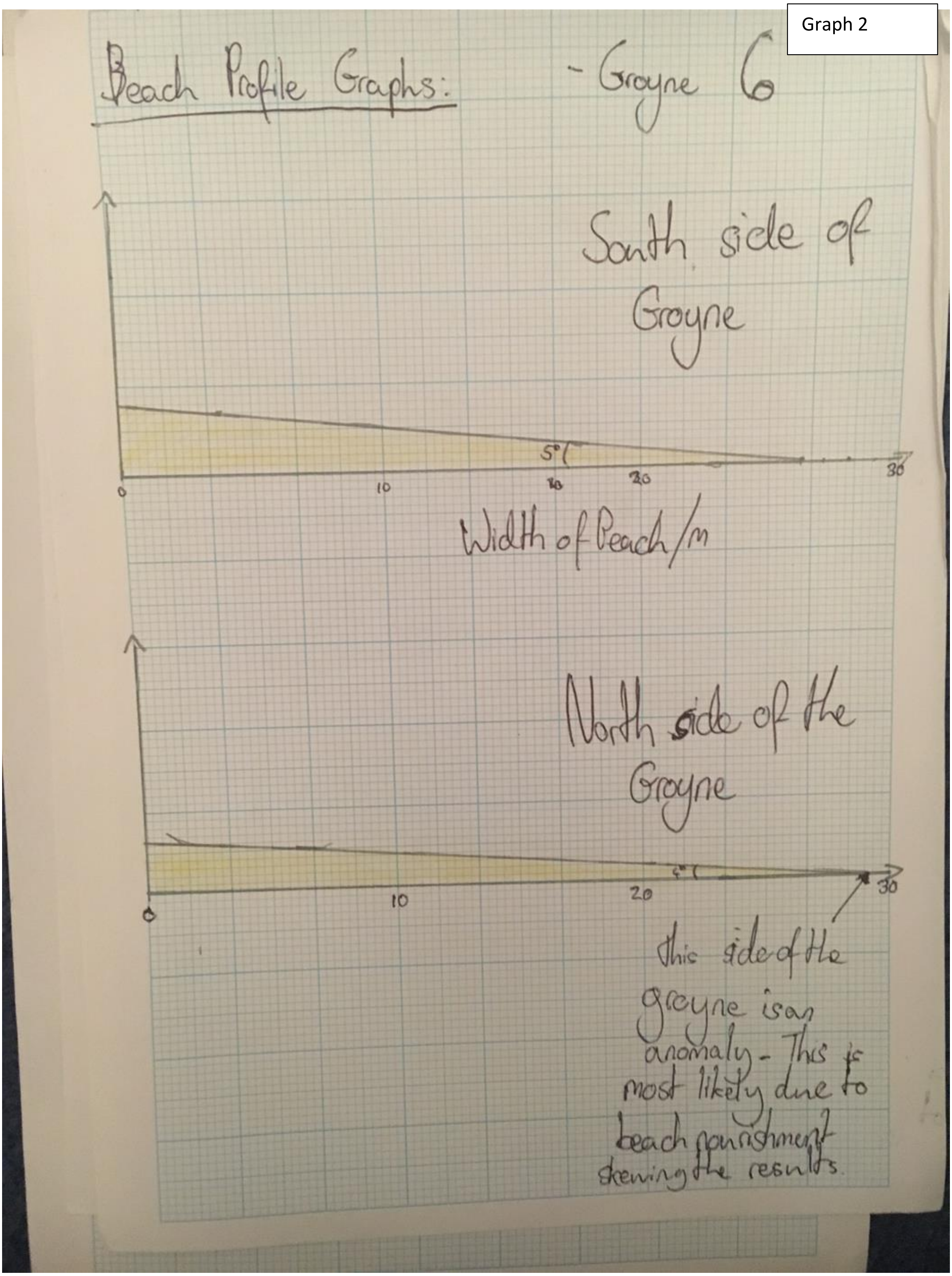
Fig 13

These graphs show the beach profiles and give us a visual representation of the beach that I can use to compare

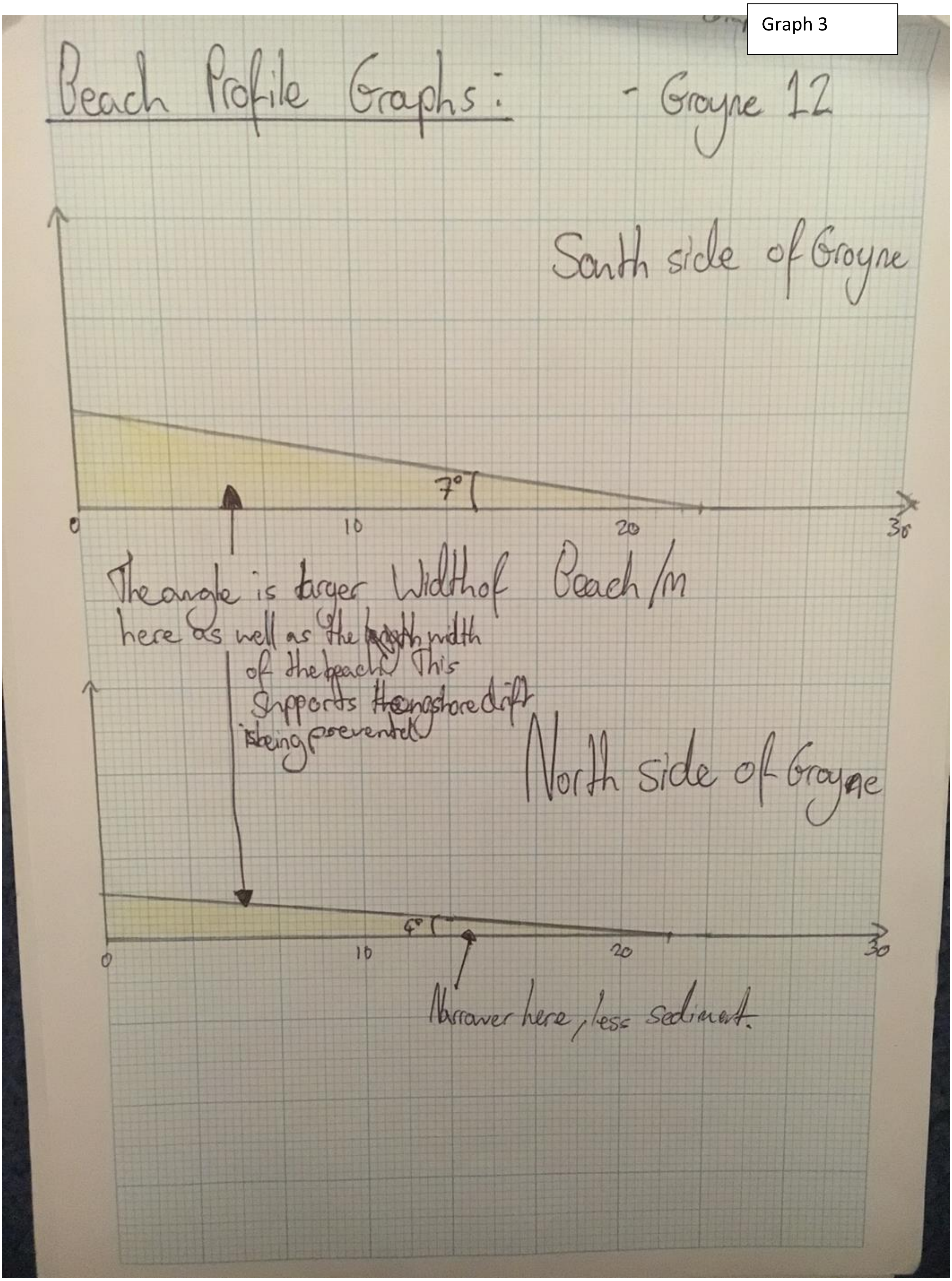
Graph 1



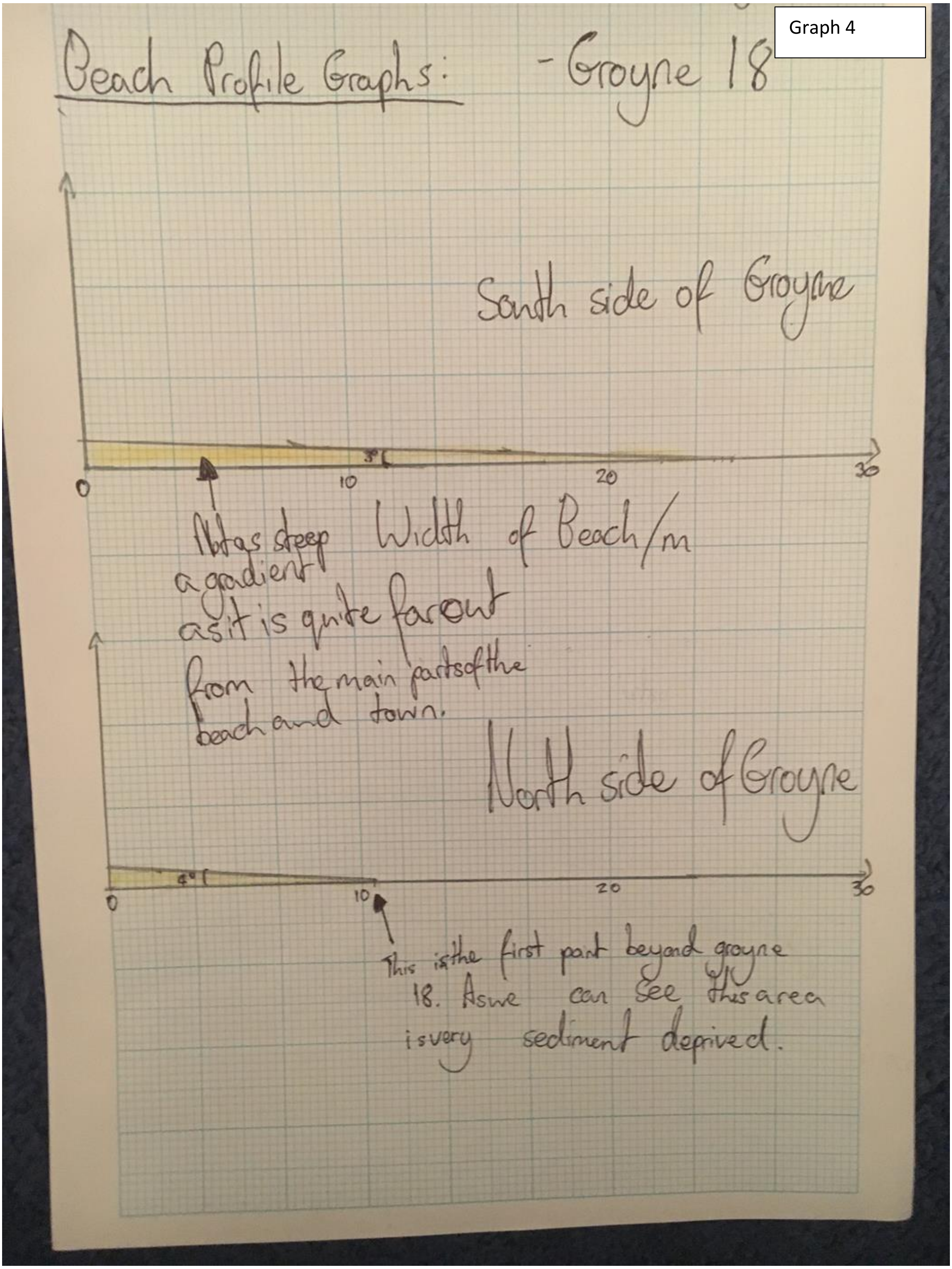
Graph 2


Beach Profile Graphs: - Groyne 6
South side of Groyne
5°
0
10
30
Width of Beach/m
North side of the Groyne
10
20
30
this side of the groyne is an anomaly - This is most likely due to beach nourishment skewing the results.

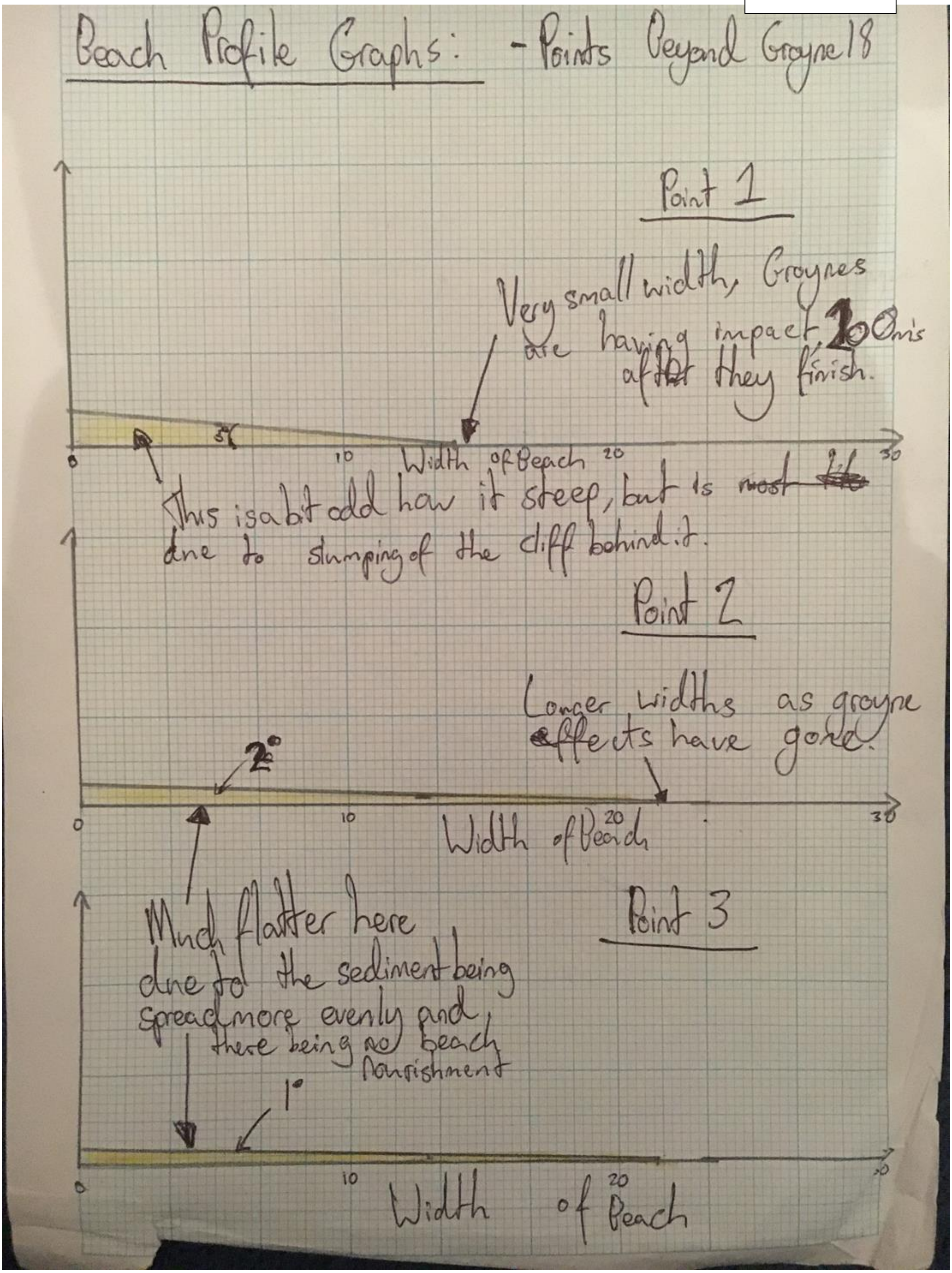
Graph 3


Beach Profile Graphs: - Groyne 12
South side of Groyne
7°
0
10
20
30
Width of Beach/m
The angle is larger here as well as the width of the beach. This supports longshore drift is being prevented.
North side of Groyne
4°
0
10
20
30
Narrower here, less sediment.

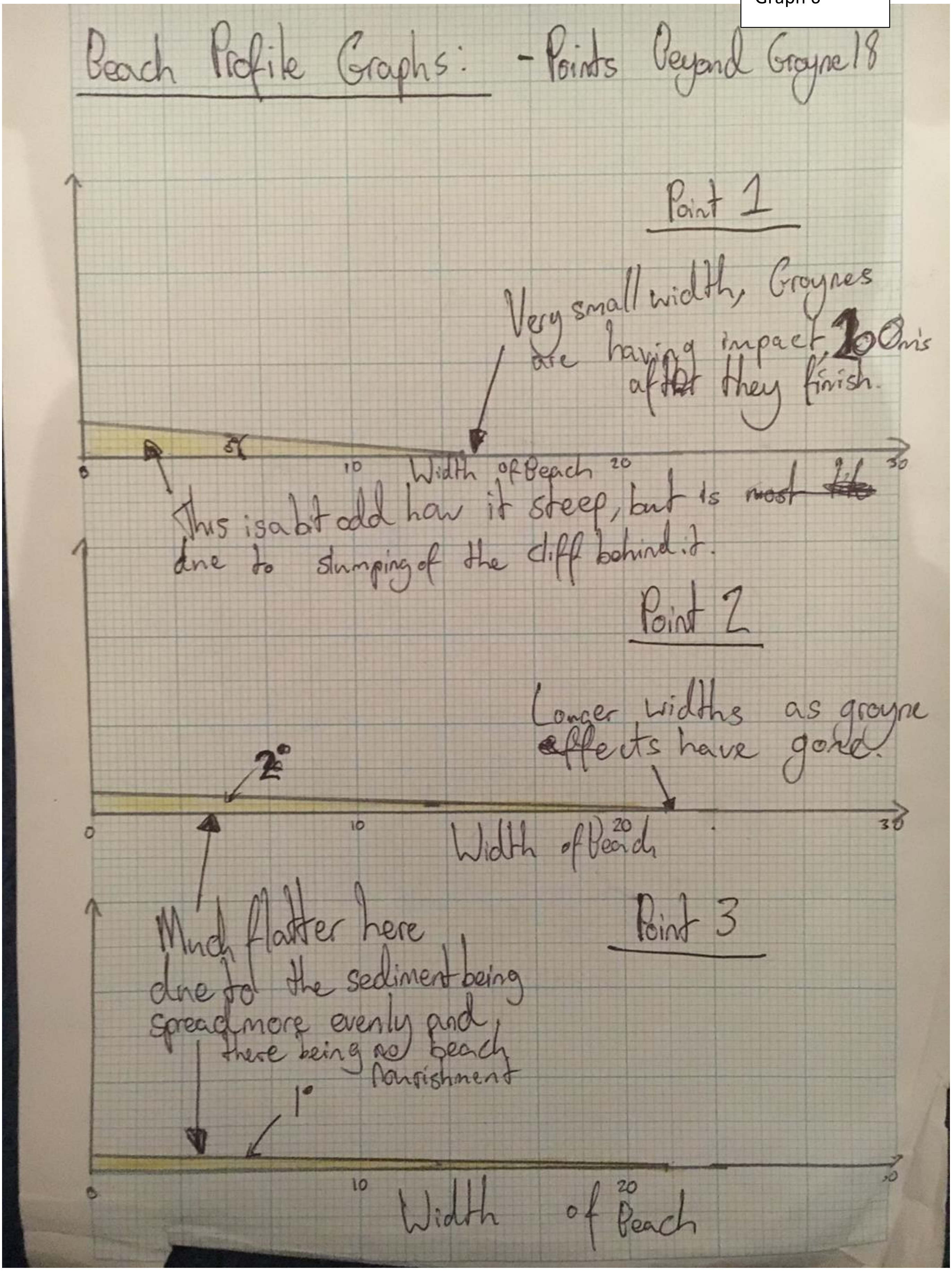
Graph 4

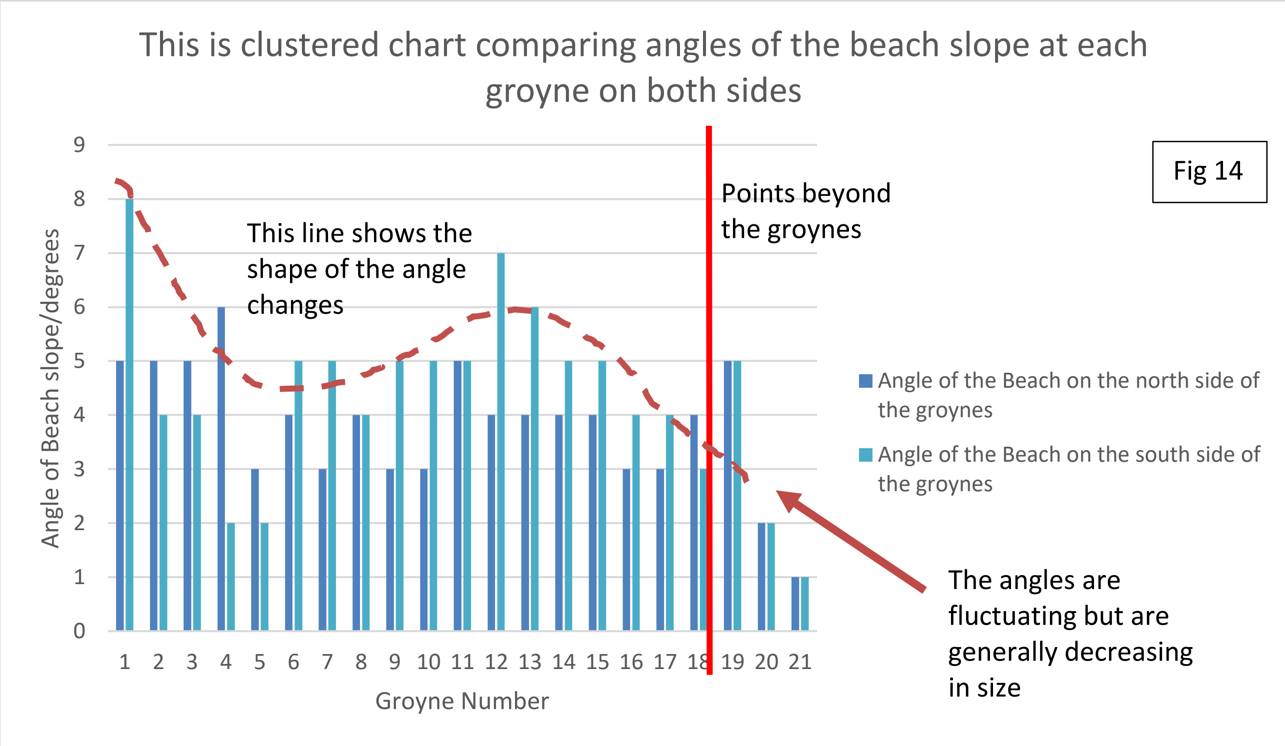

Beach Profile Graphs: - Groyne 18
South side of Groyne
3°
0
10
20
30
Not as steep a gradient as it is quite far out from the main parts of the beach and town.
Width of Beach/m
North side of Groyne
4°
0
10
20
30
This is the first part beyond groyne 18. As we can see this area is very sediment deprived.

Graph 5

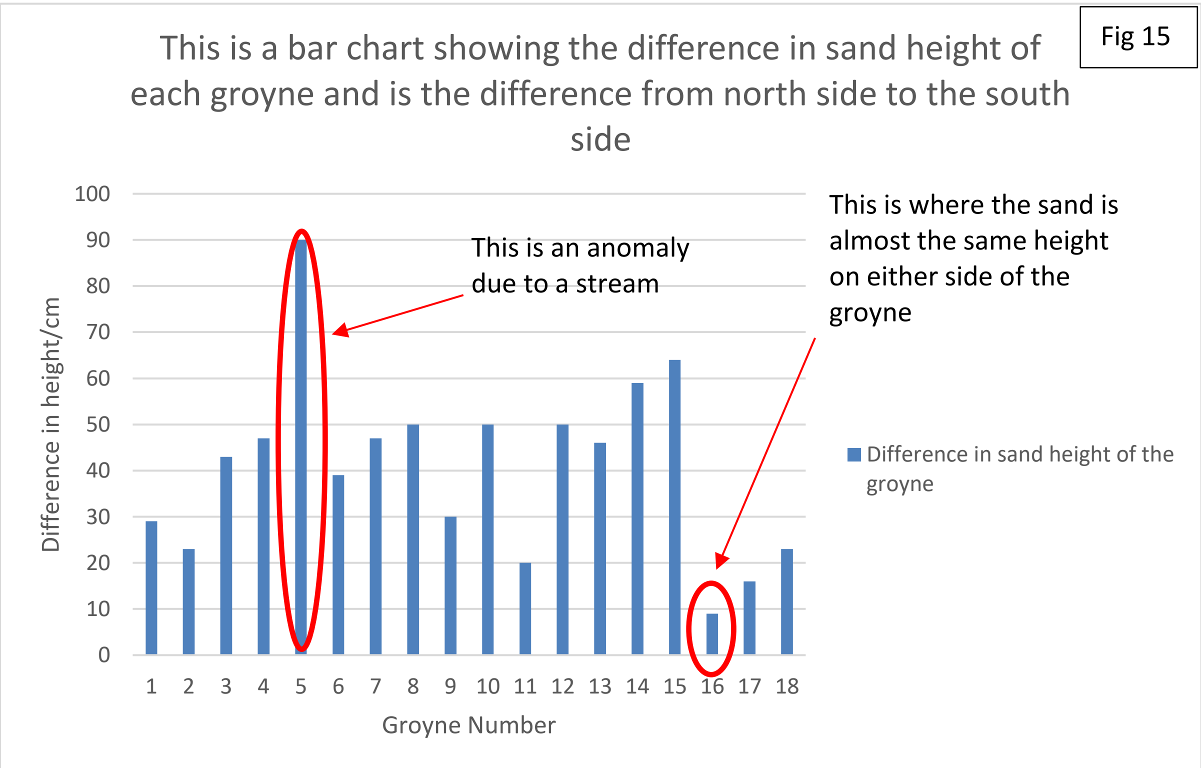

Beach Profile Graphs: - Points Beyond Groyne 18
Point 1
Very small width, Groynes are having impact 100m's after they finish.
5°
0
10
Width of Beach
20
30
This is a bit odd how it steep, but is due to slumping of the cliff behind it.
Point 2
Longer widths as groyne effects have gone.
2°
0
10
Width of Beach
20
30
Much flatter here due to the sediment being spread more evenly and there being no beach nourishment
Point 3
1°
0
10
20
Width of Beach

Graph 6


Beach Profile Graphs: - Points Beyond Groyne 18
Point 1
Very small width, Groynes are having impact 100m's after they finish.
5°
10
Width of Beach
20
30
This is a bit odd how it steep, but is due to slumping of the cliff behind it.
Point 2
Longer widths as groyne affects have gone.
2°
0
10
20
30
Width of Beach
Point 3
Much flatter here due to the sediment being spread more evenly and there being no beach nourishment
1°
10
20
Width of Beach



Difference in Sand height of Groyne:



Questionnaire:

Key quotes from the questionnaire

Fig 16

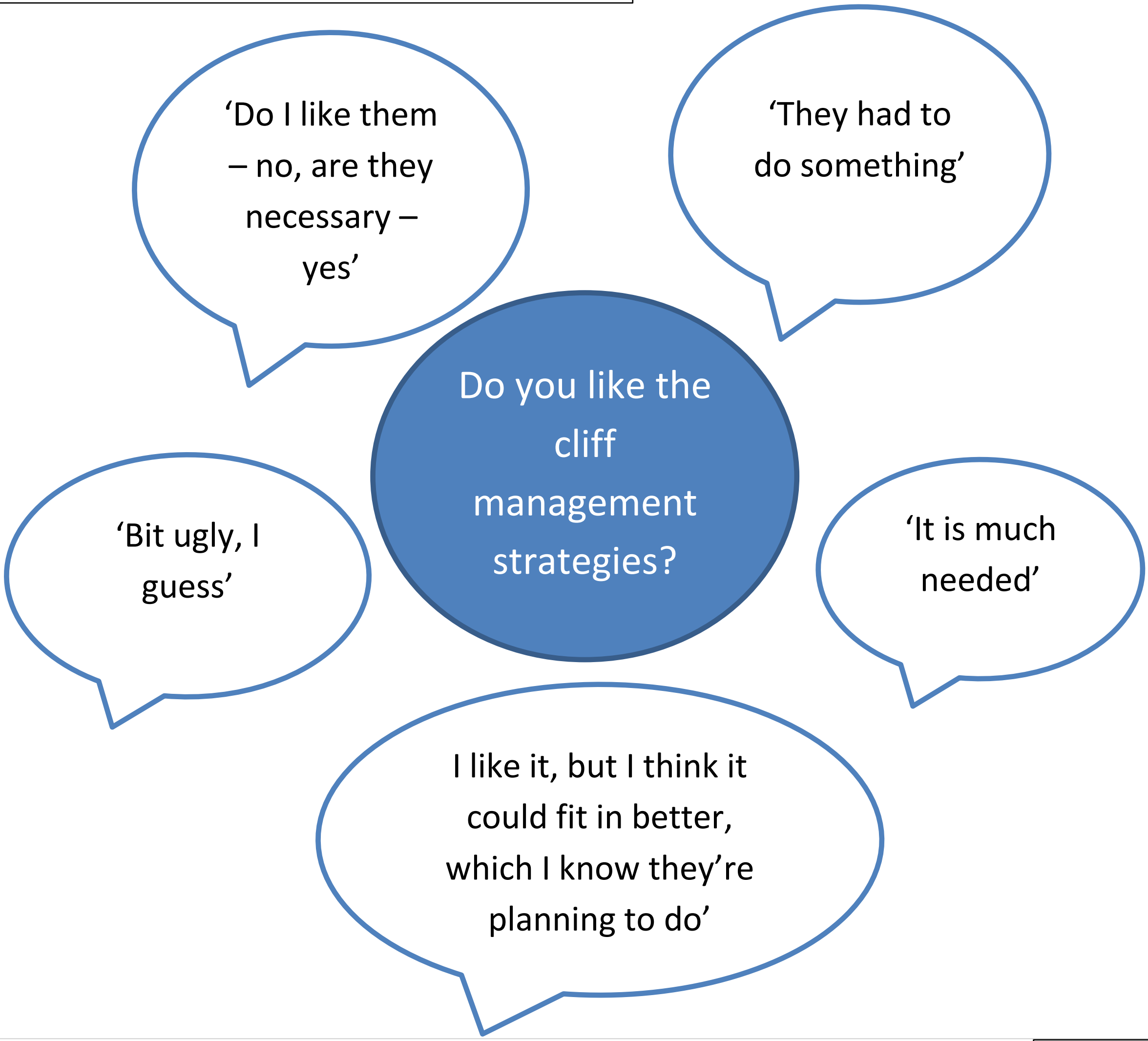
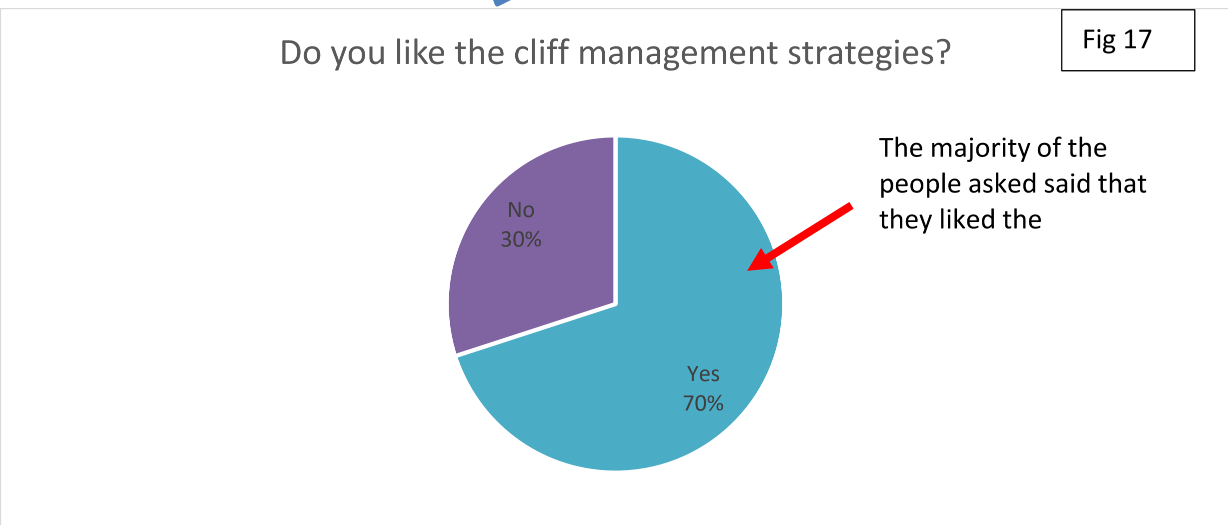
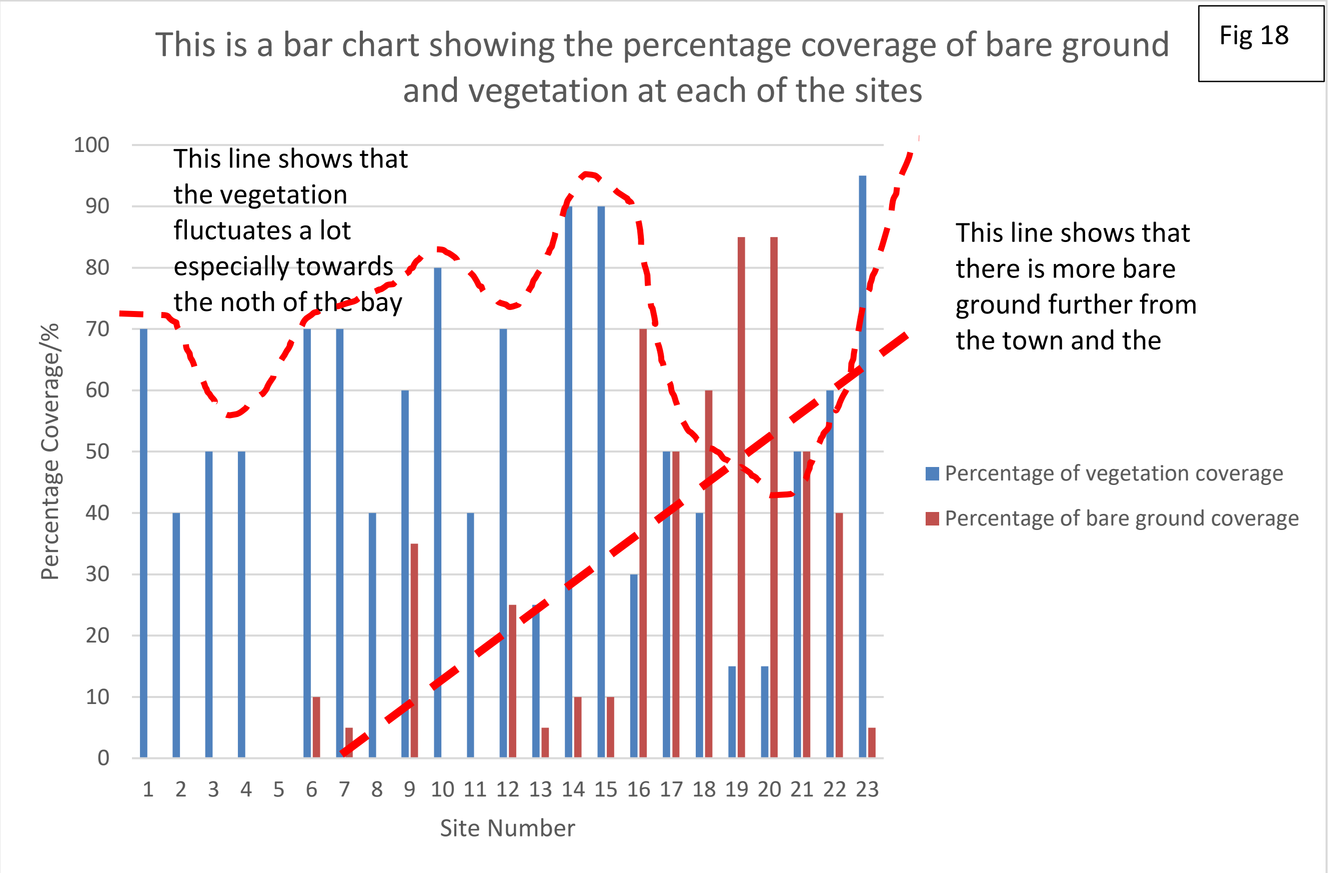


Fig 17



Percentage Coverage of the cliffs:

Fig 18

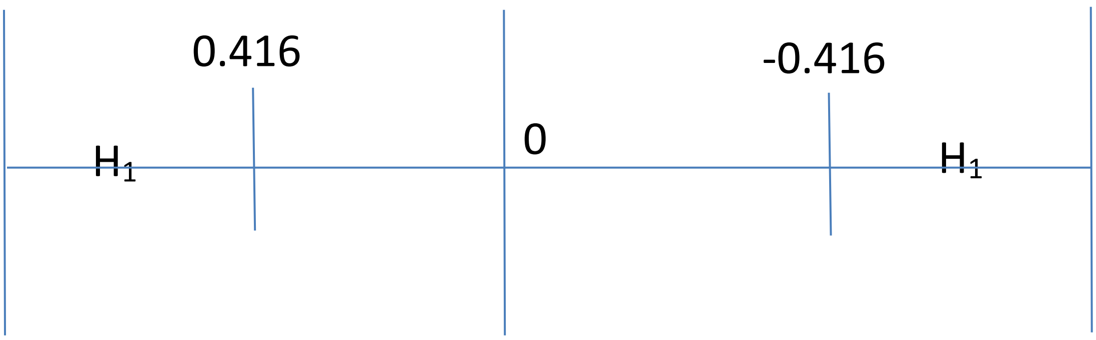


Spearman's Rank:

Fig 19

Alternate Hypothesis (H_1): There is significant correlation between the percentage coverage of bare ground and cliff gradient.

Null Hypothesis (H_0): There is no correlation between the percentage coverage of bare ground and cliff gradient.



Percentage of bare ground coverage/%	Rank 1	Cliff Gradient Grade (1-5)	Rank 2	Difference (d)	d^2
0	4.5	4	20	-15.5	240.25
0	4.5	5	22.5	-18	324
0	4.5	4	20	-15.5	240.25
0	4.5	2	9	-4.5	20.25
0	4.5	5	22.5	-18	324
10	13	2	9	4	16
5	10	2	9	1	1
0	4.5	2	9	-4.5	20.25
35	16	2	9	7	49
0	4.5	3	17	-12.5	156.25
0	4.5	4	20	-15.5	240.25
25	15	2	9	6	36
5	10	2	9	1	1
10	13	3	17	-4	16
10	13	2	9	4	16
70	21	2	9	12	144
50	18.5	1	1.5	17	289
60	20	2	9	11	121
85	22.5	2	9	13.5	182.25
85	22.5	1	1.5	21	441
50	18.5	2	9	9.5	90.25
40	17	3	17	0	0
5	10	2	9	1	1
				Σd^2 = 2969	

$$r_s = 1 - \frac{6\sum D^2}{n\left(n^2 - 1\right)}$$

r_S = -0.467

My Spearman's Rank value of -0.467 is less than the 95% confidence level of -0.416. Therefore, I can accept my alternate hypothesis (H_1).

Photo Analysis:

Fig 20 – This is a photo from groyne 2

Fig 21 – This is a photo from groyne 5

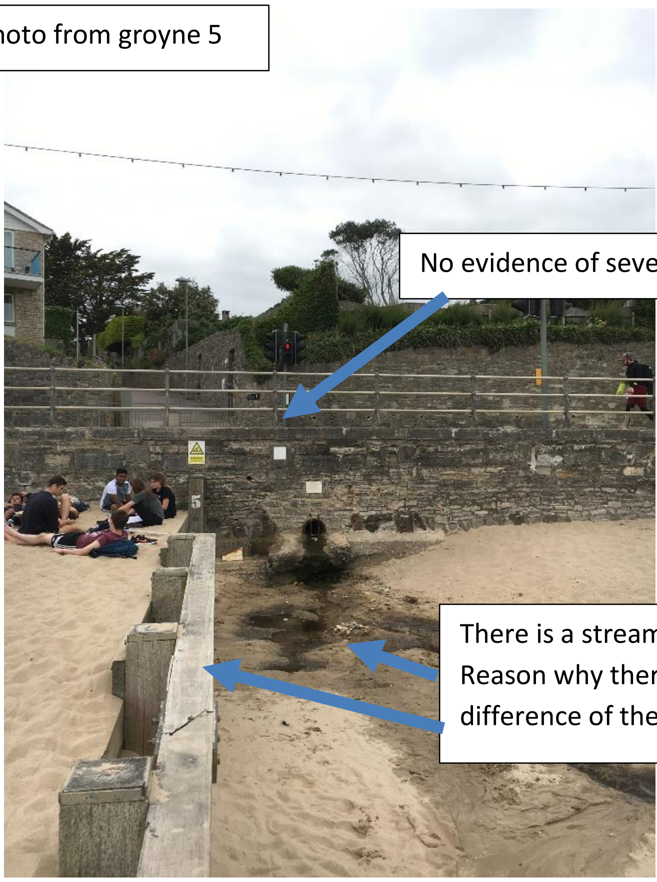
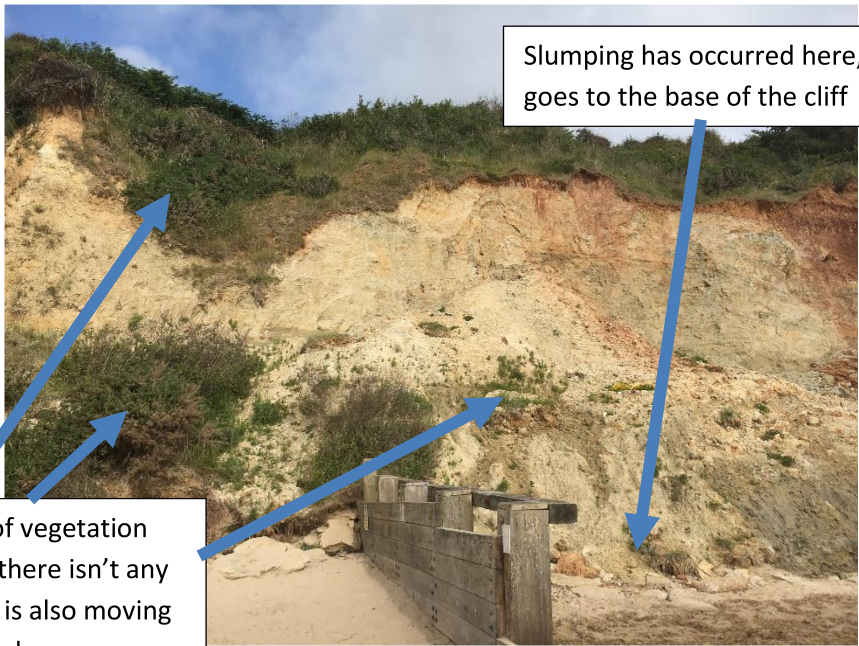


Fig 22 – This is a photo from groyne 7

The cliff has bare ground showing here. This is due too subaerial processes, causing slumping

Beach Huts are at the bottom of this cliff, the coastal defences must be protecting this area sufficiently

Fig 23 – This is a photo from groyne 18 of the cliff



Slumping has occurred here, and it goes to the base of the cliff

There are some patches of vegetation here and where they are there isn't any slumping. The vegetation is also moving to areas that have slumped.

Fig 24 – This is a photo from groyne 13 and the cliff defences at the Pines Hotel

Fig 25 – This is a photo from beyond the groynes

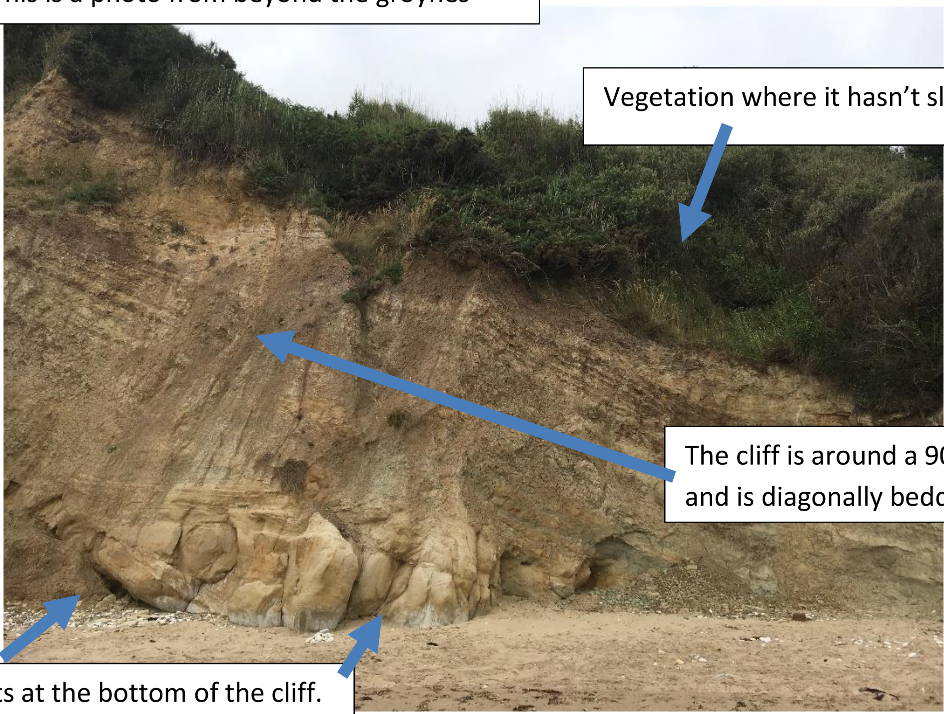


Fig 26 – This is a photo from beyond the groynes

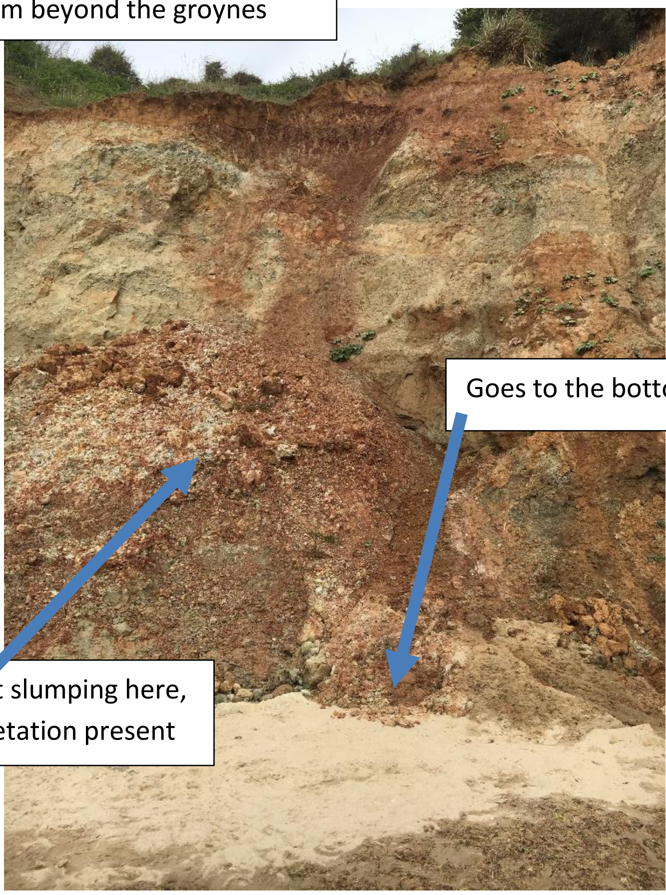


Fig 27 – This is a photo from beyond the groynes

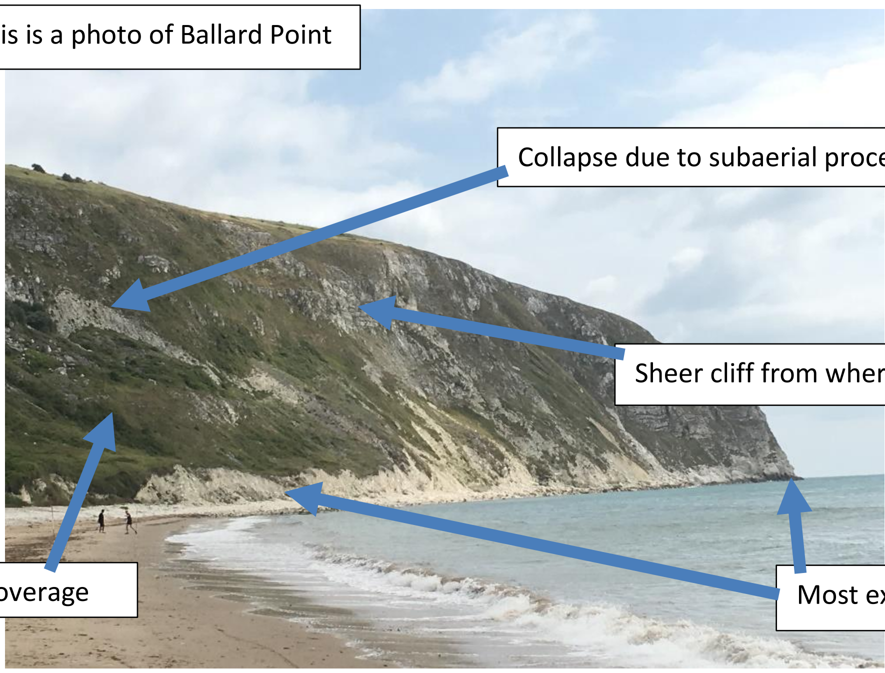
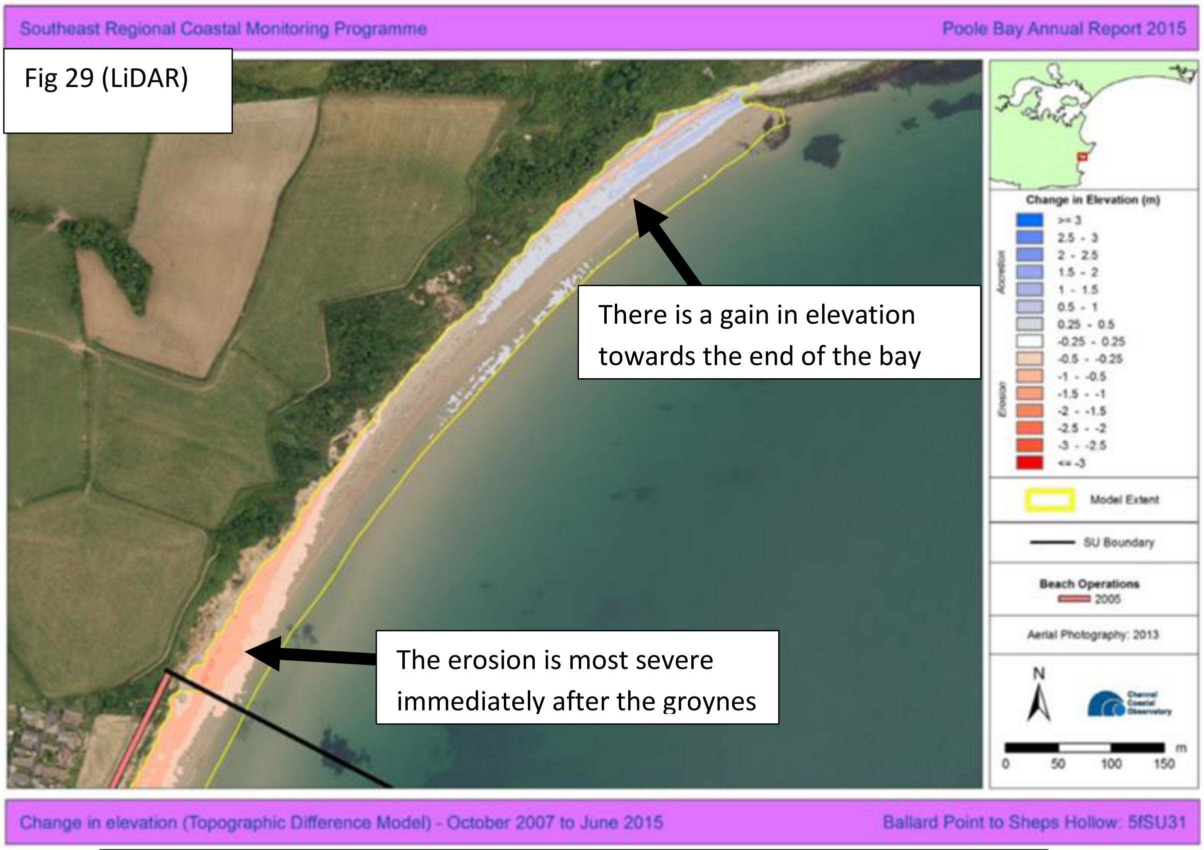


Fig 28 – This is a photo of Ballard Point

3.2 Secondary Data:

LiDAR:

Change in Elevation of Post Groynes (2007 – 2015)



This shows the change in the Mean High-Water line in 2003 and 2014

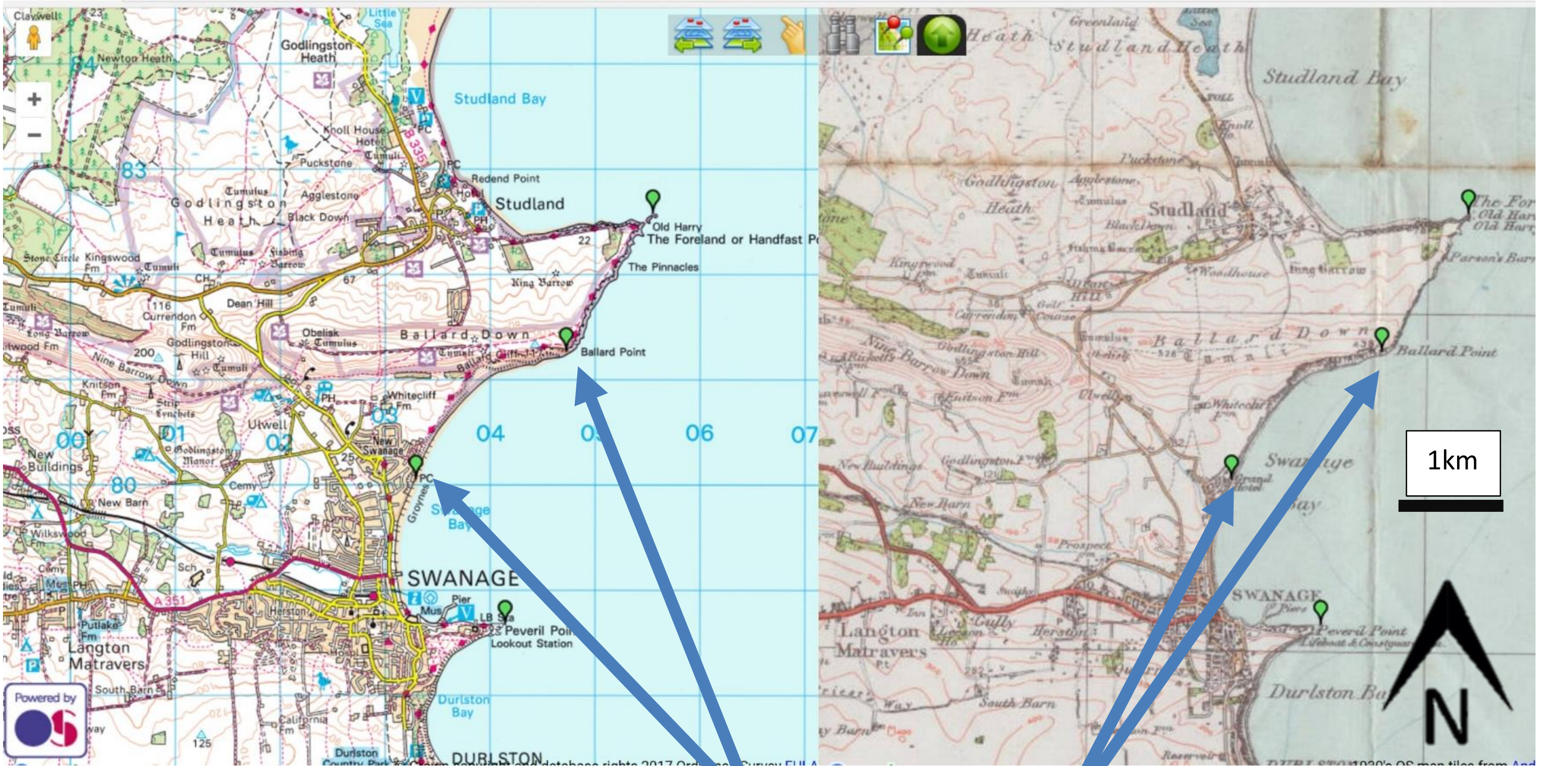
This shows the percentage change in cross-sectional area (2003 – 2015)

Fig 31 (LiDAR)

There is a lot of accretion present from where the coastal defences have been implemented, proving their success

Historical Maps:

Fig 32 (https://wtp2.appspot.com/)



These waypoints show subtle changes in the beach since 1925 (left being current OS, right being 1925 OS)

4.0 Analysis of the Results:

For the key question *'How have the cliffs changed along the bay?'*, the CISA is very important in answering it. I have displayed the information in the form of clustered bar chart and a couple of line graphs (see fig 10-12). From these graphs, we can see a trend of how the cliffs become steeper (fig 12), more vulnerable to erosion (fig 10-11) as the further you go North in the bay away from the town. In fig 10, we can see how the cliffs undergo more abrasive action further North of the bay, with it going from '5' at groyne 1, to '2' from the final groynes through to the points past the groynes. The same can be seen with how the cliff gradient changes (fig 12) from being gentle in the town and stable ('5' at site 2, '4' at site 4) to being steep ('1' at site 20, '2' at site 23). Although these may be a trend there are still anomalous results with there being a large amount of abrasive action around groyne 5 ('2') and the cliff gradient it fluctuates a lot from being '4' at site 11, '2' at site 4 and '3' at site 22. These discrepancies are due to the change in physical landscape, with there being a stream and site 5 making it more vulnerable (see fig 21) to abrasion and there being more landscaping for town with buildings and its tourist industry. At site 22-23 the cliff is more gently slope than the sites around it and if you look at figure 20 and 27, you can see why, with the there being a lot more vegetation there to support the cliffs. In figure 27, the slope is also at a lesser angle to its surroundings, most likely due to it slumping in the past.

Slumping is a form of mass movement and in fig 11, there is a line graph displaying the evidence of mass movement. This graph was uses data only from groyne 11 onwards as this was where the mass movement of the cliffs started. At groynes 14-15, there is a significant amount of mass movement present (grade '1'), even though the area has coastal defences protecting it. This is because the mass movement has been caused by weather, as the substantial amount of the rainfall the area has received has caused the soft Wealdon stone to weaken and cause the cliff to collapse. At site 22 and 23 there is quite a high grade of '3' in comparison to the points previously. The area was covered in a lot of vegetation (see fig 23 and 27) which meant the roots of the plants have added extra stabilisation of the cliffs. We know the plants provide extra support for the cliffs as in fig 24, part of its defence is to use plants along with the other protection methods.

Although these anomalous results can be explained using other data, I feel that to gain more accurate and precise results, the tests should be done regularly throughout the year, as the cliffs change a lot due to the recent weather and strength of the lithology. This would also provide more data to answer my enquiry question of '*How does coastal management impact cliff recession in the Swanage Bay?*'.

We can also see how the cliffs have changed in my photo analysis, with there being no cliffs or erosion present in the early groynes as shown in fig 20, however with the more northern groynes, there are some substantial changes, especially around groyne 7 (fig 22) with there being no erosion at the bottom of the cliff due to a small sea wall but slumping at the top of the cliff. This indicates that although there is the threat from the sea, the weather can be much more destructive. This is due to the amount of rainfall the area has had in past and as a result it would have weakened the soil and caused the cliff to slump. In fig 24, we can see how the Pines Hotel owner has implemented cliff defences to stop this from happening.

This differs even further north in the bay at groyne 18 (fig 23). Here we can see how the cliff is being eroded from the base by the sea. The material of this part of the cliff is also the same as the material seen in fig 22, and this shows us that as well as the sea eroding the cliff, the weather is also inflicting damage. Even though there is a groyne here, the cliff is still being eroded – this is because there is no sea wall protecting the cliff base here. The groyne here is in place to secure protection for Swanage. From the photo analysis, we can also see what the cliffs are like beyond the groynes, and this can be seen in figures 25-28. In figure 25, the cliff is clearly getting undercut by the sea (something that is not present further south in the bay), as well as there being large cracks at the base. This shows us that the cliff is more vulnerable here. There was also much more slumping further north in the bay (fig 26) with the cliffs becoming more and more at risk from the sea.

In fig 28, it shows a photo of Ballard Point. This is the chalk headland to the north of the bay and is the most exposed to the sea, but in comparison to the Wealdon stone, it hasn't retreated as much. This is because it is a much harder rock. The cliff is steep in general but does have a more gradual gradient towards the middle to top half of the cliff. This cliff face's main threat isn't so much the sea but more subaerial processes. The chalk of the cliff is weathered by the rain, as the it chemically reacts to the chalk, and mechanical processes. In this photo, we can see that the cliff has collapsed due to these processes. The cliff is also covered in lots of vegetation, which may stabilise the Wealdon stone cliffs, but it in the chalk, the roots of the plants case chunks of rock to be broken off as it they grow. At the foot of the cliff, we can see that there isn't a beach but pieces of broken chalk. This is because it is the most exposed to the sea. This data shows that the subaerial processes effects certain rock types in separate ways and has useful information on the impacts of subaerial erosion on the cliffs.

These photos link to the other data I collected, with the Beach profiles (fig 13-15 & graph's 1-6), the CISA (fig 10-12) and the spearman's rank I did (fig 19). As we can see from fig 13, the beach tends to be wider on the south side than on the north (at groyne 3, 21.7 metres on the north side whilst 24.4 on the south side, at groyne 16, 23.3 ad 27.5 in retrospect). This shows us at the groynes are being effective at stopping longshore drift and leaving enough material to protect the town. Another indicator that longshore drift is being prevented can be seen in fig 15 with their always being a positive difference from the north side to the south side (50cm at groyne 10).

There are also the areas beyond where the beach narrows significantly and then widen to the same width as can be seen from the beach profile graphs. From these we can see that where the beach narrows beyond the groynes, there is significant erosion present as can be seen from fig 26. As well as this, the beach has a width of 13.7m which is where the groynes knock-on effect has continued with longshore drift being stopped. The beach here though does have a larger angle (5 degrees) than the other areas beyond the groynes and is larger than some of the angles of the southern sides of the groynes in fig 14. The difference of the beach profile beyond the groyne is much clearer with the graphs (graph 5) with it showing both the changes in beach gradient and width. At point 1, we can see why it has a steeper gradient in fig 26, with the cliff recently slumping. Further along the beach past the groynes it becomes approximately 21.5m wide and have a 2-degree gradient. This is roughly the same as the areas that are protected by the groynes, but the gradient is considerably lower. This is due to longshore drift being uninterrupted by groynes and the beach being allowed to become more natural.

In the spearman's rank I did (fig 19), it shows how the percentage coverage of bare ground has significant correlation to the cliff gradient (-0.467). This tells us that where there isn't any bare ground showing, the cliff gradient is a lot more gradual, whilst where there is lots of bare ground showing like at site 19 (85%) and 20 (85%) in fig 21, the cliff gradient is steeper, as we can see from fig 12, with the gradient being grade '2' for both sites.

At the Pines Hotel, it also has cliff defences as well as coastal (fig 24). These were implemented as the coastal defences weren't doing enough to protect the hotel. The defences are very different to the other parts of the bay and had caused a previous divide in opinion. In my questionnaire, I asked 20 people for their opinions and the majority said that they liked them (fig 16 and 17), some of them even went on to say that '*they had to do something'* and that is was '*necessary'*. This shows that although the defences don't have any negative social impact and even though someone said it was '*ugly*' it is later planned that the indent in the cliff side where the sea wall is; beach huts will be located. The question asked did not touch any sensitive areas.

The LiDAR was particularly useful as it provided an insight into what the bay was like before the coastal defences. Figure 29 shows us the change in elevation post groynes. We can see that there is a large amount of erosion close to the cliffs and after the groynes. There is also a gain in elevation towards the most northern part of the bay. This is due to the lack of groynes and the opportunity for longshore drift to occur uninhibited. Figure 30 shows us the Mean High-Water line from 2003 and 2014. From this comparison, we can see that the replenishment of the coastal defences has meant the mean high-water line has retreated. This shows that the defences are effective at preventing longshore drift but the additional height is also down to the beach nourishment that has occurred. As more proof that the coastal defences are doing their job, we can look at the fig 31. This shows the accretion of where the coastal defences are and that the cross-sectional area has increased. This increase in accretion is due to the coastal defences preventing longshore drift from happening. The LiDAR data shows that the coastal defences are doing their job but have had knock on effects further north in the bay. This LiDAR data links to my own data with my beach profiles and change in groyne height also proving longshore drift and the photo analysis showing a visible erosion after the groynes (fig 25-26) and fig 29 giving us a cause with the loss of sediment.

5.0 Conclusion:

How have the cliffs changed along the bay?

The cliffs have changed significantly along the bay, especially with the change from the urban, tourist environment of the town to the quieter more distant northern part of the bay. In the town the cliffs aren't present due to the urban development of there area, with roads flattening the area (fig 20) and promenades for the locals and tourists to use stabilising and protecting the land (fig 21). As soon as you go north of the town, there is a change in the gradient of the cliff, with more signs of abrasion and cliff collapse (fig 23 -26). The structure of the rocks as seen in these figures is diagonally bedded or not clear, which shows us the cliff is unstable. This is due to the area being more isolated from the populated, commercialised town and therefore there are less methods used for prevention. The lithology of cliff is also different in the northern parts of the bay. The area the groynes are protecting and the area just beyond the groynes is Wealdon stone, and as we can see from the CISA data and my photo analysis; the cliffs are a lot weaker and vulnerable to erosion, unlike when you go further north in the bay where the Greensand is, where the cliffs are a lot more stable as can be seen from the substantial amounts of vegetation coverage from fig 27 and fig 18. At the north of the bay (fig 28), the rock is limestone, which is a harder rock in comparison to the softer rocks further south. This can be seen by that fact it is a headland and that there isn't as much significant slumping that is caused by the sea.

The data has backed up what I would expect from my theory as it shows where the weaker rocks the greater the erosion. It also indicates that some areas are worth protecting more than others for tourism.

What are the subaerial impacts on the cliffs?

The subaerial impacts on the cliffs is mainly noticeable at the end of the where the limestone is present. This is due to the rock being more resistant and the sea having less of an impact on the erosion as can be seen in fig 28. From this photo, we can see there has been significant slumping caused by subaerial processes, however we can only see biological slumping occurring as it is neither raining or winter. This is caused by the roots of plants forcing apart cracks in the cliff and making chunks of material break off. This would be the same in Winter when it is colder and freeze thaw occurs. Chemical erosion occurs when the carbonic acid in the rain reacts with the limestone (calcium carbonate) causing collapses to happen. Although we cannot see some of the processes, we can see the results with slumping high up the cliffs and there being sheer cliffs at the top where the rock has broken off. From this we can see that it is not the human coastal management that is affecting the most northern part of the bay, but the subaerial processes that are changing the cliffs.

The main subaerial process that effects the Wealdon stone cliffs is the weather as when the ground becomes too saturated with rainwater, it slumps and causes rotational slip. This can be seen clearly in figures 22, 23 and 26 with them being an example of recent slumping. In fig 24, the hotel owner has even put a drainage built into their sea wall to help get rid of the water. The plants have a different effect on the Wealdon stone and the Greensand than on the limestone, with adding more support to the cliffs through their roots.

From my data and my theory, it is clear to see that some subaerial processes are more effective on different lithology, as the biological, mechanical and chemical has the most impact on the limestone cliffs whilst it has very little impact on the Wealdon stone and Greensand cliffs, with the plants adding more structure to the cliffs. However, the latter two are a lot more susceptible to rotational slip from the weather as they are permeable and therefore more likely to become saturated with rainfall than the limestone.

Why have the Coastal Management strategies been in some parts of the bay but not others?

This question was relatively clear to answer as the coastal defences are all situated around the around the town, with the intention to protect the buildings but also support its tourist industry. This can be seen from figure 6 with there being the SMP of hold the line around the town. This shows that the town is a lot more valuable than the area to the north of the groynes. These coastal management strategies have also been seen to have been used to protect individual properties such as the Pines Hotel with its wall to protect the slumping of the building (fig 24). From my theory, we also now that is with the council's interest to allow erosion to occur at Ballard Point for the tourist interest of fossil collecting.

How is cliff erosion being managed and are the strategies successful?

Cliff erosion in the Swanage bay is being managed differently in certain areas. Around the town, there aren't any cliff's, but it still has successful defences that have been put into effect with the sea wall, groynes and the beach nourishment. They are successful from what the data tells us with there being a sustained beach width where the groynes have been implemented (fig 13 and graphs 1-6). The SMP strategy, hold-the-line, has been effective at keeping the cliffs protected around the town, however the SMP changes the further north up the bay you go where it changes to no active intervention (see fig 6). Because of this, there is change to the cliffs, with there being more slumping (fig 23-26) due to the deprivation of material (decreased width) via longshore drift, which is being prevented by the groynes. From this we can see that the coastal defences, although may protect the area of beach where it is situated, it causes repercussions as we can see from fig 23, where there is no longer a sea wall and figures 25 and 26 where we can see the impacts of being immediately after the groynes end.

There is also the cliff protection at the Pines Hotel, which although was expensive to build, has been very successful at supporting the cliff beneath the hotel (fig 24). It has performed its job of supporting the cliff, whilst allowing drainage to occur and is deemed a requirement by the locals and will be used to hold beach huts in the future.

To conclude this question, the cliff/coastal protection strategies have been a success at protecting the areas that need to be protected, however they have had further consequences on cliff recession further north with there being an acceleration in erosion.

Hypothesis:

To conclude the data analysis, I would say that I have been able to prove my hypothesis, *'The coastal defences have been successful at reducing cliff recession in the Swanage Bay.'* The data shows obvious signs that cliff recession is worse at the areas without defences and that when the groynes finish, the area after is the most effected with the beach being the narrowest ('13.7m') and the cliffs being in worst condition, as can be seen from the CISA and in fig 26. I would also say that most of the data was a success, with it showing clear trends in some of the results, however there were some discrepancies, but these could be found out why through my other data. To get more precise and accurate results, the tests could have been done more than once in the year or annually. This would show how the cliffs change in a year with different seasons bringing different weather and would also show what happens each year. The beach profile data, could have also have been in done in more detail to show a full profile of the beach as there were undulations in some parts. There were also some parts of the tests carried out that I would change with being able to complete more of the CISA, as it would give a better profile of the cliffs at each point and there would be more useful data that could be used. The data methods I used were not harmful to the environment, as they did not involve damage the environment and nothing was left on the beach at the end.

On a broader geographical scale, this investigation has helped to validate the effects of coastal management, with it proving that where coastal defences are implemented, there is a knock-on effect further along the coast to the cliff recession in a negative way. It has also helped show that the lithology has a significant impact on the recession with some being soft rock and others being hard rock. It also shows how the SMP's are effective and where they should be implemented as with Swanage it uses coastal defences to protect the town, yet it doesn't to protect the low-valued land to the north of the town. This is all down to figuring out a cost benefit analysis. The sediment transportation has been disrupted as the natural flow of longshore drift (fig 5) is north and the groynes are preventing longshore drift from happening, which is having a negative impact on the cliff recession as there is less beach to protect the cliffs. Most of my data findings confirms my theory, as it shows that the coastal defences do have a positive impact on the cliffs that they are protecting and how they are preventing longshore drift, which has led to a deprivation of material to the north of the defences and led to more severe cliff recession than other areas.

There are also other impacts that lead to cliff collapse such as subaerial processes and the weather. This had some effect on my results as it had rained heavily a few weeks prior to the trip and therefore the cliffs were saturated with rainwater more than usual, which would have been one of primary causes for the slumping whilst I was there and would be one of causes all year round. Regarding this, we can assume that not all the changes in the cliffs are down to the coastal defences but because of the weather and subaerial processes.

6.0 Evaluations and Critical reflections:

The data I collected was relatively reliable with none of the results showing anything unexpected. There were a couple of anomalies but that due to a change from a town to a rural environment along the bay or down to factors such as a stream that cut through the beach making an anomaly. The results would have been better if I had more time (i.e. visiting every week), so that I could document the change in the cliffs for a longer time scale. I could have also looked at the wider area, so examining more of bay than I did. I think the methods were also good as they did not interrupt the natural environment in any negative way and when I did my questionnaire it did not touch any sensitive areas as it was either 'yes' or 'no' answer and if the person wanted to give an opinion they could.

The results were accurate however there were improvements that could have been made, with regards to judging the cliffs in the CISA as it was only myself who was creating the data. To change this, I could have looked at previous results on the CISA for the bay and compared them to my own results, or have gotten someone else to also record the results to compare with. This could also have been applied to my 'percentage coverage of vegetation on the cliff face' method. The beach profiles could have also been changed so that it showed a more precise representation of the beach by every change in angle that occurred. This would have given a clearer representation on how the beach was being affected by the coastal defences and give a more conclusive piece of data to see how the defences effect cliff recession.

The conclusions I have obtained from my data compares well with that of the LiDAR data and what the SMP's are trying to do. The LiDAR data (fig 29-31) shows a distinct change in when the coastal defences were implemented and the knock-on effects they have had on the bay. It links to show that where the coastal defences have been implemented, it has affected longshore drift which has meant a deprivation of material to the beach which has led to more cliff recession. My data also shows that the SMP's are working as they are protecting the town and its tourist industry. It shows us how when a sediment cell is interrupted (fig 5) through coastal management schemes it influences the other areas of the bay, often increasing the erosion. My findings have proven what I would have expected from doing my background research at the start of this report, with the softer rocks being the most susceptible to cliff collapse and the area being immediately after where the coastal defences end being the worst affected.

The site I used for my investigation was good as it allowed me to see a transition from the urban area of the town to the rural area of the cliffs beyond the groynes. For extension of this study it would be better to make the area smaller from where the sea wall ends and to beyond the groynes, as it could be then done in more detail and see how the cliffs change on a smaller scale. The investigation could also be more focused on the geology with a consideration for how different rock types are affecting cliff recession or it could be more directed at the effectiveness of the Pines Hotel defences. My methods could also be applied elsewhere to see the how coastal management impacts cliff recession.

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