Coastal erosion at Chanonry Ness

Fig 1

Contents:

Introduction:

Aim-

The aim of this study is to investigate the types of coastal erosion at Chanonry Ness and how they affect the land use. In addition, the management strategies employed in dealing with this erosion were looked at in detail.

Hypotheses-

1. Coastal erosion has no effect on the East coast of Chanonry Ness.
2. Coastal erosion has no effect on effect on the West coast of Chanonry Ness.
3. There is no difference in erosion between the West and East coast of Chanonry Ness.
4. Coastal erosion has no effect on the land use around Chanonry Ness.

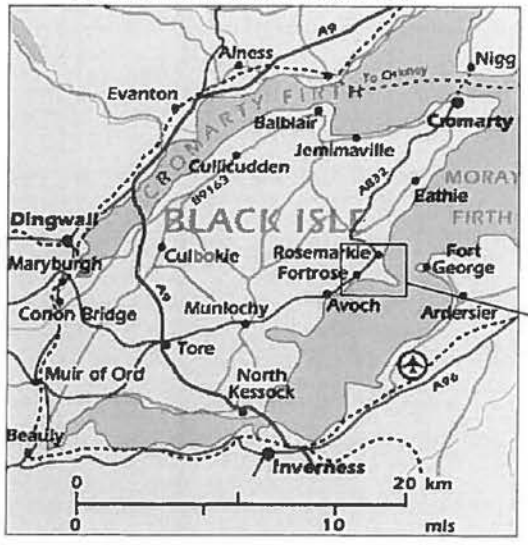
Research Questions-

1. What are the land use types at Chanonry Ness?
2. **(A)** What type of erosion occurs at Chanonry Ness?
   (B) Is there a difference between coastal erosion on the West coast and East coast of Chanonry Ness?
3. How does coastal erosion affect land use?
4. What management strategies are employed in combatting coastal erosion?

Background

Chanonry Ness is an area on the Black Isle peninsula; between the two villages of Fortrose and Rosemarkie. (Fig 2) Chanonry Ness is situated at the coast and the land use types include a links golf course; caravan parks at both Fortrose and Rosemarkie; beach and recent housing development.

Fig 2 (www.fiddleweekend.co.uk)



The promontory of Chanonry Ness is built up on top of a push moraine (www.snh.org.uk). This moraine from the ice age has moved backwards and forwards for a few million years. Consequently, coastal erosion at Chanonry Ness is a significant problem. By trying to combat this problem; it is an attempt to stabilise an unstable environment. Coastal erosion involves the destruction and removal of material along a coastline due to wind and the power of the sea. The prevailing wind direction In Scotland is from South, South West (www.gov.scot). This is influenced by the North Atlantic drift and is a fairly constant feature. The wind direction will vary from day to day, according to the current weather systems. The Black Isle is composed mainly of old red sandstone and Chanonry Ness is a raised beach. Consequently, at the coast the land will be fairly soft and susceptible to erosion (Geological survey of Scotland-sheet 84).

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Methodology:

1. Using a basic outline map of Chanonry Ness- encompassing the area of land between Fortrose high street and Chanonry Ness- a land use map of the area was produced using a variety of colours to represent each land use. (Fig 4)
2. Starting from Fortrose sailing club and finishing at Crofters Bistro in Rosemarkie; photos were taken of sites along the coast affected by coastal erosion. It was noted what type of protection system had been implemented to combat the problem. Notes that were taken relating to levels of erosion and type of protection at each site were used as annotations on my land use map. Photos of each site were also included on the map. (Fig 4)
3. Eleven sites around the coast were chosen to conduct fieldwork at. (Fig 4) These sites were chosen at random. At these eleven sites the following fieldwork was carried out.

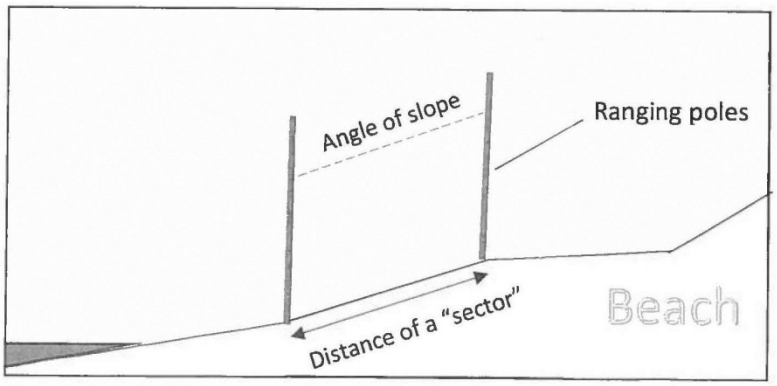
- Beach profiling
- Wave frequency tests

4. From these eleven sites; 4 (two from each side) were monitored over time. These sites were chosen because they were situated at the main land uses of Chanonry Ness- the golf club and the two caravan sites. Once a week, photos were taken of the affected areas to compare the images over time. Measurements were also taken.
5. Personal communication was established with several local authorities on coastal erosion and representatives from both caravan sites and the golf club. They were contacted in order to gain information about the management strategies involved; the relevant organisations involved with these strategies and the effect of coastal erosion on land use.

Gathering information:

Beach profiling- At each site, from the water's edge to the top of the beach, tent pegs were pushed into the sand at every change in angle of the beach along a straight-line transect. (Fig 3) These changes in angle were chosen from observation so won't have been entirely accurate. With the help of , two ranging poles were planted into the sand at consecutive tent pegs. Using a measuring tape, the distance was measured between each pole. The beach gradient of each "sector" was found with a clinometer. The clinometer was lined up with a fixed point on one ranging pole and aimed at the same point on the ranging pole further up the beach. This process was repeated for all the "sectors" at each site. Beach profiles were produced from these results and can be found in Fig 4.

Fig 3



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Wave frequency tests- The number of waves were counted which broke at the coastline in one minute. This test was repeated 3 times at each site to get an average. The wave frequency tests for each site were all carried out on 1/4/16. The average wind speed for Fortrose on this day was 14km/h (www.wunderground.com).

Monitoring over time- Using tent pegs and a measuring tape, the distance between the edge of the small beach cliff and a known point was measured in order to investigate the rate of erosion. Photos were taken from the same perspective at each site to investigate changes in the coastline. These two fieldwork techniques were conducted over several months; from February to May, during a period of particularly bad weather and frequent storms.

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Research Question 1: What are the land use types at Chanonry Ness?

The primary function of Chanonry Ness is for housing. (See Fig 3) Fortrose is an attractive area for people to live because of its beautiful coastal location. The small village also boasts a high achieving secondary school, Fortrose Academy (www.fortroseacademy.co.uk) and is within 13 miles driving distance from the city of Inverness, where the majority of the 9954 residents of the Black Isle (www.highland.gov.uk) will commute to work. As well as residential areas, Chanonry Ness contains associated leisure facilities such as an 18-hole golf course and two caravan sites for tourists.

The short links course, "Fortrose and Rosemarkie golf club" was established in 1793 and is a major leisure facility on the Black Isle. This land use takes up most of the promontory. In September 1940, the golf course was requisitioned by the military authorities as a training ground, where sea landing tactics were practiced in preparation for the D-Day landings. There was considerable damage done to the links course and also the coast. £4000 was given to the golf club by the War Department as means of compensation (www.fortrosegolfclub.co.uk). The golf course is surrounded on either side by strips of beach which are popular with dog walkers. At the tip of Chanonry Ness is Chanonry Point; where thousands of tourists a year come to see the resident bottlenose dolphins.

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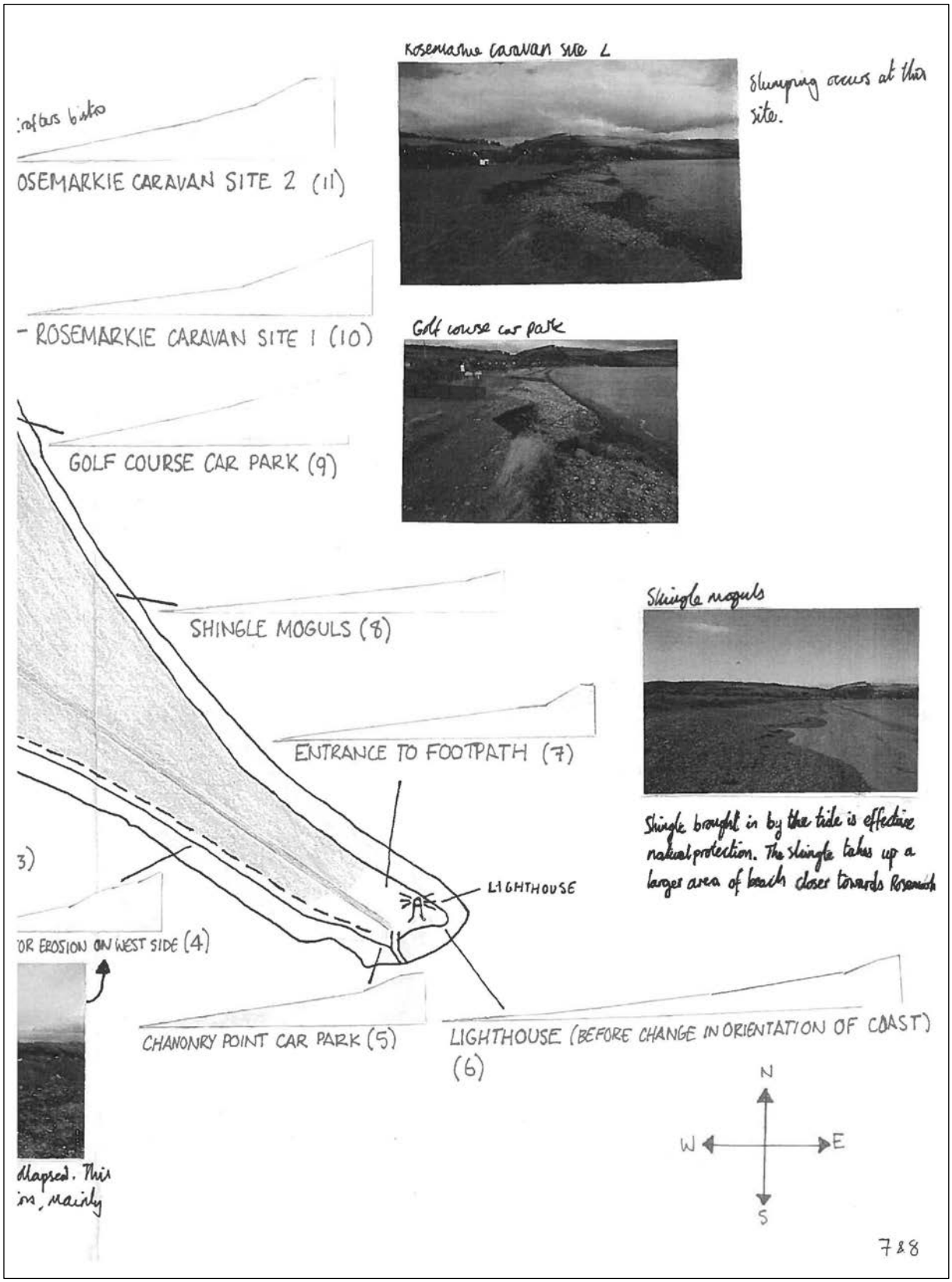
Rosemarkie caravan site 2
slumping occurs at this site.
rafters back
OSEMARKIE CARAVAN SITE 2 (11)
- ROSEMARKIE CARAVAN SITE 1 (10)
Golf course car park
GOLF COURSE CAR PARK (9)
SHINGLE MOGULS (8)
Shingle moguls
ENTRANCE TO FOOTPATH (7)
Shingle brought in by the tide is effective natural protection. The shingle takes up a larger area of beach closer towards Rosemarkie
3)
LIGHTHOUSE
OR EROSION ON WEST SIDE (4)
CHANONRY POINT CAR PARK (5)
LIGHTHOUSE (BEFORE CHANGE IN ORIENTATION OF COAST) (6)
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elapsed. This is, mainly
7&8

Research Question 2 (A): What type of erosion occurs at Chanonry Ness?

At Chanonry Ness, the type of erosion most likely to occur is abrasion (Guinness et al. 2010). Abrasion is the effect of rock fragments held within the water, gradually wearing down rocky beach material by grinding against it. In particularly stormy conditions, a lot of sediment may be hurled at the beach cliff; contributing towards its erosion. The biggest factor affecting the rate of erosion is the strength of the waves hitting the coastline. The higher the wave's energy; the faster the rate of erosion (geographyas.info). A longer fetch allows for larger waves with more erosive power to form. The fetch areas for each side of Chanonry Ness can be compared using Fig 6. Underwater elevation also affects wave strength because as waves approach the coastline, they lose energy because friction with the seabed increases. Bathymetry, therefore, dictates how close waves break to the coastline. Furthermore, energy can be lost from waves on shingle and pebbled beaches due to infiltration. Sandy beaches allow for less infiltration so less erosive energy is lost (www.tutor2u.net). If the beach gradient is steep; this will encourage steeper waves with more erosive power. Fig 5 shows the average beach gradient for all 11 sites around the coast. Each site can be referenced from the land use map of Chanonry Ness (Fig 4) Site numbers highlighted in yellow are on the west side of the coast and those in blue are on the East side. Further discussion of average beach gradient can be found in Fig 6.

Fig 5

Site number	Average beach gradient
1	3.5
2	8.5
3	16
4	17
5	10
6	6.7
7	6.2
8	9.5
9	14
10	15
11	14

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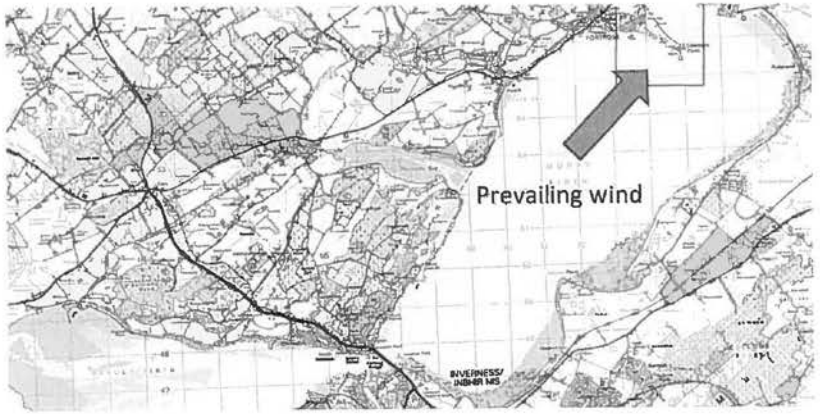
The average beach gradient from 5 sites on the West side of the coast was 11° but on the East side, from another 5 sites it was only marginally higher at 11.74°. However, from my monitoring of the 11 sites and personal communication; I found that the sites which have experienced the most erosion are also some of the steepest.

From observation, the waves breaking on the East side of the Ness break much later and are much larger than those on the West side. The frequency of waves breaking on this side of Chanonry Ness is 23 waves per minute. This side of Chanonry Ness has a huge fetch area; stretching out over the North Sea, approximately 600km (www.google.co.uk) to Norway. This will give waves time to build in height and therefore erosive power.



(www.bing.com)

From observation, the waves on the West side of the Ness are frequent, averaging 23 waves per minute. They are quite weak compared to the East side. They also break much earlier. This side of the Ness has a very small fetch area which is the Beauly Firth. It is a wide and shallow bay which results in waves diverging and energy being lost.

Fig 6 Fetch areas for Chanonry Ness

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A statistical test was set up to find whether there is a relationship between wave frequency and average beach gradient. A scatter graph was first constructed as shown in Fig 8. This method was inconclusive in inferring a relationship, so Spearman's rank correlation was employed. This test was chosen as it can infer a relationship. It was also chosen because the data used was in interval format and could easily be converted into ordinal format. Fig 7 shows wave frequency data.

Fig 7

Sites	1st minute	2nd minute	3rd minute	Average
1	23	25	27	25
2	22	26	23	24
3	23	25	23	24
4	23	23	24	23
5	21	21	22	21
6	19	19	19	19
7	12	12	12	12
8	13	10	11	11
9	10	11	10	10
10	14	12	12	13
11	12	11	10	11

Null hypothesis: There is no relationship between wave frequency and average beach gradient.

Fig 8

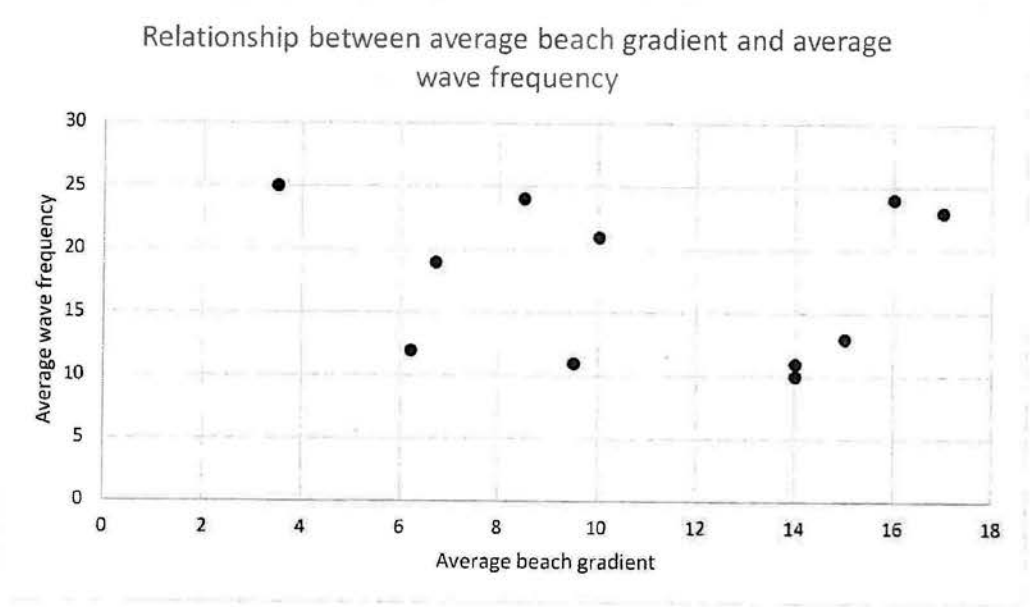

Fig 9

Site number	Wave frequency (X)	Beach gradient (Y)	Rank X	Rank Y	d(X-Y)	$d^2(X-Y)^2$
1	10	14	1	7=	-6	36
2	11	9.5	2=	5	-3	9
3	11	14	2=	7=	-5	25
4	12	6.2	4	2	2	4
5	13	15	5	9	-4	16
6	19	6.7	6	3	3	9
7	21	10	7	6	1	1
8	23	17	8	11	-3	9
9	24	8.5	9=	4	5	25
10	24	16	9=	10	-1	1
11	25	3.5	11	1	10	100

$\sum d^2=235$ n=11 $d.f = n - 1 = 10$

$$Rs = 1 - \frac{6\sum d^2}{n^3 - n}$$

$$Rs = 1 - \frac{(6x235)}{(11^3 - 11)}$$

$$\underline{Rs = -0.068}$$

The result for Spearman's rank of -0.068 at 10 degrees of freedom lies below the 90% significance level of 0.6. The null hypothesis must therefore be accepted; that there is no relationship between wave frequency and average beach gradient. This is unexpected because if the beach gradient is steep; this will produce steeper waves with more energy. A steeper gradient ensures that the waves break later and more frequently. With a shallow gradient, the waves are slowed down more gradually by friction and so their wavelength is longer.

It is possible that no relationship was found because this study of 11 sites wasn't rigorous enough and the sample of sites chosen didn't give a true representation of the population of beach gradients.

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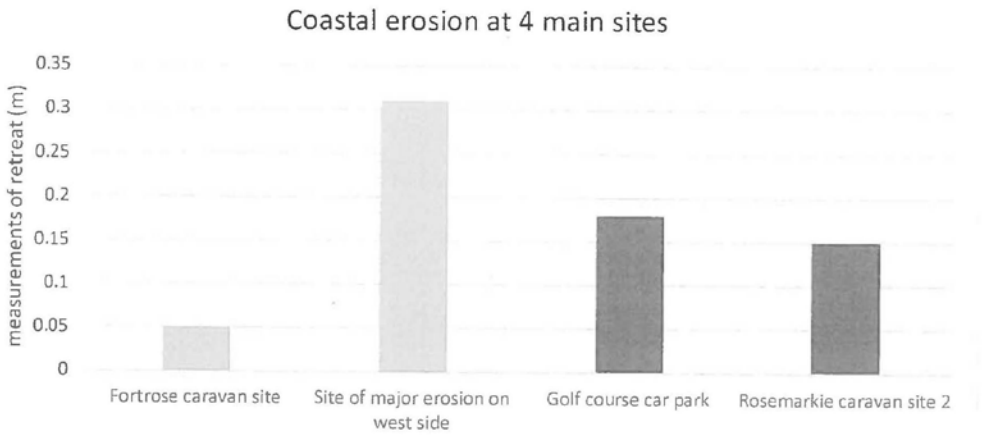
Research Question 2 (B): Is there a difference between coastal erosion on the West coast and East coast of Chanonry Ness?

The four sites that were monitored over a period of three months were sites 2, 4, 9 and 11. These sites were chosen because they were unprotected and it was thought that as a result of this, they would be the most active sites in terms of erosion. Fig 10 compares the level of retreat at each of the main sites.

Fig 10



There was negligible erosion from February to May at the Fortrose caravan site. However, on the same side of the coast, halfway along the golf club footpath there was the highest level of erosion at 0.31m of retreat. On the East side of Chanonry Ness, there was a more constant amount of erosion. There was 0.18m of retreat over a three month period at the golf course car park and 0.15m of retreat at the edge of the Rosemarkie caravan site over the same period.

To investigate the variability from the average retreat at each side of the Ness, the standard deviation (SD) calculation was used.

Fig 11.1 SD of retreat on West side

X	X (mean)	x-X	$(x-X)^2$
0.05	0.18	-0.13	0.0169
0.31		0.13	0.0169

$\sum(x-X)^2 = 0.0338$ n= 2

$$SD = \sqrt{\frac{\sum(x-X)^2}{n}}$$

$$SD = \sqrt{\frac{0.0338}{2}}$$

$SD = 0.13$

Fig 11.2 SD of retreat on East side

x	X (mean)	x-X	(x-X)2
0.18	0.165	0.015	0.000225
0.15		-0.015	0.000225

$\sum(x-X)^2 = 0.00045$ n= 2

$$SD = \sqrt{\frac{\sum(x-X)^2}{n}}$$

$$SD = \sqrt{\frac{0.00045}{2}}$$

$SD=0.015$

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The standard deviation for the west side of the Ness is relatively large at 0.13 in comparison to the East side. This shows that the values for retreat are spread apart. The much smaller standard deviation of 0.015 for the East side shows that the values for retreat are tightly bunched around the mean.

The two sites monitored on the West side of the Ness are unprotected. Therefore, it would be expected that they would both suffer heavily from erosion. However, the minimal level of retreat at site 2 suggests that coastal erosion doesn't have a huge effect on the West side. The west side of the Ness has a small fetch area (Fig 6) therefore the erosive power of the waves will be low and the rate of erosion will be slow. The beach at this site is comprised mainly of shingle so waves may lose erosive energy due to infiltration.

Site 4 lost 0.26m more land than site 2 in three months. The beach gradient at this site is much steeper than site 2 (Fig 4) so steeper more destructive waves will break against the land. The gradient will also have an effect on underwater elevation. The steeper gradient here will mean that underwater elevation is greater so waves will break closer to shore with maximum erosive power. However, the "maximum erosive power" of waves breaking on this side will be limited by the small fetch area. The main factor contributing towards erosion at site 4 will be the prevailing wind. (Fig 6) Fig 12 illustrates erosion over time at site 4.

Fig 12.1 (15/02/16)

Fig 12.2 (15/03/16)

The level of retreat on the East side is fairly similar at the two sites as illustrated by the result for standard deviation. This suggests that coastal erosion is a consistent problem on the East side; more so than on the West side. The East side has a much larger fetch area of around 600km (Fig 6) across the North Sea. The waves will build up more erosive power and will release a huge amount of energy when the break against the land. The waves were observed on the East side as being much more destructive.

The East side of the Ness has a much wider beach (see beach profiles-Fig 4). This would suggest that wave energy is dissipated before the waves reach land. Despite this, the beach profiles on this side of the coast have a much more gradual slope compared to the West side so friction will potentially be less. The beach transects at sites 9 and 11 are more "sandy" than sites 2 and 4 so infiltration by

shingle will be negligible. Figures 13.1 and 13.2 illustrate erosion over time at sites 9 and 11 respectively.

Fig 13.1 (A) (15/02/16)

Fig 13.1 (B) (8/03/16)

Fig 13.1 (C) (12/04/16)

Fig 13.2 (A) (15/02/16)

Fig 13.2 (B) (12/04/16)

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Research Question 3: How does coastal erosion affect land use?

The main land uses around Chanonry Ness are the golf club; two caravan sites and housing.

Fortrose and Rosemarkie golf club is a short links course and there is a constant demand for expansion and more tees. (Pers com-) The secretary of Fortrose and Rosemarkie golf club, , informed me that there was a proposal for an extra tee to be implemented near the out of bounds area and the golf course car park. This plan was scrapped as it was too close to the shore and so there was a possibility of coastal erosion affecting the tee. So, coastal erosion is detrimental to the expansion of the golf course. Each hole at the perimeter of the course needs to be protected from the erosional powers of the sea. The golf course are responsible for managing coastal erosion at their site because Highland Council don't consider this leisure facility a priority. Consequently, the golf course are having to spend more money on coastal protection.

from Fortrose Bay caravan site can be quoted from email correspondence as saying (Pers com-):

"Coastal erosion on the site appears to be minimal so doesn't impact our business as such at the moment".

(Pers com-) The Rosemarkie caravan site have lost four pitches to coastal erosion. New charging ports for the caravans have been established in the past year all the way along the seafront. However, views this as an exercise in futility because if erosion continues; they will be destroyed again resulting in greater financial impact. The footpath at the edge of the caravan site will eventually collapse due to undercutting of the beach cliff. Resultantly, people will start walking on the pitches and this will lead to "footpath" erosion.

The residential land use is not directly affected by coastal erosion because the main areas of housing are not situated at the coastline.

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Research question 4: What management strategies are employed in combatting coastal erosion?

was one of several people in the Fortrose community council whose job it was to look at coastal erosion around Chanonry Ness. During a phone conversation with ; he focussed mainly on erosion at the Rosemarkie caravan site. He noted that:

"Coastal erosion has been a major problem at Rosemarkie caravan site for many years."

(Pers com-) 10 years ago £35000 was put aside by the Highland Council to combat erosion at the Rosemarkie caravan site. This money wasn't spent and no work was done at this time. The coastline has been continually eroding since then but a big storm on 15th December 2012 caused a huge amount of damage to the site.

Due to this event and continuous erosion since then; the cost of dealing with this erosion has risen to between £70000 and £100000.

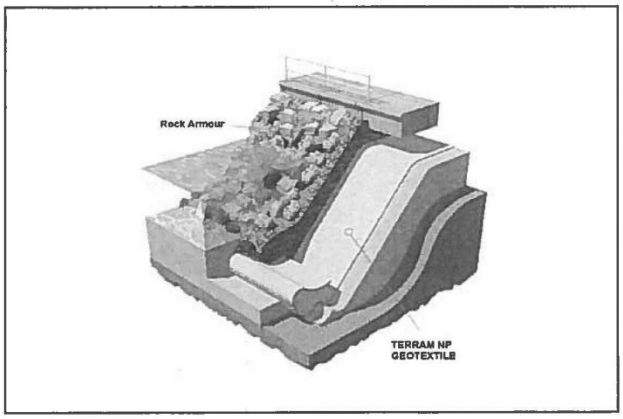
Management strategies proposed for the caravan site are as follows (Pers com-):

- Even out coastline with digger
- Terram filter
- Interlocking boulders which slope upwards

Terram filter

Geotextiles from the company "Terram" can be used to prevent coastal erosion. The hydraulic and filtration properties of Terram geosynthetics allows them to be used highly effectively in place of traditional filter layers (www.terram.com). A single layer of geotextile fabric can replace a succession of stone filter layers.

Fig 14 (www.terram.com)



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Interlocking rocks sloping upwards

Fig 15 (Fortrose sailing club Boat Park)

If you present a slope of large rocks which interlock; the force of the waves crashing against them will push the rocks downwards and therefore secure the rock slope. A disadvantage to this method is that because it is a slope; on a particularly stormy day, waves will crash over the rocks onto land.

The large boulders required might also be expensive and difficult to transport.

This is a very effective management strategy and has already been employed in Fortrose at the Fortrose sailing club boat park. It was proposed for Rosemarkie caravan site but the Highland Council aren't keen on this method. They would prefer a "softer option". (Pers com) , who works an independent tourism consultant; with expertise in the conservation, recreation and tourism sectors, gave his opinion on what management strategies would be most effective.

suggested that if there was more space on the coastal area of Chanonry Ness. "Rock armour" from both interlocking rock slopes and Terram filters wouldn't be used because the force of the waves would just be distributed elsewhere. He reiterated the opinion of the Highland Council that a "softer option" should be used but had more reasoning in his argument.

The idea behind a "softer option" management strategy is that a more shallow slope over a larger distance; made up of shingle or similar, would dissipate the energy of the waves and minimise coastal erosion.

Gabions

Gabions have been employed as a means of erosion protection at areas all around the coast. At the golf course and at one section along the West coast, they have collapsed and the metal baskets have ripped. They are a complete eyesore and are a danger to wildlife and people walking along the beach. They have collapsed due to the rocks just being dumped into the baskets. An effective use of the gabions is at the Rosemarkie caravan site where the rocks have been placed "properly into the baskets.

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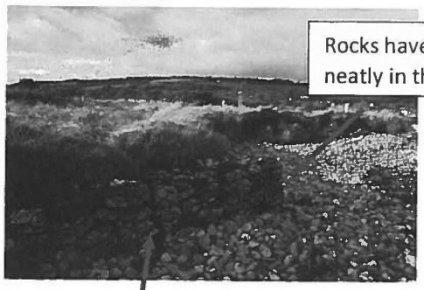
Fig 16.1 Gabions at site 11



Rocks have been arranged neatly in the basket in shelves.

Gabions are at a slight angle to reduce the force of impact from the waves.

Fig 16.2 Collapsed gabions at site 9

Collapsed gabions have left the soil completely unprotected from the force of the sea. They are also not very attractive.

(Pers com-) At site 9, there is a sewage pipe protruding from the soil due to erosion. This site of erosion is therefore the responsibility of Scottish Water because the sewage pipe is their property. Scottish Water are currently working with the golf club to repair this as soon as possible.

A report from the Highland Council is due to be published at the end of the month (May) laying out the council's plans for combatting the erosion around Chanonry Ness. . thinks that stepped gabions and big rock boulders are the most likely preventative measure to be suggested in the report.

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Conclusion:

Coastal erosion, specifically abrasion occurs at Chanonry Ness. Erosion from the prevailing wind also has an impact on the West side of the promontory. The East side of Chanonry Ness is worse affected than the West side in terms of coastal erosion. Fortrose caravan site have noted that there has been no impact on their business. However, the land use on the East side of the Ness; the golf club and Rosemarkie caravan site, have suffered significant financial impact. Coastal erosion is a major problem at Chanonry Ness because the land is a raised beach; therefore the land is very easily eroded. Another contributing factor is that there is not enough protection in place. The sites studied had suffered a large amount of coastal erosion mainly because management strategies hadn't been well maintained or were non-existent. This was particularly evident on the west side, where site 2 showed that coastal erosion on that side of the coast should be minimal. There was some ambiguity as to who was responsible for managing erosion around the Ness. It is not immediately clear what the Highland Council are doing to combat the problem as they own most of the land. This is evidenced by the fact that money has been put aside and nothing has been done with it.

From personal communication with several sources as well as personal observation around the Ness, interlocking boulders are the most effective management strategy. Gabions can also be effective if they are implemented correctly. In relation to the report that is due to be published at the end of the month, it would be very interesting to discover what is being planned to minimise erosion around Chanonry Ness. A much longer temporal survey over several years would give an insight into how effective the new management strategies were. It would also give a better representation of the rate of erosion at the Ness and which sites are most affected.

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