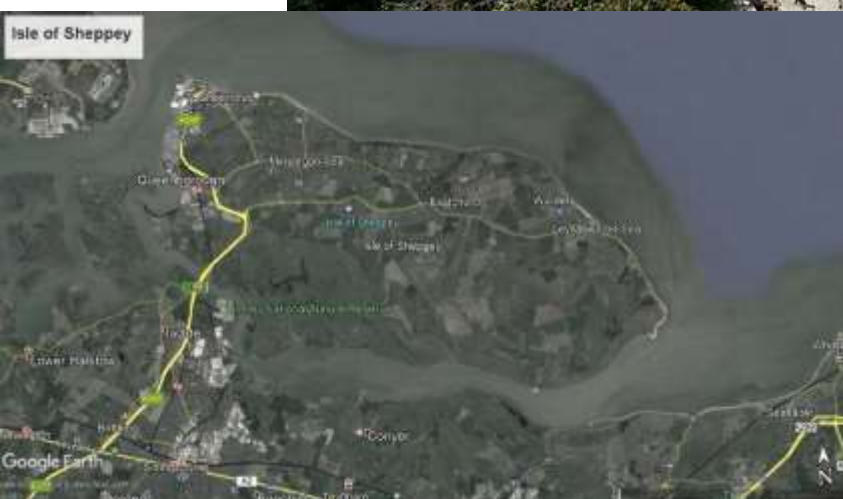


2021

A Remote Rapid Assessment of Coastal Erosion for the Isle of Sheppey, South-East England



Marie West

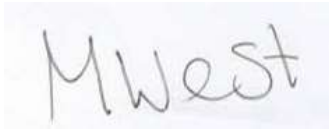
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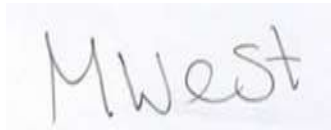
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Abstract

Coastal erosion threatens coastal areas globally; the Severe Acute Respiratory Syndrome Coronavirus 2 pandemic led to a lockdown around the world, meaning many environmental jobs were unable to be conducted. This study focused on using already established data such as historic and present aerial satellite images with documents on geology, precipitation, wind speed, and a GIS to assess whether a rapid assessment of coastal erosion could be achieved remotely. Thomas *et al.*, (2018) was the chosen method with adaption made to suit the selected location, The Isle of Sheppey. Thomas *et al.*, (2018) method consisted of using RMSE to assess coastal erosion from satellite images; this project used this method with added variables such as weather conditions, wind speed, precipitation and geology. These images were viewed in the GIS Google Earth Pro; a base line of 400m with TL laid every 50m set the control points, measurements were taken on each line from the years 1940, 1960, 1970, 1980, 1990, 2003, 2009, 2020 and 2021. The findings were then compared with current SMP for the area and the variables considered. The most significant finding was that the SMP rate of erosion appear to be too low and the remote method of assessing coastal erosion show promises but the method does need work. In conclusion findings suggest that a rapid assessment could be carried remote to assess coastal erosion.

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Abbreviations

- United Kingdom: **UK**
- Shoreline Management Plan: **SMP**
- Percentage: **%**
- Millimetre: **mm**
- Severe Acute Respiratory Syndrome Coronavirus 2: **SARs-Cov-2 or Covid-19**
- Site of Special Scientific Interest: **SSSI**
- Area of Outstanding Natural Beauty: **AONB**
- Great British Pound: **GBP**
- Miles Per Hour: **mph**
- United Nations: **UN**
- European Union: **EU**
- Non-Governmental Organisations: **NGO**
- Root Mean Square Error: **RMSE**
- Geographical Information System: **GIS**
- Linear Regression Rate: **LRR**
- End Point Rate: **EPR**
- Digital Shoreline Analysis System: **DSAS**
- Metres: **m**
- Square Metre: **m²**
- Square Kilometre: **km²**
- Light Detection and Ranging: **LIDAR**
- United States of America: **USA**
- National Ocean Service: **NOS**
- Minster-on-Sea: **Minster**
- Mean Absolute Error: **MAE**
- Transect Line: **TL**

1.0 Introduction

“The coast is the land along a sea. The boundary of a coast, where land meets water, is called the coastline. Waves, tides, and currents help to create coastlines, when the waves crash into the shore, they wear away at, or erode the land” (Boudreau et al., 2011. p.1)

In recent years there has been a continuing interest and awareness in coastal erosion around the world within society, this could possibly be due to the media publishing these events more often; for example, a news report from the Guardian on the 15th of April 2021 discussed a land slip on the Jurassic Coast, Dorset, United Kingdom (UK), where an estimated 300 metres of cliff top had slipped resulting in approximately 4,000 tonnes of sediment being deposited on the beach below (Marsh, 2021); or awareness could be due to communities vocalising concern about the effects on income or employment within the area and the increase in storms and flooding (Allan et al., 2021). The interest in coastal erosion has been present within the environmental community and the scientific community for many years (Mestanza, Piccardi and Pranzini, 2018; Aucelli et al., 2018), but has become more of a public interest due to the effects and impacts on the communities living on the coastline (Allan et al., 2021).

The interest has increased and moved towards possible solutions on how to tackle the decline of the coast line; for example, the use of oyster reefs and possible living shorelines is one of many ways that is thought to help protect the coastline, whether a solution is found now or in the future there is a clear interest in coastal erosion and a solution (Omuombo, Olago and Odada, 2013; Yincan et al., 2017; Neeman, Servis and Naro-Maciel, 2018; Amara et al., 2019; Kumar et al., 2019; Licuanan, Cabreira and Alino, 2019; McLeod et al., 2019; Song and Duan, 2019; Stark et al., 2019).

The risk to coastal communities and wildlife has generated an interest in finding and developing a solution, to slow the process or to be more informed about erosion, for example, Increasingly between 2019 and 2021, other articles have been published that are examining the effect of soil movements, its impacts and solutions for the particular problem, such studies as Unpaved Road Surface Erosion Based on Terrestrial Laser Scanning (Cao, Wang and Liu, 2021), National-scale Geodata Describe Widespread Accelerated Soil Erosion (Benaud et al., 2020) and High-resolution Monitoring of Diffuse (Sheet or Interrill) Erosion Using Structure-from-motion (Candido et al., 2020), these are just to name a few.

The issue of coastal erosion is complex, not every location will have the same parameters and with this knowledge, in recent years the argument of ‘one size’ does not fit all has been made; this is evident in the articles mentioned above (Cao, Wang and Liu, 2020; Candido et al., 2020), instead of focusing on a global phenomenon and solution the interest has changed to individual locations with its own erosion difficulties. This has raised the question of how well do we understand individual erosion locations.

Climate change is becoming an ever-looming problem for current and future occupants of the planet and is a topic that is discussed regularly by leaders around the world (McGrath, 2021). However, a side effect of this change can be seen through coastal erosion, and the longer this change continues the more erosion and desecration is seen by the coastal community and wildlife (Environmental Protection Agency, 2021). Hartmut Aumann, alongside a team – studied the effects of the sea’s temperature on the globe. They found a correlation between the sea’s temperature and an increase in storm frequency (Aumann et al., 2018). The study was carried out over a fifteen-year period, the data concluded that if the surface water temperature was higher than twenty-eight degrees Celsius a storm would be triggered (Aumann et al., 2018). This triggered storm would produce three millimetres (mm) of rain per hour, covering a 16-mile area (Aumann et al., 2018). Further data showed that for every one degree increase in water surface temperature it would produce twenty-one storms (Aumann et al., 2018). This study has shown a consequence of sea temperature increase on coastal erosion; increases in water temperature leads to thermal expansion of sea water, this leads to increase in sea levels which then leads to an increase in storms and flooding. Although the warming is a part of the earth’s natural cycle, it is being intensified by a human-induced climate change; with all these factors it is of no surprise that low-lying areas are being greatly impacted (United Nations, 2017). The study of erosion and coastal erosion has become more prevalent, and many different types of studies have been carried out by scores of scientists and academics.

Although coastal erosion is a natural occurrence it appears that through human influences the process has been antagonised (Adjei-Boateng et al., 2016), currently this discussion continues to take place. The relationship between climate change and human impact, has seen the problem of in-land erosion and coastal erosion increase at rapid rates over the past few years (Borrelli et al., 2017), some areas will see no increase and others will see a large increase; this

is dependent on what the geology and use of land is, among a number of factors, globally the erosion rate has increased by an average of 2.5 percent (%) since 2012 (Borrelli *et al.*, 2017).

The 2019 'State of Nature' report concluded that 41% of UK wildlife species has declined in the past fifty years and a further 13% of wildlife is threatened with extinction in England. Flooding has increased, with '1 in a 100-year event' of flooding happening more frequently, for example, in February 2020 – three named storms hit the UK in rapid succession and created significant flooding inland, forcing the Environment Agency to declare the events 'uncharted waters' (Davies, 2020). The National Ocean Service has been monitoring the rise of sea levels since 1993 and found that rate of sea level rise is "one-eighth of an inch" (National Ocean Service, 2021). To further understand sea level rise, on the 8th of September 2010 sea level had risen to 1.92 inches, by 25th September 2020 the sea level was 3.81 inches (NASA Goddard Space Flight Centre, 2020). In a little over 10 years the sea levels have risen by 1.91 inches, this is actually more than they predicted. As stated above, all these factors when added together, or individually, have serious consequences. With extreme precipitation, the river basins are impacted, and this leads to soil erosion, depending on the geological area, some soils are vulnerable to degradation and landslides (Young, 2014).

There are many different methods used to assess erosion rates, the method used mostly in the UK is the Shoreline Management Plan (SMP). The assessment is carried out by a contracted body for the Environmental agency (or the Environmental department within the government). The assessment will work with other strategies and policies to arrive at a conclusion (Plymouth Coastal Observatory, 2021). The aim of a SMP is to reduce possible risks to property, people, historic places, and the natural environment by providing a long-term management plan for coast communities (Plymouth Coastal Observatory, 2021). There are a number of steps to this assessment such as, a Strategic Environmental Assessment Background, The appraisal Process, Stakeholder Engagement, The Existing Environment, Environmental Objectives, identification and Review of Possible Policy Scenarios, Environmental Effects of the Preferred Plan, Monitoring Requirements, Habitat Regulations Assessment and Water Framework Compliance (Halcrow Group Limited, 2010) – all of these areas will need to be assessed to provide a conclusion of what SMP would best suit the area.

1.1 Links to Present Work

In section 1.0, it is clear to see that the environment needs great care. In the first few months of 2020 there were a few events that happened, such as, devastating wildfires in Australia, conflict between different countries with talks of war, the Taal Volcano erupted which was classed as a level 4 and a mysterious virus spreading around the world (Salo, 2020). By February, the virus was named Severe Acute Respiratory Syndrome Coronavirus 2 (SARs-COV-2) (World Health Organisation, 2021), also known as Covid-19. This virus put the world at a standstill, as if the globe just stopped moving while the Homosapiens acted. March 23rd, 2020, the UK was put into lockdown (Government, 2020).

By April 2020 46.6% of the population in the UK was working from home or remotely (Cameron, 2020). Although the world has seen many different pandemics throughout history it seems that Covid-19 took the planet by surprise and caused the global economy to take a hard hit (Fuentes and Moder, 2021: West 2020). Due to the rapid spread of the virus many other world issues took a step back and Covid-19 became the foremost problem to solve, this meant that environmental issues and solutions by bodies in power were no longer considered or acted upon during this time, in the opinion of the author, and this left the environment to care for itself with great results; however, climate change did not stop, and erosion still took place all over the world. The global lockdown had a few positives regarding the environment, for example air pollution levels improved with approximately 30% drop in Nitrogen Dioxide (NO₂) levels in June 2020 (Kumar *et al.*, 2020: West, 2020).

Since the lockdown it has become apparent that new methods and technology is needed to assess and manage the environment. Lockdown caused a lot of people to experience hardship due to not being unable to go to work, individuals employed in construction, environmental assessments and driving services (Taxis, Ubers etc) were not able to work from home. While the world was at a standstill it was incredibly hard to carry out environmental

assessments, conservation and monitoring of the environment and wildlife; This dissertation research utilised the circumstances to see if it was at all possible to undertake the same research using digital tools in contrast to , what would have been the norm pre-Covid, to site visits.

1.2 Present Work

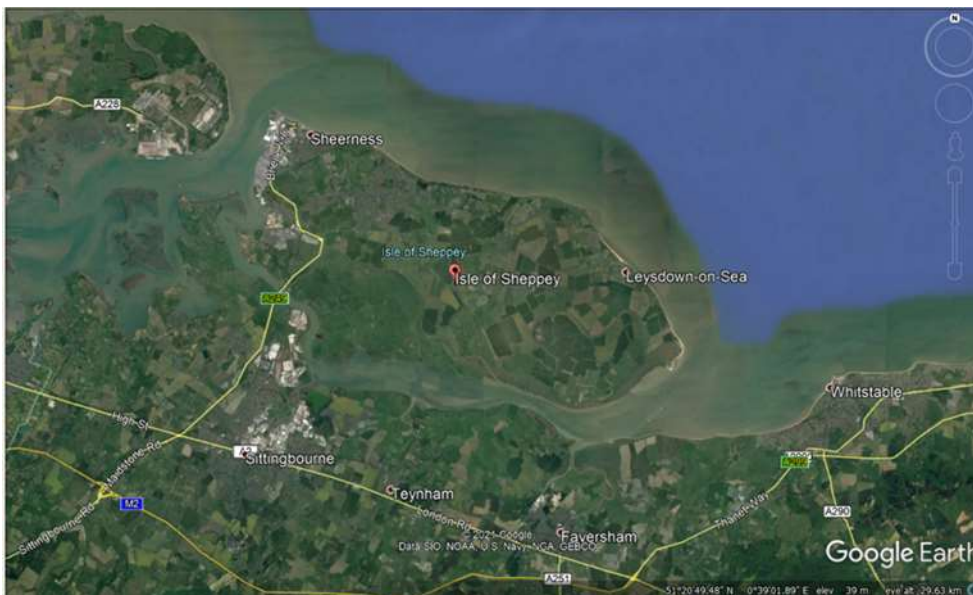
As mentioned in section 1.0 the subject area of erosion is focusing more on solutions or management then the actual process of assessing how much erosion is happening in one place.

A research project in 2020 carried out by Marie West, examined the Physical Vulnerability of Coastal Areas on the Isle of Sheppey. Applying Palmers 2011 method and Shoreline Management Plans, the study concluded that one of the most vulnerable locations was Surf Crescent Road (West, 2020); by using these methods it was found that the house that was situated in this location would have an estimated 18 years before succumbing to erosion (West, 2020). However, in June 2020, a month after the research project was completed, the house and all personal belonging in Surf Crescent Road was taken over the side of the cliff. Therefore, one can conclude that these methods are no longer accurate in estimating the rate of erosion. The ongoing Covid-19 situation made it apparent that a new method that allows monitoring and time scales of erosion is required, and one that enables the carrying out of these types of tasks from a safe distance.

The main goal of this research project is to establish whether the rate of erosion can be rapidly assessed with accurate results remotely by only using photographs, present and historic satellite images, documented information such as precipitation, wind speed and documentation of past landslips. A location for this project has already been selected, The Isle of Sheppey, Kent, UK is the test area for this project.

1.2.1 Location

In the South-East of England there is a 16 kilometre long, 7 kilometre wide with an area of 90 square kilometre (Young, 2014) island called the Isle of Sheppey. The island sits in the North-East of Kent, at the mouth of the River Thames and the River Medway (Judge, 1997), with a Swale that detaches it from the mainland (Young, 2014). The population is an estimated to be 22,021 (Kent County Council, 2019) and the main source of income for the area is tourism with approximately 20 caravan parks. Sheppey is surrounded by water on all sides, with the rise in sea level the island is in danger of succumbing to the sea (Young, 2014).



With an array of different habitats on Sheppey there is a need for individual strategies to manage each environment in regards the impact of coastal erosion. Sheppey's geology consists of London Clay, with large amounts found on the North Side (Young, 2014). The North side is one of the sides most exposed to the sea (Hopps, 2018).

Coastal erosion has been happening for a very long time on Sheppey, the first documented account was in

Figure 1.1: Isle of Sheppey's Location in England

1595, St James Church, which was first lived in by James Barnard (Hasted, 1798); was erected to replace the previous church that

had been lost to the sea due to erosion (Tyler, 1995).

"The small hamlet of Warden had almost disappeared, for here the coast erosion is at its worst, and within 700 years, two churches have been claimed by the sea" (Tyler, 1994: p.132)

These records show that Sheppey has been experiencing coastal erosion since at least the 16th century. By 1883, St James Church remaining churchyard was deposited into the sea below by a large land slip at Warden Point; after the

churchyard was taken the remaining land was estimated to be one hundred and fifty acres, but this land was once five hundred acres in size (Judge, 1997). At present, it is thought that 1.5 metres per annum on average is eroding on Sheppey (Canterbury City Council Engineering Service, 2011).

Although there is a large population at risk of losing their homes on the Island, Swale Borough Council has yet to commission an up-to-date vulnerability assessment for the area. The last report was undertaken in 2011 by the Engineering Services, and while recommendations were made, some do not appear to have been adhered to. However, in 2018 the Environment Agency did complete a ‘flood and erosion risk management’ assessment. This report highlighted the need for recommended actions to be undertaken that differed to those recommended in the Engineering Services Report of 2011.

Cost is a serious consideration that often limits the options available to local councils and currently the UK Government is challenging Local Planning Authorities to take a long-term view. In some cases, communities could be faced with coastal retreat rather than ‘defend the line’ options. In the case of the Isle of Sheppey, environments are very different and will likely need different, site-specific management.

1.2.2 History of the Isle of Sheppey

“Sheppey was first mentioned in “Geographike Huphegesis” written by the Greco-Roman historian, Ptolemy in the year 161 A.D. It was then called “Toliapis”” (Tyler, 1994: p.1)

The Isle of Sheppey has an abundance of history, some of the different locations can be seen on Figure 1.1 and historical moments are listed in table 1.1.

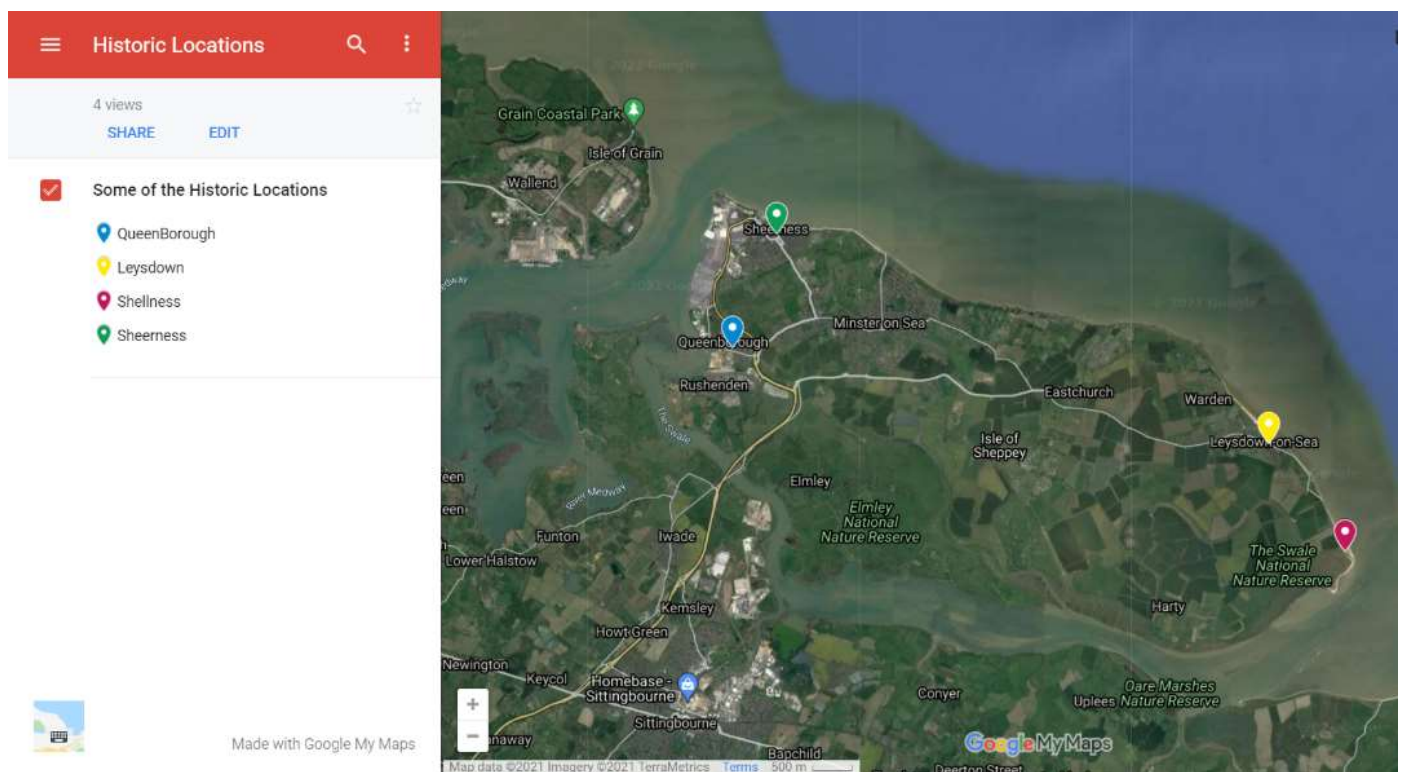


Figure 1.2: Historic Locations on the Isle of Sheppey

Table 1.1: Historical Moments on the Isle of Sheppey (West, 2020)

Location and Year	Historical Event
Queenborough, 1338	King Edward III and Queen Philippa, started building Queenborough Castle (completed in 1361); The King and Queen held much love for Sheppey, and they converted Minster and the Bynne marshlands into towns (Tyler, 1994)
Leysdown, 1752	Mr. Edward Jacobs from Faversham moved to the island (Tyler, 1994) and was one of the first geologists to attempt to catalogue and identify fossils found on Sheppey (Judge, 1997). Mr. Jacobs found many rare and interesting items, a few are a skull and tusks like elephants, bones of primitive animals with hooves, a large, scaled fish with teeth meant for crushing (Judge, 1997) and many more fossils. Mr Shrubsole (hundred years after Mr. Jacobs), from Sheerness, a geologist also found fossils (Judge, 1997). these findings are thought to provide evidence the island was once a tropical land. It is because of these fossils and ones still being found that the cliffs from Minster to Warden Bay was given a Site of Special Scientific Interest (SSSI) (Swale Borough, 1984)
Eastchurch, 1911	The Short Brothers built a twin-engine for an aircraft (Tyler, 1994). The Short brothers were the first to build a British manufactured aircraft and built the first aircraft factory on the Isle of Sheppey, situated in Eastchurch and then Shellbeach (English Heritage, n/d) (now known as Shellness).
The Isle of Sheppey, 1916	The whole island is declared a controlled military location, becoming one of the largest military bases – known as ‘Barbed Wire Island’ (Hughes, 2006). The Royal Navy base in Sheerness was considered a key location to fight against any enemy attacks (Hughes, 2006).
Sheerness, 1940	While the Dunkirk operation was active the Navy dockyard at Sheerness was used as an assembly point for the ‘little ships’ (Hughes, 2006).
	One and half miles off the shore at Sheerness on the 20th of August 1944 the SS Richard Montgomery sank; at the time of her sinking she was carrying ‘13,064 general purpose 250lb bombs, 9,022 cases of fragmenting bombs, 7,739 semi-armour piercing bombs, 1,522 cases of fuses, 1,429 cases of phosphorus bombs, 1,427 cases of 100lb demolition bombs and 817 cases of small arms ammunition’ (Tony, 2007: p.1). By September of the same year half of the explosives were removed by a company in Rochester (Tony, 2007). The SS Richard Montgomery is still in this location and is talked about every year because of the danger to the surrounding areas located around the ship. In 1970 an assessment was carried out on the wreck by the Royal Military College of Science which predicted what would happen if the remaining bombs were to explode. <i>‘a 3,000-metre-high column of water and debris and a five-metre-high tsunami. This would overwhelm Sheerness and the Water wave, possibly carrying burning phosphorus’</i> (Harris, 2019: p.1)

1.2.3 Weather and Previous Erosion Events

The weather conditions on Sheppey are very typical of the South of England; In the spring the weather is moderate precipitation with the occasional warm day, summers tend to be hot, very humid and can reach up to 25-30 degree Celsius on Average (BBC Weather, 2020). Autumn is very similar to the spring weather, while the winter can be very cold and wet with snow in January-February months (BBC Weather, 2020). Table 2 shows some of the noteworthy weather events that Sheppey has been subjected to in the past, along with erosion events that happened in the same year.

Table 1.2: Note Worthy Weather and Erosion Events on the Isle of Sheppey (West, 2020)

Year and Weather	Erosion Event
<u>Winter 1971-1972:</u> Very Wet and overcast, lasted for 3 months (Anon, 2002a)	<u>November 1971:</u> Landslip at Warden Point, 30 metres of land lost over a 200-metre area (Swale Borough Council, 2013)
<u>Winter 1978-1979:</u> Coldest winter in 20 years (Anon, 2020a). <u>Spring 1979:</u> The coldest and wettest in the 20th Century (Anon, 2020a). <u>Winter 1979-1980:</u> Winter listed as one of five winters to have five or more gale storms (Anon, 2020a). <u>Spring 1980:</u> Driest spring experienced in 30 years (Anon, 2020a)	<u>March 1979:</u> Landslip at Swanley Farm, 1 acre was lost, dropping by 30 metres (Swale Borough Council, 2013). <u>January 1980:</u> Ashcroft Coast Holiday Park, landslip of 30 metres, two caravans were lost (Swale Borough Council, 2013).
<u>March 2013:</u> low pressure with large snowfall and high winds, lasting approximately 10 days (Anon, 2020a). <u>Spring 2013:</u> Coldest recorded for the area since 1962 (Anon, 2020a). <u>Summer 2013:</u> Warmest since 2006 with thunderstorms, high winds, heavy precipitation, and large hail (Anon, 2020a). <u>Winter 2013:</u> Heavy precipitation and very wet (Anon, 2020a).	<u>Date unknown 2013:</u> Ashcroft Coast Holiday Park have a large landslide, lending to the owners having to retreat their caravans further inland (Nurden, 2016a)
<u>September 2016:</u> heatwaves with flash flooding (Met Office, 2020). <u>November 2016:</u> Strong winds and heavy precipitation from Storm Angus; rain caused flooding damaging the South Coast (Anon, 2020a).	<u>October 2016:</u> Ashcroft Coast Holiday Park lost 70 feet of land to a landslide due to heavy precipitation (Nurden, 2016a)
<u>Winter 2019-2020:</u> 5th wettest winter since (1862), the 5th Mildest (Met Office, 2021). Strong and high winds, storms Ciara, Dennis and Jorge carried on through the first few months of 2020 (Met Office, 2021). <u>February 2020:</u> Above average precipitation by 237%, some locations experience three times their average (Met Office, 2021). <u>Spring 2020:</u> Drier and more consistent weather, 626.2 hours of sunshine (Met Office, 2021). <u>Summer 2020:</u> Warmer, wet, and dull, a few hot moments, the highest temperature being 37.8 degree Celsius (Met Office, 2021). <u>Autumn 2020:</u> warmer than average, a few wet days with storm Alex in October and flooding in places (Met Office, 2021).	<u>May 31st 2020:</u> A home worth £195,000 started to topple over the edge of Minsters Cliff, the house was located on Surf Crescent Road (Pyman, 2020). By the 2nd of June, the house and personal belongings were fully over the edge (Pyman, 2020) (can be seen in figure 2 and 2.1). This landslide has left the owner and family homeless with two properties close by also being asked to vacate their homes (Pyman, 2020).

These are just a few documented events. For unknown reasons, the Isle of Sheppey appears to be forgotten by the governing bodies, and information is not regularly documented, for example a weather report dated from 1097 can be found but there are no other reports until 1760.



Figure 1.3: The position of the House on the 1st of June 2020



Figure 1.4: The House at Surf Crescent Road over the Cliff, sat on top of the landslide, 2nd of June 2020

1.2.4 Economics

The Isle of Sheppey is part of Swale Borough; this Borough consist of four towns and many different villages (CPRE Kent, n.d.). Sittingbourne and Faversham are two of the towns and are located on the mainland, while Sheerness and Queenborough are located on the Isle of Sheppey (CPRE Kent, n.d.). Swale Borough is comprising of countryside and villages, the borough contains North Down Area of Outstanding Natural Beauty (AONB).

A large percentage of Sheppey's economy is made through tourism (Tyler, 1994). This can clearly be seen in the Destination Research report from 2015 on the Economic Impact of Tourism in Kent, this report showed that Swale Borough ranked 6th for domestic trips (West, 2020). Overnight stays in Swale Borough equate to £45 Million Great British Pounds (GBP) per annum; regarding international stays, the Borough ranked 9th with £11 Million GBP being spent by people overseas in the area, this was in comparison to the 13 districts in Kent (West, 2020).

In section 1.2.1, the Isle of Sheppey is estimated to have 20 caravan parks. Twelve of these parks are located along the cliff tops in Minster, Eastchurch and Warden Bay. With this information there is no question that the Sheppey and Kent economy would suffer greatly if these parks were to disappear. It is not just these parks at risk but the residential homes that also preside on the cliff tops. A report carried out by the environmental agency from 2015 identified at least 16 homes that are in danger of toppling over the edge in Eastchurch (BBC, 2015). This report did not include the farmland and residential home in Minster and Warden Bay, this report was carried out 6 years ago and appears to have had no more assessments carried out since.

Not only would the residents and economics be affected if these cliffs continue to be left unmonitored, but so would large parts of the UK. The Isle of Sheppey has a Port in Sheerness which handles shipments of cars, vegetables, and meat (Anon, 2020b), which is later despatched to parts of the UK, the there is a concern that this shipping route could be impacted with large amounts of sediment being deposited into the route, this one of the main concerns of the locals.

1.2.5 Fauna and Flora

Sheppey is home to some uncommon, rare, and endangered species of fauna and flora. Elmley Nature Reserve is situated on the south side of the island facing the mainland, on this reserve Lapwings (*Vanellinae*), Redshank (*Tringa tetanus*), different species of butterflies, a few rare bee species, and many other Fauna (Elmley National Nature Reserve, 2020). Several different flora species can be found on Sheppey, such as, House Ash (*Fraxinus spp.*), Sycamore (*Acer pseudoplatanus*), Hawthorn (*Crataegus spp.*) and English Elm (*Ulmus minor 'Atinia'*) (Bamin, 2014).

Another interesting fauna species that can be found on Sheppey is the *Euscorpis flavicaudis*, commonly known as the Yellow-Tailed Scorpion, which can be found near the dockyard in Sheerness (Bamin, 2014). The population is estimated to be 15,000 – this nest is the longest established and most fruitful within the UK, which dates all the way back to the 1800's (Finnie, n.d.).

Sheppey is also home to 207 red listed or county conservation ranked species of invertebrates (Bamin, 2014). Table 1.3 shows the rare species of invertebrates and their locations.

Table 1.3: A Few of the Rare Invertebrates Species Found on the Isle of Sheppey (West, 2020)

Species	Located
Stag Beetle (<i>Lucanus Cervus</i>)	All over Sheppey
Great Silver Water Beetle (<i>Hydrophilus piceus</i>)	All over Sheppey
Striped Horsefly (<i>Hybomitra expollicata</i>) and Saltmarsh Horsefly (<i>Atylotus latistriatus</i>)	Northern parts of Sheppey (Cliffs)
Sea-aster Bee (<i>Colletes halophilus</i>)	West and South sides of Sheppey
Shrill Carder Bee (<i>Bombus sylvarum</i>)	Along the Northern parts of Sheppey
Hairy Rove Beetle (<i>Emus hirtus</i>)	This species can only be found in two places in the whole of England, one being Elmley on Sheppey

1.2.6 Geology, Precipitation and Wind Speed

The Isle of Sheppey has an interesting assortment of sediment; predominantly Sheppey consists of Alluvium sediment and London Clay, with Head, Bagshot Beds, Claygate Beds, Blackheath Beds and Upper Chalk found on this cliffs (Young, 2014), this can be seen in Figure 1.5.

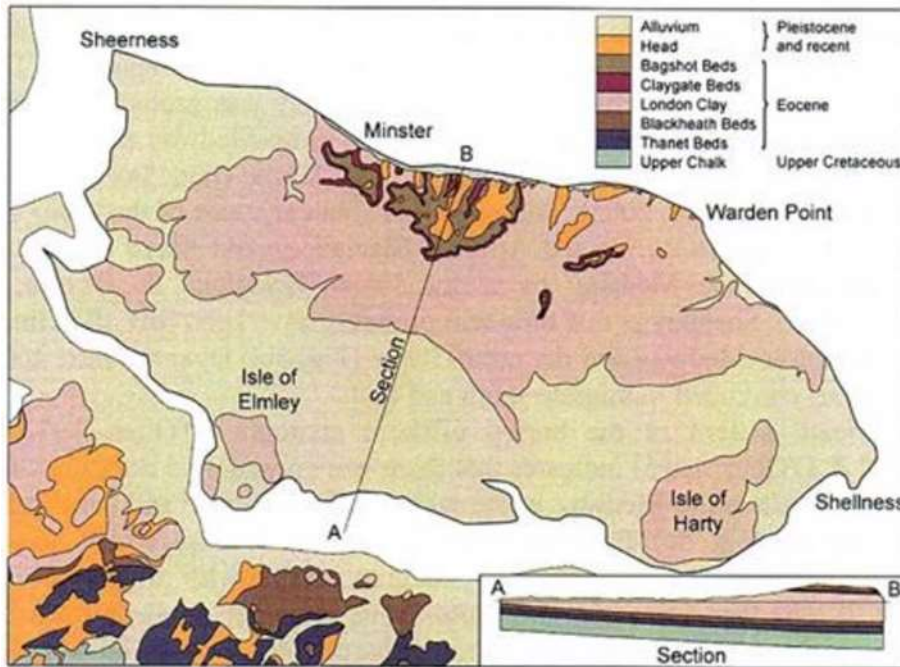


Figure 1.5: Sediment Break Down on the Isle of Sheppey (Young, 2014)

The London Clay is thought to have been laid in the Eocene period 48-52 million years ago; along the Thames Estuary (Young, 2014). The thickest part of the London Clay is located in Minster, estimated to be 146-157 metres thick (Young, 2014). The Claygate beds are thought to be up to 3 metres thick while the Bagshot Beds have 10 metres or less thickness, this is thought to give a form of protection to the London Clay (Young, 2014).

Due to the location of the Isle of Sheppey its climate is oceanic, on average 162 days of the year it is dry, with average temperatures of 14 degree Celsius and a humidity of 82%; the average annum precipitation is 283mm (Best Time to Visit, 2021). The Wind speed can vary

from 3 or greater miles per hour (mph) to greater than 38 mph, however, the average windspeed on Sheppey is 18.8 mph (Meteoblue, 2021).

1.3 Rational

Climate change and subsequently coastal erosion is a global phenomenon. Some erosion is natural, but climate change is speeding this process up, which will impact an estimated 2.4 billion people that live on the coast (United Nations, 2017). It is estimated the 17% of the UK coastlines are impacted by erosion (Marine Climate Change Impacts Partnership, 2020); England's coastline is impacted 30%, Wales is 23%, Northern Ireland is 20% and Scotland's is 12% (Masselink and Russell, 2008).

When Covid-19 caused the UK to go into lockdown in March 2020, a lot of the population was forced to work from home, and try and work as normally as they could, but many became unemployed. By April 2020, 46.6% of the UK population was working from home or remotely (Cameron, 2020). It was a necessity that the population stayed home, however, this was impossible for certain jobs, this led to the realisation that many environments were not being monitored or environmental assessments were not being carried out. The realisation of the benefits of being able to carry out remote evaluations was considered. This new approach would allow Agencies, organisations, and Government bodies to carry out quick and relatively inexpensive assessments in the future should something like Covid-19 happen again.

1.4 Research Question

The research question is: Would using remote methods such as historic and present aerial satellite images with documents of geology, precipitation, wind speed, and a Geographical Information System (GIS) aid in achieving rapid, accurate results of coastal erosion by applying remote methods?

1.4.1 Aim and Objectives

The aim is to determine if a rapid assessment on coastal erosion can be carried out remotely with accurate results.

The objectives of this research are:

- 1) Calculate the distance of land lost by analysing historic and present satellite images in a Geographical Information System of locations experiencing coastal erosion.
- 2) Compare and establish the rate of erosion in the current shoreline management plans with collected finding, and weather patterns
- 3) Evaluation of these areas will be inspected by applying the Root Mean Square Error calculation (RMSE) method.

1.5 Contribution of the Research

This research would allow rapid assessments to be done from anywhere in the world, instead of using many different types of tools, equipment and could be applied to any area, instead of having to adapt a method to suit the location. The rapid assessment would allow results to be gained quickly, safely and inexpensively thus allowing a management plan to be swiftly put into action. With some methods, a geotechnical survey for example, by the time the results are collected and reported the situation of the location has changed, due to climate change, land use, population etc. This research remote model has a great potential to contribute to the environmental, conservation and scientific community by applying these steps. However, this is a method that has been adapted and combined with others, which means it is experimental and has the possibility of not gaining the results that the author hopes for, in addition the selected location lacks a lot of documentations and incorrect information.

1.6 Structure of Dissertation

The structure of this research project will be laid out as follows:

1.0 Introduction

1.1 Links to Present Work

1.2 Present Work

- 1.2.1 Location
- 1.2.2 History of the Isle of Sheppey
- 1.2.3 Weather and Previous Erosion Events
- 1.2.4 Economics
- 1.2.5 Fauna and Flora
- 1.2.6 Geology, Precipitation and Wind Speed

1.3 Rational

1.4 Research Question

1.4.1 Aim and Objectives

1.5 Contribution of the Research

1.6 Structure of Dissertation

1.7 Conclusion

2.0 Literature Review

2.1 Objectives and Focus of Research

2.1.1 How the Literature Review was Conducted and Structured

2.2 Geographical Information System (GIS)

2.2.1 History of Geographical Information System

2.2.2 How Geographical Information System that have been used in Studies of Coastal Erosion

2.2.3 Historic and Present Satellite Photographs

2.2.4	
2.3	Weather Patterns and Sea Level Rise
2.3.1	Weather and Erosion
2.3.2	Shoreline Management Plan
2.4	Root Mean Square Error (RMSE) Formula
2.4.1	Studies where RMSE has been used
2.5	Conclusion
3.0	Methodological Review
3.1	Introduction
3.1.1	Tool Used to Gather Data
3.2	Justification Against Other Methods not used
3.2.1	Root Mean Square Error (RMSE) Formula
3.2.2	Sample Area
3.3	Research Method Limitations
3.4	Conclusion
4.0	Results
4.1	Location Imagery
4.2	Yearly Transect for Each Site
4.2.1	Redcot Resort World to Bellfarm Lane
4.2.2	Empty Field to Bellfarm Lane
4.2.3	Warden Springs Caravan Park to Warden Road
4.2.4	All Years Transects Over Lapped
4.2.5	Root Mean Square Error
4.3	Conclusion
5.0	Discussion
5.1	Introduction
5.1.1	Location Imagery Results
5.1.2	Yearly Transect for Each Site: Results
5.2	Review of Literature in Section 2
5.2.1	Weather and Erosion
5.2.2	Shoreline Management Plan
5.2.3	Root Mean Square Error
5.3	Research Question, Aim and Objectives
5.4	Conclusion
6.0	Conclusion
6.1	Introduction
6.2	Contribution to Knowledge
6.3	Limitations
6.4	Future Research and Recommendations
7.0	References
8.0	Appendices

1.7 Conclusion

In Conclusion, coastal erosion has been a continued problem for many parts of the world. The increased erosion is thought to be caused by climate change and the influence of humans but is still a natural occurrence (Adjei-Boateng *et al.*, 2016). For every increase in Celsius the seas warms, 21 storms can be expected (Aumann *et al.*, 2018) and the sea has risen by 1.91 inches since 2010 (NASA Goddard Space Flight Centre, 2020); which could be linked to the 2.5% increase (Borrelli *et al.*, 2017) in Global erosion rates.

There is not one method to measure erosion that fits every location experiencing erosion. The subject of erosion has changed direction within the last few years, and the focus is now on finding a solution by focusing on one site instead of every location experiencing erosion, this can be seen in studies such as Unpaved Road Surface Erosion Based on Terrestrial Laser Scanning (Cao, Wang and Liu, 2021), National-scale Geodata Describe Widespread Accelerated Soil

Erosion (Benaud *et al.*, 2020) and High-resolution Monitoring of Diffuse (Sheet or Interrill) Erosion Using Structure-from-motion (Candido *et al.*, 2020).

The need for new methods with new technology has become more apparent with the Covid-19 pandemic; with nearly half the UK population having to work remotely and many more unemployed (Cameron, 2020). While the world did see some positive reactions within the environment in the time frame humans were locked inside, this will not last as the world returns to some sort of normalcy (Fuentes and Moder, 2021).

This project could prove beneficial to many communities around the world, as it will allow rapid assessments to be carried out, allow quicker response time, and potentially lower the risk to coastal communities and wildlife.

2.0 Literature Review

The aim of this research project is to apply a method that would allow a rapid, remote assessment to be conducted on eroding coastlines, this will initially be applied to a selected location with varying sites. For this method to be effective It is important to collect geology, precipitation rates, wind speed, current SMPs, present and historical patterns; this data could aid in showing insights into future events and a review of relevant literature is necessary to lay the foundations of the research project.

2.1 Objectives and Focus of Research

The objectives of this research project are to:

- 1) Calculate the distance of land lost by analysing historic and present satellite images in a Geographical Information System of locations experiencing coastal erosion.
- 2) Compare and establish the rate of erosion in the current shoreline management plans with collected findings, weather patterns and sea level rise.
- 3) Evaluation of these areas will be inspected by applying the Root Mean Square Error calculation (RMSE) method.

The main focus of this research project is to determine if a rapid assessment of coastal erosion can be carried out by using documents and data already available, such as, wind speeds, SMP's, precipitation rates, geology of locations, historic and present satellite images.

2.1.1 How the Literature Review was Conducted and Structured

The literature review has been conducted by examining and using previous studies carried out by other members within the environmental and scientific community. Journals such as, Geodrama, Nature Communications, CATENA, Science Direct, just to name a few, have been used to conduct this literature review. Government documents have been used to obtain certain information regarding the UK and the selected location, other countries government documents have been used when applicable. Intergovernmental organisations such as the United Nations (UN) and European Union (EU) document have been used; and Non-Government Organisations (NGO) data and documents have been used when applicable. The documents and data help to lay the foundation of the research and investigation that will be carried out in later chapters.

The following structure will focus on the literature surrounding the three objectives, the structure will be as follows:

2.2 Geographical Information Systems (GIS)

2.2.1 History of Geographical Information System

2.2.2 How Geographical Information System have been used in Studies of Coastal Erosion

2.2.3 Historic and Present Satellite Photographs

2.3 Weather Patterns and Sea Level Rise

2.3.1 Weather and Erosion

2.3.2 Shoreline Management Plan

2.4 Root Mean Square Error (RMSE) Calculation

2.4.1 Studies where RMSE has be used

2.5 Conclusion

2.2 Geographical Information System (GIS)

A Geographical Information System (GIS) is a method that allows the user to capture, store and display data collected on different locations around the world, it permits further understanding of spatial patterns and the relationships that connects the different data together (Evers, 2017). There are many different systems such as Mapinfo, QGIS, Google

My Maps and Google Earth Pro, just to name a few; all are GIS systems and allow such data as cartographic, photographic, digital and spreadsheets to be displayed in a visual format (Evers, 2017). The data, once imported into the software, can be overlaid on top of one another to create a single map with the data points visible (Evers, 2017).

There are different resources where the variation of data can be obtained, such as Digimaps which is an online data base that requires a subscription to access data (The University of Edinburgh, 2021). The data that can be collected is global maps, spatial data, ordnance surveys, historical, geological, Light Detection and Ranging (LIDAR) and marine information (The University of Edinburgh, 2021).

These different types of software are just tools to use alongside other methods; the software can provide visuals, but the proposed research method will also provide an understanding of what is being seen.

2.2.1 History of Geographical Information System

The GIS is first thought to be created by Doctor John Snow in London, England, in 1854 (at this time it would not have been used on a computer but on a paper map) (Cricket, 2003). Doctor Snow used the GIS method to map an outbreak of Cholera, this was achieved by adding outbreak locations, roads, property boundaries and water lines (Cricket, 2003). Once this information was plotted on the map Doctor Snow was able to see that the common area was the water line, this begins the use of spatial analysis (Cricket, 2003). This also created epidemiology which is the study of incidences, distribution, and control of disease (Cricket, 2003); however, the use of GIS has been used in many other studies.

2.2.2 How Geographical Information System that have been used in Studies of Coastal Erosion

There have been several different studies conducted where GIS has been used to assess coastal erosion or coastal vulnerability.

One study conducted in 2017 used the GIS to assess the Karnataka coastal line on the west coast of India. The study focused on the long-term erosion by using remote sensing, GIS, Linear Regression Rate (LRR), and End Point Rate (EPR) techniques (Sowmya *et al.*, 2017). The study used 26 years (1990-2016) of images of the erosion and compiled a Digital Shoreline Analysis System (DSAS), which allowed the team to establish that Ullal, located on the Karnataka coast, had the highest rate of erosion with LRR of 1.3 meters (m) per year (Sowmya *et al.*, 2017).

Another study conducted in 2017 used GIS, paired with, slope of land, geomorphology, erosion rate, dune width, tide direction, tidal range, wave height, protection methods and adjacent land use, already established maps, google images and field observations to assess the vulnerability of southern coastline of Sri Lanka (Lin and Pussella, 2017). This study found that 7.5% of the coastline was very highly vulnerable, 23.7% highly vulnerable, 27.11% moderately vulnerable, 29.4% lower vulnerable and the remaining 12.25% was very low vulnerability (Lin and Pussella, 2017).

A study based on Ponta Negra Beach, Natal City, North-eastern Brazil in 2014 used GIS and satellite images to analyse coastal erosion (Amaro *et al.*, 2013). The GIS was used to evaluate the balance and morphological changes in the sediment of Ponta Negra Beach, wind, tides, waves, and current data was applied to estimate the erosion rate (Amaro *et al.*, 2013). Using sensing images from 1973 to 2012 and high-resolution images from 2003 to 2011 it was found that 121,494.52 Square Meter (m²) was affected by coastal erosion in Brazil (Amaro *et al.*, 2013).

All of these studies used GIS as an aid to obtain results of coastal erosion in their selected locations. While Sowmya *et al* (2017), Lin and Pussella (2017) focused on a large area, Amaro *et al* (2013) focused on one location. Each study achieved their aims, which was to use documents and images in a GIS to establish rate of erosion or vulnerable areas. These studies show that a GIS can be beneficial to use when investigating erosion and that it is possible to use this method to perceive the changes within the environment.

2.2.3 Historic and Present Satellite Photographs

When using GIS to examine coastal erosion, certain data is needed. Amaro *et al* (2013) used photographs, along with other data, to carry out their study; this is not the only study to have done this.

A study conducted in 2018 used satellite images to examine 'Global Long-term Observation of Coastal Erosion and Accretion' (Mentaschi *et al.*, 2018). This study used satellite images from 1984 to 2015 to observe land loss and land gained, it was estimated that 28,000 square kilometre (km²) of land was lost which was twice the amount of land gained (Mentaschi *et al.*, 2018).

The United States of America (USA) use the historical National Ocean Service (NOS) to estimate erosion rates and monitor locations (Crowell, Leatherman, and Douglas, 2017). The NOS allows them to examine erosion rates over a period of 150+ years (Crowell, Leatherman, and Douglas, 2017). This means that the USA have been using historic data to assess long-term erosion rates, future erosion events and to recognise what areas are vulnerable (Crowell, Leatherman, and Douglas, 2017).

It appears that there have been many studies conducted using historic information and images, which has shown some desired results in regard to estimated erosion rates. Both GIS and historic data show promising results to estimating coastal erosion rates. With the combination of using GIS and historic data, a promising result is expected for this dissertations experimental method of remotely calculating coastal erosion rates.

2.3 Weather Patterns and Sea Level Rise

Changes in weather patterns and sea level rise can be attributed to global warming (Natural Environment Research Council, 2021). The National Ocean Service has been monitoring the rise of sea levels since 1993 and found that the rate of sea level rise is "*one-eighth of an inch*" (National Ocean Service, 2021). On the 8th of September 2010 sea level had risen to 1.92 inches, by 25th September 2020 the sea level was 3.81 inches NASA Goddard Space Flight Centre, 2020: West 2021). Coastal Communities are already experiencing the effects of sea level rise, with increased flooding, higher tides, and more frequent storms, this will increase until coastal communities are driven to retreat inland (Buchanan, 2019).

2.3.1 Weather and Erosion

Two of the studies examined in section 2.2.2 used a form of weather to aid in finding results to their investigation. For example, Amaro *et al.* (2013) used wind, tides, and waves to further provide an accurate assessment of the erosion; while Lin and Pussella (2017) used similar data, they used tidal range, and wave height. Along with many other studies it appears that weather plays an important role in calculating erosion rate.

Although this information is not new, weather plays an important role in contributing to erosion; one of the studies in section 2.2.2, Sowmya *et al.* (2017), decided not to use the weather as a component to their study.

Even if global warming and climate change is not considered, weather has always played an important role in shaping and moving the land, rocks, and sediment (National Geographic, 2021).

"Weather is the mechanical and chemical hammer that breaks down and sculpts the rocks. Erosion transports the fragments away" (National Geographic, 2021. p.1)

Water, in particular, is a very adaptable element. When it rains the water will seep into cracks and holes, but when the air turns cold, and the water freezes it expands and causes the ground to crack further (National Geographic, 2021).

2.3.2 Shoreline Management Plan

In the United Kingdom 17% of all coastlines are experiencing considerable coastal erosion (Marine Climate Change Impacts Partnership, 2020). If broken down further, 30% of England's coastlines, 23% of Welsh coastlines, 20% of Northern Ireland coastline and 12% of Scotland's coastlines are being affected by erosion (Masselink and Russell, 2008).

A SMP is a component of an Operational Management Strategy that is used to plan and prepare for any anticipated natural resource management or development (UK Government, 2019). A SMP will consider tidal patterns, wave direction and height, movement of beach and seabed materials, and conflict of coastal user (UK Government, 2019). This type of assessment is carried out to hopefully help lower the risk to people, culture, natural environments, and possible future developments (UK Government, 2019). After the full SMP assessment has been completed further action can be taken, for example, sustainable and suitable plans can be put into place for the short, medium, and long term (UK Government, 2019).

A SMP has four approaches to managing coastlines, these approaches will consider risk to humans and the environment (DEFRA, 2006). The approaches are:

“Hold the Line (HTL), this means sea defences need to be maintained, upgraded or replaced. This enables the shoreline to be kept in its current position.

Managed Realignment (MR), this means that sea defences can be moved inland to make way for a natural shoreline or estuary.

No Active Intervention (NAI), this means sea defences should no longer be maintained, replaced, or upgraded. It also means that defences should not be put in if there are not some in place already and it can mean that old defences are to be removed. There is no longer any economic justification to protect this area.

Advance the Line (ATL), this means new sea defences can be built seaward from old defences.” (West, 2020. p. 10).

2.4 Root Mean Square Error (RMSE) Formula

Root Mean Square Error (RMSE) is a form of standard deviation which allows prediction of error (Glen, 2021).

“RMSE is a measure of how spread out these residuals are. In other words, it tells you how concentrated the data is around the line of best fit. Root mean square error is commonly used in climatology, forecasting, and regression analysis to verify experimental results.” (Glen, 2021. p.1)

2.4.1 Studies where RMSE has been used

With the RMSE being used in study areas such as climatology, forecasting and regression analysis (Glen, 2021), it is of no surprise that there are a number of studies that have used the calculation for coastal erosion.

A 2011 study investigated ‘Shoreline Change Rate estimation and its forecast: Remote Sensing, geographical information system and statistics-based approach’ (Deepika, Avinash and Jayappa, 2011). The study was conducted on the Udupi coast in Western India, using 98 years of satellite photographs and topographic maps (Deepika, Avinash and Jayappa, 2011). With this data in hand, the statistical methods were applied, these method being, end point rate, average of rates, linear regression and RMSE (Deepika, Avinash and Jayappa, 2011). Fifty-three percent of the transects demonstrated ± 10 m RMSE values, meaning, that the alignment between the estimated and satellite images based on the shoreline positions, while the transects being closer to the cell boundaries showed 57% uncertainties in shoreline change rate (Deepika, Avinash and Jayappa, 2011). With these results it was concluded that the transects and cells dominated by the natural process was low in RMSE (Deepika, Avinash and Jayappa, 2011).

Although the RMSE calculation has been used on different studies to aid in the measurement of coastal erosion, there have been debates on whether it is the best fitting statistical calculation.

A study in 2014 conducted a debate on whether RMSE or mean absolute error (MAE) would be the more accurate calculation to use when indicating the average error (Chai and Draxler, 2014). A previous debate in 2005 by Willmott and Matsuura, suggested that RMSE would not be a good indicator for error due to the average error, however, MAE was a better system of measurement (Chai and Draxler, 2014). In a later study by Willmott in (2009) suggested that RMSE should be avoided, and MAE used to evaluate statistics (Chai and Draxler, 2014). However, Chai and Draxler (2014) studies suggested that MAE was not the only solution to this but in fact *“a combination of metrics, including but certainly not limited to RMSEs and MAEs, are often required to assess model performance”* (Chai and Draxler, 2014. p.1).

There is still a continued debate as to whether one calculation should be used, or a collection of different metrics should be used; there has been no established calculation to use when trying to estimate error, leaving it to the discretion of the researcher to select the metric that they find will best suit their study.

2.5 Conclusion

In conclusion, the literature review is essential to building a greater understanding of the research project. The literature review for this project was conducted by using a variety of different resources e.g., journal articles, UK government, international government, intergovernmental organisations, and NGO documents when applicable.

The GIS was first used by Doctor Snow in 1854, London (Cricket, 2003). Doctor Snow used GIS to map an outbreak of cholera, by using this system the practice of epidemiology was created (Cricket, 2003). This system begins the use of spatial data (Cricket, 2003). Many different studies have conducted research using GIS; three previous research projects were examined and a summary of how GIS was used to establish coastal vulnerability and erosion rate (Amaro *et al.*, 2013: Sowmya *et al.*, 2017: Lin and Pussella, 2017). Two of the studies, Sowmya *et al.*, (2017), Lin and Pussella (2017) focused on a large area, while Amaro *et al.*, (2013) focused on a smaller location to use the GIS on.

The USA uses NOS to estimate erosion rates while also monitoring locations (Crowell, Leatherman, and Douglas, 2017). The NOS is used to show historic satellite images which allows erosion rates to be measured (Crowell, Leatherman, and Douglas, 2017).

Weather patterns and sea level rise have an impact on coastal erosion (Natural Environment Research Council, 2021). The National Ocean Service (2021) reported that the sea levels rise by “*one-eighth of an inch*” each year, which can result in increased flooding, higher tides, and more frequent storms (Buchanan, 2019). Even if global warming and climate change is not considered, weather has always played an important role in shaping and moving the land, rocks, and sediment (National Geographic, 2021).

“Weather is the mechanical and chemical hammer that breaks down and sculpts the rocks. Erosion transports the fragments away” (National Geographic, 2021. p.1)

Root Mean Square Error (RMSE) is a form of standard deviation which allows prediction of error (Glen, 2021).

“RMSE is a measure of how spread out these residuals are. In other words, it tells you how concentrated the data is around the line of best fit. Root mean square error is commonly used in climatology, forecasting, and regression analysis to verify experimental results.” (Glen, 2021. p.1)

The literature review has established that there are many studies that have been conducted using a varying of methods, showing good results.

To conduct and archive the aim and objectives of this research project the methodology needs to be examined in further detail; this will be discussed in the next chapter.

3.0 Methodological Review

The purpose of a methodology is to use a technique or specific procedure which will aid in identifying, selecting, processing, and analysing information about your chosen topic (Wilkinson, 2000). The Methodological Review permits the reader to critically appraise a studies overall legitimacy and dependability (Wilkinson, 2000). This section of the research project is to examine and review the methodology used in the study.

3.1 Introduction

The method that has been considered to carry out this research project is Thomas *et al.*, (2018).

The methodology complies with Thomas *et al.*, (2018) with adaptations made to fulfil the aim of the project. These adaptations are to focus solely on the use of remote methods. This has been considered and discussed at length due to the current Covid-19 situation.

To map erosion rate utilising already collected data, RMSE and GIS. Google Earth Pro was selected for this project as it gives the ability to view historical photographs and overlay present photographs; Google Earth Pro is a free to use software platform and is compatible with many different operating systems. The methodology discussed in this section is suitable for this research project as it enables a rapid assessment to be conducted and when the images are collected there will be no further cost, allowing the complementation of the aim stated in section 1.4.1.

3.1.1 Tools used to Collect Data

The main data collected was a combination of historical and present aerial photographs and satellite images of three locations on the Isle of Sheppey. Google Earth Pro and Digimaps data bases were used to compile the data. The images were then exported from the database and imported into the software platform mentioned in section 3.1.

The software allows 'advanced' tools to be accessed. These tools were used to measure current land size, the past land size and then calculating the amount of land that has been lost through deducting the current land size from the past land size. The RMSE used by Thomas *et al.*, (2018) has been applied to these figures which was used to allow for a margin of error.

The aerial photographs and satellite images were compiled from 1940 onwards with ten-year intervals, and one for each site for this year (2021), totalling 27 images. Unfortunately, the 1950 aerials imaging was unattainable, also 2003 was the closest year to 2000 and this was the same for 2010, which meant the year 2009 had to be used. Each image collected was dated with the year, and location they were obtained from; this approach allowed for easy location when needed. Each image was able to be obtained from the same data base.

The images were then imported into Google Earth Pro. Documentation of wind speeds and precipitation rates, patterns in weather and erosion event have also been applied to allow additional insight into the coastal erosion happening at this location. The RMSE helps to calculate a certain margin of error when using aerial photos.

The final results were then compared with the current SMP for the location.

By using Thomas *et al.*, (2018) with the adaptations stated above, the aim and objectives was:

The aim is to determine if a rapid assessment on coastal erosion could be carried out remotely with accurate results. with the following objectives:

- 1) Calculate the distance of land lost by analysing historic and present satellite images in a Geographical Information System of locations experiencing coastal erosion.
- 2) Compare and establish the rate of erosion in the current shoreline management plans with collected findings, weather patterns and sea level rise.
- 3) Evaluation of these areas will be inspected by applying the Root Mean Square Error calculation (RMSE) method.

These steps could lead to credible results; however, it could lead to no useable results; but these foundations could create a new method to assess the erosion in a quicker and easier manner.

3.2 Justification Against Other Methods Not Used

There were a number of different method's considered for this research project, such as:

- Geotechnical Investigation
- Bi-polar Scale
- Thomas *et al.*, (2018)

Each method was considered and discussed at length with what the positive and negative aspects would be if using that method.

For example, Geotechnical Investigation has a number of different steps in the process to obtain findings, but also has a large cost. Usually, the first process when calculating coastal erosion is to carry out a ground investigation, which requires specialised engineers and geologists (Technics Geospatial Surveyors, 2021). The ground investigation examines the geology, soil consistency, strength and structure, groundwater, and potential for contamination (Technics Geospatial Surveyors, 2021). This is then further developed with a desktop study, factual report, interpretative report, and a detailed assessment (Technics Geospatial Surveyors, 2021). The factual report requires ground inspections and sample testing (Technics Geospatial Surveyors, 2021). The issue that arose from the method were, cost, safety, equipment, and time. To be able to take samples at the project selected location would have required the hiring of a boat and the correct personnel. The location poses a health and safety risk and with the unknown future of the UK due to Covid-19 this was considered an unreliable method to proceed with and this approach was discounted.

The next method considered was the use of a Bi-polar Scale. This method is used in geography to 'measure' the environmental quality to the residential and perception factors, this is accomplished by using a grading range of -5 to 5+, the score of 0 is neither bad nor good (Barcelona Field Studies Centre, 2021). The areas examined in the survey are all dependent on the surveyor, but a variety of things could be considered such as, vulnerability of erosion, aesthetics of location, access to area and levels of risk (Barcelona Field Studies Centre, 2021). There were a number of issues that arose with this method, the survey can be subjective in terms of scoring as it focuses more on human perception instead of quantifiable metrics and this is why the method is often criticised for lack of quantifiable and replicable results. Due to these reasons, this method was withdrawn from consideration.

The final method that was considered Thomas *et al.*, (2018). In Thomas *et al.*, (2018) paper, he examined and calculated changes in the Port Eynon Bay, Gower, Wales, UK, shoreline (Thomas *et al.*, 2018). In this research project there was a two- step approach to the aerial and transect-based data that would help to predict possible shoreline position in the future (Thomas *et al.*, 2018). In this project QGIS was used, which is similar to GIS, it was used to calculate the shoreline position from historical aerial images from the past 60 years (1944 to 2014) (Thomas *et al.*, 2018). Once this data was collected the RMSE calculation was applied which allowed a more accurate result (Thomas *et al.*, 2018). This method was more applicable to the research topic as it would be much easier to apply, with no cost, easier to adapt to the area and would allow the study to be carried out remotely.

3.2.1 Root Mean Square Error (RMSE) Formula

The letters in RMSE calculation will vary depending on the researcher and what the author decides to use. However, the RMSE will appear in this format:

$$RMSE = \left[\frac{(\sum(Nc - Nt)^2 + \sum(Ec - Et)^2)}{n} \right]^{1/2}$$

Using the letter above, the Nt and Et would represent coordinates from the photograph transformation, while Nc and Ec are the controlled coordinates and n is the number of data points (Thomas *et al.*, 2018).

3.2.2 Sample Area

As stated in section 1.2, the location, the Isle of Sheppey, was chosen with three different sites selected to conduct this study. Each of the sites are located in villages on the London Clay cliff (See Figure 4.2, 4.3 and 4.4).

Minster-on-Sea (Minster), Eastchurch and Warden Bay are the villages that sit upon the cliff top; these sites were picked due to their location, the experience of erosion, the impact the erosion will have on them and due to having an identification indicator that would allow the reader to locate the site. Some of sites are called by the road names that they are situated on, these being residential or by the caravan park name.

Redcot Resort World and Warden Spring Caravan Park are the holiday parks and are also some of the biggest parks on the Isle of Sheppey. Bellfarm Lane, Surf Crescent and Warden Road are the residential areas. Table 4 shows the sites and what village they are found in.

Table 3.1: Selected sites and their Villages

Minster-On-Sea	Eastchurch	Warden Bay
Bellfarm Lane	Surf Crescent	Warden Road
Redcot Resort World	Empty Field	Warden Springs Caravan Park

This study was conducted online so access and consent to the locations was not needed as the site was not physically visited. Ethical consideration was considered but due to research subject there was no need to interview or interact with the community, public or questions other than within the scientific or environmental field.

The data is presented in the form of figures, tables, statistics, graphs, and description's given of what is being shown. The graphs have been created using Microsoft Excel and can be seen in this format.

3.4 Research Method Limitations

Every research project comes with some limitations. Regarding this project, there was an issue with obtained up-to-date satellite images, this could be due to Covid-19 as there have been no new satellite photographs taken since 2020 of the locations. The other is Data collection, the Isle of Sheppey is an area of England that appears to have been forgotten, with there being little documentation obtainable for periods in its history, then there would, erratically, be a few years with documentation and then there would be nothing recorded for another few years.

3.3 Conclusion

In conclusion, there are several different software's, Mapinfo, QGIS, Google Earth Pro and data bases, Digimaps, Google My Map, Google, that can be used in this project. With the Thomas et al., (2018) method selected for use and other tools that were used to collect data, there should be little margin of error in the study. Google My Map, Google Earth Pro and QGIS are free and easy to use, meaning that there would be no cost to the study.

After considering the positive and negative benefits to using Geotechnical Investigation and Bi-polar scale it was found that neither of these methods would be suitable for this study, either due to cost or through lack of quantifiable results.

The sample areas are a manageable size with enough variation to obtain results from most if not all sites. The ethics, access and consent were also considered but due to the project there was no need for further discussion as the project is remote based and there was no need to interact with the local people or community.

The data was collected, the analysis and results are shown in a variation of different ways, including figure, tables, statistics and more. There were a number of limitations, such as, up-to-date satellite images due to Covid-19 and lack or missing data. But the results have been compiled of what could be found.

The data and results will be compiled in the next chapter.

4.0 Data

This chapter will follow on from the methodology Section 3 This chapter focuses on the results of the data collection using the method mention in section 3. The data that will be presented is the locations, erosion rate, the average erosion rate for each yeah, RMSE for each site and the average for each site, along with the average windspeed and precipitation rate for each year. The consideration of other variables and the analysis will be discussed in section 5. The data collected will be displayed in the form of tables and graphs. The structure of the results will be laid out as follows:

- Location imagery
- Yearly Transects
- Root Square Mean Error
- Conclusion

4.1 Location Imagery

As previously mentioned in section 3, Google Earth Pro was used as the GIS system. This allowed for historical images already in the system to be examined, historical images imported and layered over the selected sites. Figure 4.1 demonstrates an image of a viewpoint from Google Earth Pro of the Isle of Sheppey.



Figure 4.1: Aerial View of the Isle of Sheppey on Google Earth Pro

Figure 4.2, 4.3 and 4.4 illustrates aerial views of the three sites examined on the Isle of Sheppey.



Figure 4.2: Aerial View of Site 1: Redcot Resort World and Bellfarm Lane, Minster-on-Sea, Isle of Sheppey



Figure 4.3: Aerial View of Site 2: Empty Field and Surf Crescent, Eastchurch, Isle of Sheppey



Figure 4.4: Aerial View of Site 3: Warden Springs Caravan Park and Warden Road, Warden Bay, Isle of Sheppey



Figure 4.5: Control Points of Redcot Resort World to Bellfarm Lane

Figures 4.5, 4.6 and 4.7 show the three sites with the controlled points outlined using images from the year 2021. These controlled points then set the president for the measurement for the historical images, allowing erosion rate to be measured ranging from 1940 to 2021.

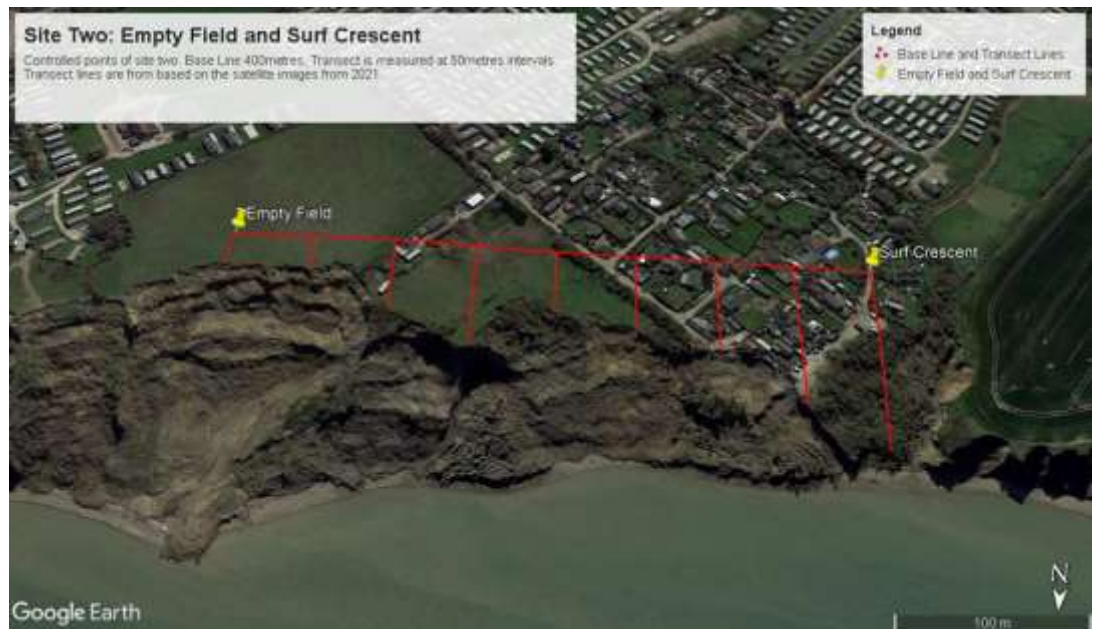


Figure 4.6: Control Points of Empty Field to Surf Crescent



Figure 4.7 Control Points of Warden Springs Caravan Park to Warden Road

4.2 Yearly Transect for Each Site

Each site had measurements taken from 1940, 1960, 1970, 1980, 1990, 2003, 2009, 2020 and 2021. In Figures 4.8 to 4.34 show the base and transect lines for each site in each of the above stated years.

4.2.1 Redcot Resort World to Bellfarm Lane



Figure 4.8: Site 1 Transect Line Measuring to the Cliff Edge in 1940



Figure 4.9: Site 1 Transect Line Measuring to the Cliff Edge in 1960



Figure 4.10: Site 1 Transect Line Measuring to the Cliff Edge in 1970



Figure 4.11: Site 1 Transect Line Measuring to the Cliff Edge in 1980



Figure 4.12: Site 1 Transect Line Measuring to the Cliff Edge in 1990



Figure 4.13: Site 1 Transect Line Measuring to the Cliff Edge in 2003



Figure 4.14: Site 1 Transect Line Measuring to the Cliff Edge in 2009



Figure 4.15: Site 1 Transect Line Measuring to the Cliff Edge in 2020

Laying out the controlled points allowed for changes in the distance to the cliff edge to be measured while also being to visually see the change. Although it is clear to see in Table, 4.1, 4.2 and 4.3 that in some of the selected years that the cliff distance appears to grow, for example Transect Line (TL) 1 1970 the distance from the controlled point is 101m but in



Figure 4.16: Site 1 Transect Line Measuring to the Cliff Edge in 2021

1980 the distance is 147m; this is clearly impossible, these type of changes in distance from the controlled points can be seen at all three sites (Section 4.2.2 and 4.2.3). However, due to the digitalising of historic images the resolution can be impacted, along with some of the data within the image to make it a better standard (University of Michigan, 2021). Due to this change in image standards the RMSE was calculated to allow for a margining of error in distance; this margining of error will be discussed later in the chapter.

Table 4.1: The Measurement of Each Transect Line for Each Year on Site 1: Redcot Resort World to Bellfarm Lane

Site 1									
Transect Line (TL)	1940	1960	1970	1980	1990	2003	2009	2020	2021
TL1	64.60m	36m	101m	147m	20.60m	13.80m	10.30m	5.50m	4.99m
TL2	67.90m	57.60m	92m	144m	97m	55m	55.80m	45.60m	46.60m
TL3	89.90m	83.50m	91.50m	148m	94.80m	79.40m	77.40m	76.30m	80m
TL4	119m	96.40m	92.30m	132m	110m	72.30m	66.80m	69.20m	70.60m
TL5	132m	89.20m	103m	147m	52.20m	49m	56.70m	49.50m	48.90m
TL6	121m	90.10m	111m	160m	31.20m	35.90m	33m	31.60m	31.60m
TL7	105m	93.40m	108m	157m	63m	46.30m	44.40m	36m	36m
TL8	127m	99.20m	106m	161m	96.10m	95.60m	92m	81.80m	81.80m
TL9	120m	138m	122m	175m	124m	127m	125m	106m	105m

4.2.2 Empty Field to Surf Crescent



Figure 4.17: Site 2 Transect Line Measuring to the Cliff Edge in 1940



Figure 4.18: Site 2 Transect Line Measuring to the Cliff Edge in 1960



Figure 4.19: Site 2 Transect Line Measuring to the Cliff Edge in 1970



Figure 4.20: Site 2 Transect Line Measuring to the Cliff Edge in 1980



Figure 4.21: Site 2 Transect Line Measuring to the Cliff Edge in 1990



Figure 4.22: Site 2 Transect Line Measuring to the Cliff Edge in 2003



Figure 4.23: Site 2 Transect Line Measuring to the Cliff Edge in 2009



Figure 4.24: Site 2 Transect Line Measuring to the Cliff Edge in 2020



Figure 4.25: Site 2 Transect Line Measuring to the Cliff Edge in 2021

Table 4.2: The Measurement of Each Transect Line for Each Year on Site 2: Empty Field to Surf Crescent

Site 2									
Transect Line (TL)	1940	1960	1970	1980	1990	2003	2009	2020	2021
TL1	138m	139m	127m	127m	148m	124m	133m	124m	124m
TL2	154m	117m	120m	102m	128m	102m	107m	103m	101m
TL3	213m	116m	127m	82.30m	140m	95m	94m	71.60m	66.80m
TL4	188m	110m	109m	96.30m	67.70m	66m	63.60m	55.20m	54.20m
TL5	182m	105m	123m	119m	62.20m	46.90m	46.70m	47.30m	45.90m
TL6	166m	94.20m	160m	97.80m	79m	74.60m	73.30m	75.10m	72.50m
TL7	178m	83m	168m	108m	57.10m	53m	52.10m	54.70m	51.90m
TL8	99.40m	67.40m	149m	97.40m	63.70m	49.60m	45.30m	28.30m	26.80m
TL9	128m	85.20m	177m	91.20m	70.30m	51.80m	49.20m	24.30m	24.30m

4.2.3 Warden Springs Caravan Park to Warden Road



Figure 4.26: Site 3 Transect Line Measuring to the Cliff Edge in 1940.



Figure 4.27: Site 3 Transect Line Measuring to the Cliff Edge in 1960



Figure 4.28: Site 3 Transect Line Measuring to the Cliff Edge in 1970



Figure 4.29: Site 3 Transect Line Measuring to the Cliff Edge in 1980



Figure 4.30: Site 3 Transect Line Measuring to the Cliff Edge in 1990

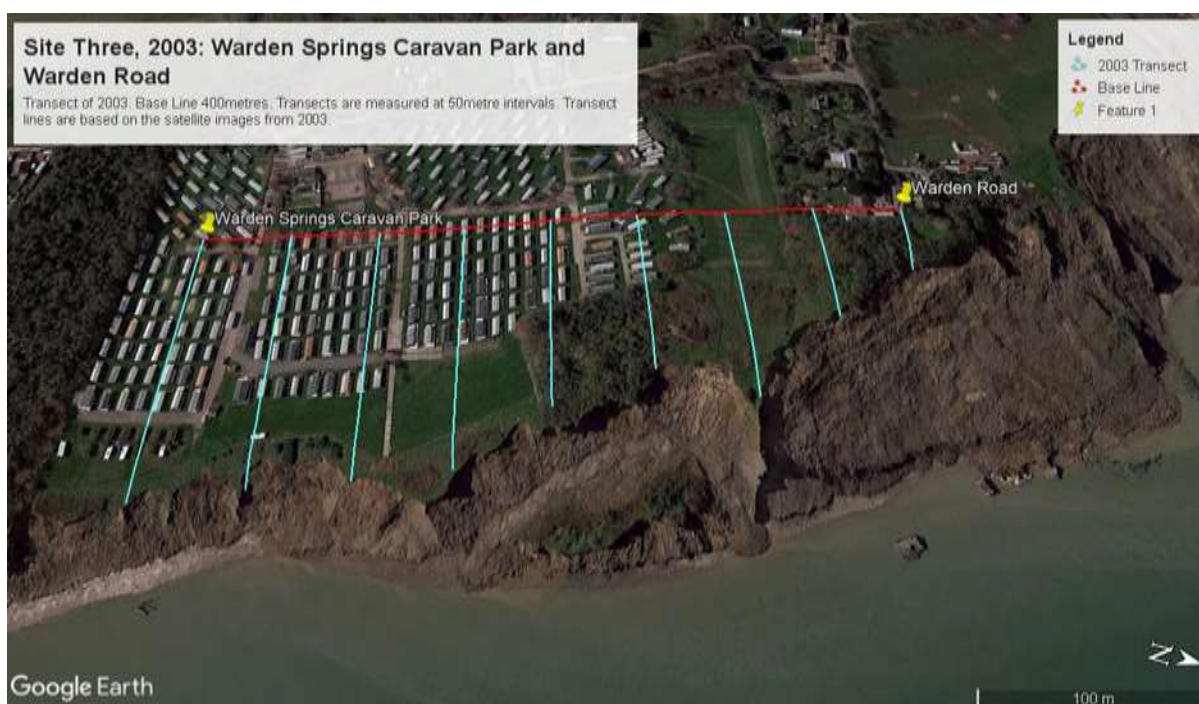


Figure 4.31: Site 3 Transect Line Measuring to the Cliff Edge in 2003



Figure 4.32: Site 3 Transect Line Measuring to the Cliff Edge in 2009



Figure 4.33: Site 3 Transect Line Measuring to the Cliff Edge in 2020



Figure 4.34: Site 3 Transect Line Measuring to the Cliff Edge in 2021.

Table 4.3: The Measurement of Each Transect Line for Each Year on Site 3: Warden Springs Caravan Park to Warden Road

Site 3									
Transect Line (TL)	1940	1960	1970	1980	1990	2003	2009	2020	2021
TL2	109m	106m	74.70m	92.20m	38m	45m	39.20m	41m	23.20m
TL2	154m	152m	112m	126m	127m	79.40m	76.30m	79m	76.50m
TL3	215m	170m	148m	151m	132m	128m	134m	126m	125m
TL4	221m	176m	175m	151m	111m	114m	114m	113m	114m
TL5	232m	192m	201m	160m	134m	135m	142m	143m	142m
TL6	246m	217m	224m	170m	164m	164m	168m	164m	165m
TL7	231m	206m	212m	175m	173m	168m	167m	169m	166m
TL8	228m	196m	192m	178m	167m	169m	172m	160m	158m
TL9	225m	193m	178m	176m	163m	176m	179m	177m	169m

4.2.4 All Years Transects Over Lapped



Figure 4.35 Redcot Resort World to Bellfarm Lane with Each Years Transect Lines



Figure 4.36: Empty Field to Surf Crescent with Each Years Transect Lines



Figure 4.37: Warden Springs Caravan Park to Warden Road with Each Years Transect Lines

Each of the site's TL were then layered on to one image to visually illustrate show the differences in the distance from the controlled base line. Figures 4.35, 4.36 and 4.37 illustrate this. From these images it is clear to see that there has been a large amount of erosion to each site. Table 4.4 shows the total loss of land on each site for each year, due to image movement some of the land loss is in the minuses. The data for 2021 has not been recorded due to the year not yet being at the end.

Table 4.5 shows the average erosion rate of erosion per year for each site. As mentioned before the aerial images have led to some error in measurements. However, we can see that Site 2 ,1940 had the most average land lost, while Site 1, 2003, had the least amount of average land lost.

Table 4.4: Total Loss of Land due to Erosion Per Year and Site

Total Loss of Land due to Erosion Per Year and Site (m)	1940	1960	1970	1980	1990	2003	2009	2020	2021
Site 1	163	-143.30	-544.30	682.10	114.60	12.90	59.90	-3.99	Unknown
Site 2	529.60	-343.20	339	105	153.10	-1.30	80.70	15.10	Unknown
Site 3	253	91.30	137.50	170.20	30.60	-13.10	19.50	33.30	Unknown

Table 4.5: The Average Loss of Land Per Site and Year

Average Erosion Rate Per Site and Year (m)	1940	1960	1970	1980	1990	2003	2009	2020	2021
Site 1	18.11	-15.92	-60.47	75.78	12.73	1.43	6.65	-0.44	Unknown
Site 2	58.84	-38.13	37.66	11.66	17.01	-0.14	8.96	1.67	Unknown
Site 3	28.11	10.14	15.27	18.91	3.40	-1.45	2.16	3.70	Unknown

Table 4.6 shows the total land lost for each site, Site 2 had the most lost with 878m in the 80-year time period, while Site 1 had the least amount of land lost, 340.91m, in the same 80-year time period. Figure 4.38, 4.39 and 4.40 each shows in a graph form the average erosion rate for each year and site.

Table 4.6: Total Loss of Land for Each Site

Location	Total Land Loss for Each Site (m)
Site 1	340.91
Site 2	878
Site 3	722.30

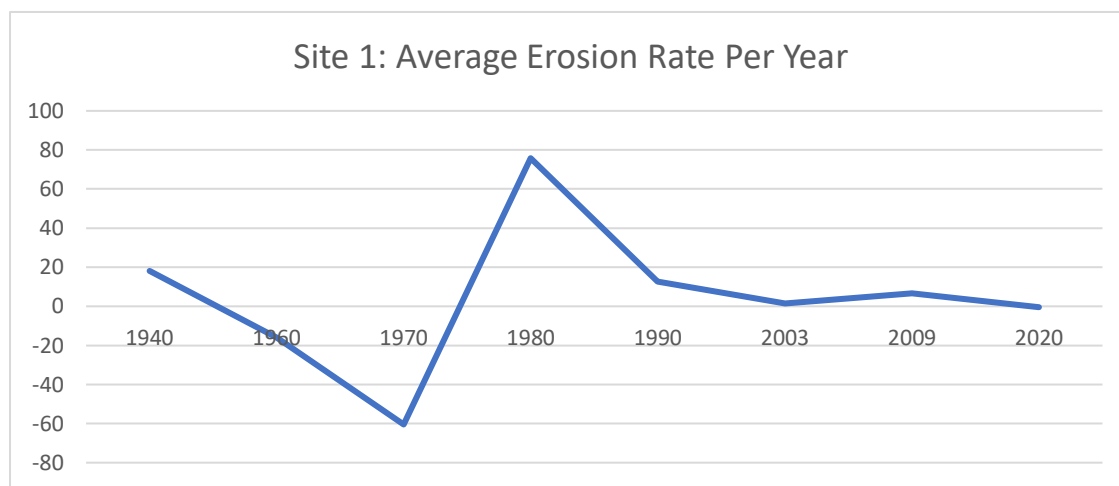


Figure 4.38: The Average Erosion Rate Per Year in Metres for Site 1: Redcot Resort World to Bellfarm Lane

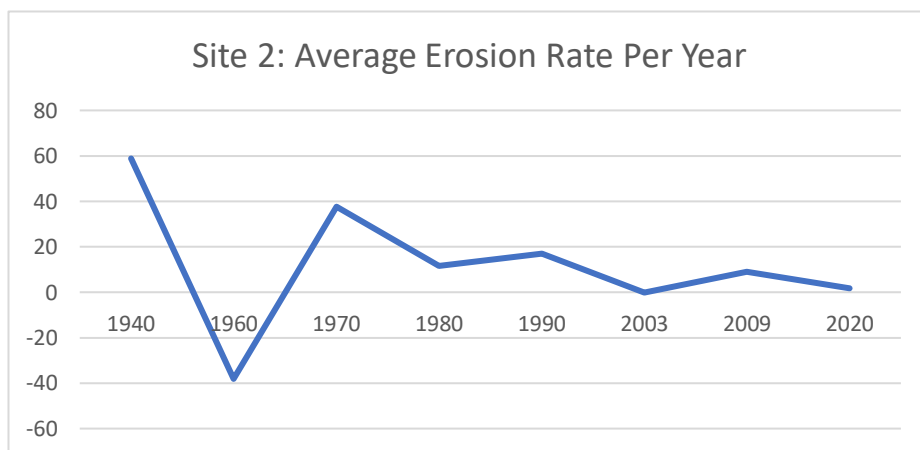


Figure 4.39: The Average Erosion Rate Per Year in Metres for Site 2: Empty Field to Surf Crescent.

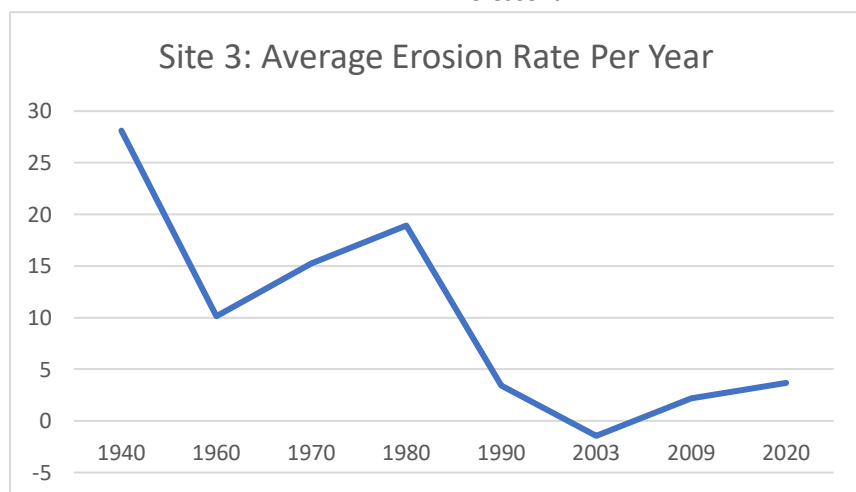


Figure 4.40: The Average Erosion Rate Per Year in Metres for Site 3: Warden Springs Caravan Park to Warden Road

4.2.5 Root Mean Square Error

As stated before, due to the digitisation of the images there is a margin of error; this is where the RMSE was applied. As mentioned in Section 3.2.1. the RMSE formula is:

$$\text{RMSE} = \left[\frac{\sum (N_c - N_t)^2 + \sum (E_c - E_t)^2}{n} \right]^{1/2}$$

Using the letter above, the N_t and E_t would represent coordinates from the photograph transformation, while N_c and E_c are the controlled coordinates and n is the number of data points (Thomas *et al.*, 2018). By using this formula with the controlled points, a margining of error was obtained, Table 4.7. shows 1.38m margin of error for Site 1, Table 4.8. shows a 2.32m margin of error for Site 2 and Table 4.9. shows 0.60m margin of error for Site 3.

Table 4.7: Average RMSE Per Year, with Total Average RMSE for Site 1: Redcot Resort World to Bellfarm Lane

Site 1	
Year	Average RMSE Per Year (m)
1940	0.96
1960	1.22
1970	1.28
1980	1.91
1990	1.88
2003	1.51
2009	1.92
2020	1.76
2021	0
Average RMSE for Site (m): 1.38	

Table 4.8: Average RMSE Per Year, With Total Average RMSE for Site 2: Empty Field to Surf Crescent

Site 2	
Year	Average RMSE Per Year (m)
1940	0.47
1960	0.19
1970	-0.37
1980	-0.27
1990	21.17
2003	-0.20
2009	0.1
2020	-0.21
2021	0
Average RMSE for Site (m): 2.32	

Table 4.9: Average RMSE Per Year, With Total Average RMSE for Site 3: Warden Springs Caravan Park to Warden Road

Site 3	
Year	Average RMSE Per Year (m)
1940	0.23
1960	-0.23
1970	4.93
1980	0.41
1990	0.13
2003	0.01
2009	0.03
2020	0.16
2021	0
Average RMSE for Site (m): 0.60	

Table 4.10: The Average Wind Speed and Precipitation Rate for Each Year

Average Wind Speeds and Precipitation Rate for The Isle of Sheeppy	1940	1960	1970	1980	1990	2003	2009	2020
Wind Speed	9mph (The Weather Company, 2021)	10.60mph (Meteologix , 2021)	11.27mph (Meteologix , 2021)	12.46mph (Offshore Energy SEA, 2009)	12.46mph (Offshore Energy SEA, 2009)	8.55mph (The Weather Company, 2021)	11.07mph (Meteocentr e, 2021)	9.45mph (Meteocent re, 2021)
Precipitation Rate	69.85mm (Meteorolo gical Office, 1949)	114.50mm (Metoffice, 2021)	131.74mm (Metoffice, 2021)	126.33m m (Metoffice , 2021)	158.93m m (Metoffice , 2021)	43.20mm (Meteocentre , 2021)	54.66mm (Meteocentr e, 2021)	134.48mm (Metoffice, 2021)

4.3 Conclusion

In Conclusion, the results that were collected has shown some interesting results, either though the margining of error ranges from 0.60m to 2.32m. With large amounts of data and a range of variables to review, the discussion of results will take place in chapter 5; this will allow a thorough examination to take place.

5.0 Results and Discussion

This chapter will examine and expand on the results displayed in Section 4. The purpose of a discussion is to explore the relevance and importance of the results, by explaining and evaluating the findings, which will also expand on the literature review, the research question, aims and objectives (McCombes, 2019).

5.1 Introduction

Due to the large amount of data and variables to consider, this chapter will be used to discuss the findings while incorporating the variables in Section 2.

5.1.1 Location Imagery Results

Google Earth Pro was used to collect all the data, from images of the locations, geo-referencing, laying the controlled points, obtaining coordinates, placing, and measuring TL.

Figure 4.1 was used to show the visual layout of Google Earth Pro and to give an idea of the size, and site locations. Figures 4.2, 4.3 and 4.4 were then used to display the 3 chosen sites size, environment, how the land is arranged and the communities. Figures 4.5, 4.6 and 4.7 demonstrate the selected sites with the controlled points set in place, using a base image of how the area would have looked in 2021. The base line was 400m with a TL placed every 50m.

These images allow the fundamental foundation to be laid for this research and play an important role to allow collection of suitable data.

5.1.2 Yearly Transect for Each Site: Results

Each site, once controlled points had been laid, had the years 1940, 1960, 1970, 1980, 1990, 2003, 2009, 2020 and 2021 images overlaid on the 2021 base image with the base line and TL for the individual years laid, measurements for each TL, for each year was noted.

Figures 4.8 to 4.16 illustrates Site one's yearly transects. Table 4.1 represents the measurements from each year. The maps for 1970 and 1980 were the only years that required the data to be imported into the software, this is a possible reason for the appearance of 'cliff growth', for example, table 4.1, TL1, in 1960 the cliff edge was 36m, however, in 1970 the cliff edge was at 147m; this illustrates clear discrepancies and can be seen in tables 4.2 and 4.3.

After collecting these measurements, it was important to know the total loss of land both per year and overall. Table 4.4 illustrates the total land lost for each year; these measurements were calculated by adding the 9 TLs for each year together, and then subtracting the total amount of the next year. As we can see from table 4.4 Site 1, in 1980 lost the largest amount of land, 682.10m, as previously stated in Section 4.2.5 there is a margin of error which is the reason for the minus amounts, these amounts represent the 'cliff growth', suggesting the cliff grew by 544.30m; Excluding these amounts, the site that had the least amount of land lost was Site 1, 2003 with only 12.90m eroding. Table 4.5 represent the average land lost each year, Site 2, 1940 had the largest average with 58.84m while Site 1, 2003 had the lowest average with 1.43m. Table 4.6 illustrates the total land lost for each site, Site 2 has the greatest length lost with 878m while Site 1 had the lowest lost with 340.91m.

Tables 4.7 to 4.9 demonstrates the average RMSE for each site. Site 3 has the lowest number at 0.60m while Site 2 had the highest with 2.32m.

After gathering this data, the logical next step was to examine if there were any weather patterns that could have played or were playing a role in contributing to loss of land. Table 4.10 signifies the average wind speed and precipitation rate of each year, while Table 1.2 in Section 1.2.3 gives a slightly more in-depth description of the weather conditions pertaining to erosion events on the Isle of Sheppey.

As mentioned, Site 1, in 1980 appears to have lost the largest amount of cliff, 682.10m, with this information combined with the information from table 4.10, indicates that 1980 had the fourth largest amount of rainfall, 126mm (Metoffice, 2001), with the highest wind speeds at 12.46mph (Offshore Energy, SEA, 2009); Table 1.2 shows that the winter between 1979-1980 was listed as one of the five winters that had five or more gales storms (Anon, 2020a), and further into 1980 the spring was the direst experienced in the last 30 years (Anon, 2020a).

Using the same tables to further examine correlations between the weather and erosion, we can examine where the second highest loss of land took place; this would be Site 2, in 1940, 529.60m of land was lost, during 9mph winds (the Weather Company, 2021) with 69.85mm of rain (Meteorological Office, 1949); unfortunately, Table 1.2 does not contain detailed information of the 1940 weather events. However, this land lost could be due to events that were happening at this time; in 1940 the world was at war. The location of the Isle of Sheppey has always played a role in helping to defend the UK for centuries (BBC, 2014), although there is little reports of what was happening on Sheppey during the Second World War period (this could be due to a Royal Navy Base situated there or that it was a military training ground for some time (Tyler, 1994)) locals know of stories of bombs exploding nearby, and recall training exercises; this is just local information with no documentation, but the author has seen photos from families that have lived on the Isle of Sheppey for generations and of what the area once was like during World War two; this could be a possible reason behind such a large amount of land lost but with relatively mild weather, this will need further investigation. If we combine the data and information on a table, it allows a clearer overview of the collated data.

Table 5.1: Review of Weather Conditions, Wind Speed, Precipitation rate, Loss of Land and Year

Year	Conditions (average wind speed and precipitation rate)	Weather Details	Sites and Loss of Land
1940	1940 had an average wind speed of 9mph (The Weather Company, 2021), with a rain fall of 69.85mm (Meteorological Office, 1949).	No Detailed information.	-Site 1: 163m -Site 3: 253m
1960	1960 had a slightly higher wind speed then 1940, with 10.60mph winds (Meteologix, 2021), and a 114.50mm average rainfall (Metoffice, 2021)	No Detailed Information.	-Site 3: 91.30m
1970	The year 1970 had the second highest wind speed of 11.27mph (Meteologix, 2021), the rainfall was the third highest at 131.74mm (Metoffice, 2021).	There is no detailed information of weather conditions in 1970, however, 1971 to 1972 was very wet and overcast weather conditions, which lasted for 3months (Anon, 2002a)	-Site 2: 339m -Site 3: 137.50m
1980	This year had one of the highest average wind speeds of 12.46mph (Offshore Energy SEA, 2009), with the fourth highest average rainfall, being 126.33mm (Metoffice, 2021)	The winter of 1979 to 1980 was listed as having 5 or more gale storms (Anon, 2020a); While the spring of 1980 was the driest in 30 years (Anon, 2020a)	-Site 2: 105m -Site 3: 170.20m
1990	The average wind speed for this year was the same as 1980, 12.46mph (Offshore Energy SEA, 2021), however, this year had the highest average rainfall with 158.93mm (Metoffice. 2021).	No Detailed Information.	-Site 1 : 114.60m -Site 2 : 153.10m -Site 3 : 30.60m
2003	This year had the lowest average wind speed with only 8.55mph (The Weather Company, 2021), and the lowest rainfall rate, 43.20mm (Meteocentre, 2021).	No Detailed Information.	-Site 1: 12.90m
2009	The third highest average wind speed was this year, being 11.07mph (Meteocentre, 2021) and the second lowest rainfall at 54.66mm (Meteocentre, 2021).	No Detailed Information	-Site 1 : 59.90m -Site 2 : 80.70m -Site 3 : 19.50m
2020	The third lowest average wind speed was 2020, being 9.45mph (Meteocentre, 2021) and the second highest rainfall of 134.48mm (Metoffice, 2021). Note: February had above average rainfall by 237%, with locations experiencing 3x the average annual rain fall (Met Office, 2021).	The winter of 2019 to 2020 was the 5 th wettest since 1862 and the 5 th mildest, with strong and high winds, many storms such as Ciara, Dennis and Jorge were all present in the first month of 2020 (Met Office, 2021). The Spring was drier with 626.2 hours of sunshine (Met Office, 2021). Summer conditions were warm, wet, and dull with the highest temperature being 37.80 Degree Celsius (Met Office, 2021) While the Autumn was warmer the average, then the present of storm Alex in October, creating flooding in places (Met Office, 2021).	-Site 2: 15.10m -Site 3: 33.30m

From Reviewing Table 5.1, an increase in the loss of land appears to occur when the wind speeds are high, and are combined with a high rain fall, even though the Spring and Summer are the dry, this combination of weather makes the perfect conditions for the London Clay to crack and slide; when clay is wet it becomes slippery and slides, but when warm the clay dries which causes cracks to form (Barker, 2019).

These results all have a margin of error by 0.60m to 2.32, as can be seen in Table 4.7 to 4.9.

5.2 Review of Literature in Section two

The literature for this research project, like any other project, plays a very important role. The GIS used in this project was not the typical software to use for such a project, for example in most of the studies in section 2.2.2 used QGIS, Mapinfo or ArcGIS (Amaro *et al.*, 2013; Sowmya *et al.*, 2017; Lin and Pussella, 2017), Google Earth Pro was selected for this project due to the free access, ease of use and built-in data. With this data it allowed the author to measure the distance of land lost by using and over laying historic and present images; as mentioned before the location, Isle of Sheppey, has very little or factual data available – when Google Earth Pro showed that aerial images were available for the years of 1940, 1960, 1990, 2003, 2009, 2020 and 2021 it seemed to be in the best interest of the project to use this software. Although, this project was also testing if this type of software was as reliable and user-friendly as the other software previously mentioned.

The studies mentioned in section 2.2.2 were a benefit to this project as they were able to provide new viewpoints and ways to continue with this project; allowing such data and results to be obtained.

5.2.1 Weather and Erosion

Two of the studies mentioned in section 2.2.2 used a form of weather to support in their investigation, Amaro *et al.*, (2013) reviewed wind, tides, and waves to provide an accurate assessment, while Lin and Pussella (2017) appraised tidal range and wave height. These two studies considered weather to play an important role in erosion, this then helped the author to provide a similar study that used weather as a contributing factor. Each study showed that there was a correlation between erosion and the weather conditions (Amaro *et al.*, 2013; Lin and Pussella, 2017), perhaps a further study could examine if there is a pattern between how much land is expected to be lost in certain weather conditions.

5.2.2 Shoreline Management Plan

As mentioned in Section 2.3.2 a SMP is used to help lower risk to people, culture, natural environments, and future development by assessing shorelines and coastlines (UK Government, 2019). The purpose of this being mentioned in this project was to review the amount of erosion happening per year according to this type of assessment used.

Mentioned in section 1.2.1, the SMP of 2011 for the Isle of Sheppey estimates that 1.5m of land is lost to erosion per annum (Canterbury City Council Engineering Service, 2011). However, from the data collected in this project the average loss of land is much more sporadic, without a continuous amount being lost each year. For example, if the total loss of land from each site, Table 4.6, was divided by 80 (the amount of time, in years, from 1940 to 2021) the average Isle of Sheppey coastline lost would still amount to more the 1.5m a year. Site 1 lost a total of 340.91m which when divided by 80 estimates 4.25m of the Isle of Sheppey coastline being lost per annum, Site 2's loss was 878m which equals 10.97m per annum, while Site 3's was 722.30m equalling 9.02m per annum. However, the total loss per site was added to give a total loss of land on Sheppey for the 80-year period, then the total would be 1,941.21m; which once divided by 80 equals 24.26m per annum. These amounts are much more than the estimated 1.5m of the SMP. This perhaps suggest that an amount of land lost to erosion cannot be accurately estimated for this location.

5.2.3 Root Mean Square Error

This calculation was used to help find the average margin of error when examining and comparing historic images with present images. This calculation is a form of standard deviation which aids in predicting error (Glen, 2021). This formula was pivotal in finding the margining of error in this project's measurement and imagery. However, there is still a question as to whether the MAE would have proven more accurate or if the use of both MAE and RMSE would

have been more adequate for this project; both Willmott (2009), Chai and Draxler (2014) made comprehensive arguments for and against the use of MAE and RMSE.

5.2.4 Research Question , Aim and Objectives

The research question for this study was:

“Using historic and present aerial satellite images with documents of geology, precipitation, and wind speed, could using a Geographical Information System (GIS) aid in achieving rapid, accurate results of coastal erosion using remote methods?”

This project has made strides in obtaining an answer to this question; however, it is still lacking. This will be discussed in further detail in Chapter 6.

The aim of the project was to determine if a rapid assessment on coastal erosion could be carried out remotely and the results be reliably accurate.

The objectives were:

- 1) Calculate the distance of land lost by analysing historic and present satellite images in a Geographical Information System of locations experiencing coastal erosion.
- 2) Compare and establish the rate of erosion in the current shoreline management plans with the research findings, weather patterns and sea level rise.
- 3) Evaluation of these areas were to be inspected by applying the Root Mean Square Error calculation (RMSE) method.

Achievement of the aim and objectives will be discussed in further detail in Chapter 6.

5.3 Conclusion

In conclusion, there was a large amount of data and results to discuss and present. Once the breakdown of the results had been completed, evidence illustrated that each site and year had a significant amount of land loss. A large percentage of land loss could be attributed to weather conditions, however, there could have been other explanations for a few; for example, the land lost in 1940 could be attributed to World War two and the blitz; this is a possible source to consider. The weather conditions that seem to coincide with large quantities of land loss in this location was the pattern of wet, windy winters with dry springs and summers.

The literature review had a pivotal role in helping to build this project, with what GIS software to use by considering previous studies carried out; providing a new viewpoint, and variables to consider.

The SMP for the location was important to this study, the purpose was to review and consider if there was another method that could be used to help protect coastlines that could be tailor to each location to obtain more adequate results.

This project demonstrates that there is the potential for this method to be a widely used assessment, however, like any new method, there is still improvement to be made.

The next chapter will conclude the project.

6.0 Conclusion

The purpose of a final conclusion is to plainly declare the answers to the projects question, while summarising and reflecting on the overall research (McCombes, 2019). This final chapter will discuss the main conclusion of this research project, what have the findings added to this area of study, the limitations, recommendations, and future research recommendations.

6.1 Introduction

A remote rapid assessment of coastal erosion for the Isle of Sheppey, South-East England. The results from this research study to create a reliable method to undertake Remote rapid assessment and management of coastal erosion for the Isle of Sheppey, South-East England, suggests that there is a possibility to obtain a rapid assessment of coastal erosion remotely. However, further development is required. Each site showed individual results of sporadic coastal erosion and the combination of the sites total land loss showed higher rates of erosion then found in the SMP; with the margining of error (0.60m to 2.32m) the suggested rate of 1.5m ((Canterbury City Council Engineering Service, 2011) a year appears to be less then what this studies results found.

Although the erosion in specific locations does not appear to be largely impacted by sea-level rise, like one would expect, it does appear to be greatly impacted by the change in weather conditions. However, the amount of land lost does appeared to be slowing down when examining Table 4.5, another variable to consider is how much of the erosion is a natural occurrence? could the large land slips from the last 80-years have formed a natural protection barrier from the sea? The results of this study have led to further questions that could be examined for this location.

The research question was perhaps not full answered, historical and present aerial satellite images were used, but there were issues with collecting them for the desired year; documents of geology, precipitation and wind speed were obtained, some were easy to find, while others took a while to source; a GIS was used but perhaps not a traditional system; the data collection and results only took 2 weeks and 1 day to gather, that could be considered rapid; the results appear to be accurate, however, as mentioned before there is room for more development; and the study was indeed carried out remotely. The author believes that a small question mark still lingers on the research question, and therefore she feels that the question has not been full answered. This could also be true in some form as to the aim of the research.

However, the objectives were fully met. The distance of land lost was indeed calculated by analysing historic and present satellite images in a GIS, which can be seen in Chapter 4. The measurements then allowed calculations to take place that led to an erosion rate that be compared to a SMP, with supporting variables, such as wind speed, precipitation rate and detailed weather conditions, as seen in section 5.1.2. The RMSE was applied which allowed for error, this error being relatively small.

6.2 Contribution to Knowledge

The research has shown that a rapid assessment is achievable while working remotely, but as stated, there is room for development. The rapid assessment could illustrate results faster, allowing action to be taken much quicker. With many assessments of this nature, it can take months to review the collected data, which can lead to the area changing while the results are being examined. The location used in this project, is an area that is hard to acquire documents and information for, which did make it difficult to gather the required information, helped to show what could be possible if the information is more readily available.

The main purpose of this research was to examine if the project **could** be accomplished, this was due to Covid-19. While the world was in lock down, the environment was not managed or assessed due to the lockdown restrictions; and much of the world began to work online, although some jobs could not make this change; environmental assessments used by the UK Government being one, this led to the idea of this project.

6.3 Limitations

The limitations of the project have been discussed in section 3.4. However, while the project was being enacted more limitations occurred.

Covid-19 seemed to have little impact on this project as was expected, which does demonstrate the success of being remote. The author did contact Google on several occasions, leading to the satellite images being updated on the 30th of March 2021; this allowed this hurdle to be overcome. Some documentation was challenging to gather, which resulted in the use of 2003 and 2009 images for example being used instead of images from 2000 and 2010. However, other images were found that were based not too far from the desired years.

There were two main limitations, when gathering some of the data and software.

One of the data bases used was Digimaps, unfortunately the images collected from this database from 1950 was impractical to use as the image was drawn backwards. For example, Surf Crescent boundaries are similar to a square shape with a triangle shape protruding on the left-hand side (looking out towards the sea), towards the cliff edge; the drawn 1950 images had that triangle pointing inland. This shifted the whole image. The only accurate, usable images for 1950, 2000 and 2010 were on a database which required a large amount of money per tile, which in this instance would have been 9 tiles: equalling to hundreds of British Pounds (GBP).

Another limitation was the software, the author had wished to use Google Earth Pro and Mapinfo the GIS- allowing forms of the same data to be collected, allowing a confirmation of the project's credibility in practice; however, with varying attempts to access and use Mapinfo, the software just appeared to not 'do what it was told'. Unfortunately resulting in only using one software, this meant that the results could not be further supported with another source.

6.4 Future Research and Recommendations

For future research this method could be applied to different locations around the globe, however, the first step should be to use the method in a different GIS to find if the results are the same or similar. By doing this it would develop the method further and indicate whether this method is consistently reliable. More variables could be investigated and incorporated to help further the accuracy.

Recommendations for this project would be to include more variable such as, tidal range, wave height and vegetation growth. Another recommendation would be to shorten the length of time between each measurement taken, for example perhaps 1940, 1945, 1950, 1955 etc; and to go further back, at least 100 years. With these recommendations the data may have given more insight into the coastline movement than this study did.

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