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EXECUTIVE SUMMARY

During the 11th January 2005 to 12th January 2005 a very severe storm hit the west coast of the Western Isles of Scotland damaging houses, roads and other infrastructure, ultimately leading to loss of life. Many parts of the naturally eroding coastline were subject to considerable erosion losses and flooding during this single event.

Gualan, which acts as a barrier island to the west of South Ford, suffered significant erosion during the storm. The island has a large effect on the hydrodynamic regime within the South Ford. There is concern from residents that should Gualan Island be allowed to erode the wave climate in South Ford would become more severe and that the people living on the shores of South Ford will be at increasing risk of harm from the effects of future storms.

During 2006 Comhairle nan Eilean Siar (CnES), the local authority for the Western Isles, made applications for funding to the Scottish Government under the Coast Protection Act 1949 for six coastal protection schemes. One of these schemes, for the Gualan Island to the west of the South Ford, was not approved as it did not meet cost/benefit criteria specified by the Scottish Government. This scheme involved dune re-nourishment using sand sourced from the South Ford together with subsequent dune stabilisation and management. However, it was recognised that further study was required in order to develop an understanding of coastal change in the South Ford area and the Scottish Government provided financial resources for the South Ford Hydrodynamics Study.

The objective of the research study was to establish the cause and effect linkages between coastal processes and coastal erosion/flooding within the study area. The study has demonstrated the risks of coastal erosion/flooding in terms of probability and consequences to people and assets on the coast as well as the impacts of different risk management interventions, thereby identifying options that would effectively manage these risks.

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INTRODUCTION

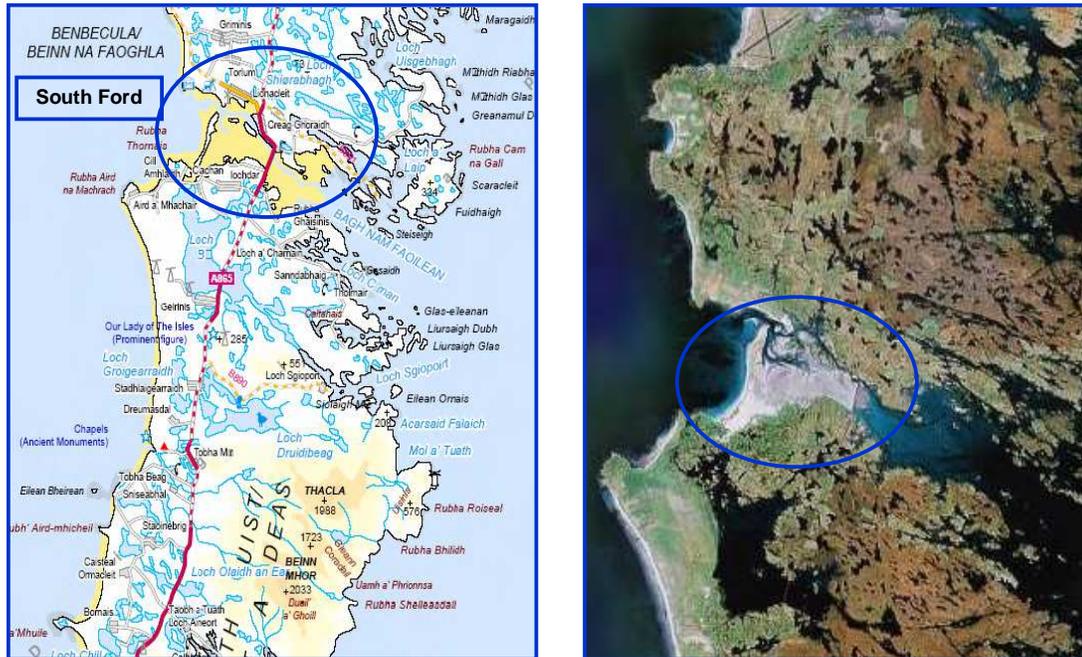


Figure 1. South Ford Hydrodynamic Study Location

The storm of January 11th, 2005, with its tragic consequences was exceptional not only in terms of its duration and intensity but also in terms of the degree to which the sea surface became elevated above normal levels sufficient to cause extensive coastal flooding. In response, two flood action groups were set up in South Uist covering the Middle District and lochdar. The lochdar Group identified **four objectives**:

1. to develop an understanding of what is happening to the local coastline and why;
2. to investigate the impact that man-made structures have had on coastal erosion, flooding and silt deposition in the local area;
3. to investigate options available for improving the situation; and,
4. to use this information to press for action to ensure the safety of people and the integrity of the land.

The lochdar Flood Action Group lobbied government and the Council as well as estates and other bodies. It completed a land survey of the extent of the flooding and prepared a map. The Group also held meetings with government and council officers and politicians to discuss the problems. It investigated the effect of the ocean surge on local causeways and completed visual surveys of the drainage system and the South Ford. Soon after the tragedy, it organised a public meeting in Talla an lochdar on 31st May 2005.

The Flood Action Group campaigned for a hydrographic survey of the coastal edge around South Ford and it requested computer hydraulic modelling of the South Ford. It asked for measures to be put in place to manage the coastal dunes as well as proposing

active management of the coastline including the drainage system. It asked for the establishment of an early warning system to alert the public to storm surge and extreme weather events. The group also proposed that flood relief routes such as the Ardnamonie side road need to be extended to connect with the main road. Importantly, it campaigned for the development of an effective coastal policy committed to alleviating flood and erosion problems.

Since the tragedy numerous achievements have been made. Repairs to the ferry terminal, roads, causeways and buildings have been completed. Balivanich Primary School that was so badly damaged by floodwaters has been replaced. Emergency communication vehicles have been provided and are based in Balivanich and in Stornoway. The breakwater at the ferry terminal in Eriskay and the North Ford causeway have been rebuilt. At the level of community engagement, an Integrated Coastal Zone Management (ICZM) Forum 'Coast Hebrides' has been established. At Ardnamonie an emergency access route was created and flood alleviation schemes put in place at lochdar and at Snishivall. A programme of coastal protection schemes has also been established in a number of areas including Stoneybridge, Craigston (Barra), Kilbride, Balivanich and Pol nan Crann.

Much attention was given to South Ford. At an early stage, a funding application to the Scottish Government for a coastal protection scheme for Gualan Island was rejected. However, it was felt that there was a need to know more about the history of coastal changes that had taken place in this area as well as on the history of past extreme weather events. The Scottish Government provided the finance for a Hydrodynamic Study of the South Ford. This study had the principal objective to establish the cause and effect linkages between coastal processes and coastal erosion/ flooding across the South Ford area. It would seek to identify the key risks of coastal erosion and flooding in the future both in terms of probability and consequences, as well to people and assets on the coast together with what effect possible future interventions would have on managing the risk. The study would also identify the various options that would effectively manage these risks.

To provide management of the Study a Joint Client Group was established having a membership of representatives from Comhairle nan Eilean Siar, the Aberdeen Institute of Coastal Science and Management (AICSM) at the University of Aberdeen, Scottish Natural Heritage (SNH), the Scottish Environmental Protection Agency (SEPA) and the lochdar community represented by the lochdar Flood Action Group.

OBJECTIVES, RESEARCH QUESTIONS AND CONCLUSIONS

The research at South Ford consisted of **seven objectives**:

1. **To quantify the physical changes in the coastal landscape of the South Ford;**
2. **to make a specific study of Gualan Island with the purpose of establishing its past history of change, its present status and likely future changes;**
3. **to undertake a hydrodynamic and sediment transport modelling study for the South Ford;**
4. **to evaluate the long-term significance of commercial and private sand and gravel removal from local beaches;**
5. **to reconstruct a history of past extreme weather and flooding events in order to place into context the storm of January 2005;**
6. **to provide an assessment of coastal flood risk; and**
7. **to evaluate the various options for hazard management.**

In attempting to answer the **seven issues** above that were highlighted by various stakeholders we identified a series of four key questions.

The **FIRST QUESTION** was to ask **what are the cause and effect linkages between coastal processes and coastal flooding within the South Ford area for the period prior to 1984 (i.e. before construction of the causeway) and separately for the period post-1984 (i.e. after causeway construction)?**

For the period prior to 1984 the report CONCLUDES that:

- Isolated areas of machair located on islands across the South Ford point to a formerly more extensive machair surface that existed during historical times and which has almost disappeared due to rising seas and storm erosion.
- Gualan Island experienced greater coastal erosion and retreat between 1946 and 1984 than it did between 1984 and 2005.
- There is quite clear air photographic evidence of widespread wave overtopping of Gualan Island during the early 1960s.
- Since AD 1805, there has been a sustained northward extension and growth of Gualan Island with the greatest northward growth having accompanied the January 2005 storm. Since the 1870s, there has been an eastward retreat of the Atlantic shoreface of Gualan Island in the order of 100 metres.
- Sometime during the early 19th century, there was large-scale and extensive sand drifting at Lionacleit that resulted in the blockage of pre-existing tidal inlets and which ultimately led to the production of drainage ditches. Subsequently, the Lionacleit coastline has experienced significant coastal erosion.
- During the 1960s, 70s and 80s the practice of removal of sand and gravel from west-coast beach areas and from South Ford was widespread. This practice, now a rare occurrence, undoubtedly contributed to accelerated coastal erosion

and retreat during this time interval and perhaps also, half a century later, is still a factor influencing present processes and rates of coastal erosion.

For the period post-1984 (i.e. after the construction of the South Ford causeway) the report CONCLUDES that:

- There has been acceleration in the rate and magnitude of coastal erosion on the south coast of Benbecula at Lionacleit.
- Parts of the South Ford basin have experienced significant sediment infilling. This includes the near-blockage of flow between Loch Bi and South Ford. In general there has been a build-up of sediment along the south side of South Ford particularly in the lee of Gualan Island. The channel between the southern end of Gualan Island and South Ford has also experienced significant infilling with sediment.
- The effects of sea level rise and winter storminess, together with local extraction of sand and gravels from beaches have together contributed to recent coastal erosion.
- Since 1984 there has been a northwards extension of the sand and gravel spit at the northern end of Gualan Island.
- On Gualan Island erosion has occurred along the entire length of the Atlantic edge with the greatest area of 30 metres of cliff retreat in the north.
- Dune vegetation is absent from the central part of Gualan Island where the Atlantic edge has experienced 20 metres of retreat. This area was breached by the January 2005 storm.
- Since 1984 there has been a vertical growth of coastal dunes at the south end of Gualan Island that, by 2005, was sufficient to prevent wave overtopping during the January 2005 storm.

The **SECOND QUESTION** was to ask **what was the role of the South Ford causeway in the flooding associated with the 2005 storm? The report CONCLUDES that:**

- Modelling of the January 2005 storm shows the extent of flooding to be greater with the causeway present than without the causeway.
- Modelling of the 1984 hydrodynamics with the causeway present shows on a rising tide increased current speed in the channel between Gualan Island and south coast of Lionacleit than without the causeway.
- The causeway was a factor which contributed to the flooding but it was not the only one. Other factors included:
 1. Sediment build-up and infilling along the southern side of the South Ford.
 2. Long-term detrimental effects of beach sediment removal for commercial and private purposes.
 3. Exceptionally low atmospheric pressure associated with the January 2005 storm that contributed significantly to the raising of the sea surface.
 4. The occurrence of a severe part of the storm during high astronomical tidal conditions.

The **THIRD QUESTION** was to ask **what are the risks of coastal erosion/flooding, probability, and consequences to people and assets? The report CONCLUDES that:**

- Analysis of daily weather records for the period AD 1869 –present showed the former occurrence of eight exceptional storms with seven (7) of these having occurred between 1869-1881. All of these events were associated with air pressures lower than during the January 2005 storm and all were at least as long-lasting (in one case longer) as the January 2005 storm. Only one other equivalent event (December 1982) occurred during the 20th century.
- Present trends in winter storminess across the northern North Atlantic do not show signs of any long-term increase – despite global warming. Similar patterns are evident in the records from North Atlantic wave buoys. The observed patterns of monthly storminess, however, show that since 1970 an exceptionally stormy month occurs during winter once every 5 – 7 years the most recent example of this being December 2011.
- Although the January 2005 event was the worst storm in living memory, there were equally severe events between 1869 and 1881.
- Modelling of varying degrees of severity of breach scenarios in the centre of Gualan Island shows increased wave heights in the eastern part of the South Ford.

Predictions of rising sea level together with field observations point to the likelihood of the central part of Gualan Island being overtopped by winter storm waves increasingly frequently. Modelling research shows this effect very clearly. A breached Gualan Island in the future would make the coastline around South Ford increasingly vulnerable to storm waves.

The **FOURTH QUESTION** was to ask **what effect would there be of possible interventions in managing the risk? The report CONCLUDES that:**

- The channel between Loch Bi and southern Gualan Island needs to be dredged/excavated in order to enable the culvert that connects the two areas to function efficiently. If this is not done, the southern area of the South Ford will continue to fill with sediment and the exchange of water between Loch Bi and South Ford will be further impeded.
- Linked to the above, it would make sense that the central area of Gualan Island is replenished with beach materials – this will represent a long-term commitment to prevent breaching of the barrier island.
- The creation of an additional number of culverts beneath the causeway would have negligible impact on reducing flood risk.
- To reduce the extent and height of flooding in the event of a similarly severe storm to that experienced in January 2005 it would require the construction of a bridge ca. 250 metres in length to replace the central section of the causeway.

RECOMMENDATIONS

In making recommendations in respect of what should be done to reduce the risk to life and property in the future, we are acutely aware of what is affordable and what is not. Accordingly we have listed the key measures that we have identified with a hazard management matrix. These range from the most expensive option of replacing a significant section of causeway with a bridge to a range of relatively inexpensive soft-engineering options. We leave it to the Comhairle to select which of these options they wish to pursue.

The options for hazard management are outlined in Table 1. Of these, the causeway bridge construction is the only high-cost and high-impact intervention. One high-impact and medium-cost measure that is proposed is the replenishment of the central part of Gualan Island with beach sand extracted from the area of South Ford adjacent to the exit point of Loch Bi. Removal of sand from this area would have the further objective of re-opening the channel that separates the southern end of Gualan Island from South Uist. The remaining high-impact measures proposed at low cost include taking active adaptation measures as recommended by CoastAdapt¹, initiating a scheme for dune management for Gualan Island, effective participation in coastal flood alert systems, using planning policy to determine the suitability or otherwise of sites for development through Flood Risk Assessment as well as participation in the development of long-term disaster recovery planning.

¹ CoastAdapt was a transnational project which was part funded by the EU Northern Periphery Programme (www.coastadapt.org). The Outer Hebrides was one of five pilot sites.

Table 1: Hazard Management Options Matrix

	HIGH IMPACT	MEDIUM IMPACT	LOW IMPACT
Low Cost	<p>1. Adaptive management measures through recommendations by CoastAdapt project</p> <p>2. Dune management scheme for south coast of Benbecula</p> <p>6. Encourage local residents to sign up for coastal flood alert system</p> <p>4. Using planning policy to determine suitability or otherwise of sites for development through Flood Risk Assessment</p> <p>8. Participate in development of long-term disaster recovery planning</p>	<p>3. Proactive and participatory approach by community to new Flood Risk Management legislation</p> <p>7. Strengthen community representation on the CoastHebrides ICZM Forum</p> <p>4. Undertake a Strategic Flood Risk Assessment (SFRA) for the South Ford area</p> <p>5. Include an assessment of public roads susceptible to coastal flooding as part of the SFRA</p>	
Medium Cost	<p>9. Beach replenishment scheme for Gualan Island</p>		
High Cost	<p>10. Create opening(s) at least 250 metres long in the causeway with bridged sections of carriageway</p>		

Description of Identified Hazard Management Options

Option 1: Adaptive management measures through recommendations set by the CoastAdapt project

Low Cost / High Impact

Using the methodology developed by CoastAdapt, coastal management options based on principles of adapting to change through adjustments in both natural and human systems have been identified to address the findings of the South Ford Hydrodynamics Study. Options that have been identified and which require further development in practice include: dune control and management; proactive and participatory approach by the community in flood risk management; use of planning policy; effective participation in the coastal flood alert system; strengthened community representation on the Integrated Coastal Zone Management (ICZM) forum; and, development of CoastAdapt long-term disaster recovery planning to suit local conditions. The outputs of CoastAdapt illustrate a transition in the management approach undertaken to tackle projected climate change impacts in coastal environments, shifting from traditional management strategies to a participatory approach and the consideration of other options working with rather than against natural processes.

Recommendation

Explore the low cost options having high or medium impact which have been identified by CoastAdapt.

Option 2: Dune management scheme for south coast of Benbecula

Low Cost / High Impact

Significant erosion of the coast has occurred in the period between 1984 and 2005 in the areas identified as Area 1 and Area 2 in the Results chapter of the Quantification of the Physical Changes in the Coastal Landscape of the South Ford report which is appended.

The dune system, where it exists, provides protection to infrastructure including the community school and playing fields, Further Education College and a hotel. The main B892 road from Creagorry to Balivanich is also located in close proximity to the coast.

The coast in these areas has been monitored by the Comhairle since 1997 on a yearly basis until 2007 plus a recent survey dating from February 2011. Recession rates recorded from 2007 to 2011 vary from 7 to 9 metres. The principal cause of erosion is due to the action of currents and waves undercutting the dune system as explained in Appendix A, however, frequent strong winds blow sand from the dune face thereby deflating the dunes and decreasing the protection they afford.

Recommendation

A Beach and Dune Management Plan should be developed for the area with appropriate measures designed to implement management practices such as dune restoration and

control and management of public access. The aim of the Plan would be to establish a robust and sustainable dune system designed to slow the effects of erosion thereby increasing protection to the built assets located behind the dunes. The dune management scheme should be combined with the proposed beach replenishment scheme for Gualan Island.

Option 3: Proactive and participatory approach by community towards new Flood Risk Management legislation

Low Cost / Medium Impact

Much of the impetus behind bringing about the South Ford Hydrodynamics Study was initiated by the lochdar Flood Action Group which was established after the January 2005 storm. It is recommended that similar energy is continued by the community participating fully in the Outer Hebrides Local Flood Risk Management Advisory Group (LAG). The LAG will provide advice to SEPA and Comhairle nan Eilean Siar as Lead Authority at key stages of the FRM Planning process. In addition to these meetings, individual stakeholders, such as the lochdar Flood Action Group, are likely to be contacted to provide contributions to the development of the Local FRM Plan for the Outer Hebrides.

Participation of the community landowner, Storas Uibhist, in the FRM Planning process is also seen as being beneficial to the development of the Plan.

Recommendation

The lochdar Flood Action Group and Storas Uibhist should be invited to participate in the Outer Hebrides Local Flood Risk Management Advisory Group.

Option 4: Use of planning policy to determine suitability or otherwise of sites for development through Flood Risk Assessment

Low Cost / High Impact

The planning system provides one of the most powerful tools available for managing flood risk. Where the Planning Authority considers that there might be a risk of flooding to the development site it has a statutory duty to consult SEPA for advice and guidance on flood risk.

The approach adopted by Comhairle nan Eilean Siar is that when the Planning Service considers development proposals are within areas of risk of flooding:

- (a) Areas of low to medium flood risk: These areas will be suitable for most development with the exception of essential civil infrastructure. A Flood Risk Assessment (FRA) may be required at the discretion of the Comhairle.
- (b) Areas of medium to high flood risk: Developers will be required to provide a FRA undertaken to a competent standard, or other suitable information that demonstrates compliance with Scottish Planning Policy.

- (c) Areas bordering areas of medium to high flood risk: a topographical survey (or a minimum of 5 spot levels referenced to Ordnance datum) may be required to inform the need or otherwise for a FRA.

The technical requirements of a FRA for any site can range from the provision of detailed topographic information to demonstrate the relative level of the development site in relation to the river/floodplain to technically-detailed hydrological and 1- or 2-dimensional hydraulic modelling to investigate the risk to the development or its impact elsewhere.

A Strategic Flood Risk Assessment (SFRA) is designed for the purposes of specifically informing the Development Planning Process, i.e. Local Plans. A SFRA involves the collection, analysis and presentation of all existing and readily available flood risk information for the area of interest. It constitutes a strategic overview of flood risk, without necessarily meeting the reporting requirements of a detailed FRA and would generally be executed as a desk top study.

Recommendation

A Strategic Flood Risk Assessment (SFRA) should be prepared for the South Ford area. The SFRA should constitute a strategic overview of flood risk and should address key objectives listed below:

- (a) Collate all sources of flooding that may affect existing and/or future development within the study area;
- (b) Identify areas and probability of flooding in accordance with Scottish Planning Policy, the SEPA Indicative River & Coastal Flood Map, taking account of design sea levels for the Coastal Flood Hazard Map;
- (c) Recommend appropriate land uses within flood affected areas in relation to the Local Development Plan for the Outer Hebrides which take account of avoidance of flood risk, except in circumstances where development has to be located in a flood risk area for operational reasons, for example harbour use.
- (d) Recommend possible flood mitigation solutions that may be incorporated into the design (by a developer) in areas where flood risk has been identified as a possible constraint to future development, which would minimize risk to property and life should a flood occur. Arrangements for flood warning and emergency planning should be included and whether improvements can be made to existing measures.
- (e) The final SFRA should be strong tool for steering development away from flood risk areas and for identifying more suitable areas for development as an alternative.

Option 5: Assess level of roads in areas vulnerable to flooding such as at Kilaulay**Low Cost / Medium Impact**

An assessment of the susceptibility of public highways to flooding should be made together with the proposed Strategic Flood Risk Assessment (SFRA) for the South Ford area. Height was added to the level of the road at the location of the Lochdar Flood Alleviation Scheme (to 3.00m AOD) which was the height of flooding experienced during the January 2005 storm at this location.

An area of particular vulnerability to coastal flooding is where the highway is located between Linique and Kilaulay. The SFRA should recommend methods designed to reduce the risk presented by flooding where the level of the highway is below the coastal flood plain.

Recommendation

Include an assessment of the susceptibility of the public highway system to flooding as part of the proposed Strategic Flood Risk Assessment (SFRA) for the South Ford area.

Option 6: Register for the coastal flood alert system**Low Cost / High Impact**

SEPA operates a direct flood warning service to which residents can sign up to receive free advance flood warning messages direct to their landline or mobile phone, notifying them when a flood warning has been issued for their local area.

However, despite the severity of the impact of the January 2005 storm and demands for such a system, take-up of the direct warning service has been low, currently only 16 people have signed-up across the Outer Hebrides with very few in the South Ford area.

Encouragement is required for local residents in the South Ford area and throughout the Outer Hebrides in general, to sign up for the direct warning system. Although SEPA ran a winter flood awareness campaign, they need to do more to encourage residents to register for the service.

The Western Isles Emergency Planning Coordinating Group (WIEPCG) has promoted the SEPA Floodline Service on their Facebook site and they are willing to continue to do so.

Recommendation

SEPA needs to do more to promote the Floodline Service and to find ways of increasing the number of people who have registered for the direct flood warning service. The WIEPCG are willing to assist, but it is the responsibility of SEPA to ensure that an effective flood warning service is delivered to the people most at risk.

Option 7: Strengthen community representation on the Coast Hebrides ICZM Forum

Low Cost / Medium Impact

The lochdar Flood Action Group has representation on the Coast Hebrides Integrated Coastal Zone Management (ICZM) Forum which also has representatives from all relevant agencies within the Outer Hebrides such as Comhairle nan Eilean Siar, Scottish Natural Heritage, and SEPA. The recent Marine Act in Scotland will change the way in which the coast and inshore seas are managed and the work of Coast Hebrides is expected to influence marine and coastal planning policy at local level.

Recommendation

Ensure that the lochdar Flood Action Group participates fully in the work of the Coast Hebrides ICZM Forum.

Option 8: Participate in development of long-term disaster recovery planning (CoastAdapt)

Low Cost / High Impact

An objective of the CoastAdapt project was to give consideration to measures that address the need for improvement in extreme weather public warning systems and post disaster recovery from natural hazards.

A report entitled 'Long-Term Response to Natural Disasters' was developed by a research project carried out by a CoastAdapt partner in Iceland from 2006 to 2008 with the aim of improving the recovery of communities that had suffered major trauma due to a natural disaster such as earthquakes, flooding, avalanches or extreme weather.

The initial responses to such events, search and rescue, are well prepared and carried out under the auspices of the Western Isles Emergency Planning Coordinating Group (WIEPCG) and they have adopted the HISCAG Recovery Guidance Document which is to be used in all 'Recovery' phases across the Highlands and Islands. The Guidance Document is designed to address generic emergency and major incidents, and is not specifically for storms and flooding.

The Scottish Flood Forum, an organisation funded by the Scottish Government which provides support for and represents those who are affected by, or are at risk of flooding, has offered advice on how the Guidance Document can be further improved in relation to helping people recover from the impact of storms and flooding.

An issue related to recovery from storms and flooding is that of adequate flood insurance for property situated in areas at risk of flooding, and provision of assistance to householders in making claims such as elderly residents.

Recommendation

The HISCAG Recovery Guidance Document should be further improved specifically in relation to recovery from the impact of storms and flooding by:

- identifying and transferring good practice from the ‘Long-Term Response to Natural Disasters’ report;
- taking advice from the experience and expertise of the Scottish Flood Forum; and,
- taking advice on flood insurance for properties in flood risk areas from the Association of British Insurers.

Where possible a participatory approach should be adopted, e.g. by incorporating post disaster recovery from natural hazards into local flood risk planning.

Option 9: Beach replenishment scheme for Gualan Island

Medium Cost / High Impact

It is proposed that a beach replenishment scheme is constructed on the central section of Gualan Island designed to prevent further breaching of the barrier island thereby protecting the coastline that surrounds the South Ford Basin from the full force of Atlantic waves under future storm conditions.

The Gualan Island Study undertaken by the Aberdeen Institute for Coastal Science and Management recommends the reconstruction of the coastal dune ridge along the central section of the barrier island through the provision of an amount of sand sufficient to create a ridge at least 20 metres in width and up to 10 metres in height. The ridge should have embedded within it lengths of biodegradable hessian or similar matting that would have the purpose of binding the sand together and diminishing its susceptibility to future erosion by storms and high tides. The Study further recommends that the defences should be reinforced by gabions embedded within the dunes, these serving as fail safe devices. A supplementary action should be the planting of marram grass using the sprigging method that, in conjunction with hessian matting, should be sufficient to establish a continuous cover of vegetation along the length of coastal ridge presently at risk from erosion and wave overtopping.

The proposal must show that the scheme will withstand and/or have sufficient resilience to protect the replenishment scheme from erosion over a design life of more than the 1 in 10 year event for that of the original proposal in 2006. The required design life must be established at an early stage for the scheme to progress through the appraisal process.

The proposal must also identify people and assets at risk from flooding and show how the scheme will provide protection.

Recommendation

A flood prevention / coastal protection scheme should be designed for Gualan Island, and should be combined with the dune management scheme for the south coast of Benbecula. The participation and support from Storas Uibhist and the local community is seen as being essential in the preparation of such a scheme.

A combined scheme for beach replenishment at Gualan Island and dune management on the south coast of Benbecula is likely to emerge as a flood prevention scheme under the Outer Hebrides Local Flood Risk Management District Plan which will be completed in 2015. The scheme would then be submitted to the Scottish Government to go through the formal Flood Risk Management appraisal process. However, although 80% grant funding is available for approved schemes, there is presently a £2m project value threshold which a proposed scheme for the South Ford scheme is unlikely to achieve. Relaxation of the threshold amount could be possible but it would require representations to be made by the Comhairle, Stòras Uibhist, the local community, and other interested parties, to the Scottish Government. These could be achieved through existing channels of communication, through the Local FRM District Plan Partnership, and through the Local Advisory Group.

Option 10: Create opening(s) at least 250 metres long in the causeway with bridged sections of carriageway

High Cost / High Impact

The model simulations indicate that increasing the size of an opening in the causeway leads to a reduction in the water that builds up to the west of the causeway during the simulation of the storm. Therefore, a larger gap in the causeway leads to less inundation around lochdar and the south shore of Benbecula.

From the results of the model simulations, a full depth opening of 250m length would have significantly alleviated the flooding experienced during the January 2005 storm. The overall length of opening would need to be increased if multiple openings are inserted into the causeway due to the flow experiencing greater friction from the sides.

However, it recognised that the construction of a bridge or other means of opening(s) in the causeway would be of high cost and a full feasibility study including cost/benefit analysis would be required to be carried out if it is decided to investigate this option.

The full report together with Appendices A - H in electronic format is contained in the accompanying Compact Disc. Paper versions can be obtained from the Project Manager on request.

APPENDICES

- A. Quantification of the Physical Changes in the Coastal Landscape of the South Ford, Outer Hebrides

Contractor: Aberdeen Institute for Coastal Science and Management,
University of Aberdeen

This study involves the provision of digital terrain models (DTMs) and maps of landscape change that have taken place in the South Ford area over recent decades. The purpose of the provision of these DTMs is to create baseline information that can be used in the development and evaluation of hydrodynamic and sediment transport models of the area designed to simulate changes in water level and inundation coupled with variable meteorological forcing. The acquired data has been used to quantify physical changes that have taken place between when the South Ford causeway was constructed and the present day.

- B. Hydrographic Digital Terrain Model of the South Ford

Contractor: Topaz Environmental and Marine

The digital hydrographical terrain model (digital bathymetric model, DBM) of the South Ford area was requested as part of the development of a hydrodynamic and sediment transport model in order to address the erosion and associated flooding from recent storms. Further use of the model was to assess the potential impact of future storms across the shores of South Ford behind Gualan Island. The report details the bathymetric and land survey conducted by Topaz Environment and Marine Ltd. (TEAM, University of St Andrews) from 4.6.09 to 12.6.09.

- C. Sediment Core Sampling, Analysis and Dating, South Ford, Outer Hebrides

Contractor: Environmental Systems Research Group, University of Dundee

This research examines the recent sedimentation history of the South Ford intertidal basin. The principle aim of this work was to use radiometric dating techniques (^{137}Cs and ^{210}Pb) to quantify rates of sedimentation across the basin and characterise the physical and chemical nature of the basin sediments. A total of 22 'undisturbed' sediment cores were extracted from the bed of the intertidal basin and from a small area of salt marsh to a maximum depth of 1 m. Soil profiles from an unploughed field above the zone of tidal influence provided the 'reference' for the atmospheric input of these radionuclides onto the basin. In addition to characterising amount (inventories) and vertical distribution of radionuclides (using gamma spectrometry), a

broader range of physico-chemical measures were undertaken including density, particle size distribution (laser granulometry), chemical element composition (x-ray fluorescence) and magnetic susceptibility. Gamma spectrometry dating was conducted on five cores (four basin cores and a saltmarsh sample), with magnetic profiling used to correlate between these and undated cores (which are archived in the University of Dundee).

D. Gualan Island Study, South Ford, Outer Hebrides

Contractor: Aberdeen Institute for Coastal Science and Management,
University of Aberdeen

The future evolution of the South Ford area, between Benbecula and South Uist, will to a large extent be influenced by what happens to the barrier island of Gualan, which almost closes the 2.7 km “gap” on the Atlantic side of South Ford. Gualan is a remnant strip of sand and a vulnerable barrier which, in the future, could disappear and open-up the west side of South Ford to the full range of Atlantic wave and tidal forces. The aim of this research project is to attempt to reconstruct the evolution of Gualan Island with an emphasis on recent trends and possible future changes. The report concludes with a number of recommendations for future courses of action.

E. Gualan Island Supplementary Report, South Ford, Outer Hebrides

Contractor: Aberdeen Institute for Coastal Science and Management,
University of Aberdeen

The aim of this research project is to add new information on the evolution of Gualan Island to supplement the information earlier gained through the analysis of aerial photographs and LiDAR data for the period between 1984 - 2005. This new information derives from the analysis of earlier aerial photographs of the area covering the period between 1946 -1984. These older sets of aerial photography have the potential to inform us of how this area has evolved since the end of World War II. This information thus has the potential to provide new insights regarding the long-term evolution of this barrier island system.

F. Hydrodynamic and Sediment Transport Modelling Study of the South Ford

Contractor: JBA Consulting

There are three main features of the South Ford that determine the local hydrodynamics and therefore flood risk from such coastal storm surges:

- Gualan Island which shields the South Ford to the west from large waves propagating towards the coastline from Atlantic Ocean storms;
- A causeway that links Benbecula to South Uist, allowing tidal flow between the Atlantic Ocean and the Minch through a 15m-wide culvert;

- Significant change in the geomorphology of the South Ford due to erosion, sediment transport and accretion determined by the local hydrodynamics.

This report details a hydrodynamic modelling study carried out to investigate how these factors contributed to the observed flooding during the January 2005 storm, how they determine the local hydrodynamic and resultant sediment transport regimes, and how the flood risk may change after 20 years of continued geomorphological change.

G. South Ford Causeway Modelling Scenarios

Contractor: JBA Consulting

This note describes the results of modelling scenarios carried out using the South Ford hydrodynamic model. The scenarios all simulate the 2005 storm, but vary in terms of the geometry of the South Ford causeway. They are designed to investigate the effect on sea-levels of incorporating an additional opening within the South Ford causeway that would allow relief flow through to the Minch. The scenarios differ by the size of the opening incorporated. The model scenarios for 'current causeway' (where the only opening is the existing north culvert) and 'no causeway' were produced for the first draft of the report. Six further simulations have been performed. These simulations incorporate 3 permutations for length of opening in the causeway (100m, 250m, 450m) and 2 permutations for depth of opening (down to the sea bed at approximately -0.7mOD and down to +2mOD, referred to as deep and shallow openings respectively). These openings are represented by one long opening as opposed to several short openings.

H. Weather and Coastal Flooding History: The Uists and Benbecula

Contractor: Aberdeen Institute for Coastal Science and Management,
University of Aberdeen

This report has the object of trying to understand the meteorological context of the storm of January 11th 2005 within the longer-term context of weather and climate changes that have taken place in the Outer Isles since the first written records. An attempt is made to address the issue of whether the 2005 storm was a unique 'rogue' event or whether there have been other similarly large storms during the historic past. In this report a discussion on storminess change is presented on the basis of newly-constructed daily time series of air pressure measurements from the Monach Isles lighthouse (AD 1869-1913) and Lews Castle, Stornoway (AD 1867-2011). Time series of gale measurements are also used in addition to transcribed records of average monthly wind speed, highest hourly wind speed and gust data for the last 30 yr in order to investigate recent trends in storminess. Historical documentary records of past storms in the Outer Isles extending back to the start of the 17th century are also used as interpretive sources (Appendix 1). Complete records of transcribed daily air pressure data are provided in Appendices 2 and 3.