Environmental Risks to Infrastructure Innovation Programme

NERC SCIENCE OF THE ENVIRONMENT

# Assessing the risk to the coastal and rural road network in Scotland due to the effects of storms and extreme rainfall events

## Project details

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| **NERC Grant award number** | NE/N013034/1 |
| **Principal investigator** | Dr Sue Dawson |
| **Lead institution** | University of Dundee, Transport Research Laboratory |
| **Co-investigators** | Prof Mike Winter, Dr Sarah Reeves, Dr Jonathan Knappett, Dr Michael Brown, Dr Fraser Milne |
| **Project length (including no cost extensions)** | Six months |
| **Total funds awarded** | £61 921 |
| **Industry and other project partners** | Transport Scotland |
| Sectors | Rail transport, road transport, flood and coastal erosion management, flood defences and flood plain management |
| Hazards | Storms and gales/wind, high impact, low probability event, multi-hazard combinations, coastal flooding, sea level rise, coastal erosion |

*Courtesy TranServ Scotland*


## Summary

The aim of this innovation project was to develop a methodology for assessing the risk of extreme events on road and coastal infrastructure in Scotland. The methodology was based on a similar approach developed by the Transport Research Laboratory (TRL) to assess the hazards and risks associated with landslides. The methodology produced was applied to a case study site on Transport Scotland's network vulnerable to coastal flooding, and an estimate of the increase in costs due to more frequent flooding was calculated. The methodology developed provides information on the magnitude of risk, and how this may be affected by climate change and economic costs. This could be used by infrastructure owners to inform decisions on adaptation action.

In addition to the methodology and the results of the case study site, the project identified a number of actions that would improve the robustness of this type of calculation and also the information available to infrastructure owners. These comprised the inclusion of flood risk factors in asset inspections and developing a national hazard coastal map that incorporates coastal morphology.

# The challenge or opportunity

Sea levels are set to rise around the UK coast because of climate change, leading to increased risk of coastal flooding that will affect road and other infrastructure. The HM Government (2017) estimated that if there was a 4°C increase in global temperature as predicted under high emission scenarios for the end of the century there would be a 129 per cent increase in the length of strategic road network in Scotland with a 1 in 75 or greater annual chance of coastal flooding. The impact of climate change on the frequency of storms experienced in Scotland is unclear, but research by the Intergovernmental Panel on Climate Change (IPCC) suggests wave height could increase in a warmer climate.

Roads in Scotland provide vital links to remote communities. Road density is often lower than in other parts of the UK, so there can be less redundancy in the network. Severance of the access of these communities to services and markets due to natural hazards, such as coastal flooding, can have significant economic and social consequences. Flooding can also result in clean-up and repair costs for road operators. The project set out to better understand the risk to coastal and rural roads from coastal flooding, and how this risk might change in the future so that the infrastructure owner could make informed decisions on the cost effectiveness of any adaptation action.

# The science

The methodology for the study was based on a similar approach developed by the TRL to assess the hazards and risks from landslide events along the Scottish trunk road network. This included economic modelling of the costs associated with an event based.Using these existing approaches, the project sought to develop an approach for assessing the risk to coastal roads from flooding.

To develop the methodology, a section of the A78 that runs along the west coast of Scotland between Skelmorlie and Largs, was selected as a case study following liaison with Transport Scotland. This location has frequently experienced flooding, often leading to the complete closure of the road and a long diversion for travellers. The research drew on data of recorded coastal water levels since 1990 available from the local tide gauge and available historic data of past coastal flood events. Projected sea level rise for low, medium and high emission scenarios was also used to help ascertain future changes to coastal flood risk. The cost of repair and clean-up was obtained from the operating company, Scotland TranServ. They also provided traffic flow data, which was used in the calculation of the direct consequential costs of flood events.

# The innovation

A new methodology to assess the risk to infrastructure from coastal flooding under different climate scenarios was developed using a section of trunk road in Scotland susceptible to marine inundation. The methodology involved:

1. Defining the analysis site and at least one benchmark event. These were selected in conjunction with the project partner and their maintenance contractor.
2. Data collection:
    a. Site investigation to identify factors indicating greater susceptibility to flooding such as road elevation.
    b. Obtaining local tide gauge data to assess historic high coastal water levels.
    c. Downloading projections for future sea level rise for the location.
    d. Obtaining traffic flow data, information on the benchmark flood event, division routes and repair costs from the maintaining contractor.
3. Hazard analysis:
    a. Analysis of the data collected to determine the issues that make the infrastructure more susceptible to flooding.
    b. Use of astronomical tide and historic high water levels to develop a flood potential value (FPV) indicating how likely flooding is.
    c. Use of the benchmark event to identify a threshold above which flooding is very likely.
    d. Calculation of how often the FPV threshold was exceeded over the past 25 years, and at 2025, 2050 and 2100.
4. Economic modelling was carried out by TRL to estimate the cost per flood event, based on the benchmark event.
5. Overall risk: the annual frequency of events 1990 to 2015 and how this frequency is projected to change under future sea level scenarios by 2025, 2050 and 2100 (from point 3) were combined with the cost of the benchmark event (point 4) to provide an assessment of how the average annual direct costs from coastal flooding change over time for the case study site.

# The outcome to date (impact or potential impact)

The study provided the project partner with an insight into the factors affecting the risk to their coastal infrastructure from storms and with a methodology for assessing this risk. The results from this type of risk assessment can help to inform the adaptation actions of infrastructure owners such as Transport Scotland, giving them information on the level of risk and how assets may be affected by climate change. This can provide the evidence required to prioritise resources, plan budgets and form a business case for action. If cost-effective adaptation action is taken using this information, it would reduce disruption for users of the network and maintenance costs for owners.

The research highlighted that the North Atlantic Oscillation (NAO) index could be used as an indicator to help infrastructure operators prepare for flooding. This relates to the fact that positive NAO values tend to coincide with stormier winters in northern Europe. This was apparent in the scoping study as the winter NAO index was seen to correlate

with the FPV. It is suggested that if the NAO index is positive in October/November, then it should be considered likely that the forthcoming winter will be stormy in northern Europe with a higher potential for coastal flooding. Further research in this area could help manage future coastal risk by increasing resilience and reducing the vulnerability of infrastructure users to coastal hazards through better preparedness.

The primary impact of the research is enabling a more resilient society by protecting the infrastructure from coastal hazards. It is also envisaged that the research will contribute towards informing policy and regulation in the UK by increasing the understanding of coastal flood risk due to climate change.

## What next?

This project was a small scoping study based on one case study site. To develop the methodology further and demonstrate its suitability for general application it needs to be applied to a variety of different types of coastline and infrastructure in a more extensive study. The project identified a number of actions that would increase the robustness of this type of calculation and also the information available to infrastructure owners. For example, it is suggested that improvements are made in recording information on the impacts of natural hazards, including the exact location, timings, narrative of events, costs incurred and actions taken. It is suggested that a national database should be established to provide a central point of access and a hazard reporting protocol is developed to ensure consistency in the information submitted. Future research should focus on developing a national coastal hazard map, which includes coastal morphology, allowing targeted calculation of flood potential for other sites where infrastructure is identified as potentially vulnerable to coastal inundation. Future research should also investigate the potential of natural flood defences (sand dunes, beaches and saltmarsh) to reduce the risk of coastal flooding. Future investigations should also consider the impact of enhanced erosion due to poor coastal management on the flood susceptibility of national infrastructure. Such research would allow the development of better guidance for infrastructure owners on the management of the coastline, in particular regarding the benefits of working with nature rather than constructing hard defences.

## Lessons learned, knowledge shared, partnerships formed

A good working relationship was established between the research organisations and the project partner. Transport Scotland was engaged throughout the project and attended meetings, provided advice, gave contractor contact details for obtaining data and highlighted areas they wanted the research to focus on. The project findings were presented to the project partner at their offices in Glasgow. Transport Scotland was happy with the outcomes of the project and found the findings useful.

*"Climate change will prove more challenging for Scotland's coasts as time moves on. Studies such as the ERIIP report and the recently issued dynamic coast report (Fitton et al, 2017) will be invaluable tools for asset owners allowing them to prioritise protection works to the most vulnerable areas.*

*The study area of the report was the A78 trunk road which runs along the coast of the Firth of Clyde. There are already gates allowing Transport Scotland to safely close the road in times of flooding. This area is ideal for a study such as this and we welcome the opportunity to work with the study team. This report and others will be used in developing our climate change adaption plans in the next few years."*

*Graham Edmond BSc CEng MICE,*
*Senior Principal Civil Engineer, Transport Scotland.*

The University of Dundee and TRL researchers worked well as a team and if the opportunity arose would like to build on this partnership.

Following this NERC-funded study the project partner agreed to participate in a pilot study as part of a European project TRL is leading, which is also related to assessing the climate change risk for road infrastructure. Some of the findings of the NERC-funded project could inform this pilot study.

## Participants and acknowledgements

The work was carried out by the University of Dundee and TRL, in conjunction with Transport Scotland, who supported the project by providing resources in-kind. Thanks go to Graham Edmond, Transport Scotland, for his support and advice during this project. The efforts of Andy Fraser and Michael Pagan, Scotland TranServ, in providing details of the A78 flooding event, and of Gareth Picken, North Ayrshire Council, in providing traffic data for the local road network, are gratefully acknowledged. Alistair Dawson provided invaluable and integral assistance in analysis of tide gauge data and the interpretation of NAO index data. Alan Long, University of Dundee, assisted with the operation of the differential global positioning system (DGPS).

**Further information**

FITTON, J M, HANSOM, J D, RENNIE, A F (2017) *Dynamic coast - national coastal change assessment: methodology*, CRW2014/2, Centre of Expertise for Waters (CREW), Scotland
**www.dynamiccoast.com/files/reports/NCCA%20-%20Methodology.pdf**

MILNE, F D, WINTER, M G, REEVES, S J, KNAPPETT, J K, DAWSON, S, DAWSON, A, PEELING, D, PEELING, J, BROWN, M J (2016) *Assessing the risks to infrastructure from coastal storms in a changing climate*, Published Project Report PPR800, TRL Limited, Wokingham, UK
**https://trl.co.uk/reports/assessing-risks-infrastructure-coastal-storms-changing-climate**

NORTH ATLANTIC OSCILLATION (NAO) Index
**www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml**

UK GOVERNMENT (2017) *UK Climate Risk Assessment 2017*, UK Government, London (ISBN: 978-1-47413-741-6)
**www.gov.uk/government/uploads/system/uploads/attachment_data/file/584281/uk-climate-change-risk-assess-2017.pdf**

IPPC reports: **www.ipcc.ch/publications_and_data**

## Lead institution

University of Dundee

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## Industry partners

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

This project was funded through the Environmental Risks to Infrastructure Innovation Programme (ERIIP). Through ERIIP the Natural Environment Research Council (NERC) is enabling collaboration between academia and infrastructure owners and operators to use the latest environmental science to identify, quantify and manage environmental risks.

The five-year, £5m initiative, which is driven by the needs of the business community, is translating the latest research into industry relevant outputs.

For more information please visit: **www.nerc.ac.uk/innovation/activities/infrastructure/envrisks**

ciria

**Further information**

NERC has contracted CIRIA to support academic–industry collaborations and manage the dissemination of outputs for this programme.

For more information visit: **www.ciria.org/Research/Projects_underway2/NERC.aspx**