Institution: Plymouth University

Unit of Assessment: C17 (Geography, Environmental Studies and Archaeology)

Title of case study: Sea-level rise and critical transport infrastructure

1. **Summary of the impact** (indicative maximum 100 words)

Research conducted at Plymouth University on the coastal environment has informed climate strategy and transport planning in the UK. The research resulted in the United Kingdom Climate Impact Programme (UKCIP) re-analysing and correcting rates of coastal land movement to improve predictions of sea-level change, in its *UK Climate Projections science report* (Lowe et al. 2009). These data now help underpin government policy related to climate change impacts. A follow-on project, focusing on the impact of sea-level rise on the Dawlish-Teignmouth stretch of the London-Penzance Railway line, was used by Network Rail in the implementation of its climate change adaptation strategy. This stretch of railway is recognised as critical infrastructure as it is the only means of access to west Devon, Plymouth and Cornwall by train from the rest of the country. Devon County Council also used the work to inform its third Local Transport Plan (LPT3) and the future management of coastal infrastructure.

2. Underpinning research (indicative maximum 500 words)

Beginning in 2007, the underpinning research was conducted at Plymouth University by *Professor Roland Gehrels* (1995-2013), ***Professor Jon Shaw*** (2006-present), *Dr William Marshall* (RCUK Fellow 2007-2012), along with former PhD students *Dr Antony Massey* (1998-2004) and *Dr David Dawson* (2007-11). The first stage sought to establish the rate of sea-level rise along the coastline of the Southwest peninsula. Sediment cores from south Devon were collected between 2004 and 2009 to produce new high-quality relative sea-level data (Gehrels et al. 2011). Previous methods to calculate rates of land motion for the Southwest were based on poor-quality data and the incorrect assumption that *relative* sea-/land-level change is equivalent to *absolute* land motion. The research criticised the methods used by UKCIP, and discussed the implications for the rest of the UK (Gehrels 2006, Gehrels and Long 2008, Gehrels 2010). As a result, a list of sites where geo-data were urgently needed to calculate rates of relative vertical land motion was published (Gehrels 2010). This work established the current rate of relative sea/land level change at ~1.1mm per year, with sea levels rising faster than for any other region in the UK (Gehrels et al. 2011).

A second research stage was then undertaken to apply these findings about regional sea-level change to the pressing regional policy concern of its potential impact on the Dawlish-Teignmouth railway line. Local and regional stakeholders have long emphasised the vulnerability of this section of track infrastructure, which runs between an exposed shoreline and coastal cliffs at just above the high water mark. Line closures and delays due to wave 'overtopping' are not uncommon, especially during the winter months, with knock-on effects throughout the region that lies to the west. As such our research was designed to combine physical and social science approaches: in particular, we set out to relate the specific impact of sea-level change on the Dawlish-Teignmouth railway line to the wider socio-economic functioning of the region.

This second stage of the research was sponsored by Great Western Research, Network Rail, and Devon and Cornwall County Councils. New information on sea-level rise was used in combination with historical data of disruptions to the railway, and UKCIP climate and socio-economic scenarios, to enable empirical projections of overtopping of the London-Penzance railway at Dawlish. We provided new estimates of service disruption, delays and damage to the sea defences. Costs to the region's economy and to Network Rail were also calculated. Projections suggest that in 2020 the current frequency of line problems on the track will be doubled and in a worst case scenario problems on the line could occur on up to 120 days annually by the end of the century. Results highlighted that a rise in sea-level of over 1 metre (e.g. UKCP09's H++ scenario) would completely inundate sections of the track and put Dawlish sea-wall defences at a significant risk of breaching.

Many communities that rely on the railway will be at increased risk of socio-economic exclusion, and in the longer term Plymouth, west Devon and Cornwall would experience significant impacts on their economic competitiveness (Dawson 2012).

3. References to the research (indicative maximum of six references)

Gehrels, R, Dawson, D, Shaw, J and Marshall, W (2011). Using Holocene relative sea-level data to inform future sea-level predictions: an example from Southwest England. *Global and Planetary Change* 78, 116-126. *Peer reviewed international journal, Impact factor: 2.930.*

Massey, A, Gehrels, R, Charman, D, Milne, G, Peltier, W, Lambeck, K and Selby, K (2008) Relative sea-level change and postglacial isostatic adjustment along the coast of south Devon, United Kingdom. *Journal of Quaternary Science* 23, 415-433. *Peer reviewed international journal, Impact factor: 2.308.*

Gehrels, R (2010) Late Holocene relative sea-level changes and crustal motion around the British Isles: lessons for the 21st century. *Quaternary Science Reviews* 29, 1648-1660. *Peer reviewed international journal, Impact factor: 3.973.*

Gehrels, R (2006) Sea-level rise and coastal subsidence in southwest England. *Reports and Transactions of the Devonshire Association* 138, 25-42. *Peer reviewed journal on regional issues with international circulation.*

Gehrels, R, Long, A (2008) Sea level is not level: the case for a new approach to predicting UK sea-level rise. *Geography* 93, 11-16. Flagship publication of the Geographical Association, presenting scholarly research to lay readership.

Dawson, D (2012) *The impact of sea-level rise on the London-Penzance railway line*. Unpublished PhD thesis, Plymouth University.

4. Details of the impact (indicative maximum 750 words)

Our research has led to an improved understanding of environmental risk associated with sea-level change in south west England, and has influenced government and institutional policies related to the management of this risk. In light of the paper *Sea-level rise and coastal subsidence in southwest England* (Gehrels 2006), UKCIP altered their website to explain that the high subsidence rates in the Southwest were based on insufficient data. *Dr Chris West*, the Director of UKCIP, wrote “Based on your work, we have decided to add… to our technical note "Updates to regional net sea-level change estimates for Great Britain.”… We would also very much like to include a link to your paper, so that those stakeholders who are interested can obtain further details of your work” (Reference 4). In 2008 *Gehrels* was invited by *Dr Jason Lowe* of the Met Office to provide input into the section on vertical land-level movements for the *UK Climate Projections science report* (Reference 7; see Lowe et al. 2009 – reference 1).

UKCIP’s published sea-level projections have since been corrected based on the Plymouth research. The debate we instigated led to UKCIP’s determining vertical land movements in a revised manner, i.e. by using a numerical model of Glacial Isostatic Adjustment that is calibrated by relative sea-level data, and the *UK Climate Projections science report* contains the revised predictions (see reference 1). In 2010 our research led to the publication of a revised map of vertical land movements in the British Isles (Gehrels 2010). Importantly, the *UK Climate Projections science report* now underpins government policy on the coastal zone impacts of future to climate change (see, for example, Reference 2).

The second stage of the research, focusing on the Dawlish-Teignmouth railway line, has proved particularly informative for both Network Rail and the Local Authorities in the south west. Network Rail’s Principal Engineer and Chair of the company’s Climate Change Adaptation Group, *John Dora*, states that “the research has been extremely useful in highlighting the wider impacts of future sea-level rise, as well as helping the British railway industry to recognise the importance of understanding the potential future impacts of climate change on railway operations. The research

has clearly illustrated the economic benefits that could arise by implementing a climate change adaptation strategy for the Dawlish section of railway, and Network Rail is currently using the outputs to aid the formation of long term plans for the future of this line in association with the Environment Agency and local authorities" (Reference 5). More broadly, the research has helped Network Rail to improve their overall approach to climate change adaptation by utilising economic indicators and leaves them better informed on how coastal railway issues in the UK could be examined in future research and network resilience programmes.

We were keen to disseminate the results of the socio-economic analysis as widely as possible to stakeholders in order to stimulate and inform debate on the future of the important regional railway links. Concrete evidence of the impact of the research is provided by *Andrew Ardley*, Transportation Manager at Devon County Council. Commenting on the research in relation to Devon and Torbay's Local Transport Plan (LTP3), he noted: "Devon and Torbay's LTP3 was written in the context of a 15 year time frame to 2026 but also looking ahead to the impacts of critical factors affecting infrastructure such as climate change. The plan places a particularly important emphasis on the economic impact of the Exeter to Plymouth rail line for Devon, Torbay and Plymouth / Cornwall in its Strategic Connections section. The plan is used as a lobbying mechanism for improvements to strategic infrastructure - a clear evidence base was essential for this and the research [i.e. that outlined in this document] provided the necessary background on climate change in the case of the rail line in the Dawlish / Exe Estuary area. The final copy will be used in future reviews of the LTP to ensure that there are clear plans for the future management of the infrastructure" (Reference 6)

Sustained heavy rain in 2012 has added further urgency to debates surrounding the need to protect the UK's critical infrastructure against extreme weather events and underlying climatic changes. Railway line flooding - described as the worst in a decade - on south-west England's rail network resulted in ~£12.5m in compensation being paid by Network Rail to train and freight operators because services did not run due to the damage caused to the lines (Reference 3). This disruption to rail services combined with our research have increased the sense of awareness of climate-related infrastructure vulnerability for both Network Rail and the Southwest Local Authorities, and the need for future adaptation and mitigation.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Lowe, J, Howard, T, Pardaens, A, Tinker, J, Holt, J, Wakelin, S, Milne, G, Leake, J, Wolf, J, Horsburgh, K, Reeder, T, Jenkins, G, Ridley, J, Dye, S, Bradley, S (2009) *UK Climate Projections science report: Marine and coastal projections.* Met Office Hadley Centre, Exeter, UK. http://ukclimateprojections.defra.gov.uk/22570. Gehrels is discussed at the following extract from this report: http://ukclimateprojections.defra.gov.uk/23028
2. DEFRA 2012 *UK Climate Change Risk Assessment: Government Report*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf
3. http://www.bbc.co.uk/news/uk-england-22361986
4. Written statement from the Director of UKCIP, 9/6/2008
5. Written statement of Principal Climate Change Engineer at Network Rail, Kings Place, 90 York Way, London, N1 9AG, 2010.
6. Written statements of Principal Environmental Policy Officer and Transportation Manager at Devon County Council, 2010.
7. Email correspondence with Head of Knowledge Integration and Mitigation Advice, Hadley Centre Met Office, and lead author of UKCP09 science report Marine and coastal projections, June 2008.