An Empirical-Conceptual Model for the Formation and Evolution of Incised Coastal Channels: The Chines on the Isle of Wight, England

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1. Introduction and aims of research

Incised channels are features of disturbed landscapes that are found in all morphoclimatic regions, operating at a range of temporal and spatial scales. Coastal incised channels can be found at various locations around the world where the shoreline morphology consists of cliffs. River channels can cut through a range of cliff materials, although the depth of incision may be limited by the erodibility of the lithology and the available stream power.

Despite the wealth of literature concerning incised channels in general (e.g. Schumm *et al.* 1984; Darby and Simon, 1999) there are only a few studies that focus on coastal incised channels (e.g. Schumm and Phillips, 1986; Burkard and Kostachuk, 1995) and only one (Flint, 1982) that specifically focuses on the coastal incised channels found on the Isle of Wight, which are the subject of this study. The lack of scientific literature concerning such features is somewhat surprising given that they are of great geomorphological significance and exhibit fundamental differences in their development compared to other incised channels. This research aims to produce a geomorphological model of sequential evolution of incised coastal channels.

2. The study site

The incised coastal channels that are the focus of this study are located along the South West coast of the Isle of Wight, located just off the Southern coast of England (Figures 1 and 2a). The shoreline consists of soft cliffs of sands, shales and marls which vary in height from 15m to 100m and which are retreating at rates of up to 2m a^{-1} due to a combination of wave erosion and landslides. This coast is divided into several low-order drainage networks that flow to the sea through deeply (up to 45m) incised valleys, known locally as 'Chines' (Figure 2b).

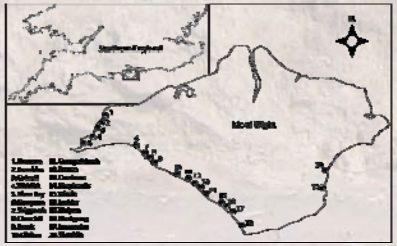


Figure 1. The locations of the principle Chines on the Isle of Wight (adapted from Ordnance Survey 1:25,000 series, sheet 29).

The combination of deep incision, which provides a sheltered environment, and unstable side-wall surfaces provides unique habitats that support a diverse range of rare flora *(Philonotis marchica, Anthoceros punctatos)* and fauna *(Psen atratinus, Baris analis, Melitaea cinxi)*. An understanding of the geomorphic evolution of the Chines therefore underpins the long term management of associated biodiversity.

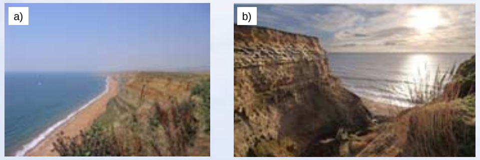


Figure 2. (a) The South West coast of the Isle of Wight (b) Whale Chine

3. Existing channel evolution models

A range of incised channel evolution models (CEMs) have been developed by the likes of Schumm *et al.* (1984), Watson *et al.* (1986) and Simon and Hupp (1986) using a space for time substitution methodology.

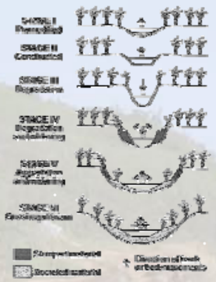


Figure 3. The incised channel evolution model of Simon and Hupp (1986).

There are two key reasons why existing models are not transferable to the Chines:

1) Models such as that shown in figure 3, were developed for river systems with large contributing areas. The Chines have very small contributing areas.
2) Channel incision in existing CEMs (Figure 3) is triggered by base-level lowering, usually as a result of dredging or incision of a master stream. In contrast, the base-level of the Chines is the sea, but the cliff recession means that the position of the base-level is both dynamic and spatially mobile.

4. Chine growth – thresholds of change

The key driver of Chine development is shoreline retreat and hence their stability status depends on the balance between rates of shoreline retreat and knickpoint recession (Figure 4).

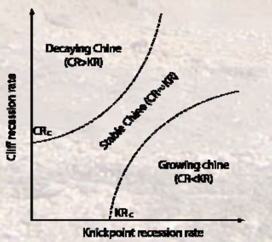


Figure 4. Chine stability as a function of rate of cliff recession and rate of knickpoint recession. (Revised from Flint, 1982).

It is proposed that geomorphic thresholds exist beyond which the system state changes significantly. These are manifested in a critical cliff recession rate (CR_c) and a critical knickpoint recession rate (KR_c).

On the Isle of Wight, cliff recession rates are well documented, however knickpoint recession rates are not. They can be calculated using a commonly used relationship (Leopold *et al.* 1964);

$$KR = A.S^{0.5} \quad (1)$$

where A is contributing drainage area and S is channel slope. The exponent 0.5 is adopted from Manning's equation. Using values obtained from surveys for contributing areas and channel slopes, a model of Chine growth/decay can be plotted (Figure 5). This can be combined with the developed CEM (see section 5) to predict future changes affecting specific Chines.

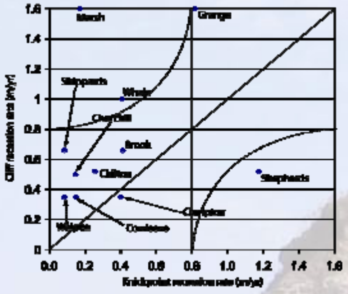


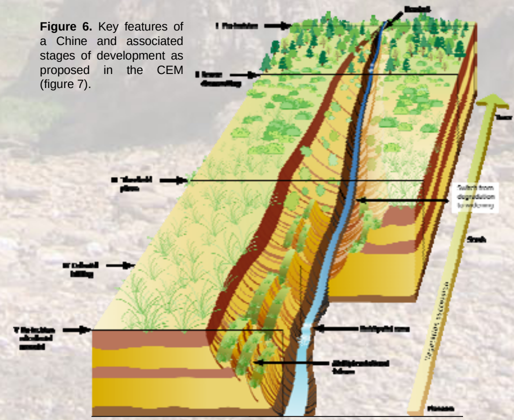
Figure 5. Chine stability plotted using a slope area model as a surrogate for stream power and knickpoint recession rate. Cliff recession rates from Bray *et al.* (2004) after various authors. Rates calculated over at least 95 years.

Figure 5 reveals that flow discharge (as predicted by the product A.S) is a fundamental control on knickpoint recession rate, consistent with the findings of Bishop *et al.* (2005).

5. Development of a new CEM

Figure 6 shows the typical morphology of the Isle of Wight Chines. The sequential stages of development can be identified using space for time modelling and then conceptualised into a CEM, as shown in Figure 7.

Figure 6. Key features of a Chine and associated stages of development as proposed in the CEM (figure 7).



A CEM has been developed (Figure 7) that accounts for evolutionary stages within growing, stable, and decaying Chines. The model can become complex when a certain stage is reached and then abandoned due to the crossing of a threshold, hence a decay sequence can be initiated from any growth or stable stage.

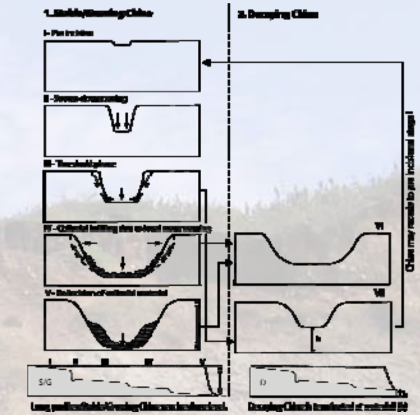


Figure 7. A CEM for incised coastal channels on the Isle of Wight.

Although the CEM presented above was developed using the Chines on the Isle of Wight, it is hoped that it can be used as a generic model of incised coastal channel evolution.

The model of growth (Figures 4 and 5) and the CEM above highlight the sensitivity of the Isle of Wight Chines to changes in external driving forces. The balance between rates of cliff and knickpoint recession is critical, and small changes in conditions could lead to significant changes in Chine stability.

6. Acknowledgements and References

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References

Bishop, P., Hoey, T.B., Jansen, J.D. and Artza, I.L., 2005. Knickpoint recession rate and catchment area: The case of uplifted rivers in Eastern Scotland. Earth Surface Processes and Landforms, 30: 767-778.

Bray, M.J., Carter, D.J. and Hooke, J.M., 2004. Quaternary history of the Solent system. Coastal sediment transport study - Report to coastal groups, University of Portsmouth.

Burkard, M.B. and Kostachuk, R.A., 1995. Initiation and evolution of gullies along the shoreline of Lake Huron. Geomorphology, 14: 211-219.

Darby, S.E. and Simon, A., 1999. Incised river channels: Processes, forms, engineering and management. Wiley, Chichester, 424 pp.

Flint, K.E., 1982. Chines on the Isle of Wight: Channel adjustment and basin morphology in relation to cliff retreat. The Geographical Journal, 148(2): 225-236.

Leopold, L.B., Wolman, M.G. and Miller, J.P., 1964. Fluvial processes in Geomorphology. W. H. Freeman, San Francisco, 522pp.

Simon, A. and Hupp, C.R., 1986. Channel evolution in modified Tennessee channels, Proceedings of the Fourth Federal Interagency Sedimentation Conference. US Government Printing Office, Washington DC, pp. 5-71 - 5-82.

Schumm, S.A., Harvey, M.D. and Watson, C.C., 1984. Incised Channels: Morphology, Dynamics and Control. Water Resources Publications, Chelsea, Michigan, 200 pp.

Schumm, S.A. and Phillips, L., 1986. Composite Channels of the Canterbury Plain, New-Zealand - a Martian Analog. Geology, 14(4): 326-329.

Watson, C.C., Harvey, M.D. and Garbrecht, J., 1986. Geomorphic-hydraulic simulation of channel evolution, Proceedings of the 4th Federal Interagency Sedimentation Conference. US Government Printing Office, Washington, DC, Las Vegas, Nevada, pp. 5-21 - 5-30.