H51G-0559 Holocene Evolution of Incised Coastal Channels on the Isle of Wight, UK: Interpretation via numerical simulation

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1. Introduction

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 model the development of the incised coastal channels of the Isle of Wight over Holocene time scales, in order to gain an insight into formative processes. Of particular interest is the question of whether the channels are relic components of an incised channel system that has now been truncated by coastal erosion during Holocene sea-level rise, or whether the channels are actively incising in response to base-level changes forced by shoreline cliff retreat. In the case of the former scenario, ancillary questions relate to the extent to which the incision was associated with low sea-level stands or climatic shifts.

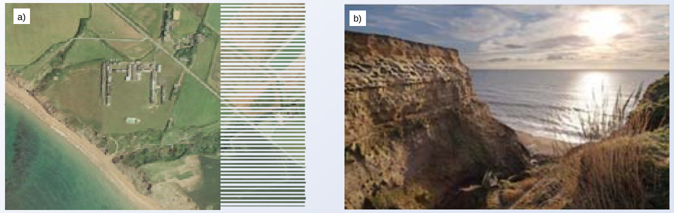


Figure 1: a) Aerial image of Shepherds Chine, Isle of Wight, southern England. b) Whale Chine ('chine' is a local word for the incised coastal channels). The cliff seen at the mouth of this feature is ~45m high.

2. 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 2 and 3). 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' (Figures 1a and b).

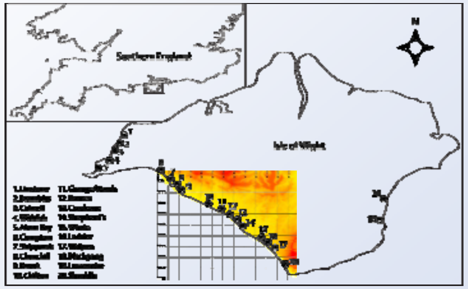
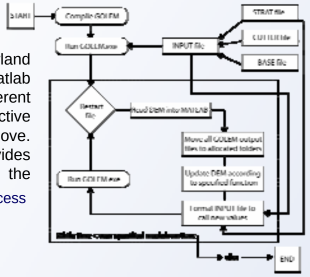


Figure 2: Location of the Isle of Wight and (inset) a DEM of the principle area of study.

Figure 3: The south west coast.

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 historical geomorphic evolution of the Chines therefore underpins the long term management of the associated biodiversity.

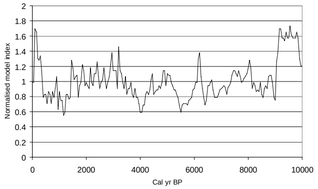
3. Setting up the model



The landscape model GOLEM (Tucker & Slingerland 1994, 1996, 1997) is used in conjunction with Matlab scripts (Figure 4) that allow us to simulate different scenarios of cliff recession, sea-level rise, effective precipitation changes, or a combination of the above. Model replication of contemporary forms then provides plausible scenarios of the erosional history of the landscape.

Figure 4: Flow chart of modelling process

Figure 5: Model climate input derived from proxy wetness index from a peat bog in Scotland, UK.



Sea-level rise throughout the Holocene is well documented for southern England, but climate data is not. To address this, annual rainfall from 1949-1999 was averaged and multiplied by a normalised rainfall index generated from Scottish peat bog data (Anderson *et al.* 1998) by Coulthard *et al.* (2002) to develop a dataset of effective precipitation over the last 10,000 years (Figure 5).

Key parameters used in GOLEM (Table 1) were derived from empirical data from the study site. In particular we quantified the parameters E, k, m and n from the commonly utilised stream power erosion law:

$$E = k A^m S^n \tag{1}$$

The ratio of m/n was calculated by averaging slope according to logarithmic bin intervals of area (e.g. Stock & Montgomery 1999, Whipple & Tucker 1999, Snyder *et al.* 2000) and regressing the resulting plot using a power function relationship (figure 6a). This yielded a m/n value of 0.45.

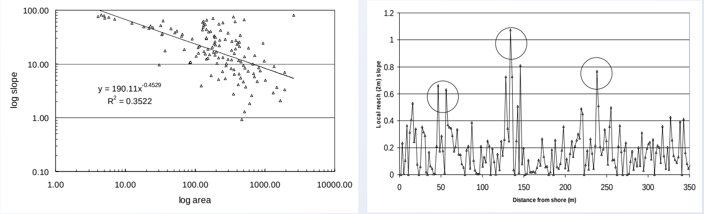


Figure 6: a) Area slope relationship for Grange Chine, Isle of Wight. b) Local reach (2m) slope plotted against distance from shore to reveal over-steepened reaches or knickpoints.

Knickpoint recession rates were defined by locating knickpoints using the method of Bishop *et al.* (2005) as shown in figure 6 b) and equating the dates of knickpoint formation to known large scale cliff retreat events. Assuming that the erosion rate (E) is equal to the knickpoint recession rate, the erodibility parameter (K) was estimated by re-arranging equation 1:

$$k = E / A^m S^n \tag{2}$$

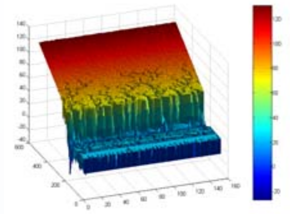
Name	Function	Units	Value used
kd	Slow mass movement coefficient	$m^2\ yr^{-1}$	$3.6x10^{-3}$
scr	Critical gradient for shallow landsliding	dimensionless	1.3
tau c	Fluvial sediment transport threshold	$m\ yr^{-1}$	3
kb	Bedrock erodibility value	$m\ yr^{-1}$	0.027
mb	Bedrock erosion discharge exponent	dimensionless	0.45
nb	Bedrock erosion slope exponent	dimensionless	1
nci	Channel initiation function exponent	dimensionless	1
tci	Channel initiation function threshold	m^2	20000
cr	Cliff recession rate	$m\ yr^{-1}$	variable
sl	Sea level rise rate	$m\ yr^{-1}$	variable
ep	Effective precipitation rate	$m\ yr^{-1}$	variable

Table 1: Key parameter values used in GOLEM simulations. Those highlighted are part of the new routines and are varied throughout the exploratory model runs.

4. Results

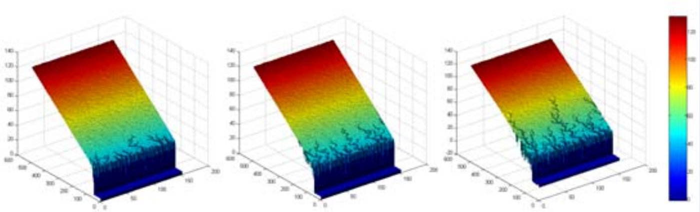
In an attempt to explore the Holocene evolution of the incised coastal channels of the Isle of Wight we modelled a range of scenarios relating to the key drivers (cliff recession and climate change) of their development:

Scenario 1: "Actual" Holocene changes in sea-level, cliff retreat and effective precipitation



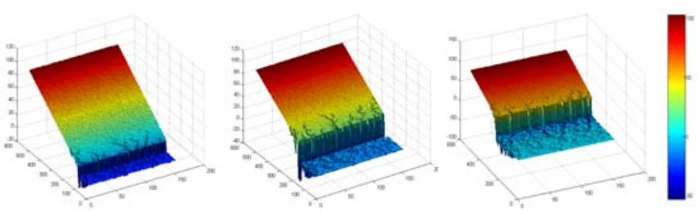
The simulation in which realistic conditions are reproduced broadly replicates observed incised coastal channel morphologies (see Figures 1a and b). This means we can have a degree of confidence in the modelling process. The next step is to begin to elucidate which of the combined drivers exert the most significant control on the formation of these features.

Scenario 2: Effect of variation in effective precipitation with no coastal erosion



0.5×Precipitation in Fig. 5 1.0×Precipitation in Fig. 5 2.0×Precipitation in Fig. 5

Scenario 3: Effect of variation in cliff erosion rate with constant effective precipitation of 1000 mm a^{-1}



0.25 ma^{-1} 0.5 ma^{-1} 1 ma^{-1}

Conclusions:

Moderate rates of effective precipitation induce a realistic incised channel network, providing there is a step cliff profile present. Such a step profile is shown to be produced by sea-level rise and associated cliff retreat, however the model reveals that high rates of cliff retreat destroy the networks.

5. Acknowledgements and References

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