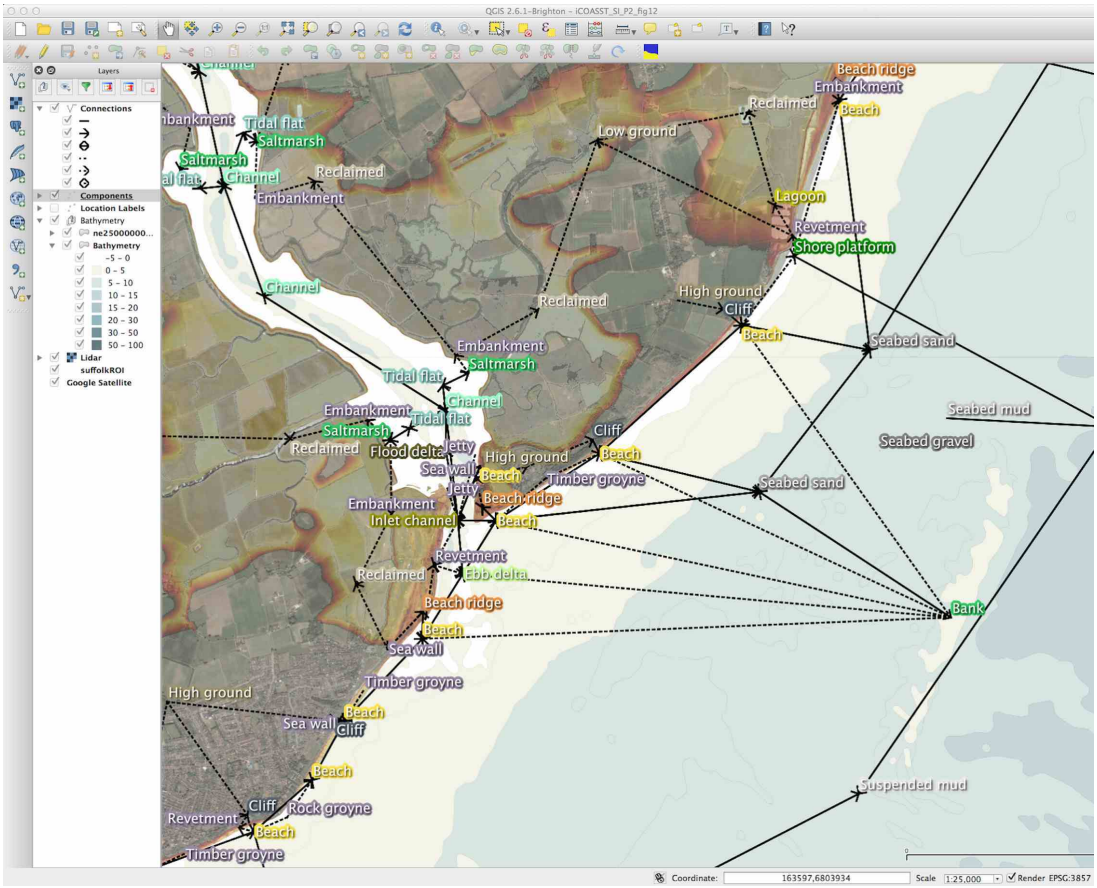
Coastal and **E**stuarine **S**ystem **Mapper**

QGIS plugin for Coastal and Estuarine System Mapping

CESMapper User Manual: release 1.5.2



UCL Coastal and Estuarine Research Unit

CESMapper User Manual

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CESMapper software repository:

https://github.com/UCL-CERU/CESMapper

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http://www.icoasst.net

http://www.channelcoast.org/iCOASST

The CESM approach is described more fully in:

French, J.R., Burningham, H., Thornhill, G., Whitehouse, R., Nicholls, R.J. 2016. Conceptualizing and mapping coupled estuary, coast and inner shelf sediment systems. *Geomorphology* 256: 17-35. http://dx.doi.org/10.1016/j.geomorph.2015.10.006 [open access]

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1 CESMapper installation

1.1 System requirements

CESMapper is written in Python as a plugin for the open-source Geographical Information System software, QGIS. Provided that a compatible version of QGIS is installed, then CESMapper should function correctly. QGIS may be freely downloaded (either as binary executable application files or source code) from www.qgis.org. QGIS, and therefore CESMapper, may be run on Linux, Mac OS-X, and Windows operating systems.

This manual describes CESMapper release 1.5.2, which requires that QGIS version 2.8.0 (Wien) or later is installed on the computer. This release has been tested up to QGIS version 2.14.3 (Essen).

As with any GIS, performance will be improved on computers equipped with faster processor(s) and larger amounts of memory (RAM).

1.2 Manual installation via GitHub repository

Assuming that a fully functional and compatible version of QGIS is already installed, CESMapper can be downloaded from the GitHub repository at:

https://github.com/UCL-CERU/CESMapper

This repository contains the current development and testing versions of CESMapper as well as more stable release versions that are more suitable for most users.

Installation step 1: download the current release from the repository, unzip the archive file, and copy the entire contents into the .qgis2/Python/plugins directory on your computer.

On Linux systems the plugins directory is typically found at

/home/{username}/.qgis2/python/plugins (where {username} is the user account name)

On Mac OS-X systems, this directory can usually be found at

/Users/{username}/.qgis2/python/plugins

On Windows systems the plugins directory is typically found at

C:\Users{username}.qgis\python\plugins

Installation step 2: Start QGIS and open the Plugins … Manage and Install Plugins menu from the upper menu bar (Fig. 1.1). Locate the CESMapper plugin on the list of plugins, and check the 'install' box. Close the menu and you should see the CESMapper icon displayed on the main QGIS toolbar (Fig. 1.2).

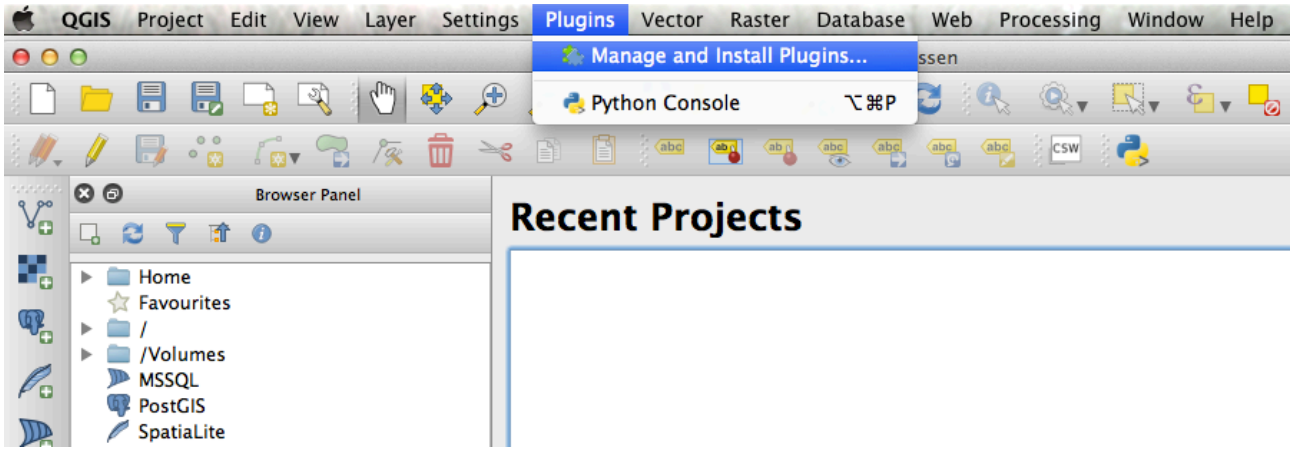

Figure 1.1 Plugin … Manage and Install Plugins on the QGIS upper menu bar.

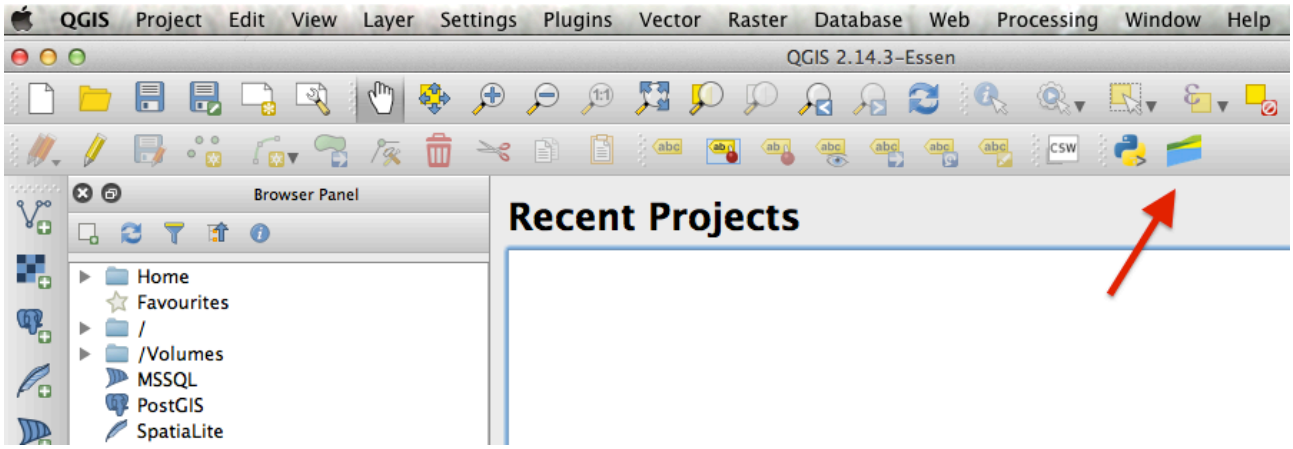

Figure 1.2 CESMapper icon (arrowed) on the QGIS toolbox indicates sucessful installation of plugin.

1.3 Installation via QGIS plugin repository

To be added

1.4 Software license

CESMapper is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or any later version.

CESMapper is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License (Appendix 1) for more details.

You should have received a copy of the GNU General Public License along with CESMapper. If not, see <http://www.gnu.org/licenses/>.

2 CESM overview and key concepts

2.1 Background

Risks to human populations, assets and activities are anticipated to increase with sea-level rise and climate change. Our ability to mitigate these risks is dependent on our understanding of how coastal landforms evolve their morphology in response to factors such as sea-level rise, the constraints imposed by widespread engineering structures and interventions in the sediment pathways that connect and sustain landforms. From a risk management perspective, a key argument is that landforms are important mediators of the *pathways* that transfer erosion and flood risk from external *sources* (wave, tide and storm surge etc.) to human *receptors* in vulnerable areas (Sayers et al., 2002; Batten et al., 2015).

Since the pioneering work of Inman and Frautschy (1966) on the coast of southern California, the concept of the littoral cell has provided a framework for analyses of coastal change and the geomorphological basis of shoreline management problems. At regional to national scales, hierarchies of cells provide a sounder geomorphological basis for coastal management than the use of arbitrary administrative boundaries (Komar, 1996). In England and Wales, for example, national mapping of major cells and sub-cells (Motyka and Brampton, 1993) provided the basis for a first generation of Shoreline Management Plans (SMPs) (Cooper et al., 2002). In Western Australia, Eliot et al. (2011) have devised a three-tier hierarchy of cells to inform marine and coastal planning.

However, some limitations of the littoral cell concept have also become apparent. The criteria used to delimit cells and the stability of their boundaries under variable wave climate or sediment supply are not always clear-cut. Also, littoral cells primarily reflect short-range transfers of non-cohesive 'beach-grade' material (i.e. sands and gravels). They are thus not well suited to handling broader scale linkages between estuarine, coastal and offshore systems, especially where longer-range suspended sediment (mud or fine sand) fluxes are important (Cooper and Pontee, 2006). Finally, the littoral cell framework has also tended to perpetuate a separation of open coast and estuary in shoreline management planning (French et al., 2016a).

A behavioural systems approach to the segmentation of the open coast was devised in the FutureCoast project (Burgess et al., 2004). This embedded littoral cells within a spatial hierarchy of geomorphological units (effectively individual landforms), shoreline behaviour units (sub-systems, such as embayments and estuaries) and regional coastal behaviour systems. This approach was applied to the entire coast of England and Wales, and provided the basis for a second generation of SMPs.

Another advance has been the concept of the 'coastal tract', developed by Cowell et al. (2003a,b). This is based on the idea of a sediment-sharing system that encompasses not only the upper shoreface of the open coast but also estuarine (backbarrier) environments as well as the lower shoreface. The tract sits at the top of a hierarchy (or 'cascade') of sediment-sharing systems that evolve their morphology over progressively shorter timescales. The tract is defined at a scale at which low-order progressive change (which presents some of the most challenging erosion and flood risk management problems) can be disaggregated from higher-order variability. It also acknowledges the interactions between estuary, open coast and the inner shelf. Although the time scales of the tract hierarchy are explicit, the associated spatial scales are largely implied through the definition of morphological complexes, units and elements.

The need for an integrative systems-based perspective has become more pressing as the strategic application and evaluation of management and engineering options has evolved to address the broader time and space scales at which progressive shifts in shoreline position, and possibly overall coastal configuration, may be expected in the face of climate change and sea-level rise (French and Burningham, 2013). Of particular importance is the integration of open coast and estuary into a common conceptual framework. At the same time, there is also need for frameworks that are transparent, and which bridge the gap between the experience and perspectives of scientists, engineers and stakeholders in areas of environmental management that have often

proved politically contentious. Communication is vital given the extent to which science has become almost wholly founded on models. In climate science, public understanding and confidence has often been impaired by poor communication of the nature and purpose of complex simulation models (Hall et al. 2014).

Qualitative modelling has a clear role as a means of arriving at shared understanding of the system being studied and the nature of the problems that need to be addressed (e.g. Sano et al. 2014). Coastal and Estuarine System Mapping (CESM; French et al., 2016b) has been developed within the Integrating Coastal Sediment Systems (iCOASST) project which was funded by the UK Natural Environment Research Council (NERC) between 2012 and 2016 (Nicholls et al., 2015). Within iCOASST, CESM was used for identifying the most important processes (and associated management issues) to be included in more quantitative modelling studies (van Maanen et al., 2016) and also as means of aligning stakeholder and scientific knowledge and fostering a 'participatory modelling' approach (Voinov and Bousquet, 2010; French et al., 2016c).

CESM renders the complexity of coastal and estuarine geomorphological systems as a simple ontology of components and interactions, and depicts these in a visual form that provides an effective catalyst for discussion and debate between scientist, stakeholder agencies and organisations, and local citizens. The CESMapper software is intended to facilitate application of this approach within a freely-available open-source GIS, QGIS.

2.2 Key concepts

2.2.1 Idealised spatial ontology for mapping the configuration of coast-estuary systems

The starting point for CESM is an idealised spatial ontology that provides a basis for mapping the configuration of coupled assemblages of landforms on the open coast, estuaries and inner shelf. The term ontology refers to a formal specification of a conceptualisation (see Gruber, 1993), but CESM adopts a fairly loose interpretation that encompasses a hierarchical classification of components and a set of permitted interactions between them. Put simply, the ontology is a classification and a set of rules.

As outlined in Figure 2.1, the CESM spatial ontology reflects some aspects of the coastal tract concept (Cowell et al., 2003a) in that it depicts a hierarchy of morphologically-active sediment sharing landform systems. These are located within the geological context of a coastal shelf that can be considered time-invariant at the decadal to centennial timescales that are most relevant for shoreline management (French et al., 2016a). In contrast to the largely timescale-based hierarchy of the coastal tract, however, CESM emphasises the spatial nesting of landform components within aggregate landform complexes (cf Burgess et al., 2004; Eliot et al., 2011). It also explicitly represents varied human interventions and the way in which these constrain landform adjustment (see, for example, Hapke et al., 2013).

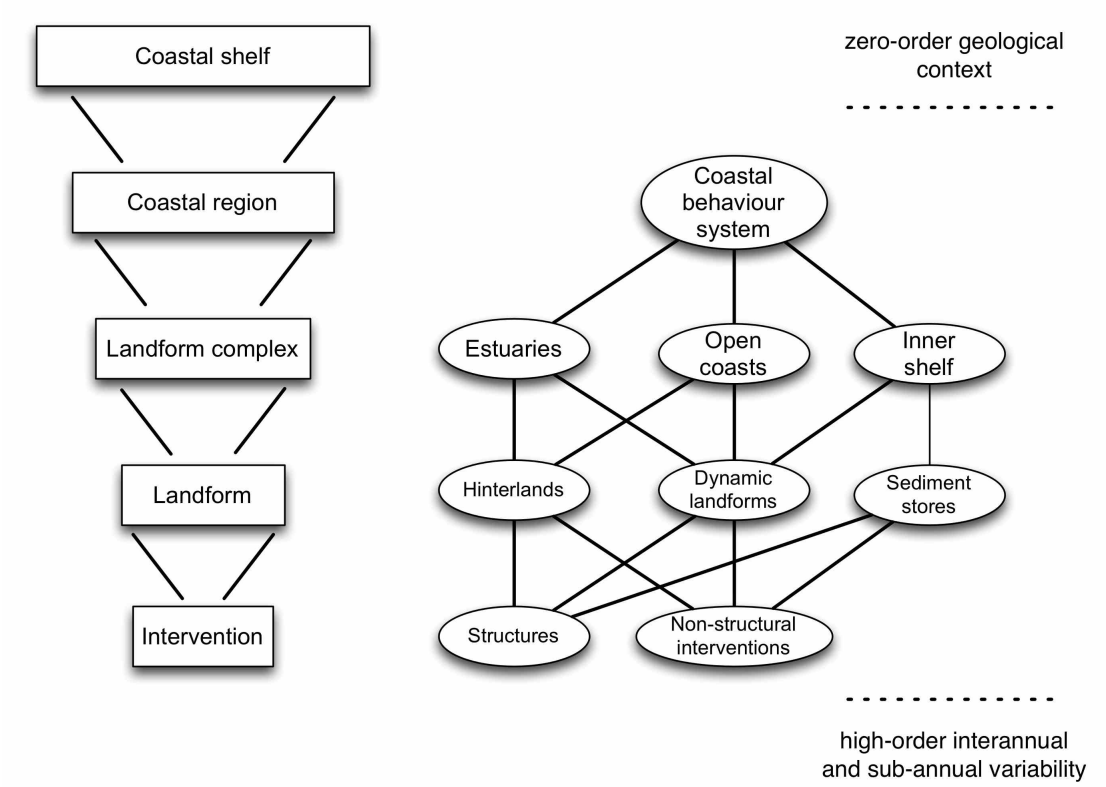

Figure 2.1: Spatial ontology of coupled estuary–coast–inner shelf geomorphic systems, showing nesting of landforms and landform complexes within broader-scale coastal regions. At decadal to centennial scales, the coastal behaviour system integrates the interaction of estuarine, open coastal and inner shelf morphodynamics, within a broader coastal shelf context that evolves only at much longer timescales. Interannual and sub-annual dynamics are generally not resolved at timescales of decades and longer.

Landform complexes

Estuarine, coastal and inner shelf landform complexes can be classified with reference to existing schemes and the range of landforms encountered in a given regional or shelf context. Figure 2.2a shows a simple estuary classification based on ABPmer (2008). The term 'inlet' is here used to define systems in which fluvial influence is negligible and sediments are purely marine in origin; this includes inlets that may be only intermittently active. Such a scheme has quite broad applicability within temperate zones (such as northwest Europe). Its relative simplicity is advantageous from a helps to reduce the 'operator variance' that inevitably arises where classificatory judgements have to be made.

Open coasts can similarly be classified (Fig. 2.2b) with headlands and bays for coasts that exhibit more obvious geological control. Cuspate forelands and spits may be large enough to be afforded the status of a landform complex. Barrier islands are also included as a landform complex in their own right and distinguished from other forms of non-detached coastal barrier.

The inner shelf is less replete with discrete landform types, although the drowned palaeo-landscapes of the last glacial are attracting increasing attention. Many shallow shelf seas are characterized by distinctive bank systems of varying morphology and origin. These may exert a significant influence on contemporary shoreline behaviour, either through their role in modifying wave climate (e.g. Chini et al., 2010) or via their participation in coastal sediment pathways. Figure 2.2c presents a simple classification based on work in the North Sea by Dyer and Huntley (1999).

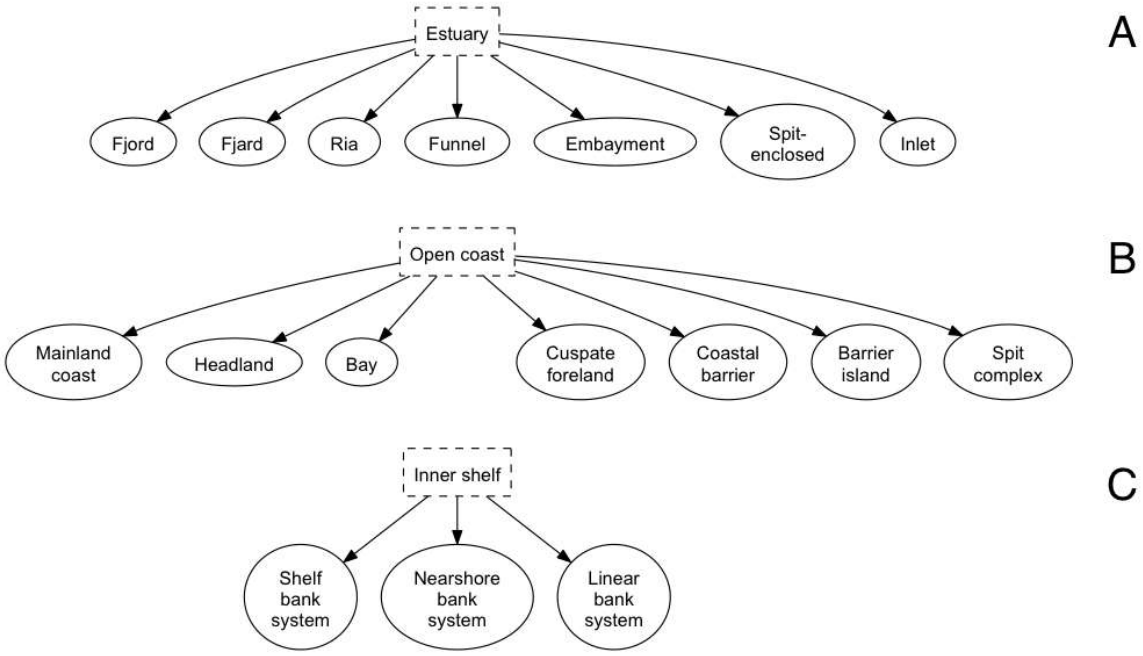

Figure 2.2: Illustrative classification of estuary, coast and inner shelf landform complexes that might be suitable for application within a temperate (e.g. northwest European) context. The basic approach can easily be modified to suit other environments.

Landforms

The estuarine, open coastal, and inner shelf complexes outlined above represent aggregations of landforms. Table 2.1 summarises a basic set of landforms applicable to temperate settings, which includes 'textbook' features such as cliff, beach, tombolo, spit etc. Some landform types may occur within more than one type of landform complex (e.g. tidal flat, which can occur in both open coast and estuarine settings). Other landform types such as spits and ebb tidal deltas, occur at the interface between estuary and open coast and, as such, could be considered to be part of either complex. Spits are a special case in that larger examples can be mapped as a complex (with component dune, beach, beach ridge etc.) whilst minor features can be considered as discrete landforms within another complex. This clearly involves an element of subjective judgement.

The set of morphologically active landforms is supplemented by a smaller set of hinterland types that are considered to exert a static boundary condition control. High ground is defined subjectively as terrain that rises well above current and projected future tide and surge elevations and which would be expected to exhibit a predominantly erosional response to sea-level rise. Low ground is identified as being more susceptible to inundation, and this may constitute a more significant hazard (though erosion also leads to increased flood risk so the two hazards are not independent). Reclaimed areas are those that have been historically converted from the intertidal and subtidal zones and are protected from tidal action by defences.

Sediment systems include distinct stores of sediment that can be locally important in mediating landform behaviour. Much of the shelf is veneered by patches of sediment, some of which are essentially inactive under current sea level, wave climate and tide regime, and some of which participate in sediment pathways that interact with coastal or estuarine environments.

Table 2.1: A basic set of landform components common to open coastal, estuarine and inner-shelf complexes. These comprise morphologically active landforms, as well as hinterlands and sediment stores.

Landform		Hinterland	Sediment store
Cliff	Inlet channel	High ground	Seabed gravel
Shore platform	Ebb delta	Low ground	Seabed sand
Beach	Flood delta	Reclaimed	Seabed mud
Beach ridge	Bank		Suspended mud
Tombolo	Channel		
Dune	Tidal flat		
Spit	Saltmarsh		
Rock outcrop	Brackish marsh		
Lagoon	River		

Human interventions

Present-day coastal behaviour is strongly conditioned by, and indeed partly a consequence of, human interventions of various forms over a period of decades to centuries. The effects of coastal protection works are evident locally (Basco, 2006), regionally (Brown et al., 2011) and even nationally at the scale of the USA (Hapke et al., 2013). The most obvious interventions have been structural, with the goal of erosion control, reclamation or flood risk reduction. Local experiences and requirements, and has given rise to a diverse terminology for interventions that perform the same basic function. Table 2.2 presents a highly generic classification of some basic types of intervention according to the function performed. Most have the effect of arresting shoreline movement, for example by limiting erosion or channel migration. Non-structural interventions in coastal and estuarine sediment systems are also pervasive, not only through dredging and aggregate extraction but also through the adoption of 'softer' approaches to coastal management.

Table 1.2: Minimal classification of generic structural and non-structural interventions in estuary, coast and inner shelf sediment systems, with their indicative purpose.

Structural	(indicative purpose)	Non-structural	(indicative purpose)
Seawall	Erosion protection	Dredging	Navigation; mining
Revetment	Erosion protection	Dredge disposal	Spoil disposal
Bulkhead	Erosion protection	Sediment recharge	Restoration of sediment deficit (beach, intertidal)
Embankment	Flood protection	Sediment bypassing	Continuity of sediment pathway; navigation
Barrage	Flood protection	Sediment recycling	Resilience (beach profiling);
Breakwater	Wave energy reduction		
Detached breakwater(s)	Wave energy reduction		
Groyne(s)	Sediment retention		
Training wall	Channel stabilisation / navigation		
Jetty	Varied		
Outfall	Drainage / dispersal		
Quay	Navigation/trade		
Dock	Navigation/trade		
Weir	Regulation of river gradient and/or tidal limit		

Interactions
From a functional perspective, system components influence each other through complex web of interactions. Interactions include any cause-effect relation between components; for example, a jetty exerts an effect on an inlet channel, stabilising its location and influencing its cross-sectional characteristics. A sub-set of the interaction network involves transfers of mass and these sediment pathways, taken together, define the sediment budget (Bowen and Inman, 1966; Rosati, 2005).

Some of the linkages may be simple unidirectional ones, for example where sequential beach units define a littoral drift system. Other interactions are clearly bidirectional, such as the interplay between a seawall and a beach (Basco, 2006). Others may represent more complex causality: a cliff may source sediment to a fronting beach (mass transfer) and the beach may influence the cliff (via an influence through which beach morphology feeds back into the cliff recession rate; Walkden and Hall, 2011). Table 2.3 illustrates some of these interaction types, and the distinction between pure influences and sedimen transfer pathways.

Table 2.3: Illustrative paired examples of system interaction rules for landforms and interventions.

From	To	Interaction	Logic (literature source)
Cliff	Beach	Sediment pathway (sand, gravel)	Cliff sources beach-grade sediment (mud typically lost offshore)
Beach	Cliff	Influence	Presence and morphology of beach feeds back into cliff recession rate (e.g. Walkden and Hall, 2011)
……	……	……	……
Seawall	Beach	Influence	Presence of seawall may cause lowering of beach (e.g. Basco, 2006)
Beach	Seawall	Influence	Beach protects toe of seawall and reduces wave energy on face
……	……	……	……
Jetty	Inlet channel	Influence	Jetty exerts stabilising influence on channel position and constrains width adjustment
Inlet channel	Jetty	none	No direct causal relation in this direction

2.2.2 Protocol for mapping the connectivity of coupled coast and estuary systems

CESMapper builds on earlier proof-of-concept work (Whitehouse et al., 2009) to define a workflow for mapping the connectivity of coupled coast and estuary systems using the ontology described in the preceding section. This workflow is summarised in Figure 2.3 and involves three main stages:

1. **Specification** of the problem or application
2. **Mapping**, in which the system is conceptualized as a spatial network of interactions
3. **Augmentation**, in which data or meta-data are appended to the system map.

The current release of CESMapper is mainly concerned with the Mapping stage, although future versions will likely support the creation of spatial databases on top of the system map.

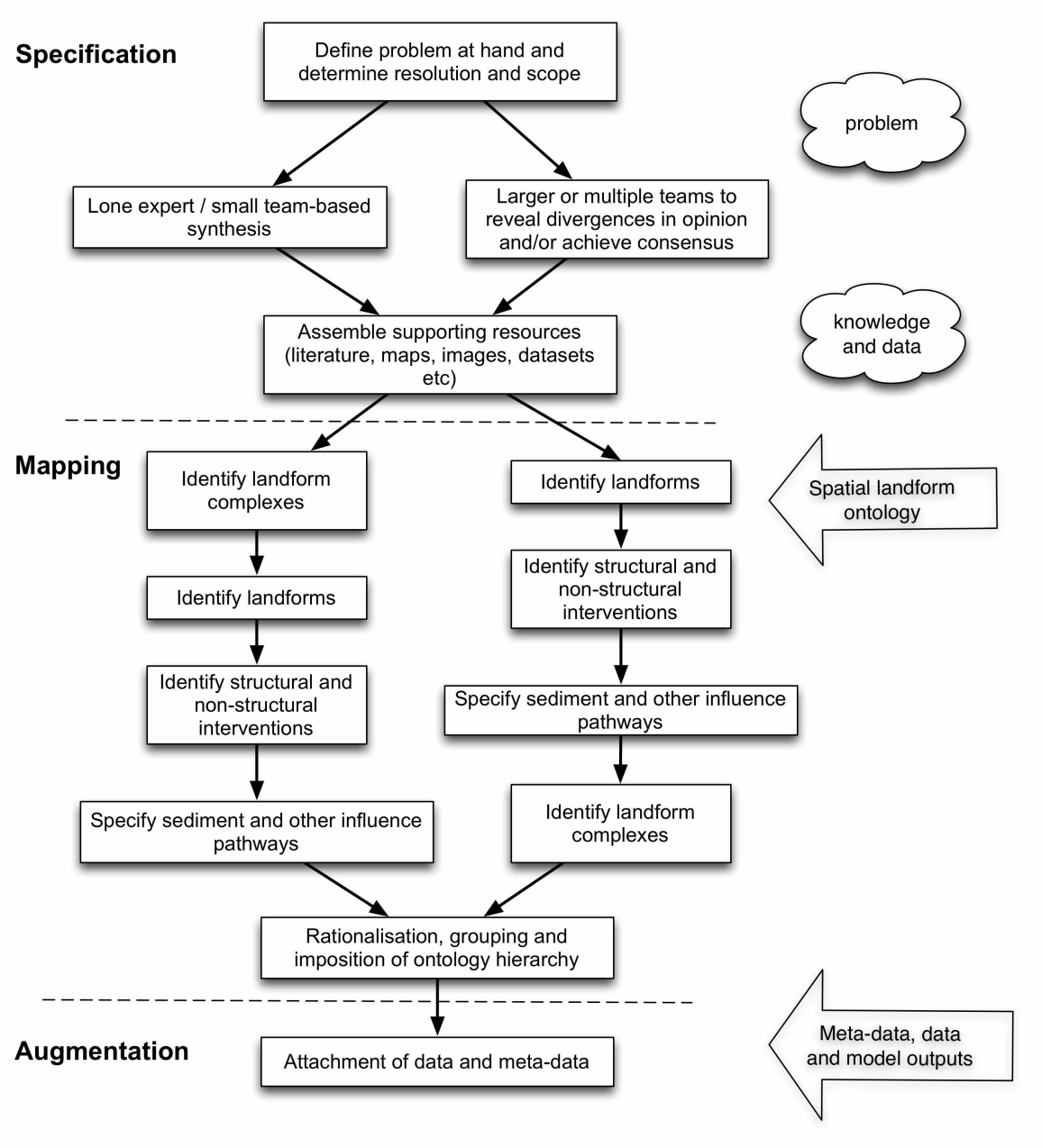

Figure 2.3 – Workflow for Coastal and Estuarine System Mapping. CESMapper is mainly concerned with the Mapping stage.

Key stages of the workflow include:

1. Specification of the problem. This starts with a judgement of the appropriate time-averaging period over which to characterise the system, an appropriate spatial resolution, and the geographical scope. The scope might vary from regional mapping to guide preparation of a shoreline management plan, to a more detailed local map as context for an engineering scheme.

For well-documented and/or understood systems, a lone 'expert' or small team of 'experts' may be able to achieve a relatively uncontentious synthesis of existing knowledge. Where the system is less well understood, CESM provides a starting point for the progression of a conceptual model and a larger team might be required to achieve a consensus. In either case, participatory involvement of stakeholders may be beneficial.

Once the problem is defined, background knowledge (published papers, reports etc.) and datasets (aerial images, geological maps, bathymetry etc.) are drawn together to inform the mapping process.

2. System mapping. Mapping is undertaken using the hierarchical set of landforms and interventions defined in the ontology. Customization of the ontology will usually be required to suit particular geographical contexts and applications and a feature of CESMapper (see section 2.2.3) is that this can be done via external library files without any modification of the software.

Landforms and interventions are first mapped in detail and then organised into broader-scale complexes. [NB need to modify Fig 2.3 to emphaise the 'bottom up' process since that is what we can do at present] Mapping of the open coast proceeds by identifying distinct hinterland – backshore – nearshore sequences and any local constraints due to structures or known non-structural interventions (e.g. beach nourishment or sediment bypassing programmes). This is similar to the approach taken by Hanson et al. (2010), who presented a scheme for mapping barrier and non-barrier coasts based on sequential transitions in cross-shore profile type, as defined by a set of prescribed landform elements. Within an estuary, distinct subtidal – intertidal – hinterland transitions are similarly mapped with reference to the dominant axis of the estuary.

Interaction pathways are then added, with the directionality of the sediment pathways indicated, and distinction made between these and 'influence only' interactions (e.g. those involving the various structures) that are not part of the sediment system. Sediment pathways will often have a preferred direction, but may also be bi-directional where movements are uncertain or oscillatory.

An illustrative map of open coast – estuary interaction is shown in Fig. 2.4.

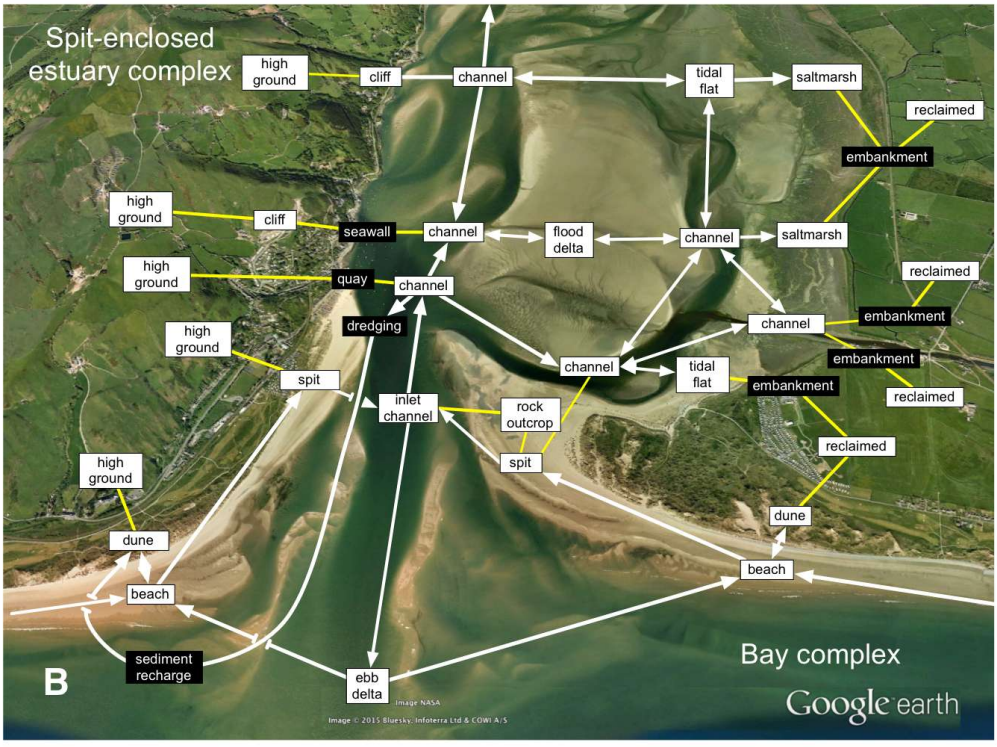

Figure 2.4 Illustrative mapping of open coast – estuary interactions at Aberdovey (Wales, UK). Base image courtesy of Google Earth. Note that this mapping is purely illustrative and not intended to be interpreted as a detailed case study. [figure is just a placeholder – re-do example]

3. Augmentation. System maps can be annotated to include metadata (e.g. references and links to relevant research and datasets) as well as data (e.g. quantitatiive sediment flux estimates).

CESMapper exports the system map as standard GIS shapefiles and the attributes of these can be modified within QGIS. Future releases of CESMapper may provide a more direct means of appending data.

2.2.3 CESMapper software architecture

The CESM approach has its origins in proof-of-concept work undertaken as part of an Environment Agency-funded project on large-scale coastal geomorphological behaviour (French and Burningham, 2009; Whitehouse et al., 2009). Mapping was initially undertaken using concept mapping software (CmapTools; Cañas et al., 2005). CESMapper provides similar functionality within the geospatial framework of a Geogtraphical Information System (GIS).

QGIS (http://www.qgis.org) was selected as a preferred geospatial platform on account of its maturity as an open source GIS, support for multiple operating systems and growing user base. QGIS is written in C++ and allows integration of software plugins coded in either C++ or Python. CESMapper is implemented as a Python plugin that enables system components to be mapped interactively over one or more QGIS data layers.

CESMapper allows the user to add landforms, interventions and interactions on top of a GIS base layer that defines the projection and co-ordinate system. Possible base layers include digital mapping, Web Map Server-based layers (including Google Maps or Bing maps), or digital photography. The base layer can be supplemented by 'helper layers' that provide useful information to guide the identification of landform types and identify human interventions. Airborne LiDAR raster layers are especially useful, as are digital bathymetric charts and geological maps, and vector layers containing information on flood and coastal defence infrastructure.

A key feature of the CESMapper architecture is that the landform ontology is completely separate from the software itself and resides in a user-editable external library file. The ontology is defined using a simple XML-like semantic markup language, which permits the inclusion of optional presentational markup to impose various label and line style settings (these can be overridden within the software). The available components (landforms, interventions) are read from the ontology and used to guide on-the-fly creation of Graphical User Interface (GUI) palettes, which provide the user with a pre-determined set of system elements and impose constraints on how these can be combined. CESMapper then allows the linkages between the various components and specify the type and directionality of the connection (influence, sediment transfer) to be defined.

The selection of a combination of landforms to be included as part of a specific landform complex can be accomplished using the software tool which will automatically provide a check that the grouping is permissible within the defined ontology; this maintains a base level of consistency between different users when producing coastal and estuary system maps. The resulting map (a point layer of components and a line layer of connections) is saved in ESRI shape file format, which can be read by a wide variety of other applications and thus provides a common platform for distribution of system maps to stakeholders.

2.3 Applications of CESM and CESMapper

Within the iCOASST project (Nicholls et al., 2015; Van Maanen et al., 2015), coastal and estuarine system maps were well received by a diverse group of stakeholders that included, inter alia, management agencies and regional authorities, non-governmental organisations, representatives of industry and agriculture, and local inhabitants. Discussions typically centred on matters of detail, such as the omission of local geological controls on shoreline position, as well as broader scale divergences in opinion – notably concerning the consistency of the direction of littoral drift. As a result we revaluated and reformulated our quantitative understanding on the Suffolk coasts. Hence, these discussions have been valuable in capturing stakeholder knowledge and feeding this into both data-driven analyses and modelling studies. The capturing of local knowledge and its

incorporation into the formulation of a problem and an approach to it, are key elements of good modelling practice that have all too often be neglected in coastal analysis.

Importantly, CESM is transparent and accessible to a wide range of users. This is partly a consequence of its implementation in open-source software. This counters one of the major shortcomings of a 'top down' approach to shoreline management planning that has historically been heavily reliant on proprietary closed-source model codes and GIS software that is available to the larger consultancies but not to local communities and smaller consultants. As French et al (2016b) note, the open source paradigm of computer science is a good exemplar here, in that it demonstrates the benefits of a genuine community effort, both in terms of transparency and accessibility and also in terms of legacy. CESM has the potential to create conceptual models that are living community efforts, stimulating a greater sense of shared endeavour between modellers and stakeholders than has thus far been possible. These conceptual models and linked databases are free to evolve beyond individual project timelines through the continuing involvement of a community of researchers and stakeholders. Hence, the system maps constitute information products that are not finalised at a project end date but, instead, remain free to evolve as knowledge accumulates and agendas change over time.

3. Using CESMapper within QGIS

3.1 Software workflow

CESMapper implements the various stages of the CESM process set out in French et al (2016a) in a simple workflow. This is summarised in Fig. 3.1.

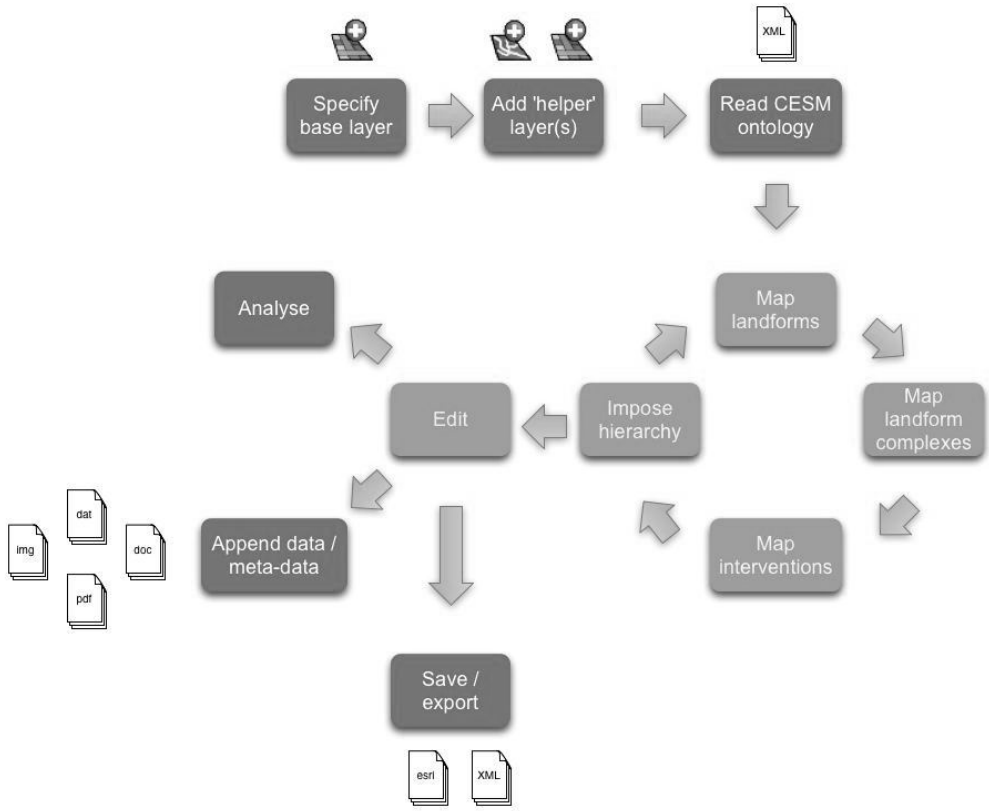

Figure 3.1 Workflow of the CESMapper software. At least one GIS base layer is required on which to interactively locate landforms, interventions and interactions. Helper layers (bathymetry, geology, flood defence lines etc.) can be used to inform the interpretation of the coastal and estuarine systems.

3.2 Loading a GIS base layer

CESMapper requires that at least one base layer is loaded within QGIS. If no suitable layer is present the user is prompted to load one (Fig 3.2). The base layer is important as it sets the base coordinate system and all subsequent maps will be referred to this. It can be any raster or vector layer but is typically a chart or georeferenced aerial image. Google or Bing Maps coverages are available via the QGIS OpenLayers Plugin and are particularly useful as a basis for coastal mapping.

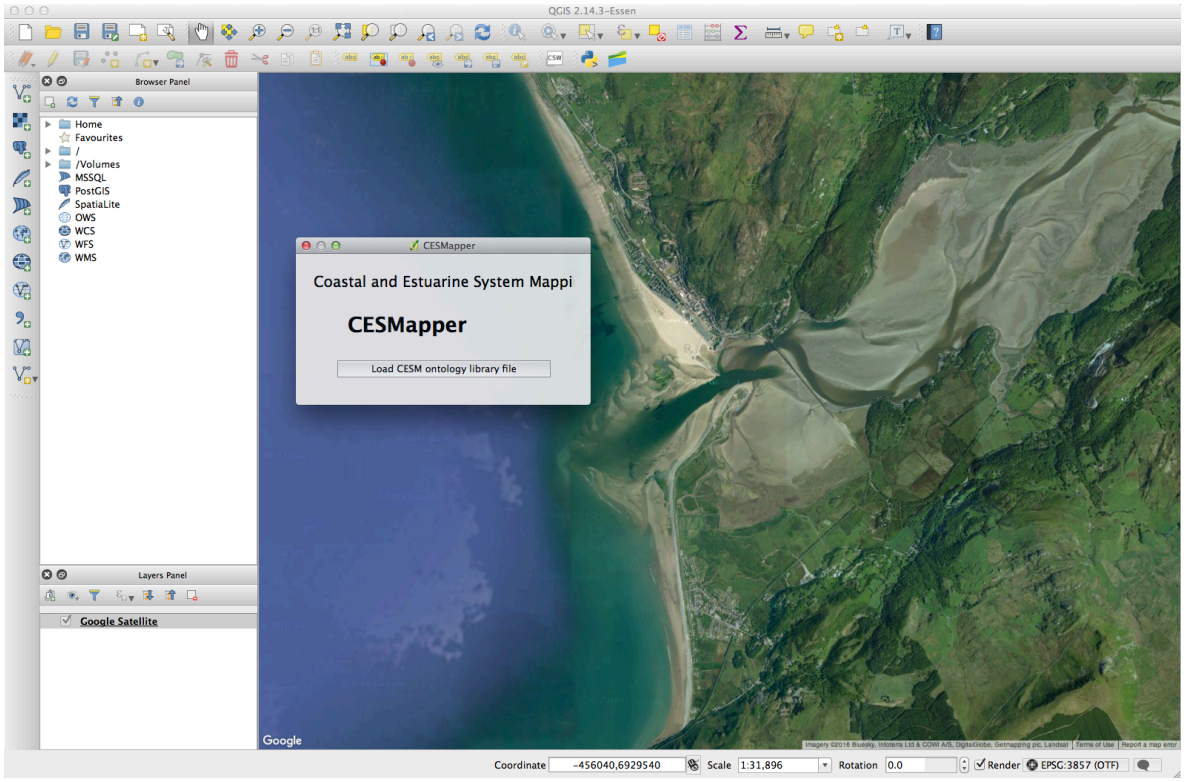

Figure 3.2 On startup, CESMapper will request that a suitable base layer is loaded into QGIS before mapping can be initiated. [placeholder figure]

3.3 Loading a CESM ontology library

A key feature of CESMapper is the separation of the overarching landform ontology from the sofware itself. The ontology, which specifies the hierarchical set of available system components and the permitted interactions between them, resides in an external library file. This follows a simple XML-based syntax (see Appendix B) and can be easily modified with a text editor. CESMapper parses the library file to generate the various interactive map creation menus.

CESMapper will automatically request that a landform ontology library be loaded (Fig 3.3). A default ontology developed in the iCOASST project for application in England and Wales is is included with the plugin distribution – the file, “iCOASSTLibraryFilev1.6.txt, should becopied to a suitable location on your computer. Select and load it. On completion, the main CESMapper menu will appear (Fig 3.3). This may be dragged to anywhere on your screen, and subsequent windows will open below it.

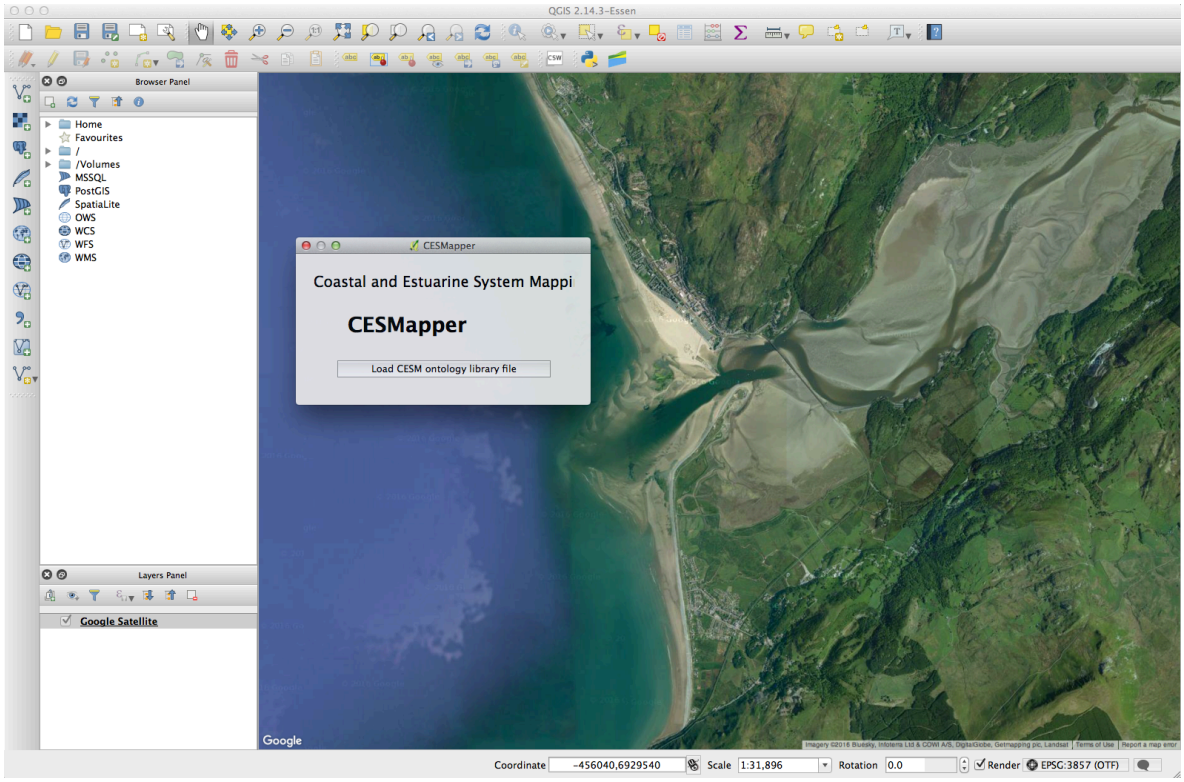

Figure 3.3 If a base layer is loaded, CESMapper prompts the user to load a CESM ontology library. [revise figure once dialogue has been adjusted in software!]

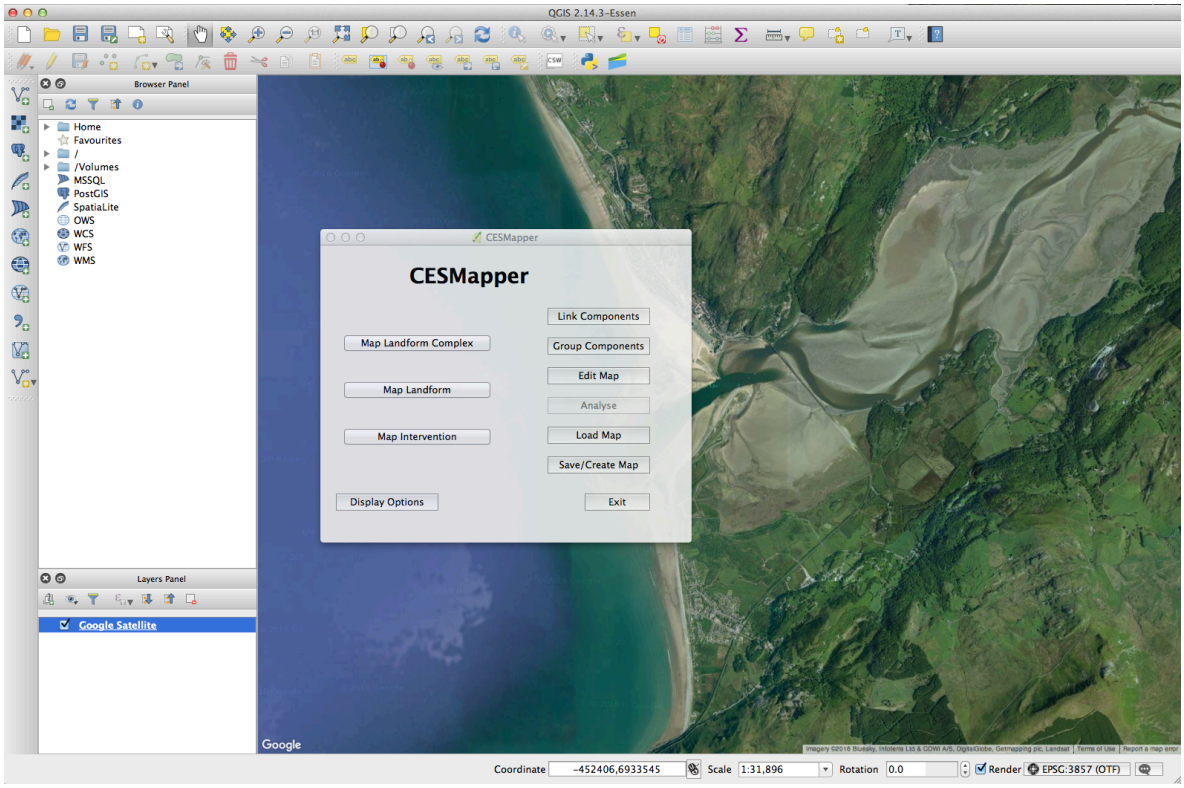

Figure 3.4 Main CESMapper user menu.

3.4 Create and save system maps

MapThe actual map is saved as two work shape files, one for the components, and one for the connections. In order to map, this file set must be created, or a pre-existing map loaded. To create a map, use the “Save/Create Map” button, navigate to a directory of your choice, and type a file name, e.g. Test1. This will create the shape files for both the components and the connections and load them as layers in QGIS. If you have a map to load, click the “Load Map” button, navigate to the map file .shp and select it. The tool will automatically load the corresponding connection file, provided the naming convention has been complied with. There will be a set of files for each layer, the component file has the selected name, the connection file has the same name with "con" appended. This naming convention must be observed to enable the tool to recognise and load the correct paired shape files.
Example:
Test1.cpg
Test1.dbf
Test1.prj
Test1.qpj
Test1.shp
Test1.shx
Test1Con.cpg
Test1Con.dbf
Test1Con.prj
Test1Con.qpj
Test1Con.shp
Test1Con.shx
Once loaded, the layers will appear in QGIS. To save the map, use the “Save/Create Map” button, select the pre-existing .shp file to overwrite, or type a new file name. The tool will automatically produce the relevant paired set of files for the component and connections layers.

3.5 Mapping of landforms and human interventions

Select the order (level) of components you wish to map - the hierarchical ontology is contained in the library file, and the name for each order (level) is applied to a “Map ….” button. When the button is clicked, a new window opens with the list of landforms, or complexes or interventions as selected. Choose the component you wish to place via the radio button, then click on the map to place it. Select other components as required. When you have completed mapping for this set of components, click “Finished Mapping”. This will save the changes to the layer, close the window, and return control to the QGIS main software. To ensure the changes are saved to the shape file you must use the “Save/Create Map” button to write out the updated files.
You may select the different orders as many times as required, but stop map must be clicked at the end of each part of the mapping.

3.6 Linking system components

Once the components are mapped, the linking tool can be activated from the “Link Components” button. This opens a window allowing you to select the type of connection (mass transfer, influence, or mixed), and the direction of the connection - the direction is established by the order in which components are selected. You can select two components, and only two components, to connect together. If you make a mistake with the selection, use “Clear Selection” to reset. When the two components are selected, click “Connection Completed” to draw the connection. The type and directionality can be changed for each connection. When you are satisfied with the connections, close the window. It is advisable to save the maps frequently, so use the “Save/Create Map” button to ensure the changes are written to the shape files.

3.7 Grouping of landforms into complexes

This

3.8 Map editing

If you wish to move or remove a component, it is best to use the editing tool in the mapping tool, to ensure that the attribute tables are updated, and the links between the two layers are synchronised

correctly. The “Edit Map” button opens the editing window, where you can select “Move Component” or “Remove Component”. Select which action you require, then click on the component. To move it, click and hold down the mouse button while you drag the component; any connections to that component should be redrawn to maintain the connection. If you select remove component, the component will disappear, along with any connections previously made to it. You must click move or remove for each such edit,to ensure he edits are correctly carried out. When you have finished editing, click done editing, and close window to return control.

3.9 How to load additional supporting layers into QGIS

If you wish to mo

3.10 Preferences

This opens a window allowing you to select the option to display only one order of the hierarchy. Click on “Display Options”, and a window opens with radio buttons for the Orders described in the library file. Select one of these, then click “Show”. This creates a new, temporary layer, with only the components of the selected layer visible. The original ma and connections layers are set to invisible, but are still present and can be made visible using the legend in QGIS. Currently this does not draw the connections in the new layer, but switching the connections layer to visible will allow these to be seen.

3.11 Manual addition of supplementary information to attribute tables

Slots are provided in the attribute tables for additional information, e.g. the values for the sediment transport rates, or links to additional documentation.

4. Frequently Asked Questions

Q: Performance seems slow with a large map – is there anything that can be done to improve the responsiveness within QGIS?

A: Performance can be slow if a large number of QGIS plugins are installed. Try uninstalling any that are not needed.

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Appendix A

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Appendix B

CESM Library file format

Coastal System Ontology Markup Language (CSOML) Version 1.4
(Document version 1.3 updated: 11 November 2013)
* Last update: Add a 'colour= ' option form component (11/11/13)

This document describes a minimal semantic markup language (with optional presentational markup elements) for the specification of coastal system ontologies. The following tags and associated fields are permitted in a CSOML Library Definition file, with those highlighted in **bold** being mandatory (though these may have empty or null entries):

<library> </library>
Define the beginning and end of any Library Definition file: <library> must always be the first tag and </library> must always be the last.

<CSOMLversion> *version* **</CSOMLversion >**
Specify the CSOML version, which is used to check compatibility with the CSM software. Value of *version* must be numeric (integer or real).

<metadata> *Author="name", Date="13/01/2013"* **</metadata>**
Optionally specify additional information, such as author, date, etc.
Syntax for metadata is *itemname1="content1",itemname2 = "content2" …* etc.

<libraryname> *libname* **</libraryname>**
Specify the name of the library, *lname* (text string).

<libraryversion> *libversion* </libraryversion>
Optionally, specify the library version. Value of *libversion* must be numeric (integer or real).

<numorders> *m* **</ numorders >**
Specify the number of orders, *m* (integer), in the system hierarchy. Order 0 is a root order that is not actually used by the CSM software, but which is used in graphical representations of the ontology. Order 0 will always be a root order with no sub-orders (see below); the lowest orders will always be landform complexes < landforms < engineering interventions. The minimum value for *m* is therefore 4.

<order0> </order0>
<order1> </order1>
…..
<order*m*> </order*m*>
Define the orders where *n*=0 is lowest order of the hierarchy and *m* the highest. Coastal system ontologies consider order 0 to represent the largest spatial and temporal scales of behavior, with higher orders (up to order *m*) representing smaller scales.

The following tags must reside inside paired **<order*n*>** and **</order*n*>** tags
<ordername> </ordername>
Specify the name of the order. This is used to populate GUI menus in the CSM software.

<property> ***numcomps=n, numsuborders=m****, shape=0, colour=#FFFFFF* **</property>**
Specify the properties, including optional presentational markup, for the current order. The following are currently permitted:

numcomps = n Define the number of components in this order (integer *n*).
In the case of an order that contains two or more sub-orders, then n will be the number of sub-orders. If there are no sub-orders, *n* will be the number of types.

numsuborders=m Defines the number of 'sub-orders' (defined below). Optional, if the components are to be separated into groups within a specific order.

shape {0 (default),1}

Defines the mapped shape of the component: 0=rectangle, 1 = circle

colour {=*#FFFFFF* }

Define the mapped colour of the component as a Hex code

<suborder>…. </suborder>

Optionally, specify a sub-order (e.g. Estuary,Open Coast and Inner shelf, for a Landform complex order). Not all orders will necessarily have sub-orders and Order 0 is never allowed sub-orders. If present, there must be at least two sub-orders. Each sub-order must contain all the components that would be otherwise associated with an order.

<subproperty>*subordername='subname', numcomps=k, shape=0, colour==#FFFFFF* </subproperty>

This defines the properties pertaining to the 'suborder', similar to those for the order.

<component> name="compname", *colour=#FFFFFF,* **children="child1,** child2, child3……..childn**" </component>**

Specify each component of current order, with the name "compname", and list the permitted children for that component in children="…." (a quote-terminated and comma-separated list). The colour for the component can be specified as a Hex code, but may be omitted, in which case the order or suborder colour is used. (N.B. if the colour keyword is used, it must appear between the '**name='** keyword and the '**children=**' keyword.

There is a special case of children="all" where all the components at the next level down are permitted, or children="none" where there are no permitted children.

Notes:

1. A **<component>** ….. **</component>** entry must be followed by a **</ordern>** tag to close the definitions for that order.

2. As noted above, the library definition file must always be terminated by a **</library>** tag.

3. The CSM software performs a check to ensure that the version of CSMOL is supported: it should always read CSMOL files at or below, but not necessarily above, its current version.
4. Blank lines are permitted and are ignored. Whitespace is ignored.