FRMRC flood risk management research consortium

School of Oriental and African Studies, 4th October 2011

Practitioner workshop on asset management

"Shoreline evolution for flood-risk assessment"

Dr Stuart Stripling

EPSRC Grant: EP/FP202511/1

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FRMRC2 WP4.3

"Broad Scale Integration of Coastal Flood and Erosion Risk Models"

- Research carried out by *HR Wallingford Ltd.*
- Industrial support from *Halcrow*

Objective

"To enhance the management of defended coastlines through integration of coastal erosion- and flood-risk models"

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FRMRC2 WP4.3

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Today's Contents

- Scope of research
- Probabilistic modelling (Erosion Risk Model)
- Application of ERM
- Integration of erosion- and flood-risk models
- Model operability
- Application of integrated model at Pilot site

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Scope (1st Phase)

- Rapid broad-scale shoreline evolution modelling
  - Numerical scheme reliable, fast and accurate
- Probabilistic shoreline evolution modelling
  - Stochastic nature allows event-based input e.g.
    - Rivers, Cliffs
  - Provides stochastic output
    - Mean, maximum, minimum positions
    - Histograms (cliff-top position, toe level at seawall)

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DATA MANAGEMENT

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Scope (2nd Phase)

- Moulding of existing RASP-SU flood-risk model
  - FRA presently considers beach to be *static defence*
  - Modified to accept histogram i.e. *dynamic defence*
- Integrated model of erosion- and flood-risk
- Pilot site proof-of-concept application
  - Holderness coastline, Hornsea in particular

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- Pilot
  - Ho

MODEL OPERABILITY

s18

Probabilistic Modelling

- Stable, rapid and accurate deterministic model
- Becomes an erosion-risk model when likelihood of beach behaviour is established:
    1. Derive morphological events from wave time-series
    2. Sample X years of morphological events at random
    3. Simulate shoreline evolution with deterministic model
    4. Repeat 2. and 3. above from same shoreline start position until variance of the mean of the final shoreline position converges
- Stochastic modelling allows event-based sources

s23

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Slide 13

s18 Or you could use the slides that were presented earlier this week for this bit. They are appended at the end of this .ppt for convenience.
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Slide 14

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s30

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s24

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Slide 15

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Slide 16

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s25

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s26

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Slide 17

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Slide 18

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s22

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- Stochastic modelling allows event-based sources

Event-based Sources

- River loading
- Nourishment
- Simple soft-cliff recession model
  - Based on observed cliff behaviour
    - Pre-fall slope (assigned confidence limits)
    - Post-fall stable slope (assigned confidence limits)
  - Toe position provided by shoreline model
  - System-state test (ie fail or no fail) each time-step

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s28

Application: Fiume Savuto, Italy

- River loads
  - From river model
  - Load v RP
  - River engineering
  - Random sampling

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s29

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Application: Fiume Savuto, Italy

- Nourishment
  - South of river
  - User defined

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Event-based Sources

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Slide 23

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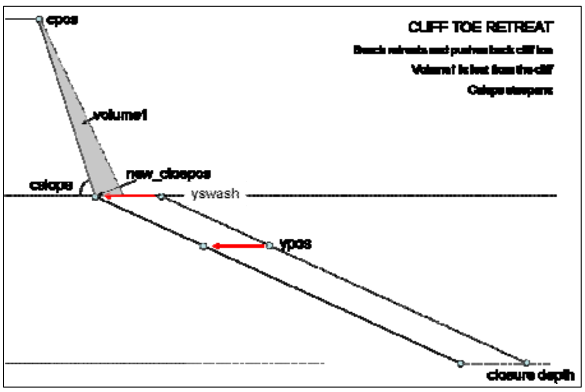
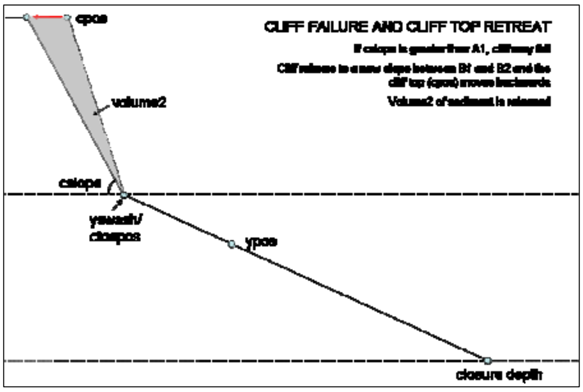
Simple Cliff-recession Model

- As beach width reduces, cliff toe recedes
  - Pre-fall slope required



Simple Cliff-recession Model

- Cliff fails
  - Post-fall stable slope required



Probabilistic Model Summary

- Provides measure of long-term Erosion-Risk
  - Histogram of cliff-top position
  - Histogram of shoreline position
  - Histogram of toe levels at seawalls
- Allows incorporation of event-based sources
- Rapid (~seconds/minutes)
- Data management by GIS data model

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- Allows incorporation of event-based sources
- Rapid (~seconds/minutes)
- Data management by GIS data model
- *PRINCIPLES CONFORM WITH THE METHODS USED TO ESTABLISH FLOOD-RISK UNDER EA's NaFRA*

NaFRA: RASP-SU

Risk **A**ssessment for **S**trategic **P**lanning

- RASP-SU models provide a Monte Carlo coastal flood-risk simulation framework for exploration of uncertainty in various modelling parameters and input variables
- RASP-SU results include histograms of overtopping volume, probability of inundation, expected annual damage (EAD) and flood depths

NaFRA: RASP-SU

Risk **A**ssessment for **S**trategic **P**lanning

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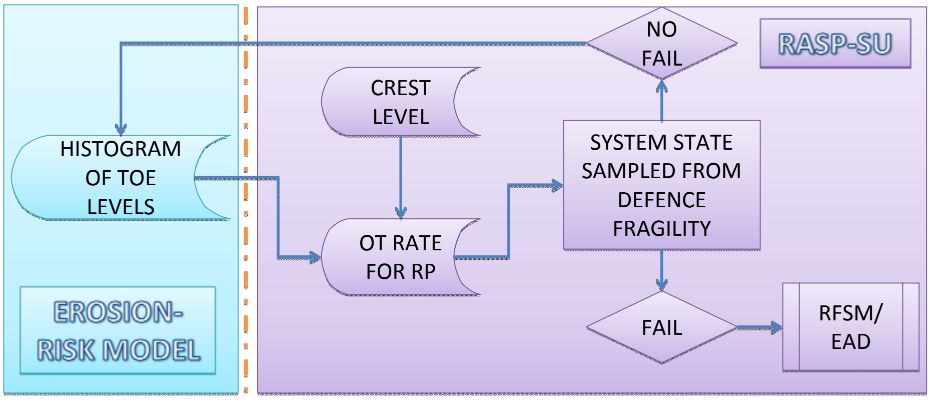
- RASP-SU results include statistics of overtopping volume, probability of inundation, expected annual damage (EAD) and flood depths

Integrated Modelling

for each defence length…….



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Integrated Modelling

- Requires thorough data management model
- Ease of operation…..

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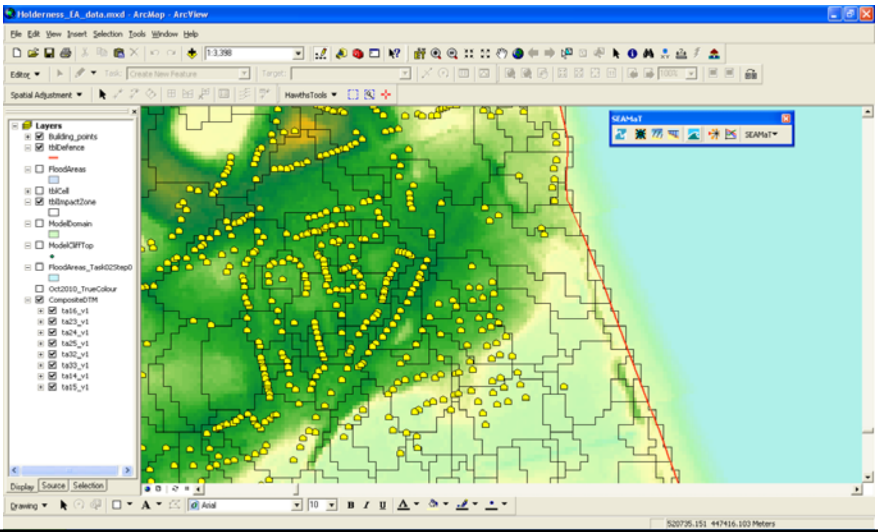
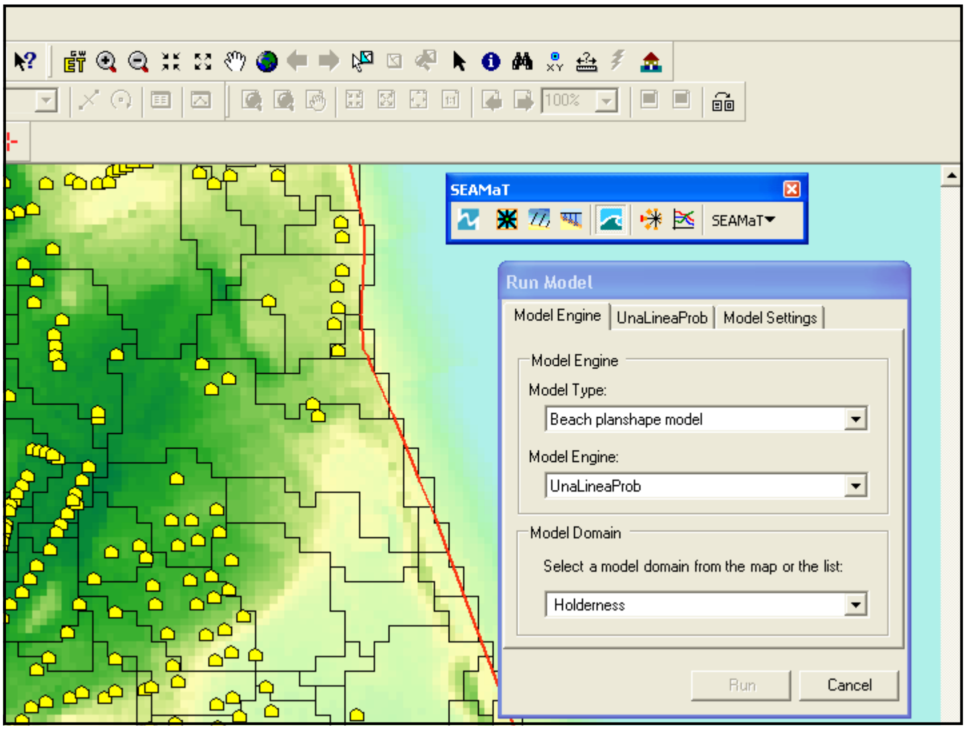
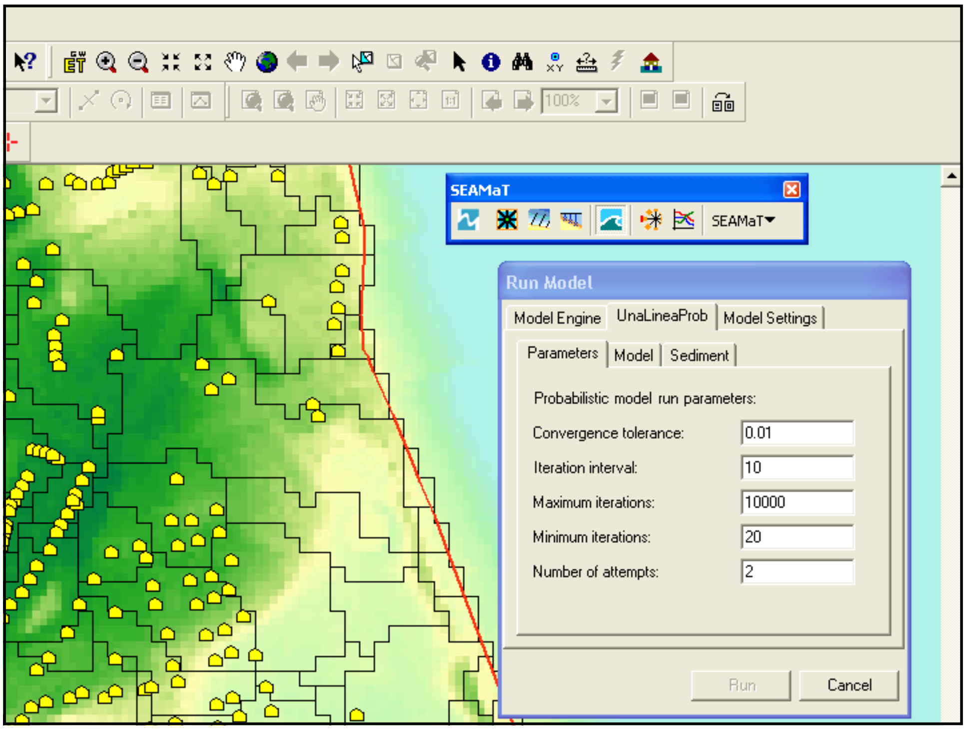
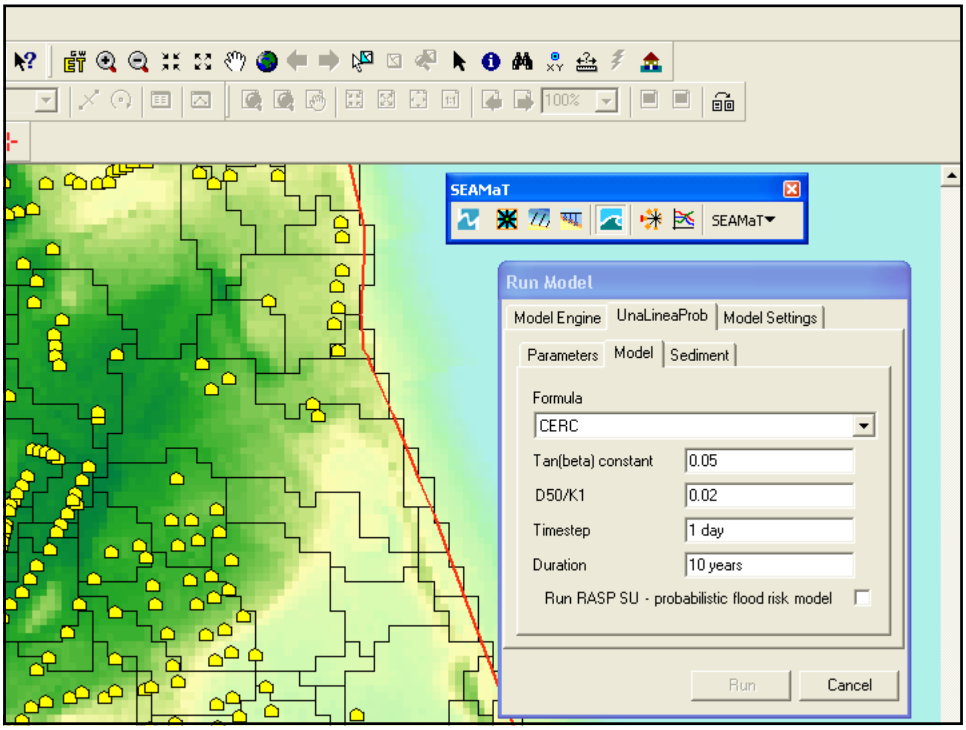
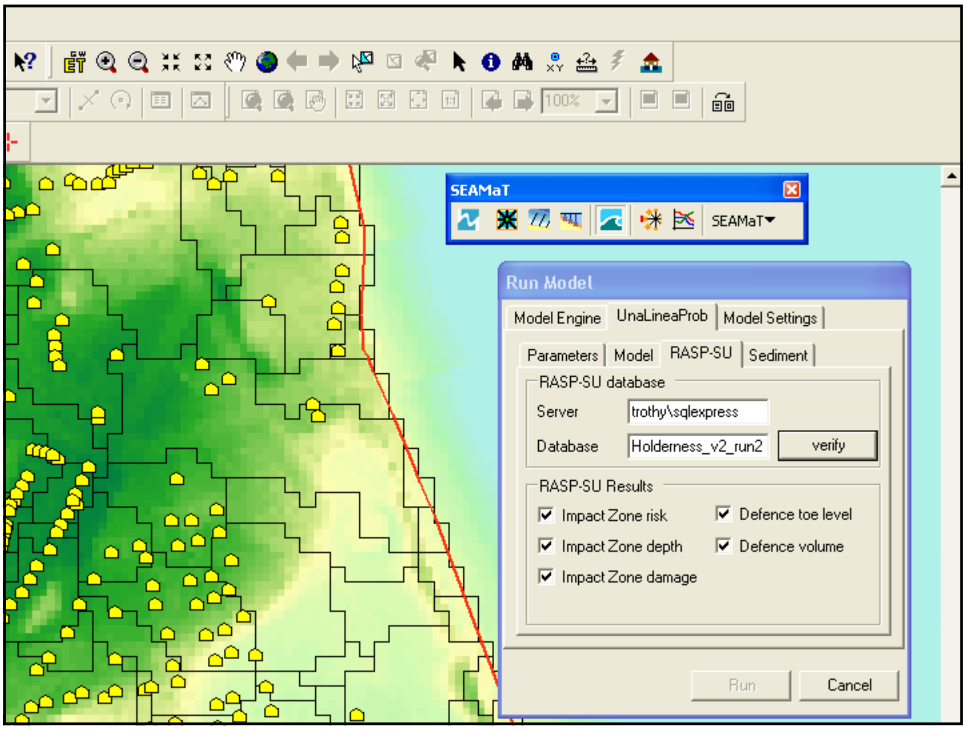
Model Operability




SEAMaT
SEAMaT
Run Model
Model Engine
UnaLineaProb
Model Settings
Model Engine
Model Type:
Beach planshape model
Model Engine:
UnaLineaProb
Model Domain
Select a model domain from the map or the list:
Holderness
Run
Cancel


SEAMaT
SEAMaT
Run Model
Model Engine
UnaLineaProb
Model Settings
Parameters
Model
Sediment
Probabilistic model run parameters:
Convergence tolerance:
0.01
Iteration interval:
10
Maximum iterations:
10000
Minimum iterations:
20
Number of attempts:
2
Run
Cancel


SEAMaT
SEAMaT
Run Model
Model Engine
UnaLineaProb
Model Settings
Parameters
Model
Sediment
Formula
CERC
Tan(beta) constant
0.05
D50/K1
0.02
Timestep
1 day
Duration
10 years
Run RASP SU - probabilistic flood risk model
Run
Cancel


SEAMaT
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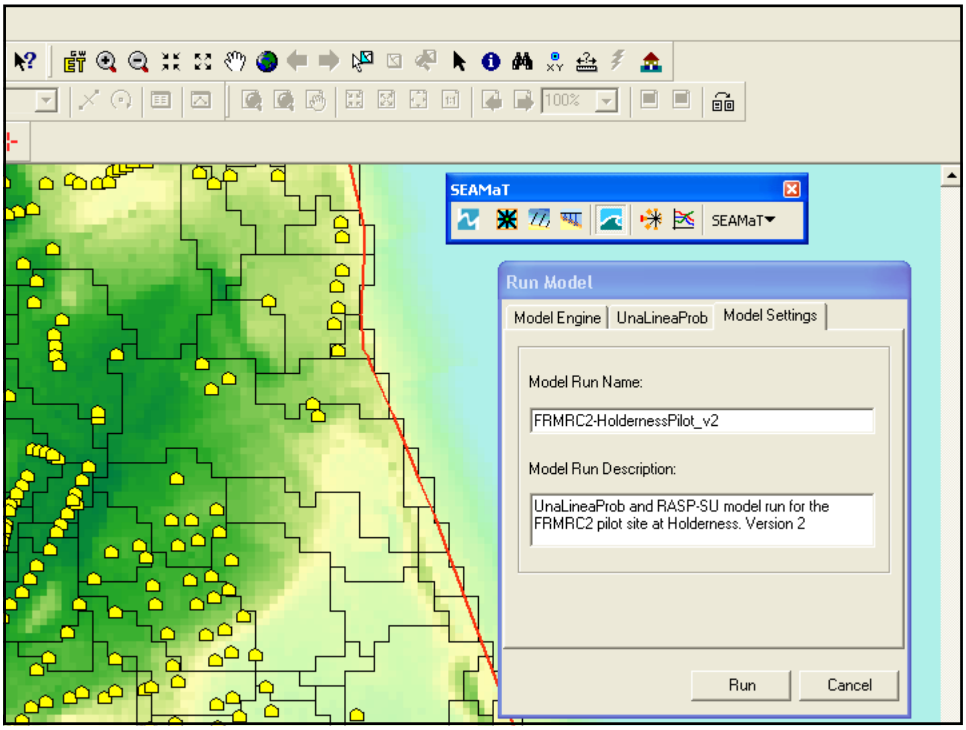
Run Model
Model Engine
UnaLineaProb
Model Settings
Parameters
Model
RASP-SU
Sediment
RASP-SU database
Server
trothy\sqlexpress
Database
Holderness_v2_run2
verify
RASP-SU Results
Impact Zone risk
Defence toe level
Impact Zone depth
Defence volume
Impact Zone damage
Run
Cancel



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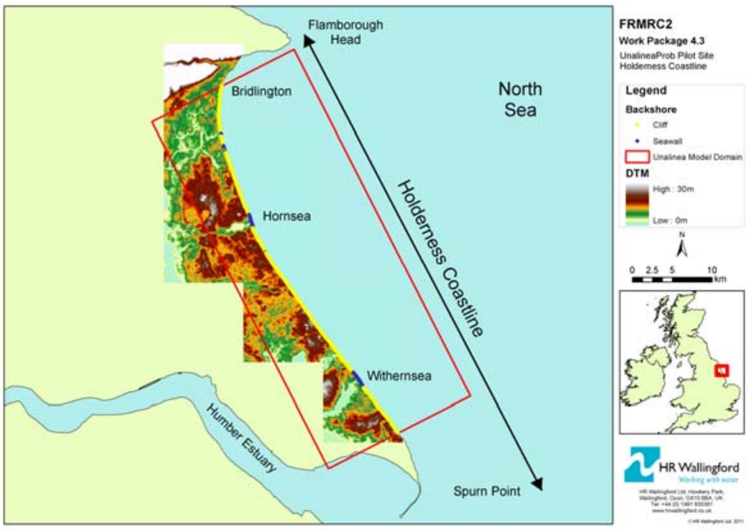
Pilot Site: Location



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Pilot Site: Seawall and Cliff…..

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Pilot Site: Groynes…….

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Pilot Site: Erosion Risk Model

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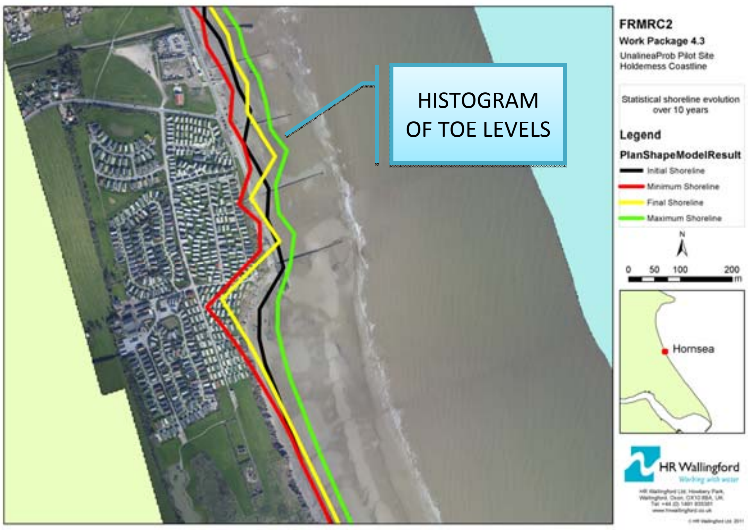
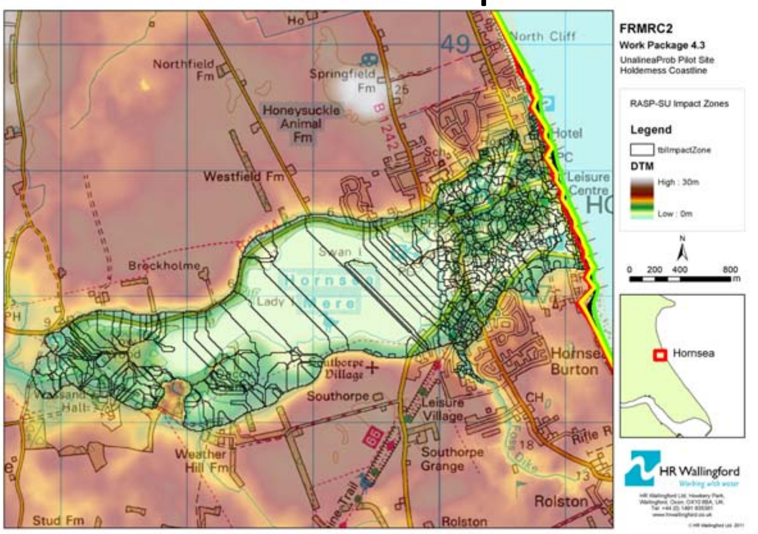
Pilot Site: Erosion Risk Model



Pilot Site: Cliff-recession Module

Pilot Site: RFSM Impact Zones



Pilot Site: Selected Impact Zone

Pilot Site: Property and Defences

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Pilot Site: Toe levels for defences

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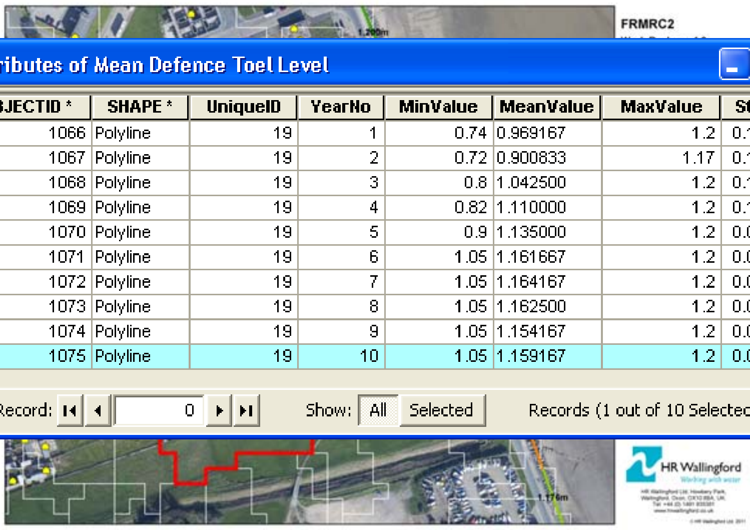
Pilot Site: Toe levels for defences



Attributes of Mean Defence Toel Level

OBJECTID *	SHAPE *	UniqueID	YearNo	MinValue	MeanValue	MaxValue	StdDev
1066	Polyline	19	1	0.74	0.969167	1.2	0.189807
1067	Polyline	19	2	0.72	0.900833	1.17	0.144503
1068	Polyline	19	3	0.8	1.042500	1.2	0.129343
1069	Polyline	19	4	0.82	1.110000	1.2	0.125843
1070	Polyline	19	5	0.9	1.135000	1.2	0.077283
1071	Polyline	19	6	1.05	1.161667	1.2	0.041742
1072	Polyline	19	7	1.05	1.164167	1.2	0.043161
1073	Polyline	19	8	1.05	1.162500	1.2	0.043301
1074	Polyline	19	9	1.05	1.154167	1.2	0.045017
1075	Polyline	19	10	1.05	1.159167	1.2	0.043371

Record: 0 Show: All Selected Records (1 out of 10 Selected)

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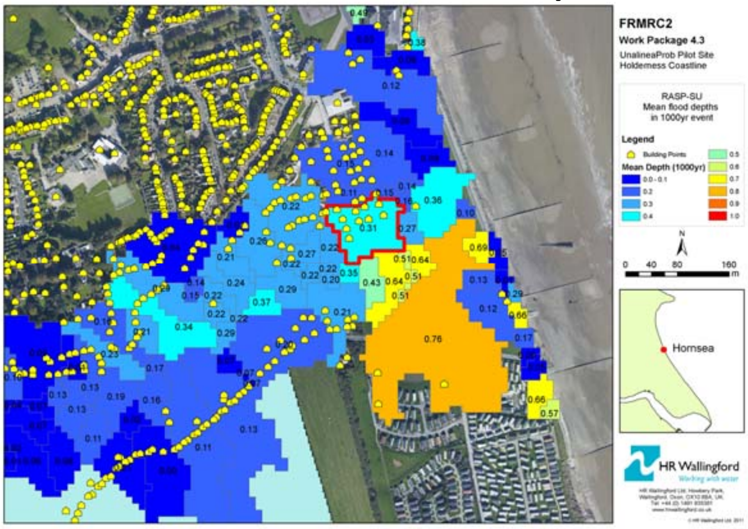
Pilot Site: Flood depths



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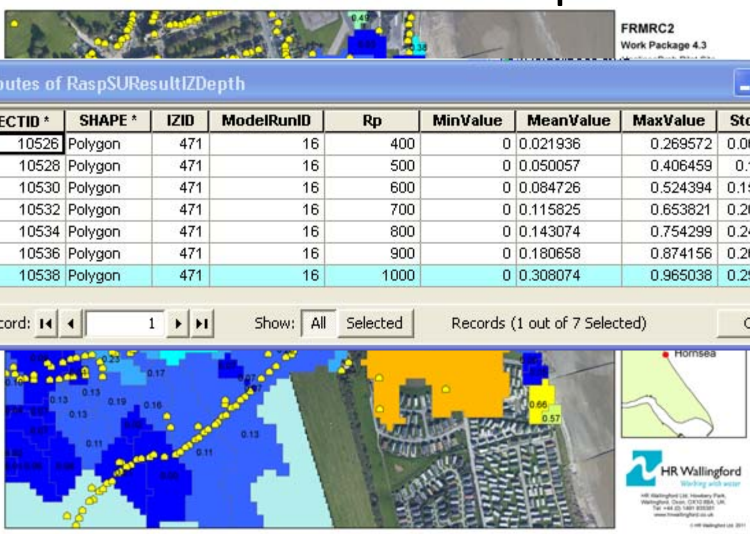

OBJECTID *	SHAPE *	IZID	ModelRunID	Rp	MinValue	MeanValue	MaxValue	StdDev
10526	Polygon	471	16	400	0	0.021936	0.269572	0.064628
10528	Polygon	471	16	500	0	0.050057	0.406459	0.10846
10530	Polygon	471	16	600	0	0.084726	0.524394	0.157548
10532	Polygon	471	16	700	0	0.115825	0.653821	0.202648
10534	Polygon	471	16	800	0	0.143074	0.754299	0.240935
10536	Polygon	471	16	900	0	0.180658	0.874156	0.261731
10538	Polygon	471	16	1000	0	0.308074	0.965038	0.295135

Record: 1 Show: All Selected Records (1 out of 7 Selected) Options

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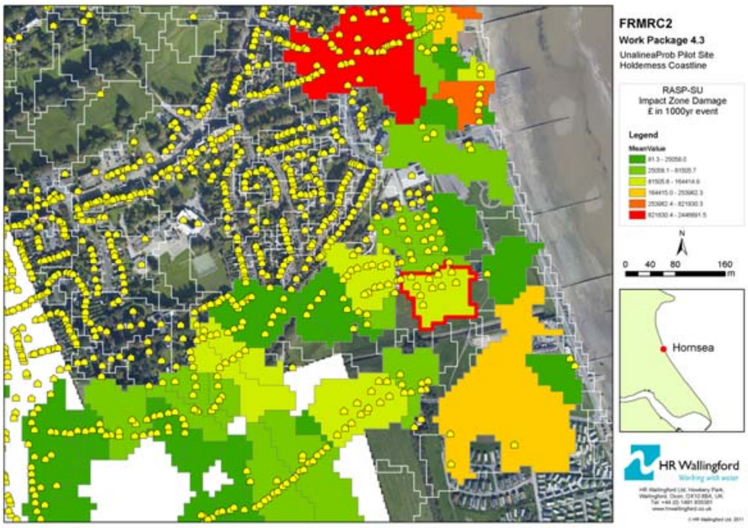
Pilot Site: Expected damage (£)



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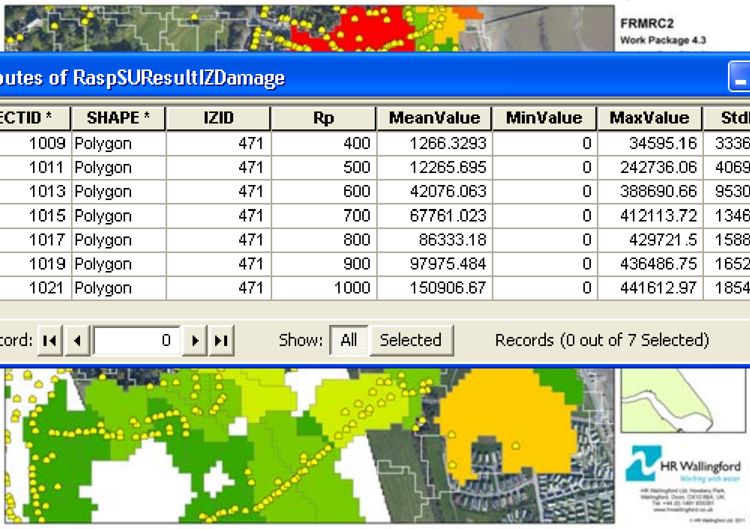
Pilot Site: Expected damage (£)



Attributes of RaspSUResultIZDamage

OBJECTID *	SHAPE *	IZID	Rp	MeanValue	MinValue	MaxValue	StdDev
1009	Polygon	471	400	1266.3293	0	34595.16	3336.8169
1011	Polygon	471	500	12265.695	0	242736.06	40692.496
1013	Polygon	471	600	42076.063	0	388690.66	95305.031
1015	Polygon	471	700	67761.023	0	412113.72	134694.11
1017	Polygon	471	800	86333.18	0	429721.5	158897.52
1019	Polygon	471	900	97975.484	0	436486.75	165248.91
1021	Polygon	471	1000	150906.67	0	441612.97	185479.44

Record: 0 Show: All Selected Records (0 out of 7 Selected)

Scenario Testing

- Return to deterministic shoreline evolution model and, e.g;
  - Remove groynes
  - Add groynes
  - Nourish
  - Increase sea-level
- Not presented here, but the underlined models would then return new statistics for flood-depth, EAD etc. and allow scheme appraisal/ optimisation

Summary

- Fast, reliable and accurate broad-scale 1-line model
- Consider the beach as a system of elements
  - Defence-types, backshore-types
- Monte Carlo running of ERM to give beach statistics
- Underlining of ERM and RFSM
- Allows improved scenario testing that takes into account the dynamic behaviour of beaches

Where next?

- Consideration of additional structures in ERM
  - Improve seawalls/ groynes/ beach levels
  - Include breakwaters
- Include further “backshore” modules in ERM
  - Dunes/ barrier-beaches
- Auto-calibration of ERM
- Climate impacts
  - Nearshore seabed updating
- Software optimisation for ease of scenario modelling

Acknowledgements

- FLOODsite
- FRMRC
- Autorita di Bacino Regione Calabria, Italy
- HR Wallingford
- Uni. Oxford (Knowledge Transfer Secondment)
- Regione Veneto, Italy

s31

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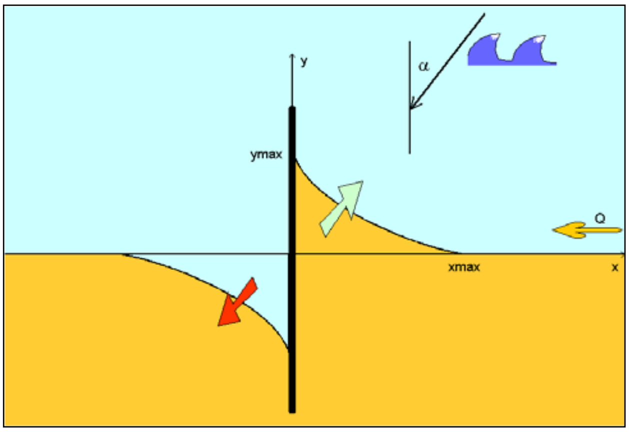
Model Development

- Simple scenario



s32

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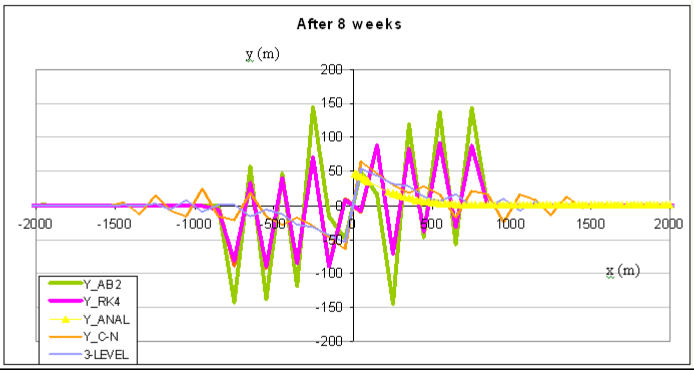
Model Development

- Investigation of numerical scheme performance for broad-scale application of 1-line model

dt=1 week, dx=100m
t=8 weeks



Slide 63

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s31 Illustration of stability issues (at a groyne) for long time and large spatial discretisation for a variety of numerical solution methods.
Explicit:
Euler, Adams-Bashforth, Runge-Kutta

Implicit:
Crank-Nicholson
3-level

Graph also includes analytical solution
ss, 09/07/2010

Slide 64

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Implicit:
Crank-Nicholson
3-level

Graph also includes analytical solution
ss, 09/07/2010

s33

Model Development

- Optimisation of time and space discretisation
  - Comparison of stability (Euler)

AS 1 - Infinite groyne analytical solution

dt	dx 75m	100m	150m	200m	250m	300m	400m
day	√	√	√	√	√	√	√
week				√	√	√	√
fortnight				√	√	√	√
month				√	√	√	√

(grey) UNSTABLE

Groyne

AS 2 - Constant discharge from a source at a point

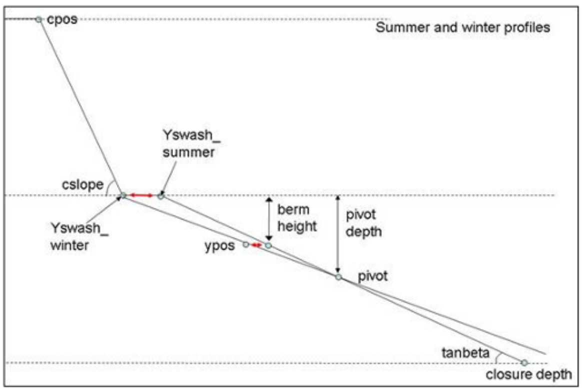
dt	dx 75m	100m	150m	200m	250m	300m
day	√	√	√	√	√	√
week				√	√	√
fortnight					√	√
month						√

(grey) UNSTABLE

Point source

Model Development

- Seasonal variation in beach slope alters “yswash”
  - Typical seasonal beach slopes required

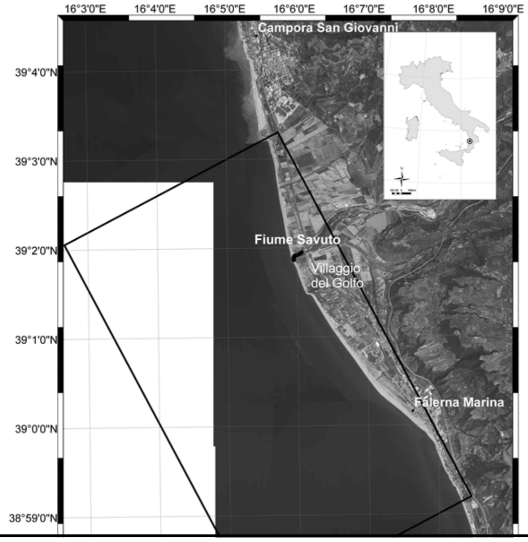


Slide 65

s33 Interesting schematisation of stability issues for numerical solver (only one of those we have tested/ are testing) given varying time and space discretisation.
ss, 09/07/2010

Application: Fiume Savuto, Italy

- Location



Slide 67

s27 Or you could use the slides that were presented earlier this week for this bit. They are appended at the end of this .ppt for convenience.
ss, 09/07/2010