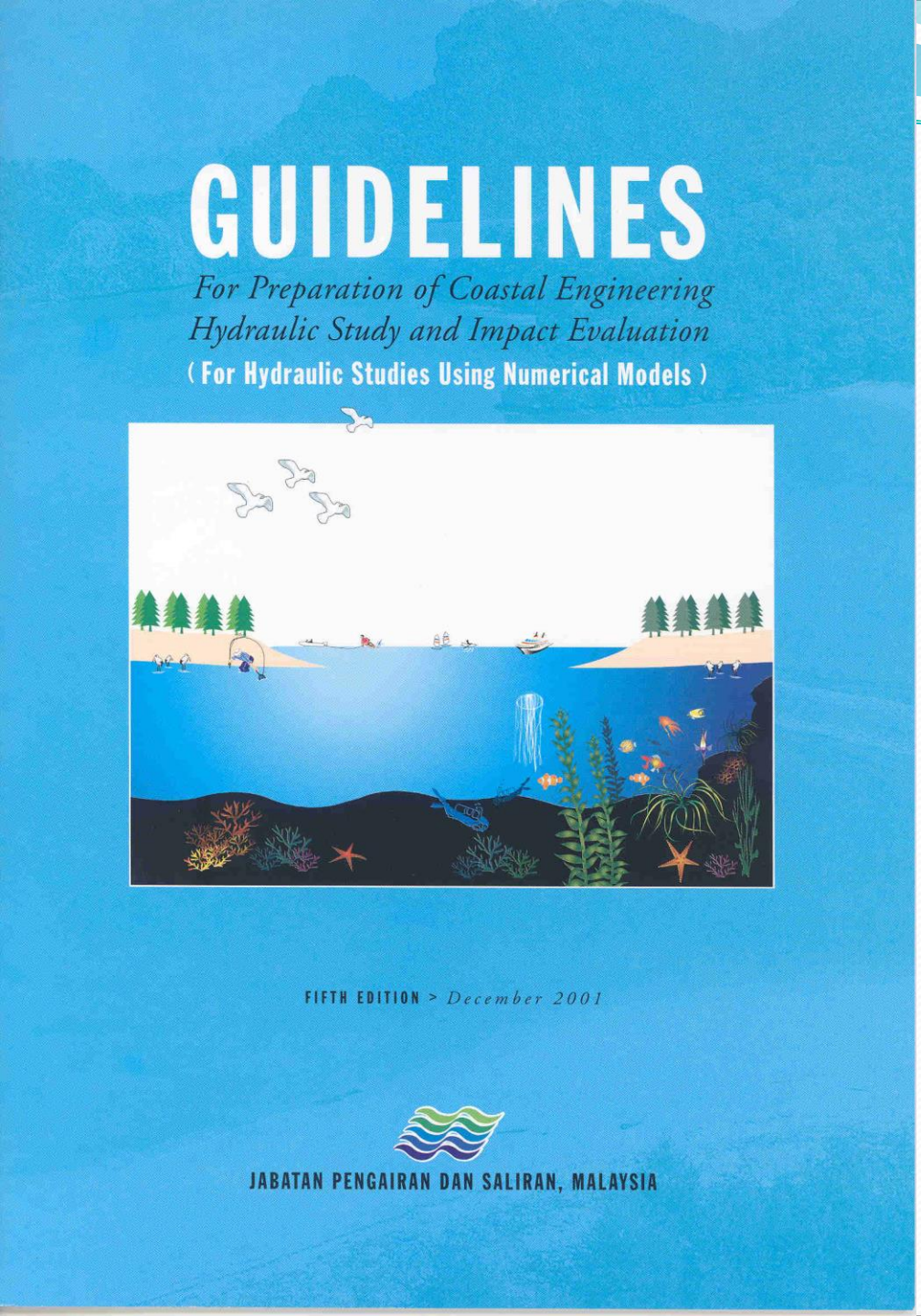

Guidelines for Preparation of Coastal Engineering Hydraulic Study and Impact Evaluation (for hydraulic studies using numerical models)

An explanatory note

By

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MIEM, P. Eng.

18 April 2018

PRESENTATION CONTENT

- Introduction
- Components of A Coastal Hydraulic Model
- Model Set-up
- Data Requirements
- Model Validation – calibration & verification
- Simulations of Model
- Impacts – types, assessment, identification
- Monitoring
- Report presentation
- Conclusion

INTRODUCTION

- A long term measures to mitigate coastal erosion is through instituting non-structural and regulatory measures such as land use planning and control development project

- Among the regulatory measures are :-
  - Environmental Quality Acts 1974 (revised 1987)
  - DID Guidelines 1/97
  - DID Guidelines for Preparation of Coastal Engineering Hydraulic Study and Impact Evaluation
  - Integrated Shoreline Management Plan (ISMP)

Environmental Quality Act 1974 (revised 1987)

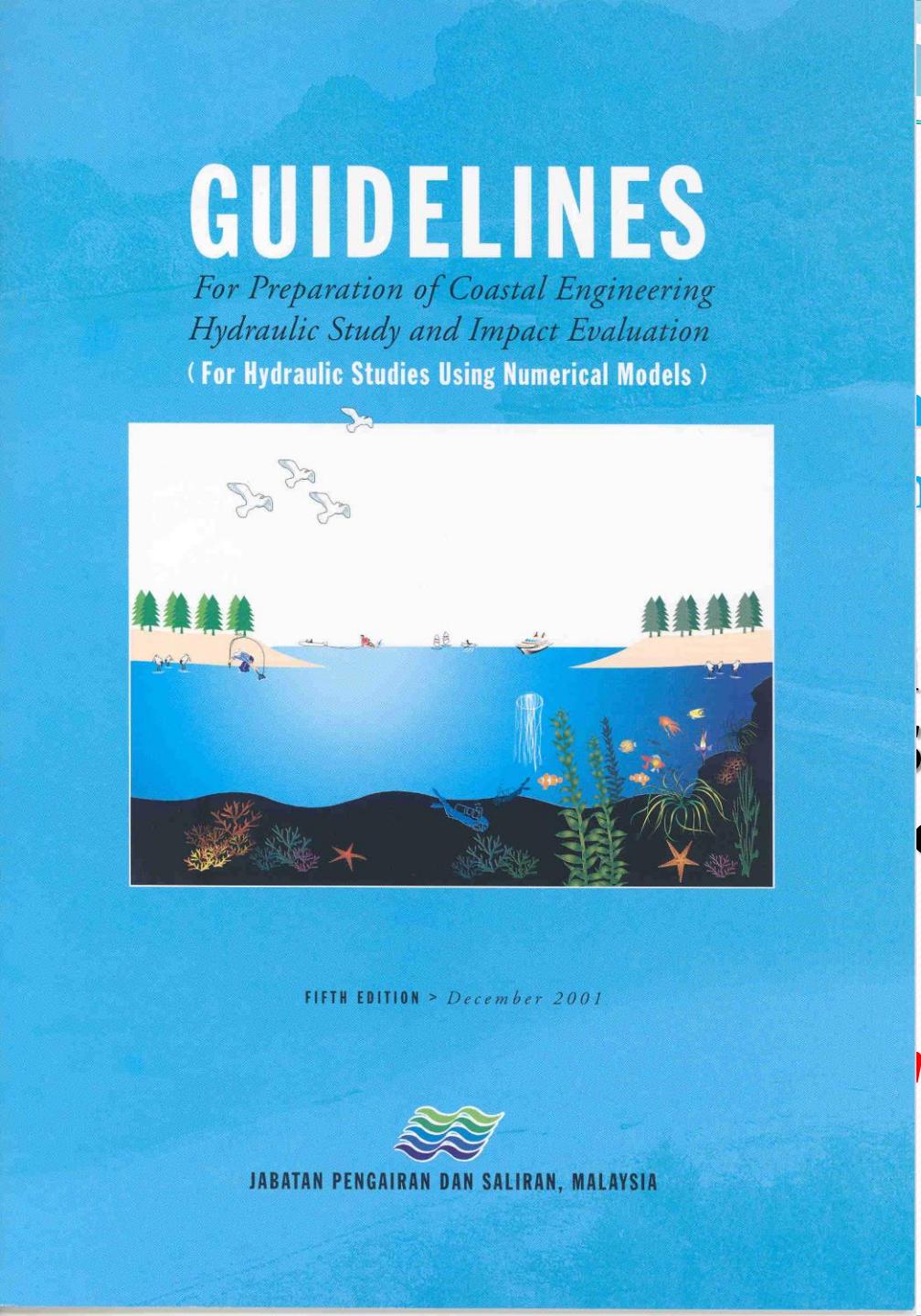
- Prescribed activities under Environmental Impact Assessment (EIA) Order 1974 (revised 1987) need mandatory EIA
- For coastal development projects, a coastal hydraulic study is part of the EIA
- With ICT advancement, computer numerical modelling is becoming more relevant and important in the hydraulic study

Computer Numerical Models for Coastal Hydraulic Studies

- A model is a simplified, schematic representations of the real world, a representations that retain enough aspects of the original system to make it useful to the modeller.
- If the modelling is not done properly, the results may not reveal the relevant impacts on the environment
- To ensure a certain consistency and quality is attained, it is therefore necessary to streamline the computer modelling studies based on relevant guidelines
- The Guidelines describe in detail the data requirements and the scope of impact assessment for various types of development projects in the coastal area

WHY DOES MODELLING NEED GUIDELINES

- Numerical models are complex tools requiring thorough understanding of coastal processes
- Why does modelling need guidelines?
  - Programming principle: garbage in = garbage out
  - Modelling is an upstream process; wrong model output leads to wrong conclusions
  - Complex data set: tide, currents, waves, wind, sediment data requires careful handling
  - Specific module for specific problems/process simulation
    - All models have limitations
    - Model selection must fit problem



ıtrol for Development
ıe (DID Guidelines 1/97)

ıon of Coastal
Study and Impact
c studies using
(DID Guidelines 2001)

ıts 1/97 on the use of

DID Guidelines 2001

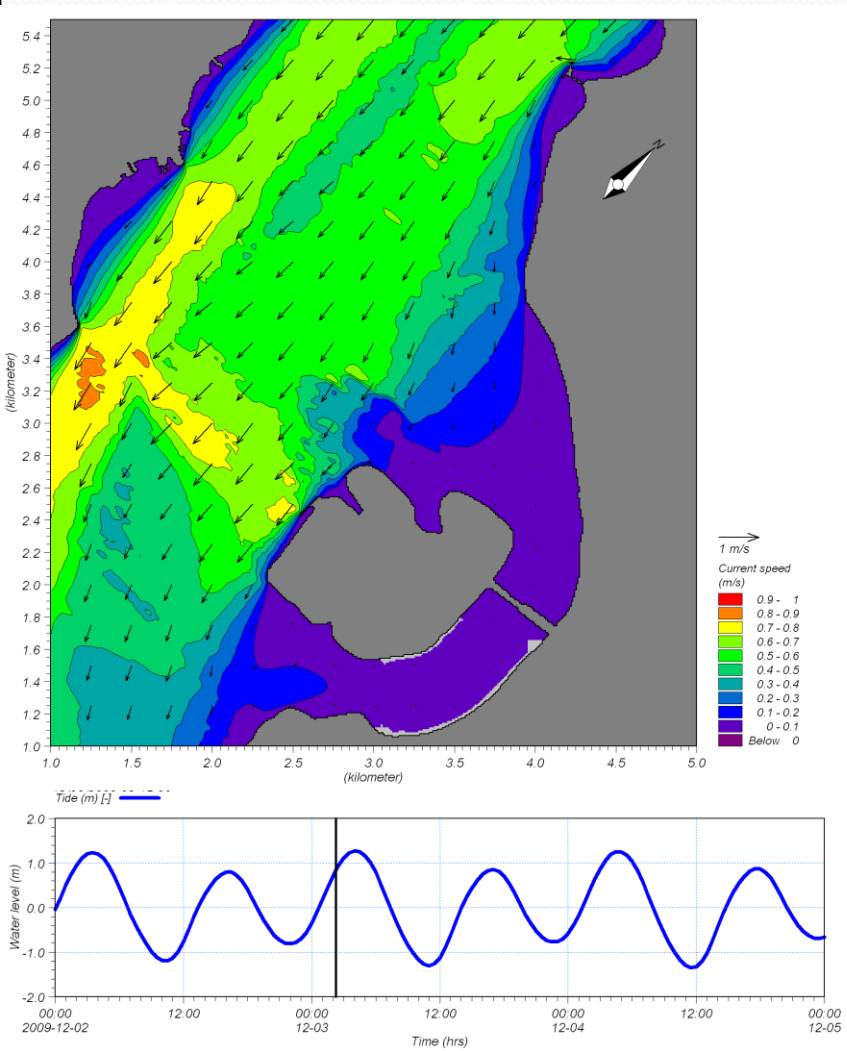
- The Guidelines broadly cover several aspects of modeling, such as :-
  1. Components of a Coastal Hydraulic Model
  2. Model Setup
  3. Data Requirements
  4. Model Validation (Calibration & Verification)
  5. Simulation of the Model
  6. Type and Assessment of Impacts (Overall Assessment)
  7. Monitoring
  8. Report Presentation

1. COMPONENTS OF COASTAL HYDRAULIC MODEL

- Hydrodynamic Module
- Wave/ Nearshore wave Module
- Mud/ Sand transport Module
- Advection/ Dispersion Module

Components of Coastal Hydraulic Model

HYDRODYNAMIC MODULE



1) Simulates current speed & direction and water level over tidal cycle

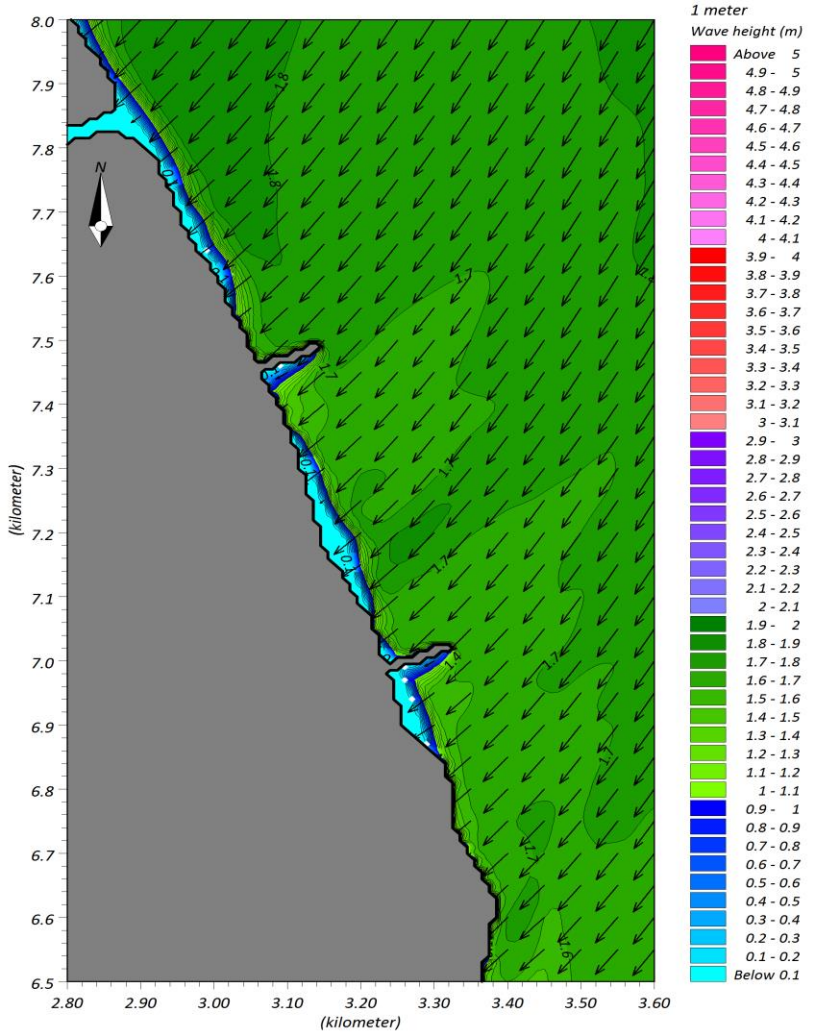
2) Data input:
   - i. Tidal time series
   - ii. Wind speed, direction
   - iii. Bathymetry & land
   - iv. Sediment information; cohesive or non-cohesive

3) Output:

   Over a period of time, predicts where and when the current is fastest/slowest and the variation in water level

Components of Coastal Hydraulic Model

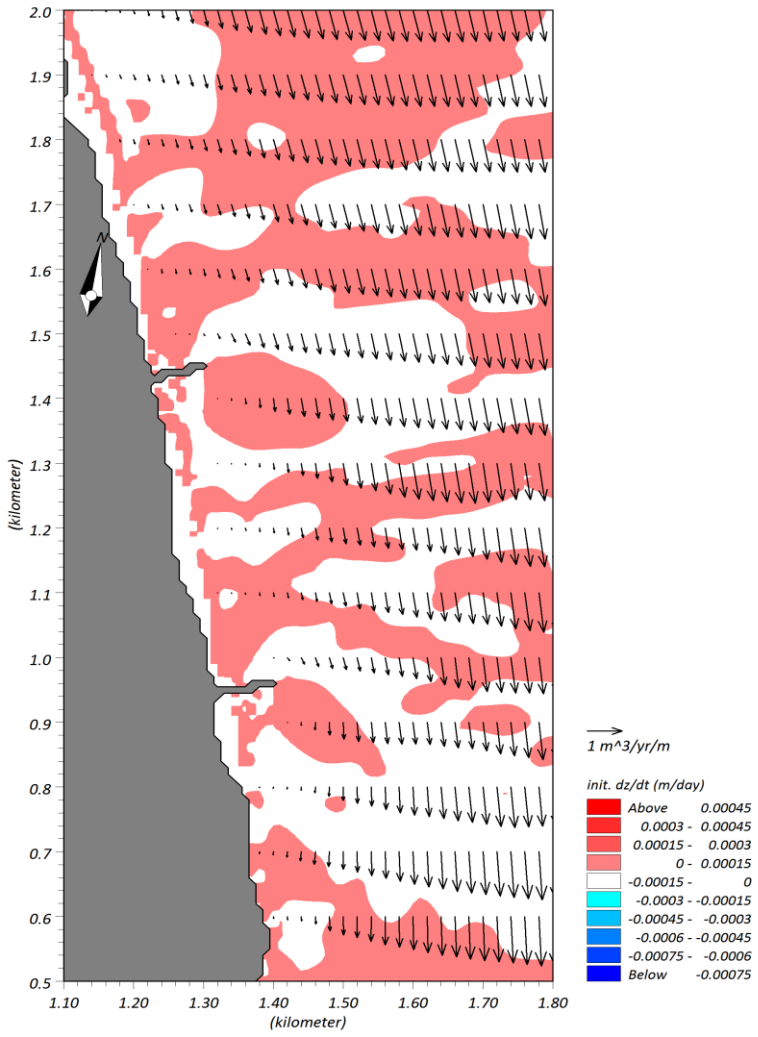
WAVE MODULE



1) Transforms offshore/deepwater wave to nearshore wave conditions
2) Data input:
   i. wave height, period direction
   ii. Bathymetry & land
   iii. Wind speed, direction
   iv. Sediment information
3) Output:
   Wave height and direction of waves as it travels from offshore to the nearshore

Components of Coastal Hydraulic Model

MUD/ SAND TRANSPORT MODULE



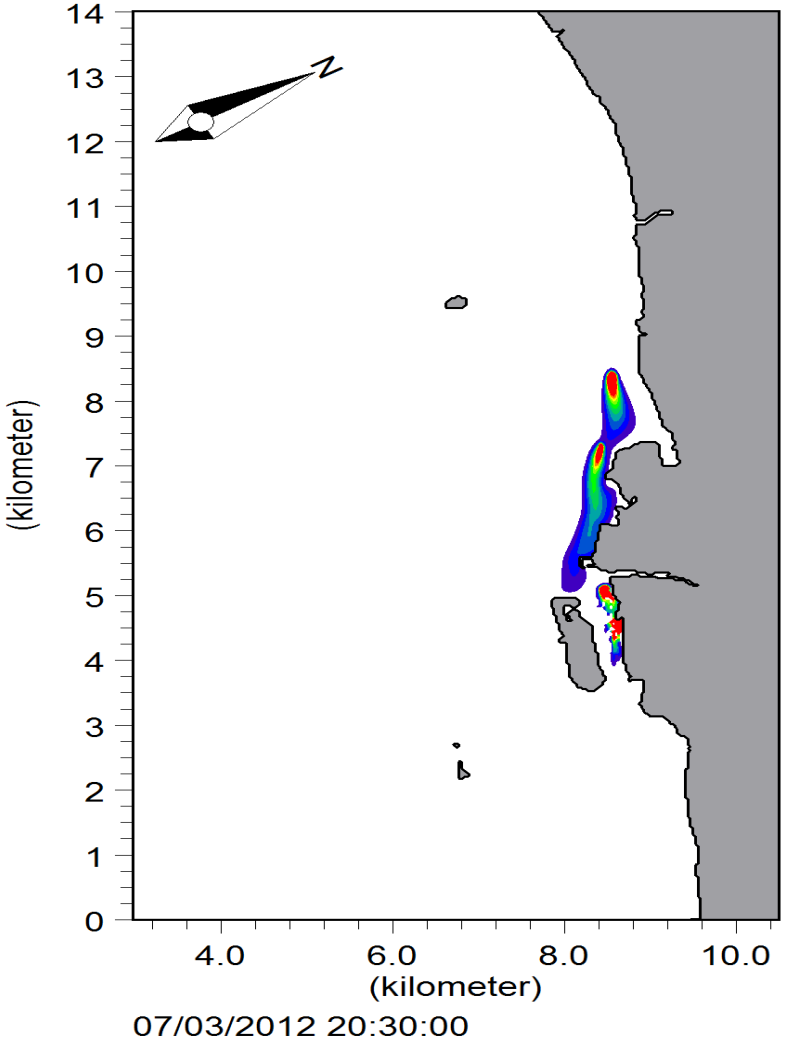
1) Simulates the erosion of the bed or deposition patterns

2) Data input:
   i. Results of hydrodynamic module
   ii. Bed material: density, gradation, critical shear velocity

3) Output:
   Predicts areas where erosion or deposition occurs?

Components of Coastal Hydraulic Model

ADVECTION/ DISPERSION MODULE



1) Simulates spreading or dispersion of:
   i. Suspended material
   ii. Thermal plume
   iii. Effluent/pollutants

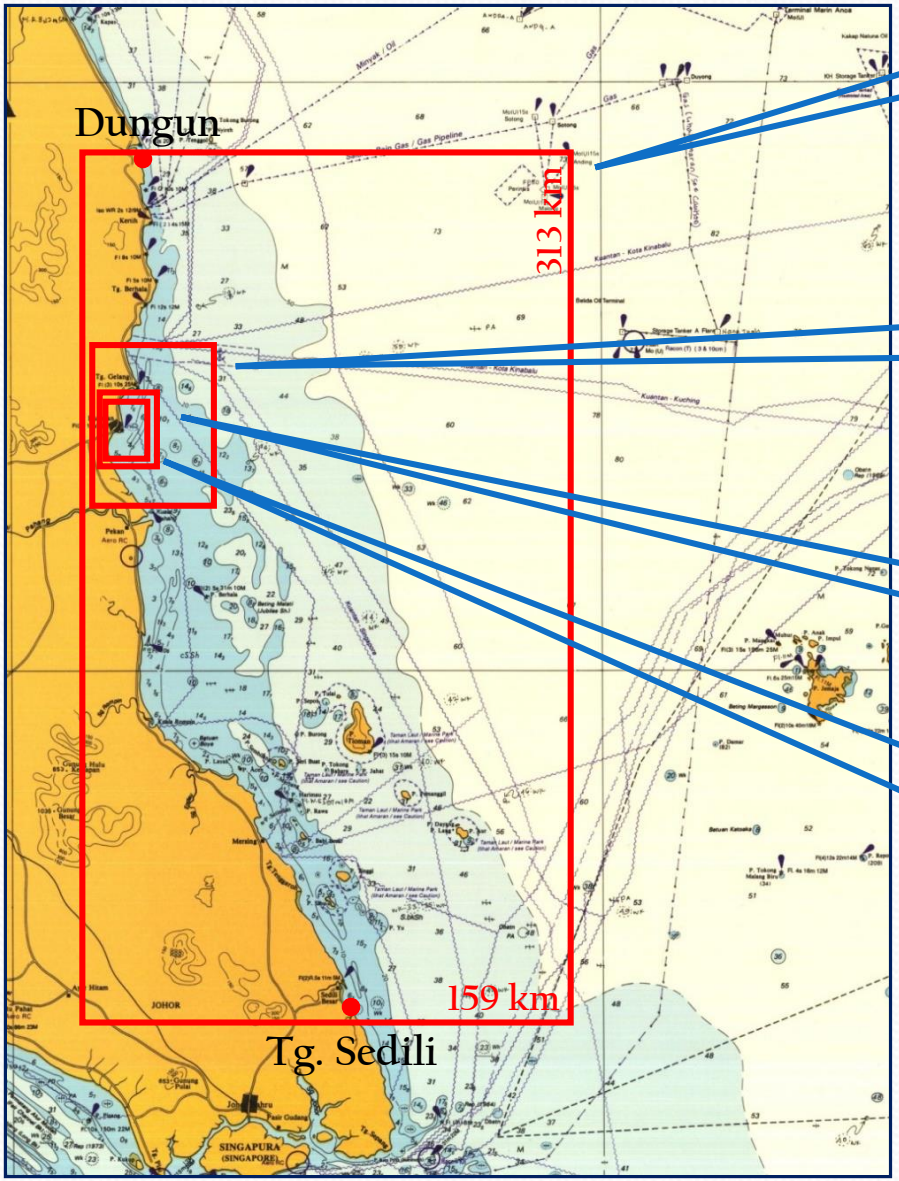
2) Data input:
   i. Results of hydrodynamic module
   ii. Concentration at source
   iii. Rate of dispersion

3) Output:
   Dispersion of plumes over time; distance of plume spread and variation in concentration over time

2. MODEL SETUP

- A model may be layered, i.e. coarse grid, medium grid and fine grid
- In the fine grid model the grid spacing should not be more than 50 m
- The point of interest should be away from the model boundary (minimum of 50 grid) to avoid boundary errors

Model Setup



Coarse grid model setup
dx,dy= 270m Grid Spacing

Medium grid model setup
dx,dy= 90m Grid Spacing

Local grid model setup
dx,dy= 30m Grid Spacing

Fine grid model setup
dx,dy= 10m Grid Spacing

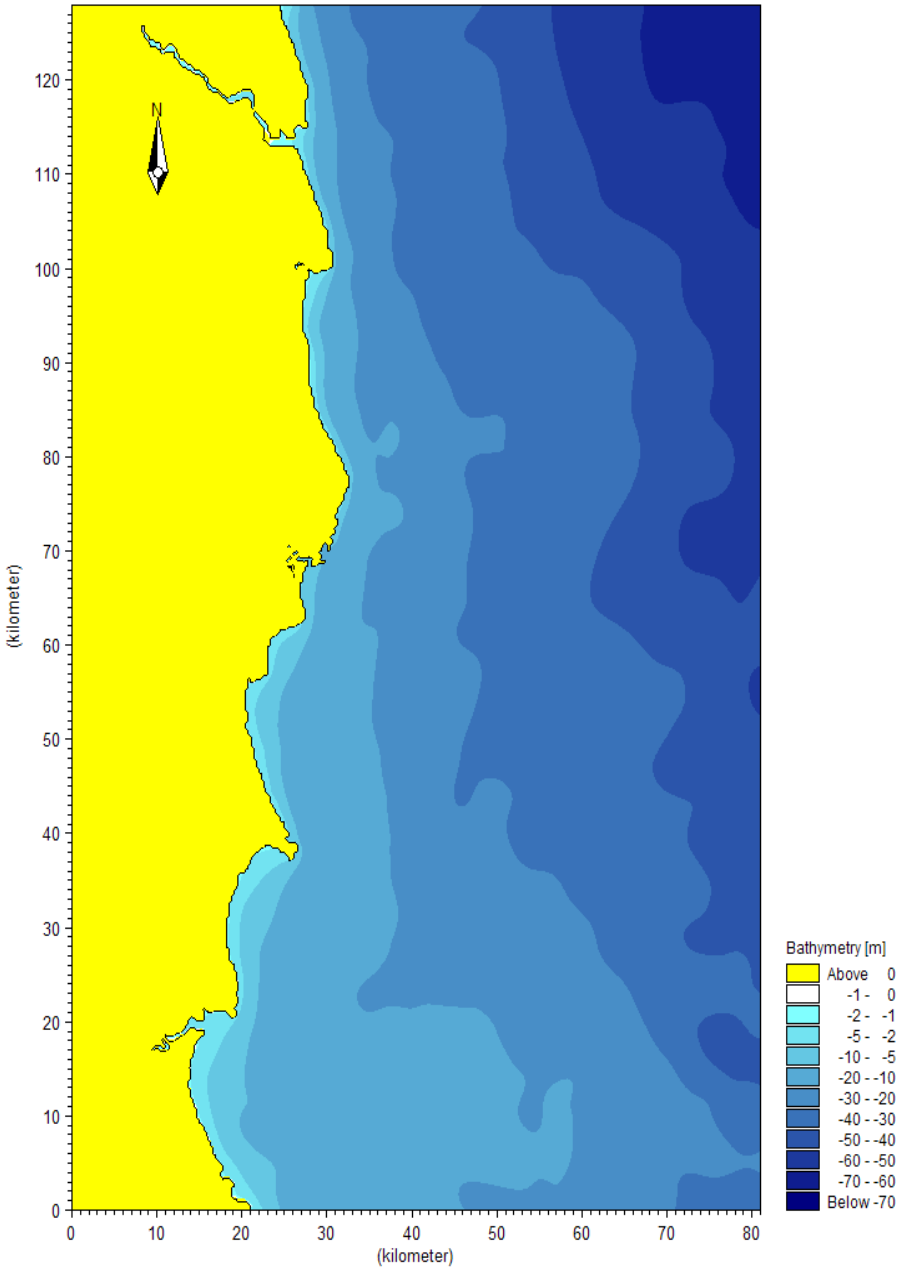
3. DATA REQUIREMENT

- Different modules require different data
- tidal data can be obtained either from on site measurements or from published data (National Hydrograpic Centre, Royal Malaysian Navy)
- Waves can be obtained from UKMO, from hindcasting techniques, etc.
- Bathymetry data can be obtained by a combination of hydrographic surveys, Admiralty charts and C-Map

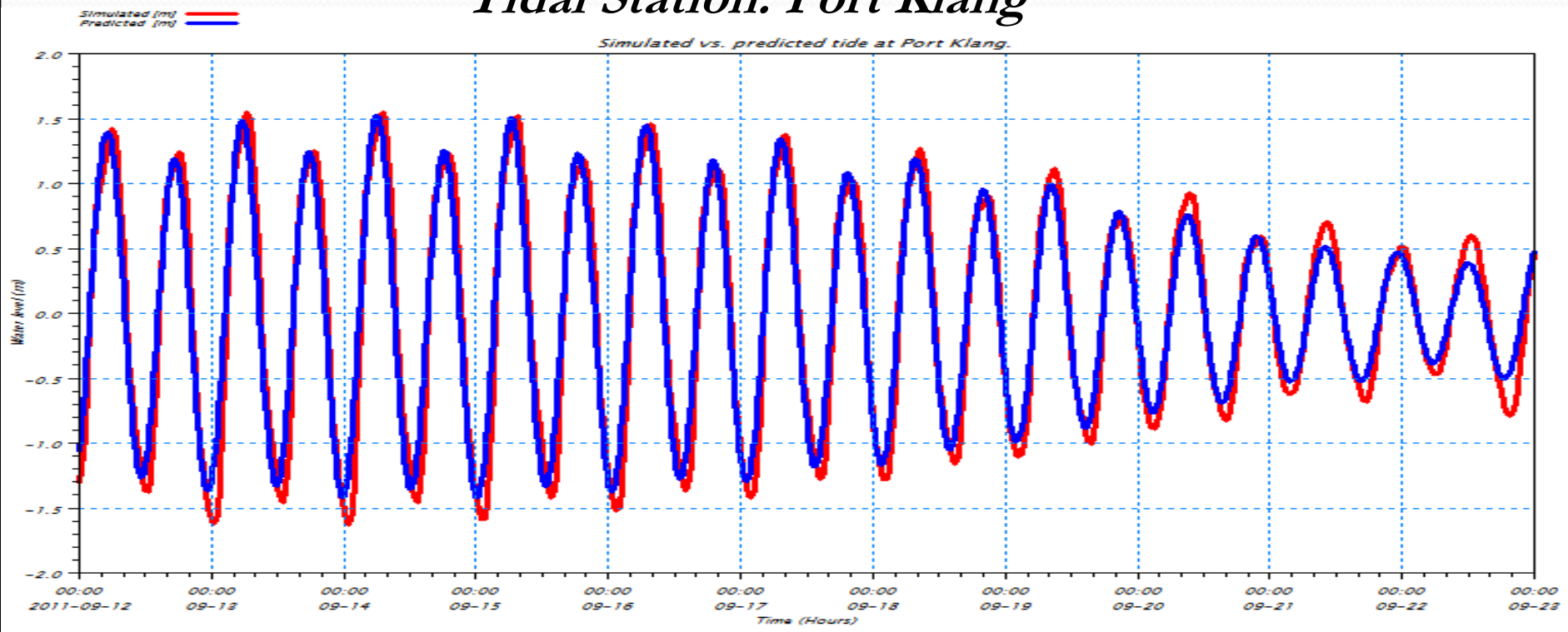
Measured data used for modelling shall be valid within 2 years before the date of report submission!

Bathymetry

- A most critical dataset required in ALL 2-D models
- Seamaps applicable for coarse regional grid only
- Nearshore area modelling requires hydrographic survey for more detail



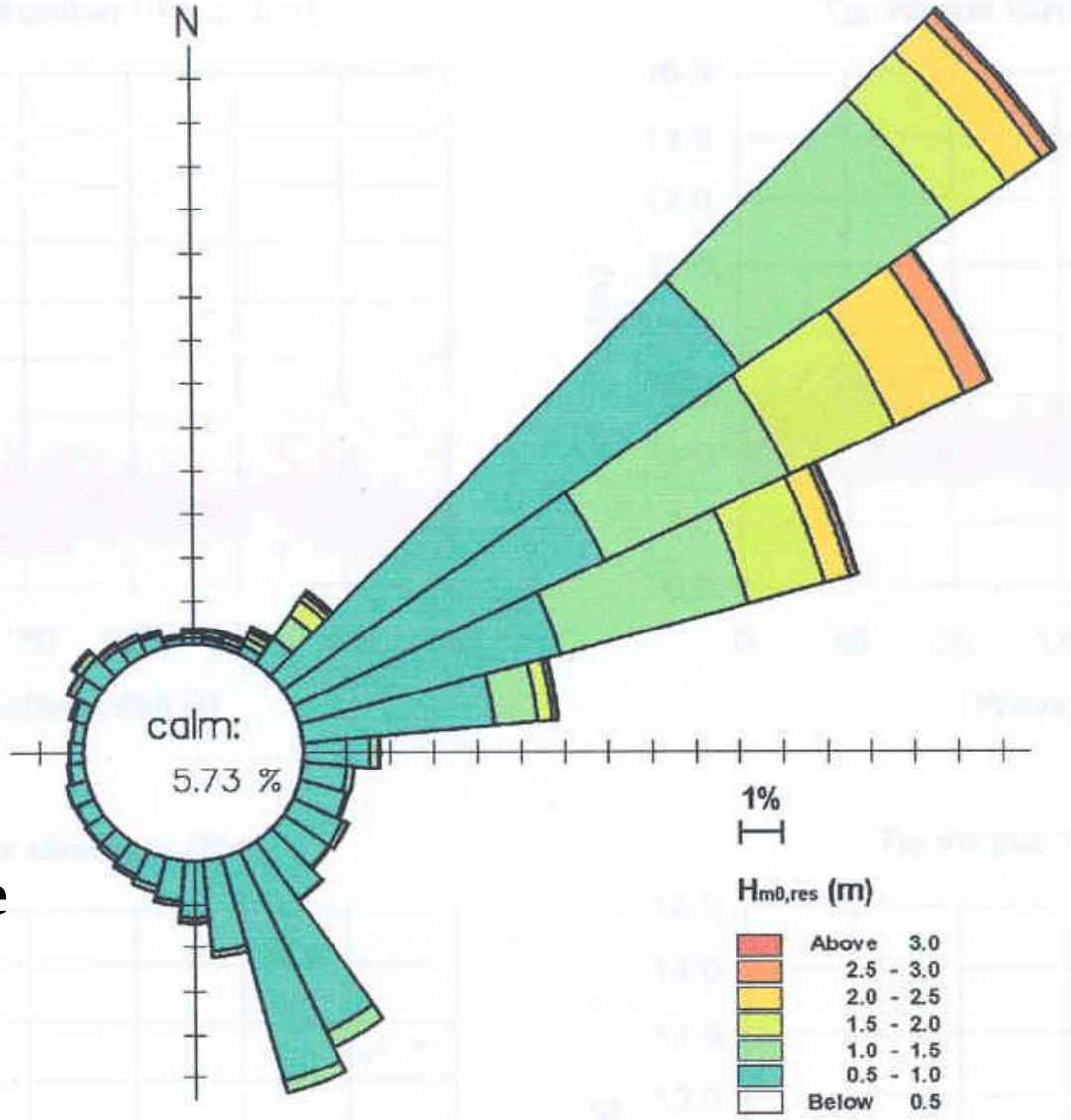
Tides



Tidal data (time series) is used on the boundaries of hydrodynamic modules

Wave

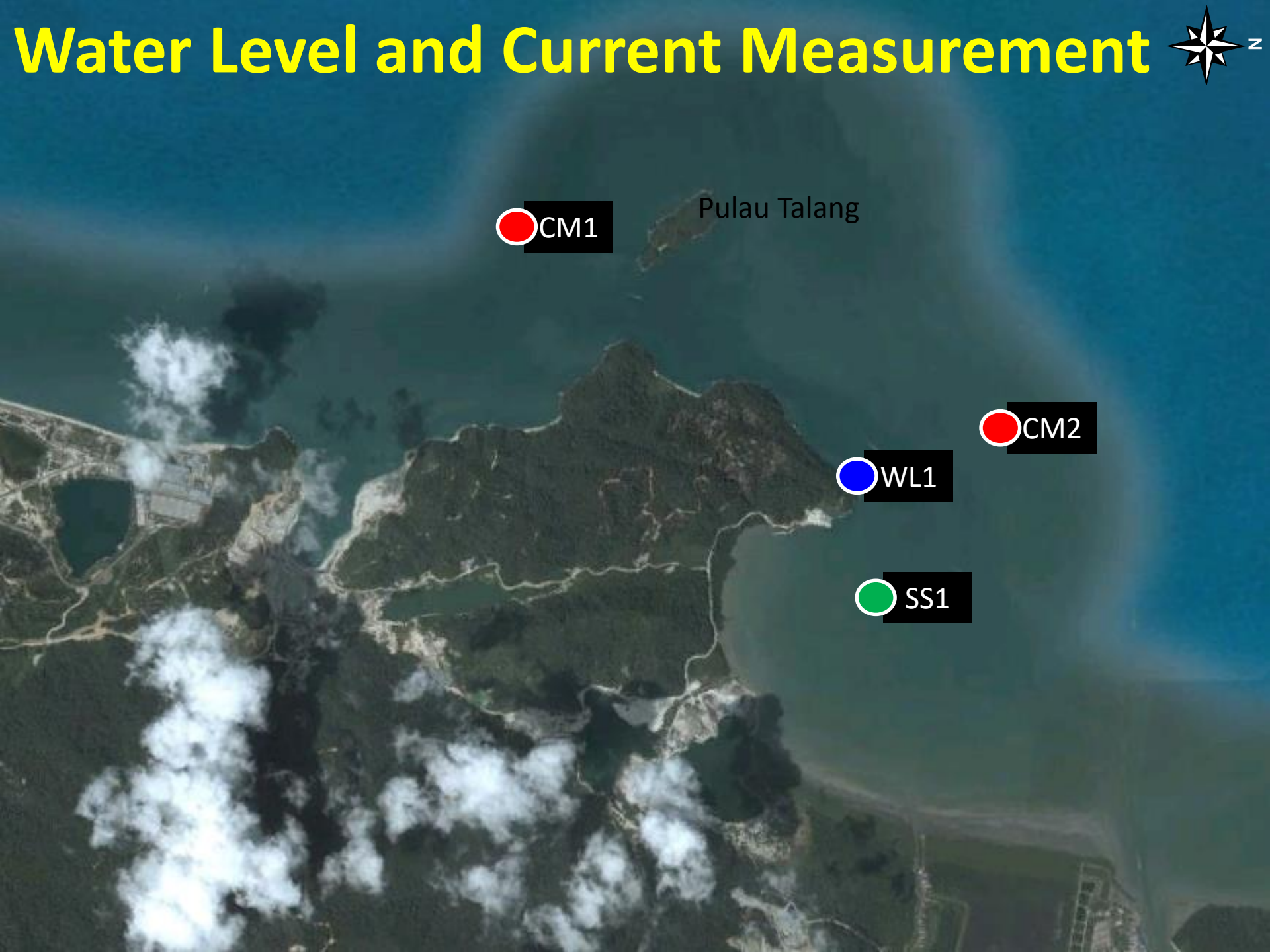
- Offshore wave data as input at boundary
- Height, period & direction
- Conduct statistical analysis to determine offshore wave condition
  - Annual & seasonal rose diagrams

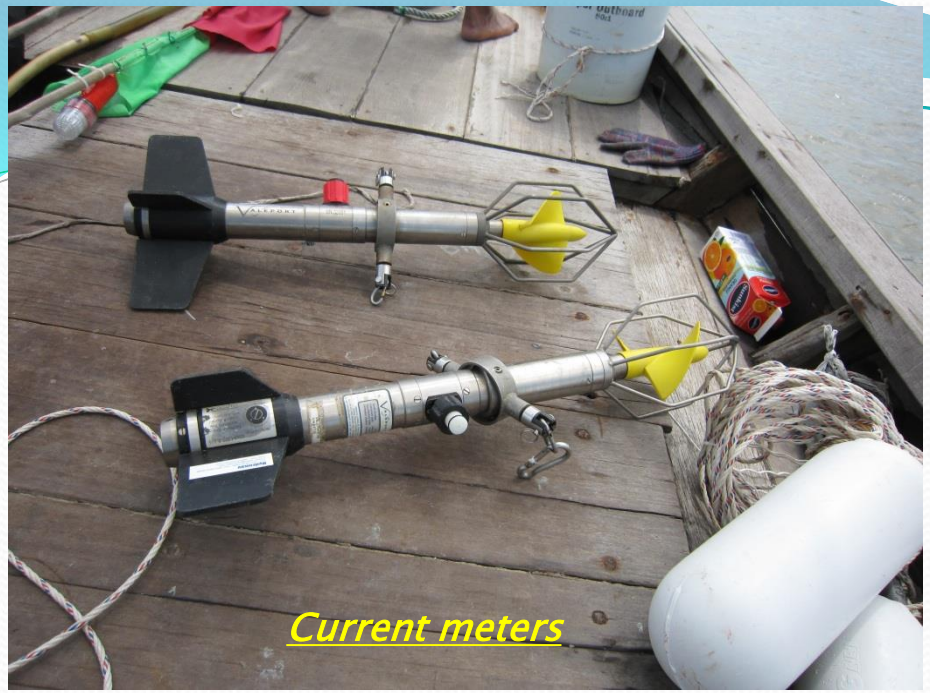


Data Collection:

- ***Water level measurement***
- ***Current measurements***
- ***Grab/ bed samplings***
- ***Suspended sediment***
- ***Hydrographic survey***

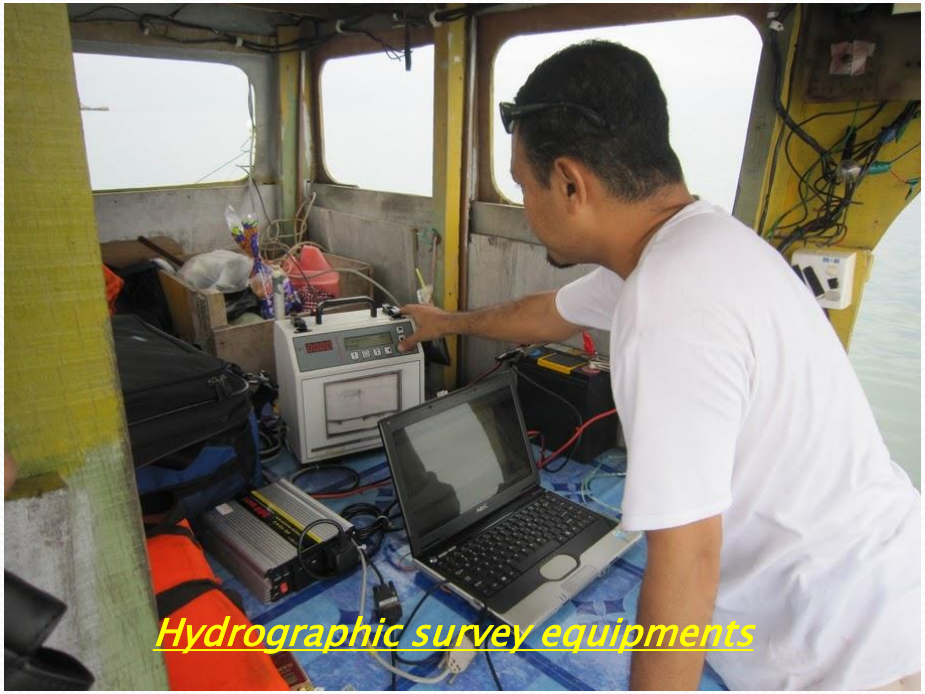
Water Level and Current Measurement





Current meters

Grab sampler



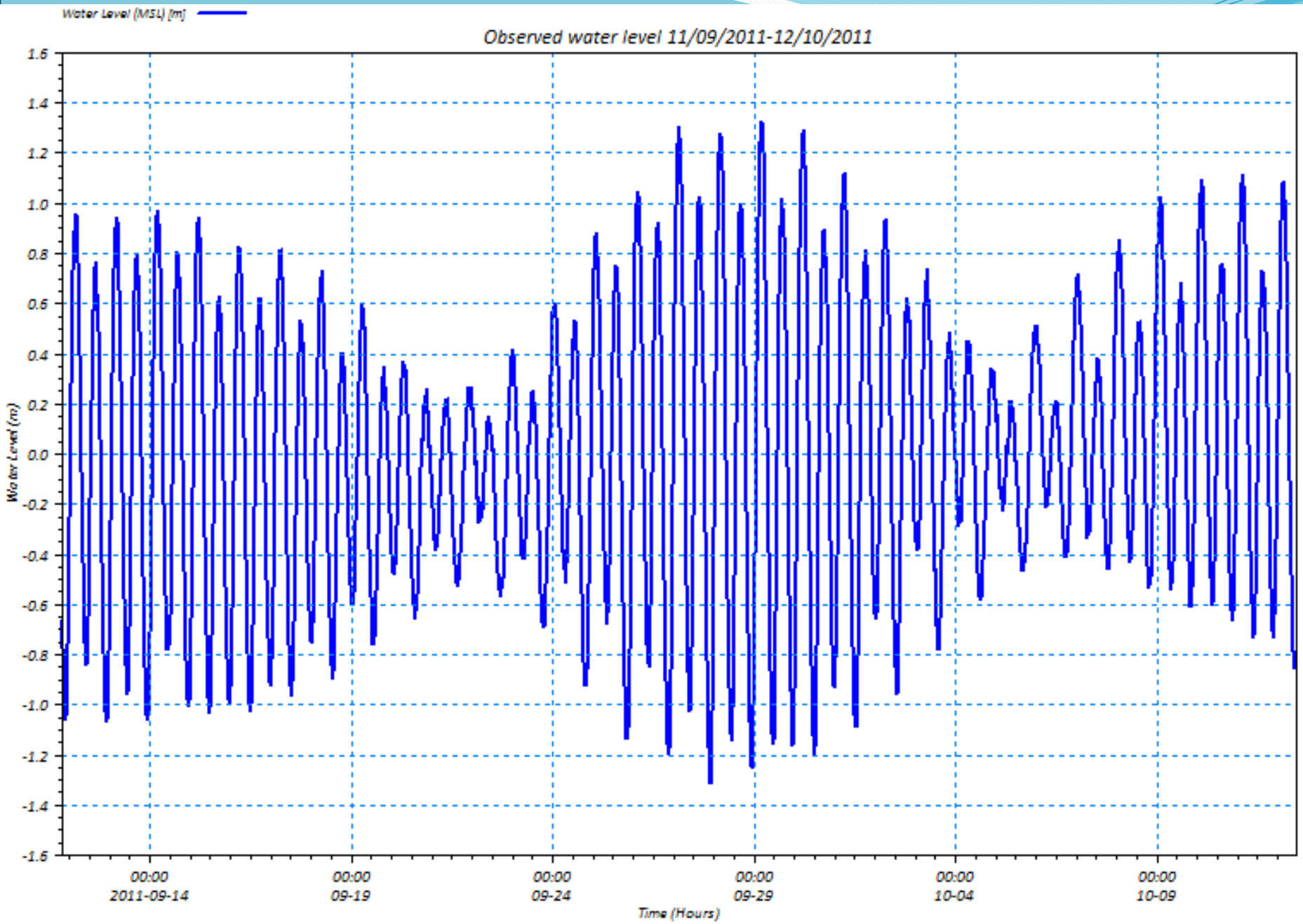
Hydrographic survey equipments

Current meter marking buoys

Tidal variations (Standard Ports):

Tidal station	Lumut
Tidal Levels	Elevation (m CD)
Highest Astronomical Tide (HAT)	+ 3.45
Mean High Water Springs (MHWS)	+ 2.94
Mean High Water Neaps (MHWN)	+2.24
Mean Sea Level (MSL)	+ 1.85
Mean Low Water Neaps (MLWS)	+ 1.47
Mean Low Water Springs (MLWS)	+ 0.75
Lowest Astronomical Tide (LAT)	0.00

Source: Royal Malaysian Navy Tide Tables Vol. I, 2011

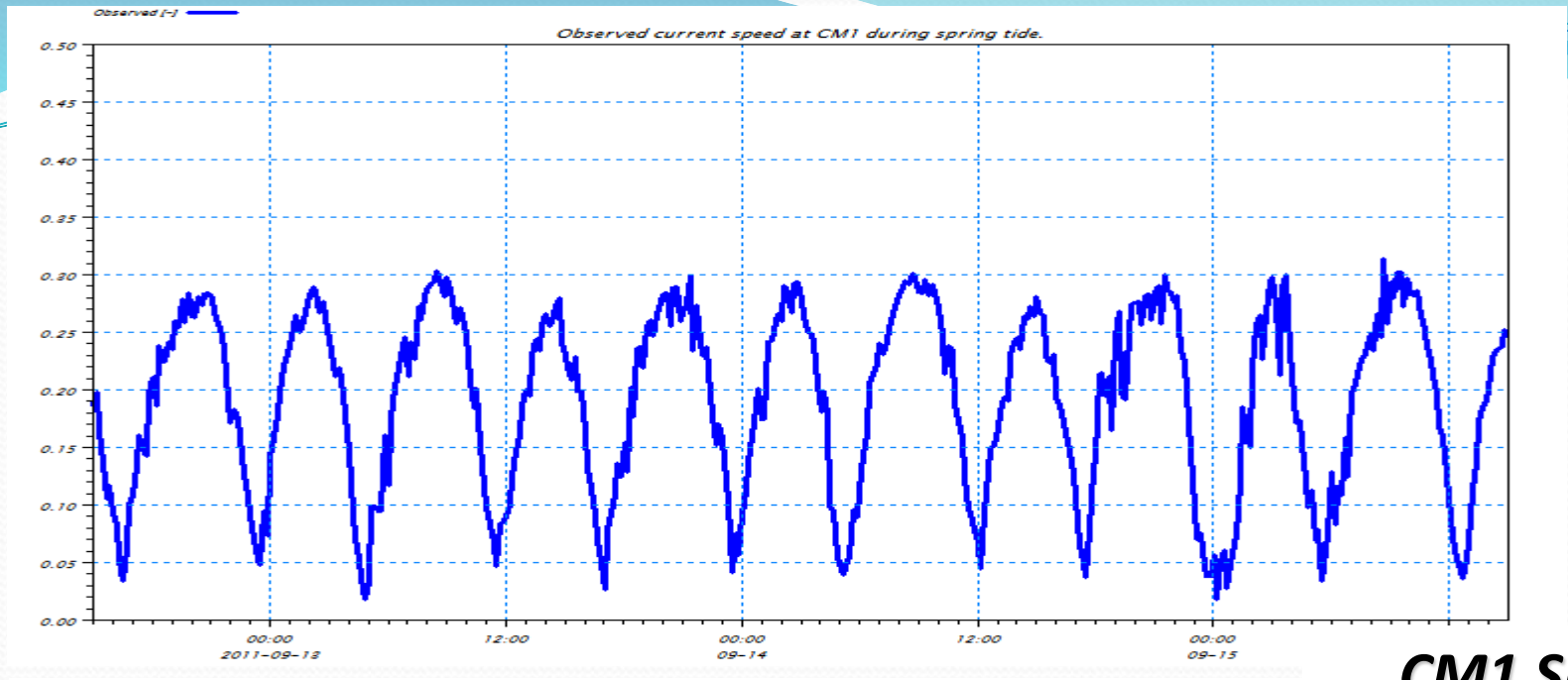

Water Level (MSL) [m]
Observed water level 11/09/2011-12/10/2011
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
Water Level (m)
00:00
2011-09-14
00:00
09-19
00:00
09-24
00:00
09-29
00:00
10-04
00:00
10-09
Time (Hours)

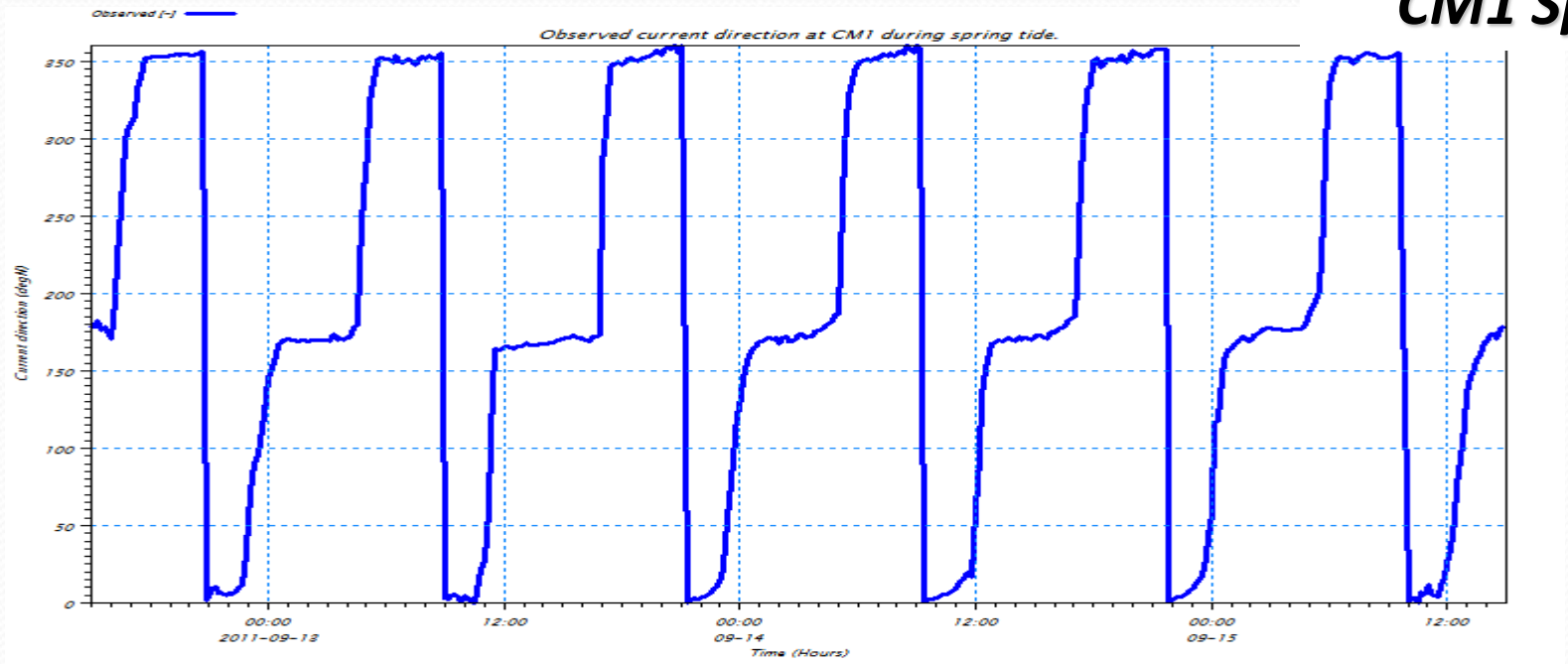
Data Collection:

Current meter

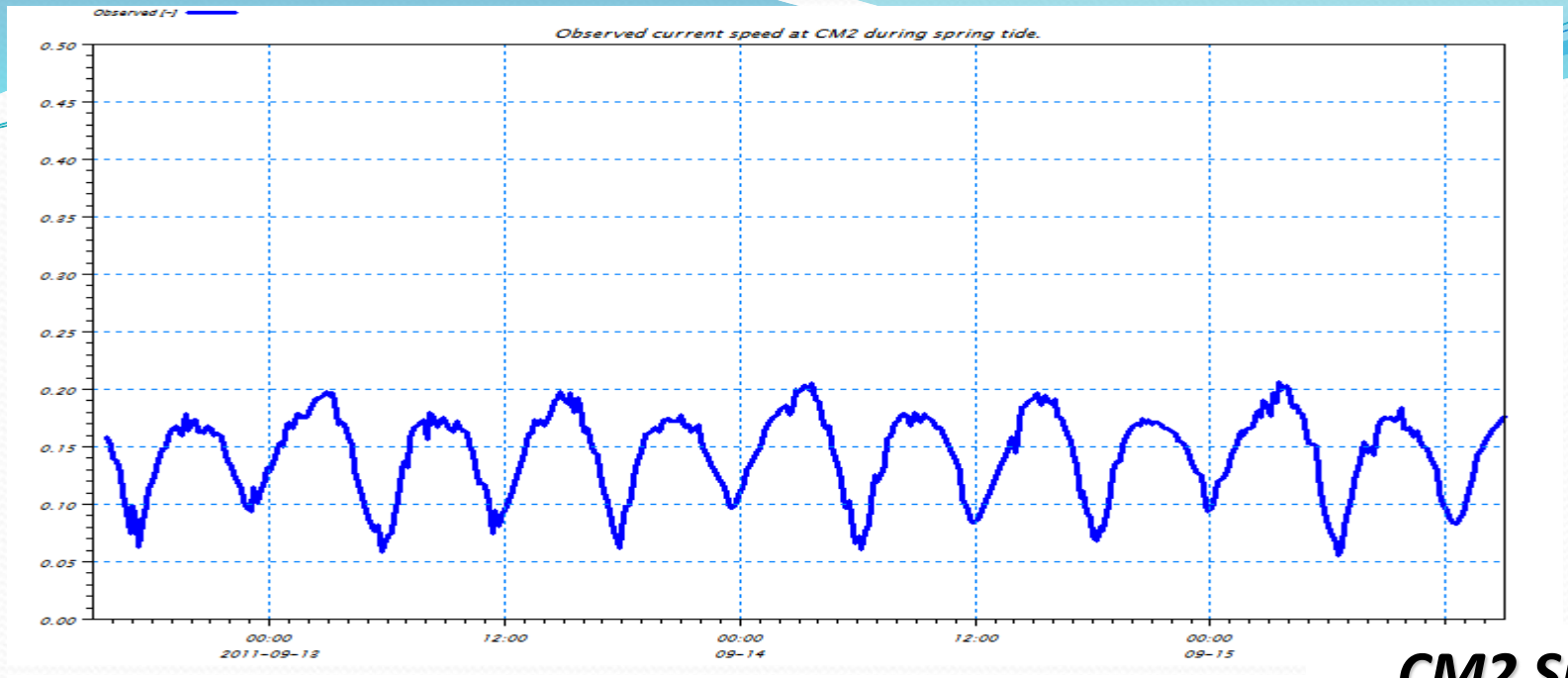
- ***3 days on each spring and neap at two (2) locations.***
- ***Spring: 12/09/2011 - 15/09/2011***
- ***Neap:20/09/2011 – 23/09/2011***

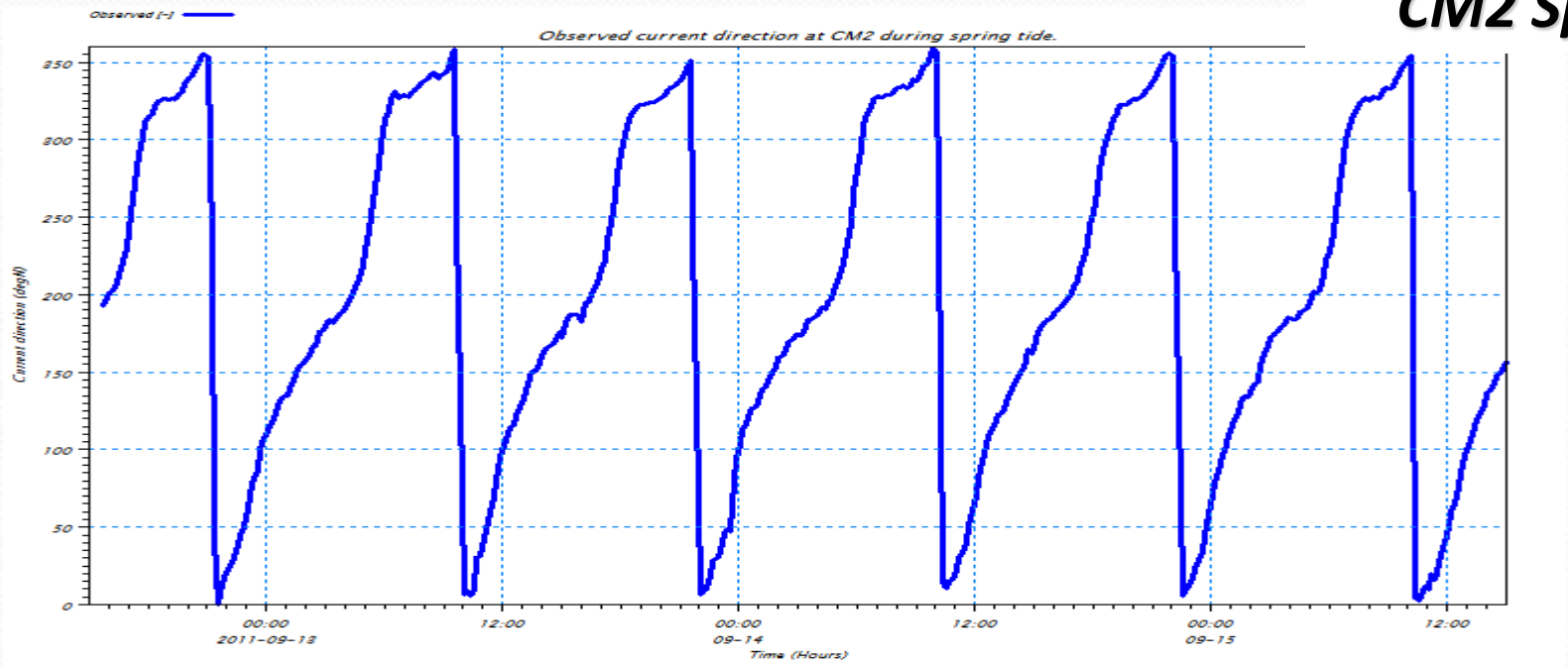
Location	Coordinates	
	Latitude (N)	Longitude (E)
CM1	4° 24’ 50.7”	100° 34’ 36.1”
CM2	4° 26’ 37.3”	100° 34’ 58.2”


Observed [-]
Observed current speed at CM1 during spring tide.
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
00:00
2011-09-13
12:00
00:00
09-14
12:00
00:00
09-15

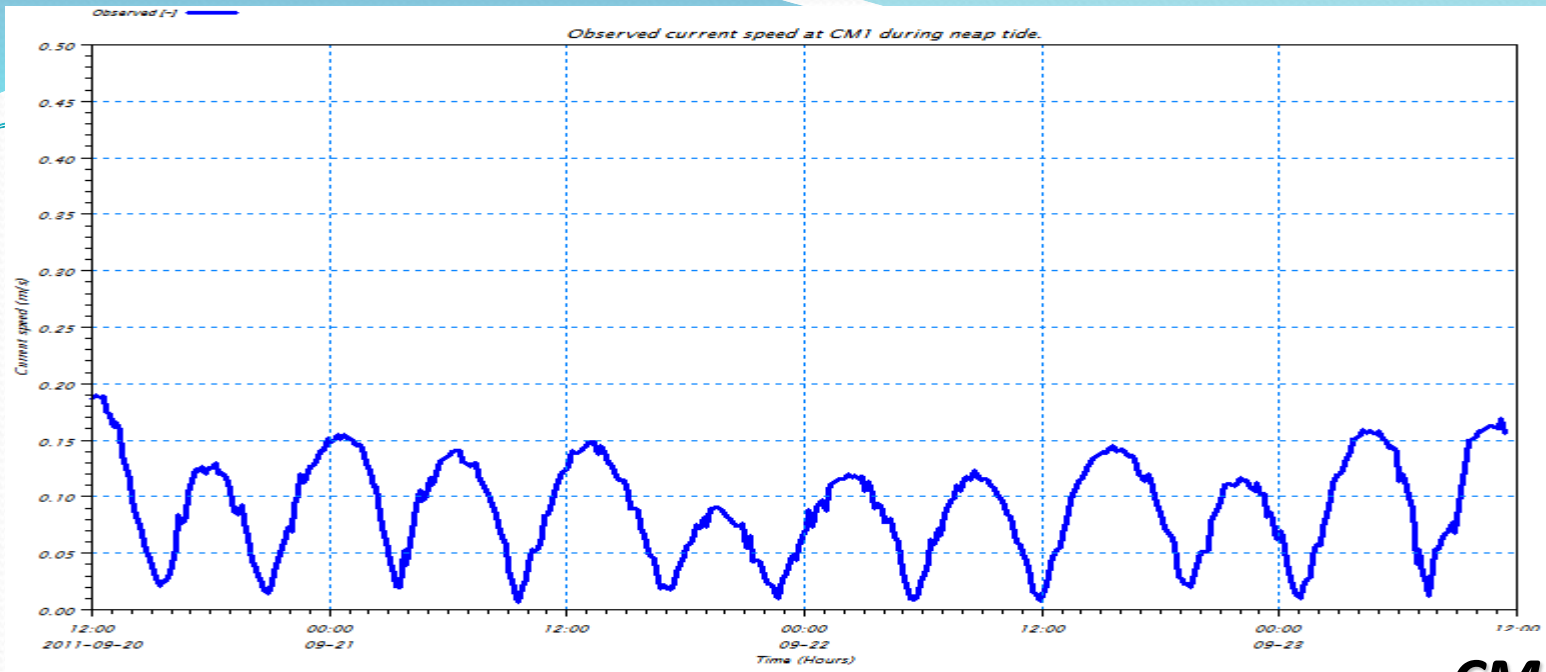

Observed [-]
Observed current direction at CM1 during spring tide.
Current direction (deg N)
350
300
250
200
150
100
50
0
00:00
2011-09-13
12:00
00:00
09-14
12:00
00:00
09-15
12:00
Time (Hours)

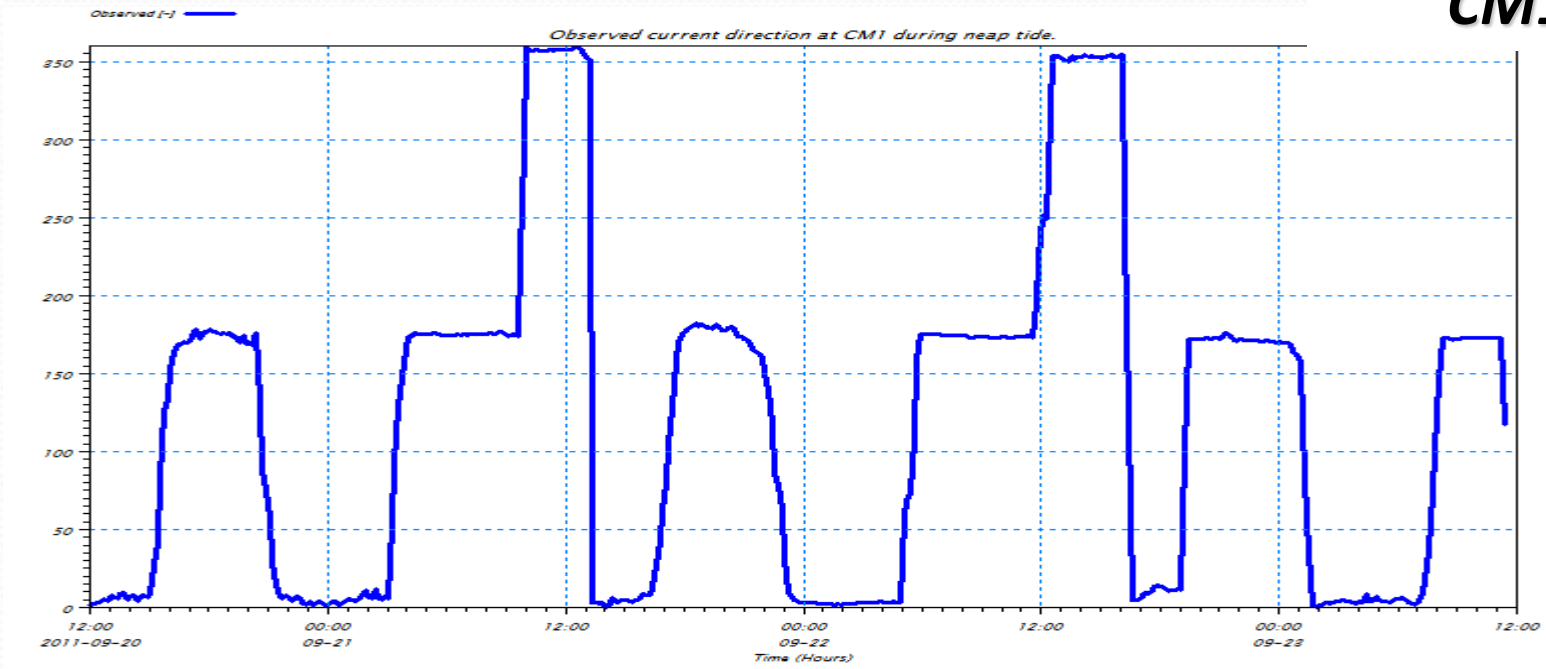
CM1 Spring


Observed [-]
Observed current speed at CM2 during spring tide.
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
00:00
2011-09-13
12:00
00:00
09-14
12:00
00:00
09-15

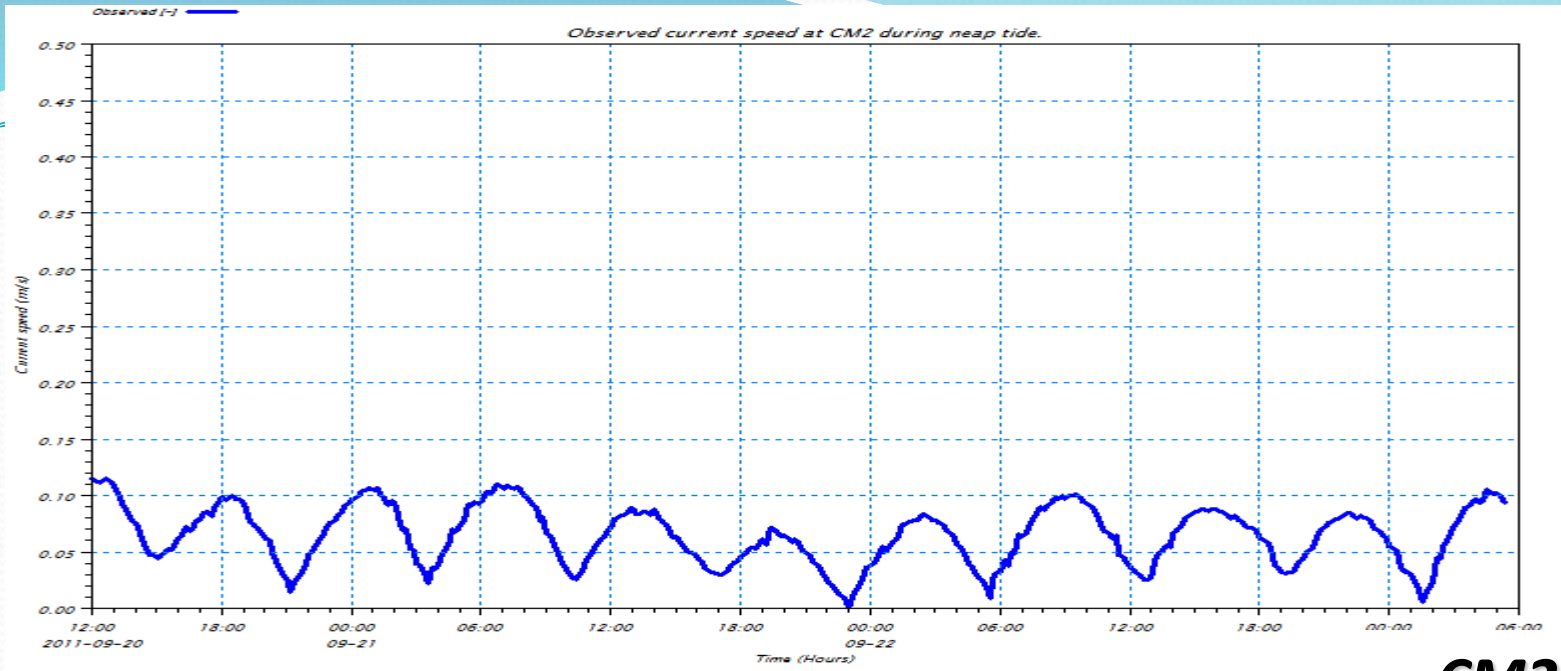

Observed [-]
Observed current direction at CM2 during spring tide.
Current direction (degN)
350
300
250
200
150
100
50
0
00:00
2011-09-13
12:00
00:00
09-14
12:00
00:00
09-15
12:00
Time (Hours)

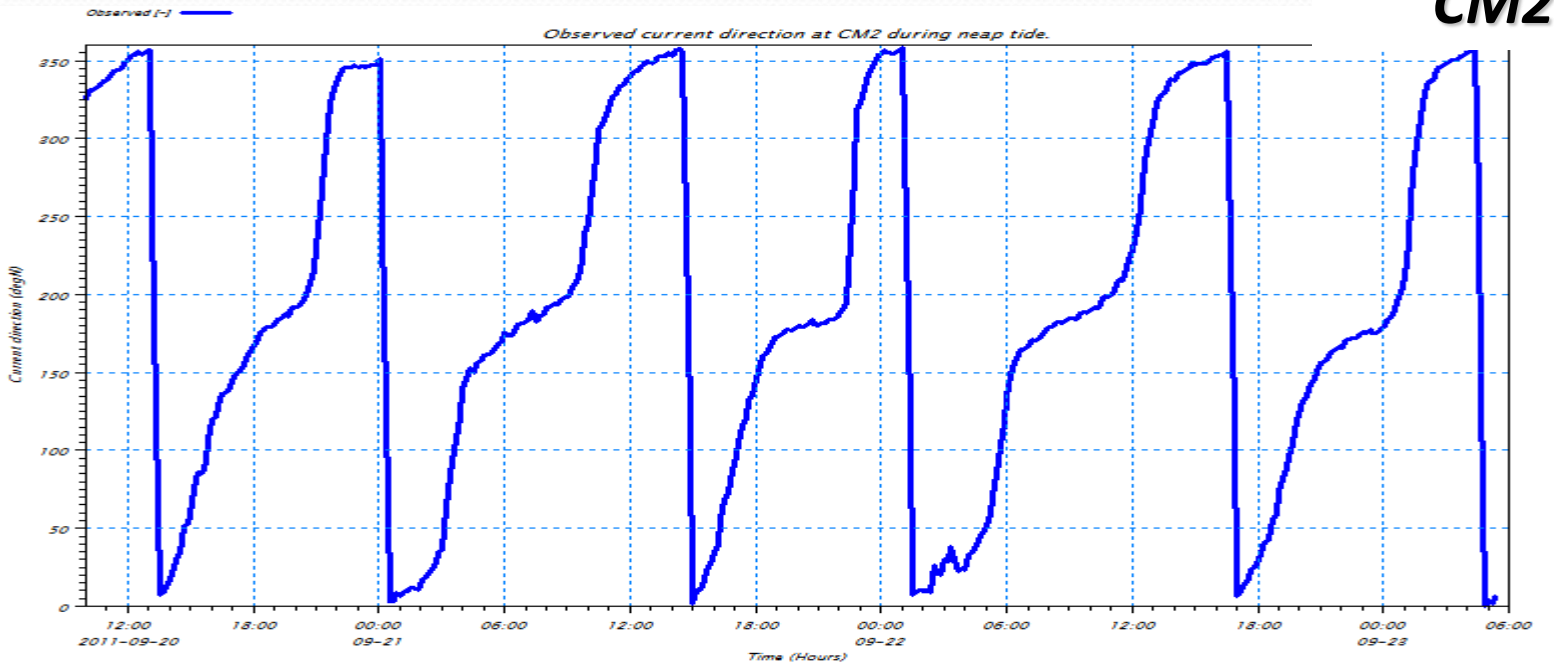
CM2 Spring


Observed [-]
Observed current speed at CM1 during neap tide.
Current speed (m/s)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12:00
2011-09-20
00:00
09-21
12:00
00:00
09-22
12:00
00:00
09-23
Time (Hours)


Observed [-]
Observed current direction at CM1 during neap tide.
350
300
250
200
150
100
50
0
12:00
2011-09-20
00:00
09-21
12:00
00:00
09-22
12:00
00:00
09-23
12:00
Time (Hours)

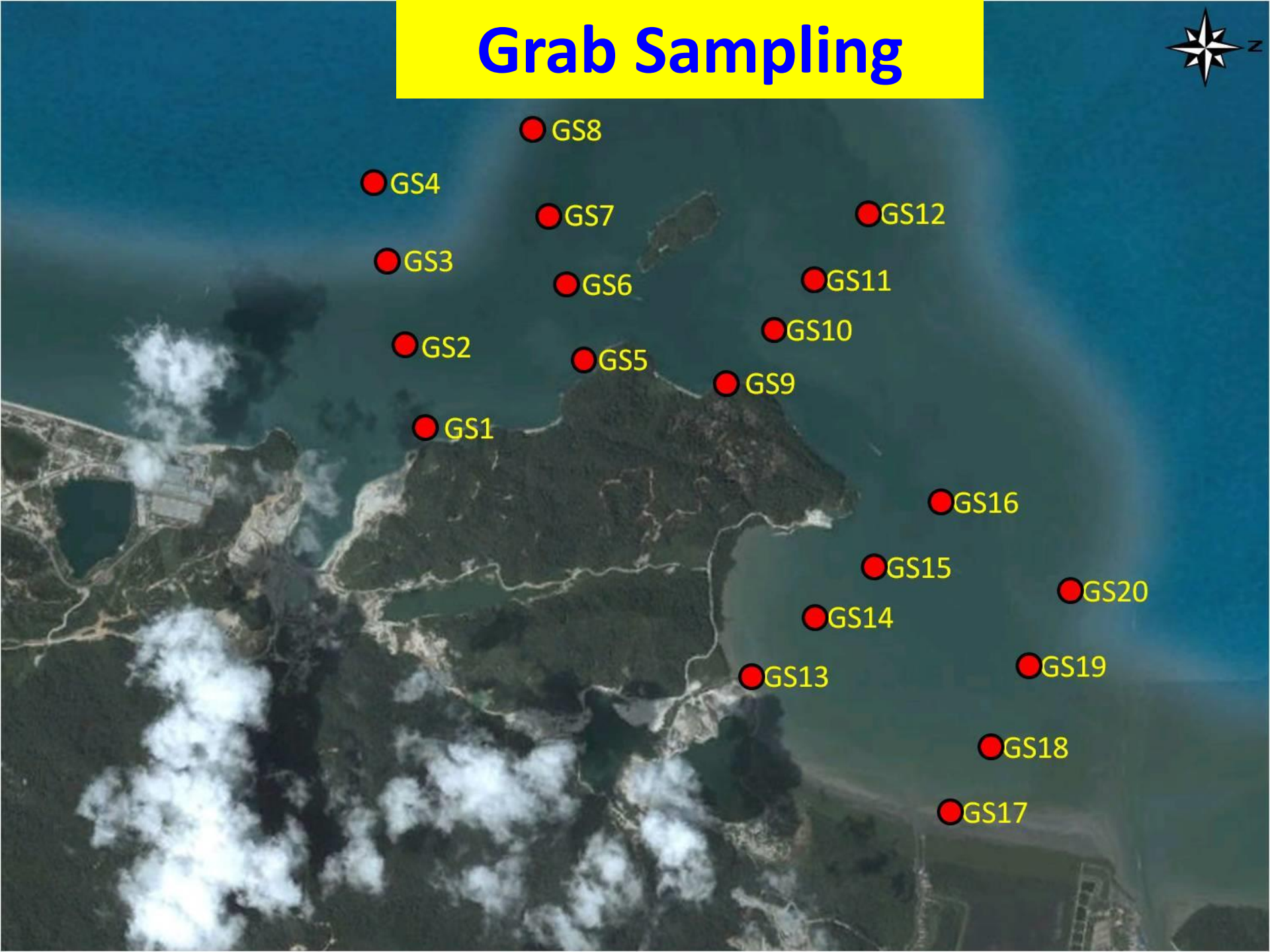
CM1Neap


Observed [-]
Observed current speed at CM2 during neap tide.
Current speed (m/s)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12:00
2011-09-20
18:00
00:00
09-21
06:00
12:00
18:00
00:00
09-22
06:00
12:00
18:00
Time (Hours)


Observed [-]
Observed current direction at CM2 during neap tide.
Current direction (degN)
350
300
250
200
150
100
50
0
12:00
2011-09-20
18:00
00:00
09-21
06:00
12:00
18:00
00:00
09-22
06:00
12:00
18:00
00:00
09-23
06:00
Time (Hours)

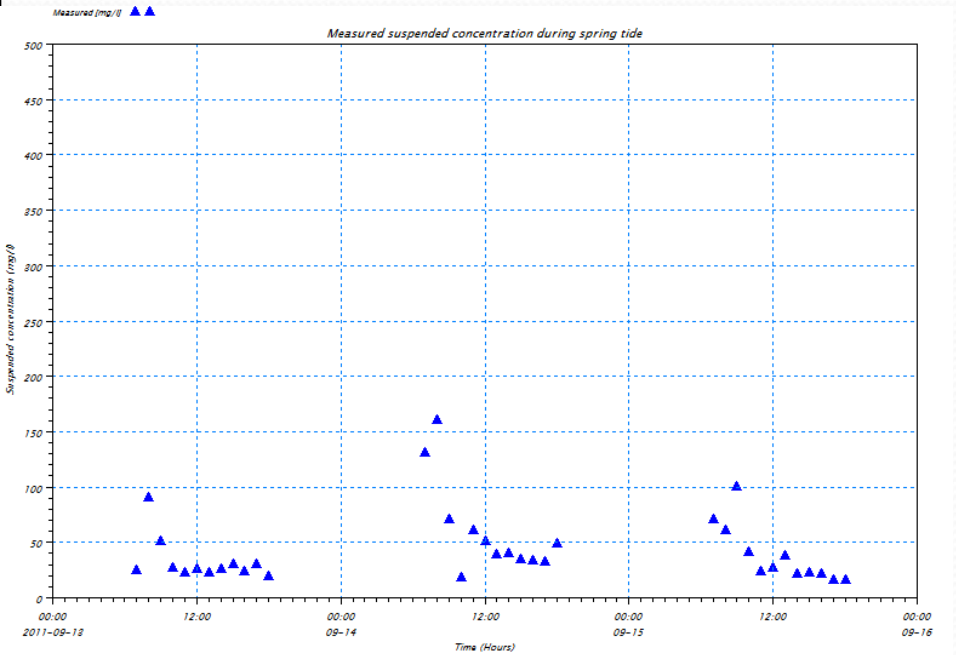
CM2 Neap

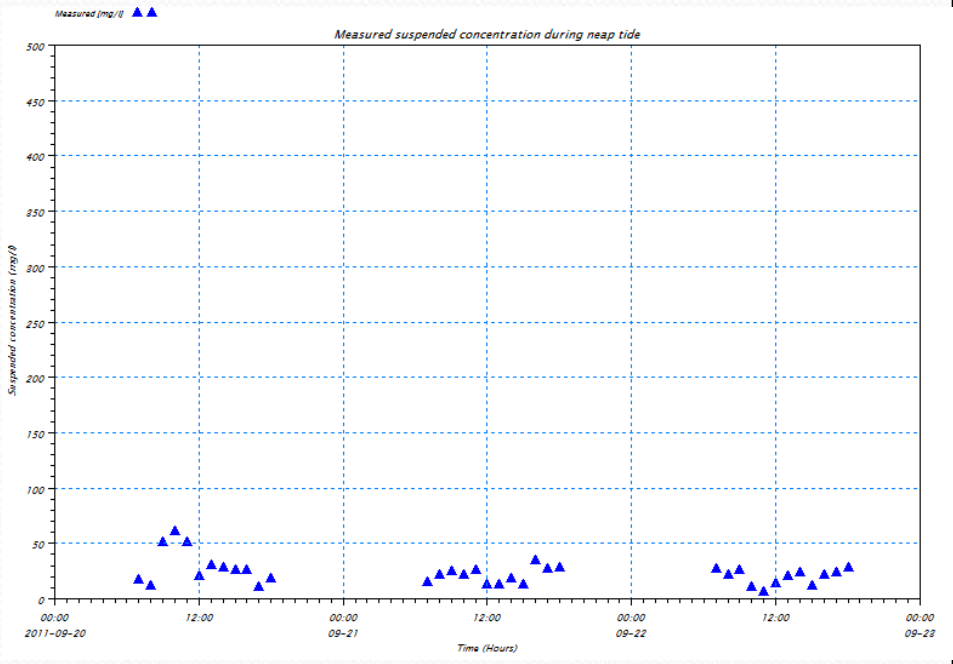
Grab Sampling



Grab Sample No.	Particle Size Distribution (PSD) (%)			
	Clay	Silt	Sand	Gravel
G1	6	23	49	22
G2	11	24	50	15
G3	10	19	63	8
G4	6	14	59	24
G5	31	45	19	5
G6	29	39	35	7
G7	13	32	42	13
G8	31	68	1	0
G9	38	61	1	0
G10	8	53	14	25
G11	22	70	7	1
G12	22	77	1	0
G13	15	32	49	4
G14	33	46	19	2
G15	23	49	26	2
G16	26	68	6	0
G17	36	61	3	0
G18	15	85	0	0
G19	19	80	1	0
G20	23	77	0	0

Suspended sediment results (TSS)





4. MODEL VALIDATION

Calibration involves

- comparison of simulated and measured water levels and current velocity
- fine tuning of model parameters to obtain good agreement

Verification involves

- comparing output of calibrated model against measured values
- ensuring that the differences are within tolerable limits . e.g. :-
  - ✓ speed = 20%, direction = 20°, water level < 10%

CALIBRATION

- Calibration
  - altering model parameters to fit /match measured values
    - bed resistance (adjusts water elevations)
    - eddy viscosity (advanced modellers)
    - bathymetry (adjusts phasing)
    - boundary conditions; water levels
    - wind friction
  - calibration periods should cover all grid types and conditions critical to the project
    - Coarse, intermediate and fine grid models
    - spring and neap tides, storm situations (extreme)

Model Validation

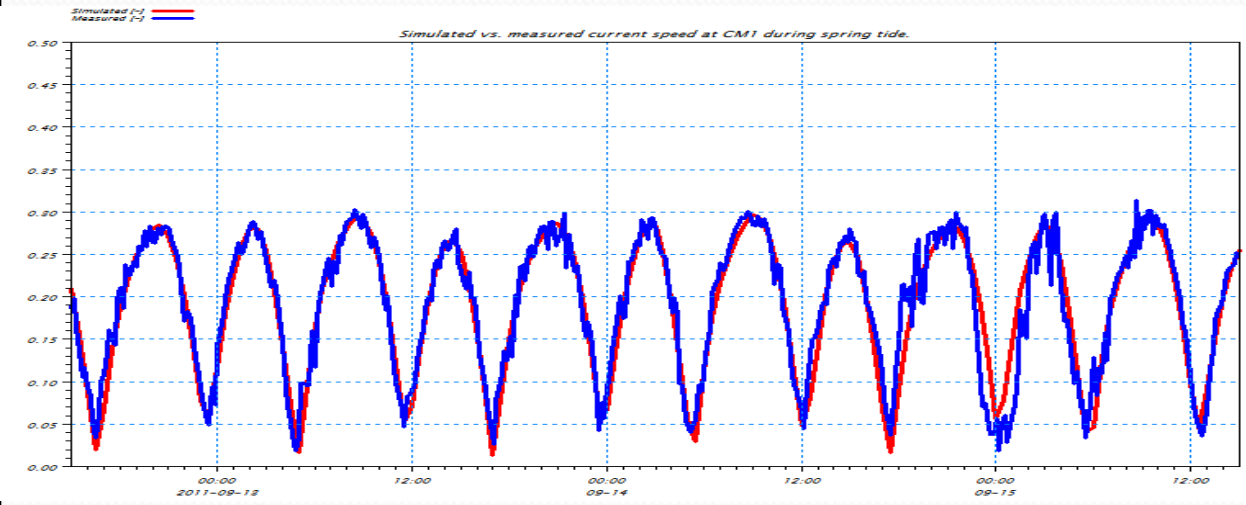
VERIFICATION

- Verification
  - testing predicted water levels and current velocities to actual measured values
    - field data must be from different locations from that used for calibration
    - The model output and the field data must agree within tolerance without further adjustment of the model parameters
  - verified results gives you more confidence in the model output and performance

Calibration and Verification

Guidelines	Water Level	Current Speed	Current Direction
JPS Guidelines 1/97 & 2001	< 10% difference 'average different'	< 30% difference 'average different'	< 45° difference 'average different'
New JPS Guidelines (Revised 2012)	< 10% difference 'Root Mean Square Error'	< 20% difference 'Root Mean Square Error"	< 20° difference 'Root Mean Square Error"

Calibration and Verification

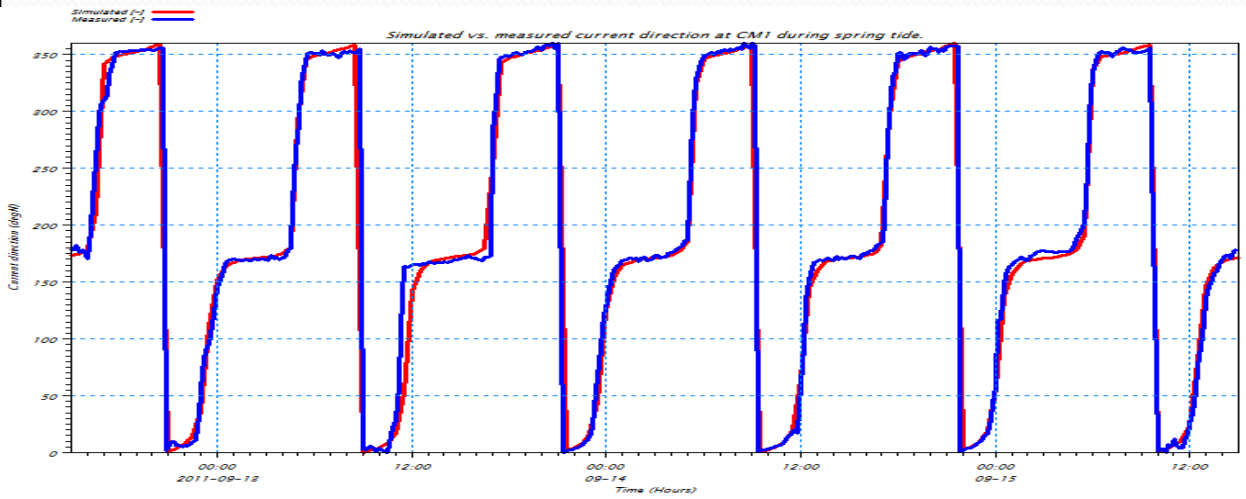


Current Speed

Simulated

vs

Measured

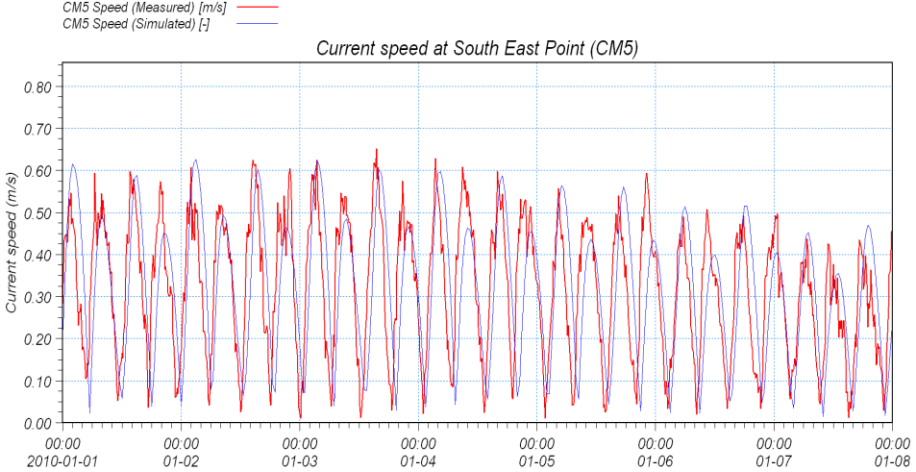


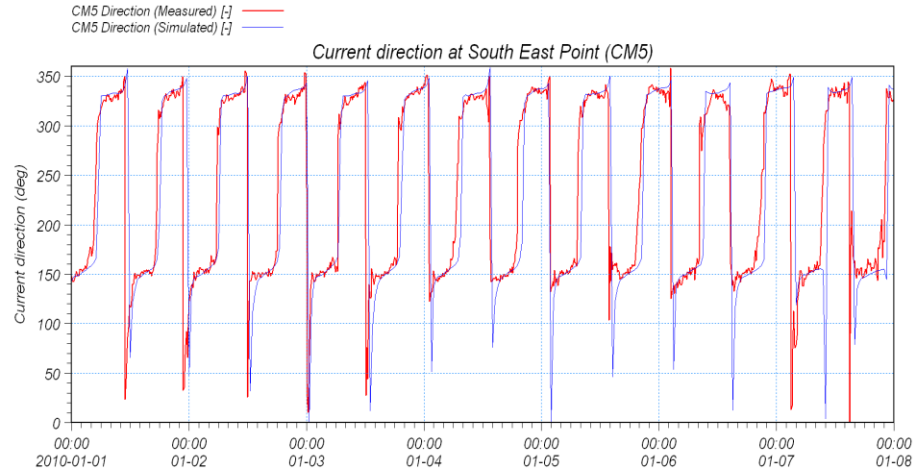
Current Direction

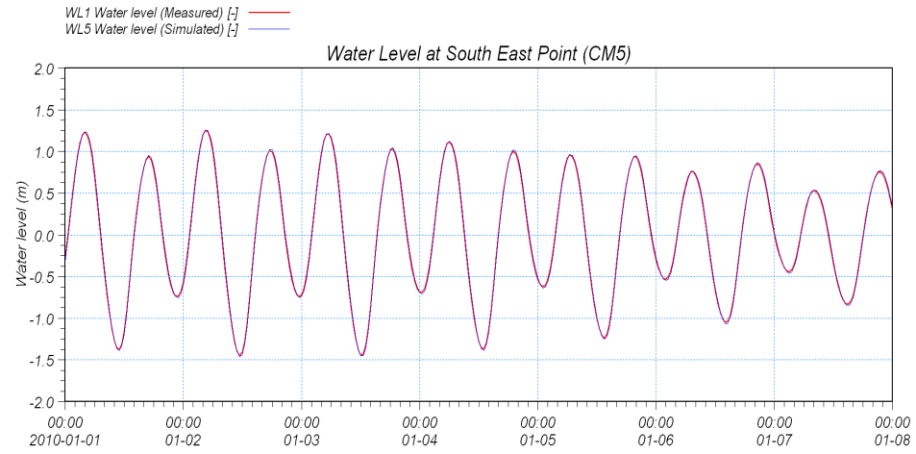
Simulated

vs

Measured







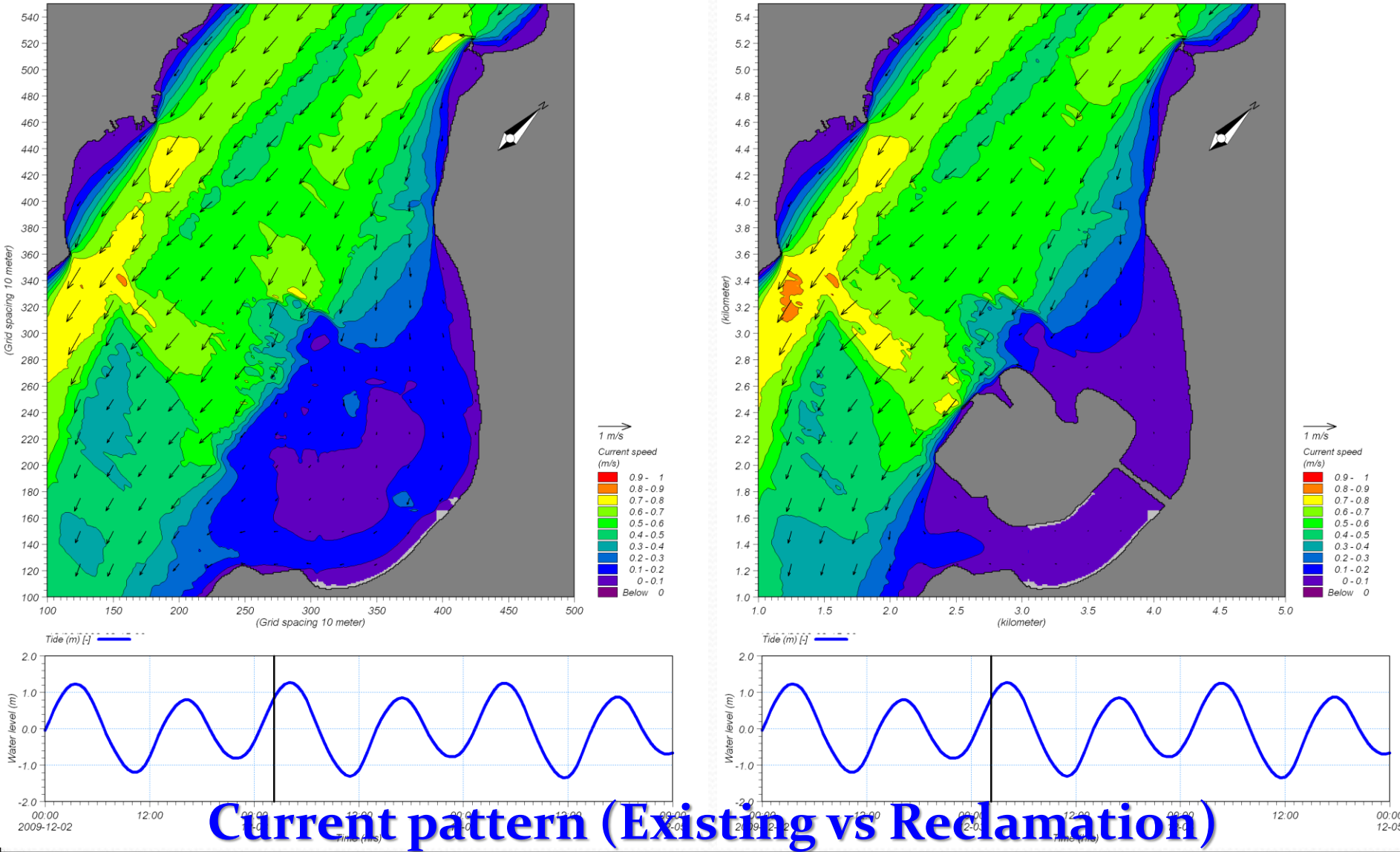
- Output of calibrated model against measured values are compared
- Differences are within tolerable limits
  - ✓ speed = 10%, direction = 10°, water level = ±10%

5. SIMULATIONS OF MODEL

- Hydrodynamic
- Nearshore waves
- Mud/ Sand Transport
- Advection/Dispersion

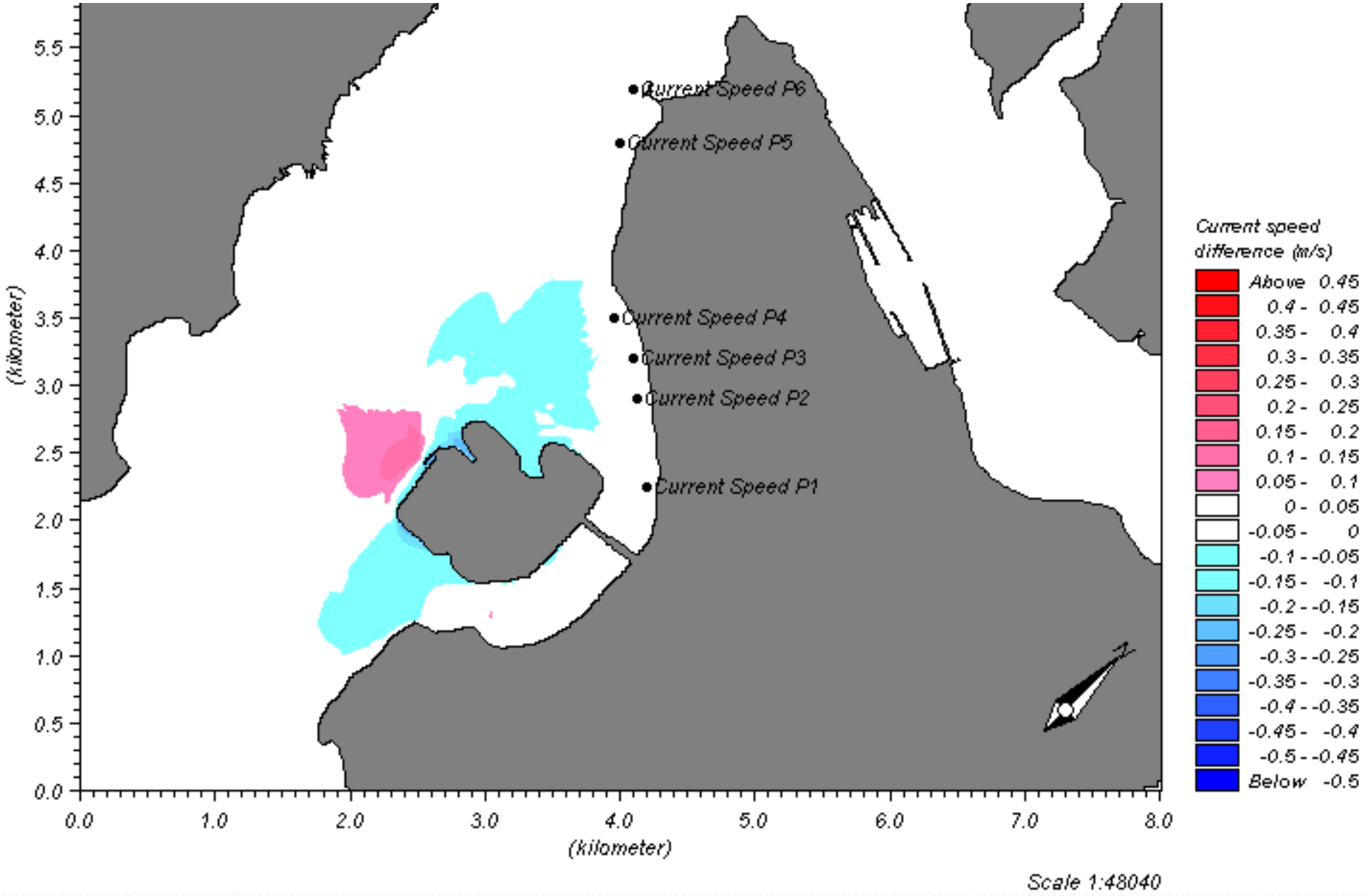
- The model should be run using the appropriate modules such as hydrodynamic module, wave model, mud/sand transport and shoreline evolution, suspended sediment dispersion
- The model should be run for the ‘before project’ and ‘after project’ cases in order to determine the impacts

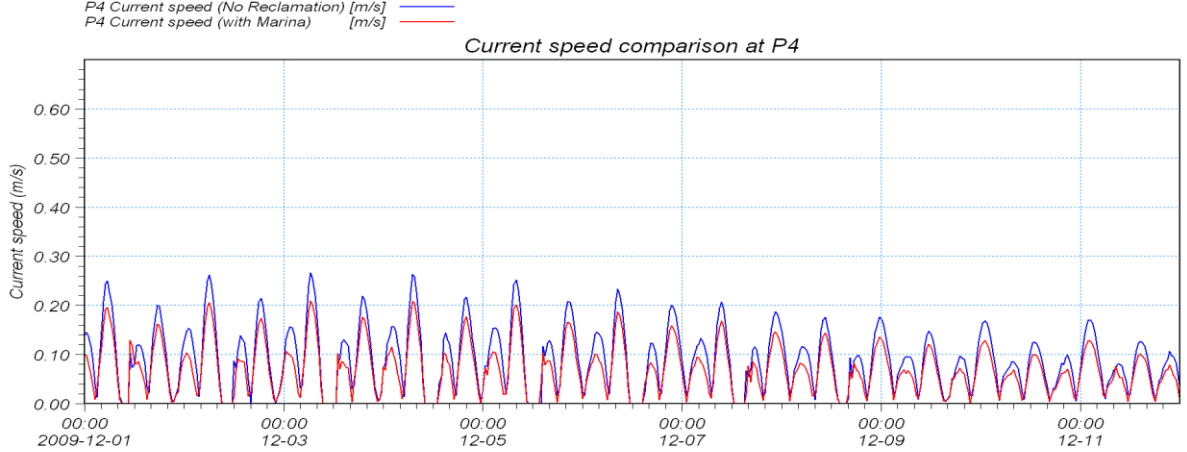
Hydrodynamic Modelling

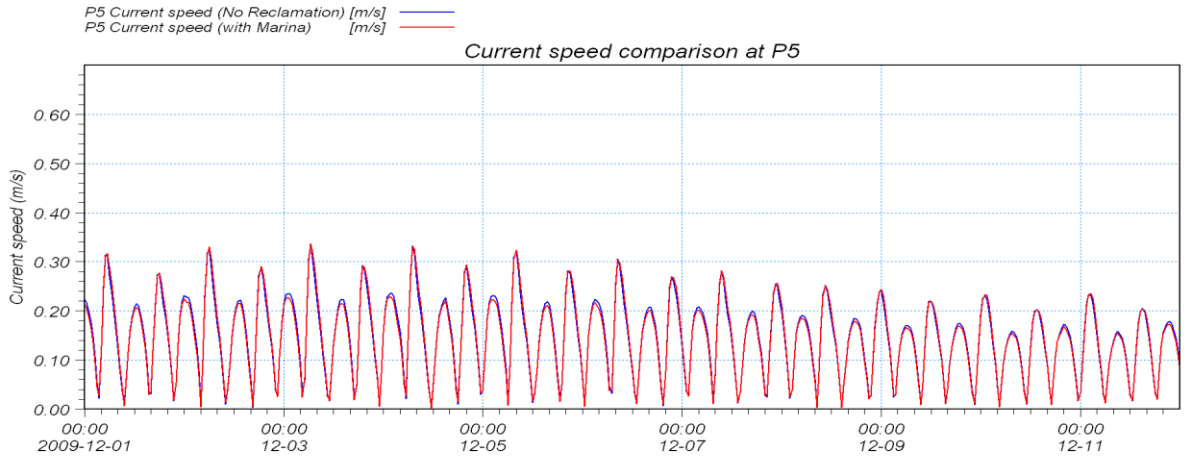


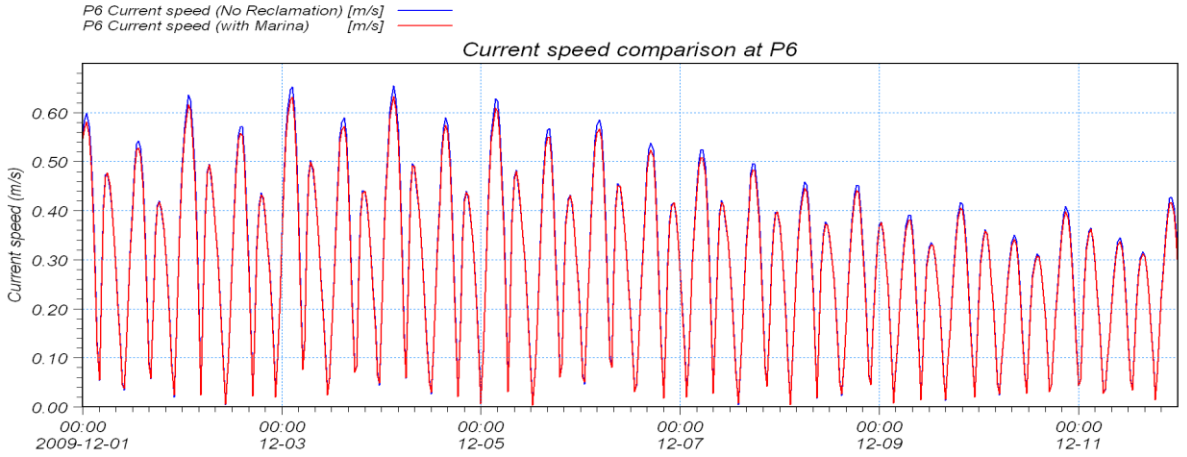
Current pattern (Existing vs Reclamation)

Current differences at P1-P6 (no reclamation vs with reclamation)

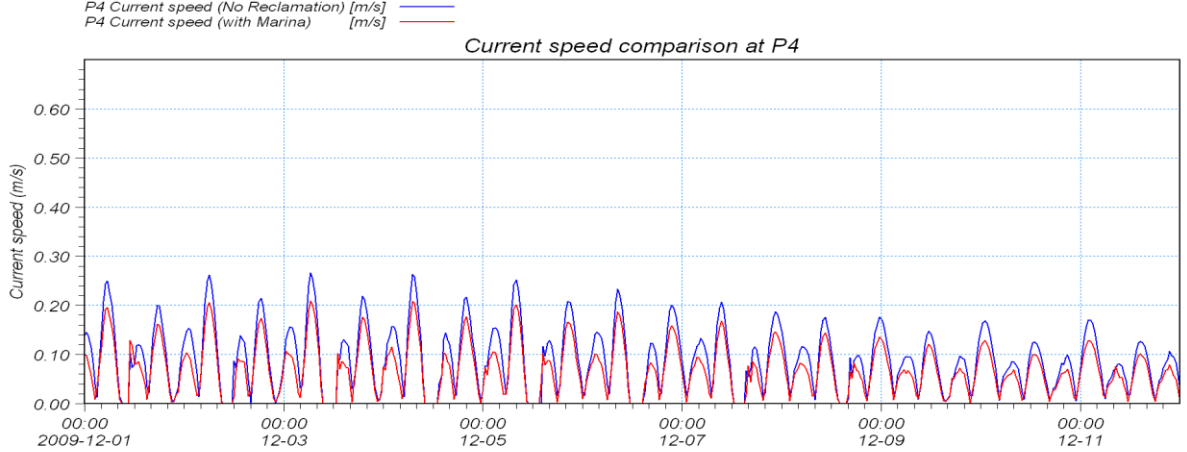


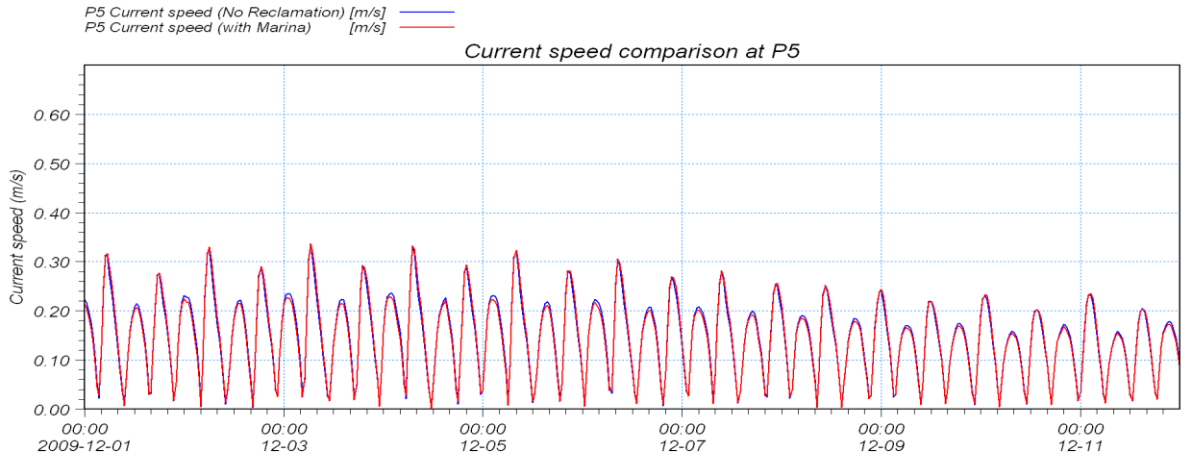


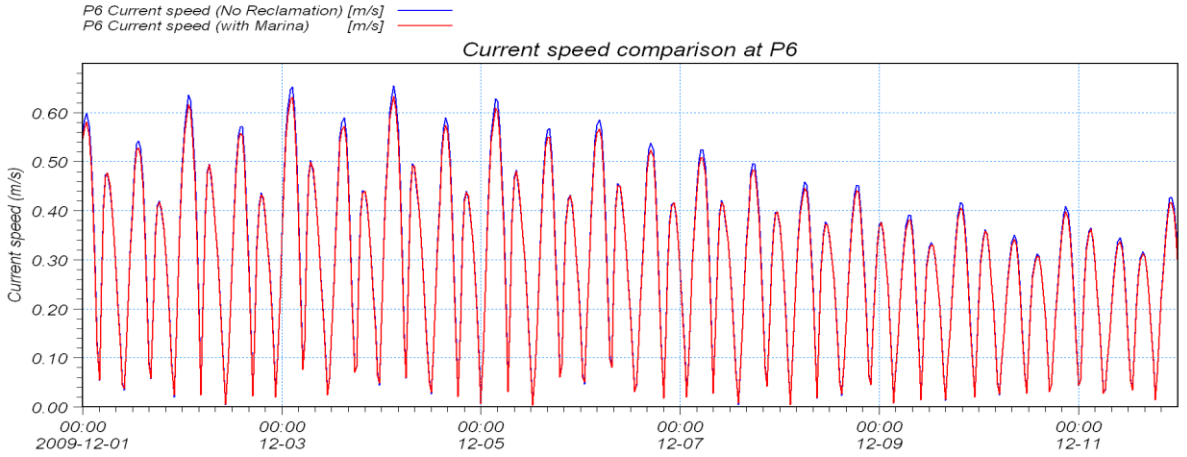




- Current differences at P1 –P3 (no reclamation vs with reclamation)

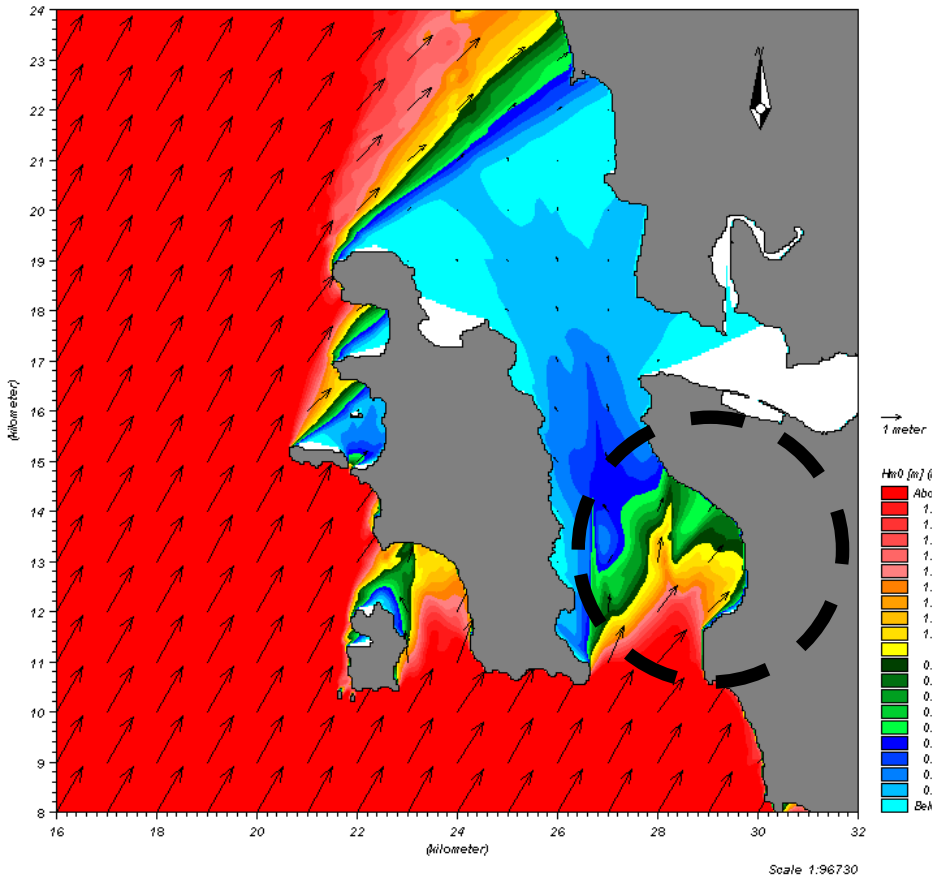


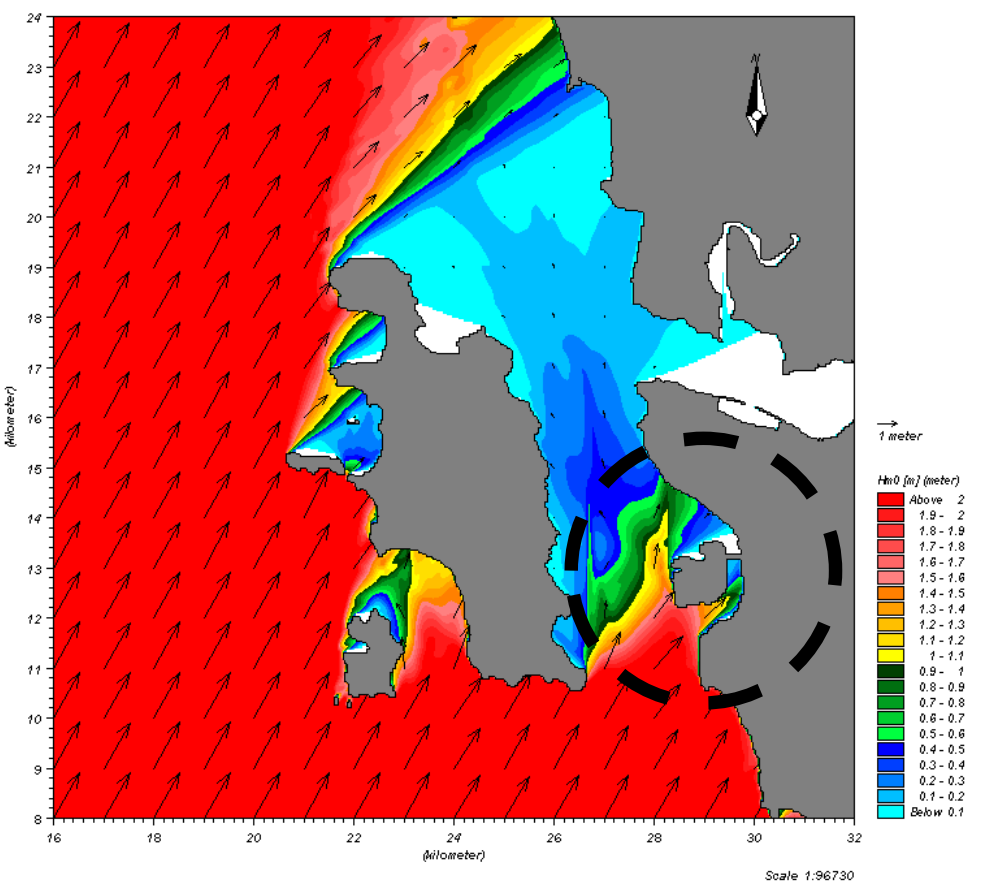




- Current differences at P4-P6 (no reclamation vs with reclamation)

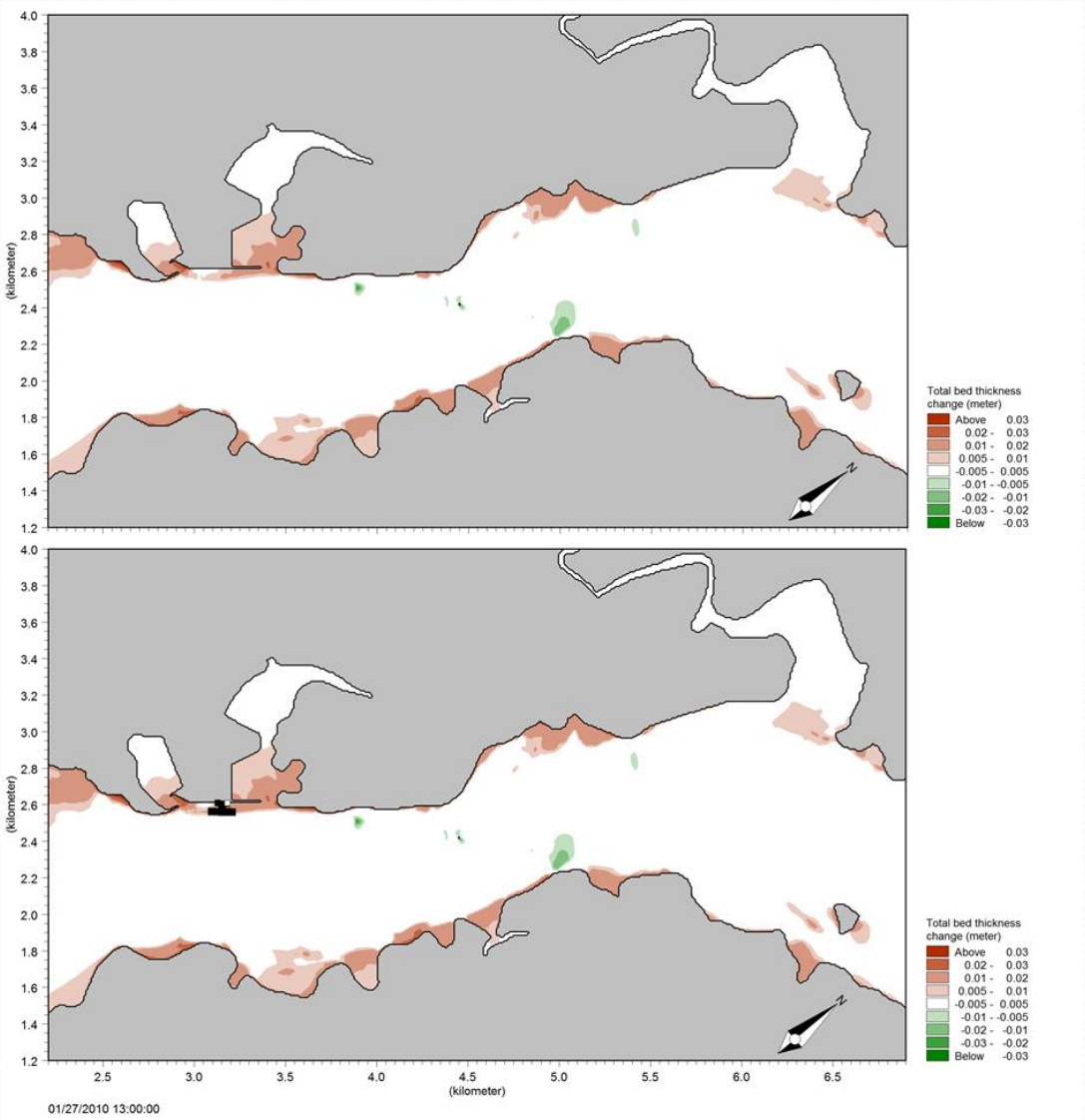
Nearshore Wave Modelling





Wave height (Existing vs Reclamation)

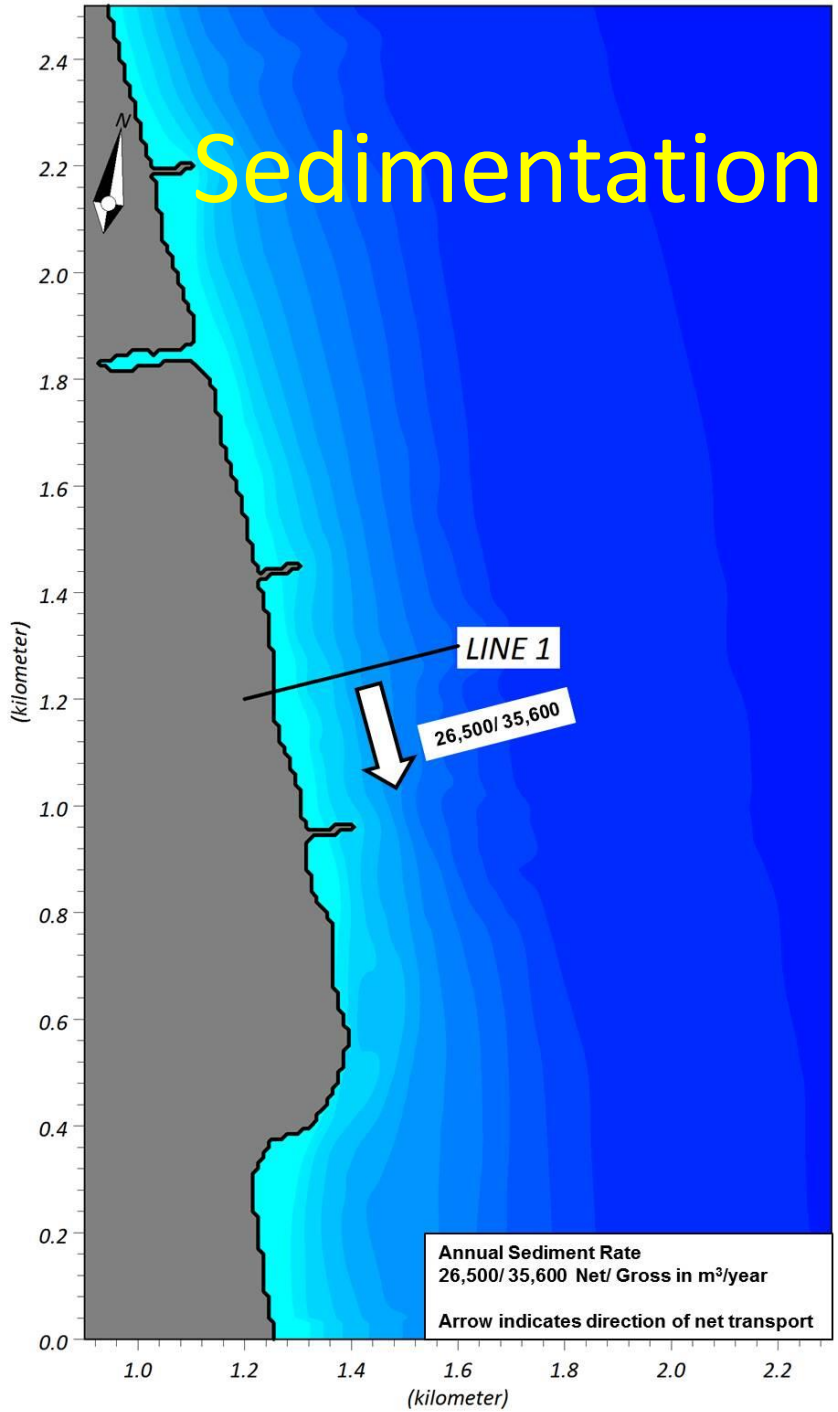
Sedimentation Modelling



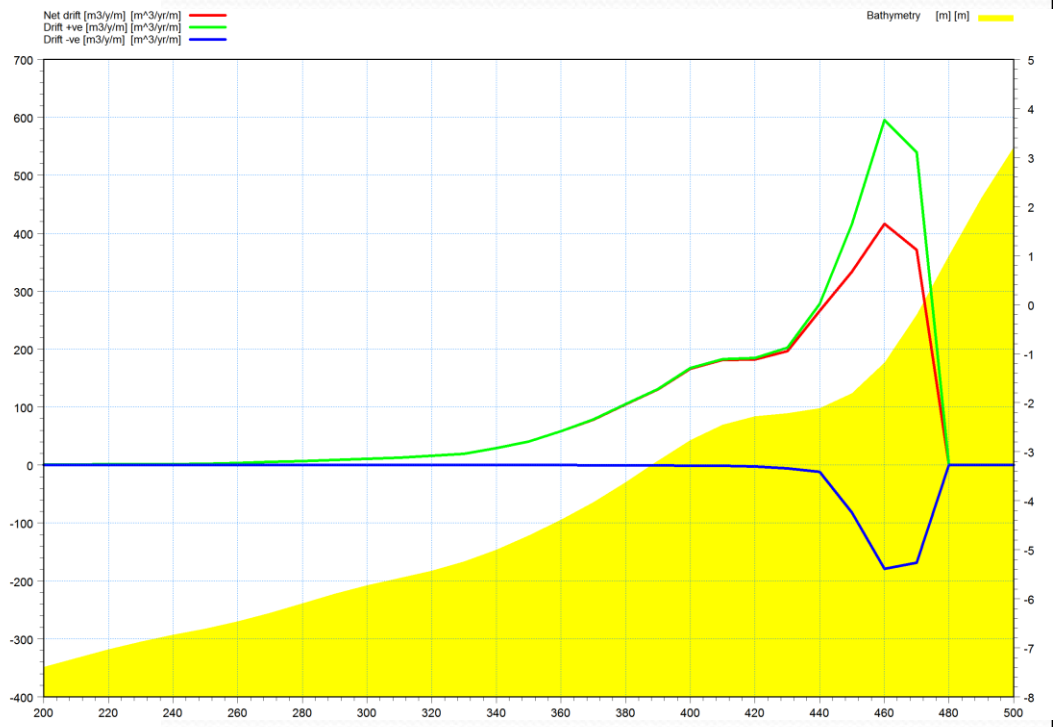
Existing Condition

Proposed Condition

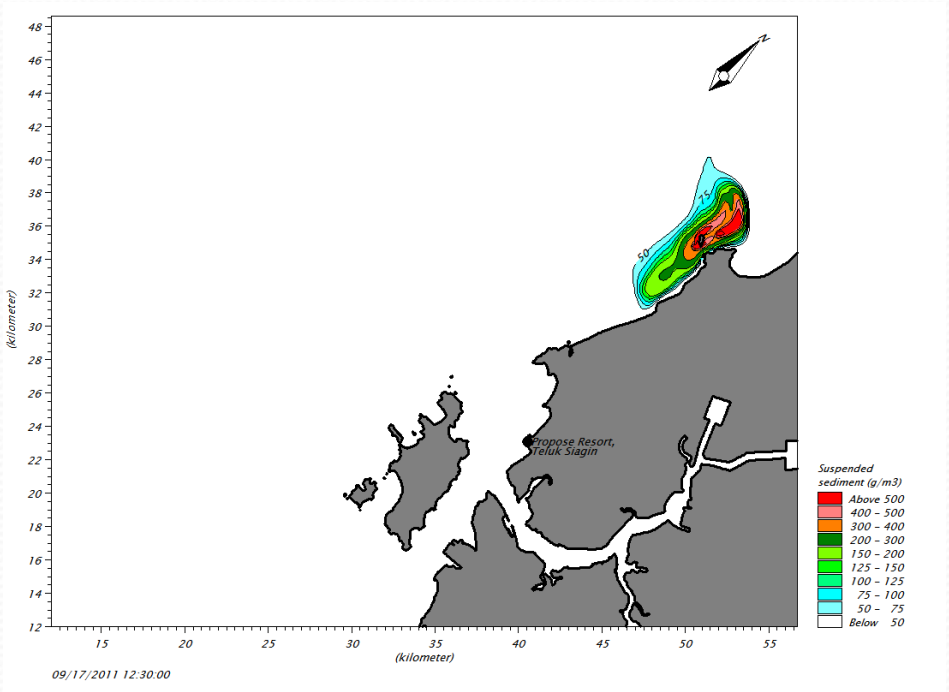
Sedimentation Modelling



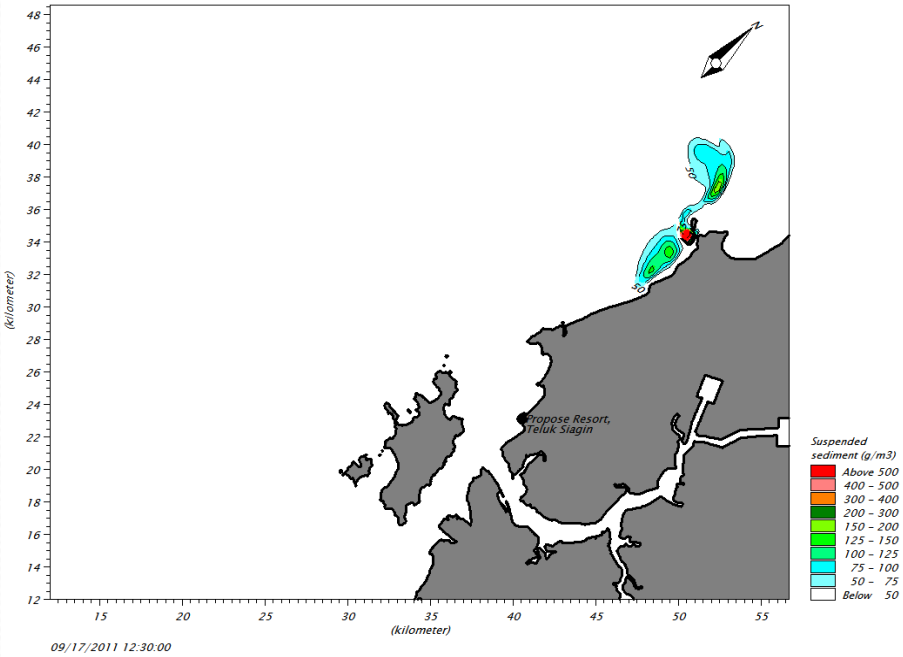
The cross-shore sediment transport distribution



Dispersion Modelling



Existing Condition



Proposed Condition (With mitigation measures)

Types of Impacts

- Coastal erosion
  - Project can interfere with natural coastal processes and disrupt littoral drift
  - Developer to be made responsible if project causes stable or accreting coasts to erode
  - Developer must propose mitigative measures i.e. coastal protection

Types of Impacts

- Adverse Impacts to Rivermouth area
  - Drainage and upstream flooding
    - Increased tidal levels at rivermouth may lead to upstream flooding
    - Reduced velocities at rivermouth encourages siltation, reduces flow capacity
    - Lengthening hydraulic gradient, may cause upstream flooding
    - Developer to bear all cost to mitigate drainage problems
    - Solution subject to DID approval

Types of Impacts

- Rivermouth area (cont'd)
  - Navigation problems at rivermouth
    - Reduced flow velocities lead to siltation at rivermouth
    - Causes navigation problems due to:
      - Shallow draft
      - Narrow passage
    - Causes berthing difficulties due to increased sedimentation
    - Developer to bear cost of mitigative measures

Types of Impacts

- Rivermouth area (cont'd)
  - Tidal prism and salinity concentration in estuary
    - effects marine ecosystems
    - Need to maintain tidal prism and salinity concentration by periodical opening of rivermouth
  - Reduced flushing capacity
    - Decrease in exchange of riverine and tidal waters
    - flushing necessary for removal and dilution of effluent

Types of Impacts

- Increase in suspended sediment concentration
  - Usually follows sand mining & reclamation activities
  - When source and disposal areas are close by, model both in a single layout
  - Suspended sediment often temporary; monitoring of threshold levels may be necessary

Assessment of Impacts

- Impacts on Coral Reefs & Sea Grass
- Impacts on Mangrove Forests
- Impacts on Public Beaches
- Impact on Fishing & Aquaculture areas

Overall Assesment

- The consultant should quantify all the identified impacts such as erosion, siltation, total suspended sediment, drainage problems, turbidity, etc.
- The project proposal should then be optimised so as to minimise the impacts
- Based on the study, the consultant should also propose :-
  - mitigation measures to overcome the impacts and
  - monitoring plan in order to ensure that the impacts are within the allowable limits

Data Submission & Presentation

- (5) coloured copies of the hydraulic study report + 1CD-ROM relevant modelling data
- A copy of datasets (modelling data) in digital

  - Model input data e.g bathymetry, water levels and currents, waves

  -Model set-up e.g Hydrodynamic, wave, sediment transport

  -validation data set e.g. water levels and currents

  -current survey (ACAD)

  -soil investigation
- A technical presentation of the hydraulic study shall be conducted to DID's RBCZM Division

Coastal Engineering Hydraulic Study Reports (GOOD AND BAD REPORTS)

- Good Reports
  - Project & area description
    - Appropriately scaled maps to describe existing and future layout, existing natural resources/economic activies
    - Secondary & primary data
  - Impacts projected
    - Comprehensive description of expected impacts
    - Elaborate description of problems and scenarios
    - Clear understanding of modelling tools to use
  - Unambiguous flow of study
    - due processes given and links are clear
    - Model scenarios as per guidelines
    - Unambiguous data presentation; correct scales and units
    - Supported conclusions
  - Commitment to mitigative measures
    - Explicit listing of mitigative measures to be undertaken
    - Monitoring programme proposed

- Bad Reports
  - Project & area description
    - Maps in large scale
    - Heavy dependence on secondary data
    - Limited primary data
  - Impacts projected
    - Focus on annual impacts
    - Poor problem description
    - Elimination of test scenarios without due process or analysis
  - Study flow disjointed
    - Linkage between study components not clear
    - Modelling guidelines not followed/partially complied
    - Scenarios not fully explored
    - Limited data presentation
    - Conclusions unsupported
  - Commitment to mitigative measures
    - Generalisation of measures and undertaking
    - No monitoring programme

CONCLUSION

- Hydraulic study is an essential component in projects that involve land/water interaction
- Numerical modelling is now a widely accepted tool in understanding, predicting and assessing impacts
- DID Guidelines 2001 is designed to guide hydraulic and impact studies that involve numerical modelling
- Numerical models are simply tools that provide an insight into what is happening and what may happen in reality
- *Not all cases require numerical modelling*

Thank you