MODELLING OF SEABED SCOUR IN SUPPORT OF A MARINE PIPELINE INSTALLATION

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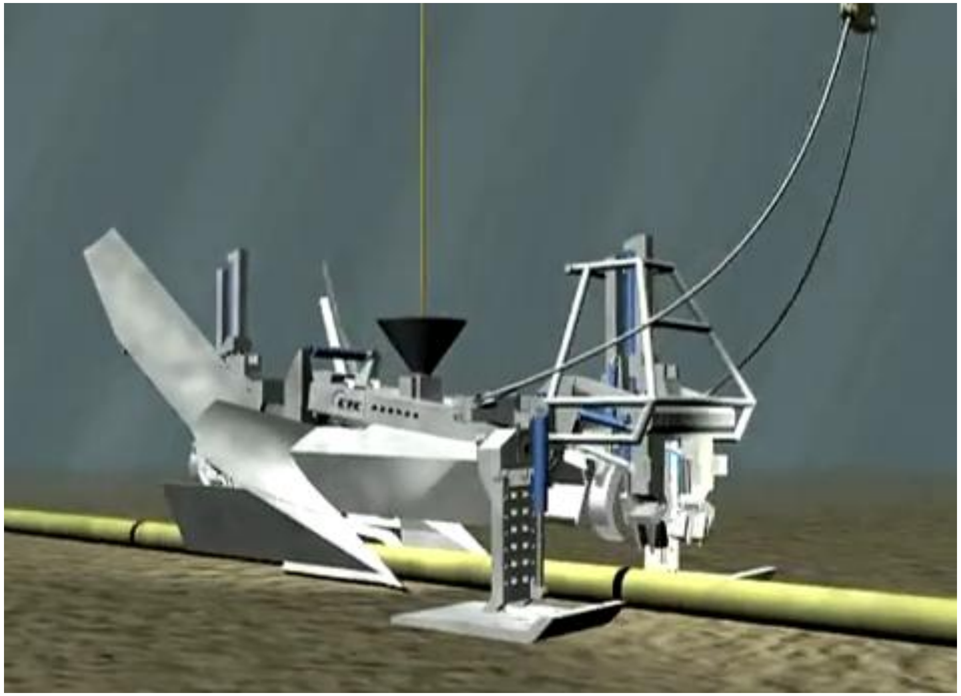
Marine Pipeline Installation

- Marine pipelines can installed using a towed pipeline plough that simultaneously cuts a trench and lowers the pipeline
- Backfill of the trench, if required, can be performed with an additional pass along the pipeline with a backfill plough

AMP500 Pipeline Plough



- Plough is lowered over pipeline

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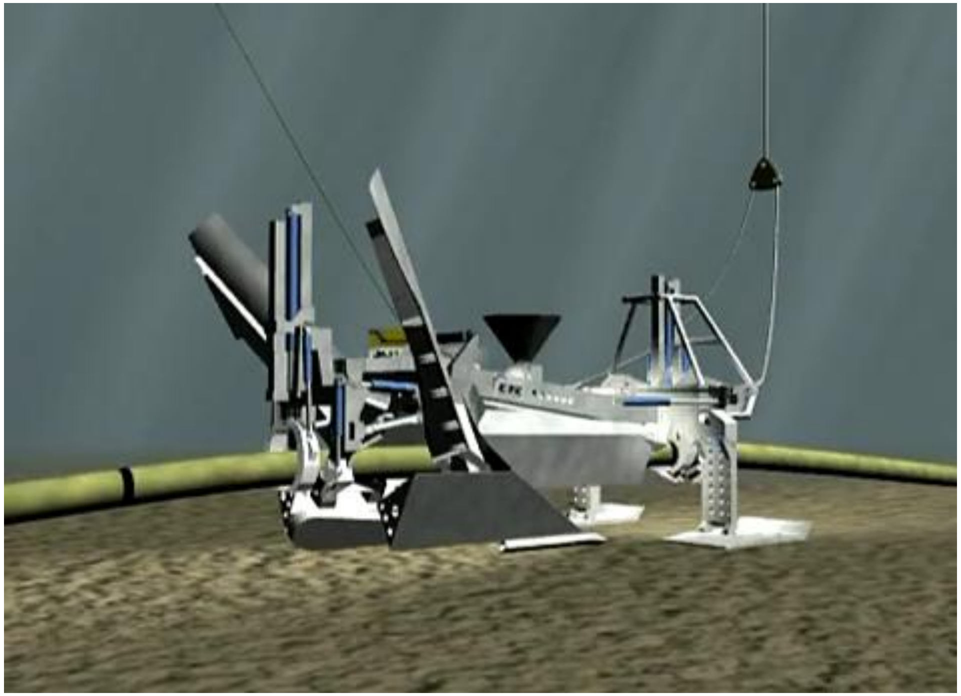
AMP500 Pipeline Plough



- Mechanical arms at front and back of plough lift pipeline off seabed

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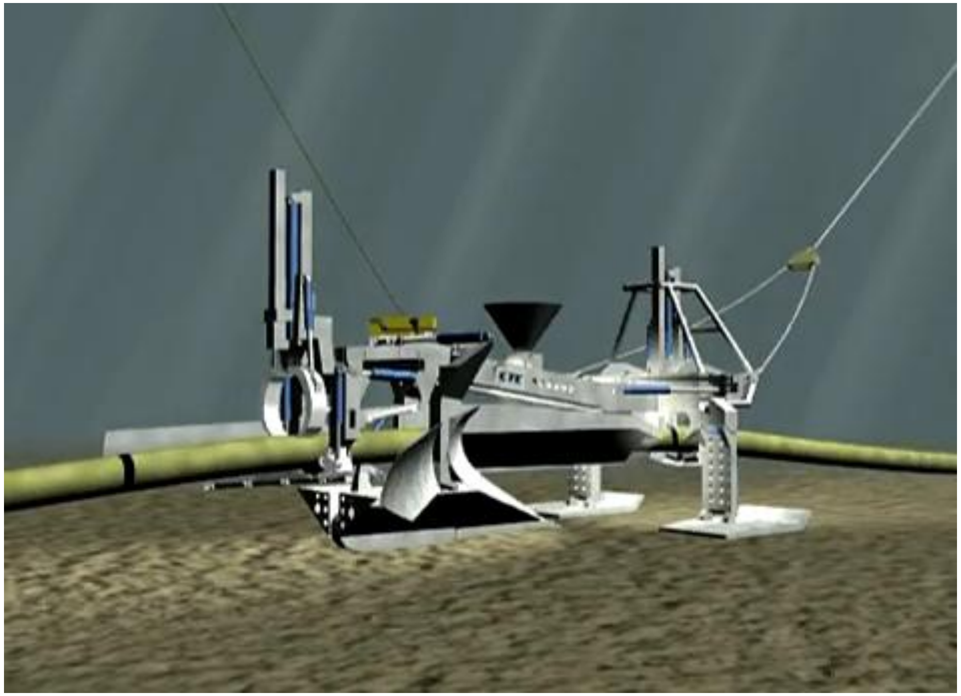
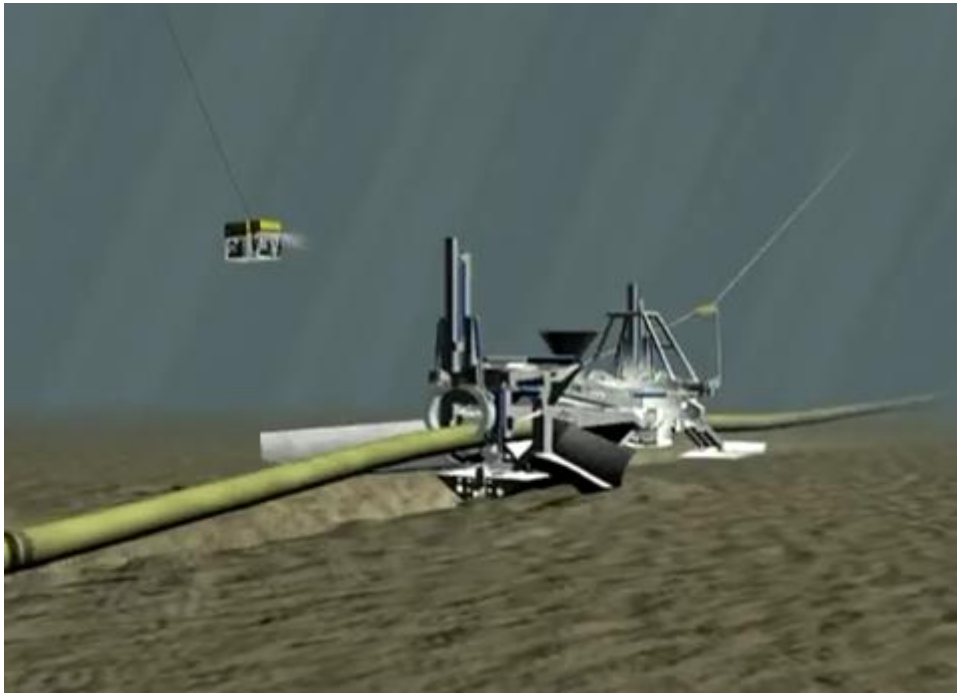
AMP500 Pipeline Plough



- Plough blades are lowered into place
- Pipeline is lowered into cradle

AMP500 Pipeline Plough



- Plough is pulled by support vessel, cutting trench and side-casting spoil

AMP500 Pipeline Plough

- Pipeline slides through cradle as plough is pulled forward
- Plough rides on skids at front, blade at rear

AMP500 Pipeline Plough

- Pipeline falls into cut trench behind plough
- Trench may be backfilled by a second pass using a backfill plough

AMP500 Pipeline Plough

- Ploughs tend to be very large
- AMP500 is approximately 10 m × 12 m × 22 m and 200 t

Support Vessel *Maersk Advancer*

- Consequently, support vessels are also very large

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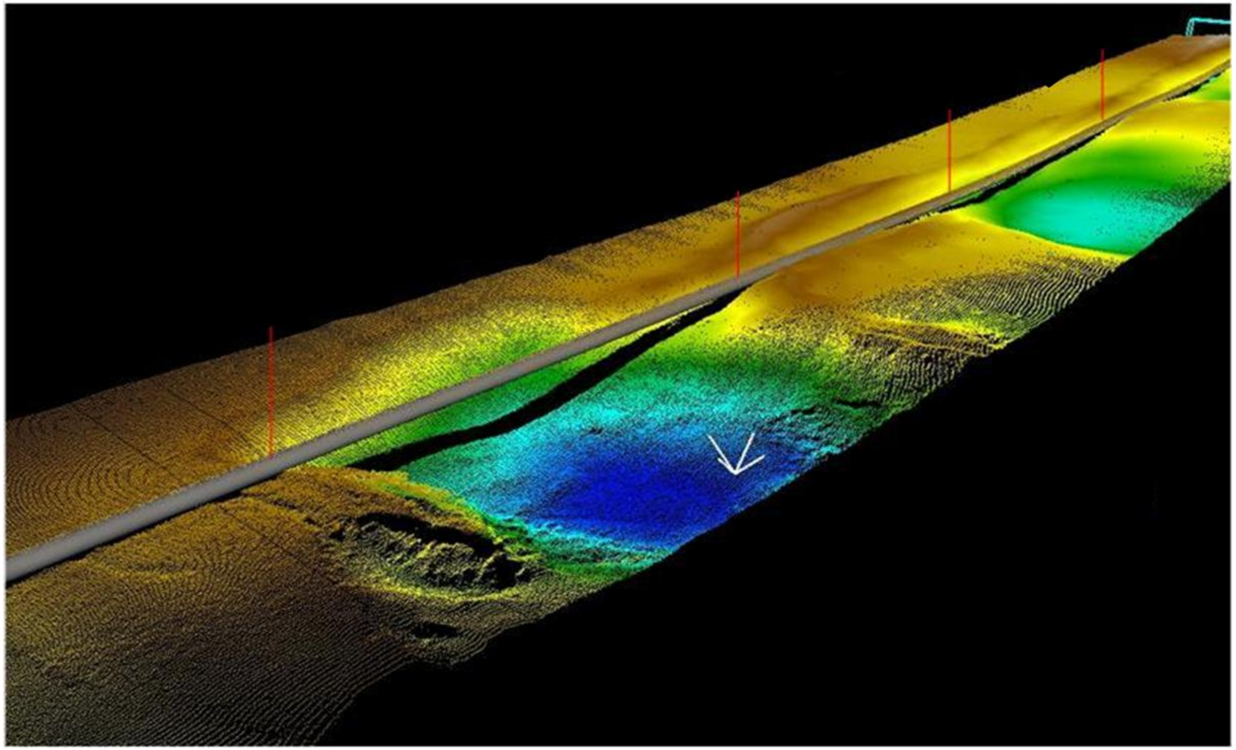
Problems

- Under certain conditions, the forces required to tow the plough can be very high
- Flow from the vessel props can scour the seabed, leaving the newly-laid pipeline exposed or worse still, spanning an scour hole
  - Softer sediments
  - Shallow water

Propwash-Induced Scour



- Propwash-induced scour holes undermining pipeline are evident in this colourized sonar image

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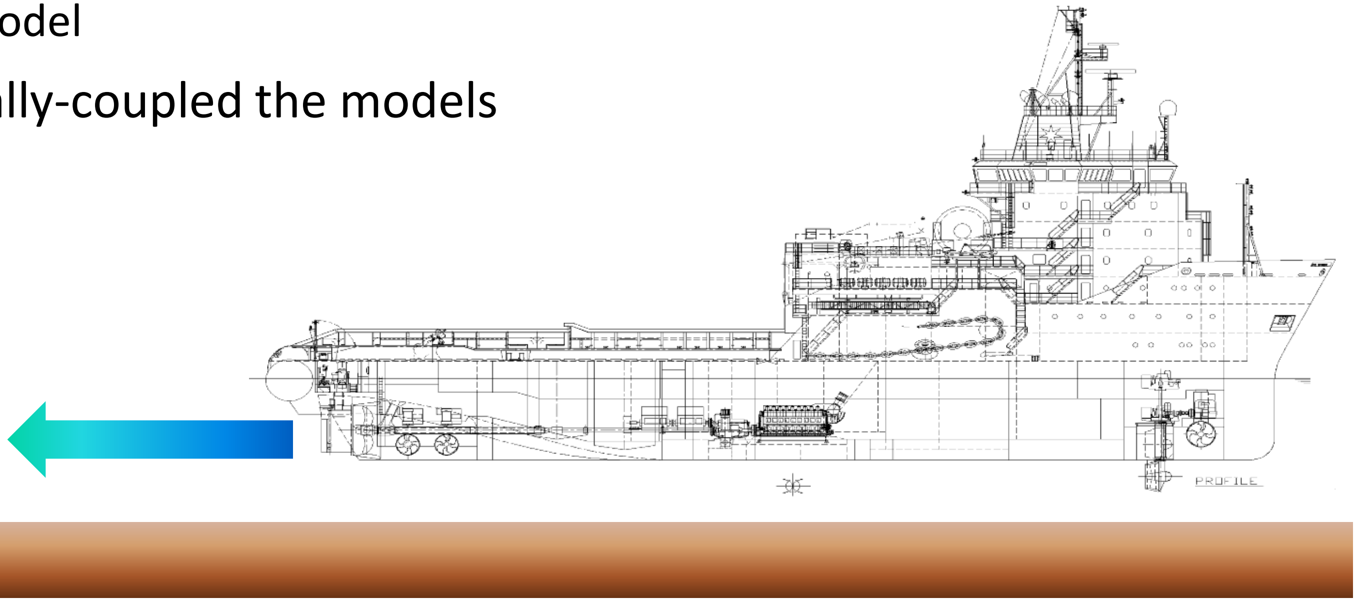
Project Aims

- Develop predictive relationships for near-bed velocities and scour growth as a function of:
  - Vessel characteristics (e.g., speed, thrust, trim, ...)
  - Local conditions (e.g., depth, soil type, ...)
- These relationships would be used to:
  - Plan the operations so as to minimize the issue
  - Enable the personnel on board the tow vessel to modify the operation as required, based on the actual performance observed

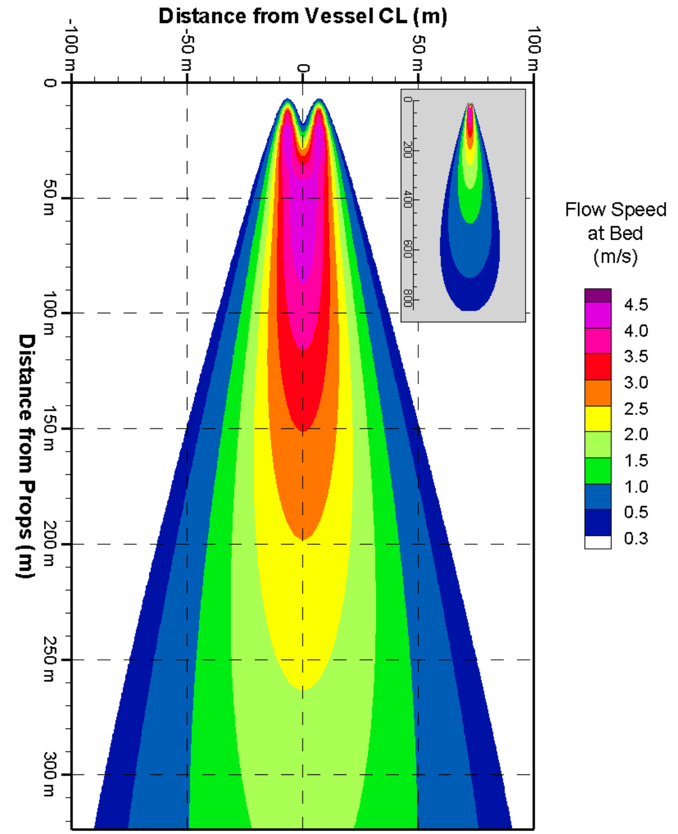
Computer Modelling

- Flows
  - 3D Propwash model
- Morphology
  - PTM model
- Dynamically-coupled the models



Flow Model

- Propwash model
  - 3D velocity fields based on jet flow assumption
  - flow spreads and decays with distance from the vessel due to turbulent diffusion
  - function of water depth, propeller diameter, spacing, trim and thrust
  - dynamically-coupled to PTM



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Sediment Model

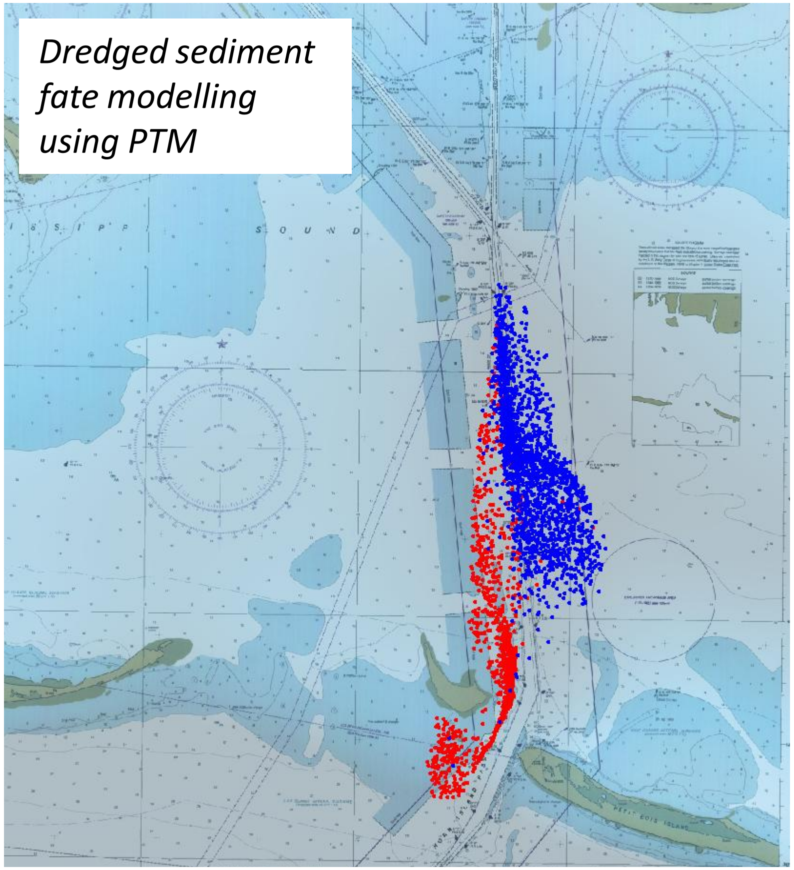
- Particle Transport Model (PTM)
- Developed by Coldwater
- Funded by two US Army Corps of Engineers Engineering Research and Development Center (ERDC) research programs:
  - Coastal Inlets Research Program (CIRP)
  - Dredging Operations and Environmental Research (DOER) Program
- Commercially-available as part of the Surface-water Modeling System (SMS) from Aquaveo

PTM

- PTM uses hydrodynamics from other models
- Multiple input
  - FE, FD, quadtree, ...
  - Waves, flows, ...
- PTM was developed for application to dredging and coastal projects
  - dredged material dispersion and fate, sediment pathway and fate, and constituent transport

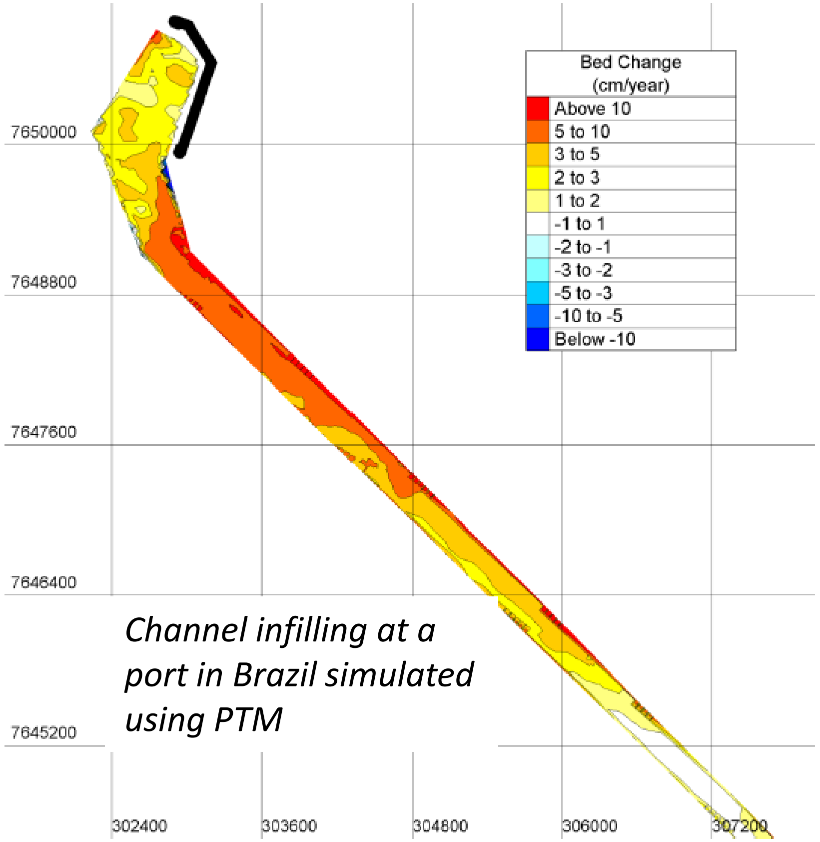
PTM

- Lagrangian (particle-based) scheme to compute the pathways and fate of sediments
- Typical application method for PTM



PTM

- Eulerian (mesh-based) calculations of bed conditions (e.g. shears, sediment transport, morphology, etc.) are always performed in the background of each run
- Present work illustrates use of these other capabilities
  - Non-cohesive and cohesive sediment transport and morphological evolution



Channel infilling at a port in Brazil simulated using PTM

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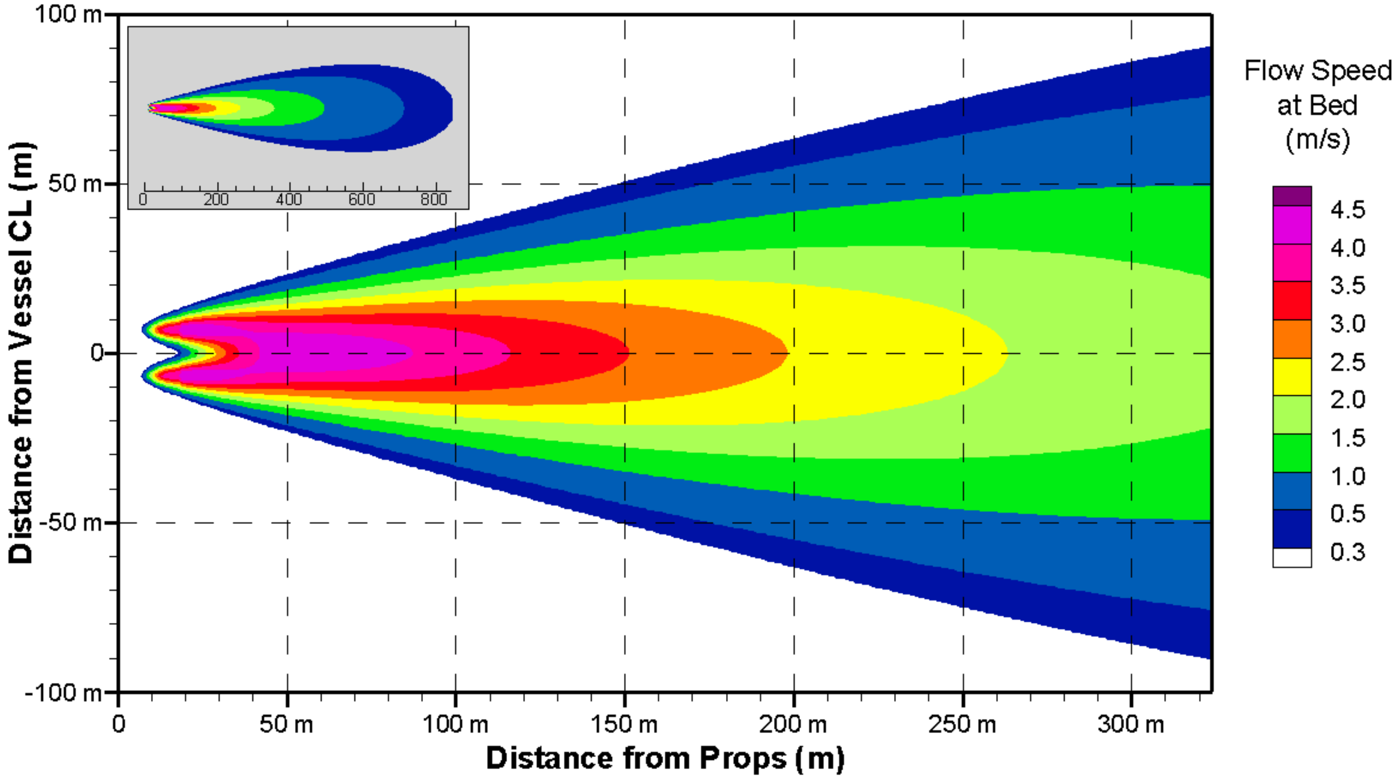
Test Conditions for Present Case

- Bed materials
  - fine, medium and coarse sand
  - soft, medium and hard clay
- Water depth
  - 12 → 24 m
- Vessel speed
  - 0 → 400 m/hr
- Bollard pull
  - 100 → 200 Te

Bed	Case	Rate (m/s)	Depth (m)	Bollard Pull (Te)
Fine Sand	A1	0	12	100
	A3	0	12	200
	A5	0	14	100
	A7	0	14	200
	A9	0	24	200
	B1	200	12	100
	B3	200	12	200
	B4	200	24	200
Med. Sand	A2	0	12	100
	A4	0	12	200
	A6	0	14	100
	A7	0	14	200
	A10	0	24	200
	B2	200	12	100
Soft Clay	C3	0	12	100
	C6	0	24	100
	D3	400	12	100
Med. Clay	C1	0	12	100
	C4	0	24	100
	D1	400	12	100
Hard Clay	C2	0	12	100
	C5	0	24	100
	D2	400	12	100

Maximum Flow Velocities



- Typical flow pattern at the bed
- Note that the vessel has two props

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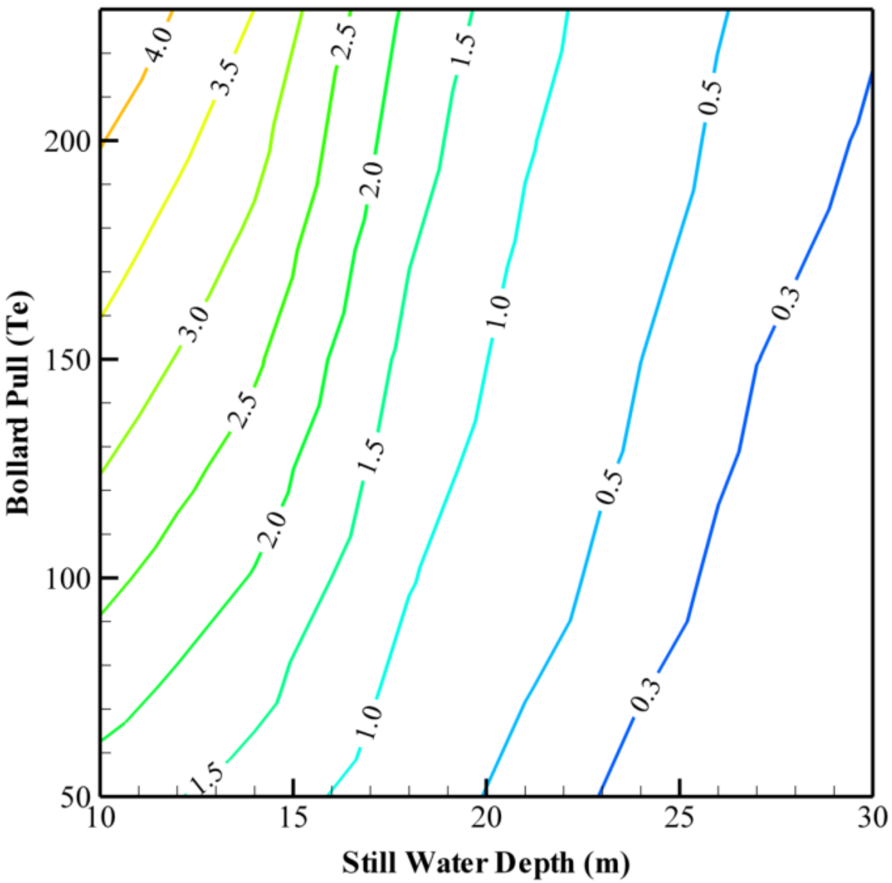
Maximum Flow Velocities



- Peak velocities from all the simulations were used to generate plots of maximum flow velocity at the bed as a function of bollard pull and water depth
- Results are unique to this case as they take into account specific characteristics of the setup
  - Prop size, blade pitch, ...
  - Vessel trim under load
  - ...
- Chart designed for use by on-board engineers

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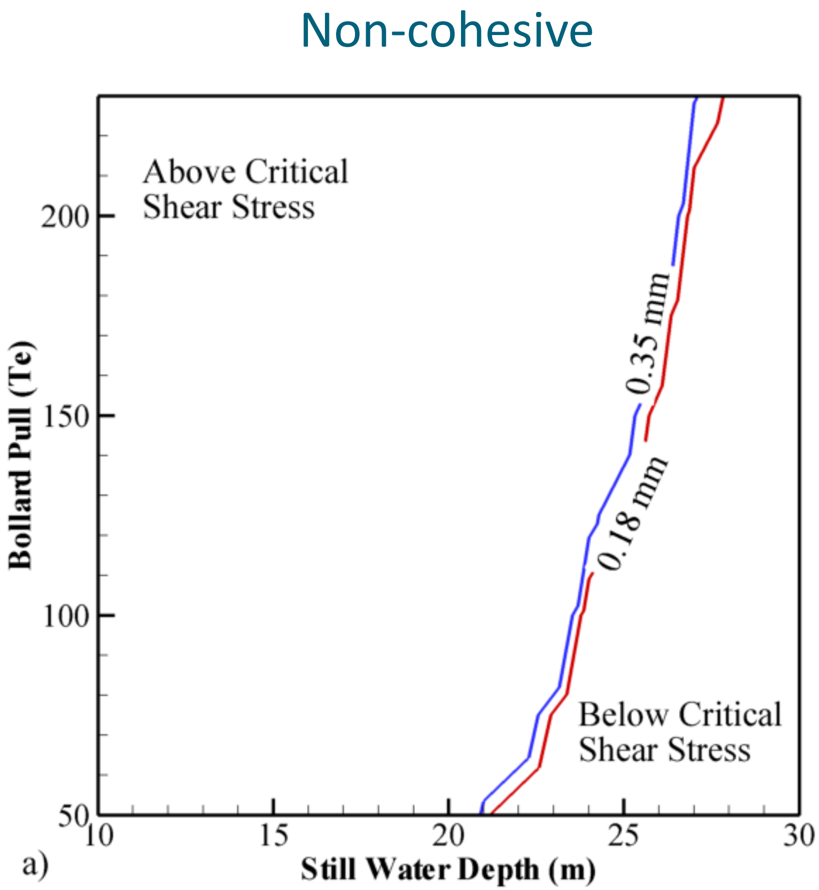
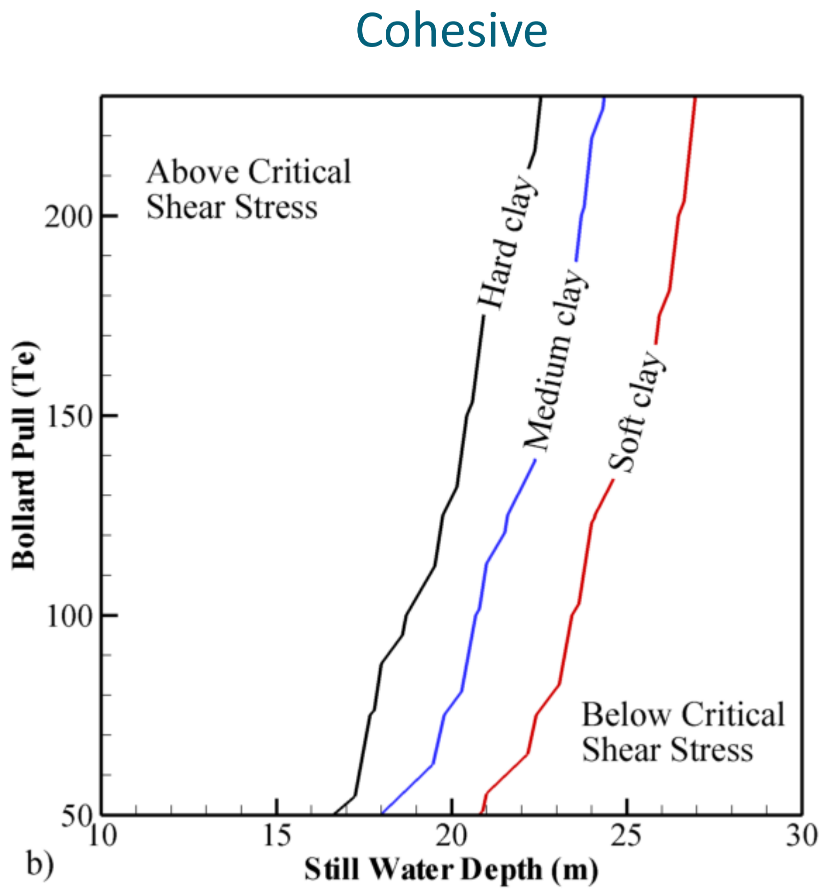
Critical Conditions





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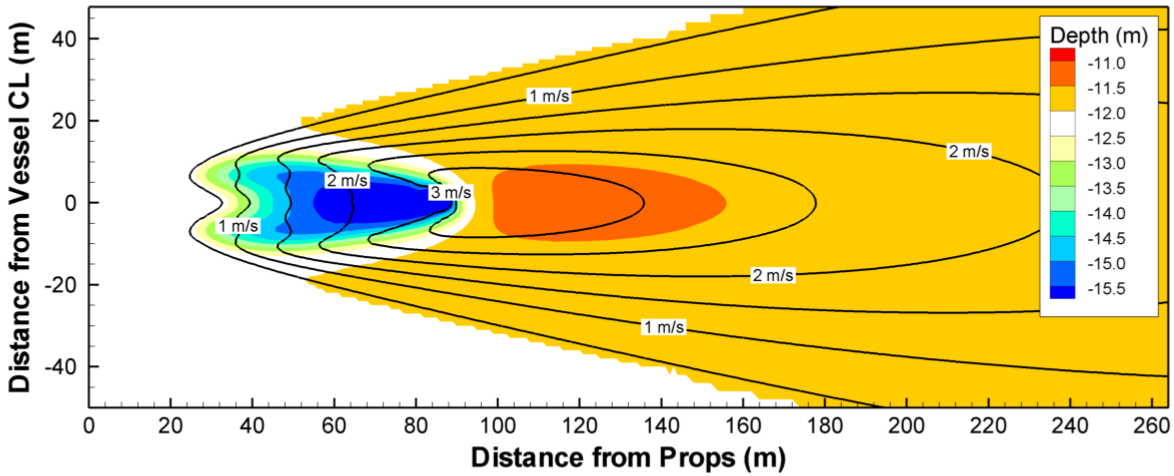
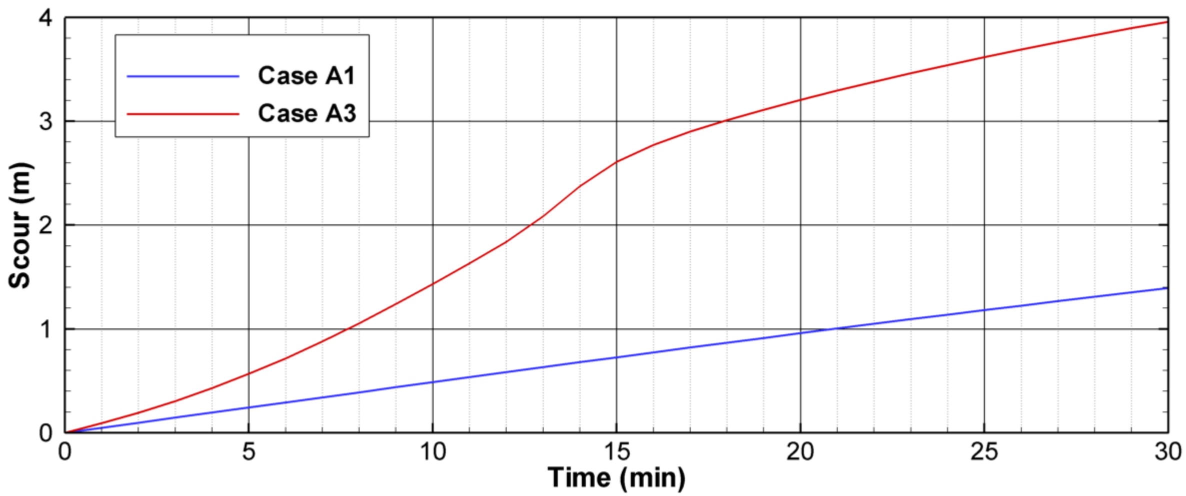
Stationary Vessel





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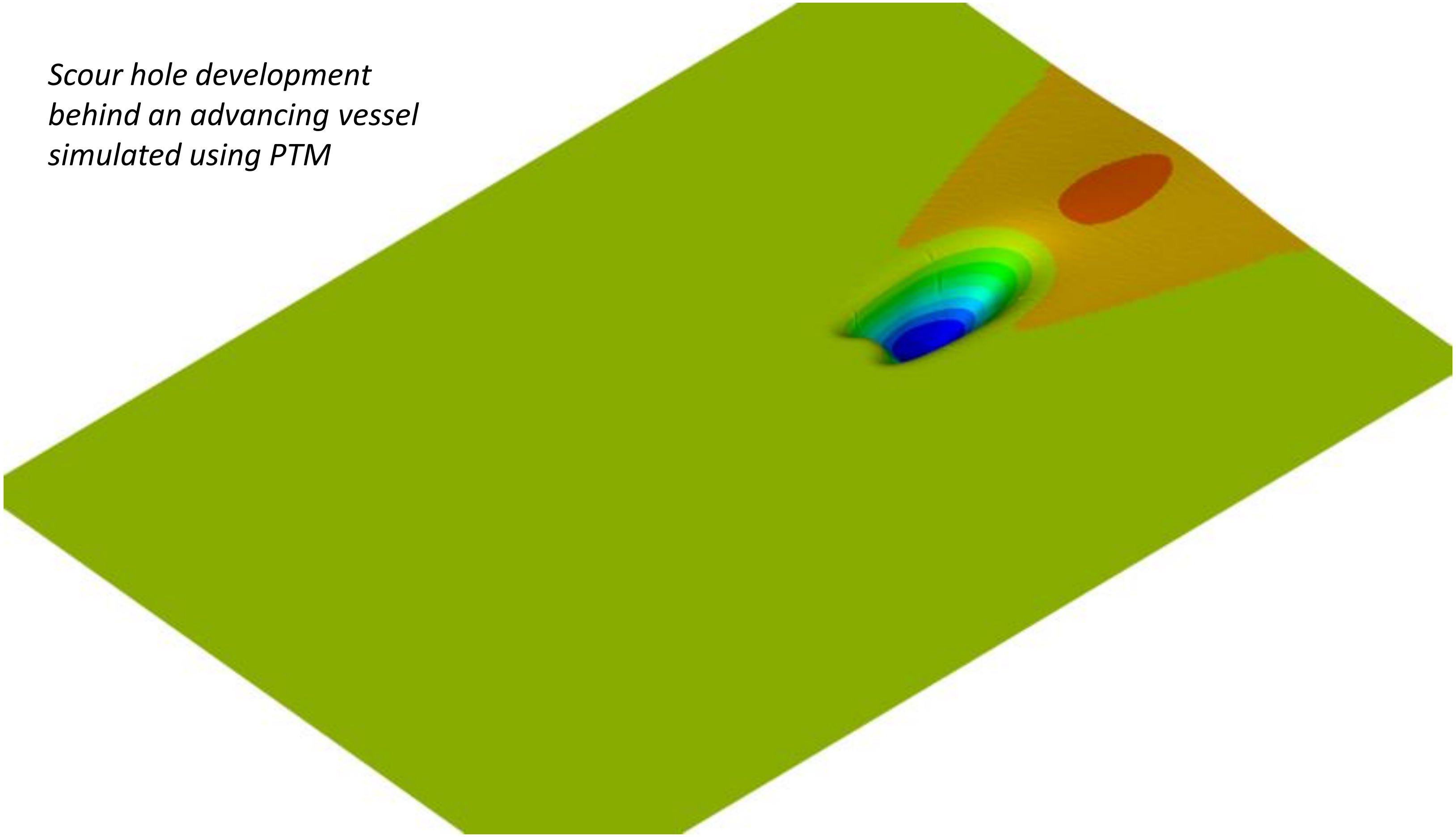
Steady Advancing Vessel

Scour hole development behind an advancing vessel simulated using PTM



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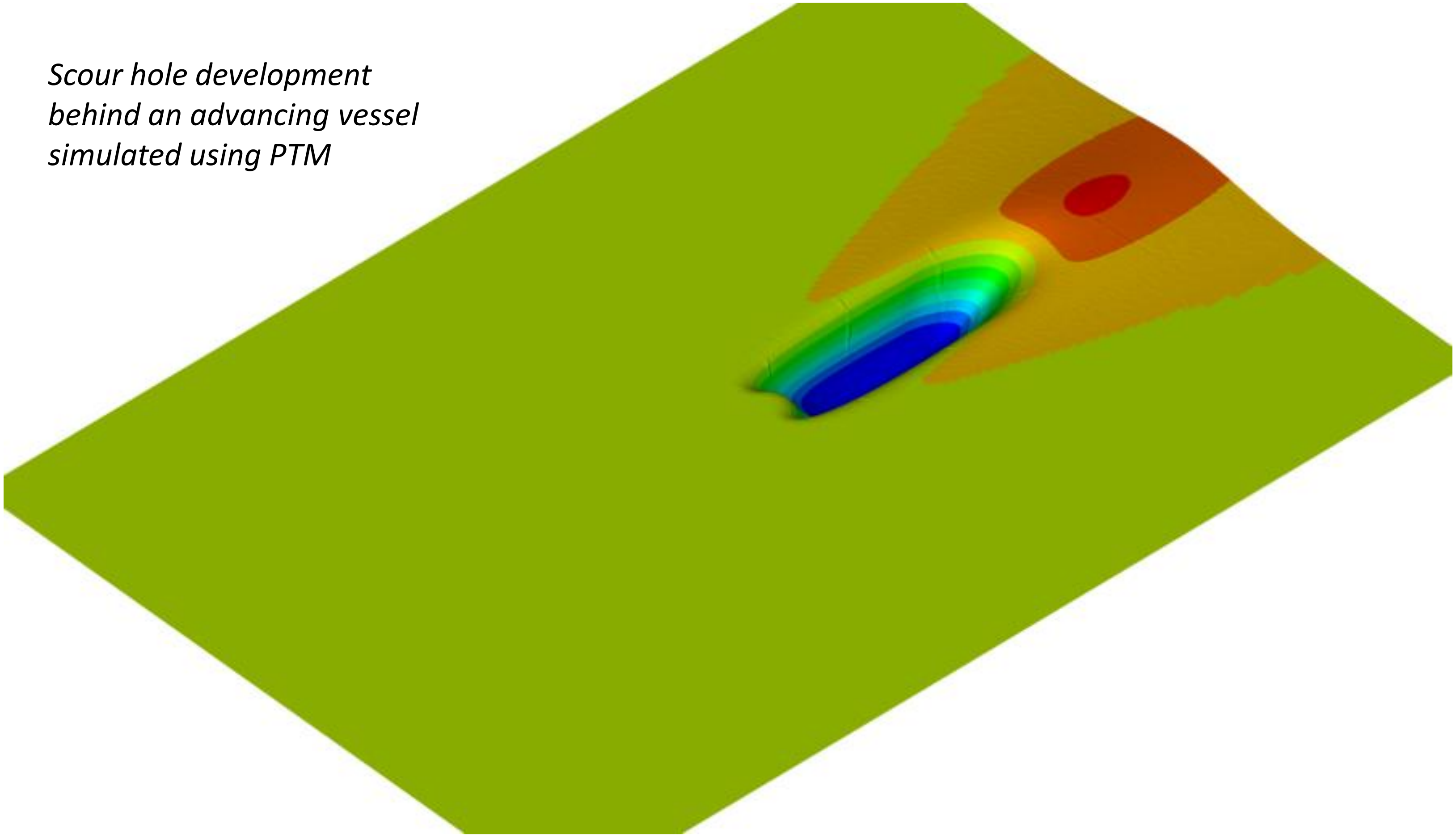

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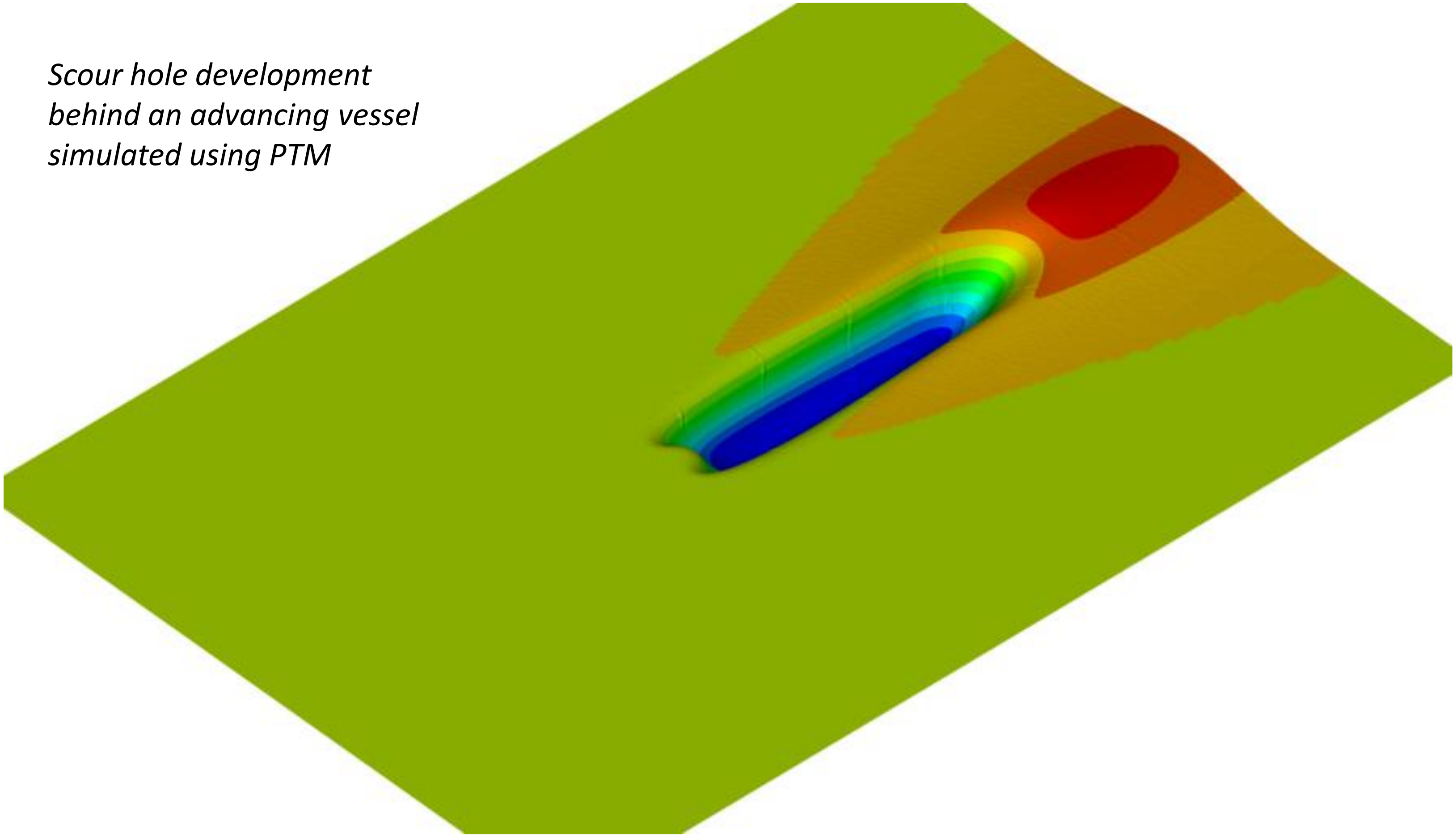

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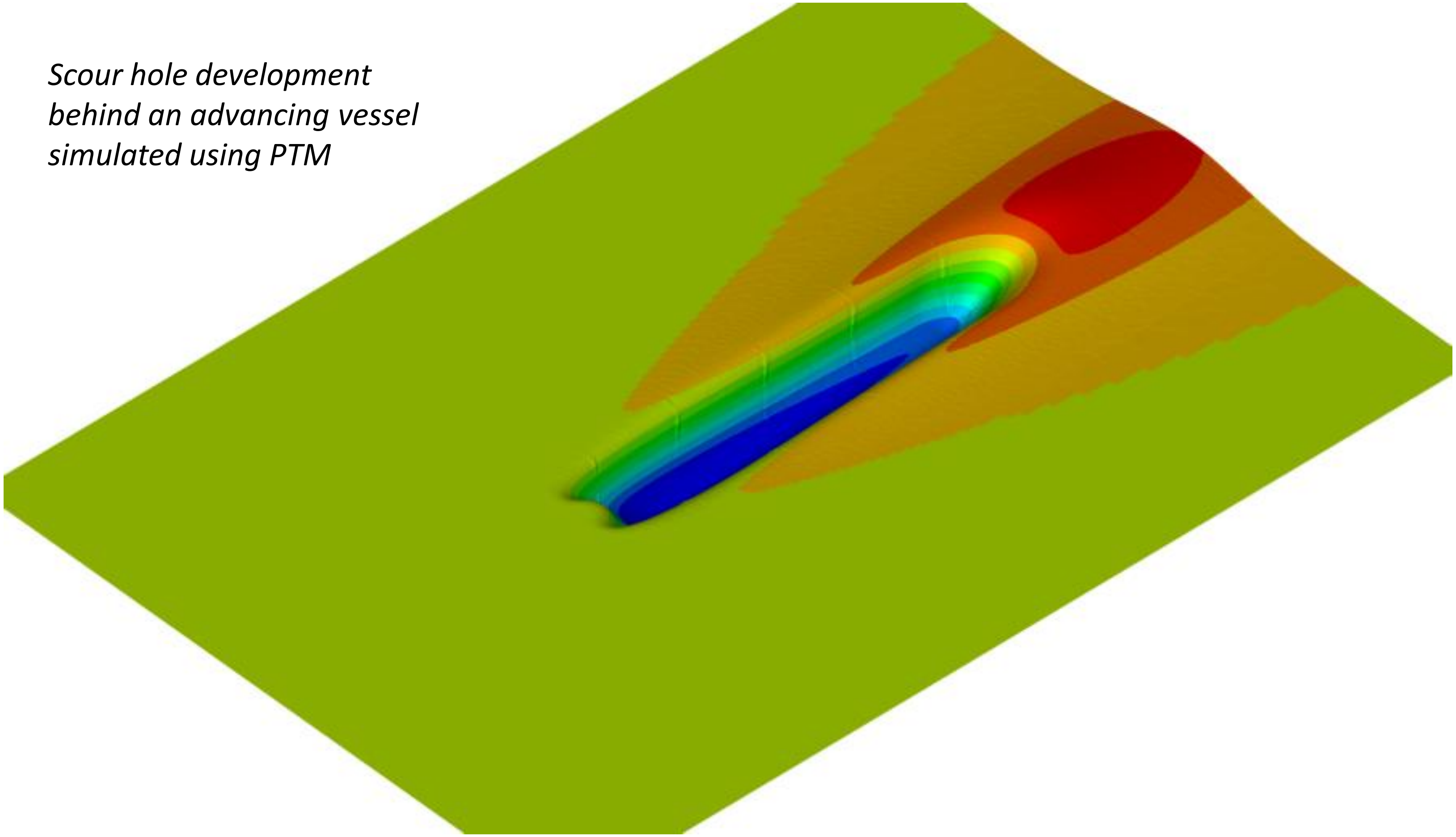

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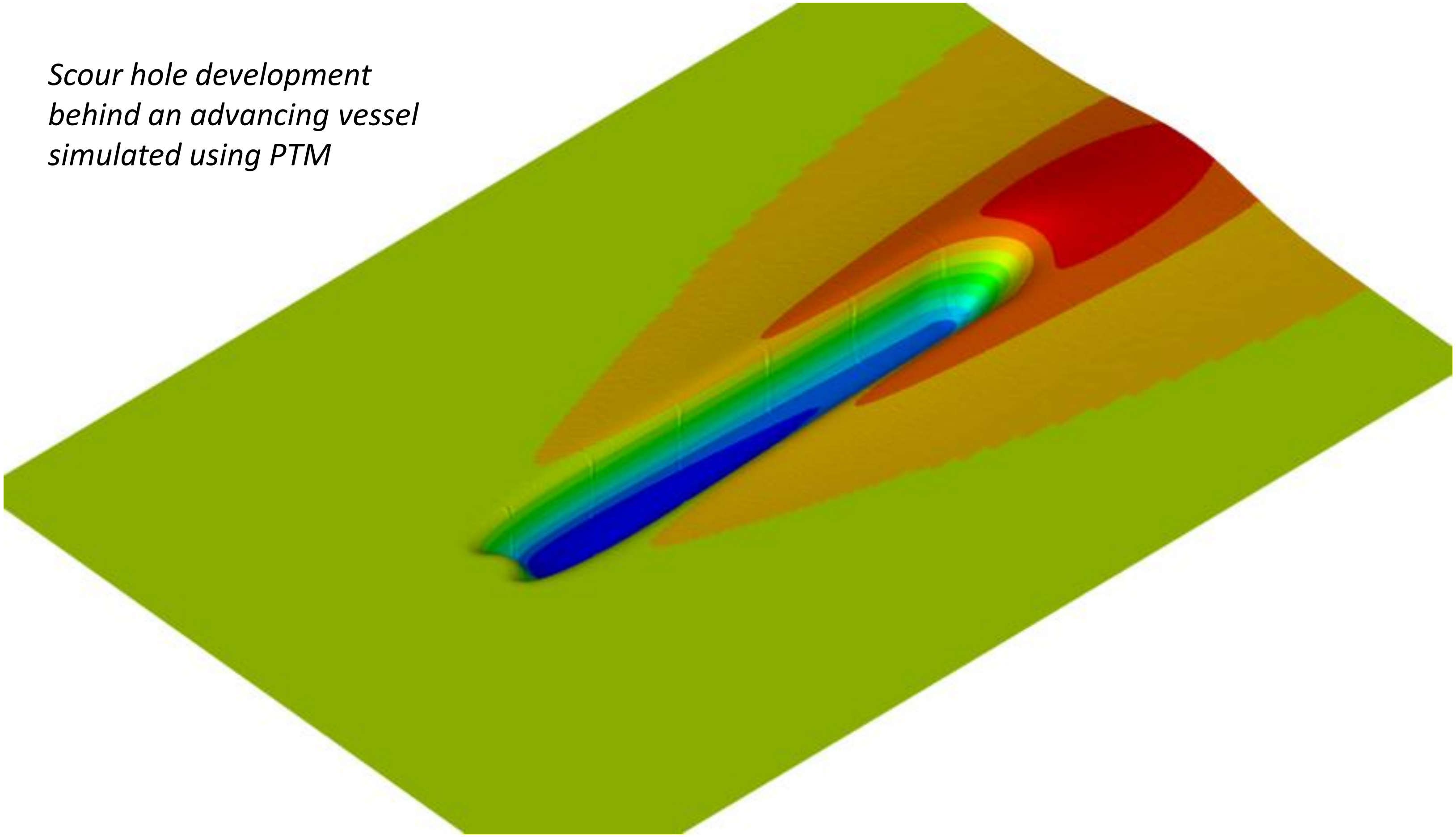

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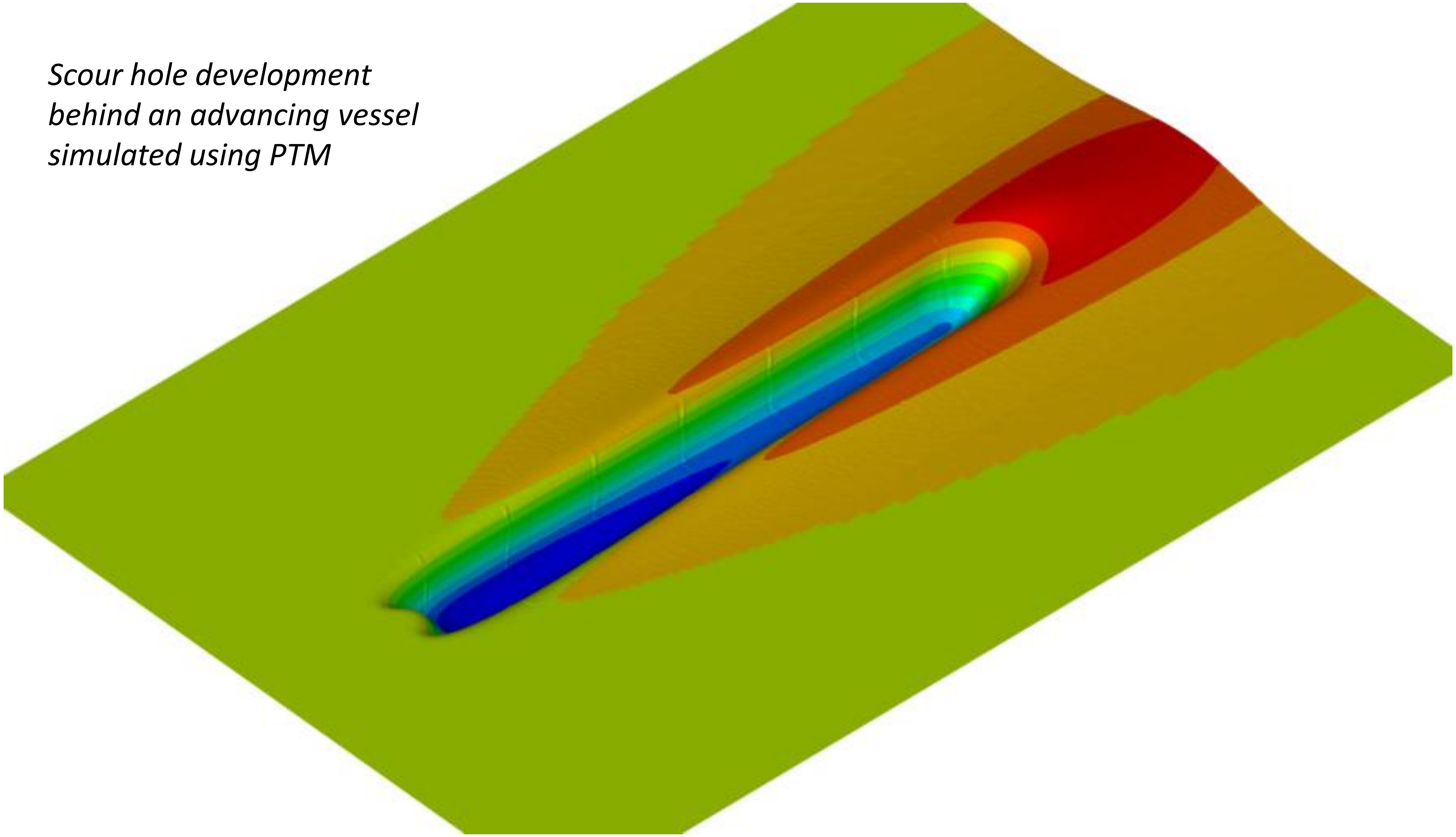
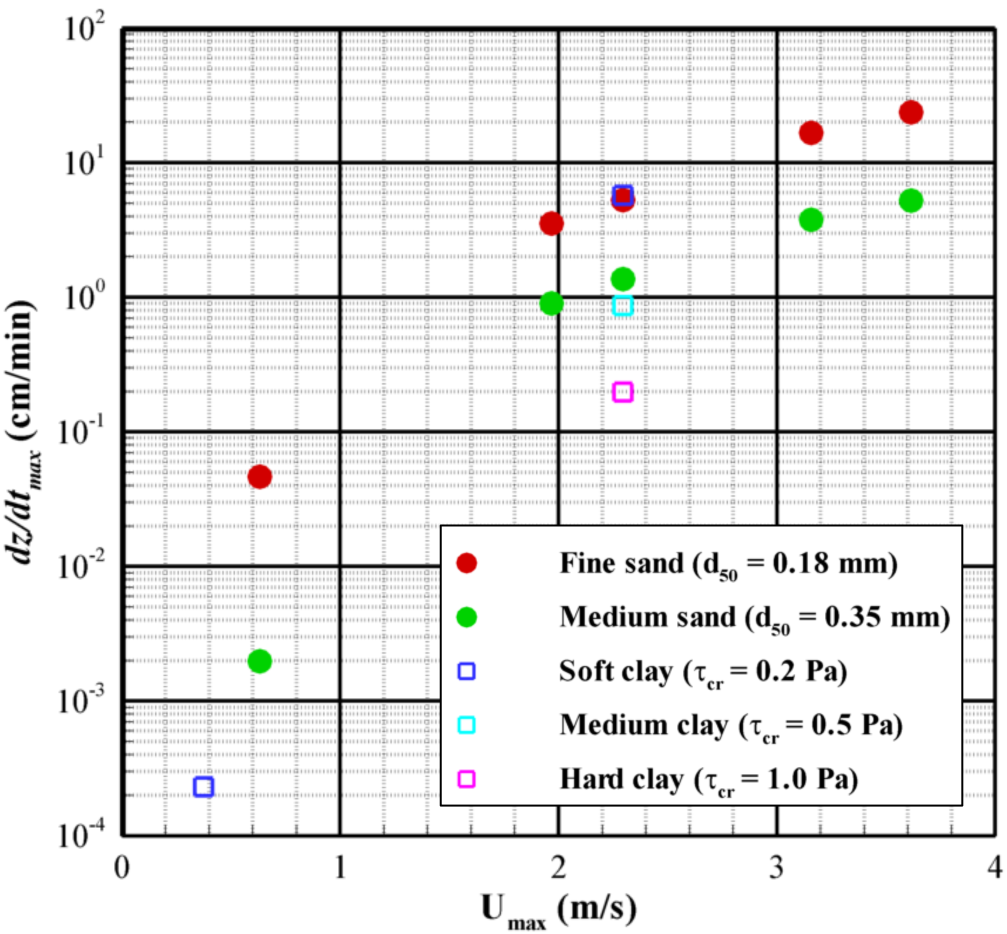


Observations

- As the vessel proceeds along a plough line, a scour hole can develop roughly 50 to 200 m behind the vessel
- Generally, the scouring action of the propwash is backfilled through deposition processes as the ship makes headway
  - Depth of sediment disturbance is significantly greater than the final scour trench depth
- Due to sediment spreading (diffusion), this infilling does not fully equal the scour hole excavation resulting in a net trenching that is shallower than the initial scour hole excavation

Maximum Scour Rate



- Scour rate chart prepared for engineers on board
- To be used in conjunction with maximum bed velocity chart presented earlier

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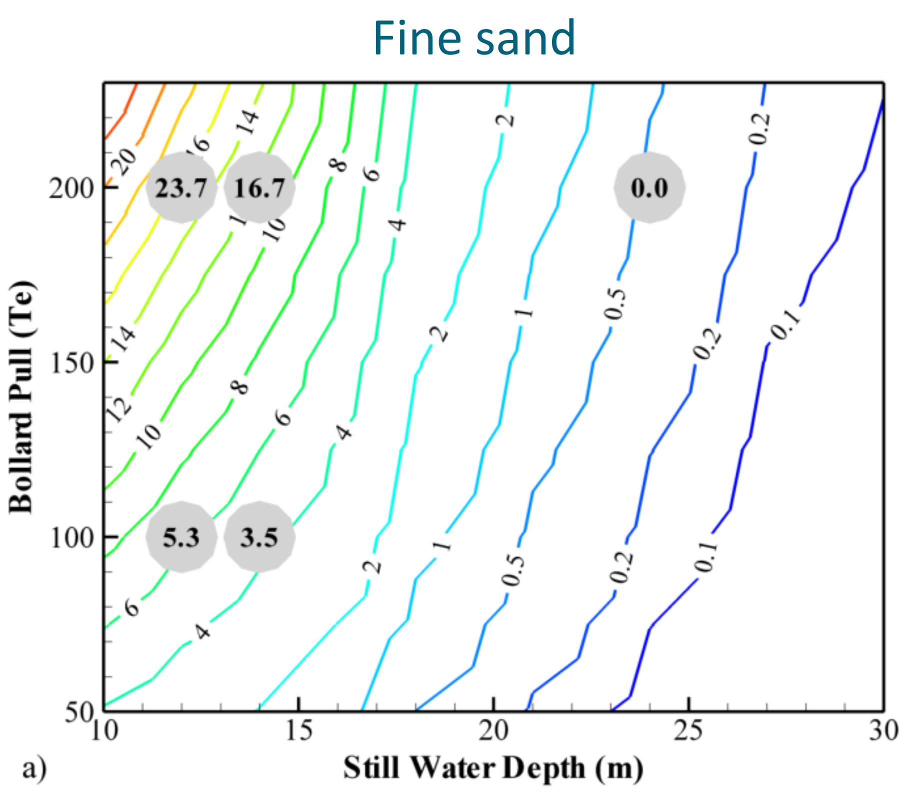
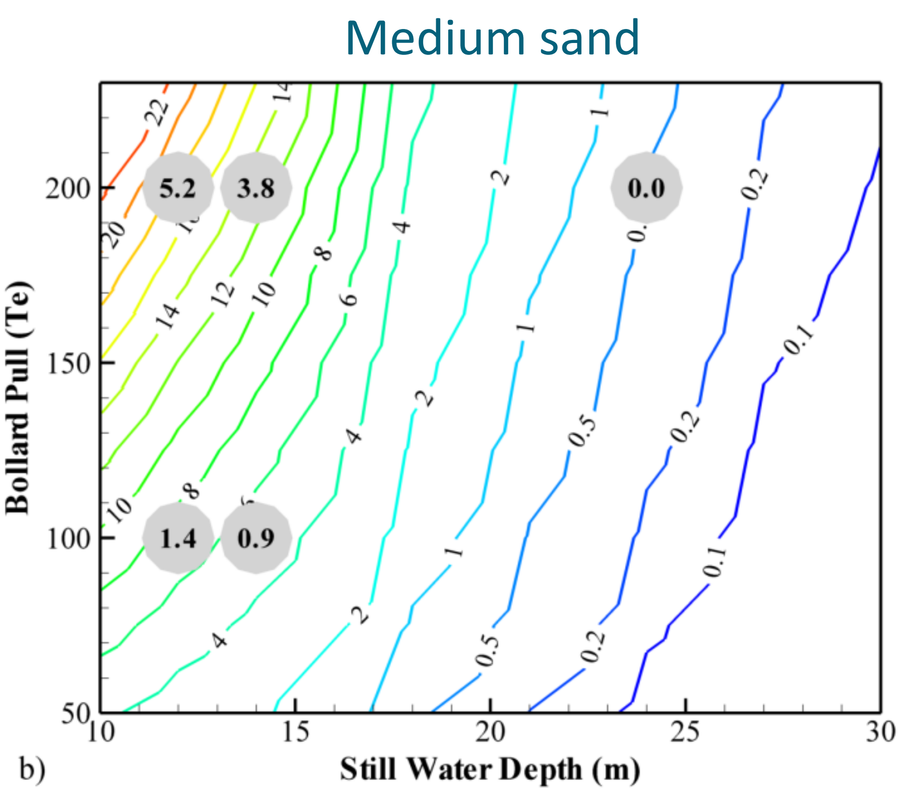
Maximum Scour Rate and Shear





Summary of Scour Rates

Bed	Case	Rate (m/s)	Depth (m)	Bollard Pull (Te)	10 min. Scour (cm)	20 min. Scour (cm)	30 min. Scour (cm)	Avg. dz/dt (cm/min)	Max. dz/dt (cm/min)	Max. Scour (cm)
Fine Sand	A1	0	12	100	50.6	96.8	139.3	4.6	5.3	
	A3	0	12	200	201.6	323.3	452.5	15.1	23.7	
	A5	0	14	100	33.1	62.1	87.6	2.9	3.5	
	A7	0	14	200	125.1	203.9	260.7	8.7	16.7	
	A9	0	24	200	0.5	0.9	1.4	0.05	0.05	
	B1	200	12	100						46.3
	B3	200	12	200						159.6
	B4	200	24	200						0.5
Med. Sand	A2	0	12	100	13.6	26.8	39.7	1.3	1.4	
	A4	0	12	200	48.1	93.6	136.8	4.6	5.2	
	A6	0	14	100	8.8	17.3	25.4	0.8	0.9	
	A7	0	14	200	35.5	66.9	95.0	3.2	3.8	
	A10	0	24	200	0.0	0.0	0.1	0.003	0.003	
	B2	200	12	100						11.5
Soft Clay	C3	0	12	100	52.4	96.9	135.7	4.5	5.7	
	C6	0	24	100	0.0	0.0	0.0	0.0	0.0	
	D3	400	12	100						76.2
Med. Clay	C1	0	12	100	8.6	16.9	25.0	0.8	0.9	
	C4	0	24	100	0.0	0.0	0.0	0.0	0.0	
	D1	400	12	100						12.2
Hard Clay	C2	0	12	100	2.0	3.9	5.9	0.2	0.2	
	C5	0	24	100	0.0	0.0	0.0	0.0	0.0	
	D2	400	12	100						2.7

Conclusions

- The scour can be backfilled by deposition as the ship makes headway; however, the depth of sediment disturbance is significantly greater than the final scour trench depth
- Irregular tow operations (e.g., occasional high thrust in shallow water) can create conditions wherein large scour holes are generated
- In situations where scour is predicted to be problematic, two tow vessels, one to each side of the trench could be used with each vessel operating at one-half the bollard pull required by the single vessel
- The width of the predicted scour holes is generally consistent with observed scour holes reported to Coldwater by DeepOcean
  - Of the order of 20 m x 20 m across and 3 to 5 m deep

For More Information

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