JIP OSCAR - Project Plan

Deltares
Enabling Delta Life
Delft Hydraulics

Joint Industry Project: Offshore SCour Assessment and Remedial Measures

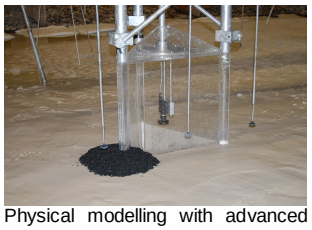
Executive summary

Scour around jack-up footings is a known phenomenon. However, no distinct guidelines are available for scour assessment, **scour prediction and scour protection** design for jack-up footings. By improving the understanding of the phenomenon of scour the operational risks, the time and costs for site preparation and for monitoring could be significantly reduced.

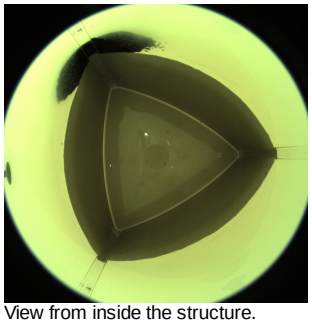
Deltares | Delft Hydraulics* is starting a joint research project to tackle scour assessment for offshore structures with a focus on **jack-up platforms**.

The main **objectives** of this JIP are to improve the understanding of scour around jack-up foundations (individual legs, mat-supported) and to obtain ready-to-use practical tools which incorporate knowledge and guidelines for scour management and scour friendly jack-up design.
The **scope of work** comprises four basic work packages (WP). WP 5 is optional and depends on the number of participants.

- WP 1: Desk assessment: Literature review, **standard recipe** for scour-related **site assessments**.
- WP 2: **Systematic physical model testing**: Test program comprises variation of hydraulic conditions, penetration depth, orientation, foundation types (mat-supported, individual legs), scour protection, detailed measurements of velocities and scour.
- WP 3: **PC tool "OSCAR – The scour manager"**: Development of easy-to-use software with comprehensive manual for various stages of the jack-up site assessment: scour prediction, design of protection (loose gravel).
- WP 4: **Field case workshop**: Application of the knowledge gained in this JIP and the PC tool in field cases.
- WP 5: Numerical modelling: Simulation of the water motion around the foundation, comparison with laboratory measurements, computation of scour-related hydrodynamic characteristics.



Physical modelling with advanced online scour monitoring. Camera mounted inside the structure captures images during testing.

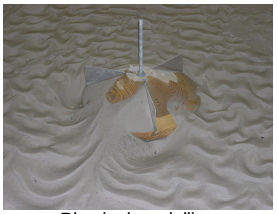


View from inside the structure.

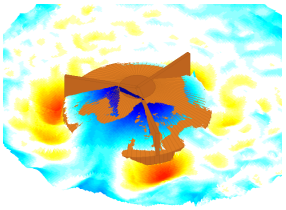
The deliverables are progress reports, desk study report, physical model testing report, numerical modelling report and the computer program "OSCAR – The scour manager" including user manual.

The **participant fee** is Euro 50,000 (for oil & gas companies, jack-up owners, shipyards) and Euro 25,000 for other companies (intended for small companies, Deltares takes a reasonable decision based on the application). JIP OSCAR will be started on **1 October 2008** (deadline for registration). For late participants the fee will be increased by Euro 10,000 (assignment not later than 31 May 2009) and +Euro 20,000 in case of assignment after 1 June 2009. Intermediate and final results will be presented and discussed during four progress meetings. JIP OSCAR will be completed in March 2010.

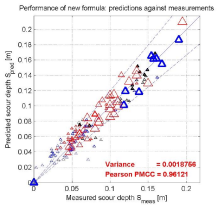
Registration is kindly requested not later than 1 October 2008. Please return the signed contract to Deltares | Delft Hydraulics, attention Mr. D. Rudolph or by email (daniel.rudolph@deltares.nl).



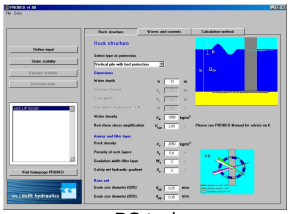
Physical modelling



Scour measurements



Analysis and Interpretation



PC tool

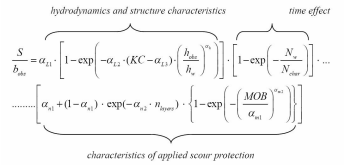
* Delft Hydraulics, GeoDelft, the Subsurface and Groundwater unit of TNO and parts of Rijkswaterstaat have joined forces in a new independent institute for delta technology, Deltares. Deltares combines knowledge and experience in the field of water, soil and the subsurface.

Background

Scour around jack-up footings is a known phenomenon. However, no distinct guidelines are available for scour assessment, scour prediction and scour protection design for jack-up footings. By improving the understanding of the phenomenon of scour, operational risks, time and costs for site preparation and for monitoring could be significantly reduced.

Deltares | Delft Hydraulics has been involved in numerous scour assessments for offshore structures. In a large number of consultancy projects it was found that hardly any systematic data are available on the behaviour of jack-ups in scour sensitive environments. Site assessments are often carried out as a desk assessment on the basis of empirical formulae regarding bed mobility and some crude rules of thumb. The accuracy of the scour prediction is often limited. Only occasionally, there is the opportunity to carry out structure-specific and site-specific laboratory experiments.

Systematic research has been carried out in the past (e.g. Sweeney et al. 1988) and more recently (e.g. Rudolph et al. 2005). Physical modelling was used to generate a large dataset of scour measurements for tubular legs and spud cans with a triangular base. This resulted in new scour prediction formulae. Reference is made to papers by Rudolph et al. (2006), Rudolph & Raaijmakers (2007) and Raaijmakers & Rudolph (2007).



The new design formulae (which are applicable for tubular legs and spud cans with a triangular base) largely improved the prediction capabilities.

For jack-up operations this means that scour related risks can be much better assessed in all operational phases. In addition to the risk aspect, we are convinced that – by applying new prediction techniques – scour management and remedial measures can be much more cost and time efficient.

Objectives

The main objectives of this JIP are

- to identify crucial points in scour management
- to obtain a systematic data base of scour measurements of various types of jack-up designs including the effectiveness of remedial measures
- to derive guidelines for scour friendly jack-up design
- to develop prediction tools for scour depths around and below spud cans
- to set-up a scour management tool (programme "OSCAR – the scour manager") including scour prediction and conceptual design of remedial measures

The intention of this JIP is to obtain products/results which are practically relevant. However, it should also be noted that this JIP has a clear research and development character.

Scope of work

The proposed scope comprises 5 work packages (WP). WP 5 is optional and depends on the number of participants (at least 12).

- WP 1: Desk assessment: Literature review, development of a standard approach for scour-related site assessments.
- WP 2: Systematic physical model testing: Test program comprises variation of hydraulic conditions, penetration depth, orientation, foundation types (mat-supported, individual legs), scour protection, detailed measurements of velocities and scour.
- WP 3: PC tool "OSCAR – The scour manager": Development of easy-to-use software with comprehensive manual for various stages of the jack-up site assessment: scour prediction, design of protection (loose gravel).
- WP 4: Field case workshop: Application of the knowledge gained in this JIP by considering selected field cases.
- WP 5: Numerical modelling: Simulation of the water motion around the foundation, comparison with laboratory measurements, computation of scour-related hydrodynamic characteristics.

The approach (technical details) for these five work packages is described below. The allocation of budget to these work packages depends on the number of participants and the total available budget. Further below, an overview is provided regarding the budget allocation for a number of financial scenarios. The determination of priorities and the distribution of budget was based on discussions with participants.

Work package 1: Desk assessment

The objectives of WP 1 are to

- to summarize existing literature
- to define a standard approach for scour assessments for jack-ups

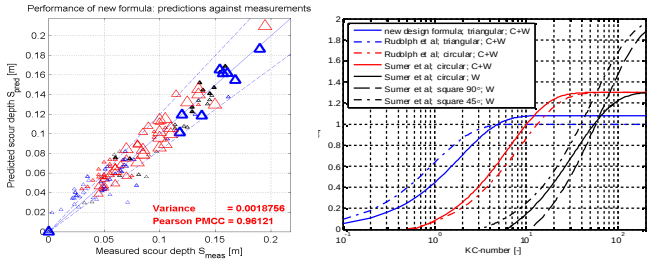
The literature review will comprise a summary and an evaluation of published jack-up related scour research. We will focus on the initiation of seabed motion, scour depth predictions, time scale of scour development and scour protection measures. Additional input from the participants is highly appreciated.

The second part of WP 1 will be to define a standard desk assessment approach. Scour assessments usually comprise 3 basic steps:

1. Check whether the seabed is mobile.
2. In case the seabed is mobile: calculate the maximum scour depth.
3. In case the predicted scour depth is unacceptable: design remedial measures.

The existing theoretical knowledge on the mobility of bed material is reasonably good. There are several validated

formulae. We will discuss the differences and which effect this has on the scour assessment. Validated formulae will be transferred into engineering design graphs which are easy to read and apply. Finally, we will propose one (standard) method and summarize all relevant formulae and input parameters. These formulae will later be implemented in the PC tool "OSCAR – The scour manager".

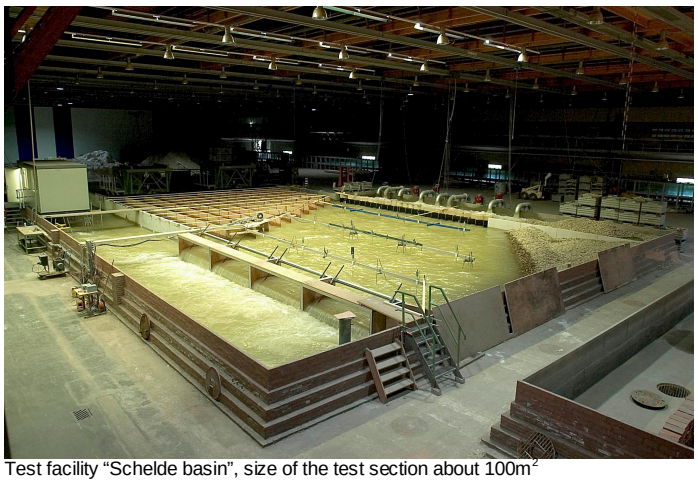


Example for data fitting and non-dimensional analysis

Furthermore, we will discuss which monitoring techniques or combinations of techniques have proven to be suitable and where improvements are needed in future. The evaluation of monitoring techniques is closely related to quality assurance (e.g. contractor has to prove that scour protection was properly applied) and to the decision making processes in the scour management (e.g. how certain are ROV images as basis for urgent and costly remedial actions). Here, an active input of the participants is requested.

Work package 2: Systematic physical model testing

Systematic physical model testing is the most appropriate way to improve the understanding of scour processes and to derive tools for the scour assessment. The situations in field cases are often very complex (e.g. bed not homogeneous) and the environmental conditions cannot be controlled. Numerical modelling of water movement close to a structure is still in its infancy and requires calibration and validation material (from physical modelling or field measurements).



Test facility "Schelde basin", size of the test section about 100m^2

The test program will cover the following:

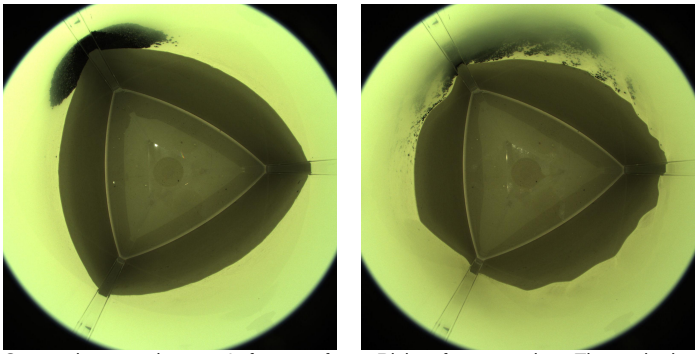
- scour development with time (unprotected structures)
- 3 typical (existing) jack-up designs
- different orientations
- different penetration depths
- different water depths
- different angles between waves and current
- different hydraulic conditions (combinations of waves and currents)
- remedial measures: loose gravel

All tests will be carried out in one of Deltares | Delft Hydraulics test facilities. The bed material will consist of fine sand.

The designs to be tested will be selected by the participants (1st progress meeting). Deltares | Delft Hydraulics will propose a test program. The envisaged number of jack-up designs and the number of tests will depend on the total budget, see also further below. The minimum number of designs to be studied is two (at least 6 participants). If there are at least 2 participants interested in a mat-supported design, one of the designs will be of the mat-supported type.

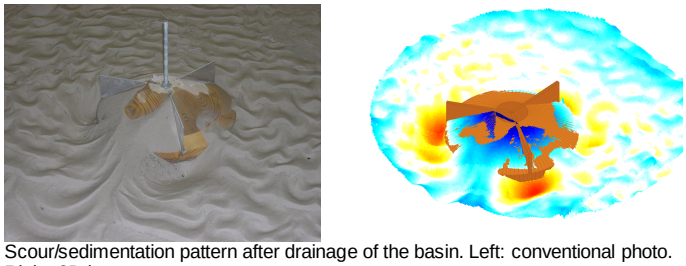
Scour development with time and scour below the jack-up foundations will be one of the core aspects to look at. For monitoring of the scour process we will install a camera system in all foundations to be considered (if not impossible due to technical limitations). In this way we will be able to follow scour development online. Videos/photos will be made and processed.

Physical modelling with advanced scour monitoring technique. A video camera is mounted inside the structure and captures images. The scour development can be followed online outside the facility.



Captured camera images. Left: start of test. Right: after some time. The seabed – water interface can be determined automatically. This provides quantitative information on the scour development with time.

During all tests we will measure wave and current characteristics in the test section and at selected positions close to the structures. After the tests, scour patterns will be scanned with a 3D laser technique which allows full recording of the dimensions of the scour hole (not only maximum depth and horizontal extent). An example of a scan is shown below.



Scour/sedimentation pattern after drainage of the basin. Left: conventional photo. Right: 3D laser scan.

Model scales will be approximately 1:30 to 1:50. Field measurements have indicated that very realistic results can be obtained with range of scales (Bos et al. 2002; Raaijmakers et al., 2007).

The analysis of all measurements will be carried out using non-dimensional parameters. This allows for a transfer of modelling results to a range of prototype scales. For example, a model footing with a diameter of 0.4m can be interpreted as a prototype footing of 12m diameter (scale 1:30) but also as a diameter of 16m (scale 1:40).

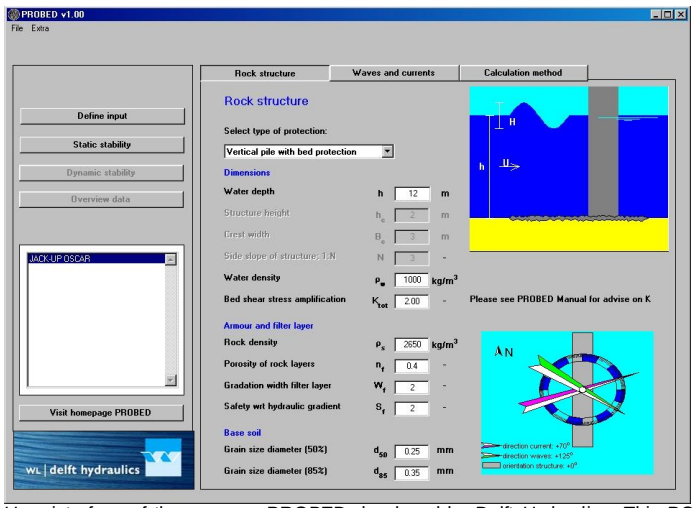
The aim of the analysis is to develop scour prediction formulae for each investigated jack-up design which describe the scour around the structure depending on hydraulic conditions, platform orientation and penetration depth.

The analysis will be based on a generic formula (applicable for all footings). For each footing individual sets of fit coefficients will be derived. This approach (generic formula + structure dependent fit coefficients) has proven to work satisfactorily (Raaijmakers & Rudolph, 2007).

Results of wave, current, scour measurements and photo/video documentation will be compiled in the test report and will be made available to the participants.

Work package 3: PC tool "OSCAR – The scour manager"

The knowledge gained in WP 1 (desk assessment), 2 (physical modelling) and 5 (numerical modelling) will be implemented in the computer program "OSCAR – The scour manager". This program intends to support site assessments and the decision making process with respect to scour related issues.

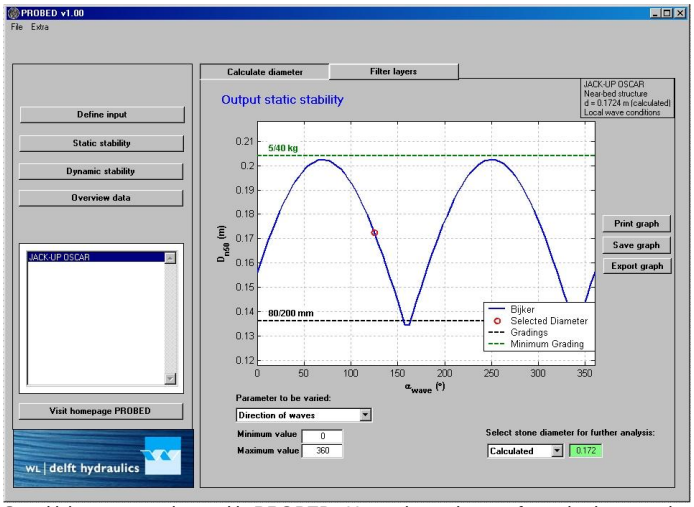


User interface of the program PROBED developed by Delft Hydraulics. This PC tool supports the design of granular bed protections. "OSCAR – The Scour Manager" will have a similar structure.

The program will come with a modern user interface and a user manual. OSCAR will be delivered as stand-alone program which can be run on any standard PC. The computational time for scour predictions will be in the order of a few seconds.

The following modules will be implemented:

- Selection of the structure. A pull-down menu will be available to select a jack-up design from the library. Future jack-up designs can be added easily to the library (after determining fit coefficients).
- Environmental conditions. Computation of offshore wave parameters depending on wind speed, duration, water depth etc. One-dimensional wave modelling (offshore – nearshore). Computation of the maximum wave height based on the significant wave height also for shallow water where the classical Rayleigh distribution is not valid anymore. Non-linear wave theory will be implemented.
- Bed mobility. Compute whether the bed material is mobile for a single condition or a user defined time series of conditions. Waves only, currents only and interaction of waves and currents.
- Risk assessment (probability of occurrence). Computation of the probability that the selected design condition will occur during the operational period. How likely is it that a storm with a 1 year return period occurs during an operational period of 3 months?
- Maximum scour depth prediction. Maximum scour depths around the structure for a given environmental condition. This is based on the analysis results of WP 2 (physical modelling) and the comparison with WP 3 (numerical modelling). The prediction is valid for an unprotected bed.



Sensitivity computations with PROBED. Here: dependency of required stone size on wave direction. "OSCAR – The Scour Manager" will have comparable functionality with respect to sensitivity analyses.

- Operational scour prediction. For a user defined event (e.g. a storm or a tidal cycle) scour depth development with time is computed and graphically displayed. This module can be used as a scour forecast. It should be noted that the time information will only become available if the jack-up designs can be equipped with a camera.
- Remedial measures. Focus will be put on scour protection consisting of loose gravel because this type of protection is reasonably well validated. Depending on the executed tests, this module will provide indications on the required extent, layer thickness and size of the protection. The user can distribute material around the spudcan and check the efficiency of this

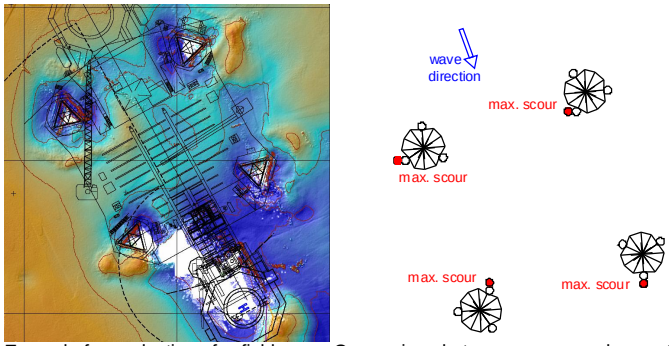
protection layout. A damage estimate will be provided for a given design condition.

The input, intermediate computations and the results can be saved per case/scenario. Output files will be available in ASCII format and as pdf.

Work package 4: Field case workshop

We consider it important to evaluate the new knowledge in a practical situation. This will be done by means of a half-day work shop.

The participants are requested to send field cases beforehand to Deltares | Delft Hydraulics. A selection will be prepared for the workshop. Participants apply the new PC tool in the field cases. Plenary discussions will be held. The advanced options of the PC program will be explained and hands-on exercises will be made. After the workshop selected field cases and discussed items will be transferred into examples with possible solutions which can be used as guideline for the unexperienced or infrequent user.



Example for evaluation of a field case. Comparison between survey and expected scour depth.

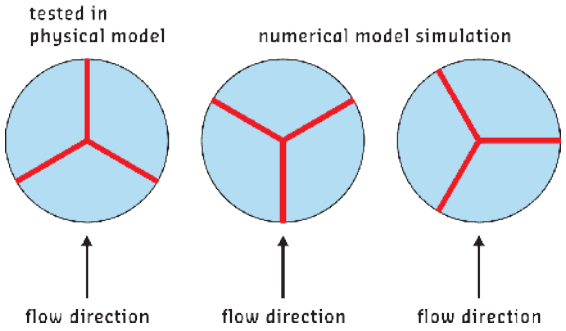
Work package 5: Numerical modelling

Since numerical modelling of water motions close to an offshore structure is still in its infancy and the practical applicability of the simulations cannot be guaranteed, this part of the JIP will be carried out by a student as part of his master thesis and only in case of at least 11 full participants (see allocation of budget further below). Deltares | Delft Hydraulics will provide guidance and support.

We will use our inhouse available CFD packages (ComFLOW, CFX). Essentially, this WP includes 2 steps:

1. validation of the numerical model by simulating selected laboratory experiments
2. computation of hydrodynamics for conditions which were not covered in the laboratory experiments

Three-dimensional numerical models will be set up for selected jack-up designs. Transient computations will be run for two selected hydraulic conditions. Flow velocity patterns will be analysed and compared with measurements taken during the laboratory experiments.



Example: Images show a simplified top view of a spud can. Physical model covers one direction (left image). Physical modelling of many direction would be very time consuming. Numerical modelling of additional directions in order to determine vortex strength and turbulence for other directions.

The present CFD codes are not yet able to combine waves, current, turbulence, partial slip and sediment transport. In view of that we will investigate a simplified approach: We will check whether instantaneous and time-integrated or time-average hydrodynamic load patterns can be used as indicator for scour development.

Numerical simulations will be carried out to investigate two aspects:

- effect of structure orientation on hydrodynamic load pattern (and thus on the expected position of maximum scour)
- effect of structural modification (e.g. add skirts, wing tanks, stiffness plates) on hydrodynamic load pattern.

The results will be summarized and its practical relevance will be evaluated.

Deliverables

WP 1: Desk assessment
- Report on literature review
- Recipe for scour assessment
- Engineering design graphs

WP 2: Physical modelling
- Test procedures for physical modelling, including test program and selection of designs
- Concise progress reports depending on execution of model tests (photos, videos, animations will be made available on a website)
- Report on model testing (incl. analysis, interpretation, conclusions)

WP 3: PC tool
- Progress reports on functionality of the new software program, user interface, implementation of technical knowledge
- Test version (beta release)
- Version 1.0 of "OSCAR – The scour manager" including user manual

WP 4: Field case workshop
- Selected field cases and PC tool computations summarized as examples, to be added to the user manual

WP 5: Numerical modelling
- Progress reports depending on simulation results
- Final report

Finally, an overall concise management summary will be provided.

All deliverables will be made available as hard copies and in digital format (pdf). The program "OSCAR – The scour manager" will be provided as a stand alone software (executable *.exe for windows).

Participants paying the full fee receive 4 licenses. Participants paying a reduced fee receive 1 license. Additional licenses can be purchased.

During project execution digital documents can be downloaded from the OSCAR-website. Upon completion of the JIP (March 2010), the participants will receive all documents on CD-ROM/DVD.

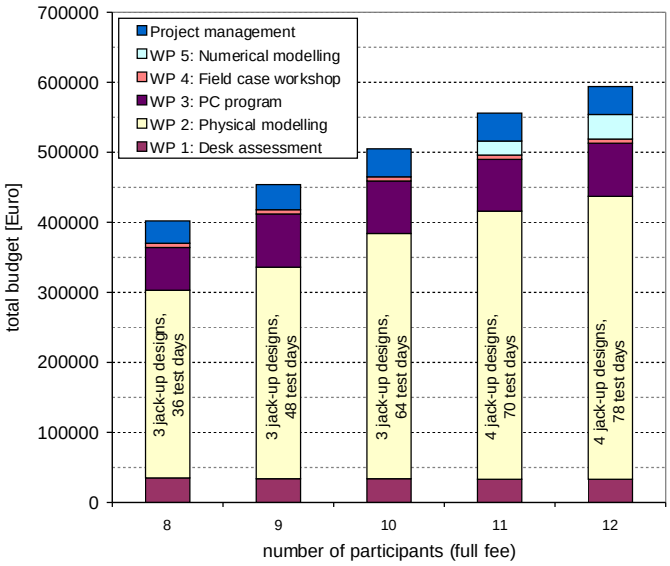
Costs

The participation fees are
- Euro 50,000 (regular fee) for oil companies, jack-up owners and shipyards
- Euro 25,000 (reduced fee) for other companies such as small engineering companies, application on request, Deltares takes a reasonable decision

The payment schedule is as follows:
- 50% end of 2008 (within 30 days after receipt of invoice)
- 50% second half of 2009 (within 30 days after receipt of invoice)

Late participants (registration after 1 October 2008) are welcome. The fee for late participants is the regular fee + Euro 10,000 (assignment not later than 31 May 2009) and +Euro 20,000 in case of assignment after 1 June 2009.

The total budget determines the allocation of the budget to the work packages. The allocation of budget for the scenarios 8 to 12 participants is shown below. Depending on the available budget, the number of jack-up designs and the number of tests will be increased. In case of at least 11 participants (full fee), WP 3 will be carried out as well.

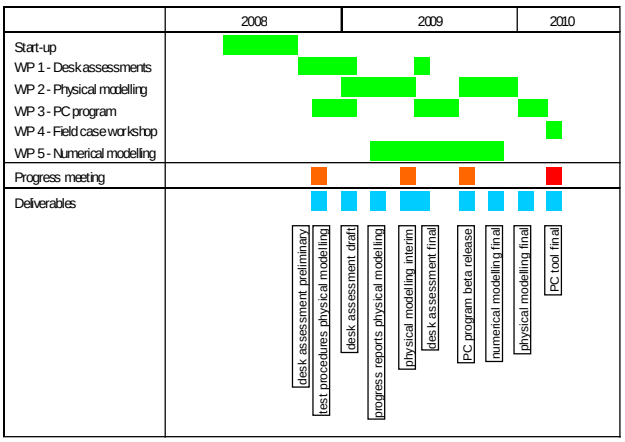


The minimum number of participants is the equivalent of 6 full fees. Presently we envisage about 10-11 participants.

Time schedule

JIP OSCAR will be officially started on 1 October 2008. The project duration is 1.5 years. Registration is requested until 1 October 2008.

The preliminary time schedule is shown below.



Four progress meetings will be held. The following is planned:
- November 2008: Singapore (in connection with the jack-up conference).
- May 2009: Houston (in connection with the OTC).
- September 2009: London (in connection with the jack-up conference).
- March 2010: Delft

Contract

Registration is kindly requested not later than 1 October 2008. Please send the signed contract to Deltares | Delft Hydraulics, fax. +31 15 285 8712 (attention Mr. D. Rudolph) or by email (daniel.rudolph@deltares.nl).

Contact information

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