GL Noble Denton

TECHNICAL POLICY BOARD

SEABED AND SUB-SEABED DATA REQUIRED FOR APPROVALS OF MOBILE OFFSHORE UNITS (MOU)

0016/ND

6 Dec 10	6	MJRH	Technical Policy Board
31 Mar 10	5	MJRH	Technical Policy Board
16 Dec 08	4	MJRH	Technical Policy Board
7 Dec 07	3	MJRH	Technical Policy Board
1 Mar 03	2	VMM	Technical Policy Board
Jan 02	1	VMM	Technical Policy Board
Jan 87	0	MJR	Technical Policy Board
Date	Revision	Prepared by	Authorised by

PREFACE

This document has been drawn with care to address what are likely to be the main concerns based on the experience of the GL Noble Denton organisation. This should not, however, be taken to mean that this document deals comprehensively with all of the concerns which will need to be addressed or even, where a particular matter is addressed, that this document sets out the definitive view of the organisation for all situations. In using this document, it should be treated as giving guidelines for sound and prudent practice on which our advice should be based, but guidelines should be reviewed in each particular case by the responsible person in each project to ensure that the particular circumstances of that project are addressed in a way which is adequate and appropriate to ensure that the overall advice given is sound and comprehensive.

Whilst great care and reasonable precaution has been taken in the preparation of this document to ensure that the content is correct and error free, no responsibility or liability can be accepted by GL Noble Denton for any damage or loss incurred resulting from the use of the information contained herein.

CONTENTS

1 INTRODUCTION

1.1 These guidelines describe the seabed and sub-seabed data required by GL Noble Denton to assess the suitability of locations for self-elevating (jack-up) platforms, anchor installation and performance assessments.

1.2 It is not feasible to produce a rigorous procedure applicable to all current and future operating areas; and, for this reason, these guidelines are not intended to overrule or contradict local experience or knowledge. Additionally, there are from time to time likely to be exceptional cases in which the stated guidelines would be inappropriate.

1.3 The purpose of the site survey is to provide data with which to evaluate potential foundation hazards.

1.4 Further details on jack-up installation and operations can be found in the current version of report 0009/ND entitled “Self-Elevating Platforms – Guidelines for Elevated Operations” which, together with other GL Noble Denton Guidelines can be downloaded from www.gl-nobledenton.com.

1.5 These guidelines are intended to lead, in part, to an approval by GL Noble Denton. Such approval does not imply that approval by designers, regulatory bodies, harbour authorities and/or any other party would be given.

1.6 Geophysical data alone is insufficient to perform a site specific assessment of the foundation conditions and should be complimented by geotechnical coring data.

1.7 Reconnaissance of soil conditions is required in order to begin to establish design criteria for the following types of mobile rig and drilling operations:

- Jack-up rigs
- Anchoring of semi-submersible drilling rigs (or jack-ups for stand-off locations)
- Conductor / casing setting for any rig type
- Initial spudding of drilling equipment, including guidebase stability, from any rig type
- Top-hole drilling

1.8 This guideline does not provide specific guidance on the seabed and sub-seabed data required for fixed offshore structures. However, it is noted that most of the requirements detailed herein are applicable for assessing the suitability of locations for the initial emplacement of fixed (non-piled) seabed structures.

1.9 Revision 2 incorporated minor changes to the text.

1.10 Revision 3 superseded and replaced Revision 2 dated March 2003. This Revision incorporated minor changes to the text.

1.11 Revision 4 superseded and replaced Revision 3 dated December 2007. This Revision included reformatting and removal of references to NDI (Noble Denton International).

1.12 Revision 5 superseded and replaced Revision 4. The only change was rebranding as GL Noble Denton.

1.13 Revision 6 supersedes and replaces Revision 5. The changes are:

- Further details provided on the investigation and requirements in Section 2.3.1. 6
- Modifications to Table 2-1, Table 2-3 and Table 2-4.

2 DATA REQUIREMENTS

2.1 GENERAL REQUIREMENTS

Figure 2.1 presents the general site investigation requirements for MOUs. Table 2-1 summarises various foundation risks relevant to MOUs that require investigation during a location assessment. Methods for evaluating these risks and procedures for minimising and/or preventing these risks from occurring are also summarised in Table 2-1.

2.1.1 LOCATION CO-ORDINATES

The co-ordinates of the location expressed in terms of degrees, minutes and seconds of latitude and longitude are required. Latitude and longitude co-ordinates should be given to at least two, or preferably three, decimal places of precision and should also include details of the Datum and Projection used (e.g. International Spheroid, European Datum 1950 (ED50), WGS84, etc.).

2.1.2 LOCATION WATER DEPTH

The water depth at the location, referred to Chart Datum (CD) or Lowest Astronomical Tide (LAT), is required.

2.2 GEOPHYSICAL INVESTIGATIONS

2.2.1 SURVEY LINE SPACING

2.2.1.1 This is determined by the key objectives of the site survey and the nature of the intended drilling rig. Table 2-2 and Figure 2.3 show typical survey line plans for a jack-up rig and a semi-submersible rig. These line plans are for guidance only and should be modified to meet the survey needs and the local foundation conditions.

2.2.1.2 In addition, tie lines should be acquired to selected nearby geotechnical boreholes or coring locations. The tie lines are necessary for the reliable prediction of anchoring / foundation conditions, potential geohazards and seabed obstructions (such as wrecks, anchor scars, shallow gas pockmarks, mud volcanoes, etc.).

2.2.1.3 For independent leg drilling units (jack-ups) where the seabed topography and/or shallow soils are complex then additional lines at a narrower spacing may be necessary in the immediate vicinity of the proposed spudcan positions.

2.2.1.4 For floating rigs, where anchors are to be deployed, the survey area should encompass the expected limit of any anchor plus 1 km.

2.2.2 BATHYMETRIC SURVEY

2.2.2.1 An appropriate bathymetric survey should be supplied for an area of approximately 1 km squared centred on the proposed location. Line spacing of the survey should be typically not greater than 100 metres x 250 metres over the survey area. For independent leg units with large foundations and mat units, interlining is to be performed within an area 200 metres x 200 metres centred on the location. This should be complemented by at least two orthogonal lines running 1 km in each direction from the proposed location. Interlining should have spacing not exceeding 25 metres x 50 metres.

2.2.2.2 Interlining should be performed if any irregularities are detected.

2.2.3 SEABED SURFACE SURVEYS

2.2.3.1 Seabed surface survey shall be completed utilising side scan sonar, swathe bathymetry and high resolution echosounder techniques[1]. The survey should be of sufficient competency to identify obstructions and seabed features and should cover the immediate area of the intended location (normally a 1 km square). The slant range selection shall give a minimum of 100% overlap between adjacent lines. Each jack-up rig site survey should include a magnetometer survey to identify any buried pipelines, cables or other metallic debris located below the mudline. A magnetometer survey is considered less crucial for semi-submersible installations, however should the presence of any pipelines, cables or other metallic debris be anticipated at a location, a magnetometer survey should be performed in the areas where the mooring system is in, on, or adjacent to, the seabed.

2.2.3.2 Seabed surface surveys can become out-of-date, particularly in areas of construction/drilling activity or areas with mobile sediments. As a general rule, most site surveys will become out-of-date after six months and will require the sidescan sonar and swathe bathymetry to be re-run.

2.2.3.3 At locations where a jack-up rig will be operating in close proximity to existing installations, an additional seabed survey should be carried out immediately prior to the jack-up rig installation.

[1] Swathe bathymetry is now available in portable units and is installed on most survey vessels so should be used as standard on all survey projects. Due to constraints imposed by calibration and processing requirements (single point obstructions may be removed in processing), conventional high-resolution bathymetry and side scan sonar should be run in conjunction.

2.2.4 SHALLOW SEISMIC SURVEYS / SUB-BOTTOM PROFILING

2.2.4.1 The principal aim of the seismic survey is to reveal the general near-surface geological structure and indicate reflectors which may represent a change in soil characteristics and/or stratigraphy. This requires the correlation of the seismic data with soil boring(s) (existing) in the vicinity. Shallow seismic data may also reveal any shallow gas that may be present at a particular location.

2.2.4.2 The seismic acquisition equipment should be capable of providing detailed information to a depth greater than or equal to 30m below mudline or the anticipated footing penetration plus 1.5 times the footing diameter. Drop cores / grab samples are also required to assist in geophysical interpretation.

2.2.4.3 The report should include, but not be limited to, at least two vertical cross-sections passing through the drilling location showing all relevant reflectors and allied information. Due to the qualitative nature of seismic surveys it is rarely possible to conduct analytical foundation appraisals (jack-up leg penetration analyses or well conductor / casing design) based purely on the data obtained.

2.2.4.4 Line spacing of the survey should, typically, not be greater than 100 metres x 250 metres over the survey area.

2.2.4.5 The shallow seismic survey shall be interpreted by the competent persons who were responsible for performing the work. Every effort should be made in the interpretation to comment on the soil type(s) and strength(s); this will require correlation with a borehole in the vicinity of the survey and some degree of local experience.

2.2.4.6 It should be noted that a high-resolution geophysical survey alone would not provide adequate information to assess rig-leg penetration and potential for punch-through.

2.2.5 GEOPHYSICAL DATA ACQUISITION

Details of resolution and approximate penetrations of different geophysical data acquisition techniques are provided in Table 2-2.

2.3 GEOTECHNICAL INVESTIGATIONS

2.3.1 REQUIREMENTS

2.3.1.1 Site-specific geotechnical data acquisition is recommended at locations where no relevant geotechnical data is available, the foundation conditions are known to be potentially hazardous (possible layered strata) or where the shallow seismic data cannot be interpreted with any certainty.

2.3.1.2 The number of boreholes required at a site should take account of the potential lateral variability of the soil conditions, regional experience and the geophysical investigation. At geologically complex 6 locations more than one borehole can be required. When a single borehole is performed, the preferred location is at the centre of the leg pattern at the intended location.

2.3.1.3 In certain limited circumstances a borehole may not be required if there is sufficient relevant historical data and/or geophysical tie lines to boreholes in close proximity to the proposed jack-up location and if no potential hazards exist on the basis of the inferred strength parameters and layer thicknesses, including consideration of the potential variability of these parameters.

2.3.1.4 The geotechnical investigation should comprise a minimum of one borehole to a depth of 30 metres below the seafloor or the anticipated penetration depth plus 1.5 times the spudcan diameter, whichever is greater. The site investigation contractor or the client representative should ensure that the borehole depth satisfies this requirement prior to termination of the borehole; this can be achieved by performing a "real time" spudcan penetration analysis during the site investigations. Conservative assumptions must be made if the data obtained is limited at the time of the penetration analysis (i.e. limited laboratory test data) in order to ensure that the borehole is sufficiently deep case should further data obtained from the soil samples indicate lower strengths or subsequent analysis indicate deeper predicted penetrations.

Note that GL Noble Denton will only confirm that a borehole has been progressed to sufficient
depth on the basis of calculations performed by one of GL Noble Denton's geotechnical 6
engineers for the particular jack-up unit(s) being assessed. The final borehole depth may, however, be inadequate for subsequent assessments of units that apply higher preload bearing pressures.

2.3.1.5 All layers shall be adequately investigated, including any transition zones between strata, such that the geotechnical properties of all layers are known with confidence and that there are no significant gaps (usually not more than 0.5m) in the site investigation record.

2.3.1.6 The site investigation report should include borehole logs and piezocone penetrometer test (PCPT) records (when acquired), together with interpreted geotechnical soil parameters.

2.3.1.7 The borehole logs should include, as a minimum, the soil stratigraphy, all laboratory shear strength measurements (clays), undrained shear strength (clays) or relative density (sands) profiles inferred from PCPT, moisture content, unit weight and Atterberg Limits. Additionally the cone tip resistance corrected for pore pressure effects shall be presented on the borehole log. These should be plotted on the same page and on appropriate scales.

2.3.1.8 The results of the cone penetration tests shall also be presented separately in terms of graphs giving the cone tip resistance (both measured values and values corrected for pore pressure effects), local sleeve friction and pore pressure versus depth. Additionally the friction ratio and the pore pressure ratio shall be presented.

2.3.1.9 A geotechnically competent person shall be responsible for determining the appropriate geotechnical soil parameters. For spudcan penetration analyses and anchor holding assessments the site investigation report should include as a minimum:

a. profiles of undrained shear strength (su) versus depth for cohesive soils (clays) and the corresponding stress-strain curve and cell pressure of the triaxial compression test;

b. effective stress strength parameters (ϕ') for cohesionless soils (sands);

c. both measured and interpreted piezocone penetration test (PCPT) records (when acquired);

d. appropriate soil classification tests including Atterberg limits (clays), water contents, particle size distributions, unit weights, relative densities (sands), sensitivity (clays), carbonate contents (carbonate soil), etc.;

e. The overconsolidation ratio (OCR) for cohesive soils should be determined, particularly where foundation fixity is an issue.

2.3.1.10 Where more comprehensive analyses are required, additional laboratory testing to determine the cyclic/dynamic behaviour and shear moduli of the soils may be required. Such analyses are more likely for suction piles and gravity base structures or for sensitive soils where the soil strength is anticipated to reduce significantly during cyclic loading.

2.3.2 SAMPLING / TESTING

2.3.2.1 The site investigation should comprise undisturbed soil sampling and/or piezocone penetrometer testing or a combination of the two methods. Table 2-3 and Table 2-4 show general guidelines on soil surveying, sampling, and testing.

2.3.2.2 If anchor holding is critical then consideration should be given to obtaining and testing soil samples at specific anchor locations.

ESTABLISH STATUTORY REQUIREMENTS

ASSIMILATE AVAILABLE GEOLOGICAL AND GEOTECHNICAL FIELD DATA AND COMPARE WITH HISTORICAL MOU PERFORMANCE
DESK STUDY

GEOPHYSICAL SITE SURVEY REQUIREMENTS

JACK-UPS

ESSENTIAL 1 km x 1 km SURVEY (CENTRED ON PROSPECT) INCLUDING:

- BATHYMETRY (echo sounder, tuned transducer and swathe techniques)
- SITE CLEARANCE / SIDE SCAN SONAR SURVEY (conventional or swath, ROV survey, scanning radar imagery or divers' walk – depending on field experience)
- MAGNETOMETER SURVEY (buried metallic objects)
- SUB-BOTTOM PROFILING & SHALLOW GAS SURVEY (pinger, boomer, sparker, airgun etc.)
- DROP CORES / GRAB SAMPLES (to assist in geophysical interpretation)

SEMISUBMERSIBLES

ESSENTIAL SURVEY OVER MOORING LINE SPREAD AREA, INCLUDING:

- BATHYMETRY (echo sounder, tuned transducer and swathe techniques)
- SIDESCAN SONAR SURVEY (conventional or swathe)
- SUB-BOTTOM PROFILING & SHALLOW GAS SURVEY (pinger, boomer, sparker, airgun etc.)
- MAGNETOMETER SURVEY (buried metallic objects) – if considered necessary in the areas where the mooring system is in, on, or adjacent to, the seabed.
- DROP CORES / GRAB SAMPLES (to assist in geophysical interpretation)

OPTIONAL SURVEY REQUIREMENTS

- 3D SUB-BOTTOM PROFILING – (reduction in resolution but increased geological interpretation)
- SHALLOW GAS SURVEY – DIGITAL PROCESSING (AVO / attribute analyses techniques)

WHERE SURVEYS CANNOT BE INTERPRETED WITH CERTAINTY & USED TO CONFIRM THE SAFETY OF THE SITE, OR IN GEOTECHNICALLY PROBLEMATIC OR NEW OPERATING AREAS, THE FOLLOWING IS REQUIRED

JACK-UPS

- **SITE INVESTIGATION (SI) PROGRAMME IN ADVANCE OF FIELD DEVELOPMENT FOR JACK-UP OPERATIONS AND DESIGN OF OFFSHORE FACILITIES**
- **SINGLE OR MULTIPLE BOREHOLE INVESTIGATION USING A DEDICATED GEOTECHNICAL VESSEL**
- **BOREHOLE SI FROM THE JACK-UP WHILE ON LOCATION** (at reduced draft in benign conditions; if it is necessary to skid the cantilever, then some initial preload is required)

NOTES:

THE BOREHOLE SHOULD BE ADVANCED TO THE GREATER OF 30M AND THE ANTICIPATED SPUDCAN PENETRATION DEPTH PLUS 1.5 x THE SPUDCAN DIAMETER.

THE INVESTIGATION MAY REQUIRE VANE TESTS (gas-charged materials) AND / OR PIEZOCONE TESTS (PCPTs) (layered, sensitive or cemented materials)

SEMI-SUBMERSIBLES

- **SITE INVESTIGATION (SI) PROGRAMMED IN ADVANCE OF FIELD DEVELOPMENT FOR SEMI-SUBMERSIBLE OPERATIONS AND DESIGN OF OFFSHORE FACILITIES**
- **BOREHOLE / PCPT / VIBROCORE INVESTIGATION USING SPECIALIST VESSEL**

NOTES:

ADEQUATE GEOTECHNICAL DATA WILL BE REQUIRED FOR ANCHOR INSTALLATION AND PERFORMANCE ASSESSMENTS

APPROPRIATE AND ADEQUATE SITE DATA SHOULD BE ACQUIRED TO ENSURE SAFE MOU INSTALLATION AND OPERATION

Figure 2.1 Site Investigation Requirements For Mobile Offshore Units (MOU's)

Table 2-1 Foundation risks, methods for evaluation and prevention

Risk	Methods for Evaluation and Prevention
Installation problems	Bathymetric survey / Seabed surface survey
Punch-through	Shallow seismic survey Geotechnical site investigation and soil testing Bearing capacity analyses to assess risk of punch-through Adopt a cautious approach to preloading at the site Adopt a reduced preload, if appropriate.
Settlement under storm loading / bearing failure	Shallow seismic survey, geotechnical site investigation and soil testing Bearing capacity analyses to assess risk of settlement / bearing failure Ensure adequate jack-up preload capacity
Sliding failure	Shallow seismic survey Geotechnical site investigation and soil testing Increase vertical footing reaction (sand foundation) Modify the geometry of the footing(s)
Scour	Bathymetric survey (identify sand waves) Sample surficial seabed soils (particle size distributions) Assess seabed currents Analysis to assess potential for scour Inspect foundations regularly Install scour protection (gravel bag/artificial seaweed) Increase spudcan penetration
Geohazards (turbidite flows and mud volcanoes)	Seabed surface survey Soil sampling and other geotechnical testing and analysis
Gas pockets / shallow gas	Geophysical survey
Faults	Geophysical survey
Metal or other object, sunken wreck, anchors, pipelines, etc.	Magnetometer and seabed survey Diver/ROV inspection
Local holes (depressions) in seabed, reefs, pinnacle rocks or wooden wreck	Side scan sonar Diver/ROV inspection
Legs extraction problems	Geotechnical site investigation and soil testing Consider change in footing geometry Jetting / eductor pipe / airlifting
Footprints of previous jack-ups	Evaluate location records Consider orientating jack-up to minimise spudcan-footprint interaction 6 Consider seabed remediation: • Stomping • Dredging • Dredging and infilling Subsea podium

Table 2-2 Details of Resolution and Approximate Penetrations of Different Geophysical Data Acquisition Methods

Survey Required	Instruments	Scale of Survey	Mesh (m)	Instrument Transmission Frequency	Penetration (m)	Resolution
Bathymetry	Echo Sounder Side Scan Sonar (Swathe)	Extent of Zone Depending on Geological Structure	200 x 400 or 200 x 200 or 100 x 100	30 to 50 Hz	≈ 0	Better than 1m
Morphology	Side Scan Sonar Swathe Bathymetry			30 to 100 Hz		Obstacles smaller than 1m
High Resolution First 50-100m	Sparker			200 to 1500 Hz	Approx. 100m	Approx. 2m
	Boomer			1 to 10 kHz	50 to 100	Approx. 1 to 1.5m
	Pinger Probe			2.5 to 9 kHz	20 to 40	Approx. 1 to 1.5m
High Resolution 500 – 1000m Shallow Gas	Air Gun Water Gun Mini-Flexichoc			10 to 300 Hz	Approx. 1,000	Approx. 100m

Table 2-3 Details of Possible Soil Surveys for a Jack-up Installation

Operations Required	Number of Boreholes	Typical Penetration Required	Applicable Techniques	Average Performance	Conditions of Use
Near-Surface Seabed Corings	A series of corings on site	1 to 10m	Piston corer or vibrocorer	10 to 20 Corings a day	From Geophysical Survey Ship / geotechnical survey vessel / jack-up
Boreholes From Dedicated Survey Vessel	One sampled and / or insitu measurements	30m or predicted penetration + 1.5 spudcan diameter whichever is greater	Homogeneous Soils: Push sampler, Penetrometer or vane probe. Heterogeneous Soils: Rotary core or hammer samples.	Average Penetration 2 to 4 m/h	From Geotechnical Survey vessel during full S.I. spread.
Borehole Drilled from Jack-up	One sampled borehole	30m or predicted penetration + 1.5 spudcan diameter whichever is greater	Pushed or Piston sampler Hammer Sampler (not recommended due to significant sample disturbance)	As Above	From Jack-up during installation

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Table 2-4 In-situ and laboratory soil testing

Testing Environment	Soil Test	Soil Property
In situ	Soil Classification Tests	Visual description Water content, w Unit weight, γ
	Torvane, motorvane, pocket penetrometer[1]	Undrained shear strength, s_u
	Unconsolidated Undrained Triaxial Test (UU)	Undrained shear strength, s_u
	Piezocone Penetration Test (PCPT), Ball Penetrometer Test (BPT), T-Bar Test	By direct measurement: cone resistance, q_c; sleeve friction, f_s; and pore pressure, u Using correlations: Soil classification Relative density, D_R (cohesionless soils) Undrained shear strength, s_u (including N_{kt} factors used) Effective stress friction angle, ϕ' Others (e.g. overconsolidation ratio OCR, Elastic Modulus E)
	Field Vane Shear Test	Undrained shear strength, s_u
	Pressuremeter	Effective horizontal stress and stress history Shear strength parameters
Laboratory	Soil Classification Tests	Water content, w Atterberg limits (cohesive soils) Unit weight, γ Particle size distribution Relative density, D_R (cohesionless soils)
	Unconfined Compression Test	Undrained shear strength, s_u
	Torvane, motorvane, pocket penetrometer	Undrained shear strength, s_u
	Triaxial Test	Shear strength parameters, s_u, ϕ'
	Oedometer (1-D consolidation)	Stress history (OCR) Consolidation properties

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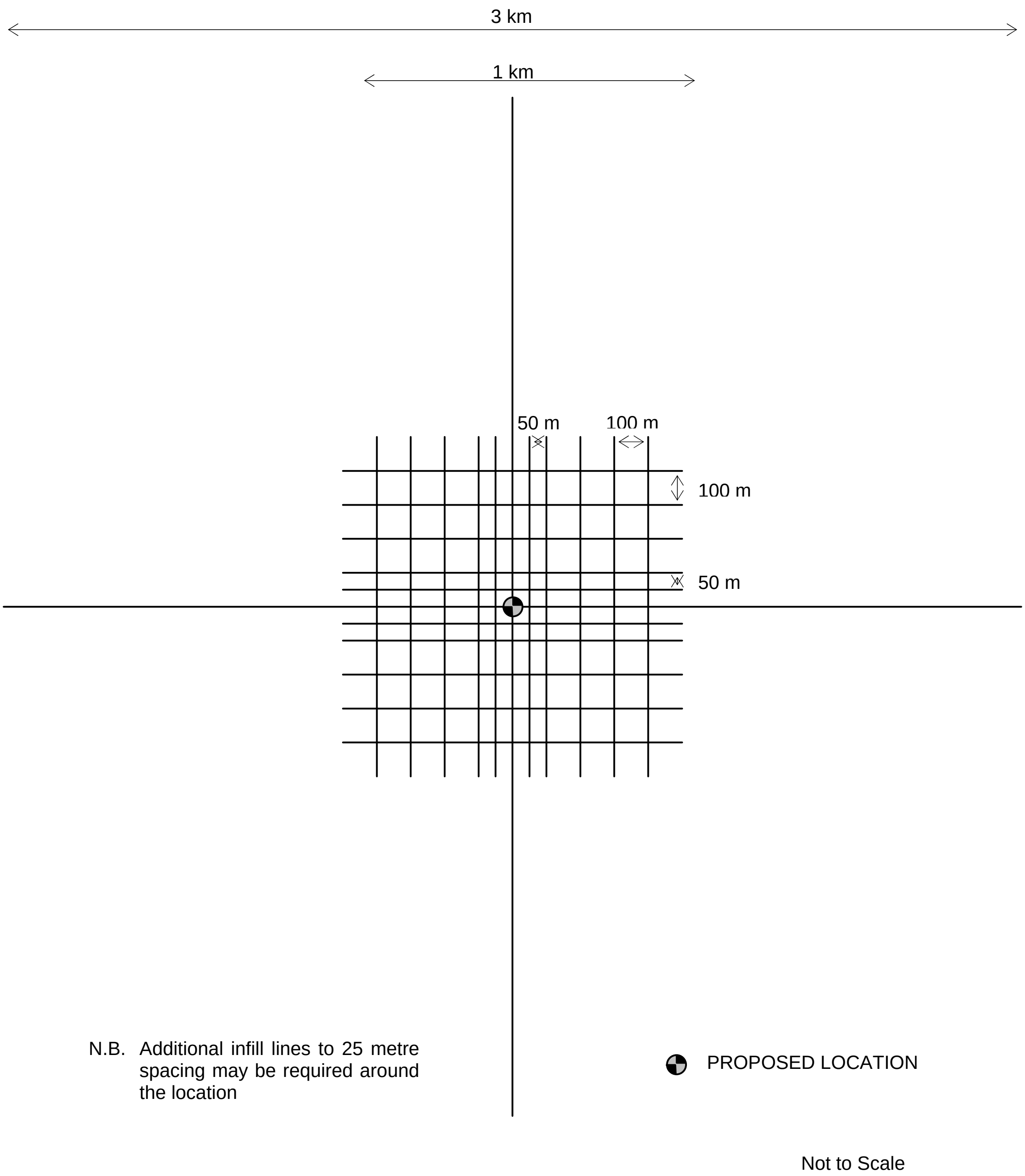
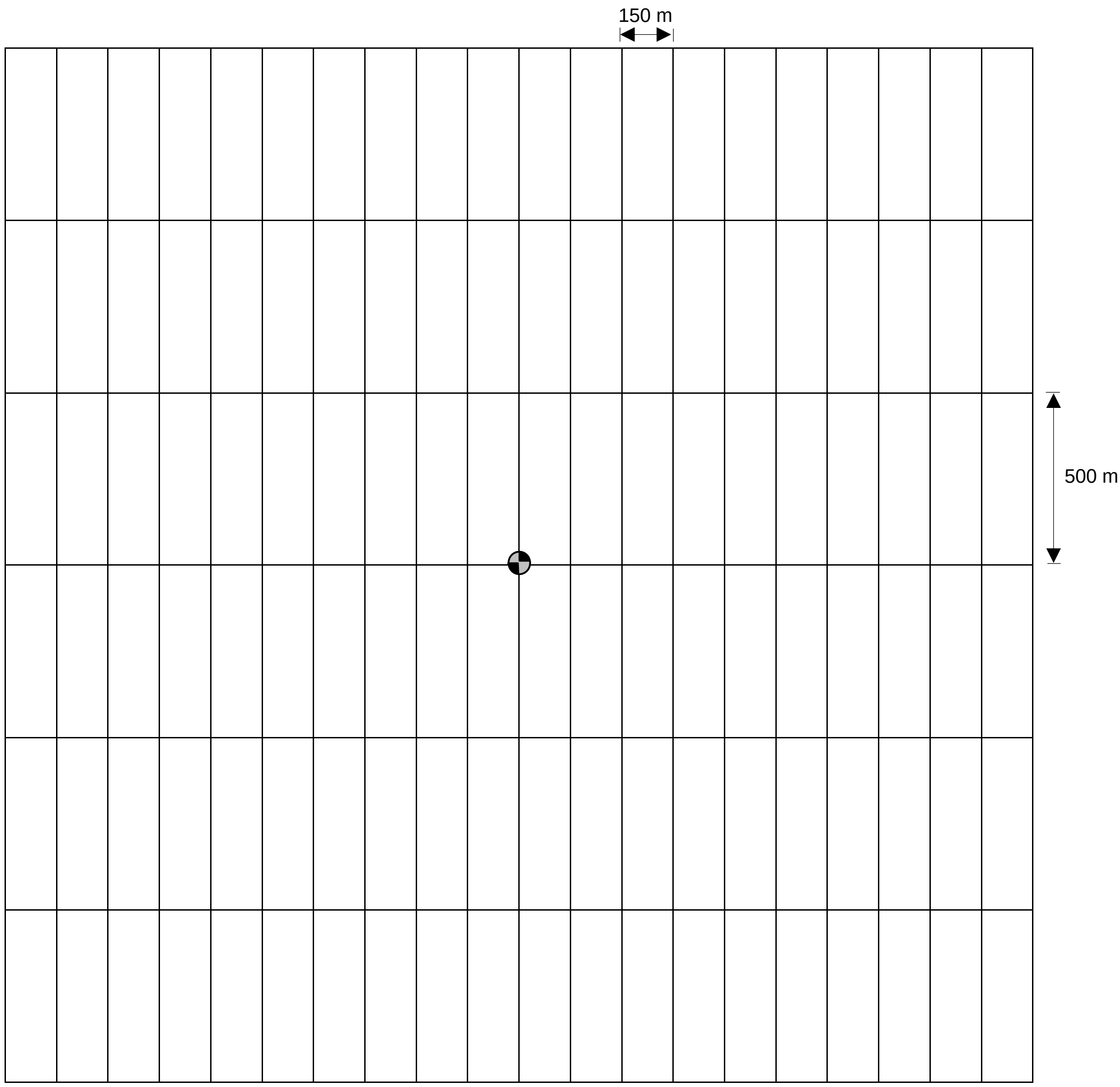


Figure 2.2 Jack-Up Rig Site Survey Line Pattern

(source: UKOOA Guidelines for conduct of mobile drilling rig site surveys, Vol 2 Issue 1)



NB: Area to be surveyed is dependant upon water depth.
Anchor Spread requirements must be known prior to selection of area

PROPOSED LOCATION

Not to Scale

Figure 2.3 Semi-Submersible Rig / Drillship Site Survey Line Pattern

(source: UKOOA Guidelines for conduct of mobile drilling rig site surveys, Vol 2 Issue 1)