Soliton Early Warning System for Offshore Applications

Alastair Stagg, Martin Goff, Gus Jeans, Liam Harrington-Missin (Fugro GEOS Ltd); Carlo Baschenis (ENI Krueng Mane Ltd)

May 2010
Contents Menu

- Introduction
- Soliton Theory
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- Real-time Warning System
- Soliton Analysis
- Conclusions
Contents Menu

- Introduction
- Soliton Theory
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- Real-time Warning System
- Soliton Analysis
- Conclusions
Introduction

Offshore exploration and development operations are impacted by ocean currents, waves and adverse weather.

Internal waves (solitons) pose a specific risk to rigs, vessels, ROV and subsea operations.

USD$ Millions rig repositioning costs

- Broken drill strings
- Supply vessels forced into rigs
- Anchor chains parting
- ROVs lost
- Excessive rig listing

March 2010

www.geos.com
Contents Menu

- Introduction
- **Soliton Theory**
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- Real-time Warning System
- Soliton Analysis
- Conclusions
Soliton Theory

- Direction of soliton propagation – up to 2.5 m/s
- Associated surface currents
- Typically packets of between 5-10 solitons
- Pycnocline displacement can exceed 50m

Sea surface

Galinity

Seawater temperature

Pycnocline
Soliton Theory

Sea surface

Pycnocline

Direction of soliton propagation
Soliton Theory

Sea surface

Water depth (m)

450 m

-1.0 ms\(^{-1}\) to 1.0 ms\(^{-1}\)

Eastward current velocity (m s\(^{-1}\))

28-Mar-1998 07:58
28-Mar-1998 08:46
Soliton Theory

Horizontal Current Velocity

- 1.0 ms\(^{-1}\)
- 0.0 ms\(^{-1}\)

- 30 m below sea level
- 46 m below sea level
- 62 m below sea level
- 78 m below sea level

0 6 12 18 24

(Hours)
Soliton Theory

Seawater temperature

Temperature (°C)

<table>
<thead>
<tr>
<th>Depth</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 m</td>
<td>30° C</td>
</tr>
<tr>
<td>80 m</td>
<td>18° C</td>
</tr>
<tr>
<td>110 m</td>
<td>18° C</td>
</tr>
</tbody>
</table>

(Hours)

(Minutes)

March 2010

www.geos.com
Soliton Theory

Vertical Current Velocity

0.25 ms⁻¹
0.0 ms⁻¹
-0.25 ms⁻¹

146 m below sea level
162 m below sea level
178 m below sea level
194 m below sea level

(Hours)
Soliton Theory

Solitons observed from an offshore platform – enhanced surface waves
ENI Krueng Mane Ltd (Indonesia) affected by solitons in a previous drilling campaign in the Andaman Sea.

Rig pushed off location 3 of 5 wells up to 189m

Drill pipe torn off at BOP

ENI required a Soliton Early Warning System (SEWS) for 2008/2009 drilling campaign in the Andaman Sea

Minimum of 10-hours warning period required
Contents Menu

- Introduction
- Soliton Theory
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- Real-time Warning System
- Soliton Analysis
- Conclusions
Soliton Desk Study

218 satellite images with 77 images subjected to detailed analysis

Propagation speed and direction calculated (1.7ms⁻¹)

Generation zone identified

Confirmed need for a SEWS

Identified best locations for SEWS moorings
Real-time Warning System - Mooring Locations

Soliton generation zone

2 x Real-time SEWS moorings
SEWS#1
SEWS#2

Andaman Sea

Malacca Strait

Sumatra

Thailand

Andaman & Nicobar Islands

March 2010
Contents Menu

- Introduction
- Soliton Theory
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- **Real-time Warning System**
- Soliton Analysis
- Conclusions
Real-time Warning System - SEWS Moorings

- Jack Bates

SEWS#1 SEWS#2

Direction of soliton propagation

Thermocline

- Oceanor Wavescan Buoy with Iridium data transmission
- TRDI 75kHz Longranger ADCP
- Aanderaa DCS3900
- 3 x Seabird SBE-37 CT Sensors

NOT TO SCALE
### Real-time Warning System - SEWS Moorings

#### Proposed Mooring - 1350m Water Depth

<table>
<thead>
<tr>
<th>Mooring Component</th>
<th>LENGTH (METRES)</th>
<th>HAB</th>
<th>DEPTH</th>
<th>Updated 25-Sep-98</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavescan Buoy with DCS:9188</strong></td>
<td>1.70</td>
<td>1350.00</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2 25T 4-Piece Crosby Bow Shackles</td>
<td>0.05</td>
<td>1242.25</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>3.0 chain</td>
<td>6.00</td>
<td>1341.95</td>
<td>6.05</td>
<td></td>
</tr>
<tr>
<td>4 25T 4-Piece Crosby Bow Shackles</td>
<td>0.04</td>
<td>8.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master Link</td>
<td>0.10</td>
<td>8.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 25T 4-Piece Crosby Bow Shackles</td>
<td>0.05</td>
<td>6.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 chain</td>
<td>1.00</td>
<td>9.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 25T 4-Piece Crosby Bow Shackles</td>
<td>0.05</td>
<td>9.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longspanner ABCF in frame</td>
<td>2.00</td>
<td>Inductive Monitor Receiver</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note: Shackles pins to be replaced with Seabird SB:17 IM CTs at depths will be reconfirmed by on-site survey.**

| **Second 25m Riser with 1/2" chain Connected to Lift Frame and to Reelhouse Body** | **Load Bearing Inductive Cable** | 100.00 | 11.25 |
| 5 links 6.0mm Chain | 0.15 | 11.40 |
| 5 links 6.0mm Chain | 0.15 | 11.55 |
| 5 links 6.0mm Chain | 0.15 | 11.60 |
| 3mm Wire Rope | 19.60 | 271.50 |
| 5 links 8.0mm Chain | 0.15 | 271.65 |
| 5 links 8.0mm Chain | 0.15 | 271.80 |
| 5 links 8.0mm Chain | 0.15 | 271.95 |
| **3mm Nylon Rope** | 200.00 | 171.68 | 571.68 |
| 3 links 8.0mm Chain | 0.15 | 171.83 | 572.10 |
| 3 links 8.0mm Chain | 0.15 | 171.93 | 572.20 |
| 4 links 8.0mm Chain | 0.15 | 172.04 | 572.25 |
| **4mm Spectra Rope** | 600.00 | 571.50 | 572.25 |
| 4 links 8.0mm Chain | 0.15 | 571.60 | 572.20 |
| 4 links 8.0mm Chain | 0.15 | 571.64 | 572.20 |
| 4 links 8.0mm Chain | 0.15 | 571.64 | 572.20 |
| 4 links 8.0mm Chain | 0.15 | 571.64 | 572.20 |
| **5 Class on HLZ 9 chain (in line)** | 5.00 | 11.49 | Scope for adding more Spectra if needed |
| 1 5 links 8.0mm Chain | 0.15 | 5.40 |
| **Water Depth** | 1350.00 |
Real-time Warning System - SEWS Moorings

- Oceanor Wavescan buoy with Iridium data transmission and AIS System
- Aanderaa DCS4100
- TRDI 75kHz Longrange ADCP
- 3 x Seabird SDC-37 TD Sensors w/ inductive modem
- Mooring consisting of 9mm Spectra buoy and 18mm nylon rope
- Sonardyne DORT
- 10 x glass buoyancy modules
- 1000kg ballast weight

Current Measurements from the EN1 Soliton Early Warning System Mooring Configuration

Ref: C10763/5423
Fig: 2.2
Real-time Warning System - SEWS Moorings
Real-time Warning System - SEWS Moorings
Both SEWS buoys deployed 2-weeks prior to the Jack Bates’ arrival on well location.

Soliton and current warnings required during the soliton sensitive rig tow and anchoring operations.
Real Time Warning System
Real-time Warning System

All sensors set to 2-minute sampling intervals.

Data transmitted to a web server hosted by Fugro Oceanor every 10-minutes.

Data displayed on a dedicated, password protected web display as time series plots and data tables.

Real-time data used to identify solitons:

- Pulses of increased horizontal and vertical current speed
- Immediate reversal in current direction
- Current shear
- High frequency oscillations in the thermocline
# Real-time Warning System - Soliton Monitoring

<table>
<thead>
<tr>
<th>Warning Level</th>
<th>Current Speed (knots)</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>&lt; 1.5</td>
<td>Record the solitons in daily 24-hour summary, but no warning required or action to be taken by the rig</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>1.5 to 2.0</td>
<td>Issue soliton warning by email, but the rig will probably not take action</td>
</tr>
<tr>
<td>HIGH</td>
<td>2.0 to 3.0</td>
<td>Issue soliton warning by email and follow up by calling OIM. The rig will tighten anchor wires and standby</td>
</tr>
<tr>
<td>VERY HIGH</td>
<td>&gt; 3.0</td>
<td>Issue soliton warning by email and follow by calling OIM. Rig will prepare for possible disconnect</td>
</tr>
</tbody>
</table>
SOLITON WARNING LEVEL HIGH

Many solitons observed over the 3-month SEWS deployment, particularly during spring tides.

Most below the warning threshold, or later downgraded at SEWS#2

A packet of 5 solitons were observed at HIGH LEVEL warning threshold (2.0 to 3.0 knots). Soliton warning email issued, followed by a phone call to the OIM.

Approximately 12-hours later on the next tide, another packet of solitons were observed with similar current speeds.

The rig tightened the anchor wires facing into the solitons and loosened the anchor wires at the rear to avoid additional rig movement.
Real-time Warning System - Soliton Monitoring

Jack Bates Radar – solitons approaching from northwest

Solitons observed approaching from the Jack Bates Helideck
Solitons approaching and passing the Jack Bates – seen as enhanced surface waves
Real-time Warning System - Soliton Monitoring

Rig tilt observed from Helideck as solitons passed through

NOTE: this was AFTER appropriate action taken

Did the SEWS avoid the previous fate - pushed off location up to 189m and a broken drill string?
Soliton Analysis

All current profile and seawater temperature and salinity data downloaded for further data processing and analysis.

3-hour running means subtracted from 2-minute horizontal velocity data to identify short duration horizontal currents associated with solitons.

327 individual soliton events were identified at SEWS#1

207 at SEWS#2.

Soliton propagation speed calculated at $1.70 \text{ms}^{-1}$, consistent with SAR desk study results and observations and forecasts during soliton monitoring.

Data available for future field development

More accurate predictions provided on when solitons were most likely to occur.
Soliton Analysis

'Classic' soliton packet observed at SEWS#1

Northward Velocity (m/s)

Eastward Velocity (m/s)

Current Velocity (m/s)
Soliton Analysis

Filtered Northward Velocity (m/s)

Filtered Eastward Velocity (m/s)

Depth (m)

(Minutes)

Current Velocity (m/s)

-0.6   -0.4   -0.2   0   0.2   0.4   0.6

Depth (m)

0   100   200

Depth (m)

0   100   200

Direction (°T)

000 045 090 135 180 225 270 315 360

March 2010

www.geos.com
Soliton Analysis

Solitons observed at SEWS#2

Northward Velocity (m/s)

Eastward Velocity (m/s)

Temperature (°C)

Current Velocity (m/s)

March 2010
Soliton Analysis

Filtered Northward Velocity (m/s)

Depth (m)

Filtered Eastward Velocity (m/s)

30° C

Temperature (°C)

18° C

(Minutes)

(Minutes)

-0.6 -0.4 -0.2 0 0.2 0.4 0.6

0 0.2 0.4 0.6 0.8 1

0 100 200

0 100 200

Direction (°T)

000 045 090 135 180 225 270 315 360

Depth (m)

March 2010
Peak soliton current speeds were predominantly higher at SEWS#1 than at SEWS#2 due to attenuation of energy over the distance travelled from soliton generation zone.
Contents Menu

- Introduction
- Soliton Theory
- Soliton Early Warning System
- Synthetic Aperture Radar (SAR) Desk Study
- Real-time Warning System
- Soliton Analysis
- Conclusions
Conclusions

- Fugro GEOS were approached by ENI Krueng Mane Ltd to provide a soliton early warning system for drilling operations on the Jack Bates semi-submersible rig. A 10-hour minimum warning period was required.

- A combination of a SAR desk study, followed by real-time measurements across the thermocline and soliton monitoring provided this requirement.

- Solitons were successfully observed and when thresholds were exceeded, early warnings were issued. As a result the rig took the necessary action to avoid significant rig movement.

- Post processing and analysis of the data proved the SEWS effectiveness.

- ENI Well Operations Manager would have the SEWS again for soliton sensitive areas.
Thank You