APPENDIX A:
FILINGS WITH RPSEA

A.1
Project Management Plan

D R A F T A

DOCUMENT TITLE:
Project Management Plan

Document No.: 10121-4407-01-102

4 October 2012

RPSEA PROJECT TITLE:
Deepwater Direct Offloading Systems

RPSEA Project No.: 10121-4407-01

By:

Peter Lovie, PE, PMP, FRINA
Principal Investigator / Project Manager
713 419 9164 peter@lovie.org

Remora Technology, Inc.
800 Town & Country Boulevard, Suite 300
Houston, Texas 77024
Phone: +1 281 598 2460 Fax: +1 281 598 2461
www.remoratech.com

LEGAL NOTICE

This report was prepared by Remora Technology, Inc. as an account of work sponsored by the Research Partnership to Secure Energy for America (RPSEA). RPSEA members, the National Energy Technology Laboratory, the U.S. Department of Energy, nor any person acting on behalf of any of the entities:

A. *Makes any warranty or representation, express or implied with respect to accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe privately owned rights,*
   or
B. *Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this document.*

Reference to trade names or specific commercial products, commodities, or services in this report does not represent or constitute an endorsement, recommendation, or favoring by RPSEA or its contractors of the specific commercial product, commodity, or service.

ABSTRACT

This Document

Remora Technology, Inc. was awarded a subcontract from Research Partnership to Secure Energy for America (RPSEA) under which the ultimate objective was to verify, for U.S. deepwater operators, that the direct offloading system called the "HiLoad DP" will meet U.S. Gulf of Mexico (GOM) requirements to enable its functioning successfully for both steady-state production situations as well as standby roles for emergency situations, to provide sufficient knowledge to proceed immediately with the final engineering and contracting process to make the HiLoad concept available to GOM operations.

That subcontract was signed on 16 August 2012 in the amount of $1,054,471. Dates of performance are 16 August 2012 – 15 August 2013. This document sets forth the basis of how the project will be managed in accordance with RPSEA requirements and follows typical project mansgemeny practices.

Context for this Project

Deepwater operators in the U.S. GOM have a need for deepwater direct offloading systems for multiple applications such as: (1) direct offloading from Floating Production Storage Offloading vessels (FPSO) of tanker (i.e., ship shape) and/or round configuration, in a steady-state production environment in ultra-deepwater (GOM), and (2) to have the ability to offload liquid hydrocarbons from existing platforms that have been isolated by pipeline breaks such as occurred in the hurricanes of 2005, and (3) to load spilled oil from whatever source it may be collected, into a quickly available tanker for delivery to a U.S. GOM port.

The restarting of offshore production in 2005 was made difficult by delays pertaining to the offloading issue and likewise the *Macondo* well blowout spill of 2010. It is the hope of this work that such delays can in future be mitigated.

SIGNATURE PAGE

Date: 4 October 2012

Kim Diederichsen
Project Sponsor (Senior Vice President, Americas)

Date: 4 Oct 12

Peter Lovie PE, PMP, FRINA
Principal Investigator / Project Manager

This page is intentionally left blank.

C O N T E N T S

1 Points of Contact (POC)

2 Project Organization Chart

3 Work Breakdown Structure (WBS)

4 Project Schedule: Gantt Chart from Microsoft Project

5 Projected Overall Expenditures over Contract Term: Excerpt from First Monthly Report

6 Projected Expenditures over Contract Term for Each of Four Team Members

1. Points of Contact

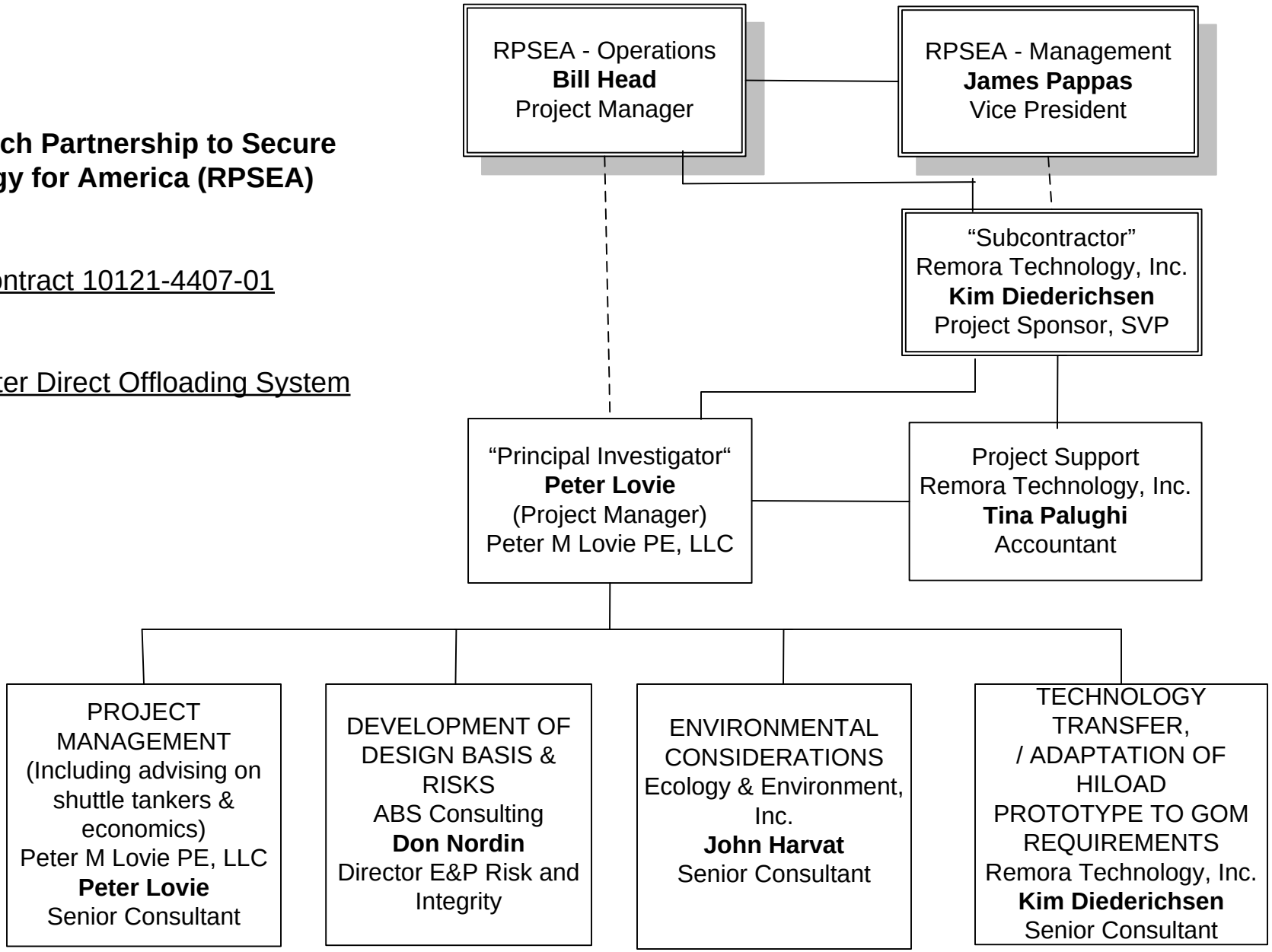
Project Sponsor:	Kim Diederschsen	281 598 2462	kdi@remoratech.com
Principal Investigator / Project Manager	Peter Lovie	713 419 9164	peter@lovie.org
Project Support / Administration	Tina Palughi	281 598 2460	palughi@gmail.com

PROJECT ORGANIZATION CHART

Research Partnership to Secure Energy for America (RPSEA)

Contract 10121-4407-01

Deepwater Direct Offloading System



Work Breakdown Structure (WBS)

Task No.	Description
Team Member: ABS Consulting	
1	A compilation of current technologies will be prepared for tandem offloading of oil from: (1) a spread moored FPSO to a tanker of opportunity, and (2) from a turret moored FPSO to a tanker of opportunity. A comparison of the current technologies with the HiLoad concept will be conducted based on technical and economic parameters.
2	A risk assessment of the HiLoad concept will be performed to identify the novel technical components, strengths, and opportunities. Conduct a two day facilitated risk assessment using the "what if" method. 2nd day will include TRL Assessment for HiLoad DP Estimated Level of effort 2 days in workshop plus 3 weeks for report issuance
3	Assist in the development of the basis of design for GOM application for three situations: (1) remote deepwater steady state, (2) pipeline disruption and loading from platform, and (3) Supporting MWCC or Helix in spill emergency.
4	A desktop technical evaluation of the maneuverability of shuttle tankers based on model tests, bridge simulations, and metocean simulations on operability
Team Member: Ecology & Environment	
5	Attachment System Evaluation
5.1	Literature review of current seachest and pump design technology and placement philosophy
5.2	Compile HiLoad DP design requirements for ballast water usage and rationale for placement of seachests and pump selection
5.3	Assess placement of HiLoad DP equipment relative to current industry practice
5.4	Estimate the impingement / entrainment of marine life for the HiLoad DP design from a Gulf of Mexico Station
5.5	Compile Final Report
6	Propulsion System Evaluation
6.1	Literature review of current underwater noise monitoring data from DP thrusters and similar equipment.
6.2	Passive acoustic field data collection and analysis program. (This task is for oversight of the field study and not the field study in and of itself), subject to data availability
6.3	Comparative analysis of literature data and HiLoad or comparable field generated data available
6.4	Compile Final Report
7	Air and Water Emissions Estimate
7.1	Compile HiLoad equipment inventory of potential emission points
7.2	Calculate estimated emissions based upon equipment specifications and / operating practices
7.3	Model Air Emissions from an Emergency Offloading Scenario

	7.4 Model primary water discharge from an Emergency Offloading Scenario
	7.5 Compile Final Report
8	Hydrocarbon Management
	8.1 Compile HiLoad OPA substance inventory
	8.2 Compile Final Report
9	Spill Response and Countermeasure Program
	9.1 Develop Spill Scenario
	9.2 Model Spill Plume
	9.3 Describe environmental effects
	9.4 Compile Final Report

Team Member: Peter M Lovie PE, LLC

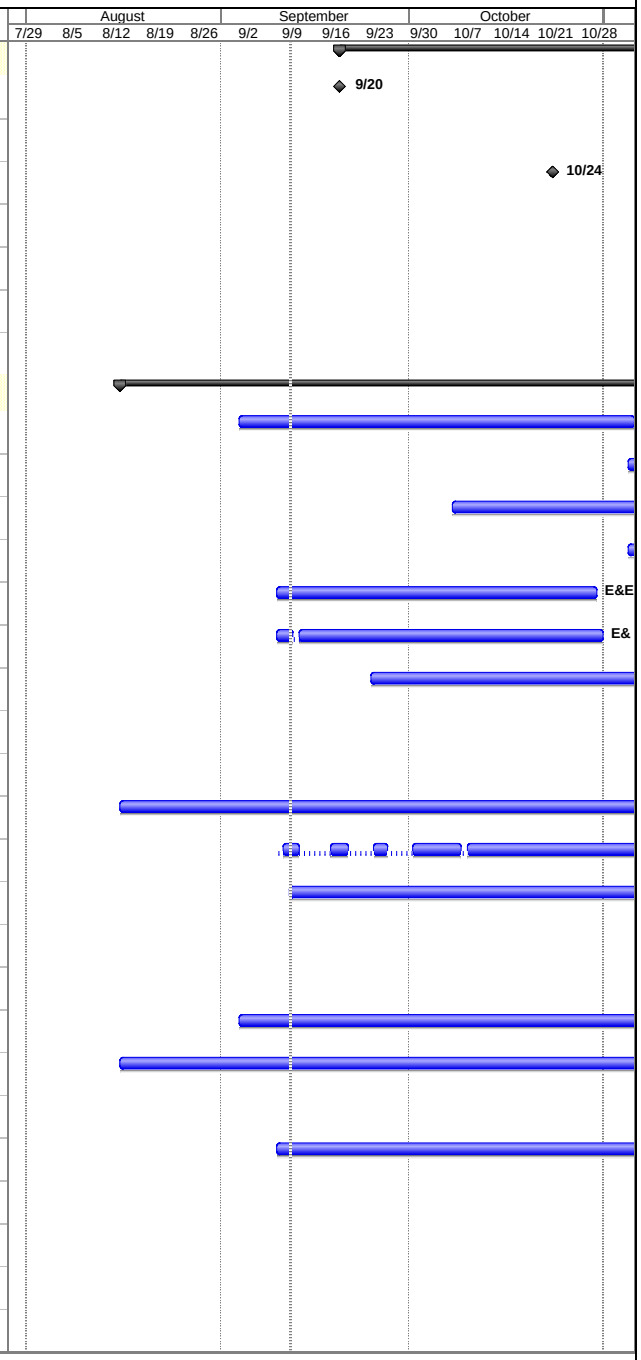
10	Communicate with Remora and subcontractors. Maintain CTR library & Gantt chart. Conduct weekly progress meeting/calls
11	Prepare presentation for each TAC and WG meeting. Communicate with each TAC and WG member 1-2 times per month by call and or visit, resolve differences.
12	Contract operation, ongoing dealings with RPSEA
13	Discuss and agree on a configuration for Hi Load DP for a pipeline disruption scenario, in conjunction with operators in TAC. Do same for spill emergency. Assemble this information, write up, input to ABS and others on team
14	Assemble info on GoM shuttle tanker vessels and operations, economics for comparisons with tankers of convenience, run basic economics

Team Member: Remora Technology, Inc.

15	Stage WG meetings at hotel: kick off, then 5 @ 2 month intervals and final, total 7
16	Record keeping for resources expended, invoice preparation and audit responses
17	Determination of changes needed in Prototype design to satisfy GoM operations for normal offloading and emergency services
18	Prepare and participate in TAC meetings, issue minutes / progress reports, ongoing discussions with members
19	Development of a GoM design of HiLoad DP, develop estimate on building in US, based in data and experience in Norway

Summary Gantt Chart for RPSEA contract 10121-4407-01

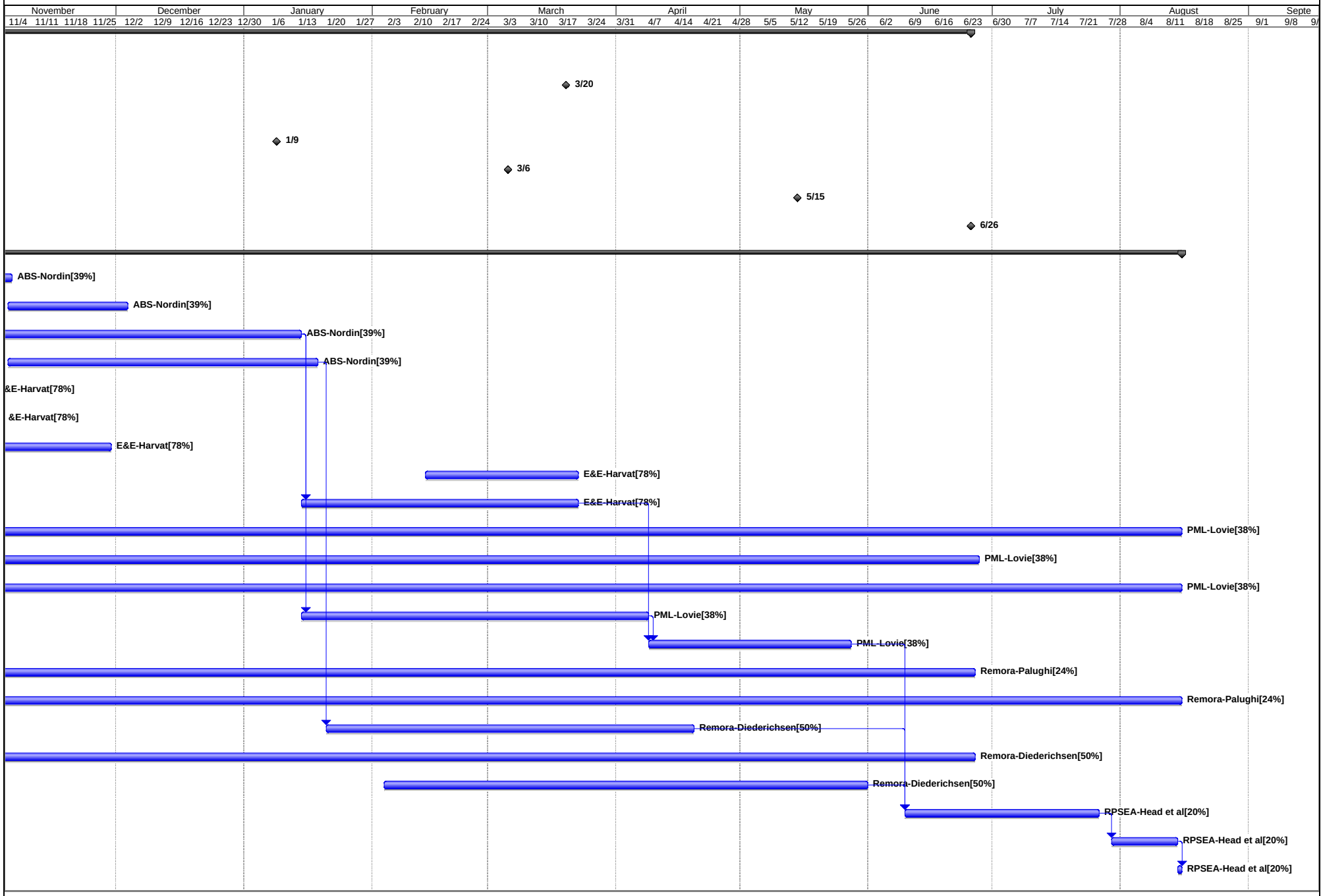
ID	Task Name	Duration	Start	Finish	Prede	Resource Names
	Milestone: Yes	**199 days**	**Thu 9/20/12**	**Wed 6/26/13**		
20	First TAC Meeting (RPSEA Task 3.0)	0 days	Thu 9/20/12	Thu 9/20/12		
21	Second TAC Meeting (RPSEA Task 3.0)	0 days	Wed 3/20/13	Wed 3/20/13		
22	First Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 10/24/12	Wed 10/24/12		
23	Second Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 1/9/13	Wed 1/9/13		
24	Third Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 3/6/13	Wed 3/6/13		
25	Fourth Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 5/15/13	Wed 5/15/13		
26	Fifth Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 6/26/13	Wed 6/26/13		
	Milestone: No	**261 days**	**Thu 8/16/12**	**Thu 8/15/13**		
1	1-4.1 Compilation of current technologies (RPSEA Tasks 2.0, 5.1)	45 days	Tue 9/4/12	Mon 11/5/12		ABS-Nordin[39%]
2	2-4.2 Risk assessment of the HiLoad concept (RPSEA Task 5.2)	21 days	Mon 11/5/12	Mon 12/3/12		ABS-Nordin[39%]
3	3-(4.3 & 4.5) Development of the basis of design for GoM (RPSEA 5.3)	71 days	Mon 10/8/12	Mon 1/14/13		ABS-Nordin[39%]
4	4-4.4 Technical evaluation of the maneuverability (RPSEA Task 5.4, 5.4)	55 days	Mon 11/5/12	Fri 1/18/13		ABS-Nordin[39%]
5	5-5.1 Attachment system evaluation (RPSEA Task 6.1)	37 days	Mon 9/10/12	Tue 10/30/12		E&E-Harvat[78%]
6	6-5.2 Propulsion system evaluation (RPSEA Task 6.2)	37 days	Mon 9/10/12	Wed 10/31/12		E&E-Harvat[78%]
7	7-5.3 Air and water emissions (RPSEA Task 6.3)	48 days	Tue 9/25/12	Thu 11/29/12		E&E-Harvat[78%]
8	8-5.4 Hydrocarbon management (RPSEA Task 6.4)	27 days	Thu 2/14/13	Fri 3/22/13		E&E-Harvat[78%]
9	9-5.5 Spill response and countermeasure program (RPSEA Tasks 6.5 & 6.6)	49 days	Tue 1/15/13	Fri 3/22/13	3	E&E-Harvat[78%]
10	10-6.1 Communicate with Remora and subcontractors. Conduct weekly progress meet	261 days	Thu 8/16/12	Thu 8/15/13		PML-Lovie[38%]
11	11-3.2 Prepare presentation for TAC & WG meetings RPSEA Task 3.0, 7.2)	200 days	Mon 9/10/12	Thu 6/27/13		PML-Lovie[38%]
12	12-6 Contract operation, ongoing dealings with RPSEA (RPSEA 1.0, 4.0)	242 days	Wed 9/12/12	Thu 8/15/13		PML-Lovie[38%]
13	13-6.2 Agree on a configuration for Hi Load DP for a pipeline disruption & spill emerge	60 days	Tue 1/15/13	Mon 4/8/13	3	PML-Lovie[38%]
14	14-6.3 Assemble info on GoM shuttle tankers, economics, comparisons (7.5)	35 days	Tue 4/9/13	Mon 5/27/13	13,9	PML-Lovie[38%]
15	15-7.1 Staging 2 TAC & 5 WG meetings (RPSEA Task 3.0)	212 days	Tue 9/4/12	Wed 6/26/13		Remora-Palughi[24%]
16	16 Record keeping, prepare invoicing, reporting RPSEA Task 8.2)	261 days	Thu 8/16/12	Thu 8/15/13		Remora-Palughi[24%]
17	17-8.1 Changes needed in prototype design to satisfy GoM operations (8.3)	65 days	Mon 1/21/13	Fri 4/19/13	4	Remora-Diederichsen[50%]
18	18-7.2 Prepare and participate in TAC & WG meetings (RPSEA Tasks 3.0, 8.4)	208 days?	Mon 9/10/12	Wed 6/26/13		Remora-Diederichsen[50%]
19	19-8.2 Indicative estimate GoM design of HiLoad DP, built in US (8.5)	85 days	Mon 2/4/13	Fri 5/31/13		Remora-Diederichsen[50%]
27	RPSEA review of draft Final Report	35 days	Mon 6/10/13	Fri 7/26/13	19,1	RPSEA-Head et al[20%]
28	RPSEA project acceptance and closeout process	12 days	Tue 7/30/13	Wed 8/14/13	27	RPSEA-Head et al[20%]
29	Project completion	1 day	Thu 8/15/13	Thu 8/15/13	28	RPSEA-Head et al[20%]



Project: Remora RPSEA RFP2010UDW004 4407
Date: Wed 9/12/12

Task | Summary | Rolled Up Progress | Project Summary
Progress | Rolled Up Task | Split | Group By Summary
Milestone | Rolled Up Milestone | External Tasks | Deadline

Summary Gantt Chart for RPSEA contract 10121-4407-01



Project: Remora RPSEA RFP2010UDW004 4407
Date: Wed 9/12/12

Task		Summary		Rolled Up Progress		Project Summary	
Progress		Rolled Up Task		Split		Group By Summary	
Milestone		Rolled Up Milestone		External Tasks		Deadline	

1. Reporting Mo/Yr: August-2012

RPSEA RESEARCH AWARD BASELINE COST/SCHEDULE/MILESTONE REPORT

Year 1

2. Project Information		3. Project Cost Summary			4. Period of Performance:	
a. Subcontract Number:	10121-4407-01	a. Total Project Cost:		$ 1,054,471	a. Start Date:	8/16/2012
		b. Cost Share:	20%	$ 210,894		
		c. RPSEA 1% for Program Tech Transfer		$ 10,545		
b. Project Title:	Deepwater Direct Offloading Systems	d. RPSEA Funding Available to Subcontractor:		$ 833,032	b. End Date:	8/15/2013
c. Prime Contractor:	Remora Technology, Inc.	e. Subcontractor Tech Transfer:		$ 15,817		

YEAR 1 - Cost by Task

5.

a. Task	b. Description	c.	1	2	3	4	5	6	7	8	9	10	11	12	Yr Total
1	Project Management Plan	Baseline	865	865	865	865	865	865	865	865	865	865	865	587	$ 10,103
		Actual													$ -
2	Technology Status Assessment	Baseline	4,399	4,399	348	0	0	0	0	0	0	0	0	0	$ 9,146
		Actual													$ -
3	Technology Transfer	Baseline	17,502	15,220	15,220	15,220	15,220	15,220	15,220	15,220	15,220	13,627	4,889	3,320	$ 161,099
		Actual													$ -
4	Other Reports & Special Items	Baseline	865	865	865	865	865	865	865	865	865	865	865	587	$ 10,103
		Actual													$ -
5	Development of Design Basis & Risk	Baseline	4,399	4,399	36,478	22,122	16,202	3,002	-	-	-	-	-	-	$ 86,602
		Actual													$ -
6	Environmental Considerations	Baseline	11,188	40,852	42,996	10,212	12,486	24,971	17,792	-	-	-	-	-	$ 160,497
		Actual													$ -
7	Project Management	Baseline	9,400	7,118	7,118	7,118	22,535	37,951	35,908	29,077	7,118	6,775	4,889	3,320	$ 178,328
		Actual													$ -
8	Adaptation of "HiLoad DP" Prototype to GoM	Baseline	6,130	5,211	5,211	5,211	14,668	33,584	32,989	56,260	60,301	4,711	1,971	1,339	$ 227,585
		Actual													$ -
9		Baseline													$ -
		Actual													$ -
10	Technology Transfer	Baseline	-												$ -
		Actual	-												$ -
Period Totals		Baseline	$ 54,748	$ 78,929	$ 109,102	$ 61,613	$ 82,841	$ 116,459	$ 103,639	$ 102,287	$ 84,369	$ 26,843	$ 13,479	$ 9,154	$ 843,463
		Actual	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cumulative Totals		Baseline	$ 54,748	$ 133,677	$ 242,779	$ 304,391	$ 387,232	$ 503,691	$ 607,330	$ 709,617	$ 793,986	$ 820,829	$ 834,308	$ 843,463	
		Actual	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	
Period Variance			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
Cumulative Variance			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
		Baseline												$ -	$ -

Project expenditures baseline by month for tasks by ABS Consulting

Remora task no.	1-Sep	2-Oct	3-Nov	4-Dec	5-Jan	6-Feb	7-Mar	8-Apr	9-May	10-Jun	11-Jul	12-Aug	12 mos., task totals
1	8,798	8,798	697										18,293
2			14,008										14,008
3			10,755	10,755	10,755	3,002							35,267
4			11,367	11,367	5,447								28,181
1-4	8,798	8,798	36,826	22,122	16,202	3,002	0	0	0	0	0	0	95,749
billable hours:	53	53	223	134	98	18	0	0	0	0	0	0	581

Project expenditures baseline by month for tasks by Ecology & Environment, Inc.

Remora task no.	1-Sep	2-Oct	3-Nov	4-Dec	5-Jan	6-Feb	7-Mar	8-Apr	9-May	10-Jun	11-Jul	12-Aug	12 mos., task totals
5			15,036	10,212									25,248
6	7,935	15,870	2,843										26,648
7	3,253	18,156	18,156										39,565
8		6,826	6,961										13,787
9					12,486	24,971	17,792						55,249
5-9	11,188	40,852	42,996	10,212	12,486	24,971	17,792	0	0	0	0	0	160,497
billable hours:	73	265	279	66	81	162	116	0	0	0	0	0	1,043

Project expenditures baseline by month for tasks by Peter M Lovie PE, LLC

Remora task no.	1-Sep	2-Oct	3-Nov	4-Dec	5-Jan	6-Feb	7-Mar	8-Apr	9-May	10-Jun	11-Jul	12-Aug	12 mos., task totals
10	14,341	9,778	9,778	9,778	9,778	9,778	9,778	9,778	9,778	9,778	9,778	6,641	118,760
11	4,459	4,459	4,459	4,459	4,459	4,459	4,459	4,459	4,459	3,771			43,899
12	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,175	20,206
13					12,676	25,352	25,352	7,922					71,302
14							2,656	15,936	7,105				25,697
10-14	20,529	15,966	15,966	15,966	28,642	41,318	43,974	39,825	23,071	15,279	11,508	7,816	279,862
billable hours:	88	68	68	68	122	177	188	170	99	65	49	33	1,196

Project expenditures baseline by month for tasks by Remora Technology, Inc.

Remora task no.	1-Sep	2-Oct	3-Nov	4-Dec	5-Jan	6-Feb	7-Mar	8-Apr	9-May	10-Jun	11-Jul	12-Aug	12 mos., task totals
15	4,862	4,862	4,862	4,862	4,862	4,862	4,862	4,862	4,862	4,113			47,874
16	2,891	1,971	1,971	1,971	1,971	1,971	1,971	1,971	1,971	1,971	1,971	1,339	23,940
17					6,437	19,311	19,311	12,042					57,101
18	6,479	6,479	6,479	6,479	6,479	6,479	6,479	6,479	6,479	5,480			63,792
19						29,055	29,055	29,055	27,482				114,648
15-19	14,232	13,313	13,313	13,313	19,749	61,679	61,679	54,410	40,794	11,564	1,971	1,339	307,355
Total hours:	77	71	71	71	100	288	288	256	195	62	12	8	1,501

APPENDIX A:
FILINGS WITH RPSEA

A.2
Technology Status Assessment

DOCUMENT TITLE:
Technology Status Assessment

Document No.: 10121-4407-01-101

RPSEA PROJECT TITLE:
Deepwater Direct Offloading Systems

RPSEA Project No.: 10121-4407-01

4 October 2012

By:

Peter Lovie PE, PMP, FRINA
Principal Investigator / Project Manager
713 419 9164 peter@lovie.org

Remora Technology, Inc.
800 Town & Country Boulevard, Suite 300
Houston, Texas 77024
Phone: +1 281 598 2460 Fax: +1 281 598 2461
www.remoratech.com

LEGAL NOTICE

This report was prepared by Remora Technology, Inc. as an account of work sponsored by the Research Partnership to Secure Energy for America (RPSEA). RPSEA members, the National Energy Technology Laboratory, the U.S. Department of Energy, nor any person acting on behalf of any of the entities:

A. *Makes any warranty or representation, express or implied with respect to accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe privately owned rights,*

   or

B. *Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this document.*

Reference to trade names or specific commercial products, commodities, or services in this report does not represent or constitute an endorsement, recommendation, or favoring by RPSEA or its contractors of the specific commercial product, commodity, or service.

ABSTRACT

This Document

Remora Technology, Inc. was awarded a contract from RPSEA under which the ultimate objective was to verify, for U.S. deepwater operators, that the direct offloading system called the "HiLoad DP" will meet U.S. Gulf of Mexico (GOM) requirements to enable its functioning successfully for both steady-state production situations as well as standby roles for emergency situations, to provide sufficient knowledge to proceed immediately with the final engineering and contracting process to make the HiLoad concept available to GOM operations.

The same offloading procedures have been in use for loading crude oil into tankers from loading buoys, FSOs or FPSOs for something like fifty years. For the last eleven years a different offloading system, well suited to deepwater operations, has been under development by Remora. Last year that system passed full scale prototype tests offshore Norway. This document is a summary comparison of this new technology with the well tried precedents.

Context for this Project

Deepwater operators in the U.S. GOM have a need for deepwater direct offloading systems for multiple applications such as: (1) direct offloading from Floating Production Storage Offloading vessels (FPSO) of tanker (i.e., ship shape) and/or round configuration, in a steady-state production environment in ultra-deepwater (GOM), and (2) to have the ability to offload liquid hydrocarbons from existing platforms that have been isolated by pipeline breaks such as occurred in the hurricanes of 2005, and (3) to load spilled oil from whatever source it may be collected, into a quickly available tanker for delivery to a U.S. GOM port.

The restarting of offshore production in 2005 was made difficult by delays pertaining to the offloading issue and likewise the *Macondo* well blowout spill of 2010. It is the hope of this work that such delays can in future be mitigated.

SIGNATURE PAGE

Date: 4 October 2012.

Kim Diederichsen
Project Sponsor (Senior Vice President, Americas)

Date: 4 Oct 12

Peter Lovie PE, PMP, FRINA
Principal Investigator / Project Manager

This page is intentionally left blank.

CONTENTS

1 CURRENT TECHNOLOGIES IN DEEPWATER OFFLOADING

1.1 OFFLOADING FROM SPREAD MOORED VESSELS

1.2. OPERATION OF OFFLOADING TANKERS

1.3 OFFLOADING FROM TURRET MOORED VESSELS

1.4 THE US GOM CONTEXT – OFFLOADING FROM PERMANENTLY MOORED AND DISCONNECABLE FPSOS

2 THE "HILOAD DP" TECHNOLOGY

3 COMPARISON – TECHNOLOGY STATUS

LIST OF FIGURES

Figure 1: Example of Internal Turret Moored FPSO Showing Load Transfers

Figure 2: The Hiload DP Configuration for Offloading Operations

Figure 3: Standard Tanker Converted to Tanker with DP Capabilities by Use of the HiLoad DP

1 CURRENT TECHNOLOGIES IN DEEPWATER OFFLOADING

Current offloading procedures are very well proven over decades of operations, initially from offshore terminals or loading buoys and in recent decades from offloading from floating storage (FSOs and FPSOs) in deepwater. So current offloading methods are clearly at Technology Readiness Level 7.

Current technologies of offloading from an FSO or FPSO in turn rely on two methods of mooring: (1) spread moored FSO or FPSO offloading to a tanker of opportunity, directly or via a CALM buoy, and (2) a turret moored FPSO offloading to a tanker of opportunity or to a shuttle tanker. Again, well proven in all these related configurations, TRL = 7.

Offloading is taken in the context here to be tandem and not side by side. Tandem is used in shallow and deep water worldwide and now in US GoM at the Petrobras operated *Cascade/Chinook* development in 8,200 ft. of water. Side by side offloading tends to be used in controlled conditions in shallower waters. It is commonly used in US GoM for lightering operations with crude imports, transferring oil from Suezmax and VLCC sizes of import tankers to smaller Aframax lightering vessels for delivery to US GoM ports.

“Tankers of opportunity” in US waters are assumed to be either existing tankers in the Jones Act fleet, or foreign flag tankers secured under a Jones Act waiver in an emergency. In either case they would not have DP systems to aid in heading control and station keeping.

“Shuttle tankers” may be obtained in US waters for longer term commitments with enhanced maneuverability such as occurs at the *Cascade/Chinook* development. Jones Act tankers with DP capability are conceivable but not available. This is a different business situation from elsewhere in the world where shuttle tankers are more freely available and a commercial circumstance affecting the value of HiLoad DP in the US GoM context.

The Remora technology may enable broader use of “tankers of opportunity”. Bearing in mind the characteristics outlined below for the vessels where offloading may occur in US GoM, Remora’s technology might simplify operations and benefit safety.

2.1 OFFLOADING FROM SPREAD MOORED VESSELS

A spread mooring system is used by ship shape FSOs or FPSOs to maintain a stable location and a fixed heading in unidirectional weather environments.

Weathervaning is not possible when a spread mooring system is used because of the fixed heading.

The mooring lines are anchored in usually symmetrical configuration at the ship's bow and stern. Winches are used to tension the mooring lines and then chain stoppers are used to maintain the tension on the lines.

The mooring lines can be either catenary or taut lines. Catenary lines maintain the FPSO's location and heading by the force associated with the weight of the mooring line hanging freely from two points not in the same vertical line. Catenary lines are usually chain or steel shackles. Taut lines are light constructed lines connected in a straight line from the anchor to the FPSO. The force associated with restoring the FPSO's position after the FPSO moves in a direction is greater in taut lines than catenary lines. Polyester lines are sometimes used for taut lines because of its properties.

The US GOM has variable direction wind and current condition, making the use of a spread moored FPSO unrealistic but is considered here as it was specifically mentioned in the RFP for this work, for completeness in considering different mooring options and since it is the type of mooring system that would be used for round FPSO designs.

A side benefit is that a spread mooring system helps allow an FPSO to have more risers at a lower cost. The FPSO can also locate the risers and riser connections midship of the FPSO or around its perimeter in the use of a round FPSO. Steel catenary risers (SCRs) are preferred for deepwater FPSOs when climate conditions permit their use.

Although unidirectional weather is sounds a simple idea, it sometimes is not completely unidirectional and variations can cause difficulties in offloading from a spread moored vessel. There have been incidents in offloading from spread moored tankers in West Africa for example and it has become necessary in a number of instances to employ a Single Point Mooring separate from the FPSO for offloading. Typically a CALM Buoy is installed about 1-1/2 miles from the FPSO. In the US GOM context here it is unlikely a spread moored FPSO would ever be deployed, the exception being when spread mooring became necessary with use of a round FPSO.

1.2. OPERATION OF OFFLOADING TANKERS

During tandem offloading, the tanker uses a mooring hawser as a single point mooring to the

FPSO. The hawser mooring system usually has a tension monitor, an alarm system for high loads, and an emergency release of the hawser under load [3]. Typically tug boats are also utilized to maintain position and heading of the tanker.

The offload tanker will offload to the FPSO via a transfer hose string. The hose string is either a floating hose string. or a catenary reeled hose string deployed from the stern of the FPSO to the offload tanker bow connection when the tanker has a bow loading system (BLS) installed.

In either event, adequate separation distance must be maintained between the FPSO and the offload tanker for safety reasons.

A floating hose string must have significant length to reach the midship manifold of the offload tanker from the discharge manifold on the FPSO. One or two floating hose strings can be used in parallel for offloading. The weight of the hose strings and the tanker lifting equipment require careful design.

An automated tension monitoring system of the hawser can send shutdown signals to pumps and activate shut-off valves for emergency disconnection or an emergency shutdown push button can be used to provide emergency pump stop, valve activation, and hose disconnect.

Maintaining good communication between the FPSO and a tanker is essential during offloading. Telemetry communication is a method for coordinating offloading operations. Another option to maintain communication between the FPSO and tanker is to send a mooring master with portable communication equipment to the tanker prior to connection.

The berthing of a tanker of opportunity requires skilled maneuvering and tugs to position the tanker at the FPSO offloading mooring location. The tugs and support craft will support and supervise the mooring, unmooring, and transfer hose connection and disconnection. A hold off tug will also be required during tandem offloading to maintain the tanker's position and be alert to potential surge and drive forward risk that might lead to collision. The pull back (or "hold off") tug would be used during normal and emergency unmooring to tow the tanker away from the FPSO. Generally tankers of convenience do not provide emergency release and shutdown of the offload operation and so the FPSO will be required to provide these provisions.

The offloading tanker would offload from a turret moored FPSO using the same method as a spread moored FPSO, via a hawser mooring system and transfer hose. However, the communication and tug support would be more complex between the FPSO and the tanker of

opportunity. Additional tug support would be required to maintain the tanker in the allowed moored position as the FPSO weathervanes to the changing environment conditions. The communication between the tanker, FPSO, and tugs would also increase to help facilitate the station keeping of the tanker.

1.3 OFFLOADING FROM TURRET MOORED VESSELS

A turret moored FPSO is an FPSO designed to align itself with the current environmental conditions. The mooring lines are then of a configuration often the same as for spread moored FPSOs, and can be either catenary or taut lines. The mooring lines are usually connected to the bottom of the turret via the mooring spider, or mooring buoy but mooring lines can also be passed through the turret to winches for tension control and inspection. Turret design is determined by the limits imposed from the riser loads, mooring loads. Turrets may be internal to the hull or mounted on an extension of the hull. Internal turrets may be either passive or active.

A passive turret system allows the hull to position itself as it responds to the environment without assistance. An active turret system requires thrusters to actively align and control the FPSO rotation with the environment. Turrets can also be disconnectable. In general, there are 5 types of internal turret systems and 2 external systems. The internal turret systems are: Internal Passive Turret (IPT), Internal Active Turret (IAT), Internal Disconnectable Turret (ITD), Submerged Turret Production (STP), and Submerged Turret Loading (STL). The external turret systems are: External Cantilevered Turret, and External Disconnectable Turret.

For reference, a Submerged Turret Loading (STL) buoy is where the mooring spider/buoy is disconnected from the turret leaving a mooring buoy with flexible riser connections submerged below the sea surface, the STL trade term being used for the configuration for lower pressures used for offloading. A Submerged Turret for Production (STP) system is generally similar in principal but requires much heavier construction to deal with production pressures that may be much higher.

Internal turrets systems are an integral component of an FPSO located in a cylindrical cavity of the FPSO and it rotates around a large main bearing. There are four main parts of an internal turret system: turret, fluid transfer system (FTS), turret transfer system (TTS), and the interfacing systems (IS). The turret consists of the turret shaft, casing, bearings, and mooring spider/buoy. The TTS is the manifold connecting the turret to the FTS. The FTS transfers the process fluids from the turret connections to the process equipment on the FPSO. The IS

consists of the mooring lines, the flexible risers below the turret, and the other auxiliary equipment. Typically the turret system will transfer forces from the environment to the FPSO via the torque arms to swivel, main turret bearings, lower bearing pads, connections to the single point mooring, bend-stiffeners on flexible risers, or the internal interface to a disconnectable system. An active turret drive may be required for designs that have increase friction on the main bearings. Figure 2 below shows an internal turret FPSO with its associated load locations:

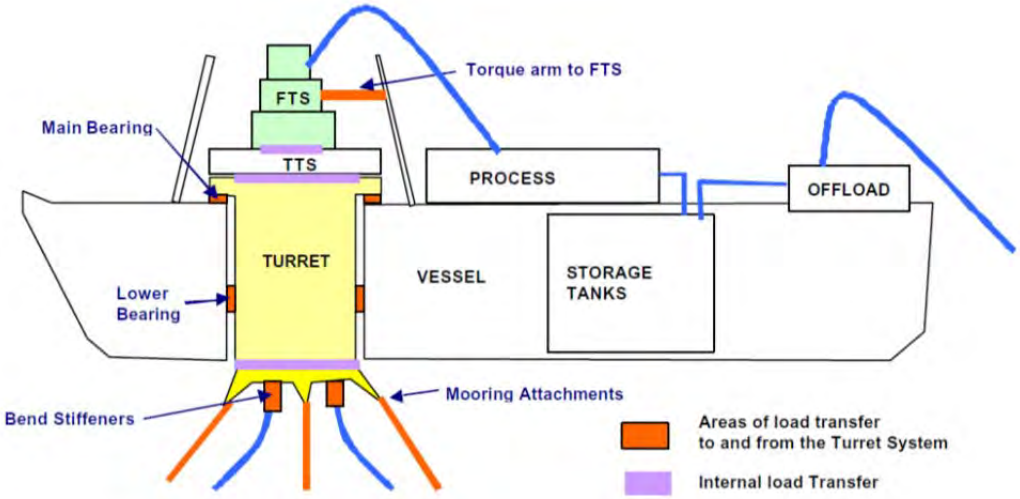


Figure 2 – Example of Internal Turret Moored FPSO Showing Load Transfers

An external turret mooring system comprises of a steel box-type structure that can be either close to or extended some distance from the bow or stern of the vessel, providing a foundation for a rotating bearing arrangement and a turret located above water. The bearing accommodates a fixed chain table to which mooring chains and fluid transfer hoses are attached. The turret may also include a TTS, flexible riser connections, seals, valves, initial separation assemblies, mooring attachments and securing bolts. Product and utility connections are made between the facilities on the vessel and the seabed via the FTS or swivel stack in the turret, allowing the vessel to weather vane around the fixed part.

1.4 THE US GOM CONTEXT – OFFLOADING FROM PERMANENTLY MOORED AND DISCONNECABLE FPSOS

With one disconnectable FPSO now working in US GoM and another expected to be sanctioned soon, operation of disconnectable turret moored FPSOs is relevant in the context

here.

Permanent turret mooring systems are designed so that the turret is an integral part of the FPSO: if they are not disconnectable and as a result the FPSO will stay on location during all environmental conditions. A disconnectable mooring system allows the FPSO to be disconnected from the turret so that it can be moved in case of a severe environmental event.

The use of a disconnectable turret is preferred by the MMS and USCG, based on inputs from GoM operators to them for GoM operations to minimize the risk of a large spill should the FPSO be damaged in a storm or collision.

Disconnectable turret mooring systems will not be beneficial in a collision event as it would take too long to disconnect the FPSO to avoid a collision with a powered large vessel.

The disconnection capability does make it easier to discontent the FPSO for repair and / or upgrades after some years in operation.

2. THE "HILOAD DP" TECHNOLOGY

The HiLoad DP system is a new concept for offshore loading, where offloading is done by means of a dynamically positioned floating loading terminal. The loading terminal called the "HiLoad DP" is capable of docking onto any standard oil tanker:

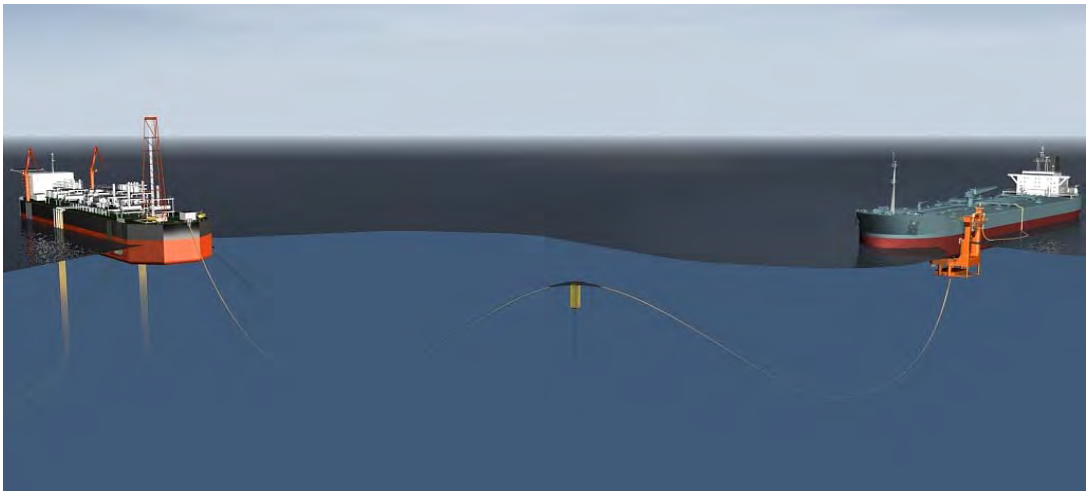


Figure 2: The Hiload DP Configuration for Offloading Operations

The prototype was designed to load from tankers up to VLCC size, i.e. up to 320 000 DWT, while keeping this tanker at a safe distance from the exporting platform/FPSO/FSO during the offloading operation.

The principal characteristics for the prototype are:

10,000 hp
102 ton Bollard Pull
DP2 Station Keeping System (Kongsberg)
Lightship weight: 4200 ton
DNV Classed
27 x 28 x 47 meters, 17 m draft

The HiLoad DP version for US GoM operations would likely be smaller as offloading tankers are expected to be smaller for GoM operations.

The HiLoad DP consists of the following major components:

- Hull and structure
- Equipment for crude oil
- DP equipment
- Equipment for crew
- Machinery main components
- Systems for machinery main components
- HiLoad DP common systems
- Integrated automation systems

The HiLoad DP is ballasted by means of filling or discharging seawater in the ballast tanks to float in upright condition with the pontoon well below the surface at all times during operation, being hydrostatically stable at all drafts. It carries the weight of the unsupported portion of the transfer hose and the hose reel with loading hose to the tanker. When disconnected from the tanker, the HiLoad DP is kept at survival draft minimising the environmental loads on the unit.

When connected to a tanker, the HiLoad DP will stay attached by means of a dedicated attachment system based on a combination of buoyancy, hydrostatic pressure and friction. The vertical force towards the tanker hull bottom is essential for obtaining the required pressure on the friction pads, to be able to transfer the horizontal loads from the thrusters to keep the tanker in position. The attachment system shall be of a redundant design, allowing failures without losing the necessary friction force. The tanker bottom plating will not be subject to high stresses due to the vertical forces or friction pads because the water pressure of same magnitude are substituted by the HiLoad DP vertical forces. In effect the conventional tanker becomes a DP tanker:

Figure 3: Standard Tanker Converted to Tanker with DP Capabilities by Use of the HiLoad DP

Deepwater offloading factors started with harsh environments and limited infrastructure and designed for:

- Demand for utilization of conventional tankers
- Robust technical/operational solution
- Economics
- Limited flexibility in current offloading solutions available.
- Risk, uncertainty and doubts toward innovation.

Key drivers in the design philosophy included:

- Increase overall safety in offloading operations
- Increase offloading availability using standard tankers
- Reduce offloading cost
- Create mutual business opportunities with shipowners and operating oil companies

The objective of the prototype test were to:

- Gradually increase HiLoad DP operations in sea states exceeding significant wave heights (Hs) of 2.5 m.
- Demonstrate controlled docking, undocking and DP station keeping capabilities of an Aframax size tanker in sea states up to Hs 3.5 m.
- Mature the HiLoad DP solution and reach an acceptable “Technology Readiness Level” (TRL) for field implementation on existing/future FPSO projects.

Prototype test results showed that in approaching a storage vessel:

- HiLoad DP positioned the tanker safely and controlled up to the selected position close to the “FPSO”
- No “overshooting” of the selected position
- Position accuracy during final approach was normally within 1-2 m.

Acceptance of the concept has included dealings with trade groups as follows:

- Tanker Owners and Operators - Remora is in stady contact with sixteen (16) leading tanker owners
- INTERTANKO - approached and documentation package submitted. HiLoad DP operational results presented to members and various committees
- OCIMF - Several presentations made to OCIMF Floating Terminal Committee. OCIMF guideline planned to be developed after first implementation.
- HiLoad DP classified as DPLT (Dynamic Position Loading Terminal)

Safety features have been recognized as:

- Dynamic Positioning (DP) used for station keeping of tanker during offloading:
- High degree of redundancy
- Weather-vaning principle = Tanker will always drift away from FPSO (“fail-safe”)
- No use of Mooring Hawser.
- Safety Systems implemented for HiLoad DP similar to DP2 Shuttle Tankers:
- Redundant DP Station Keeping System (DP2)
- Quick Connect/Disconnection of Hose
- “Green Line” Cargo Safety System
- Crew extensively trained for Offloading Operations
- Less number of vessels involved in overall operations
- Hose Connection Operation carried out from Deck Level on Tanker
- No Operation in “splash zone” or use of Hose Handling Vessels

3 COMPARISON – TECHNOLGY STATUS

The advance of new technologies in the offloading business is slow and marches to a quite different drummer for innovation than happens in (say) the computer business. It is probably slower than in many sectors in the petroleum industry!

An overriding factor in this community is marine safety. By the nature of that, it takes time to successfully prove safe operating equipment, particularly for something as novel in the industry as HiLoad DP. Thus in addition to the Technology Readiness Level (TRL) scale, the acceptance by leading tanker owning companies plus key trade groups like INTERTANKO and OCIMF is a critical parallel hurdle.

For the US GoM, regulatory acceptance of HiLoad DP is similarly a critical and parallel hurdle to jump over in the race to TRL 7.

Existing offloading methods relevant for US GoM can be taken as TRL 7. In comparison, we believe that HiLoad DP is between TRL 5 and TRL 6.

APPENDIX A:
FILINGS WITH RPSEA

A.3
Technology Transfer Plan

DOCUMENT TITLE:
Technology Transfer Plan

Document No.: 10121-4407-01-103

RPSEA PROJECT TITLE:
Deepwater Direct Offloading Systems

RPSEA Project No.: 10121-4407-01

15 October 2012

By:

Kim Diederschen
Project Sponsor
Remora Technology, Inc.
800 Town & Country Boulevard, Suite 300
Houston, Texas 77024
Phone: +1 281 598 2460 Fax: +1 281 598 2461
www.remoratech.com

LEGAL NOTICE

This report was prepared by Remora Technology, Inc. as an account of work sponsored by the Research Partnership to Secure Energy for America (RPSEA). RPSEA members, the National Energy Technology Laboratory, the U.S. Department of Energy, nor any person acting on behalf of any of the entities:

A. *Makes any warranty or representation, express or implied with respect to accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe privately owned rights,*

   or

B. *Assumes any liability with respect to the use of, or for any and all damages resulting from the use of, any information, apparatus, method, or process disclosed in this document.*

Reference to trade names or specific commercial products, commodities, or services in this report does not represent or constitute an endorsement, recommendation, or favoring by RPSEA or its contractors of the specific commercial product, commodity, or service.

ABSTRACT

This Document

This document is a summary of how Remora Technology Inc. has already transferred technology to RPSEA in the form of model test results already completed and paid for by Remora. These comprise work done to show the satisfactory performance of Remora 's Hiload DP design under the latest GoM hurricane criteria. This document additionally sets forth how Remora intends to actively transfer technology and learnings that may be generated in this project for RPSEA.

This Project

Remora Technology, Inc. was awarded a contract from RPSEA under which the ultimate objective was to verify, for U.S. deepwater operators, that the direct offloading system called the "HiLoad DP" will meet U.S. Gulf of Mexico (GOM) requirements to enable its functioning successfully for both steady-state production situations as well as standby roles for emergency situations, to provide sufficient knowledge to proceed immediately with the final engineering and contracting process to make the HiLoad concept available to GOM operations.

Traditional offloading procedures have been in use for loading crude oil into tankers from loading buoys, FSOs or FPSOs for something like fifty (50) years. For the past decade a different offloading system, well suited for harsh environment and deepwater operations, has been designed, built and commissioned by Remora. In 2011 that system passed full scale prototype tests offshore Norway.

SIGNATURE PAGE

Date: 15 Oct 2012.

Kim Diederichsen
Project Sponsor (Senior Vice President, Americas)

Date: 15Oct12

Peter Lovie PE, PMP, FRINA
Principal Investigator / Project Manager

This page is intentionally left blank.

CONTENTS

1 COMPANY INTRODUCTION & BACKGROUND

1.1 COMPANY INTRODUCTION

1.2. BACKGROUND

1.3 MOTIVATION FOR INNOVATION

2 TECHNOLOGY DESCRIPTION

3 TECHNOLOGY TRANSFER

LIST OF FIGURES

Figure 1: HiLoad DP vessel

Figure 2: Station keeping of Tanker

Figure 3: Function of the Friction Attachment System

Figure 4: Typical Field Layout with offloading from spread moored FPSO

Figure 5: Station keeping of tanker by use of HiLoad DP

1. COMPANY INTRODUCTION & BACKGROUND

1.1. COMPANY INTRODUCTION

Remora is an oil service company, focusing on providing the international market with innovative solutions for offshore loading of oil. The company was incorporated in 2002 and has its registered head office in Stavanger, Norway, with a branch office in Houston, USA.

Remora's business model is built on the same principles as those of a ship-owner, focusing on building, owning, leasing and operating HiLoad units.

For further information please see: www.remoratech.com

1.2. BACKGROUND

Traditionally, offloading of crude oil from FPSOs to tankers is carried out either in tandem configuration or via a remote Single Point Mooring (SPM) buoy solution. Tandem operations are normally carried out by use of specially built Dynamically Positioned (DP) tankers or with conventional tankers along with the use of several tugs in order to keep the tanker at a safe distance from the FPSO. The HiLoad DP concept is designed to dock onto and keep any of the existing 2200 conventional tankers, from Panamax to VLCC size, safe on position during offloading operations.

Most of the conventional tankers referred to are not equipped with any special means for offshore loading, other than mooring brackets on the bow and a hose handling crane midships. All these tankers are therefore dependant on use of assisting vessels such as tugs and line handling boats for maneuvering, station keeping and cargo hose handling. For deepwater field developments these vessels will become dedicated and will become a significant addition to the operation cost.

The ideas behind the DP vessel is to use the features and experience gained from using purpose-built shuttle tankers in the North Sea and basically incorporate these on any conventional tanker during offloading operations. North Sea shuttle tankers are all equipped with dynamic positioning, specialized equipment for mooring and hose connection and

extensive safety systems. All onboard personnel go through training programs on a regular basis, such as emergency shut-down simulations.

The HiLoad DP vessel concept is an innovative utilization of basic laws of nature. The ballasting system combined with a large square area of friction rubber enable the HiLoad to replace the water pressure on the tanker hull with no mechanical connection - resulting in a friction force 20 times larger than needed to keep a tanker vessel in position in rough sea states.

Furthermore, its generic feature utilizes the common design criteria for all tanker vessels of the world: flat bottom and straight sides. This creates a unique flexibility for the standardized HiLoad DP vessels: they can operate in any water depth, with any tanker of opportunity and on any oil field or terminal with no or only limited modifications required.

Throughout the entire period a systematic technology qualification approach was undertaken in order to maintain all the important features of a purpose-built tanker even when being used in conjunction with conventional tankers of convenience.

1.3 MOTIVATION FOR INNOVATION AND DEVELOPMENT

It was at an early stage recognized that development and implementation of the HiLoad DP vessel would introduce uncertainties that might imply significant adverse consequences and risk elements to the end-users and field operators. It was also recognized that some of the traditionally and well-proven offloading methods would probably be preferred to the HiLoad DP vessel, which at that time was considered non-proven technology, even if it later would provide significant operational improvement or cost-efficiency.
Throughout the 10 year long developing period the following could simplified describe the main drivers and motivation factors for entering into Innovation and the Technology Development, hence the HiLoad DP vessel was believed to:

- Increase overall safety in offloading operations
- Increase offloading availability/accessibility
- Reduce offloading cost
- Create mutual business opportunities

2. TECHNOLOGY DESCRIPTION

The HiLoad DP vessel is a complete self powered unit which has been designed and constructed according to DNV's Offshore Service Specifications, Standards and relevant Rules for Ships and it complies with the functional requirements for typical deepwater SPM. The HiLoad DP vessel can accommodate and perform station keeping of any size tanker from 70.000 dwt (Panamax) to 320.000 dwt (VLCC).

Figure 1 – HiLoad DP

The DP vessel is equipped with a dual redundant DP system configured to satisfy class notations equivalent to Dynamic Position Class 2 applications, whereas most of the DP vessel's equipment is located in the Pontoon. The general arrangement of the pontoon reflects the high level of redundancy implemented, whereas critical rooms and systems have been duplicated.

The vessel is equipped with three direct driven azimuth thrusters (2,350 kW each) and powered by individual diesel engines. Each of the three thrusters provides 50% of the required thruster force to keep a VLCC in position. Potential loss of one thruster is considered as a single point failure in a DP class 2 set up and will due to the redundant system not affect the position keeping capability of the vessel. The DP vessel is therefore fully maneuverable with only two thrusters in operation.

Figure 2 – Station keeping of Tanker

In order to move the overall centre of gravity down below the centre of buoyancy and obtain the required stability margin, a large keel is implemented below the pontoon, where 1700 tons of fixed ballast has been installed in three separate ballast steel boxes. The keel arrangement ads a significant dampening effect of the combined set-up (DP vessel and tanker) is designed to give high hydrodynamic dampening, thereby reducing overall roll and pitch motions during operations as well as in survival condition. All contact forces between the DP vessel and the tanker are transferred by the fender system (Friction Attachment System) installed on top of the pontoon.

The fender system basically consists of 6 cells each covered by high friction rubber elements and individually surrounded by a heavy duty compression seal.

During contact with the tanker, the fender system will establish 6 independent and closed cells against the bottom of the tanker. The hydrostatic pressure acting on the bottom of the DP vessel will then be transferred to the tanker hull through the fender system. As a result, the attachment force on the fender system is increased and will vary as a function of the draft of the tanker. Since distributed loads are only replacing the hydrostatic pressure, it will only have limited impact on the local and global loads on the tanker.

The function of the system is shown below:

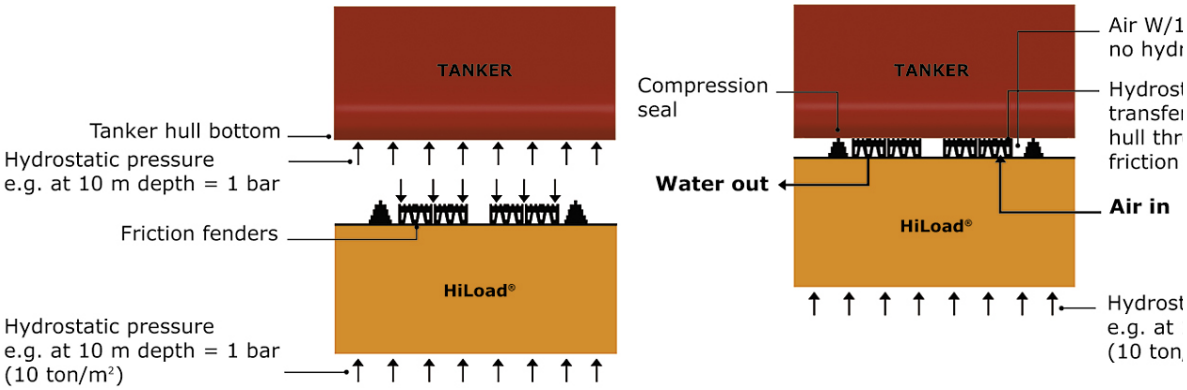


Figure 3 – Function of the Friction Attachment System

A typical Field Layout with offloading from an FPSO is shown below.

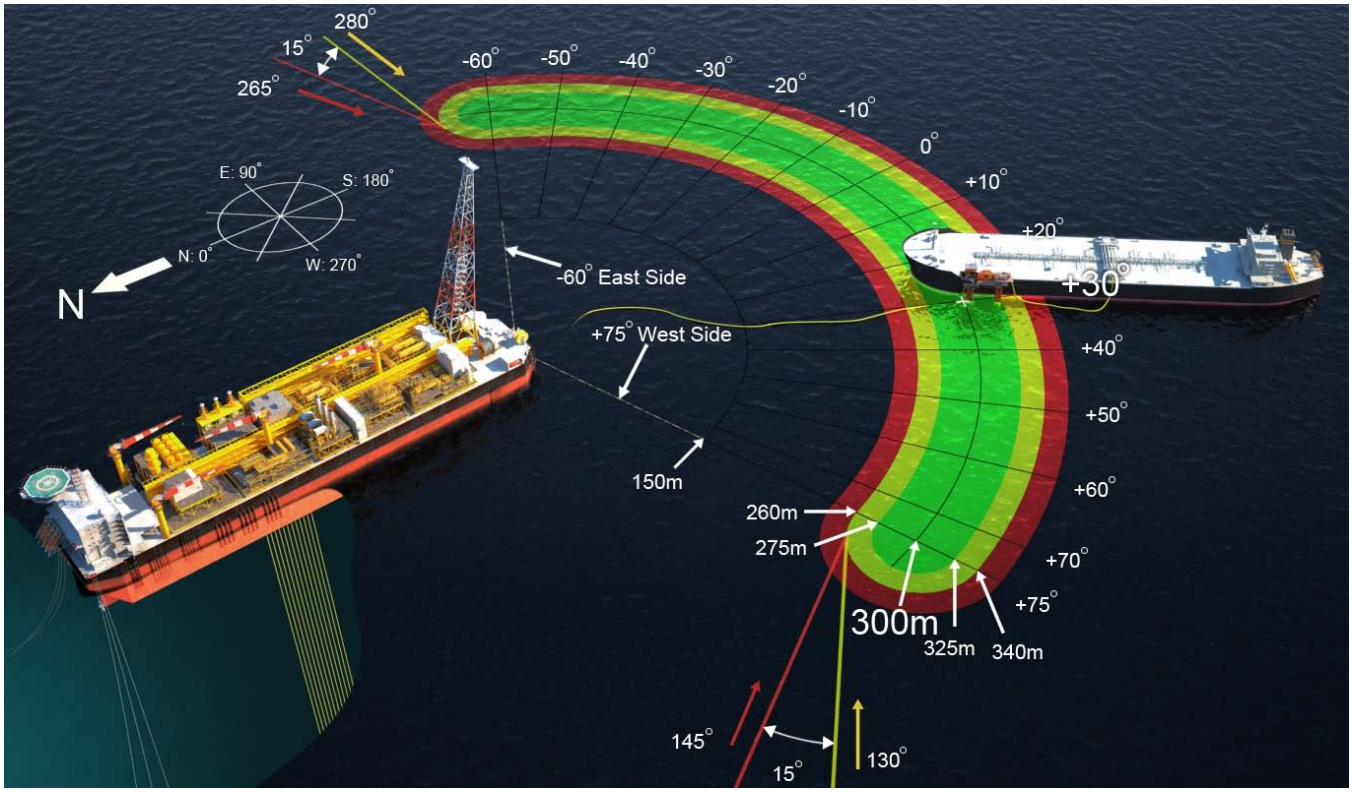


Figure 4 – Typical Field Layout with offloading from spread moored FPSO

Once the HiLoad DP vessel is connected to the tanker, the HiLoad DP vessel supports the tanker approach and maneuvering operations as well as the station keeping of the tanker during the entire offloading operation (typically 24 hours). The HiLoad DP vessel's onboard crew comprises of three people: Two DP operators and one marine engineer.

The DP operators have visual contact with all critical areas of the operation at any given time, providing additional safety to the technically fully redundant system.

Figure 5 - Station keeping of tanker by use of HiLoad DP

3 TECHNOLOGY TRANSFER

Remora Technology, Inc. intends to actively transfer technology and learnings to RPSEA in this project, in addition to other deliverables, through the following mechanisms:-

RPSEA Technical Advisory Committee

Remora Technology Inc. will provide PowerPoint presentations for all of RPSEA's Technical Advisory Committee (TAC) meetings. From time to time, Remora Technology Inc. will participate in the TAC meetings to provide in-person presentations for particular milestones.

Remora's website www.remoratech.com provides public access to:

- General information on Remora and the RPSEA project scope of work
- Link to press center
- Link to technology downloads
- Link to performance tests and performance results
- Link to Final RPSEA Project report
- Links to all published articles based on Remora deliverables
- Abstracts of conference presentations based on Remora deliverables

Conferences

- RPSEA UDW Conference 19-20 Sept 2012, Houston: Presentation on RPSEA project plans and relevance to Gulf of Mexico. (100%RPSEA)

- 2nd Annual Emerging FPSO Conference 26-27 September, 2012, Galveston: Deepwater Offloading Special Session. Remora presentation of HiLoad DP Gulf of Mexico application (50% RPSEA)

- OTC May, 2013, Houston: Paper on RPSEA deliverables (100%RPSEA)

At the moment Remora does not have any further conference commitments in place, however, typically another 2-3 opportunities arise during a 12 month period, at which we present technical HiLoad DP information to publicly accessible conferences.

Remora remains available to conduct a reasonable number of presentations in Houston as requested by RPSEA throughout the project period.

Working Group Meetings

- November 2012, 1st RPSEA HiLoad DP Work Group Meeting/Workshop, Houston,TX

- December 2012, 2 day Risk Assessment hosted by ABS, Houston, TX

- January 2013, 2nd RPSEA HiLoad DP Work Group Meeting / Workshop, Houston, TX

- March 2013, 3rd RPSEA HiLoad DP Work Group Meeting / Workshop, Houston, TX

- May 2013, 4th RPSEA HiLoad DP Work Group Meeting / Workshop, Houston, TX

- June 2013, 5th RPSEA HiLoad DP Work Group Meeting / Workshop, Houston, TX

The work product from these meetings is expected to be available in Powerpoint presentations and meeting notes which will be uploaded to RPSEA.

Financial Contributions

- RPSEA will benefit immensely from the fact that the costs of preparing papers and presentations authored by Remora and other users of RPSEA deliverables will be paid by employers and not charged to the RPSEA project.

- Remora will provide the HiLoad DP model test reports and associated videos for the model tests performed for Gulf of Mexico Hurricane conditions that represent the latest post 2007 environmental criteria – that will now be used in the design for the HiLoad DP for GOM. This work was performed by Remora at MARINTEK in Norway. It represents a cost to Remora of **$396,000** out of a total model test investment of about **$2,3000,000**.

APPENDIX B:
TASKS 1-4 – SUPPORTING INFORMATION

B.1
2009 HAZID Report

HILOAD DP

HAZID REPORT

RS-REP-09-008-001 Rev 1

20 May 2009

© 2009 IRC Risk and Safety

Protecting life by shaping design and operation of hazardous facilities

10497 Town & Country Way, Suite 800, Houston, Texas, 77024, USA
t: 713 647 7929, f: 713 467 9757, Email: irc@irc-americas.com, Web: www.irc-americas.com

Title:	**Report Number:**
HiLoad DP: HAZID Report	RS-REP-09-008-001 Rev 1
Client:	**IRC Office:**
Remora	Houston

Keywords:

HiLoad, DP, HAZID, FPSO

Country:

USA

Document Revision Status

Revision	Description	Author	Review	Approval	Date
A	Internal Review	CN	DN		06 April 2009
0	Issue to Client	CN	DN	JFK	14 April 2009
1	HAZID Team Comments Incorporated	CN	DN	JFK	20 May 2009

This report has been prepared for use by, and is confidential to Remora for the specific purpose to which it refers. No responsibility is accepted to any third party. This report is copyrighted, and neither the whole nor any part of this report or the information contained in it may be published or disclosed to third parties without the prior written approval of IRC and/or Remora.

Table of Contents

ABBREVIATIONS 4

1 INTRODUCTION 5

1.1 Background 5

1.2 Objective 5

1.3 Scope 6

2 METHOD 7

2.1 Overview 7

2.2 HAZID Nodes and Subsystems 9

2.3 HAZID Guidewords 10

2.4 Date and Schedule 10

2.5 HAZID Team 10

2.6 Workshop Recording and Reporting 11

3 RESULTS 12

3.1 Team Members' Areas of Concern 12

3.2 Recommendations 12

3.3 Parking Lot Issues 12

3.4 Post-HAZID Discussion Regarding Transfer of Mooring Master (Pilot) to Tanker 13

4 ATTACHMENTS 14

ATTACHMENT 1: GUIDEWORDS

ATTACHMENT 2: TEAM MEMBERS' AREAS OF CONCERN

ATTACHMENT 3: RECOMMENDATIONS

ATTACHMENT 4: PARKING LOT ISSUES

ATTACHMENT 5: HAZID WORKSHEETS

ABBREVIATIONS

ABS	American Bureau of Shipping
CALM	Catenary anchor leg mooring
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea, 1972
DP	Dynamic positioning
DNV	Det Norske Veritas
EER	Escape, evacuation, and rescue
ESD	Emergency shutdown
F-A/M/C	DNV class notation for increased fire protection on accommodation, machinery spaces, and cargo areas
FMEA	Failure modes and effects analysis
FOI	Floating offshore installation
FPSO	Floating production, storage, offloading
FSA	Formal safety assessment
GoM	Gulf of Mexico
HAZID	Hazard identification
HC	Hydrocarbon
HL	HiLoad DP
HVAC	Heating, ventilation, air conditioning
IMO	International Maritime Organization
OSV	Offshore support vessel
QC/DC	Quick connect / disconnect
RAM	Reliability, availability, maintainability
SIMOPs	Simultaneous operations
USCG	U.S. Coast Guard

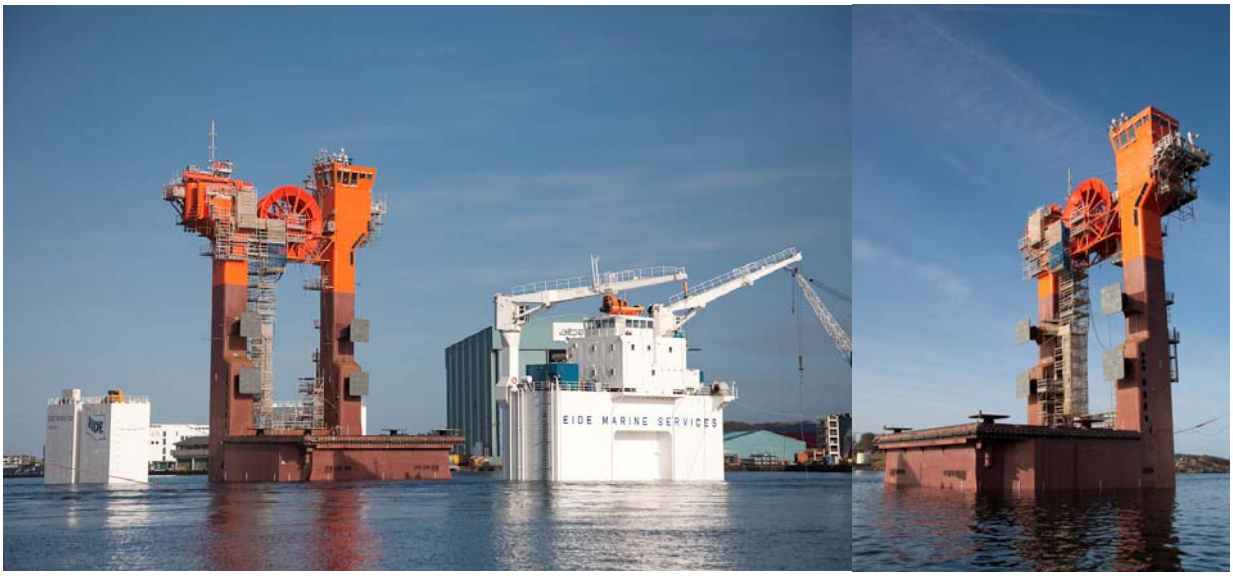
1 INTRODUCTION

1.1 Background

Remora ASA (Remora) is building a HiLoad® DP for use in offshore offloading. The primary use being considered for the HiLoad DP is the offloading of an FPSO and subsequent transfer of liquid product to tankers. In addition, a secondary application involving the use of a HiLoad DP as an emergency offloading system for assets with damaged infrastructure (e.g. due to hurricane damaged pipelines) is also being considered. A significant amount of development work and engineering has been conducted to assess and validate the HiLoad DP design. Recent photos of the HiLoad DP are shown in Figure 1.1.

In order to assess the safety of the design, Remora requested that IRC Risk and Safety, LLC (IRC) facilitate a hazard identification (HAZID) analysis, which will include the participation of several members of the oil and gas industry. This document presents the results of the HAZID.

Figure 1.1: HiLoad DP during Sea Launch in March 2009



1.2 Objective

The objectives of the HAZID were to:

- Identify and understand all hazards associated with the operation of the HiLoad DP
- Identify design elements that act as safeguards to prevent or mitigate the hazard
- Make recommendations to reduce risks and improve the design and operation of the HiLoad DP to meet the needs of Remora's clients

1.3 Scope

The scope of the HAZID addressed the following operational modes of the HiLoad DP:

- HiLoad DP between offloading operations (i.e., HiLoad parked on the FPSO)
- HiLoad DP travel from the FPSO to the tanker
- HiLoad DP connection/disconnection to tanker
- Dynamic positioning (DP) station keeping of tanker
- Product transfer
- HiLoad DP operations during a hurricane

The HAZID scope considered consequences and risks in terms of:

- Personnel safety
- Environmental impacts
- Loss of production
- Loss of plant or equipment
- Liability
- Insurability

2 METHOD

2.1 Overview

HAZID is a systematic team based technique for identification and assessment of hazards and risks. The HAZID process systematically reviews facilities and their operation to assess:

- Hazards and associated accident events
- Potential consequences associated with accident events
- Barriers and recovery measures in place to prevent and recover from accident events

The HAZID process is most effective when undertaken early in the design or planning stage for a facility or operation. At this stage, changes to the design and/or operation can be made most cost effectively.

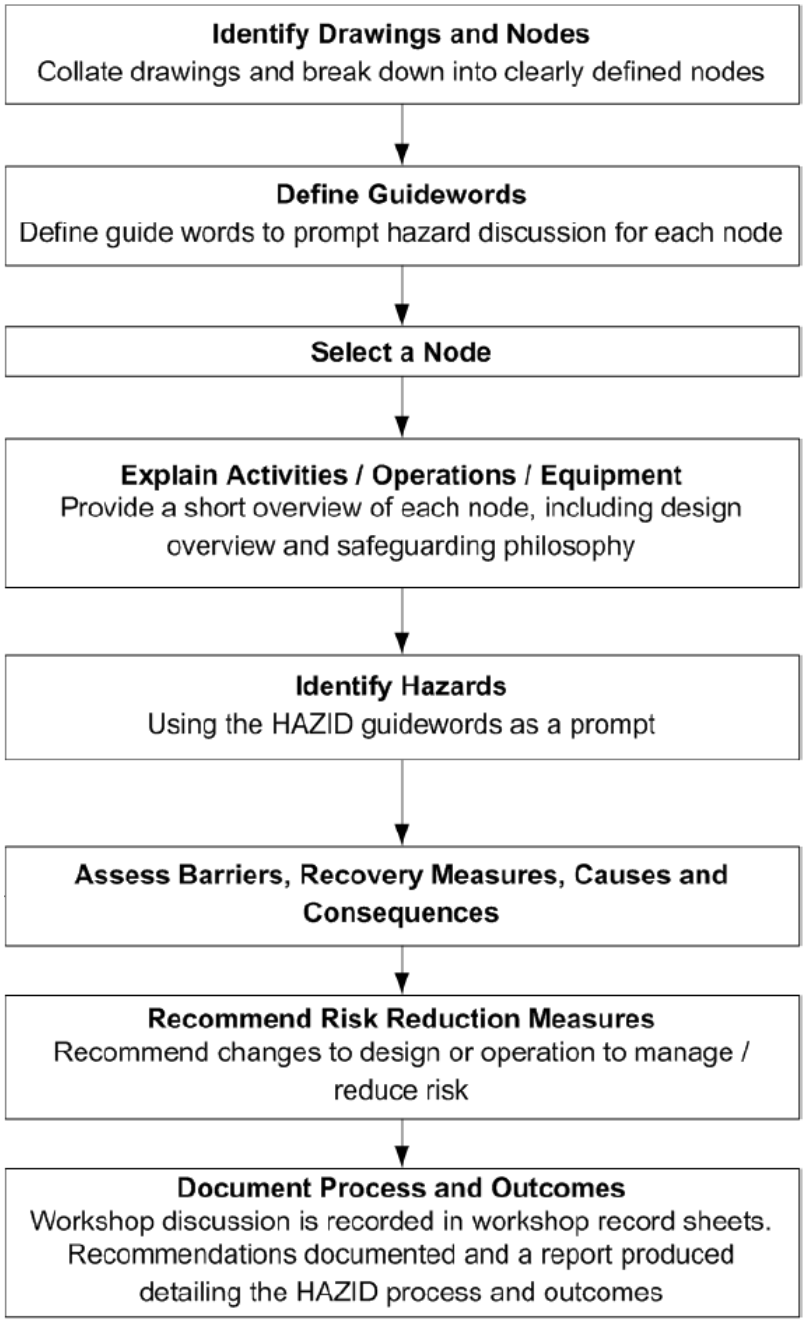
For this project, the emphasis was to focus on issues related to operation of the first HiLoad DP, which is approaching mechanical completion; however design related recommendation could be applied to future HiLoad DP units.

The methodology used for the Remora HAZID is shown graphically in Figure 2.1.

Following completion of the workshop session, the recommendations were assigned a time-based priority by Remora and IRC as follows:

1. Close-out of recommendation expected within one month
2. Close-out of recommendation expected at least three months prior to HiLoad deployment
3. Close-out of recommendation expected prior to HiLoad deployment

Figure 2.1: HAZID Methodology



2.2 HAZID Nodes and Subsystems

The node listing for the Remora HAZID is given in Table 2.1.

Table 2.1 HAZID Node Listing

Description	Facility Location
1. HiLoad DP between offload operations	Spread moored FPSO (W Africa or Brazil); or GoM
2. HiLoad DP travel from the FPSO to the tanker	Spread moored FPSO (W Africa or Brazil); or GoM
3. HiLoad DP connection / disconnection to tanker	Spread moored FPSO (W Africa or Brazil); or GoM
4. DP station keeping of tanker	Spread moored FPSO (W Africa or Brazil); or GoM
5. Product transfer	Spread moored FPSO (W Africa or Brazil); or GoM
6. Emergency offloading, GoM hurricane	GoM: FPSO or platform emergency offload

For each of the nodes defined above, the following subsystems of the HiLoad DP were considered:

1. General
2. Attachment system (fenders, seals, valves, etc)
3. Ballast and bilge (tank configuration, pump system, etc)
4. Offloading hose (handling, reel, lines, etc)
5. Maneuvering and station keeping (thrusters, DP, tug assist, etc)
6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)
7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)
8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)
9. Loss of station ("drive off", etc)
10. Links with the offtake tanker (e.g., communications)

2.3 HAZID Guidewords

Guidewords were reviewed for each node to prompt team discussion and development of hazards and associated accident events. The team was not restricted or constrained by the supplied guidewords. Where appropriate, additional guidewords were used by the team to describe scenarios particular to that node.

Guidewords provided to the HAZID team are listed in Attachment 1.

2.4 Date and Schedule

The date, venue, and schedule for the HAZID are given in Table 2.2.

Table 2.2 HAZID Date and Venue

Date	Tuesday, 31 March 2009
Location	IRC office: 10497 Town and Country Way, Suite 800, Houston, TX 77024
Time	8:30 am to 5:00 pm

2.5 HAZID Team

The HAZID team list is given in Table 2.3.

Table 2.3 HAZID Team List

Last Name	First Name	Role	Company
Adhia	Gautam	Team Leader, FPSO Projects	Chevron Shipping Company
Carson	Bob	Manager, Safety and Technical	OSG
Davis	Dean	Staff Marine Development Engineer	ConocoPhillips
Eiermann	Byron	Vice President, Surface Facilities Engineering	Murphy (Doris, Inc.)
Gill	Keith	Nautical Services Advisor, LNG Ships and Marine Systems	ExxonMobil
Hellesmark	Svein B.	Technology Manager	Remora
Høifødt	Fred A.	Technical Superintendent	Remora (by video conference)
Johansen	Knut-Erik	Engineering Manager	Remora (by video conference)
Lee	Ming-Yao	Team Manager, Offshore and Marine Structures	Chevron Energy Technology Company
Lovie	Peter	Senior Advisor, Floating Systems	Devon
Messel	Capt. Erik	HiLoad DP Captain	Remora (by video conference)

Last Name	First Name	Role	Company
Moseid	Joerund "Jay"	Project Engineer	TORP Technology Inc.
Muddusetti	Suman	Marine Operations Advisor	Shell
Newby	Mark	Manager, Global Production	ConocoPhillips
Newman	Carolyn	Principal Safety and Risk Consultant (Scribe)	IRC
Nordin	Don	Business Development and Marketing Director (Facilitator)	IRC
Olsen	Claes	VP, Business Development	Remora
Olsen	Capt. Frode	Operation Manager	Remora (by video conference)
Robison	Eldon	Manager Marine Operations	Exmar Offshore
Sandvik	Andreas	did not attend	StatoilHydro
Siewe	Thomas	Terminals- FSO-FPSO Specialist	Total
Srinivasan	Sanjay	Floating and Fixed Systems	Chevron Energy Technology Company
Strøm	Øyvind	HMS Manager, GoM	StatoilHydro
Willey	Ed	Advisor, Facilities Engineering	Chevron

2.6 Workshop Recording and Reporting

HAZID worksheets were generated throughout the session using PHA-Pro software and presented to the team by projector.

A preliminary list of recommendations and the HAZID worksheets were issued to Remora following completion of the session. This report contains the final list of recommendations and the worksheets generated during the session.

3 RESULTS

3.1 Team Members' Areas of Concern

In order to use the HAZID time most efficiently, team members' major areas of concern were documented. A summary of major interest areas expressed by the team included:

- Floating transfer hose handling, coupling, venting, control, etc.
- Redundancy and availability of critical components (e.g., ballast, DP, attachment system)
- Prevention, detection, and mitigation of fire and gas releases

The complete list of team members' major areas of concern is given in Attachment 2.

3.2 Recommendations

The HAZID team developed a total of 24 recommendations related to operation of the HiLoad DP. The six highest priority recommendations, targeted for close-out within one month are listed in Table 3.1.

Table 3.1 High Priority Recommendations

No.	Recommendation
4	Determine if classification notations include DNV F-A/M/C.
10	Ensure that the HiLoad offloading hoses can be drained safely with no adverse affects on the environment or personnel.
15	Ensure that, as a minimum, navigational aids (i.e., navigation lights) meet full COLREGs for all potential facility locations, and ensure flag state requirements are met.
17	Evaluate means for safely delivering and positioning sensors and fan-beam antenna on the tanker for mating purposes.
18	Consider increasing the 3m approach gap between HiLoad and tanker if there is potential for the HiLoad to contact the hull of the tanker.
21	Develop a procedure that allows the mooring master to get safely onto the tanker prior to HiLoad connection.

The complete list of recommendations is given in Attachment 3. The HAZID worksheets which give full context for the recommendations, are given in Attachment 5.

3.3 Parking Lot Issues

A "Parking Lot" document was also generated during the HAZID to capture issues of interest that were either intended to be addressed at a later point in the session, or were out of scope for the HAZID. The Parking Lot list is included as Attachment 4.

3.4 Post-HAZID Discussion Regarding Transfer of Mooring Master (Pilot) to Tanker

Considerable discussion took place between Remora and Shell representative in the HAZID regarding transfer of the mooring master (pilot) from the FPSO to the tanker. It is recognized that the typical transfer method is for the mooring master to be brought alongside the tanker by pilot boat, with boarding via ladder.

An option being considered is to use the HiLoad for mooring master transfer, thus eliminating the need for the pilot boat to be in close proximity to the tanker. Mooring master transfer via HiLoad would include:

- Transfer by use of the HiLoad crane and a personnel basket
- Transfer to take place prior to HiLoad connection to tanker
- HiLoad crane and winch to be upgraded for personnel transfer

A detailed procedure for transfer will be established as per Recommendation # 21 (Attachment 3).

4 ATTACHMENTS

ATTACHMENT 1: GUIDEWORDS

Category	Guideword
Aircraft	Weather patterns Flight patterns • Duration of flight • Visiting helicopters (size capacity) • Passing helicopters • Traffic Direction of approach Mechanical failure Pilot error Wind shear
Diving Operations	Dropped Objects Life support failure Entanglement Oxygen deficient
Environmental Hazards	Weather Marine Life
Environmental Damage	Impact on water Emergency / Upset Discharges Waste Disposal
Lifting Equipment	Dropped / swinging loads Collapse of lifting equipment – cranes, drawworks etc Helicopter slung loads Rigging failure (dynamic lift, center of gravity) Human Error Offshore communications Onshore communications Emergency Response

Category	Guideword
Fire and Explosion Hazards	Offshore / onshore communications Emergency Response Stored Flammables (chemicals, process fluids) Release of Inventory (loss of containment) • Equipment defects • Human error • Degradation (corrosion, erosion, chemical attack etc.) • External impact • External erosion (sand blasting) • Material embrittlement • Fatigue • Vibration Sources of Ignition • Electricity • Flares • Sparks • Hot surfaces Equipment Layout • Confinement • Escalations • Egress and escape • Ventilation Structural failure • Blast overpressure (process equipment failure, Temporary refuge impaired etc.) • Fire attack Personnel Protection Non-process Fires • Paint stores • Galley • Accommodation offices • Gas bottle store • Explosive store • Refueling operations • Helicopter refueling

Category	Guideword
Maintenance Hazards	Equipment / Personnel Access Requirements
	Personnel exposures (to hot surfaces, process fluids, etc.)
	Material handling
	Overrides
	Bypass of safety systems
	Abandon
	Adverse weather
	Allision / Collision
	Ballast System
	Confined Space Entry
	Communications Failure
	DP System Failure (Drive Off / Drift Off / Reference Systems)
	Fatigue (Vessel Crew)
	Fire
	Flooding
	Grounding
	Man Overboard
	Marine Growth
	Mooring System (Anchors)
	Navigation Systems (Propulsion Failure / Steering)
	Spill
	Stability
	Watch keeping
	Attending / Supply Vessel Operations
	Exclusion Zones
	Mooring Buoys
	Passing Vessels
	Platform Operations (Hazards)
	Proximity to Shipping Lanes (Vessel Traffic Density)

Category	Guideword
Operating Philosophy	Manning Accommodation • Noise • Bed space • Catering requirements Emergency Response / Evacuation Philosophy Simultaneous Operations Controls system (DCS / local panels) Start-up / shutdown Equipment / Personnel Access Requirements Personnel exposures (to hot surfaces, process fluids, etc.) Material handling Overrides Bypass of safety systems Regulatory (e.g., US Coast Guard Requirements for GoM)
Process Hazards	Process deviation (pressure, temperature, flow, composition) Extreme design operating envelopes • High pressures • Hot / cold surfaces Leaks/Spills Carcinogenic materials Toxic System Complexity Air ingress Relief (rupture discs, pressure relief valves, cold vents etc.) Flaring Electricity Ionizing radiation Asphyxiates

Category	Guideword
Structural Failure	Weather overload – wind, waves, surge, snow, ice etc Earthquake Foundations – subsidence, scour Marine buildup Corrosion Fatigue Weight control Primary structure – jacket, module members etc Secondary structures – flare, derrick, module members etc Temporary structures
Security	Terrorism Sabotage Hijack

ATTACHMENT 2: TEAM MEMBERS' AREAS OF CONCERN

Participant	Major Area of Concern[1]
Suman Muddusetti (Shell)	• Transfer of people from FPSO to tanker • Hose coupling • Ballast control on HL
Peter Lovie (Devon)	• Use of HL facility via Contractor in GoM • Timeline and process for USCG approval for GoM
Ming-Yao Lee (Chevron) Sanjay Srinivasan (Chevron) Gautam Adhia (Chevron) Ed Willey (Chevron)	Remora is requested to provide documentation on the following: • Redundancy and reliability of critical components • Knock for knock effect (liability implications) • Details of the DP2, DP2+ system
Thomas Siewe (Total)	• Use of HL for replacing tugs for positioning (considering HL use aft tanker, possibly tandem) • Floating hose connection at manifold • Emergency disconnect from tanker • Firefighting on HL • More detail on swivel FPSO to HL • Station keeping • Hose retrieval during connection; • Hose line flushing from HL
Dean Davis (ConocoPhillips)	• Venting forward tanker (e.g. affect on accommodation) during offloading • Connection of transfer hose to HL, has Class approved? • Is HL comparable to existing technologies?
Mark Newby (ConocoPhillips)	• Electrical hazardous area rating of unit; tanker will be venting HC during offloading • Hose connection, new coupling, HL HVAC
Øyvind Strøm (StatoilHydro)	• Technology qualification for the new arrangement of proven components • ABS approval, results of recent discussion • Firefighting • EER, other FSA studies
Andreas Sandvik (StatoilHydro)	Not present

Participant	Major Area of Concern[1]
Keith Gill (ExxonMobil)	• Corner to corner concern of HL to tanker hull • Ballast valves redundancies • Firefighting in HL engine space • Sea state limit for staying connected and for disconnection
Bob Carson (OSG)	Addressed by others
Eldon Robison (Exmar Offshore)	• Redundancies for ballast, cargo operations and station keeping
Byron Eiermann (Doris, Murphy)	• Redundancies for thruster system

[1] Code for text color:

- Red = out of scope for HAZID
- Yellow= should be addressed in HAZID
- Black = addressed at least partially during HAZID

ATTACHMENT 3: RECOMMENDATIONS

Recommendations	Place(s) Used	Time-frame for Closeout[1]
1. Develop a SIMOPS matrix and assess the SIMOPS associated with the operation of HiLoad and FPSO, including normal operations, emergency, commissioning, maintenance, and repair activities.	Causes: 1.1.1.1, 1.7.2.1	2
2. Prior to the commencement of operations the command structure for the HiLoad and FPSO is to be determined. A bridging document is to be developed, prior to operations, that outlines the command structure.	Causes: 1.1.1.1, 3.8.1.1	2
3. Establish emergency response procedures for when the HiLoad is connected to the FPSO, in transit to/from the tanker, or connected to the tanker; the procedure should include manning levels and command structure and ensure compliance with flag state requirements.	Causes: 1.1.3.1, 2.10.1.1	2
4. Determine if classification notations include DNV F-A/M/C.	Causes: 1.1.4.1	1
5. Reconsider need for HiLoad 5 year dry-dock frequency; compare to frequency of similar facilities (e.g. ,CALM buoy)	Causes: 1.1.6.1	2
6. Calculate HiLoad ballast flooding times for emergency operation scenarios and failure of ballast system scenarios.	Causes: 1.2.2.1	2
7. Extend the previously performed FMEA to cover entire HiLoad attachment system.	Causes: 1.2.1.1	2
8. Develop a plan for safe entry of HiLoad ballast tanks while HiLoad is offshore.	Causes: 1.3.1.1	2
9. Consider addition of oil discharge monitoring equipment on HiLoad in accordance with Class and IMO.	Causes: 1.3.2.1	2
10. Ensure that the HiLoad offloading hoses can be drained safely with no adverse affects on the environment or personnel.	Causes: 1.4.1.1	1
11. Consider maintaining the telemetry link between HiLoad and the FPSO at all times.	Causes: 1.6.1.1	2
12. Develop an ESD philosophy that will be applied between the FPSO and the HiLoad.	Causes: 1.6.1.1	2
13. Develop lift plan for the HiLoad and evaluate risks due to lifts (i.e., Dropped Objects study).	Causes: 1.7.3.1	2

Recommendations	Place(s) Used	Time-frame for Closeout[1]
14. Ensure bridging document includes operations of the HiLoad as part of the FPSO emergency response plan.	Causes: 1.8.1.1, 1.8.2.1, 2.8.1.1, 2.8.2.1	2
15. Ensure that, as a minimum, navigational aids (i.e., navigation lights) meet full COLREGs for all potential facility locations, and ensure flag state requirements are met.	Causes: 2.5.1.1	1
16. Establish training criteria for HiLoad facility personnel.	Causes: 2.5.1.1	3
17. Evaluate means for safely delivering and positioning sensors and fan-beam antenna on the tanker for mating purposes.	Causes: 2.5.2.1	1
18. Consider increasing the 3m approach gap between HiLoad and tanker if there is potential for the HiLoad to contact the hull of the tanker.	Causes: 3.5.1.1	1
19. Validate HiLoad and tanker vessel motions during sea trials.	Causes: 3.5.1.1, 3.5.2.1	2
20. Consider assessing HiLoad attachment scenarios with elevated tanker speed (i.e., minimum speed needed to maintain steerage) during sea trials.	Causes: 3.5.4.1	2
21. Develop a procedure that allows the mooring master (pilot) to get safely onto the tanker prior to HiLoad connection. See Section 3.4.	Causes: 3.8.1.1	1
22. Consider using a pre-defined HiLoad parking space on GoM outer continental shelf.	Causes: 6.1.1.1	2
23. Consider re-evaluating HiLoad attachment capability at speeds the tanker may travel if it intentionally leaves location with the HiLoad attached.	Causes: 6.1.2.1	3
24. If the HiLoad is utilized as an emergency offloading system following a hurricane, the project team is to formally evaluate the case where a subsequent hurricane enters the Gulf, and develop a contingency plan for this event.	Causes: 6.1.1.1	3

[1]Timeframe guidelines:

1. Close-out of recommendation expected within one month
2. Close-out of recommendation expected at least three months prior to HiLoad deployment
3. Close-out of recommendation expected prior to HiLoad deployment

ATTACHMENT 4: PARKING LOT ISSUES

1. Is the 3m clearance enough as the HL approaches tanker (before cushion effect) in rough seas?
2. Consider roll of HL and tanker during HL approach.
3. Test tanker coating before and after connection.
4. Consider coating types (e.g., silicon based) with different (i.e., reduced) friction capacities.
5. Ballast system redundancies are major concern of HAZID team.
6. Quick disconnect hose with hose rope (for pulling) through connection. New technology. Double seal (North sea typical is single seal) with leak monitoring, simpler connection process (less twisting with pull from center).
7. Have team members participating by video from Norway confirm firefighting and fire detection details.
8. Remora to provide existing FMEA to participants.
9. Remora to provide ship collision analysis to participants.
10. Existing manning count does not cover all scenarios (e.g., tandem offloading).
11. Comparison of HL solution to existing facilities is key interest to HAZID team. Cost, liability, insurability, availability, etc.
12. Clarify normal procedures for draining of offloading hoses at similar facilities (e.g., CALM buoy).

ATTACHMENT 5: HAZID WORKSHEETS

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. SIMOPS	1. Maintenance, repair, lifting; material handling, etc	1. At least 1 person will be on HL at all times when docked to FPSO	1. Dropped objects, equipment damage, injury	1. Develop a SIMOPS matrix and assess the SIMOPS associated with the operation of HiLoad and FPSO, including normal operations, emergency, commissioning, maintenance, and repair activities.	
		2. Integrated Control system	2. Personnel transfer issue	2. Prior to the commencement of operations the command structure for the HiLoad and FPSO is to be determined. A bridging document is to be developed, prior to operations, that outlines the command structure.	
		3. Designated HL master			
2. Parking location of HL on the FPSO	1. Parking at location other than bow (base case); proximity to flare, vent, etc	1. Designated parking area will be established prior to Operations	1. People on wrong side of blast wall		
		2. FPSOs typically have designated OSV working	2. Interference with risers		

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
		areas.	3. Interference with FPSO mooring system		
3. Communications issues between FPSO and HL	1. Fire alarms, ESD, etc are not hard wired.	1. At least 1 person will be on HL at all times when docked to FPSO	1. Delayed or improper response; potential equipment damage or personnel injury	3. Establish emergency response procedures for when the HiLoad is connected to the FPSO; the procedure should include manning levels and command structure and ensure compliance with flag state requirements.	
		2. Manning levels have been established, min 3 or 4 personnel on HL at all times, including during parking			
4. Fire on HL or FPSO	1. Any of multiple fire events, e.g. fuel or HC release	1. Ability to quickly disconnect loading line	1. Potential injury or equipment damage	4. Determine if classification notations include DNV F-A/M/C.	Possibility for foam monitors to provide coverage to FPSO
		2. 2 x100 Firewater pumps			
		3. Fixed fire suppression in engine space (water mist).			
		4. Foam monitors cover HL loading area.			
		5. Fire detection on HL: part of integrated control system, covering entire HL			

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
5. Gas release from FPSO	1. Leak, vent, etc	1. Gas detection on HL: part of integrated control system, covering entire HL	1. Potential explosion, injury or equipment damage		DNV FOI; Subnotation: Dynpos (for the Integrated Control System)
6. Reduced availability of unit for Offloading	1. Extended downtime due to drydock	1. Planned freq 5 yrs, planned DT 14 days	1. Reduced availability of unit	5. Reconsider need for HiLoad 5 year dry-dock frequency; compare to frequency of similar facilities (e.g. CALM buoy)	
		2. RAM study by DNV showed 99.8% mechanical uptime for the HL			
		3. Much of the HL maintenance can be done in situ			

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Inadvertent release of HL	1. Outer seal failure (Gina seal) or other; extreme weather	1. Approx 6 x 50% attachment cells with independent valves and drainage giving safety factor 18x	1. Potential equipment damage (e.g. from gangway moving) or injury	7. Extend the previously performed FMEA to cover entire HiLoad attachment system.	

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
	event; ballast tank failure/rupture	2. 2 ballast and 2 trim pumps for each cell	2. HL will drop away from FPSO; no significant effect anticipated		
		3. Auto detection of cell failures (pressure switch, bubble monitor)			
		4. Typical 200 - 300 ton buoyancy			
		5. Auto monitor and adjustment of draft when connected			
		6. FMEA has been done for ballast system			
2. Failure to release HL from FPSO when required	1. HPU failure	1. Filling ballast tanks is through same paths as for draining	1. Delay of offloading operations	6. Calculate HiLoad ballast flooding times for emergency operation scenarios and failure of ballast system scenarios.	
		2. 2x100 HPU and 2x100 10" hydraulic valves to each cell			
		3. Can fill directly from sea via single 10" manual valve to each cell. These valves to sea provide backup to auto ballast valves.			

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Tank entry / confined space	1. Unable to access tank for maintenance, inspection	1. Confined space entry procedures 2. Multiple means of venting ballast tanks (e.g., opening drainage valves brings air into tanks via blowers)	1. HL must disconnect from FPSO and possibly move to shore for tank entry.	8. Develop a plan for safe entry of HiLoad ballast tanks while HiLoad is offshore.	
2. Dirty bilges	1. Normal operation is to have some bilge	1. Three sludge tanks to collect bilge 2. Manifold on tower to transfer from sludge tanks to FPSO. 3. Emergency overboard connection as per Class requirements. 4. Bilge alarms (two levels: gauge and isolation)	1. Potential for bilge spillage to sea.	9. Consider addition of oil discharge monitoring equipment on HiLoad in accordance with Class and IMO.	

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Overpressure of hose	1. Hose maintenance; yearly testing; solar heating of fluid remaining in hose (on reel) between offloadings	1. Exhaust from CW pumps can be used for pressure testing. Flushing with these pumps is normal operation	1. Hose damage	10. Ensure that the HiLoad offloading hoses can be drained safely with no adverse affects on the environment or personnel.	

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. NA					

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Loss of utilities from FPSO	1. ESD most likely cause	1. HL has 300 kW backup generator, with startup dependent on ESD level	1. Delayed or improper response; potential equipment damage or personnel injury	12. Develop an ESD philosophy that will be applied between the FPSO and the HiLoad.	
		2. UHF telemetry communication	2. Delay of offloading operations	11. Consider maintaining the telemetry link between HiLoad and the FPSO at all times.	
2. Blackout on the HL	1. Loss of power generation; human error, etc	1. HL has 300 kW backup generator, with startup dependent on ESD level	1. Delayed or improper response; potential equipment damage or personnel injury		
		2. FMEA has been done for DP and power generation system.	2. Delay of offloading operations		

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Personnel transfer between HL and FPSO by crane	1. No credible cause to transfer personnel by crane when HL is parked on FPSO	1. Gangway is default method for personnel transfer when HL is parked on FPSO	1. None identified		
2. Lifting materials over HL by FPSO crane	1. Moving supplies to FPSO	1. Ability to quickly disconnect HL	1. Equipment damage; injury due to dropped objects	1. Develop a SIMOPS matrix and assess the SIMOPS associated with the operation of HiLoad and FPSO, including normal operations, emergency, commissioning, maintenance, and repair activities.	
3. Lifting materials by HL crane	1. Replenishment of spares, supplies, etc	1. Material handling study has been done. 2. Ability to quickly disconnect and move HL	1. Equipment damage; injury due to dropped objects	13. Develop lift plan for the HiLoad and evaluate risks due to lifts (i.e., Dropped Objects study).	

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Personnel transfer from FPSO to HL over water	1. Normal operation is to use HL for personnel transfer	1. No relative motion on gangway because HL is connected 2. Handrails on gangway	1. Man overboard	14. Ensure bridging document includes operations of the HiLoad as part of the FPSO emergency response plan.	
2. Man overboard (other than normal transfer)	1. Maintenance, etc	1. Life saving equipment on HL and FPSO; rescue boats from FPSO 2. Barriers and handrails	1. Injury	14. Ensure bridging document includes operations of the HiLoad as part of the FPSO emergency response plan.	

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. NA					

Node (Operation of Interest): 1. HiLoad DP between offload operations

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. NA					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Collision in transit	1. Human error; adverse weather; errant vessel; OSV bringing pilot to FPSO (extra vessel traffic); blackout on HL	1. Navigation lights (modified COLREGs)	1. Vessel damage; injury; 3rd party injury	15. Ensure that, as a minimum, navigational aids (i.e., navigation lights) meet full COLREGs for all potential facility locations, and ensure flag state requirements are met.	
		2. 500m exclusion zone		16. Establish training criteria for HiLoad facility personnel.	
		3. QC/DC enables HL to move away quickly			
		4. Dedicated HL crew with manual joystick control; option for semi-DP mode			

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
		5. Bridge is manned by 2 DP operators during approach (DP2 requirement)			
		6. Collision avoidance radar			
		7. Training simulator			
		8. Checklist for transit operation			
		9. Night vision appliances			
		10. 5-6 knots max normal speed; approach speed limit is less as HL approaches tanker			
		11. Tanker pilot (mooring master) will be on HL if required by tanker			
		12. Safety fender on HL corners			
		13. HL has 300 kW backup generator, with startup dependent on ESD level			
		14. FMEA has been done for DP and power generation system.			

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
		15. Relative position sensors and docking targets between HL and tanker; and HL and FPSO			
		16. HL has 300 kW backup generator, with startup dependent on ESD level			
		17. FMEA has been done for DP and power generation system			
2. Placement of fan-beam antenna and position sensors on tanker in preparation for HL / tanker connection	1. Heavy seas	1. None identified	1. Inability to transfer personnel or equipment to tanker	17. Evaluate means for safely delivering and positioning sensors and fan-beam antenna on the tanker for mating purposes.	
			2. Delay of offloading operations		

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Blackout on the HL	1. Loss of power generation; human error, etc	1. HL has 300 kW backup generator, with startup dependent on ESD level	1. Delay of offloading operations		
		2. FMEA has been done for DP and power generation system.	2. Potential collision of HL with tanker		

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. NA					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Personnel transfer from HL to tanker over water	1. Normal operation is to use HL for personnel transfer	1. Barriers and handrails	1. Man overboard	14. Ensure bridging document includes operations of the HiLoad as part of the FPSO emergency response plan.	

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
2. Man overboard (other than normal transfer)	1. Maintenance, etc	1. Life saving equipment on HL and FPSO; rescue boats from FPSO	1. Injury	14. Ensure bridging document includes operations of the HiLoad as part of the FPSO emergency response plan.	
		2. Barriers and handrails			

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. See collision event this Node: Subsystem 5 (Maneuvering and Station Keeping), Issue 1 "Collision in Transit"					

Node (Operation of Interest): 2. HiLoad DP travel from the FPSO to the tanker

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Communications issues between HL and the tanker	1. Fire alarms, ESD, etc are not hard wired	1. Manning levels have been established, min 3 or 4 personnel on HL at all times	1. Delayed or improper response; potential equipment damage or personnel injury	25. Establish emergency response procedures for when the HiLoad is en route to the tanker; the procedure should include manning levels and command structure and ensure compliance with flag state requirements.	

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Corner to corner impact	1. High relative motion before cushion effect takes place	1. Minimal relative motion even in heavy seas	1. Vessel damage	18. Consider increasing the 3m approach gap between HiLoad and tanker if there is potential for the HiLoad to contact the hull of the tanker.	
		2. Cameras and sonar to monitor space between tanker and HL		19. Validate HiLoad and tanker vessel motions during sea trials.	
		3. Well established weather criteria			
		4. All model testing to-date has validated current 3m gap			
2. HL tower contact with hull of tanker	1. Roll of HL or tanker	1. Minimal relative motion even in heavy seas	1. Vessel damage	19. Validate HiLoad and tanker vessel motions during sea trials.	
		2. Well established weather criteria			
3. Incomplete or improper contact with tanker	1. HL positioned too far forward or aft	1. Docking targets	1. Vessel damage		
			2. Interference with FPSO mooring system		
			3. Interference with risers		

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
4. Tanker approaching too fast	1. Tanker needs to maintain steerage	1. HL acts as movable buoy	1. HL will not be able to attach at tanker speeds (approx 5 knots)	20. Consider assessing HiLoad attachment scenarios with elevated tanker speed (i.e., minimum to maintain steerage) during sea trials.	

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Transfer of mooring master to tanker prior to HL connection	1. gangway is normal ops for personnel to go from HL to tanker	1. HL crew will not normally board tanker	1. Injury	21. Develop a procedure that allows the mooring master to get safely onto the tanker prior to HiLoad connection.	
		2. Rails and other safety equipment		2. Prior to the commencement of operations the command structure for the HiLoad and FPSO is to be determined. A bridging document is to be developed, prior to operations, that outlines the command structure.	
		3. Typical transfer using pilot boat and ladder			

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 3. HiLoad DP connection / disconnection to tanker

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 4. DP station keeping of tanker

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. HC vapors (from tanker) intake to HL diesels	1. Use of HL diesels during offloading	1. Intake and vent location	1. Potential explosion, injury or equipment damage		

Node (Operation of Interest): 5. Product Transfer

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. Loss of position during offloading	1. Bad weather (e.g., squall); human error (e.g., tanker operation); blackout on HL	1. Defined operating area	1. Hose tangled, loss of offloading; hose damage; environmental release		
		2. Defined weather window			
		3. DP2+ on HL			
		4. Tanker will have engines available			

Node (Operation of Interest): 5. Product Transfer

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
		5. HL has 300 kW backup generator, with startup dependent on ESD level			
		6. FMEA has been done for DP and power generation system.			

Node (Operation of Interest): 5. Product Transfer

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 5. Product Transfer

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified / not addressed during HAZID					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. HL remain in area to ride out a hurricane (emergency offloading case)	1. Hurricane in GoM	1. The 22 most likely facilities to utilize emergency offloading have been identified	1. Equipment damage or loss of HL	22. Consider using a pre-defined HiLoad parking space on GoM outer continental shelf.	Water depths for the 22 most likely locations range from shallow to very deep (700 to 3000 ft)
		2. HL not manned when riding out hurricane	2. Requires pre-installed 3 pt mooring to be connected as hurricane approaches	24. If the HiLoad is utilized as an emergency offloading system following a hurricane, the project team is to formally evaluate the case where a subsequent hurricane enters the Gulf and develop a contingency plan for this event.	
		3. HL model testing of 3 pt mooring was successful for Katrina conditions			

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 1. General

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
2. Tanker leaves area with HL attached	1. Hurricane in GoM	1. Tanker will always be available for emergency offloading case (first hurricane only)	1. Tanker speed is reduced	23. Consider re-evaluating HiLoad attachment capability at speeds the tanker may travel if it intentionally leaves location with the HiLoad attached.	Base case is to park HiLoad and ride out hurricane
		2. Excess attachment capacity	2. Potential for HL to be disconnected at tanker speed		
			3. Tanker maneuvering is inhibited		
3. Tow HL away	1. Hurricane in GoM	1. None identified	1. Delay in securing HL		Base case is to park HiLoad and ride out hurricane

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 2. Attachment System (fenders, seals, valves, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 3. Ballast and Bilge (tank configuration, pump system, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 4. Offloading Hose (handling, reel, lines, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 5. Maneuvering and Station Keeping (thrusters, DP, tug assist, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 6. Shutdown, start-up, re-start (normal operations, interruption, draining, purging, venting, etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 7. Cranes (FPSO, tanker, HiLoad DP; material or personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 8. Personnel transfer using the HiLoad DP (e.g., regulatory personnel)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 9. Loss of Station ("drive off", etc)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

Node (Operation of Interest): 6. Part 2: emergency offloading, GoM hurricane

Subsystem: 10. Links with the offtake tanker (e.g. communications)

Issue / Event	Causes	Safeguards	Consequences	Recommendations	Comment
1. None identified as unique to GoM (refer to Nodes 1 through 5)					

APPENDIX B:
TASKS 1-4 – SUPPORTING INFORMATION

B.2
2013 HAZID Worksheets

Attachment 2 – HAZID Worksheets

1. FPSO OFFLOADING: Direct offloading from Floating Production Storage Offloading vessels (FPSO) of tanker (i.e., ship shape) and/or round configuration, in a steady-state production environment in ultra-deepwater GoM.

Node (Operation of interest): 1. HiLoad DP between offload operations

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. GoM Base case: • HL parked on FPSO, • Electric power from FPSO, • Crew lives on FPSO, • Re-fuel from FPSO, • Use FPSO supply chain to service HL, • Tanker crew for tanker loading (mooring master) to ride on HL	1. No accommodations on HL to support crew for extended time 2. Fueling 3. Servicing/ maintenance	1. FPSO may not have space or capacity for HL personnel 2. HL may park in class 0 hazardous area Mothership concept may not be viable with limited (low) number of FPSOs	2 2	1 2	3 4	1. Riser interference not a concern due to turret moored FPSO configuration (risers in bow of FPSO through turret) 2. Fixed gangway for personnel transfer between HL and FPSO 3. A60 rated topsides and towers facing FPSO	1. If the HiLoad DP (HL) utilizes FPSO as host, FPSO needs to be designed to accommodate HL (Loads from HiLoad in extreme conditions if it should stay attached, 8 add people, spare parts container, fuel for HL). 2. Design of the HL should ensure compatibility with any electrically classified (hazardous zoned) areas that may be present on the FPSO in the area where HL will be parked. 3. Provide minimum safe manning on HL while parked. COMMENT- Brazil case: - Ref only, not considered for GoM • Spread moored FPSO – very crowded with equipment/riser

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
							so not able to park on FPSO, • Use suezmax as mother ship, can hold up to 4 HL • Use mother ship to sail HL to FPSOs "logistic hub"
2. Fire on FPSO, prepare for quick departure of HL from FPSO	1. Any of multiple fire events, eg fuel or HC release	1. Potential injury to personnel, equipment damage, loss of HL	3	1	4	1. Standby crew (3) (safe manning) 2. Quick disconnect coupling for electrical power cable 3. Unmanned engine room, fast starting engines high-speed diesel engines 4. 2x100 Firewater pumps 5. Foam monitors cover HL loading area 6. Fire detection and gas detection on HL	4. In case the HL need to leave the host during an emergency, design should ensure that safe means to retrieve gangway, sever electrical/power cables and any hoses is provided (consider use of remotely operated gangway, remote disconnect for power cables/hoses). 5. Fire rating for the HL towers should be designed in accordance with the results of the Formal Safety Assessments (FSA) it may be necessary to consider uprating fire rating for hydrocarbon fire/jet fire event. 6. Reconsider designing the HL to be unmanned when parked on host vessel and ensure that design of HL will provide for remote monitoring of essential systems from FPSO control room. 7. FSA conducted on FPSO or other host should consider the HL (include ERA, blast walls, jet

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
							fire, window shields).
3. Gas release from FPSO*	1. Leak, vent, other release sources such as process upset	1. Potential for explosion, injury or equipment damage	3	1	4	Gas detection on HL: Part of integrated control system covering entire HL	
4. Collision/allision with other vessels*	1. Piloting error 2. Weather conditions 3. Equipment failure/malfunction	1. Damage and or loss of HL 2. Oil spill 3. Fire or blackout on HL	3 3 2	1 1 1	4 4 3	Exclusion zone COLREGs DP2 notation Specified operating criteria with respect to weather conditions	

* indicates scenario copied from previous HAZID performed on 20 May 2009, Remora document number RS-REP-09-008-001, which is available in attachment.

1. FPSO OFFLOADING
Node (Operation of interest): 2. HiLoad DP travel to the tanker or other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.4							

1. FPSO OFFLOADING
Node (Operation of interest): 3. HiLoad DP connection/disconnection to other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.4							

1. FPSO OFFLOADING
Node (Operation of interest): 4. Dynamic positioning station keeping of tanker

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments

1. Loop current while station keeping	1. Metocean event, site dependent	1. Operating in high loop current with associated high loading on DP thruster system and squall or other condition occurs resulting in loss of station keeping due to operating close to max power consumption (and associated consequence: damage to vessel, hose, etc)	2	3	5	1. Adequate forecast and historical data of LC to predict strength and occurrence	8. Ensure well defined operational procedures are provided and are to include limit on thruster power usage (use UK OP060-Tandem Loading Guidelines for reference and/or template). 9. Follow Marine Technology Society (MTS) DP Vessel Design Philosophy Guidelines (as recognized by USCG) for design of the HL dynamic positioning (DP) system. 10. Utilize local weather buoy to monitor loop currents on site 11. Establish loop current (LC) design criteria (uptime comparison/analysis/etc…) and ensure that powering requirements and design for HL consider LC criteria (Use statistical metocean data and API 2MET). 12. Design should consider effects of LC on HL propulsion (Limiting case will be station keeping of Aframax tanker with site specific max LC required for desired uptime/operability).
		2. May affect HL/loading uptime	2	2	4		
		3. LC could increase extent of oil spill impact on shore	2	1	3		
		4. LC could affect overall HL power consumption	2	2	4		

1. FPSO OFFLOADING
Node (Operation of interest): 5. Product transfer

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. Hose rupture	1. Excessive pressure, aged hose, mechanical damage, others	1. Potential release of oil (full transfer rate is 35k bph)	3	1	4	1. Telemetry system 2. ESD system/protocol 3. Maintenance inspection and replacement via OCMF hose requirements, industry guidelines	13. Consider providing a flow meter on the HL with connection to the loading telemetry system that will shut down the transfer pumps if a low/no flow condition is identified by the meter on the HL. 14. Consider utilization of infrared camera systems to monitor for oil spill on sea surface.

1. FPSO OFFLOADING

Node (Operation of interest): 6. HiLoad DP operations during a hurricane

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. Hurricane in GoM w/ pre-warning, HL stays attached to host	1. Metocean event	1. Reduced speed of FPSO: Impacts lost production/ increase tee-time, FPSO may not be able evacuate	3	2	5	1. Potential ability to use HL thrust for FPSO propulsion	
		2. Impact on FPSO seakeeping	2	2	4		
		3. Impact on FPSO hull integrity	3	2	5		
		4. Impact on HL attachment system: If HL comes too close to surface (ventilation), will lose sufficient water	3	2	5		

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
		column to maintain attachment. Potential to damage both FPSO and HL if HL becomes unattached 5.Impact on FPSO POB	2	2	4		
2. Hurricane in GoM w/ pre-warning, HL separates from host before storm	1. Metocean event	1. Present design fuel capacity may not be sufficient for long duration separation or run by HL	3	2	5	1. No impact on FPSO tee-time 1. Reduce FPSO POB by 8 1. Present HL design structural, buoyancy and stability to survive hurricane Katrina type storm (Hs 16m)	15. Ensure HL is designed to accommodate 8 people for duration of separation during hurricane event (approximately 7 days) 16. Ensure facilities on board and fuel capacity are designed for 7 days + operation time for separation and run in case of impending hurricane. 17. Design hull and powering on HL to travel at 5-6 kts speed.
3. Sudden hurricane (<48 hrs notice)	1. Metocean event	1. Similar to other hurricane with less severe metocean conditions	2	2	4	1. HL can be moved/disconnected in 1-2 hours	18. Ensure that the HL is refueled after each operation to ensure readiness for departure. (HL should always sufficient fuel and provision onboard to enable immediate evacuation in the event of hurricane during all operation and standby conditions).

2. Emergency Offloading from Platforms: To have the ability to offload liquid hydrocarbons from existing platforms that have been isolated by pipeline breaks such as occurred in the hurricanes of 2005.

Node (Operation of interest): 1. HiLoad DP between offload operations

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. MOB/DEMOB: Assume HL stored at some location not within GoM (ie Bahamas approx. 800 miles from central GoM)	1. Avoid damage to HL by same storm which damaged platforms. 2. May not be suitable port in US GoM for HL	1. Extended (longer) MOB time 2. Need to get COI to re-enter GoM	1 1	3 3	4 4	1. Ability to regularly operate engines and systems to keep ready. Already have operational experience with this arrangement (pier-side) 2. Potential to rest HL on bottom in advance of hurricane	19. Ensure that the HL is designed for bottoming event. 20. Ensure that the sea bottom is suitable for HL resting on bottom. 21. Identify port of refuge/bottom resting location(s).
2. MOB/DEMOB: Moored in GoM	1. Shorter MOB times	1. Need additional accommodations* - may not need if daytime team utilized 2. HL may be damaged by GoM hurricane	2 2	2 2	4 4	1. Potential to rest HL on bottom in advance of hurricane	(Recommendation 21) Identify port of refuge/bottom resting location(s).

2. EMERGENCY OFFLOADING FROM PLATFORMS

Node (Operation of interest): 2. HiLoad DP travel to the tanker or other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.2							

2. EMERGENCY OFFLOADING FROM PLATFORMS
Node (Operation of interest): 3. HiLoad DP connection/disconnection to other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.3							

2. EMERGENCY OFFLOADING FROM PLATFORMS
Node (Operation of interest): 4. Dynamic positioning station keeping of tanker

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. Loss of DP event	1. Blackout, fire, collision, others	1. Worst case: tanker collides with platform	3	1	4	1. Quick disconnect hoses and HL from tanker 2. Propulsion on tanker (kept in standby) 3. DP2+ capability on HL 4. Supply boat with slack rope connection 5. Use of “Banana sector” concept to determine safe loading position relative to prevailing weather 6. FMEA and DP trials	

2. EMERGENCY OFFLOADING FROM PLATFORMS
Node (Operation of interest): 5. Product transfer

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
1. Hose rupture	1. Contact with subsea	1. Potential release of oil (full xfr rate is 35k bph)	3	1	4	1. Telemetry system for loading 2. ESD system/protocol	22. Consider providing a swivel in offloading hose for tanker weathervaneing.

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
	infrastructure including moorings					3. Use of "Banana sector" concept to determine safe loading position relative to prevailing weather 4. Maintenance inspection and replacement via OCMF hose requirements, industry guidelines	(Recommendation 13) Consider providing a flow meter on the HL with connection to the loading telemetry system that will shut down the transfer pumps if a low/no flow condition is identified by the meter on the HL. (Recommendation 14) Consider utilization of infrared camera systems to monitor for oil spill on sea surface. 23. Adjust safe operation sector based on mooring and subsea infrastructure specific arrangement.
2. Sour/dirty crude (low flash)	1. Unknown origin of crude	1. Impact on materials (NACE MR-0175) for transfer/loading equipment 1. Potential for impact of h2s on crew	2 3	2 1	4 4		24. Design of HL should assume transfer of sour crude including h2s detection near flanges and bolted connections, also see USCG mitigation measures in 30 CFR 250.490.
3. Extended duration of operations	1. Fueling 2. Stores 3. Human factors	1. If HL is considered as autonomous ship, it may not be permitted to heel more than 17 deg (static) in damaged	3	2	5	1. MSV on station 1. Accommodation on tanker (base case)	25. Ensure that lifting apparatus on HL to be suitable for offshore operations, including lifts from supply boat decks. 26. Design should consider providing crew accommodations

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
		condition…currently can go to 25 deg					on the HL if the tanker does not have sufficient bed space. 27. Ensure that the HL flagstate is acceptable to US regulatory bodies for GoM operations.

2. EMERGENCY OFFLOADING FROM PLATFORMS
Node (Operation of interest): 6. HiLoad DP operations during a hurricane

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.6.2 and 1.6.3							

3. Offloading from Oil Spill Recovery Systems: To load spilled oil from whatever source it may be collected, into a quickly available tanker for delivery to a U.S. GoM port.

Node (Operation of interest): 1. HiLoad DP between offload operations

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Substantially similar to FPSO with extended duration (1.1 and 2.5.3)							
Sour/dirty crude (low flash), same as 2.5.2							

3. OFFLOADING FROM OIL SPILL RECOVERY SYSTEMS
Node (Operation of interest): 2. HiLoad DP travel to the tanker or other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.2							

3. OFFLOADING FROM OIL SPILL RECOVERY SYSTEMS
Node (Operation of interest): 3. HiLoad DP connection/disconnection to other vessel/platform

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.3							

3. OFFLOADING FROM OIL SPILL RECOVERY SYSTEMS
Node (Operation of interest): 4. Dynamic positioning station keeping of tanker

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.4 and/or 2.4							

3. OFFLOADING FROM OIL SPILL RECOVERY SYSTEMS
Node (Operation of interest): 5. Product transfer

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 2.5							

3. OFFLOADING FROM OIL SPILL RECOVERY SYSTEMS
Node (Operation of interest): 6. HiLoad DP operations during a hurricane

Scenario Description	Causes	Consequences	S	L	R	Safeguards	Recommendations/Comments
Same as 1.6.2 and 1.6.3							

APPENDIX B:
TASKS 1-4 – SUPPORTING INFORMATION

B.3
Description of the Diffraction Theory

APPENDIX S01

Description of the diffraction theory

REVISION	DATE	DESCRIPTION OF REVISION	Author
0	May 19, 2009	First version of the appendix.	

DESCRIPTION OF THE DIFFRACTION THEORY

First order wave loads and motions

The ship is considered as a rigid body, oscillating sinusoidally about a state of rest, in response to excitation by a long-crested regular wave. The amplitudes of the motions of the ship as well as of the wave are supposed to be small, while the fluid is assumed to be ideal and irrotational. A right-handed, fixed system of coordinates $O\text{-}X_1\text{-}X_2\text{-}X_3$ is defined with the origin in the waterline and the $O\text{-}X_3$ axis vertically upwards.

The oscillating motion of the ship in the j-th mode is given by:

$$x_j = \zeta_j \, e^{-i\omega t} \qquad j = 1,\ldots,6 \tag{1}$$

in which ζ_j is the amplitude of the motion in the j-th mode and ω the circular frequency. The motion variables x_1, x_2 and x_3 stand for the translations surge, sway and heave, while x_4, x_5 and x_6 denote rotations around $O\text{-}X_1$, $O\text{-}X_2$ and $O\text{-}X_3$ axis respectively.

The free surface at great distance from the ship is defined by:

$$\zeta = \zeta_0 \, e^{ik(x_1 \cos\alpha + x_2 \sin\alpha) - i\omega t} \tag{2}$$

where:

ζ_0 = amplitude of the wave
k = wave number = $2\pi/\lambda$, where λ is the wave length
α = angle of incidence.

The flow field can be characterized by a first order velocity potential:

$$\Phi(x_1, x_2, x_3, t) = \phi(x_1, x_2, x_3) e^{-i\omega t} \tag{3}$$

The potential function ϕ can be separated into contributions from all modes of motion and from the incident and diffracted wave fields:

$$\phi = -\, i\omega \, \zeta_0 \, (\phi_0 + \phi_7) - i\omega \sum_{j=1}^{6} \phi_j \, \zeta_j \tag{4}$$

The incident wave potential is given by:

$$\phi_0 = \frac{1}{\nu} \frac{\cosh k(x_3 + d)}{\cosh k.d} \, e^{ik(x_1 \cos\alpha + x_2 \sin\alpha)} \tag{5}$$

in which:

ν = ω^2/g
d = water depth
α = angle of incidence of the waves.

The cases j = 1,....,6 correspond to the potentials due to the motion of the ship in the j-th mode, while ϕ_7 is the potential of the diffracted waves. The individual potentials are all solutions of the Laplace equation, which satisfy the linearized free surface condition and the boundary conditions on the sea floor, on the body's surface and at infinity.

The potential function ϕ_j can be represented by a continuous distribution of single sources on the boundary surface S_0:

$$\phi_j(x_1,x_2,x_3)\ \frac{1}{4\pi}\iint_{S_0}\ \sigma_j(a_1,a_2,a_3)\cdot\gamma_j(x_1,x_2,x_3,a_1,a_2,a_3)\,dS \tag{6}$$

for j = 1,2,....,7

where:

$\gamma_j(x_1,x_2,x_3,a_1,a_2,a_3)$ = the Green's function of a source, singular in a_1, a_2, a_3
a_1, a_2, a_3 = the vector describing S_0
$\sigma_j(a_1, a_2, a_3)$ = the complex source strength.

For the Green's function a function is chosen which satisfies the Laplace equation and the boundary conditions on the sea bottom, in the free surface and at infinity. This function is given by (see Wehausen and Laitone [1]):

$$\begin{aligned}\gamma\ =\ &\frac{1}{r}+\frac{1}{r_1}+\\ &+PV\int_0^\infty \frac{2(\xi+\nu)e^{-\xi d}\cdot\cosh\xi(a_3+d)\cdot\cosh\xi(x_3+d)}{\xi\sinh\xi d-\nu\cosh\xi d}\,J_0(\xi R)d\xi+\\ &+i\frac{2\pi(k^2-\nu^2)\cdot\cosh k(a_3+d)\cdot\cosh k(x_3+d)}{k^2d-\nu^2\ d+\nu}\,J_0(kR)\end{aligned} \tag{7}$$

in which:

$$\left.\begin{aligned} r &= \sqrt{(x_1-a_1)^2+(x_2-a_2)^2+(x_3-a_3)^2}\\ r_1 &= \sqrt{(x_1-a_1)^2+(x_2-a_2)^2+(x_3+2d+a_3)^2}\\ R &= \sqrt{(x_1-a_1)^2+(x_2-a_2)^2}\end{aligned}\right] \tag{8}$$

John [2] has derived the following series for γ, which is the analogue of (7):

$$\gamma = 2\pi \frac{\nu^2 - k^2}{k^2 d - \nu^2 d + \nu} \cosh k(a_3 + d) \cdot \cosh k(x_3 + d) \cdot \{Y_0(kR) - iJ_0(kR)\} + \\ + \sum_{i=1}^{\infty} \frac{4(\mu_i^2 + \nu^2)}{d\mu_i^2 + d\nu^2 - \nu} \cos \mu_i(x_3 + d) \cdot \cos \mu_i(a_3 + d) \cdot K_0(\mu_i R) \tag{9}$$

where μ_i is the positive solution of:

$$\mu_i \tan(\mu_i d) + \nu = 0 \tag{10}$$

Although these two representations are equivalent, one of the two may have preference for numerical computations depending on the values of the variables. In general, equation (9) is the most convenient representation for calculations. When R = 0 the value of K_0 becomes infinite; therefore equation (7) must be used when R is small or zero.

The unknown source strength function σ must be determined in such a way that the boundary condition on the body's surface S is fulfilled. Due to the linearization this boundary condition is applied to the surface in its equilibrium position S_0.

$$n_j = \tfrac{1}{2}\sigma_j(x_1, x_2, x_3) + \\ + \frac{1}{4\pi} \int_{S_0}\int \sigma_j(a_1, a_2, a_3) \cdot \frac{\partial}{\partial n}\gamma(x_1, x_2, x_3, a_1, a_2, a_3)\ dS \quad \text{for } j = 1,\ldots 6 \tag{11}$$

$$n_j = -\frac{\partial \phi_0}{\partial n} \qquad \text{for } j = 7$$

n_1 through n_6 are the generalized direction cosines on S_0, defined by:

$$\left.\begin{aligned} n_1 &= \cos(n, x_1) \\ n_2 &= \cos(n, x_2) \\ n_3 &= \cos(n, x_3) \\ n_4 &= x_2 n_3 - x_3 n_2 \\ n_5 &= x_3 n_1 - x_1 n_3 \\ n_6 &= x_1 n_2 - x_2 n_1 \end{aligned}\right] \tag{12}$$

To solve equation (6) numerically the surface S is subdivided into a number of finite, plane elements on which the source strength is constant. The boundary condition is applied in one control point on each element, being the centre of the element. The integral equation (6) then reduces to a set of algebraic equations in the unknown source strengths. In general, the Green's function γ may be computed with sufficient accuracy as if the source strength is concentrated in the centre (control point) of each element. When, however, the influence of an element on its own control point is evaluated, γ has a singularity of the type 1/r, which can be removed by spreading the source uniformly over the element. When the influence of an element on a control point, which is at a

close distance of this element and not lying in the same plane, is considered the source is spread uniformly and integrated numerically to obtain its contribution to ϕ or $\partial\phi/\partial n$.

After solving the equations for the source strengths, the first order potential function is known. The pressure on the surface S can then be found from Bernoulli's theorem. The linearized pressure is given by:

$$\begin{aligned} p(x_1,x_2,x_3,t) &= -\rho \frac{\partial \Phi}{\partial t} \\ &= \{\rho\omega^2 \zeta_0(\phi_0+\phi_7) + \rho\omega^2 \sum_{j=1}^{6} \phi_j \zeta_j\} e^{-i\omega t} \end{aligned} \tag{13}$$

Subsequently, the first order wave exciting forces and moments can be found from:

$$X_k = -\rho\,\omega^2 \zeta_0\, e^{-i\omega t} \iint_{S_0} (\phi_0+\phi_7)\, n_k\, dS \tag{14}$$

The oscillating hydrodynamic forces (k = 1,2,3) and moments (k = 4,5,6) in the k-th direction are:

$$F_k = -\rho\,\omega^2 \sum_{j=1}^{6} \zeta_j\, e^{-i\omega t} \iint_{S_0} \phi_j\, n_k\, dS \tag{15}$$

According to common practice the hydrodynamic forces are represented by means of added mass and damping coefficients:

$$a_{kj} = -\rho\, \mathrm{Re}\, \{\iint_{S_0} \phi_j\, n_k\, dS\} \tag{16}$$

$$b_{kj} = -\rho\,\omega^2 \mathrm{Im}\, \{\iint_{S_0} \phi_j\, n_k\, dS\} \tag{17}$$

where:

a_{kj} = the added mass coefficient in the k-th mode due to motion in the j-th mode

b_{kj} = the damping coefficient in the k-th mode due to motion in the j-th mode.

Finally, the motion response to first order excitation is computed by means of the well known equations of motion in the frequency domain:

$$\begin{aligned} &\sum_{j=1}^{6} \{-\omega^2 (M_{kj}+a_{kj}) \cdot \cos(\omega t+\varepsilon_j) - b_{kj} \cdot \omega \cdot \sin(\omega t+\varepsilon_j) + C_{kj} \cdot \cos(\omega t+\varepsilon_j)\}\zeta_j \\ &= X_k \cdot \cos(\omega t+\delta_k) \qquad \text{for } k = 1,\ldots,6 \end{aligned} \tag{18}$$

in which:

X_k = wave excited force in the k-th mode

ε_j, δ_k = phase angles.

M_{kj} is an inertia matrix:

$$M_{kj} = \begin{vmatrix} m & 0 & 0 & 0 & 0 & 0 \\ 0 & m & 0 & 0 & 0 & 0 \\ 0 & 0 & m & 0 & 0 & 0 \\ 0 & 0 & 0 & I_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & I_5 & 0 \\ 0 & 0 & 0 & 0 & 0 & I_6 \end{vmatrix} \tag{19}$$

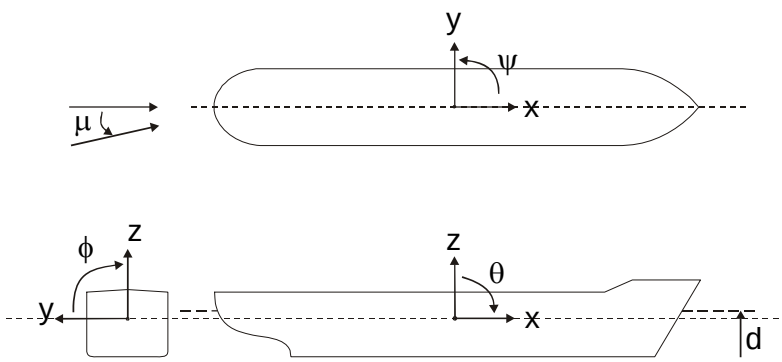
where:

m = mass of the ship

I_k = moment of inertia in the k-th mode.

DEFINITION OF WAVE DIRECTION, MOTIONS AND RESPONSE FUNCTIONS

Wave direction and motions



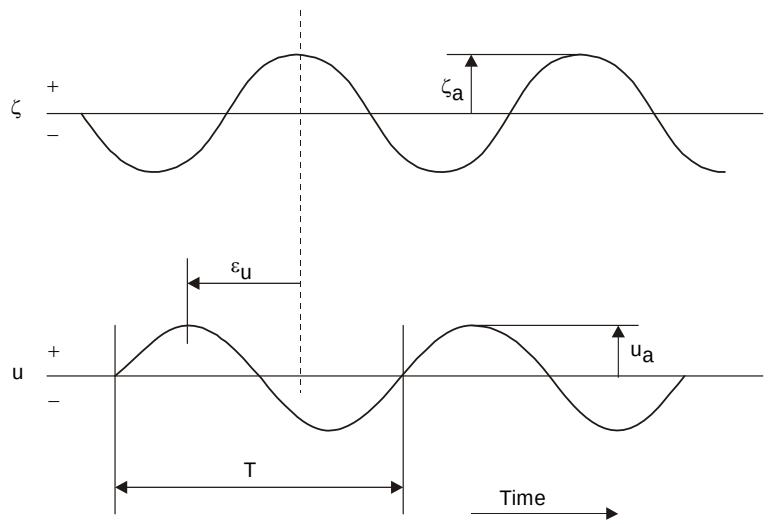
Motions:
x = surge
y = sway
z = heave
ϕ = roll
θ = pitch
ψ = yaw

μ = wave direction
d = water depth

Response functions

Wave elevation in centre of gravity G

Particular



Phase $\varepsilon_{u\zeta} = (S/T) \times 360°$	:	$u(t)$	=	$u_a \cos(\omega t + \varepsilon_{u\zeta})$
In phase component	:	u_i	=	$u_a \cos \varepsilon_{u\zeta}$
Out of phase component	:	u_u	=	$-u_a \sin \varepsilon_{u\zeta}$
Amplitude	:	u_a	=	$\sqrt{(u_i^2 + u_u^2}$
Phase	:	$\varepsilon_{u\zeta}$	=	$\arctan(-u_u/u_i)$

References

1. Wehausen, J.V. and Laitone, E.V.; “Handbuch der Physik”, Vol. 9, Springer Verlag, Berlin, 1960.

2. John, F.; “On the motions of floating bodies”, Comm. on Pure and Applied Mathematics, Part I: 2, pp. 13-57, 1949 and Part III: 3, pp. 45-100, 1950.

APPENDIX C:
TASKS 5-9 – SUPPORTING INFORMATION

C.1
CORMIX Modeling Report

Potential Effects of Thermal Cooling Water Discharge Report

January 2013

Prepared for:

Remora Technology, Inc.

Prepared by:

ecology and environment, inc.
Global Environmental Specialists

TABLE OF CONTENTS

LIST OF TABLES **2**

LIST OF FIGURES **3**

ACRONYMS AND ABBREVIATIONS **4**

1 INTRODUCTION AND BACKGROUND **5**

2 MODELING APPROACH AND DEVELOPMENT **6**

2.1 Approach 6

2.2 Model Input Data 8

2.2.1 Ambient 8

2.2.2 Outfall Discharge Hydraulic Data and Effluent Data 9

3 MODEL RESULTS **10**

4 REFERENCES **11**

APPENDIX A: CORMIX MODELING FILES **12**

LIST OF TABLES

Page

Table 1 Ambient Input 9

Table 2 Model Results 10

LIST OF FIGURES

Page

Figure 1 A 3D View of Single Port Outfall Simulation Example by CORMIX1 Model 8

Figure A-1 Simulated Effluent Plume (Heated Flow) - 3D View (Effluent V=1.5 m/s, Temp Diff = 21.5°C) 13

Figure A-2 Simulated Existing Effluent Plume Concentration Changes (Heated Flow) in the Near Field (Effluent V=1.5 m/s, Temp Diff = 21.5°C) 14

Figure A-3 Simulated Effluent Plume (Heated Flow) – Delta T (degrees Celsius) Changes along X Axis (Effluent V=1.5 m/s, Temp Diff = 21.5°C) 15

Figure A-4 Simulated Effluent Plume (Heated Flow) – Side View X-Z (Effluent V=1.5 m/s, Temp Diff = 21.5°C) 16

Figure A-5 Simulated Effluent Plume (Heated Flow) - 3D View (Effluent V=3.0 m/s, Temp Diff = 21.5°C) 17

Figure A-6 Simulated Existing Effluent Plume Concentration Changes (Heated Flow) in the Near Field (Effluent V=3.0 m/s, Temp Diff = 21.5°C) 18

Figure A-7 Simulated Effluent Plume (Heated Flow) – Delta T (degrees Celsius) Changes along X Axis (Effluent V=3.0 m/s, Temp Diff = 21.5°C) 19

Figure A-8: Simulated Effluent Plume (Heated Flow) – Side View X-Z (Effluent V=3.0 m/s, Temp Diff = 21.5°C) 20

Figure A-9: Estimated Two Cooling Boxes Effluent Plumes (Heated Flow) –X-Y (Effluent V=1.5 m/s, Temp Diff = 21.5°C) 21

Figure A-10: Estimated Two Cooling Boxes Effluent Plumes (Heated Flow) –X-Y (Effluent V=3.0 m/s, Temp Diff = 21.5°C) 22

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
BOET	Bienville Offshore Energy Terminal
CORMIX	Cornell Mixing Zone Expert System
DP	dynamic positioning
E & E	Ecology and Environment, Inc.
kg/m^3	kilogram(s) per cubic meter
m/s	meter(s) per second
NDBC	National Data Buoy Center
USEPA	United States Environmental Protection Agency

1 INTRODUCTION AND BACKGROUND

As one of the subtasks under Task 7 for the Deepwater Direct Offloading System Project, Ecology and Environment, Inc. (E & E) conducted a study to evaluate the heat impact caused by box coolers from HiLoad dynamic positioning (DP) system engines. The HiLoad DP has three thrusters controlled by a DP position-keeping system, and each thruster is driven by a diesel engine that is equipped with a shaft alternator. The engine lube oil cooling system is based on circulating fresh water through box coolers installed outside the hull. The main purpose of the study was to provide an analysis for the heat impact created by the box coolers. A computer model analysis was performed using the Cornell Mixing Zone Expert System (CORMIX; Jirka, Doneker, and Hinton 1996, as amended) to evaluate the potential effects of thermal cooling water discharges from the box coolers.

2 MODELING APPROACH AND DEVELOPMENT

2.1 APPROACH

While there are different models that could be used, each with its strengths and weaknesses, CORMIX was selected as a predictive tool. The rationale for model selection and model limitations is discussed below.

CORMIX is a United States Environmental Protection Agency (USEPA)-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. A mixing zone is the region in which the initial dilution of a discharge occurs. The CORMIX system contains a collection of about 30 regional flow modules to simulate the physics of mixing zones. In application, CORMIX selects one of several hundred possible combinations of these regional flow modules in sequence to construct a simulation model (i.e., flow class) for a complete site-specific mixing zone analysis. The strength of CORMIX is that it assesses dispersion of single port discharges, particularly in proximity to the zone of discharge. Also, the model contains several advanced tools specially built for outfall designs, which provide a very good fit for simulating the proposed consolidated outfall. In addition, data inputs are not as extensive as with some other models; thus CORMIX can be easier and less costly to run and can be more easily executed in situations where data are limited. The downside is that the model does not account for far-field tidal influences and more complex hydrodynamic conditions, and thus is a less accurate tool in more dynamic environments and more approximate in projecting impacts at distances further downstream of the outfall. Also, the model does not simulate tidal cycles, so dispersion over greater distances caused by tidal movement is not fully considered and far-field plume concentrations may be over-predicted. The downsides are not applicable to the HiLoad because the setting is in deep water far outside the area of tidal effects.

Development of the CORMIX model contained several major tasks: data collection, model buildup, and simulation runs. The intent of the data collection effort was to use available existing data. The existing data were input into the model and, where gaps existed, assumptions were made. Some of the most significant assumptions included ambient water quality concentrations, water depth, and steady state flow conditions.

One of the first decisions in the model setup and development was the selection of the discharge scenario module. CORMIX has three different discharge modules which depend on source discharge characteristics. These modules include:

- **CORMIX1**. Addresses single port discharges into flowing unstratified or stratified water environments such as rivers, lakes, estuaries, and coastal waters. It includes the limiting cases of non-buoyant and negatively buoyant discharges and of stagnant ambient conditions.

- **CORMIX2**. Deals with submerged multiport diffuser discharges into similar environments and with similar limiting cases. Unidirectional, alternating, and staged diffuser types are simulated by the system. A multiport diffuser is a linear structure consisting of many closely spaced ports or nozzles that inject a series of turbulent jets of waste flow at high velocity into the ambient receiving water body. These ports or nozzles may be connected to vertical risers attached to an underground pipe or tunnel, or they may simply be openings in a pipe lying on the bottom.

- **CORMIX3**. Models buoyant surface discharges into similar environments; however, it is constrained to positively buoyant discharges.

The box coolers discharge heated seawater through outlets which are 20 to 30 meters under the ocean water surface. The depth varies depending on the ballast state of the HiLoad. CORMIX1 was used to simulate one single box cooler discharge into the ocean currents. It includes the limiting cases of non-buoyant and negatively buoyant discharges and of stagnant ambient conditions. A CORMIX1 flow example similar in stratified cross-flow mixing behavior is illustrated on Figure 2. The figure shows an example of a pollutant plume generated by an outfall. The x-axis represents flow direction, and the y-axis and z-axis show the width and depth of the plume, respectively. The color changes represent the pollutant concentration from high (yellow/red) to low (green/blue) along the flow direction; these concentrations are relative to selected water criteria used in the model. Each outfall has to be modeled separately since the model does not simulate multiple outfalls simultaneously.

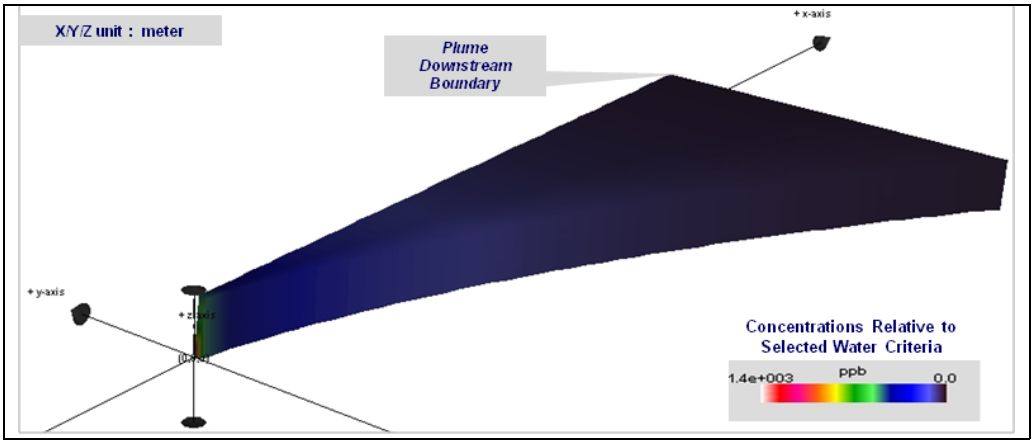


Figure 1 A 3D View of Single Port Outfall Simulation Example by CORMIX1 Model

2.2 MODEL INPUT DATA

The CORMIX model requires several groups of data which include ambient conditions, outfall discharge hydraulic data, and effluent data.

The following sections discuss the data input and sources, as well as assumptions made when there are data gaps for existing and proposed conditions.

2.2.1 AMBIENT

The parameters for ambient conditions such as current velocity, wind velocity, depth of water and sea water density are shown in Table 1. Most of data are based on previous studies located at the Bienville Offshore Energy Terminal (BOET) site about 62 miles south of Mobile Bay, Alabama, in Main Pass Block 258 in the Gulf of Mexico.

Table 1 Ambient Input

Parameters	Parameter Values
Current Velocity	0.42 meters per second (m/s)
Wind Velocity	8.5 m/s
Depth of Water	> 25 meters
Sea Water Density	1,030 kilograms per cubic meter

Manning's n 0.020 was selected based on the CORMIX-referenced value for smooth earth channel, no weeds.

Based on meteorological ocean data for the BOET project, current rates ranged from 0.35 to 0.49 meters per second (m/s). A rate of 0.42 m/s was used in the model to represent an average condition. Wind speed at National Data Buoy Center (NDBC) 42040 for 2011 ranged between 7 and 10 m/s. An average value of 8.5 m/s was used in the simulation.

A sea water density of 1,030 kilogram per cubic meter (kg/m^3) was assumed (http://hypertextbook.com/facts/2002/EdwardLaValley.shtml). Water temperatures average 18.5 degrees Celsius (°C) in the winter and 25.0°C in the summer. Simulations were conducted for two different water temperatures: one with 18.5°C and the other with 28.2°C.

2.2.2 OUTFALL DISCHARGE HYDRAULIC DATA AND EFFLUENT DATA

The area of the cooling box heat outlets is calculated from the HiLoad DP box cooler drawing and is shown below:

$$\text{Area} = 1.25*0.65*2\ (m^2) + 1.25*0.9\ (m^2) = 2.75\ (m^2)$$

The heated discharge flow rates (1.5 m/s and 3.0 m/s) and water temperature (40°C) used in the model simulations were from the Technical Description GF112798-0218-TED.

3 MODEL RESULTS

The following text provides the results of these model simulations. A total of two simulations were conducted by the CORMIX1 model: one with effluent velocity of 1.5 m/s and the other one with velocity of 3.0 m/s. These velocity values covered the velocity range mentioned for the box cooler in Section 5, Technical Description GF112798-0218-TED.

Table 2 presents simulated mixing zone results for two different effluent discharges. The plumes generated by the heated flow from the box cooler have their widths extending seaward and the plume lengths along downstream flow direction. For example, with the effluent velocity of 1.5 m/s, when the water plume traveled to 21 meters downstream, the plume width was 6 meters, and the temperature difference between the heated plume and the ambient water at flow centerline decreased from 15°C to 3°C.

Table 2 Model Results

Modeling Run	Effluent Discharge Velocity	Water Temp Difference Between Effluent and Ambient	CORMIX Model Results when Delta T = 3°C Distance (meters)
Run 1	Velocity=1.5 m/s	11.8°C	17
Run 2	Velocity=1.5 m/s	21.5°C	21
Run 3	Velocity=3.0 m/s	11.8°C	9
Run 4	Velocity=3.0 m/s	21.5°C	31

The modeling output graphics and input/output data for simulation Runs 2 and 4 are included in Appendix A of this report.

Although only one cooling box was simulated using the CORMIX model, an estimate was also conducted for possible impacts for two cooling boxes with a distance of 16.5 meters by overlaying modeling results from single box simulation. The overlay (shown on Figures A-9 and A-10) indicated that no significant interactions between the two box coolers near the HiLoad bow would be created.

4 REFERENCES

Jirka, G.H., R.L. Doneker, and S.W. Hinton. 1996. "User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters." U.S. Environmental Protection Agency, Tech. Rep., Environmental Research Lab, Athens, Georgia.

APPENDIX A: CORMIX MODELING FILES

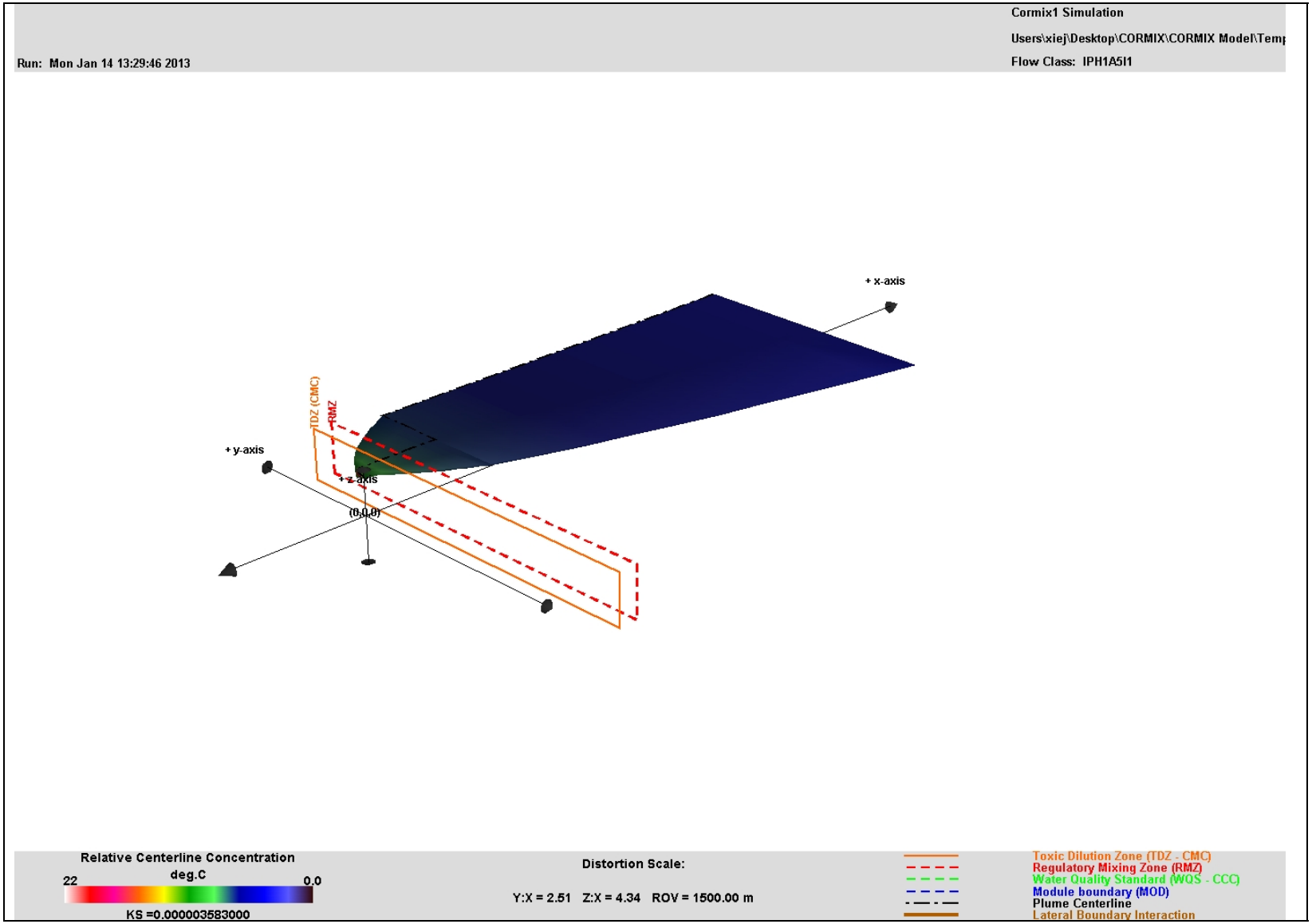


Figure A-1 Simulated Effluent Plume (Heated Flow) - 3D View (Effluent V=1.5 m/s, Temp Diff = 21.5°C)

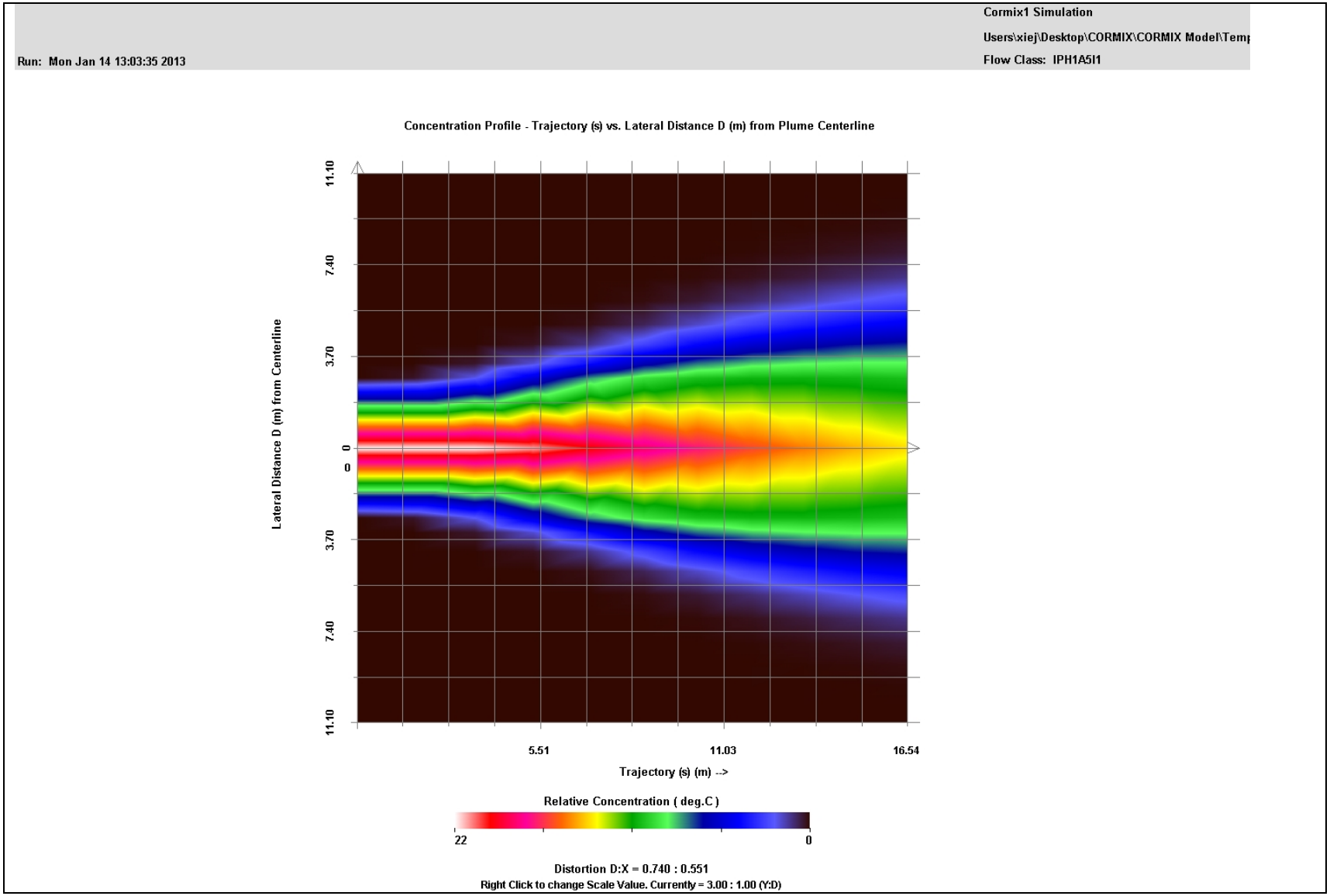


Figure A-2 Simulated Existing Effluent Plume Concentration Changes (Heated Flow) in the Near Field (Effluent V=1.5 m/s, Temp Diff = 21.5°C)

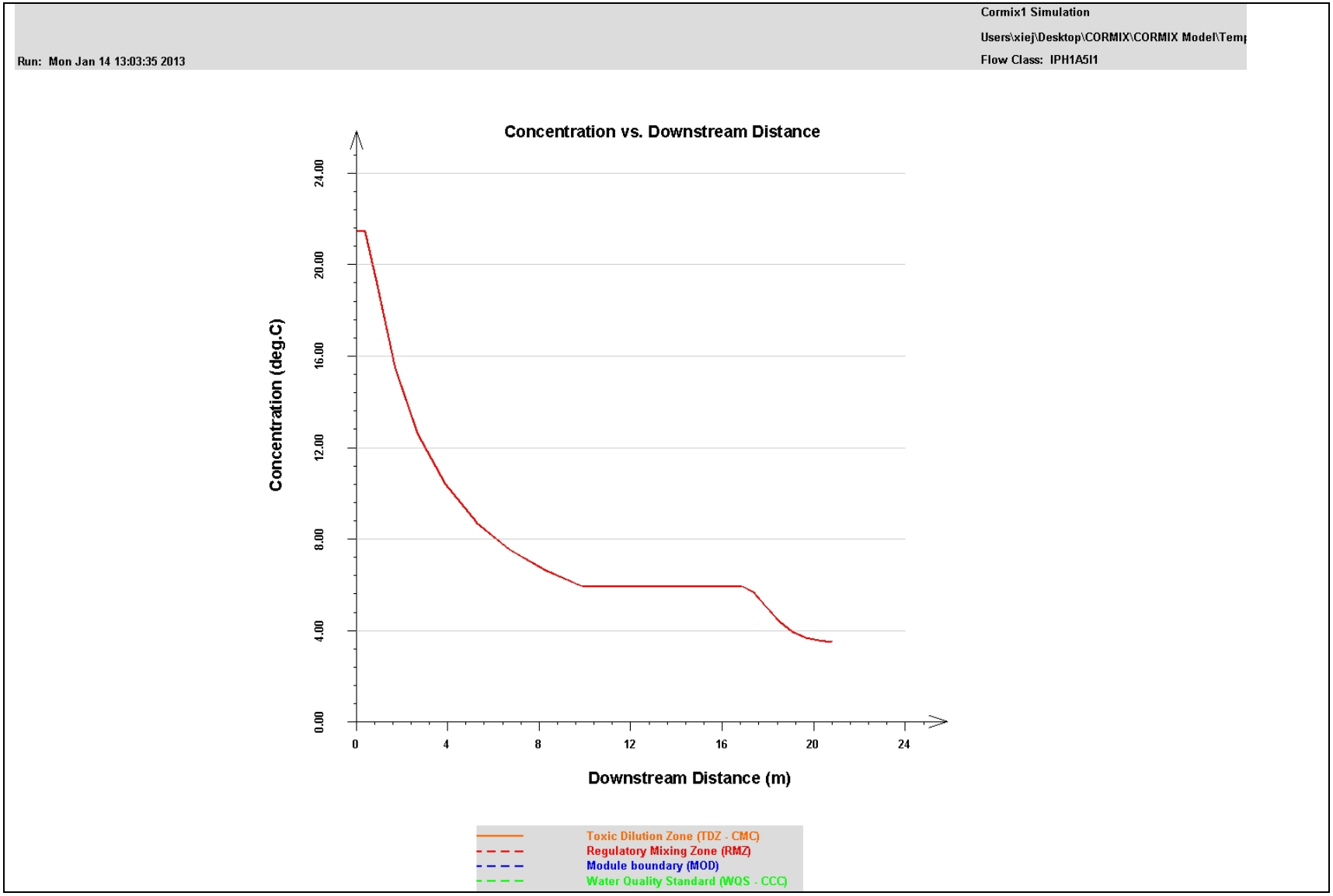


Figure A-3 Simulated Effluent Plume (Heated Flow) – Delta T (degrees Celsius) Changes along X Axis (Effluent V=1.5 m/s, Temp Diff = 21.5°C)

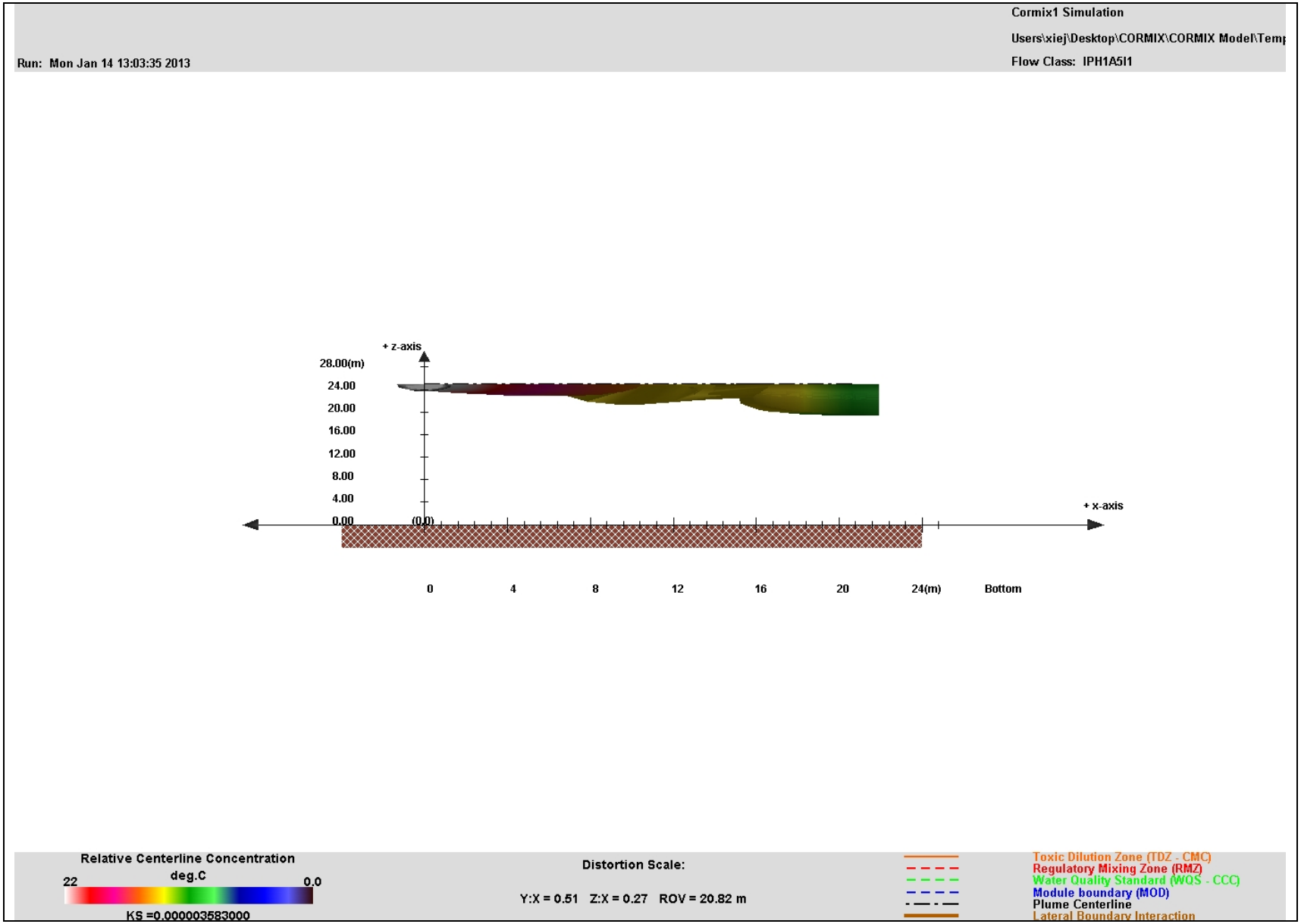


Figure A-4 Simulated Effluent Plume (Heated Flow) – Side View X-Z (Effluent V=1.5 m/s, Temp Diff = 21.5°C)

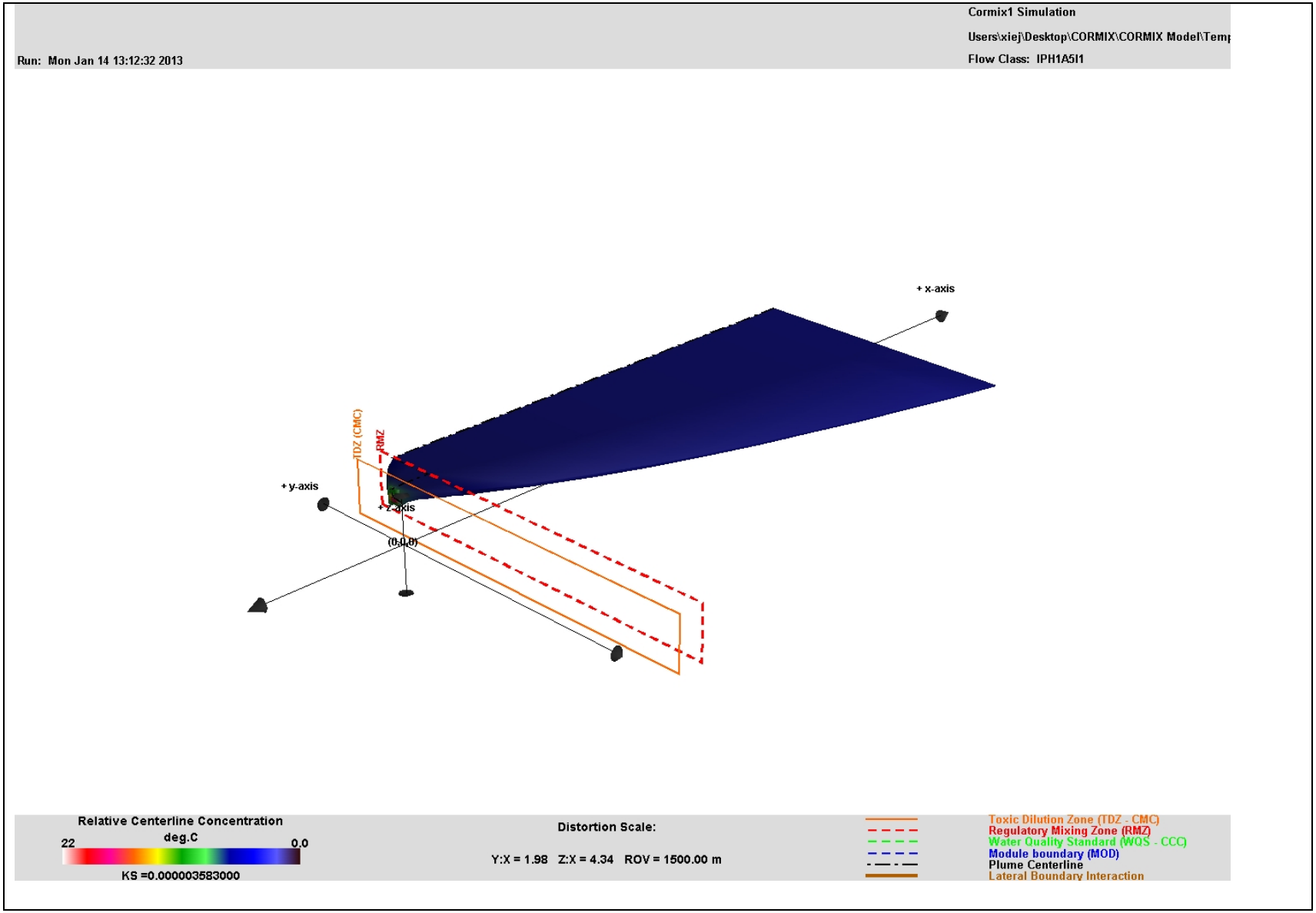


Figure A-5 Simulated Effluent Plume (Heated Flow) - 3D View (Effluent V=3.0 m/s, Temp Diff = 21.5°C)

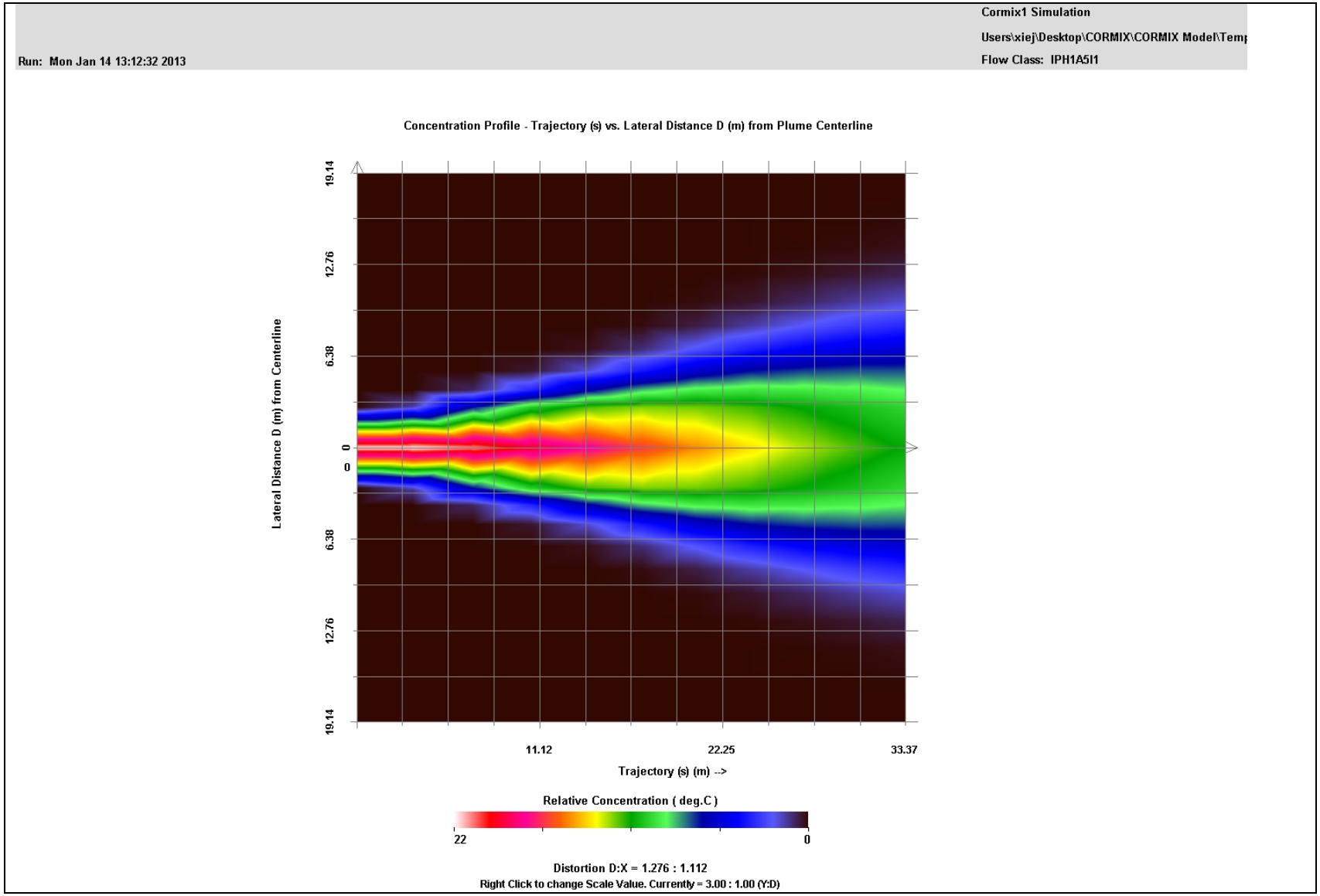


Figure A-6 Simulated Existing Effluent Plume Concentration Changes (Heated Flow) in the Near Field (Effluent V=3.0 m/s, Temp Diff = 21.5°C)

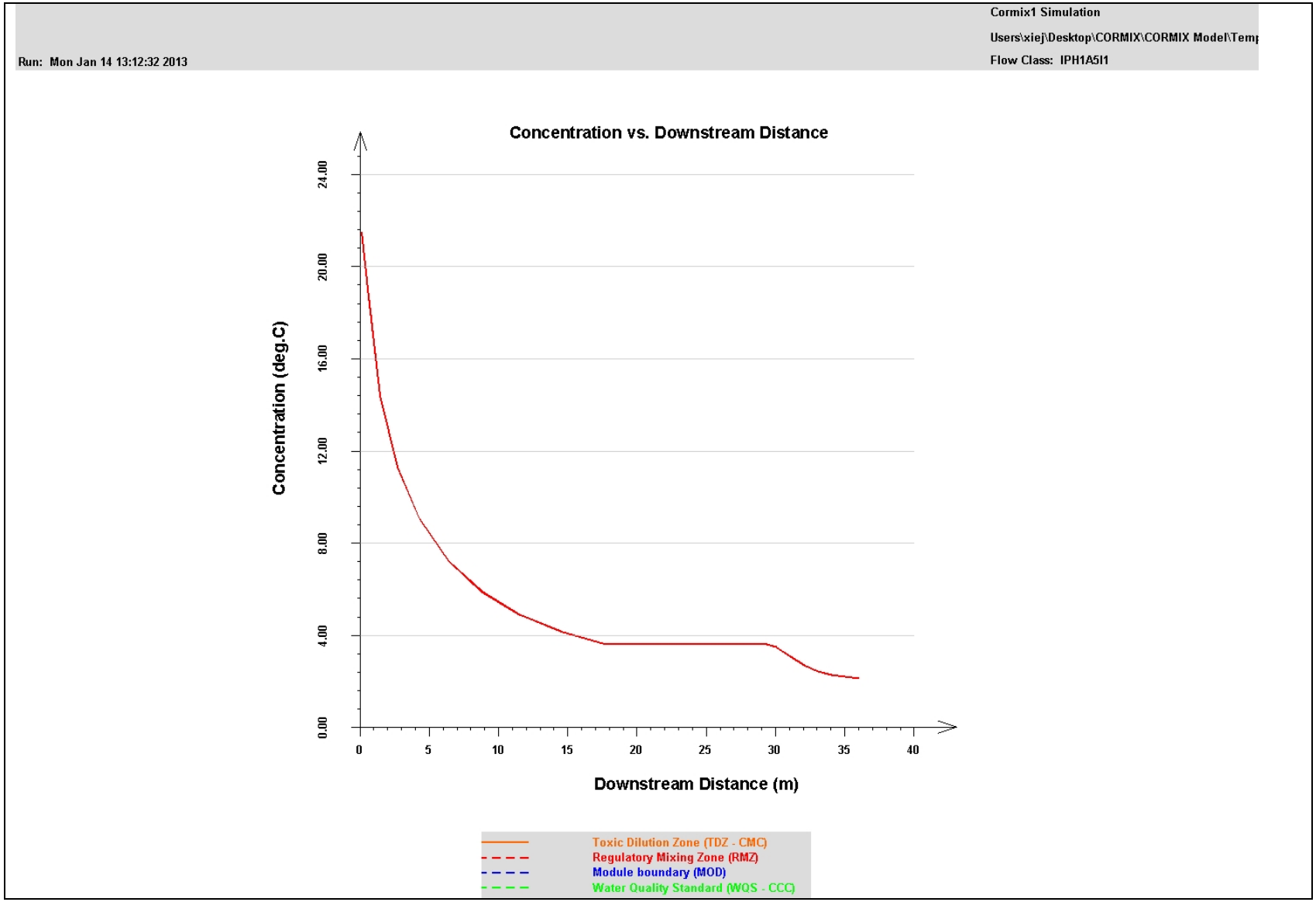


Figure A-7 Simulated Effluent Plume (Heated Flow) – Delta T (degrees Celsius) Changes along X Axis (Effluent V=3.0 m/s, Temp Diff = 21.5°C)

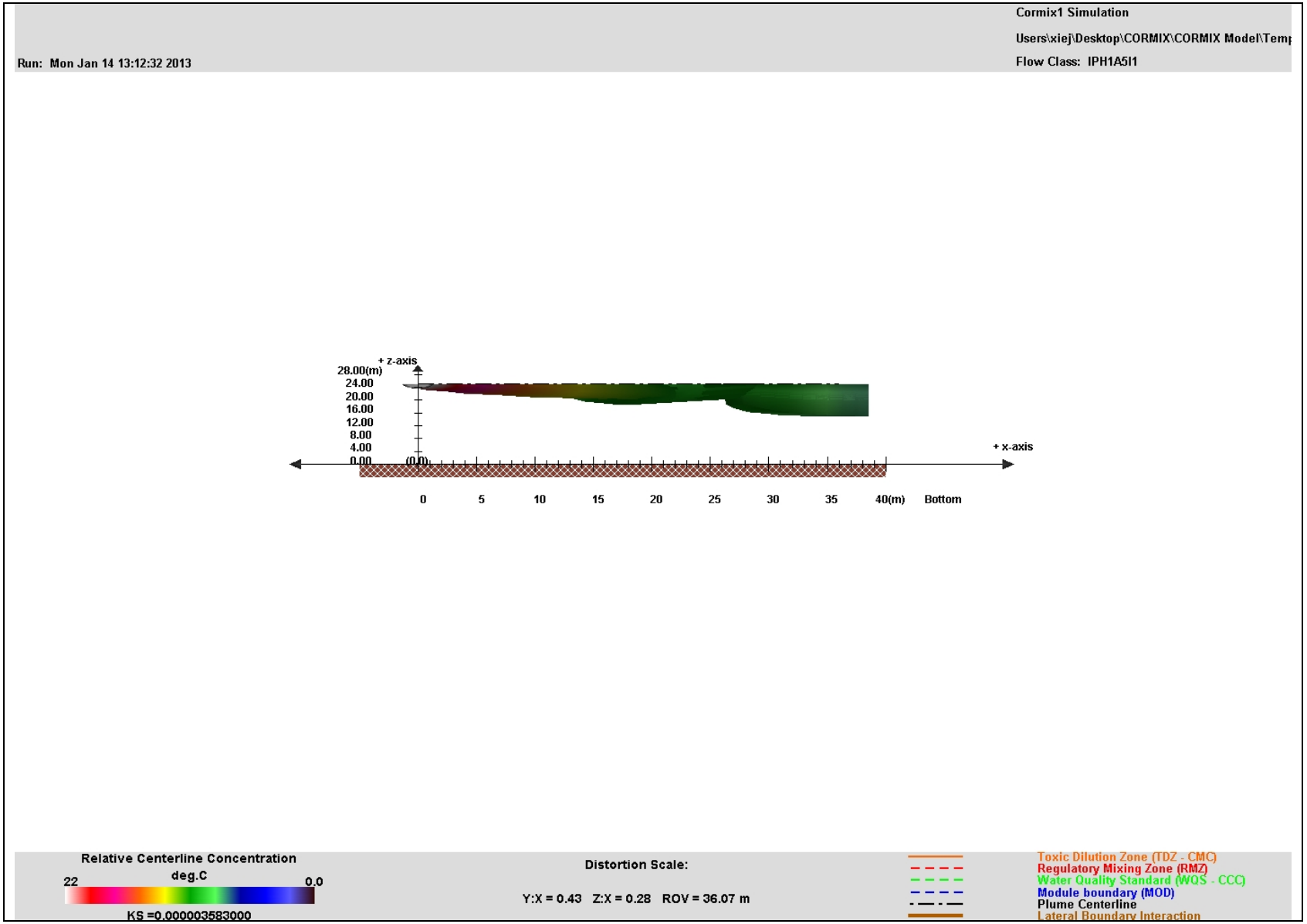


Figure A-8: Simulated Effluent Plume (Heated Flow) – Side View X-Z (Effluent V=3.0 m/s, Temp Diff = 21.5°C)

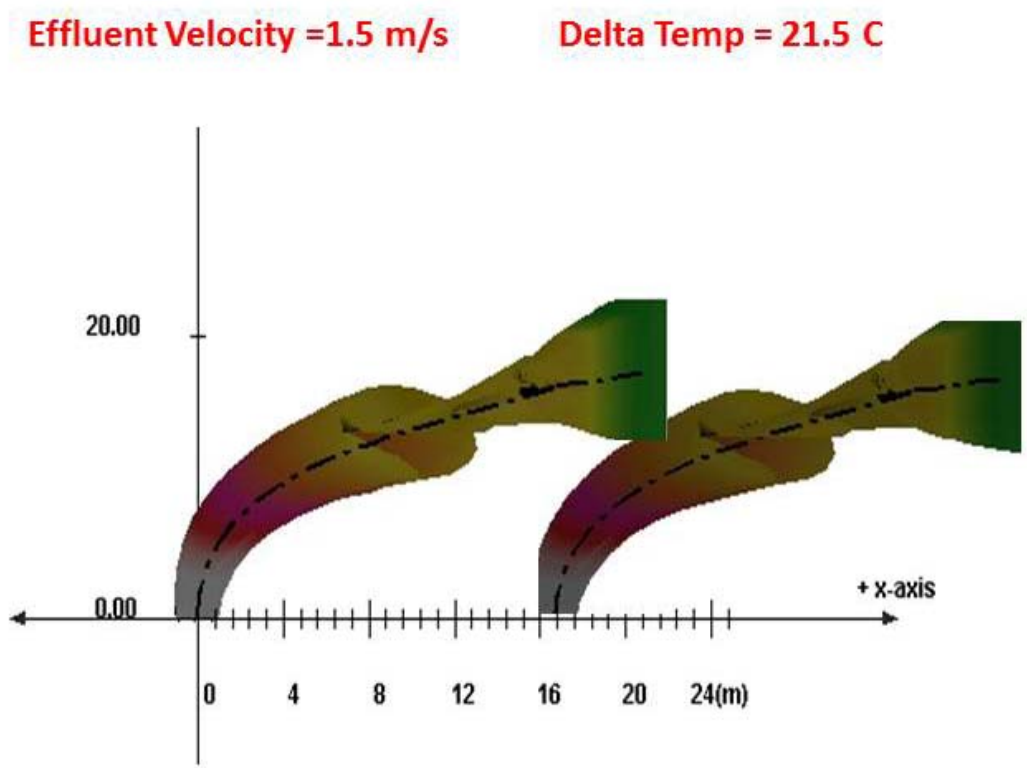


Figure A-9: Estimated Two Cooling Boxes Effluent Plumes (Heated Flow) –X-Y (Effluent V=1.5 m/s, Temp Diff = 21.5°C)

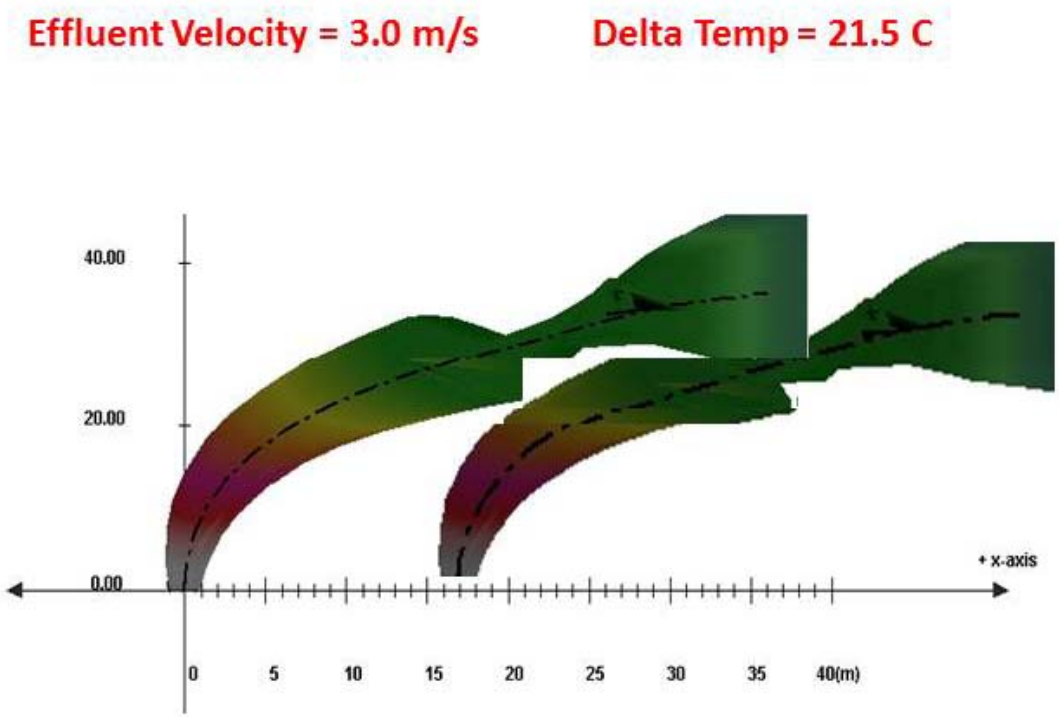


Figure A-10: Estimated Two Cooling Boxes Effluent Plumes (Heated Flow) –X-Y (Effluent V=3.0 m/s, Temp Diff = 21.5°C)

CORMIX Output Files

A total of four simulations were completed in this study. Two of the simulation output files are provided below. Both simulations have 21.5°C difference between the effluent and ambient temperatures; but one with effluent velocity = 1.5 m/s and the other one with effluent velocity = 3.0 m/s.

File 1: Model Prediction (V=1.5 m/s)

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
                        CORMIX MIXING ZONE EXPERT SYSTEM
                    Subsystem CORMIX1: Single Port Discharges
                              CORMIX Version 8.0GT
                      HYDRO1 Version 8.0.0.0 April 2012
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   HiLoad DP - Box Cooler - Thermal Simulation
 Design case:
 FILE NAME:         C:\...\CORMIX\CORMIX Model\Temperature - V1.5-T21.5.prd
 Time stamp:        Mon Jan 14 13:29:46 2013

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA    =     30.00  HD    =     25.00
 UA    =      0.420 F     =      0.010 USTAR =0.1493E-01
 UW    =      8.500 UWSTAR=0.1074E-01
 Uniform density environment
 STRCND=  U         RHOAM = 1030.0000

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =    100.00
 D0    =      1.871 A0    =      2.750 H0    =     25.00  SUB0  =      0.00
 THETA =      0.00  SIGMA =     90.00
 U0    =      1.500 Q0    =      4.125       =0.4125E+01
 RHO0  =  992.2107  DRHO0 =0.3779E+02  GP0   =0.3598E+00
 C0    =0.2150E+02  CUNITS=  deg.C
 IPOLL =  3         KS    =0.3583E-05  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.4125E+01  M0    =0.6188E+01  J0    =0.1484E+01  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      1.66  LM    =      3.22  Lm    =      5.92  Lb    =     20.03
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =      1.83  R     =      3.57
```

```
FLOW CLASSIFICATION
 1111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    IPH1A5I1
 1  Applicable layer depth HS =    25.00  1
 1111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2150E+02  CUNITS=  deg.C
 NTOX  =  1         CMC   =0.3000E+01  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.0000E+00
 REGMZ =  1
 REGSPC=  1         XREG  =    100.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   1500.00  XMAX  =   1500.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
       100.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
-------------------------------------------------------------------------------------------

NOTE on dilution/concentration values for this HEATED DISCHARGE (IPOLL=3):
   S  = hydrodynamic dilutions, include buoyancy (heat) loss effects, but
        provided plume has surface contact
   C  = corresponding temperature values (in "deg.C"!) include heat loss,
        if any
-------------------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00   25.00     1.0 0.215E+02   1.32    1.500   .00000E+00

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Surface-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
             Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time
```

```
       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00   25.00     1.0 0.215E+02   0.95    1.500   .29944E-01
      0.09     1.68   25.00     1.0 0.215E+02   1.14    1.500   .66558E+00
      0.40     3.52   25.00     1.0 0.215E+02   1.39    1.500   .15359E+01
      0.94     5.21   25.00     1.1 0.192E+02   1.67    1.400   .25667E+01
      1.73     6.80   25.00     1.4 0.155E+02   1.98    1.048   .38410E+01
      2.70     8.19   25.00     1.7 0.126E+02   2.30    0.787   .53148E+01
      3.91     9.48   25.00     2.1 0.104E+02   2.63    0.585   .71613E+01
      5.27    10.62   25.00     2.5 0.873E+01   2.94    0.446   .92993E+01
      6.74    11.62   25.00     2.9 0.753E+01   3.22    0.351   .11695E+02
      8.29    12.49   25.00     3.2 0.663E+01   3.48    0.285   .14306E+02
      9.88    13.27   25.00     3.6 0.594E+01   3.70    0.238   .17093E+02
 Cumulative travel time =          17.0930 sec  (    0.00 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------------------
 Residual BUOYANCY in deflected wall-jet is sufficiently strong
   to cause DROP-OFF.
 Further flow configuration resembles flow class A3I.
-------------------------------------------------------------------------------------------
BEGIN MOD152: LIFT OFF/FALL DOWN

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  TT = Cumulative travel time

  Inflow (attached) and outflow (free) conditions:
       X        Y       Z        S       C       B        TT
      9.88    13.27   25.00     3.6 0.594E+01   3.70 .17093E+02
     16.63    16.33   25.00     3.6 0.594E+01   2.62 .29487E+02
 Cumulative travel time =          29.4867 sec  (    0.01 hrs)

END OF MOD152: LIFT OFF/FALL DOWN
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Plume-like motion after lift off/fall down.

 The WIDTH PREDICTION B in the first entry below may exhibit some mismatch
   (up to a factor of 1.5) relative to the last entry of the previous module.
   This is unavoidable due to differences in the width definitions.
   The actual physical transition will be smoothed out.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
```

```
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time

       X        Y       Z        S       C       B        Uc        TT
     16.63    16.33   25.00     3.6 0.594E+01   1.95    0.490   .29488E+02
     16.65    16.34   25.00     3.6 0.594E+01   1.95    0.488   .29517E+02
     16.68    16.36   25.00     3.6 0.594E+01   1.95    0.487   .29547E+02
     16.70    16.37   25.00     3.6 0.594E+01   1.96    0.486   .29577E+02
     16.72    16.38   25.00     3.6 0.594E+01   1.96    0.485   .29607E+02
     16.75    16.39   25.00     3.6 0.594E+01   1.96    0.483   .29637E+02
     16.77    16.40   25.00     3.6 0.594E+01   1.96    0.482   .29668E+02
     16.79    16.41   25.00     3.6 0.594E+01   1.97    0.482   .29698E+02
     16.82    16.42   25.01     3.6 0.594E+01   1.97    0.481   .29728E+02
     16.84    16.43   25.01     3.6 0.594E+01   1.97    0.480   .29759E+02
     16.87    16.44   25.01     3.6 0.594E+01   1.98    0.480   .29789E+02
 Cumulative travel time =          29.7889 sec  (    0.01 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B        TT
     16.87    16.44   25.01     3.6 0.594E+01   1.98 .29789E+02

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time

       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
     15.06    16.04   25.00     3.6 0.594E+01   0.00     0.00   25.00   25.00 .29789E+02
     15.63    16.17   25.00     3.6 0.594E+01   3.46     1.74   25.00   21.54 .29789E+02
     16.21    16.30   25.00     3.6 0.594E+01   4.10     2.46   25.00   20.90 .29789E+02
     16.79    16.42   25.00     3.6 0.594E+01   4.51     3.01   25.00   20.49 .29789E+02
     17.36    16.55   25.00     3.8 0.570E+01   4.81     3.48   25.00   20.19 .30971E+02
     17.94    16.68   25.00     4.3 0.504E+01   5.04     3.89   25.00   19.96 .32343E+02
     18.52    16.80   25.00     4.9 0.440E+01   5.21     4.26   25.00   19.79 .33715E+02
     19.09    16.93   25.00     5.4 0.396E+01   5.34     4.60   25.00   19.66 .35087E+02
     19.67    17.06   25.00     5.8 0.370E+01   5.43     4.91   25.00   19.57 .36459E+02
     20.24    17.19   25.00     6.0 0.358E+01   5.48     5.21   25.00   19.52 .37831E+02
     20.82    17.31   25.00     6.1 0.350E+01   5.49     5.49   25.00   19.51 .39202E+02
 Cumulative travel time =          39.2025 sec  (    0.01 hrs)
```

```
END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH
-----------------------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-----------------------------------------------------------------------------------------------
BEGIN MOD141: BUOYANT AMBIENT SPREADING

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
     20.82    17.31   25.00     6.1 0.350E+01   5.49     5.49   25.00   19.51 .39202E+02
** CMC HAS BEEN FOUND **
 The pollutant concentration in the plume falls below CMC value of 0.300E+01
   in the current prediction interval.
 This is the extent of the TOXIC DILUTION ZONE.
     45.07    17.31   25.00     8.6 0.251E+01   2.04    20.59   25.00   22.96 .96931E+02
     69.31    17.31   25.00     9.5 0.227E+01   1.50    30.98   25.00   23.50 .15466E+03
     93.56    17.31   25.00    10.1 0.213E+01   1.25    39.66   25.00   23.75 .21239E+03
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =   100.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
    117.80    17.31   25.00    10.6 0.203E+01   1.10    47.33   25.00   23.90 .27011E+03
    142.05    17.31   25.00    11.0 0.196E+01   0.99    54.29   25.00   24.01 .32784E+03
    166.30    17.31   25.00    11.3 0.190E+01   0.91    60.70   25.00   24.09 .38557E+03
    190.54    17.31   25.00    11.6 0.185E+01   0.85    66.68   25.00   24.15 .44330E+03
    214.79    17.31   25.00    11.9 0.181E+01   0.81    72.31   25.00   24.19 .50103E+03
    239.03    17.31   25.00    12.1 0.177E+01   0.77    77.63   25.00   24.23 .55876E+03
    263.28    17.31   25.00    12.4 0.174E+01   0.73    82.69   25.00   24.27 .61648E+03
 Cumulative travel time =         616.4835 sec  (    0.17 hrs)

-----------------------------------------------------------------------------------------------
 Plume is ATTACHED to LEFT  bank/shore.
   Plume width is now determined from LEFT  bank/shore.

 Plume Stage 2 (bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
    263.28   100.00   25.00    12.4 0.174E+01   0.73   165.38   25.00   24.27 .61648E+03
    386.95   100.00   25.00    13.0 0.166E+01   0.70   183.07   25.00   24.30 .91094E+03
    510.62   100.00   25.00    13.6 0.158E+01   0.67   199.19   25.00   24.33 .12054E+04
    634.29   100.00   25.00    14.2 0.151E+01   0.65   214.11   25.00   24.35 .14999E+04
    757.97   100.00   25.00    14.9 0.144E+01   0.64   228.07   25.00   24.36 .17943E+04
```

```
    881.64   100.00   25.00    15.6 0.138E+01   0.63   241.26   25.00   24.37 .20888E+04
   1005.31   100.00   25.00    16.4 0.131E+01   0.63   253.81   25.00   24.37 .23832E+04
   1128.98   100.00   25.00    17.2 0.125E+01   0.63   265.83   25.00   24.37 .26777E+04
   1252.66   100.00   25.00    18.0 0.119E+01   0.64   277.40   25.00   24.36 .29721E+04
   1376.33   100.00   25.00    18.9 0.114E+01   0.64   288.58   25.00   24.36 .32666E+04
   1500.00   100.00   25.00    19.9 0.108E+01   0.65   299.43   25.00   24.35 .35611E+04
 Cumulative travel time =        3561.0588 sec  (    0.99 hrs)

 Simulation limit based on maximum specified distance =   1500.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD141: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
1111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
```

File 2: Model Prediction (V=3.0 m/s)

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
                        CORMIX MIXING ZONE EXPERT SYSTEM
                    Subsystem CORMIX1: Single Port Discharges
                              CORMIX Version 8.0GT
                      HYDRO1 Version 8.0.0.0 April 2012
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   HiLoad DP - Box Cooler - Thermal Simulation
 Design case:
 FILE NAME:         C:\...\CORMIX\CORMIX Model\Temperature - V3.0-T21.5.prd
 Time stamp:        Mon Jan 14 13:12:32 2013

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA    =     30.00  HD    =     25.00
 UA    =      0.420 F     =      0.010 USTAR =0.1493E-01
 UW    =      8.500 UWSTAR=0.1074E-01
 Uniform density environment
 STRCND=  U         RHOAM = 1030.0000

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =    100.00
 D0    =      1.871 A0    =      2.750 H0    =     25.00  SUB0  =      0.00
 THETA =      0.00  SIGMA =     90.00
 U0    =      3.000 Q0    =      8.250       =0.8250E+01
 RHO0  =  992.2107  DRHO0 =0.3779E+02  GP0   =0.3598E+00
 C0    =0.2150E+02  CUNITS=  deg.C
 IPOLL =  3         KS    =0.3583E-05  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.8250E+01  M0    =0.2475E+02  J0    =0.2968E+01  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      1.66  LM    =      6.44  Lm    =     11.85  Lb    =     40.06
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =      3.66  R     =      7.14

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    IPH1A5I1
 1  Applicable layer depth HS =    25.00  1
 111111111111111111111111111111111111111111
```

```
MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2150E+02  CUNITS=  deg.C
 NTOX  =  1         CMC   =0.3000E+01  CCC   =  CSTD
 NSTD  =  1         CSTD  =0.0000E+00
 REGMZ =  1
 REGSPC=  1         XREG  =    100.00  WREG  =      0.00  AREG  =      0.00
 XINT  =   1500.00  XMAX  =   1500.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
       100.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  10 display intervals per module
-------------------------------------------------------------------------------------------

NOTE on dilution/concentration values for this HEATED DISCHARGE (IPOLL=3):
   S  = hydrodynamic dilutions, include buoyancy (heat) loss effects, but
        provided plume has surface contact
   C  = corresponding temperature values (in "deg.C"!) include heat loss,
        if any
-------------------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00   25.00     1.0 0.215E+02   1.32    3.000   .00000E+00

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Surface-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
             Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time

       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00   25.00     1.0 0.215E+02   0.96    3.000   .30241E-01
```

```
      0.13     3.37   25.00     1.0 0.215E+02   1.34    3.000   .72711E+00
      0.63     7.07   25.00     1.2 0.187E+02   1.79    2.991   .17862E+01
      1.48    10.52   25.00     1.5 0.144E+02   2.28    2.251   .31158E+01
      2.75    13.83   25.00     1.9 0.113E+02   2.82    1.699   .48145E+01
      4.35    16.81   25.00     2.4 0.903E+01   3.39    1.297   .68303E+01
      6.42    19.68   25.00     3.0 0.722E+01   4.03    0.976   .94338E+01
      8.86    22.27   25.00     3.7 0.588E+01   4.67    0.743   .12565E+02
     11.57    24.57   25.00     4.4 0.490E+01   5.28    0.579   .16216E+02
     14.49    26.59   25.00     5.1 0.419E+01   5.86    0.463   .20348E+02
     17.56    28.38   25.00     5.9 0.366E+01   6.38    0.381   .24898E+02
 Cumulative travel time =          24.8984 sec  (    0.01 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------------------
 Residual BUOYANCY in deflected wall-jet is sufficiently strong
   to cause DROP-OFF.
 Further flow configuration resembles flow class A3I.
-------------------------------------------------------------------------------------------
BEGIN MOD152: LIFT OFF/FALL DOWN

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  TT = Cumulative travel time

  Inflow (attached) and outflow (free) conditions:
       X        Y       Z        S       C       B        TT
     17.56    28.38   25.00     5.9 0.366E+01   6.38 .24898E+02
     28.78    34.46   25.00     5.9 0.366E+01   4.51 .44745E+02
 Cumulative travel time =          44.7454 sec  (    0.01 hrs)

END OF MOD152: LIFT OFF/FALL DOWN
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Plume-like motion after lift off/fall down.

 The WIDTH PREDICTION B in the first entry below may exhibit some mismatch
   (up to a factor of 1.5) relative to the last entry of the previous module.
   This is unavoidable due to differences in the width definitions.
   The actual physical transition will be smoothed out.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
```

```
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time

       X        Y       Z        S       C       B        Uc        TT
     28.78    34.46   25.00     5.9 0.366E+01   3.38    0.611   .44748E+02
     28.82    34.48   25.00     5.9 0.366E+01   3.39    0.609   .44794E+02
     28.86    34.50   25.00     5.9 0.366E+01   3.40    0.607   .44840E+02
     28.90    34.52   25.00     5.9 0.366E+01   3.40    0.606   .44886E+02
     28.94    34.54   25.00     5.9 0.366E+01   3.41    0.604   .44933E+02
     28.98    34.57   25.00     5.9 0.366E+01   3.41    0.602   .44979E+02
     29.02    34.59   25.01     5.9 0.366E+01   3.42    0.601   .45023E+02
     29.06    34.61   25.01     5.9 0.366E+01   3.43    0.599   .45070E+02
     29.10    34.63   25.01     5.9 0.366E+01   3.43    0.598   .45116E+02
     29.14    34.65   25.01     5.9 0.366E+01   3.44    0.597   .45163E+02
     29.18    34.67   25.01     5.9 0.366E+01   3.44    0.596   .45209E+02
 Cumulative travel time =          45.2095 sec  (    0.01 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B        TT
     29.18    34.67   25.01     5.9 0.366E+01   3.44 .45209E+02

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time

       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
     26.13    33.87   25.00     5.9 0.366E+01   0.00     0.00   25.00   25.00 .45209E+02
     27.13    34.13   25.00     5.9 0.366E+01   6.23     3.13   25.00   18.77 .45209E+02
     28.12    34.39   25.00     5.9 0.366E+01   7.39     4.43   25.00   17.61 .45209E+02
     29.11    34.65   25.00     5.9 0.366E+01   8.13     5.43   25.00   16.87 .45209E+02
     30.11    34.91   25.00     6.2 0.348E+01   8.68     6.27   25.00   16.32 .47416E+02
     31.10    35.18   25.00     7.0 0.308E+01   9.09     7.01   25.00   15.91 .49781E+02
** CMC HAS BEEN FOUND **
 The pollutant concentration in the plume falls below CMC value of 0.300E+01
   in the current prediction interval.
```

```
 This is the extent of the TOXIC DILUTION ZONE.
     32.09    35.44   25.00     8.0 0.269E+01   9.40     7.68   25.00   15.60 .52146E+02
     33.09    35.70   25.00     8.9 0.243E+01   9.63     8.29   25.00   15.37 .54511E+02
     34.08    35.96   25.00     9.5 0.227E+01   9.79     8.86   25.00   15.21 .56876E+02
     35.07    36.22   25.00     9.8 0.220E+01   9.88     9.40   25.00   15.12 .59241E+02
     36.07    36.48   25.00    10.0 0.215E+01   9.91     9.91   25.00   15.09 .61606E+02
 Cumulative travel time =          61.6062 sec  (    0.02 hrs)

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH
-------------------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-------------------------------------------------------------------------------------------
BEGIN MOD141: BUOYANT AMBIENT SPREADING

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
     36.07    36.48   25.00    10.0 0.215E+01   9.91     9.91   25.00   15.09 .61606E+02
     46.33    36.48   25.00    11.7 0.184E+01   6.20    18.52   25.00   18.80 .86040E+02
     56.59    36.48   25.00    12.7 0.170E+01   4.89    25.40   25.00   20.11 .11047E+03
     66.85    36.48   25.00    13.3 0.161E+01   4.17    31.42   25.00   20.83 .13491E+03
     77.12    36.48   25.00    13.9 0.155E+01   3.70    36.89   25.00   21.30 .15934E+03
     87.38    36.48   25.00    14.4 0.150E+01   3.36    41.95   25.00   21.64 .18378E+03
     97.64    36.48   25.00    14.7 0.146E+01   3.10    46.70   25.00   21.90 .20821E+03
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =   100.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
    107.90    36.48   25.00    15.1 0.142E+01   2.89    51.19   25.00   22.11 .23264E+03
    118.17    36.48   25.00    15.4 0.140E+01   2.73    55.48   25.00   22.27 .25708E+03
    128.43    36.48   25.00    15.7 0.137E+01   2.58    59.58   25.00   22.42 .28151E+03
    138.69    36.48   25.00    15.9 0.135E+01   2.46    63.53   25.00   22.54 .30595E+03
 Cumulative travel time =         305.9473 sec  (    0.08 hrs)

-------------------------------------------------------------------------------------------
 Plume is ATTACHED to LEFT  bank/shore.
   Plume width is now determined from LEFT  bank/shore.

 Plume Stage 2 (bank attached):
```

```
       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
    138.69   100.00   25.00    15.9 0.135E+01   2.46   127.03   25.00   22.54 .30595E+03
    274.82   100.00   25.00    17.2 0.125E+01   2.01   168.02   25.00   22.99 .63007E+03
    410.95   100.00   25.00    18.1 0.119E+01   1.76   202.02   25.00   23.24 .95419E+03
    547.08   100.00   25.00    18.8 0.114E+01   1.60   231.53   25.00   23.40 .12783E+04
    683.21   100.00   25.00    19.5 0.110E+01   1.48   257.88   25.00   23.52 .16024E+04
    819.34   100.00   25.00    20.1 0.107E+01   1.40   281.84   25.00   23.60 .19266E+04
    955.48   100.00   25.00    20.7 0.104E+01   1.34   303.93   25.00   23.66 .22507E+04
   1091.61   100.00   25.00    21.3 0.101E+01   1.29   324.51   25.00   23.71 .25748E+04
   1227.74   100.00   25.00    21.9 0.982E+00   1.25   343.86   25.00   23.75 .28989E+04
   1363.87   100.00   25.00    22.5 0.956E+00   1.22   362.15   25.00   23.78 .32230E+04
   1500.00   100.00   25.00    23.1 0.931E+00   1.19   379.56   25.00   23.81 .35472E+04
 Cumulative travel time =        3547.1619 sec  (    0.99 hrs)

 Simulation limit based on maximum specified distance =   1500.00 m.
   This is the REGION OF INTEREST limitation.

END OF MOD141: BUOYANT AMBIENT SPREADING
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
CORMIX1: Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
```

APPENDIX C:
TASKS 5-9 – SUPPORTING INFORMATION

C.2
Potential Effects of Oil Spill Report

Potential Effects of Oil Spill Report

April 2013

Remora Technology, Inc.

Prepared by:

ecology and environment, inc.
Global Environmental Specialists

TABLE OF CONTENTS

LIST OF TABLES **2**

LIST OF FIGURES **3**

ACRONYMS AND ABBREVIATIONS **4**

1 INTRODUCTION AND BACKGROUND **5**

2 MODELING APPROACH AND DEVELOPMENT **6**

2.1 Approach 6

2.2 Model Input Data 7

2.2.1 GNOME 8

2.2.2 CORMIX 8

3 MODEL RESULTS **10**

3.1 Model Results 10

3.1.1 GNOME Results 10

3.1.2 CORMIX Results 11

4 REFERENCES **12**

APPENDIX A: MODELING FILES **13**

LIST OF TABLES

Page

Table 1: Model Input Data (GNOME) 9

Table 2: Model Input Data (CORMIX) 9

Table 3: Model Results (GNOME).....10

Table 4: Model Results (CORMIX) 11

LIST OF FIGURES

Page

Figure A- 1: GNOME One-Minute Oil Spill Simulation 14

Figure A- 2: GNOME Simulation for Six Hours After One-Minute Oil Spill 15

Figure A- 3: GNOME Simulations Results for One Minute and Six Hours After the Spill 16

Figure A- 4: CORMIX Modeling Result (X-Z).....17

Figure A- 5: CORMIX Model Results (X-Y).....18

Figure A- 6: CORMIX Model Result (Trajectory).....19

Figure A- 7: CORMIX Model Result (Concentration).....20

ACRONYMS AND ABBREVIATIONS

2D	two dimensional
3D	three-dimensional
BOET	Bienville Offshore Energy Terminal
CORMIX	Cornell Mixing Zone Expert System
E & E	Ecology and Environment, Inc.
GNOME	General NOAA (National Oceanic and Atmospheric Administration) Oil Modeling Environment
HAZMAT	Hazardous Materials Response Division
m^3	cubic meter(s)
mg/L	milligram(s) per liter
NOAA OR&R	National Oceanic and Atmospheric Administration Office of Response and Restoration
USEPA	United States Environmental Protection Agency

1 INTRODUCTION AND BACKGROUND

As a subtask under Task 9 for the Deepwater Direct Offloading System Project, Ecology and Environment, Inc. (E & E) conducted a study to evaluate the impact of an oil spill caused by a crude oil spill in the hose transfer system of the HiLoad DP. The hose transfer system is exposed to the environment on the stern of the HiLoad. The crude oil in the hose transfer system is determined to have the greatest potential for environmental damage and will be described in a worst-case discharge model. The purpose of the study was to provide an analysis of the oil spill impact created by a release from the hose transfer system. A computer model analysis was performed using the General NOAA (National Oceanic and Atmospheric Administration) Oil Modeling Environment (GNOME) to evaluate the potential effects of the oil spills in two dimensions. To understand better the oil spill distributions in the water columns, an analysis was performed using the three-dimensional (3D) hydrodynamic model, Cornell Mixing Zone Expert System (CORMIX; Jirka, Doneker, and Hinton 1996, as amended).

2 MODELING APPROACH AND DEVELOPMENT

2.1 APPROACH

While there are different models that could be used and each has its strengths and weaknesses, GNOME was selected as a main predictive tool. The rational for model selection and model limitations are discussed below.

GNOME is a publicly available oil spill trajectory model that simulates oil movement due to winds, currents, tides, and spreading. GNOME was developed by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA OR&R).

GNOME is a trajectory model that can:

- estimate the trajectory of spills by processing user provided information about wind and weather conditions, circulation patterns, and the oil spill(s) the user wants to simulate;
- predict the trajectories that can result from the inexactness (uncertainty) in current and wind observations and forecasts;
- use weathering algorithms to make simple predictions about the changes the oil will undergo while it is exposed to the environment'
- quickly be updated, re-run, and saved with new information; and
- provide trajectory output (including uncertainty estimates) in a geo-referenced format that can be used as input to GIS (geographic information system) programs.

The model is found at: http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/response-tools/gnome.html.

While the GNOME model was selected because of its wide applications, available data templates, and user friendly functions, it does have limitations. It is a two-dimensional (2D) model that simulates oil movement on the water surface, and it cannot produce moving prediction along the water column. This may be effective for most oil spill conditions because most oil particles stay in the upper layers, which means the upper water is the most polluted.

CORMIX is a United States Environmental Protection Agency (USEPA)-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. A mixing zone is the region in which the initial dilution of a discharge occurs. The CORMIX system contains a collection of about 30 regional flow modules to simulate the physics of mixing zones. In application, CORMIX selects one of several hundred possible combinations of these regional flow modules in sequence to construct a simulation model (i.e., flow class) for a complete site-specific mixing zone analysis. The strength of CORMIX is in assessing dispersion of single port discharges, particularly in close proximity to the zone of discharge, and the model contains several advanced tools specially built for outfall designs, which provides a very good fit for simulating the proposed consolidated outfall. Also, data inputs are not as extensive as with some other models such as OILMAP; thus, CORMIX can be easier and less costly to run and can be more easily executed in situations where data are limited. The downside is that the model does not account for far-field tidal influences and more complex hydrodynamic conditions, and thus is a less accurate tool in more dynamic environments and is more approximate in projecting impacts at distances further downstream of the outfall. The model also does not simulate tidal cycles, so dispersion over greater distances caused by tidal movement is not fully considered and far-field plume concentrations may be over predicted. The downsides are not applicable to the HiLoad because the setting is in deep water far outside the area of tidal effects.

Another limitation of the CORMIX model is that the model requires the simulated liquid is well mixed. More than 70 percent of the spilled crude oil is light oil and would most likely float on the water surface. The rest of the oil is heavier and would move downward along with the current and wind. Although CORMIX is not an ideal model for the oil spill case, it does provide an indication of dispersion within the water column for a chemical that is well mixed with the water.

Development of the model contained several major tasks: data collection, model buildup, and simulation runs. The intent of the data collection effort was to use available existing data. The existing data were input into the model and, where gaps existed, assumptions were made.

2.2 MODEL INPUT DATA

The following sections discuss the data input and sources, as well as assumptions made when there were data gaps for existing and proposed conditions.

2.2.1 GNOME

The GNOME model requires several groups of data which include model setting, location file, wind, and spill data (Table 1). Most of input data are from previous studies located at the Bienville Offshore Energy Terminal (BOET) site about 62 miles south of Mobile Bay, Alabama, in Main Pass Block 258 in the Gulf of Mexico.

The oil spill of the hose transfer system is floating at or slightly below the water surface, and the depth of the water at the location of the spill is approximately 425 feet. Two model simulations were conducted: the first was for one minute of oil flow with a total spill volume of 46.38 cubic meters (m^3), and the other simulation was for six hours after the spill. A wind speed of 8.5 m/s was used in the model which was taken from a previous study done at the BOET site; and the worst wind direction (south, toward to the shoreline) was selected. The spill information was estimated by estimating the volume of the hose and the time required to recognize the leak and reach valve closure. The location file, which includes generalized information about the tides, currents, and shorelines in the region, was based on a GNOME location file for Mobile Bay. The Mobile Bay location file of GNOME covers a general area of 10 miles south of the Bay. To simulate the project location, which is about 62 miles south of the bay, an assumption was made that the tides and the currents at the oil spill site were similar to a location 10 miles south of the bay. Although these data may not be ideal, they are the best available that contain all the tides, currents, and shorelines information in the region. The simulation setting has a built-in uncertainty factor that can compensate for typical errors in the wind and current input data.

2.2.2 CORMIX

The CORMIX simulation was set up for a chemical discharge with the same ambient environment and discharge rate as the oil spill.

The chemical discharge simulated by the CORMIX had a density of 261,200 milligrams per liter (mg/L) which is estimated as the heavy oil fraction of medium grade crude oil. The CORMIX input data are listed in Table 2.

Table 1: Model Input Data (GNOME)

Data	Data Value/Source
Model Simulation Settings	1 Minute Spill and 6 Hours After the Spill with Uncertainty Analysis
Location File	GNOME Default Location File for Mobile Bay
Wind Speed and Direction	8.5 m/s (South)
Spills Total Volume	46.38 m^3

Table 2: Model Input Data (CORMIX)

Data	Data Value/Source
Discharge Rate and Volume	1.55 m^3/s; 46.38 m^3
Discharge Depth	425 m
Wind Speed	8.5 m/s
Discharge Duration	Entire Period of Simulation (9.5 hours)
Chemical Density	262,100 mg/L

3 MODEL RESULTS

The following text provides the results of the model simulations. A total of two simulations were conducted by the GNOME model. One simulation was performed using CORMIX.

3.1 MODEL RESULTS

3.1.1 GNOME

The first simulation run provided the oil spread within one minute of the spill, and the second run showed the trajectory of the oil movement in six hours after the one-minute spill. Based on the six-hour simulation results for the spilled oil, approximately five days were estimated to reach the shoreline after the one-minute spill from the guillotine cut hose.

Table 3 presents results of two different simulations. The oil spreads of each simulation have their areas (X * Y), a general distance traveled from the spill site to the center of the oil spread, and a distance from the center of the oil spread to the Mobile Bay shoreline.

Table 3: Model Results (GNOME)

Modeling Run	Simulations	Spread Area (X * Y)	Distance from the Spill Site	Distance to the Mobile Shoreline
Run 1	1 Minute Spill	1300 feet * 1300 feet	300 feet	62 miles
Run 2	6 Hours After Spill	4.5 miles * 4.8 miles	2.6 miles	59.8 miles

The modeling output graphics for simulations Run 1 and Run 2 of the GNOME model are included in Appendix A of this report.

3.1.2 CORMIX

Table 4 shows simulated results from the CORMIX runs. CORMIX does not provide an option for the model to simulate a case of mixing without a discharge, so the discharge was set to "on" for the length of the standard simulation run of 9.5 hours. The modeling output graphics and input/output data for the CORMIX model simulation are included in Appendix A of this report.

Table 4: Model Results (CORMIX)

Modeling Run	Chemical Location at Z Direction at Beginning of Discharge	Chemical Location at Z Direction at 30 Seconds After the Discharge	Chemical Location at Z Direction at 8 Hours After the Discharge
Run 1	425 meters	404 meters	0 meters (bottom)

4 REFERENCES

Jirka, G.H., R.L. Doneker, and S.W. Hinton. 1996. "User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters." U.S. Environmental Protection Agency, Tech. Rep., Environmental Research Lab, Athens, Georgia.

APPENDIX A: MODELING FILES

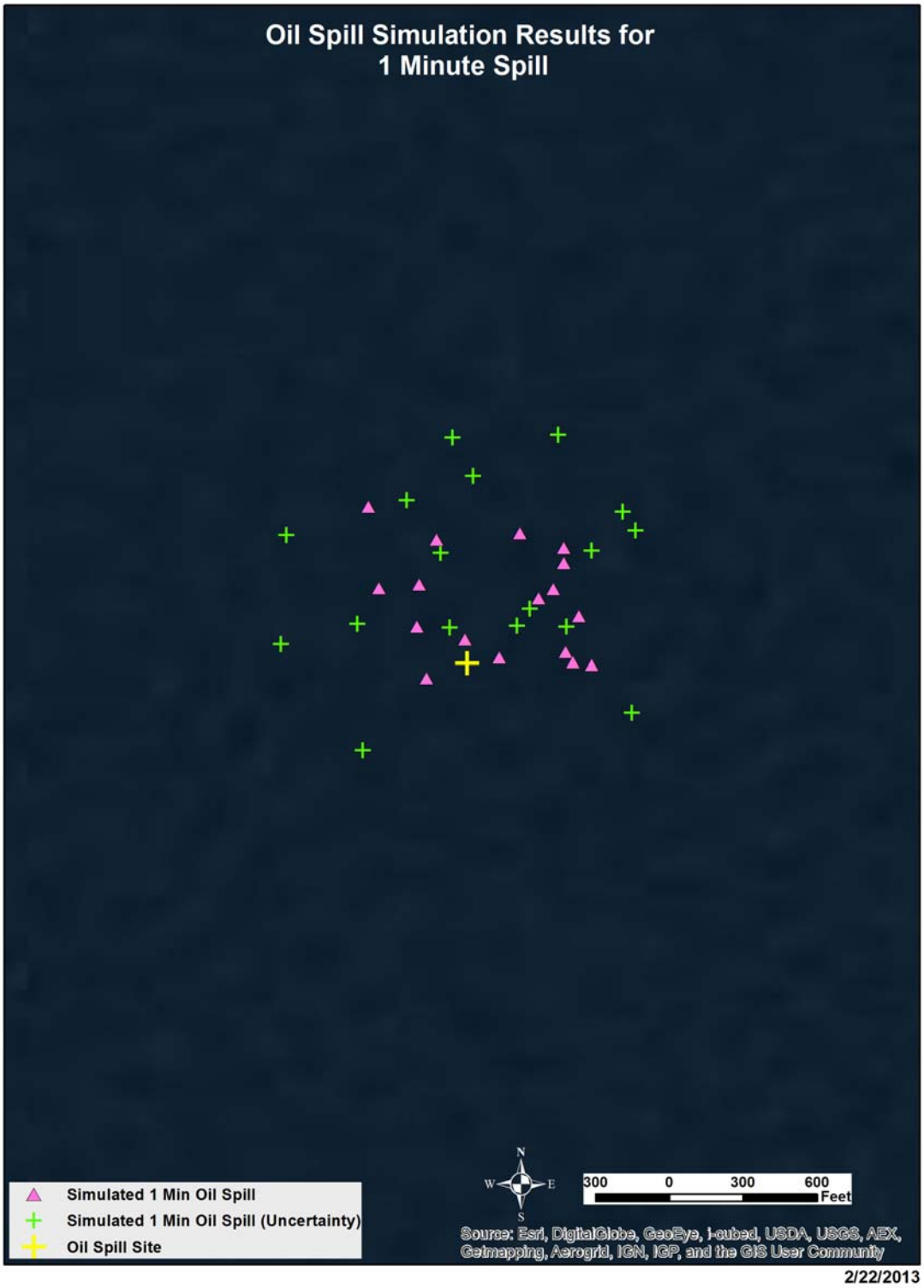


Figure A- 1: GNOME One-Minute Oil Spill Simulation

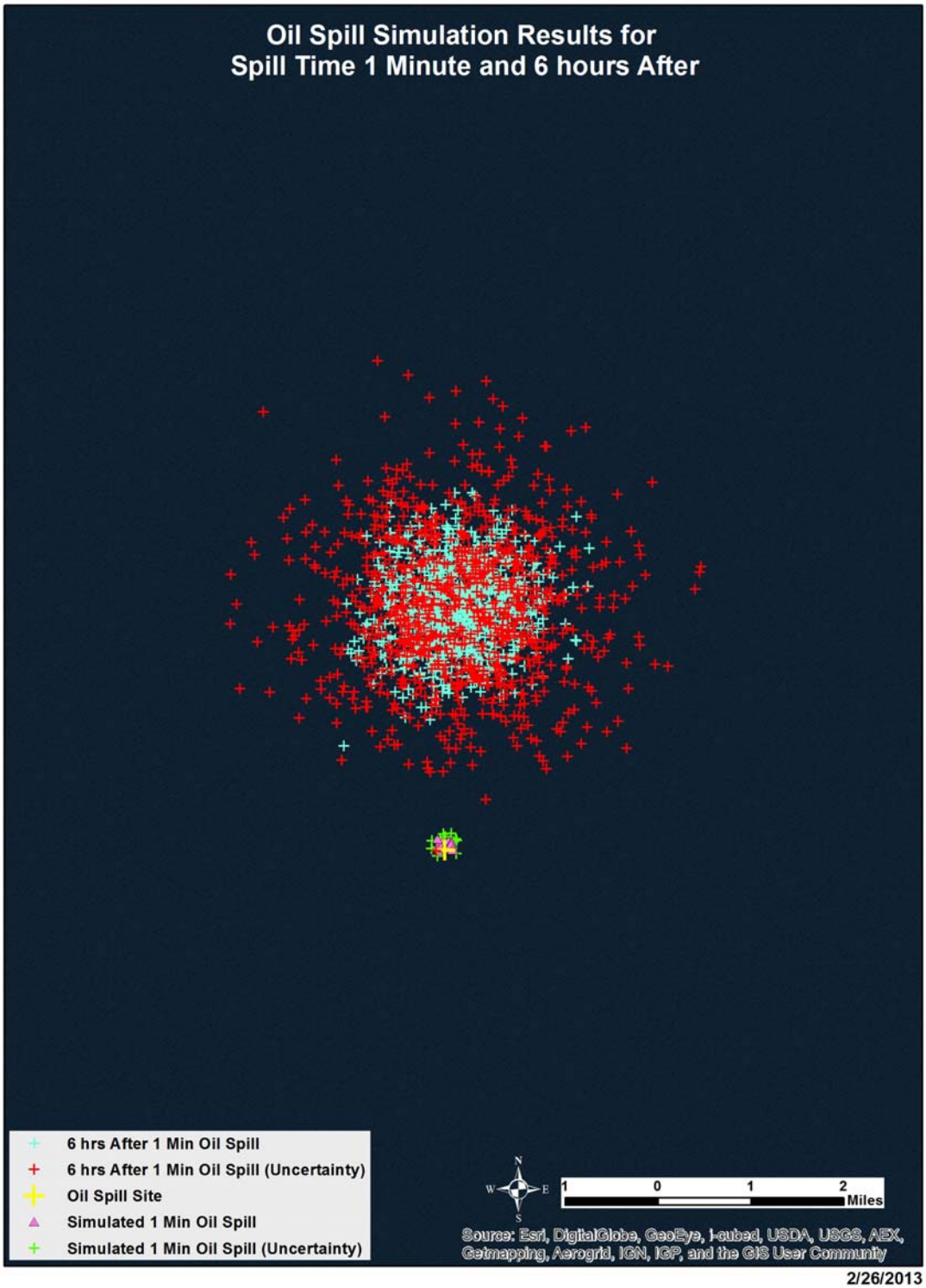


Figure A- 2: GNOME Simulation for Six Hours After One-Minute Oil Spill

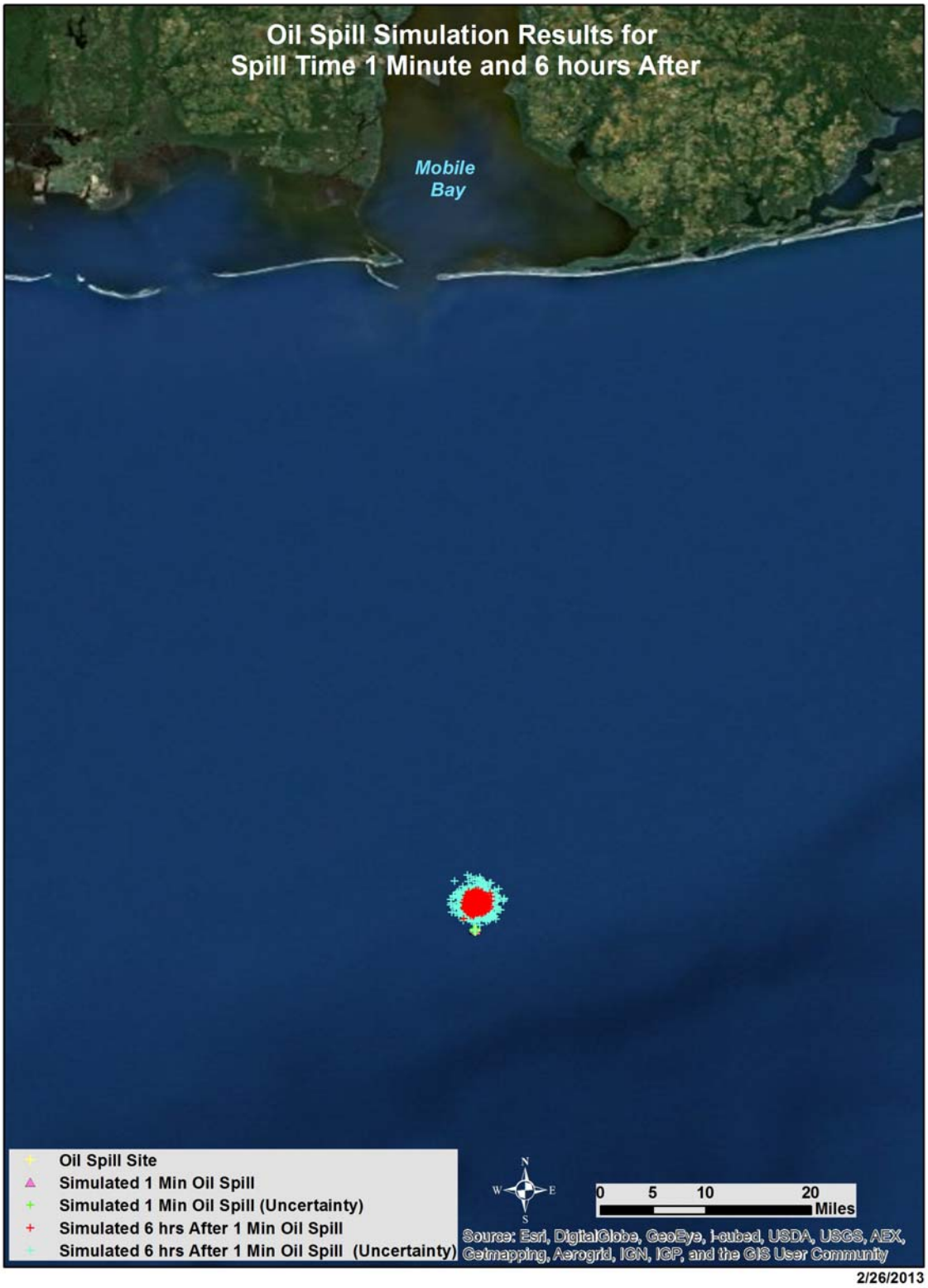


Figure A- 3: GNOME Simulations Results for One Minute and Six Hours After the Spill

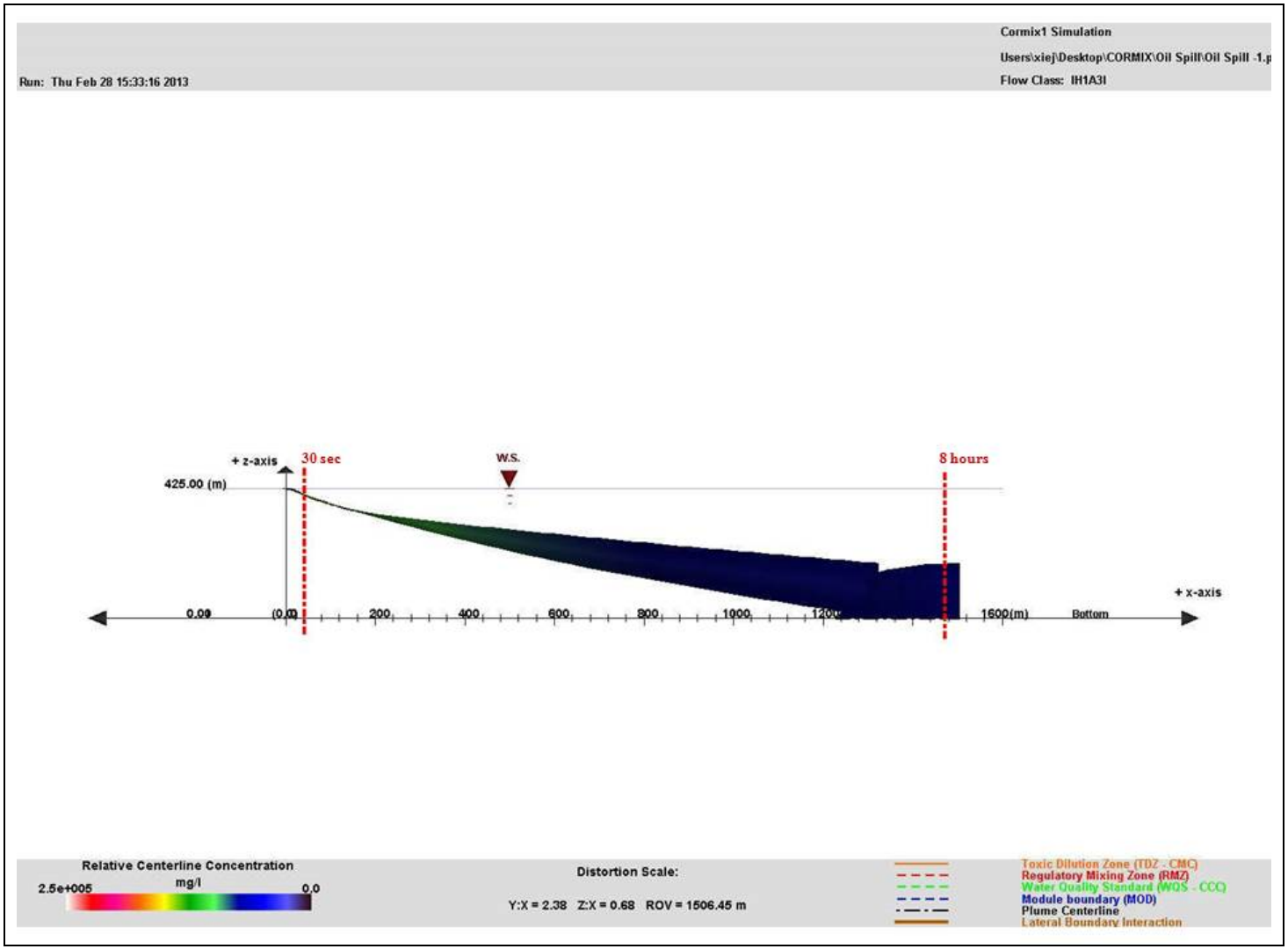


Figure A- 4: CORMIX Modeling Result (X-Z)

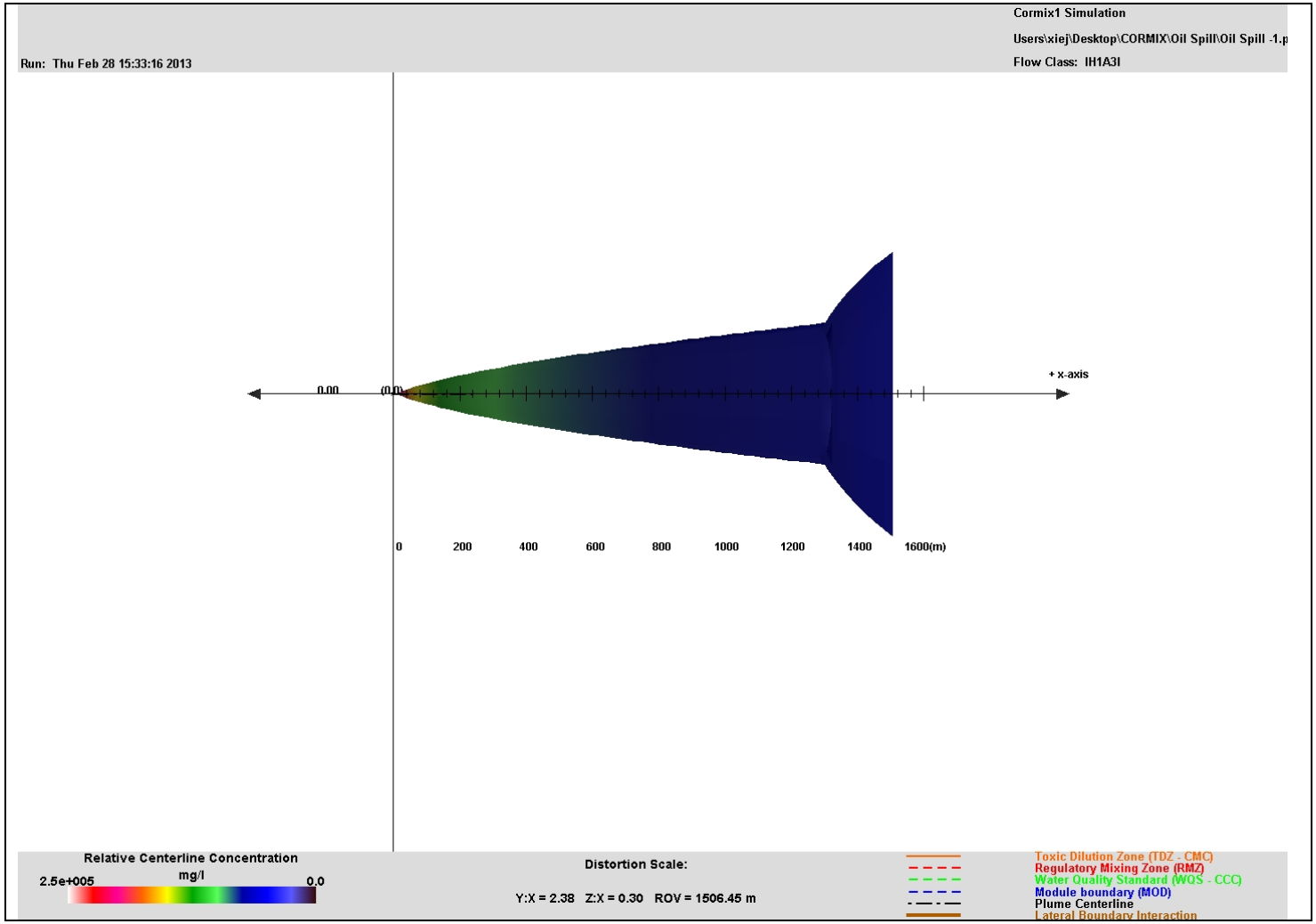


Figure A- 5: CORMIX Model Results (X-Y)

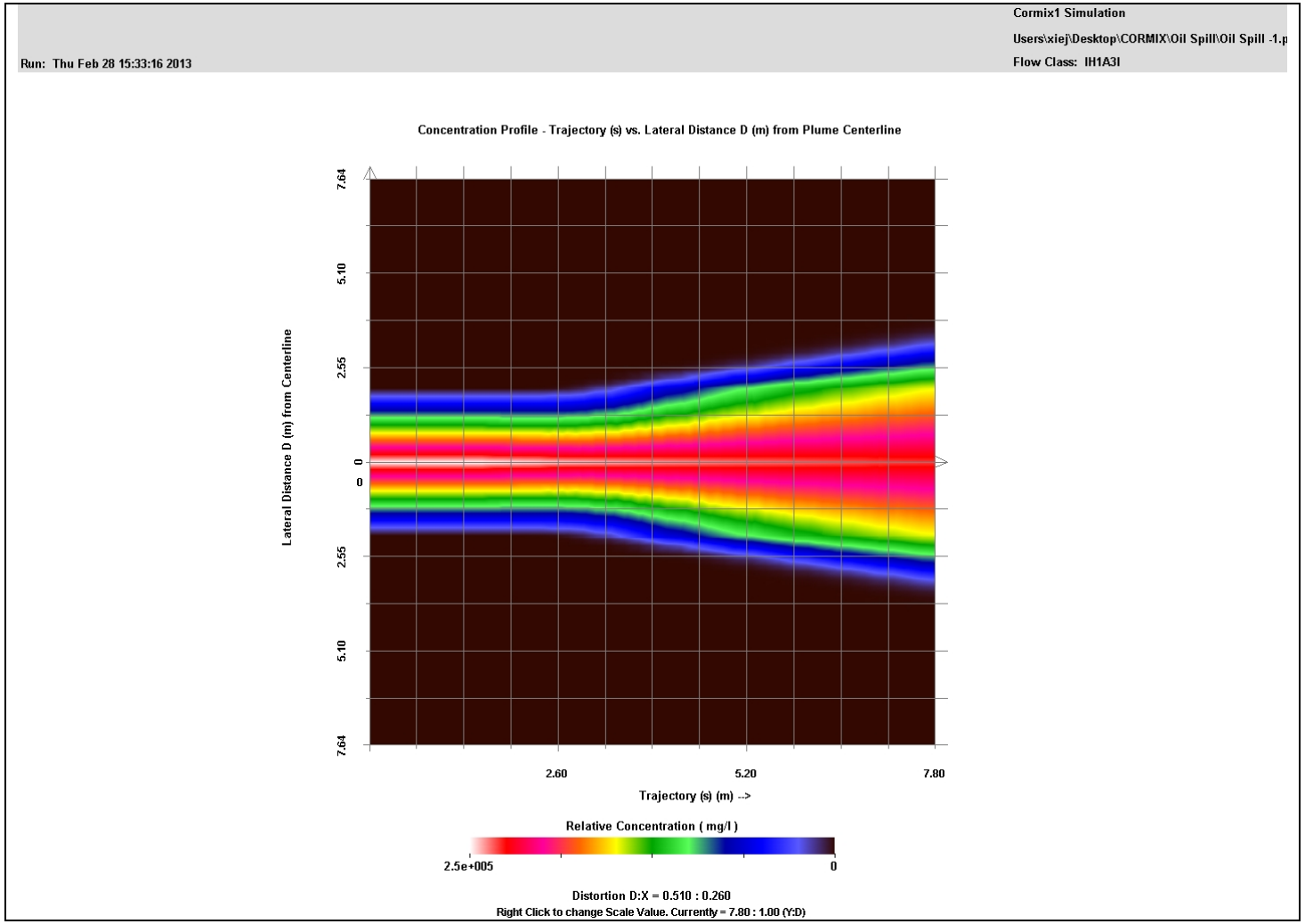


Figure A- 6: CORMIX Model Result (Trajectory)

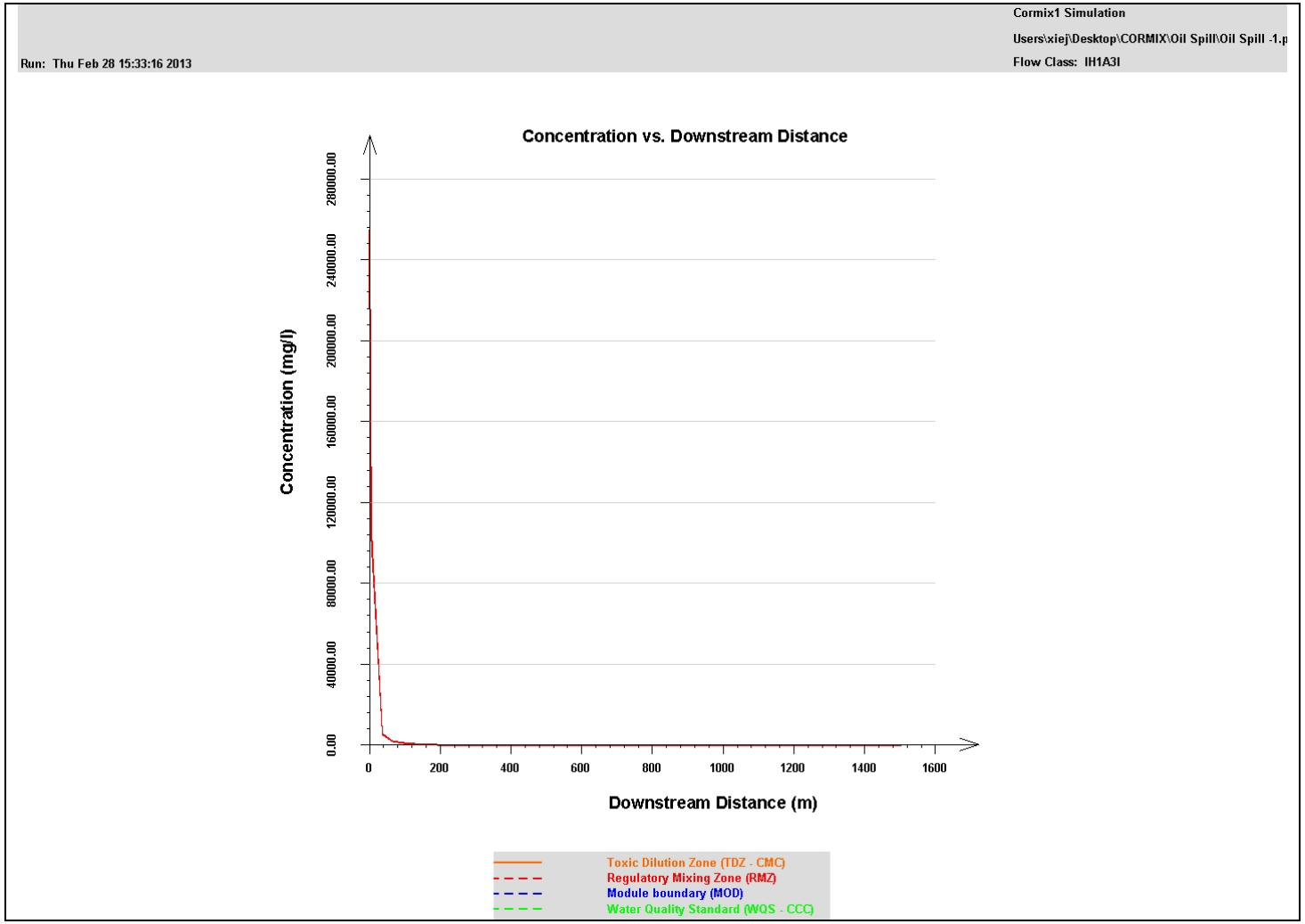


Figure A- 7: CORMIX Model Result (Concentration)

CORMIX Output Files

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
                        CORMIX MIXING ZONE EXPERT SYSTEM
                    Subsystem CORMIX1: Single Port Discharges
                              CORMIX Version 8.0GT
                      HYDRO1 Version 8.0.0.0 April 2012
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:
 Design case:
 FILE NAME:         C:\...top\CORMIX\Oil Spill\Simulations\Oil Spill -1.prd
 Time stamp:        Fri Mar  1 09:59:23 2013

ENVIRONMENT PARAMETERS (metric units)
 Unbounded section
 HA    =    340.00  HD    =    425.00
 UA    =      0.500 F     =      0.025 USTAR =0.2795E-01
 UW    =      8.500 UWSTAR=0.1074E-01
 Uniform density environment
 STRCND=  U         RHOAM = 1002.5000

DISCHARGE PARAMETERS (metric units)
 BANK  =  LEFT      DISTB =  96000.00
 D0    =      0.508 A0    =      0.203 H0    =    425.00  SUB0  =      0.00
 THETA =      0.00  SIGMA =      0.00
 U0    =      7.647 Q0    =      1.550       =0.1550E+01
 RHO0  = 1102.0000  DRHO0 =-.9950E+02  GP0   =-.9733E+00
 C0    =0.2621E+06  CUNITS=  mg/l
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.1550E+01  M0    =0.1185E+02  J0    =-.1509E+01  SIGNJ0=     -1.0
 Associated length scales (meters)
 LQ    =      0.45  LM    =      5.20  Lm    =      6.89  Lb    =     12.07
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     10.88  R     =     15.29

FLOW CLASSIFICATION
 111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    IH1A3I 1
 1  Applicable layer depth HS =   425.00  1
 111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    =0.2621E+06  CUNITS=  mg/l
 NTOX  =  0
 NSTD  =  1         CSTD  =0.1000E+03
 REGMZ =  1
 REGSPC=  1         XREG  =     40.00  WREG  =      0.00  AREG  =      0.00
 XINT  =  17000.00  XMAX  =  17000.00

X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
     96000.00 m  from the LEFT  bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP =  40 display intervals per module
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.
```

```
       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00  425.00     1.0 0.262E+06   0.36    7.147   .00000E+00

END OF MOD101: DISCHARGE MODULE
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Surface-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
            Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time

       X        Y       Z        S       C       B        Uc        TT
      0.00     0.00  425.00     1.0 0.262E+06   0.26    7.147   .26781E-02
      0.16     0.00  425.00     1.0 0.262E+06   0.27    7.147   .13805E-01
      0.35     0.00  425.00     1.0 0.262E+06   0.29    7.147   .28644E-01
      0.59     0.00  425.00     1.0 0.262E+06   0.32    7.147   .47805E-01
      0.78     0.00  425.00     1.0 0.262E+06   0.34    7.147   .64897E-01
      0.98     0.00  425.00     1.0 0.262E+06   0.36    7.147   .83003E-01
      1.17     0.00  425.00     1.0 0.262E+06   0.38    7.147   .10212E+00
      1.37     0.00  425.00     1.0 0.262E+06   0.40    7.147   .12224E+00
      1.56     0.00  425.00     1.0 0.260E+06   0.41    7.147   .14335E+00
      1.76     0.00  425.00     1.1 0.248E+06   0.43    7.147   .16546E+00
      1.95     0.00  425.00     1.1 0.237E+06   0.45    7.147   .18856E+00
      2.15     0.00  425.00     1.2 0.226E+06   0.47    7.147   .21264E+00
      2.34     0.00  425.00     1.2 0.217E+06   0.49    7.147   .23769E+00
      2.54     0.00  425.00     1.3 0.208E+06   0.51    6.884   .26372E+00
      2.73     0.00  425.00     1.3 0.200E+06   0.53    6.624   .29071E+00
      2.93     0.00  425.00     1.4 0.193E+06   0.55    6.383   .31866E+00
      3.12     0.00  425.00     1.4 0.186E+06   0.57    6.160   .34757E+00
      3.32     0.00  425.00     1.5 0.179E+06   0.58    5.951   .37742E+00
      3.51     0.00  425.00     1.5 0.173E+06   0.60    5.756   .40822E+00
      3.71     0.00  425.00     1.6 0.168E+06   0.62    5.573   .43996E+00
      3.90     0.00  425.00     1.6 0.162E+06   0.64    5.402   .47264E+00
      4.10     0.00  425.00     1.7 0.157E+06   0.66    5.241   .50624E+00
      4.29     0.00  425.00     1.7 0.153E+06   0.67    5.089   .54077E+00
      4.49     0.00  425.00     1.8 0.148E+06   0.69    4.946   .57622E+00
      4.68     0.00  425.00     1.8 0.144E+06   0.71    4.810   .61259E+00
      4.88     0.00  425.00     1.9 0.140E+06   0.73    4.682   .64986E+00
      5.07     0.00  425.00     1.9 0.136E+06   0.75    4.561   .68804E+00
      5.27     0.00  425.00     2.0 0.133E+06   0.76    4.446   .72711E+00
      5.46     0.00  425.00     2.0 0.129E+06   0.78    4.336   .76709E+00
      5.66     0.00  425.00     2.1 0.126E+06   0.80    4.232   .80795E+00
      5.85     0.00  425.00     2.1 0.123E+06   0.82    4.133   .84970E+00
      6.05     0.00  425.00     2.2 0.120E+06   0.83    4.038   .89233E+00
      6.24     0.00  425.00     2.2 0.117E+06   0.85    3.947   .93584E+00
      6.44     0.00  425.00     2.3 0.115E+06   0.87    3.861   .98021E+00
      6.63     0.00  425.00     2.3 0.112E+06   0.88    3.778   .10255E+01
      6.83     0.00  425.00     2.4 0.110E+06   0.90    3.699   .10716E+01
      7.02     0.00  425.00     2.4 0.107E+06   0.92    3.623   .11185E+01
      7.22     0.00  425.00     2.5 0.105E+06   0.93    3.550   .11663E+01
      7.41     0.00  425.00     2.5 0.103E+06   0.95    3.480   .12150E+01
      7.61     0.00  425.00     2.6 0.101E+06   0.97    3.413   .12645E+01
      7.80     0.00  425.00     2.6 0.994E+05   0.98    3.361   .13047E+01
 Cumulative travel time =           1.3047 sec  (    0.00 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
```

```
BEGIN MOD152: LIFT OFF/FALL DOWN

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  TT = Cumulative travel time

  Inflow (attached) and outflow (free) conditions:
       X        Y       Z        S       C       B        TT
      7.80     0.00  425.00     2.6 0.994E+05   0.98 .13047E+01
      9.76     0.00  425.00     2.6 0.994E+05   0.69 .26663E+01
 Cumulative travel time =           2.6663 sec  (    0.00 hrs)

END OF MOD152: LIFT OFF/FALL DOWN
-----------------------------------------------------------------------------------------------
-----------------------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in strong crossflow.
 Plume-like motion after lift off/fall down.

 The WIDTH PREDICTION B in the first entry below may exhibit some mismatch
   (up to a factor of 1.5) relative to the last entry of the previous module.
   This is unavoidable due to differences in the width definitions.
   The actual physical transition will be smoothed out.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)
  Uc = Local centerline excess velocity (above ambient)
  TT = Cumulative travel time

       X        Y       Z        S       C       B        Uc        TT
      9.76     0.00  425.00     2.6 0.994E+05   0.62    2.700   .28070E+01
  Maximum jet height has been reached.
     37.60     0.00  406.57    47.8 0.549E+04   4.84    0.702   .25715E+02
 ** REGULATORY MIXING ZONE BOUNDARY is within the Near-Field Region **
 In this prediction interval the plume DOWNSTREAM  distance meets or exceeds
 the regulatory value =    40.00 m.
 This is the extent of the REGULATORY MIXING ZONE.
     66.99     0.00  389.08   148.2 0.177E+04   9.05    0.433   .61094E+02
     97.85     0.00  374.31   284.0 0.923E+03  12.85    0.323   .10277E+03
    129.01     0.00  361.33   443.5 0.591E+03  16.28    0.263   .14769E+03
    161.03     0.00  349.27   625.8 0.419E+03  19.52    0.225   .19585E+03
    193.35     0.00  338.04   825.5 0.318E+03  22.57    0.198   .24596E+03
    225.88     0.00  327.43  1040.3 0.252E+03  25.47    0.178   .29760E+03
    258.14     0.00  317.46  1265.5 0.207E+03  28.20    0.162   .34975E+03
    290.96     0.00  307.78  1505.8 0.174E+03  30.86    0.150   .40360E+03
    323.88     0.00  298.47  1757.2 0.149E+03  33.42    0.139   .45830E+03
    356.89     0.00  289.46  2018.8 0.130E+03  35.91    0.131   .51373E+03
    389.54     0.00  280.85  2286.4 0.115E+03  38.28    0.123   .56904E+03
    422.68     0.00  272.36  2566.4 0.102E+03  40.63    0.117   .62565E+03
**WATER QUALITY STANDARD OR CCC HAS BEEN FOUND**
 The pollutant concentration in the plume falls below water quality standard
   or CCC value of 0.100E+03 in the current prediction interval.
 This is the spatial extent of concentrations exceeding the water quality
   standard or CCC value.
    455.88     0.00  264.09  2854.7 0.918E+02  42.91    0.111   .68275E+03
    489.13     0.00  256.01  3151.1 0.832E+02  45.14    0.106   .74030E+03
    521.99     0.00  248.22  3450.9 0.760E+02  47.30    0.102   .79748E+03
    555.32     0.00  240.48  3762.0 0.697E+02  49.43    0.098   .85578E+03
    588.68     0.00  232.90  4079.9 0.642E+02  51.53    0.094   .91441E+03
    621.64     0.00  225.55  4400.1 0.596E+02  53.56    0.091   .97257E+03
    655.06     0.00  218.24  4730.8 0.554E+02  55.58    0.088   .10318E+04
    688.51     0.00  211.04  5067.7 0.517E+02  57.57    0.085   .10913E+04
```

```
    721.99     0.00  203.96  5410.5 0.484E+02  59.52    0.083   .11510E+04
    755.04     0.00  197.08  5754.3 0.455E+02  61.43    0.080   .12101E+04
    788.56     0.00  190.20  6108.3 0.429E+02  63.32    0.078   .12702E+04
    822.10     0.00  183.42  6467.5 0.405E+02  65.19    0.076   .13306E+04
    855.65     0.00  176.73  6832.0 0.384E+02  67.04    0.074   .13911E+04
    888.78     0.00  170.21  7196.6 0.364E+02  68.84    0.072   .14510E+04
    922.37     0.00  163.69  7570.9 0.346E+02  70.64    0.071   .15119E+04
    955.97     0.00  157.24  7950.0 0.330E+02  72.42    0.069   .15729E+04
    989.59     0.00  150.86  8333.8 0.315E+02  74.17    0.067   .16340E+04
   1022.77     0.00  144.64  8717.0 0.301E+02  75.89    0.066   .16945E+04
   1056.42     0.00  138.39  9109.7 0.288E+02  77.61    0.065   .17559E+04
   1090.07     0.00  132.22  9506.8 0.276E+02  79.31    0.063   .18175E+04
   1123.29     0.00  126.18  9902.8 0.265E+02  80.97    0.062   .18784E+04
   1156.97     0.00  120.13 10308.2 0.254E+02  82.64    0.061   .19402E+04
   1190.65     0.00  114.13 10717.6 0.245E+02  84.29    0.060   .20020E+04
   1224.35     0.00  108.18 11131.1 0.235E+02  85.92    0.059   .20641E+04
   1257.61     0.00  102.37 11542.9 0.227E+02  87.52    0.058   .21253E+04
   1291.32     0.00   96.52 11964.1 0.219E+02  89.12    0.057   .21875E+04
   1325.04     0.00   90.73 12385.5 0.212E+02  90.70    0.056   .22493E+04
 Cumulative travel time =        2249.3237 sec  (    0.62 hrs)

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------------------
-------------------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B        TT
   1325.04     0.00   90.73 12385.5 0.212E+02  90.70 .22493E+04

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time

       X        Y       Z        S       C       BV       BH      ZU      ZL       TT
   1234.34     0.00    0.00 12385.5 0.212E+02   0.00     0.00    0.00    0.00 .22493E+04
   1261.55     0.00    0.00 12385.5 0.212E+02 113.61    57.13  113.61    0.00 .22493E+04
   1288.76     0.00    0.00 12385.5 0.212E+02 134.69    80.79  134.69    0.00 .22493E+04
   1315.97     0.00    0.00 12385.5 0.212E+02 148.29    98.95  148.29    0.00 .22493E+04
   1343.18     0.00    0.00 12725.5 0.206E+02 158.18   114.26  158.18    0.00 .22856E+04
   1370.39     0.00    0.00 14303.3 0.183E+02 165.66   127.74  165.66    0.00 .23400E+04
   1397.60     0.00    0.00 16483.8 0.159E+02 171.33   139.93  171.33    0.00 .23944E+04
   1424.81     0.00    0.00 18470.0 0.142E+02 175.52   151.15  175.52    0.00 .24489E+04
   1452.03     0.00    0.00 19834.1 0.132E+02 178.40   161.58  178.40    0.00 .25033E+04
   1479.24     0.00    0.00 20573.5 0.127E+02 180.10   171.38  180.10    0.00 .25577E+04
   1506.45     0.00    0.00 21055.4 0.124E+02 180.65   180.65  180.65    0.00 .26121E+04
 Cumulative travel time =        2612.1362 sec  (    0.73 hrs)

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH
-------------------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-------------------------------------------------------------------------------------------
BEGIN MOD141: BUOYANT AMBIENT SPREADING

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)
   TT = Cumulative travel time
```

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL	TT
1506.45	0.00	0.00	21055.4	0.124E+02	180.65	180.65	180.65	0.00	.26121E+04
1893.79	0.00	0.00	22387.0	0.117E+02	152.36	227.74	152.36	0.00	.33868E+04
2281.12	0.00	0.00	23480.4	0.112E+02	134.61	270.37	134.61	0.00	.41615E+04
2668.46	0.00	0.00	24445.7	0.107E+02	122.29	309.85	122.29	0.00	.49362E+04
3055.80	0.00	0.00	25339.9	0.103E+02	113.21	346.94	113.21	0.00	.57108E+04
3443.14	0.00	0.00	26197.1	0.100E+02	106.26	382.15	106.26	0.00	.64855E+04
3830.48	0.00	0.00	27039.5	0.969E+01	100.80	415.79	100.80	0.00	.72602E+04
4217.82	0.00	0.00	27882.6	0.940E+01	96.44	448.12	96.44	0.00	.80349E+04
4605.16	0.00	0.00	28738.2	0.912E+01	92.93	479.31	92.93	0.00	.88096E+04
4992.50	0.00	0.00	29614.9	0.885E+01	90.09	509.52	90.09	0.00	.95842E+04
5379.84	0.00	0.00	30520.0	0.859E+01	87.79	538.85	87.79	0.00	.10359E+05
5767.17	0.00	0.00	31459.3	0.833E+01	85.94	567.40	85.94	0.00	.11134E+05
6154.51	0.00	0.00	32437.5	0.808E+01	84.47	595.24	84.47	0.00	.11908E+05
6541.85	0.00	0.00	33458.8	0.783E+01	83.32	622.45	83.32	0.00	.12683E+05
6929.19	0.00	0.00	34526.9	0.759E+01	82.45	649.06	82.45	0.00	.13458E+05
7316.53	0.00	0.00	35644.9	0.735E+01	81.83	675.14	81.83	0.00	.14232E+05
7703.87	0.00	0.00	36815.5	0.712E+01	81.44	700.72	81.44	0.00	.15007E+05
8091.21	0.00	0.00	38041.4	0.689E+01	81.24	725.84	81.24	0.00	.15782E+05
8478.55	0.00	0.00	39324.9	0.666E+01	81.21	750.53	81.21	0.00	.16556E+05
8865.88	0.00	0.00	40668.0	0.644E+01	81.36	774.82	81.36	0.00	.17331E+05
9253.22	0.00	0.00	42072.8	0.623E+01	81.65	798.73	81.65	0.00	.18106E+05
9640.56	0.00	0.00	43541.0	0.602E+01	82.07	822.28	82.07	0.00	.18880E+05
10027.90	0.00	0.00	45074.3	0.581E+01	82.63	845.51	82.63	0.00	.19655E+05
10415.24	0.00	0.00	46674.4	0.562E+01	83.31	868.41	83.31	0.00	.20430E+05
10802.58	0.00	0.00	48342.7	0.542E+01	84.10	891.02	84.10	0.00	.21204E+05
11189.92	0.00	0.00	50080.7	0.523E+01	84.99	913.34	84.99	0.00	.21979E+05
11577.26	0.00	0.00	51889.6	0.505E+01	85.98	935.39	85.98	0.00	.22754E+05
11964.60	0.00	0.00	53770.9	0.487E+01	87.07	957.18	87.07	0.00	.23528E+05
12351.93	0.00	0.00	55725.7	0.470E+01	88.25	978.73	88.25	0.00	.24303E+05
12739.27	0.00	0.00	57755.2	0.454E+01	89.52	1000.04	89.52	0.00	.25078E+05
13126.61	0.00	0.00	59860.5	0.438E+01	90.86	1021.13	90.86	0.00	.25852E+05
13513.95	0.00	0.00	62042.8	0.422E+01	92.29	1042.00	92.29	0.00	.26627E+05
13901.29	0.00	0.00	64303.1	0.408E+01	93.79	1062.66	93.79	0.00	.27402E+05
14288.63	0.00	0.00	66642.4	0.393E+01	95.37	1083.12	95.37	0.00	.28176E+05
14675.97	0.00	0.00	69061.7	0.380E+01	97.01	1103.40	97.01	0.00	.28951E+05
15063.31	0.00	0.00	71562.0	0.366E+01	98.73	1123.48	98.73	0.00	.29726E+05
15450.65	0.00	0.00	74144.2	0.354E+01	100.51	1143.39	100.51	0.00	.30501E+05
15837.98	0.00	0.00	76809.2	0.341E+01	102.36	1163.13	102.36	0.00	.31275E+05
16225.32	0.00	0.00	79557.9	0.329E+01	104.27	1182.70	104.27	0.00	.32050E+05
16612.66	0.00	0.00	82391.2	0.318E+01	106.23	1202.11	106.23	0.00	.32825E+05
17000.00	0.00	0.00	85309.8	0.307E+01	108.26	1221.37	108.26	0.00	.33599E+05

Cumulative travel time = 33599.2422 sec (9.33 hrs)

Simulation limit based on maximum specified distance = 17000.00 m.
This is the REGION OF INTEREST limitation.

END OF MOD141: BUOYANT AMBIENT SPREADING

CORMIX1: Single Port Discharges End of Prediction File

111111111

APPENDIX D:
TASKS 10-14 – SUPPORTING INFORMATION

D.1
TRL Voting Paper and Explanation Material

TECHNOLOGY READINESS LEVEL FOR HILOAD DP

Deepwater Direct Offloading Systems: RPSEA Project 10121-4407-01
Second Working Group Meeting on 9 January 2013

VOTING PAPER

	TODAY	THREE YEARS FROM NOW
HiLoad DP in my judgment has a Technology Readiness Level as follows: (Give round number chosen from RPSEA Technology Readiness Level Definition)	_____	_____

Comments, Rationale _____
for my choice of TRL:_____
_____

Signature and date: _____
Printed Name: _____
_____
Phone Number Email Address
Company: _____
Job Title: _____

THIS IS ONE PERSON'S PROFESSIONAL OPINION AND NOT AN EXPRESSION OF THE POSITION ANY EMPLOYER OR OTHER ORGANIZATION.

Reference Materials Attached: RPSEA Technology Readiness Level (TRL) Definition, 1 page;
Summary of what TRLs are about and their use here, 1 page;
Example of TRLs applied to offloading systems and FPSOs, 1 page.

RPSEA Technology Readiness Level (TRL) Definition

TRL Designation		Definition
TRL 0	**Unproven Idea** (paper concept, no analysis or testing)	At TRL 0, a technical need has been identified and a concept has been conceived. The description of the technical need is general in nature without specific performance or functional requirements. The concept has been refined to the point that the physical principles have been documented and simple sketches, if applicable, have been produced. No analysis or testing has been performed.
TRL 1	**Proven Concept** (functionality demonstrated by analysis or testing)	At TRL 1, the concept has been refined to the point where the basic physical properties (dimensions, material types, rates, etc.) have been developed and documented and preliminary drawings, if applicable, have been produced. The primary technical requirements are documented. Analysis and/or testing have been performed demonstrating that the concept functions as conceived. The testing may be conducted on individual subcomponents and subsystems without integration into a broader system. The concept may not meet all of the technical requirements at this level, but demonstrates the basic functionality with promise to meet all of the requirements with additional development.
TRL 2	**Validated System Concept** (breadboard tested in "realistic" environment)	At TRL 2, the concept is developed into an ad-hoc system of discrete components (breadboard/mock-up) to establish that the components work together prior to prototype construction. The system validates that it can function in a "realistic" environment, with the key environmental parameters simulated. Appropriate material testing and reliability testing may be performed on key parts or components.
TRL 3	**Prototype Tested** (prototype developed and tested)	At TRL 3, the technical specifications are developed further and a prototype has been developed. The technical specifications include details of the performance, functional, environmental, and interface requirements. The prototype is tested in a robust design development test program over a limited range of operating conditions to demonstrate its functionality. Reliability growth tests and accelerated life tests may also be performed. The relevant lab test environment may not be field realistic. This is an isolated test program for this technology, without its integration into a broader system.
TRL 4	**Environment Tested** (prototype tested in field realistic environment)	At TRL 4, the technology meets all of the requirements of TRL 3 and below, except that the testing is conducted in a relevant environment (simulated or actual) over its full operating range.
TRL 5	**System Integration Tested** (prototype integrated with intended system and functionally tested)	At TRL 5, the technology meets all of the requirements of TRL 4 and below and is integrated into its intended operating system and tested. The testing includes full interface and functional testing. The system integration test environment may not be field realistic. (This TRL may not be applicable for all technology.)
TRL 6	**Technology Deployed** (prototype deployed in field test or actual operation)	At TRL 6, the technology has been developed into a field-ready prototype or production unit and has been integrated into its intended operating system and installed in the field. The technology has successfully operated for <10% of its expected life.
TRL 7	**Proven Technology** (production unit success-fully operational for >10% of expected life)	At TRL 7, the technology is now in production and has been fully integrated into its intended operating system and installed in the field. The technology has successfully operated with acceptable performance and reliability for >10% of its specified life.

Summary of what TRLs are about and their use here

History: Technology Readiness Levels have their origin with NASA in the late 1980s where they had to contend with technologies urgently needed but of varying maturity, affecting decisions on many projects. A concept evolved using a nine level set of Technology Readiness Levels (TRLs). Use spread to other industries such as the nuclear industry and work for the US Department of Defense. Use also spread to other countries and the similar work they were engaged in. TRLs in the petroleum industry appear to have started largely in Norway, encouraged by Statoil, using a seven level TRL definition. DeepStar was similarly addressing choices on new technologies in the US and adopted the same TRL concept and definition for their work on behalf of a number of operating oil companies, largely in the US but also with some headquartered outside the US (Petrobras, Statoil, Total). RPSEA with its links to DeepStar adopted the DeepStar TRL definition as shown here. Over the API 17N and DOE versions.

The Delphi Method: The US Strategic Air Command in the 1950s researched the effectiveness of making judgments on critical future events by polling well experienced people in relevant fields. The concept evolved of how sound judgments on possible future events could indeed be made by such groups. In retrospect it all sounds like common sense – get a group of really knowledgeable people to think about and express their opinions on the matter at hand. This principle is applied in the TRL VOTE with the group of representatives from operating oil companies, who each have deepwater and offloading systems experience and hence may be able to provide as authoritative a reading as practically possible on the maturity of the technology in the HiLoad DP and even identify their rationale for the TRL choice made.

Recent Development with Remora: In recent weeks a commitment has been negotiated by Remora to employ the prototype HiLoad DP on a long term basis in a production environment offshore, outside the US, all subject to (a) final board approvals and then (b) continuing operations if satisfactory performance is demonstrated. This involves modifying the prototype HiLoad DP that successfully underwent sea trial offshore Norway. If these operations starting in 2013 turn out to be successful, then after two to three years there will be a significant impact on the TRL of the current technology. Hence the request for voters to consider (1) what the TRL should be today, and then (2) what the TRL might be three years from now, assuming the overseas operation all go satisfactorily.

Relevance in the RPSEA Context: The RSPEA project calls for technical assessments for what it may take for HiLoad DP to be adapted for use in US GoM, with the scenarios likely there. Simultaneous with these determinations, it becomes important to have a reading on how this technology is “ready for prime time” in the views of the operators that may at some future date use the HiLoad DP as a metric for RPSEA and industry use.

Examples of Use of Technology Readiness Level (TRL)

Technology	Source of Technology	**T R L** (a)	Comments	
Direct Offloading Systems				
HiLoad DP today	Remora (c)	5-6	Under development for 12 years, prototype sea trials in 2011	
HiLoad DP 3 years from now	Remora	6-7	Expectation after successful operational progress under long term contract	
DP Shuttle tankers	Many	7	About 100 now operating worldwide, experience since 1980	
FPSOs (b)				Vote (b)
ShipShape FPSO	Many	7	About 165 now operating, FPSOs been in use for many years	41
Round FPSO	Sevan (c)	7	3 hulls in use as FPSOs, 2 hulls in use as MODUs	43
Round FPSO	SSP	2-3	None built or contracted, multiple model tests, many studies	9
Round FPSO	Nagan Srinivasan	1-2	None built or contracted, limited model tests and studies	7
				100

Notes

(a) The TRL scale used here is that adopted by RPSEA, consisting of seven (7) levels defined carefully for petroleum industry use. The TRL values given here are by Peter Lovie. The views of other SMEs obviously may be different.

(b) The TRLs estimated here for round FPSOs show some correlation with a vote by a conference audience on their willingness to accept these different designs (Round FPSO design shootout in Session IX at the Second Emerging FPSO Forum, Galveston, 26-27Sep12)

(c) The Sevan design of round FPSO was conceived in Norway - like HiLoad DP - and in about the same year. The first full scale production application was in 2007 at the *Piranema* developmeny in Brazil, compared to the possibility of full scale operations of HiLoad DP in 2013. Both are in the Floating Systems sector. A conclusive reason for the disparity in acceptance times is not known.

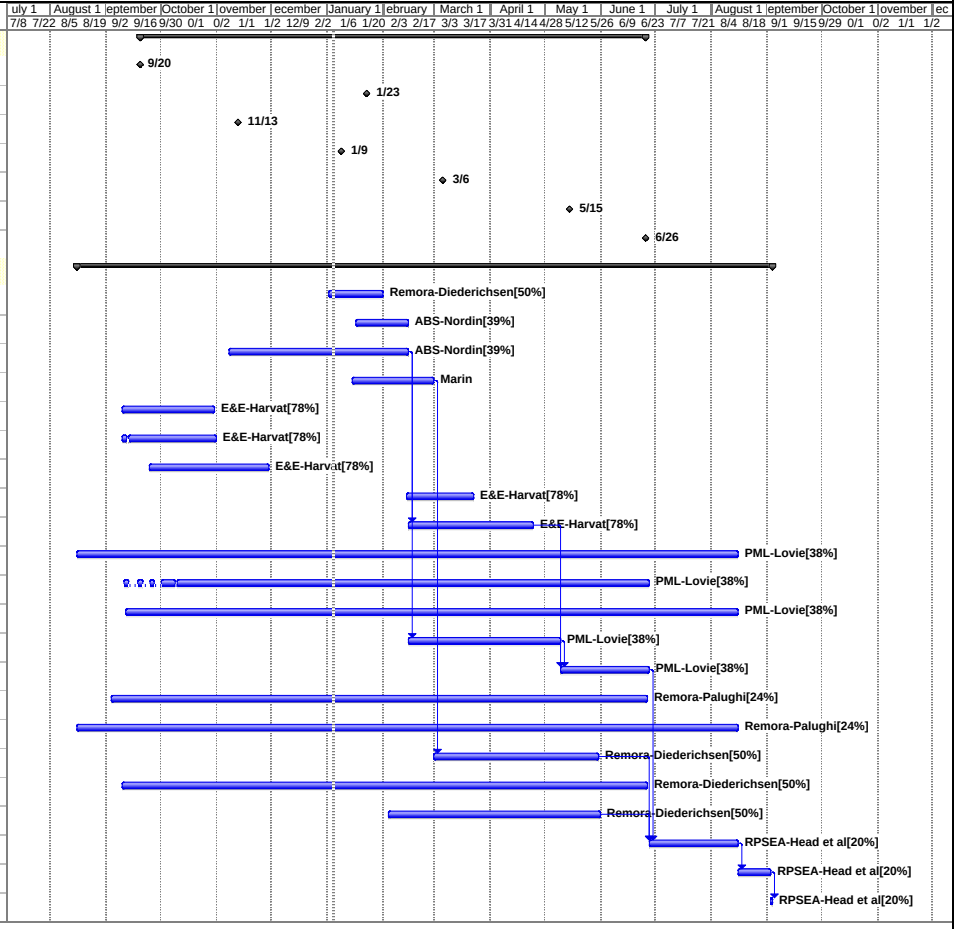
(d) For purposes of this RPSEA project, suggest discussion by operators and RPSEA on their frames of reference for the use of TRLs at the Second Working Group meeting on 9Jan13.

APPENDIX D:
TASKS 10-14 – SUPPORTING INFORMATION

D.2
Gantt Chart as of January 2013

Summary Gantt Chart for RPSEA contract 10121-4407-01

ID	Task Name	Duration	Start	Finish	Prede	Resource Names
	Milestone: Yes	**199 days**	**Thu 9/20/12**	**Wed 6/26/13**		
20	First TAC Meeting (RPSEA Task 3.0)	0 days	Thu 9/20/12	Thu 9/20/12		
21	Second TAC Meeting (RPSEA Task 3.0)	0 days	Wed 1/23/13	Wed 1/23/13		
22	First Working Group Meeting (RPSEA Task 3.0)	0 days	Tue 11/13/12	Tue 11/13/12		
23	Second Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 1/9/13	Wed 1/9/13		
24	Third Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 3/6/13	Wed 3/6/13		
25	Fourth Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 5/15/13	Wed 5/15/13		
26	Fifth Working Group Meeting (RPSEA Task 3.0)	0 days	Wed 6/26/13	Wed 6/26/13		
	Milestone: No	**274 days**	**Thu 8/16/12**	**Tue 9/3/13**		
1	1-4.1 Compilation of current technologies (RPSEA Tasks 2.0, 5.1)	22 days	Wed 1/2/13	Thu 1/31/13		Remora-Diederichsen[50%]
2	2-4.2 Risk assessment of the HiLoad concept (RPSEA Task 5.2)	21 days	Thu 1/17/13	Thu 2/14/13		ABS-Nordin[39%]
3	3-(4.3 & 4.5) Development of the basis of design for GoM (RPSEA 5.3)	71 days	Thu 11/8/12	Thu 2/14/13		ABS-Nordin[39%]
4	4-4.4 Technical evaluation of the maneuverability (RPSEA Task 5.4, 5.4)	33 days	Tue 1/15/13	Thu 2/28/13		Marin
5	5-5.1 Attachment system evaluation (RPSEA Task 6.1)	37 days	Mon 9/10/12	Tue 10/30/12		E&E-Harvat[78%]
6	6-5.2 Propulsion system evaluation (RPSEA Task 6.2)	37 days	Mon 9/10/12	Wed 10/31/12		E&E-Harvat[78%]
7	7-5.3 Air and water emissions (RPSEA Task 6.3)	48 days	Tue 9/25/12	Thu 11/29/12		E&E-Harvat[78%]
8	8-5.4 Hydrocarbon management (RPSEA Task 6.4)	27 days	Thu 2/14/13	Fri 3/22/13		E&E-Harvat[78%]
9	9-5.5 Spill response and countermeasure program (RPSEA Tasks 6.5 & 6.6)	49 days	Fri 2/15/13	Wed 4/24/13	3	E&E-Harvat[78%]
10	10-6.1 Communicate with Remora and subcontractors. Conduct weekly progress meeting/calls (RPSEA 1.0, 7.1)	261 days	Thu 8/16/12	Thu 8/15/13		PML-Lovie[38%]
11	11-3.2 Prepare presentation for TAC & WG meetings RPSEA Task 3.0, 7.2)	200 days	Mon 9/10/12	Thu 6/27/13		PML-Lovie[38%]
12	12-6 Contract operation, ongoing dealings with RPSEA (RPSEA 1.0, 4.0)	242 days	Wed 9/12/12	Thu 8/15/13		PML-Lovie[38%]
13	13-6.2 Agree on a configuration for Hi Load DP for a pipeline disruption & spill emergency (7.4)	60 days	Fri 2/15/13	Thu 5/9/13	3	PML-Lovie[38%]
14	14-6.3 Assemble info on GoM shuttle tankers, economics, comparisons (7.5)	35 days	Fri 5/10/13	Thu 6/27/13	13,9	PML-Lovie[38%]
15	15-7.1 Staging 2 TAC & 5 WG meetings (RPSEA Task 3.0)	212 days	Tue 9/4/12	Wed 6/26/13		Remora-Palughi[24%]
16	16 Record keeping, prepare invoicing, reporting RPSEA Task 8.2)	261 days	Thu 8/16/12	Thu 8/15/13		Remora-Palughi[24%]
17	17-8.1 Changes needed in prototype design to satisfy GoM operations (8.3)	65 days	Fri 3/1/13	Thu 5/30/13	4	Remora-Diederichsen[50%]
18	18-7.2 Prepare and participate in TAC & WG meetings (RPSEA Tasks 3.0, 8.4)	208 days?	Mon 9/10/12	Wed 6/26/13		Remora-Diederichsen[50%]
19	19-8.2 Indicative estimate GoM design of HiLoad DP, built in US (8.5)	85 days	Mon 2/4/13	Fri 5/31/13		Remora-Diederichsen[50%]
27	RPSEA review of draft Final Report	35 days	Fri 6/28/13	Thu 8/15/13	19,14,1	RPSEA-Head et al[20%]
28	RPSEA project acceptance and closeout process	12 days	Fri 8/16/13	Mon 9/2/13	27	RPSEA-Head et al[20%]
29	Project completion	1 day	Tue 9/3/13	Tue 9/3/13	28	RPSEA-Head et al[20%]



Project: Remora RPSEA RFP2010UDW004 4407 R2
Date: Fri 1/4/13

Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

APPENDIX D:
TASKS 10-14 – SUPPORTING INFORMATION

D.3
DOT 09 Paper No. 138

This document differs from the Conference CD as it corrects the typos on pages 4 and 17 and the 15 slide presentation is now attached

The Lower Tertiary Trend and the Oil Export Economic Prize

Peter Lovie

Devon Energy Corporation

ABSTRACT

Competition between traditional pipeline export in GOM and shuttle tanker newcomers has gone on intermittently in the deeper waters of the US Gulf of Mexico since 2001, but now the competition is heating up with the prospects of developments in the remote ultra deep waters of the Lower Tertiary trend. At these locations, the laws of economics and physics may now be at a tipping point, possibly tilting towards tankers.

This paper examines the factors at play in the economics, sensitivities to volumes and risks associated with commitments to use pipelines or shuttle tankers, based on studies underway for the last two years for a portfolio of Lower Tertiary prospects, and the impact the export solution may have on field development decisions and their timing.

Pipeline export and shuttle tanker export is surprisingly not an easy comparison, with issues of scalability, initial risk exposures, and, since 2005, the ability to resist harsher hurricane criteria. These Lower Tertiary prospects are also one of the most challenging anywhere to drill and produce, causing changes in the way the choice for export method may be made.

2005 changed the way export hazards are looked at with 'optionality' being a key word heard from both the pipeline and tanker factions after the multiple pipeline breaks and incapacitation of shore facilities by *Katrina* and *Rita*.

The very high pipeline investments that would be required for these developments also encourage consideration of tankers, particularly as the delivery of the US built tankers required under the Jones Act for this service can now be delivered in a timely manner by US yards. In the event of a field being a bust, operators are realizing that tankers' redeployability can mitigate the commercial risk on export service commitments.

Aggregation of large enough volumes to enable an economic pipeline is more difficult in the Lower Tertiary trend than discoveries made closer to shore and very difficult indeed for early production. For example, towards the end of 2007, two tankers were committed for use at *Cascade/Chinook* to service the Early Production System being employed there by Petrobras America and its partners (Devon and Total).

Finally, economic insights are suggested for each of the export modes with respect to the business and field conditions that would apply in developments in the Lower Tertiary trend, based on economic study data and the methodology developed here.

OBJECTIVES

This paper examines the Facility Options and the Transportation Options relevant to deciding on the method of oil export from locations in the Lower Tertiary Trend in the remote ultra deepwater regions of the US Gulf of Mexico, with the intent of demonstrating the size of the economic prize that can be at stake from weighing the differences between different export options, while employing reasonable judgment and realistic typical figures to gain insights on when and where each export option might be best suited.

Secondary objectives are those of identifying key cost components, creating a methodology for such comparisons and the opening up of a rational debate on what has often appeared as a murky

decision making process in the past, such that a clear basis can be arrived at for weighing all export options now available in the marketplace for a field development in the Lower Tertiary Trend.

PRACTICAL FACILITY AND EXPORT OPTIONS

Two practical facility choices are possible in these Lower Tertiary locations in generally 6,000 to 9,000 foot water depths: I) Facility without storage (typically a spar or a semisubmersible), or: II) Facility with storage (typically an FPSO). The choice of facility might be influenced by export options or it might have nothing to do with that and be driven by reservoir production considerations to enable maximum recovery.

Which ever of these two facility choices is made, multiple export options are now feasible:

I Facility without Storage – Export Options

1. Pipeline.
   Commonly will consist of an export riser and a length of new line to connect the facility to one of a number of choices of existing trunk lines that in turn connect to others and ultimately deliver production to sales points onshore, typically refinery destination(s). This is by far the most widely used and accepted export option in GoM.
2. FSO + Shuttle Tankers.
   Stabilized crude from the production facility is transferred to a Floating Storage Offloading (FSO) tanker moored about a mile distant from the production facility, from which shuttle tankers are loaded and transport the production to any one of a number of sales points that might be located around the Gulf of Mexico. The shuttle tankers would be equipped with a Bow Loading System (BLS), bow thrusters, a high lift rudder, a controllable pitch propeller (CPP) and may be dynamically positioned (DP), all to ensure a high degree of maneuverability and hence the maximum in safety while near an FSO, FPSO or other production facility.
3. HiLoad + Direct Loading of Conventional Tankers.

This is a new alternative to Option 2 employing a new concept, whereby two HiLoad systems are employed. Each HiLoad unit is a manned floating vessel that looks somewhat like a fork lift truck and is dynamically positioned with a transfer hose from the facility. One HiLoad unit continuously loads a conventional tanker at its midship manifold as the oil is produced from the facility. When the first tanker is full, it leaves to deliver its cargo to its destination. Meantime a second HiLoad system has latched on to a second tanker and as the first tanker completes loading, production is transferred to the second without interruption. The number of tankers employed needs to be at least two (2) and there might easily be three or four tankers as volumes dictate. The idea of Direct Loading has been successfully employed at the *Heidrun* TLP in the Norwegian North Sea for many years, pioneered by Conoco and now operated by StatoilHydro. Direct loading usually is cost effective with large volumes of production, e.g. the system at *Heidrun* started with around 225,000 bopd.

II Facility <u>with</u> Storage – Export Options

4. Shuttle Tankers.

   Widely used in North Sea for 20+ years, their first use in GoM will start at the Petrobras operated *Cascade/Chinook* development in mid 2010 (50:50 Petrobras:Devon at *Cascade* and 67:33 Petrobras:Total at *Chinook*).

5. HiLoad + Conventional Tankers.

   Only one HiLoad is used and its function is to allow the use of conventional tankers instead of shuttle tankers with their added CAPEX for their special features mentioned above. The rationale for this option is thus an economic one: can the investment in a HiLoad system offset the added costs of the special features on two or three shuttle tankers that might be employed for a field development? Use of conventional tankers has the additional commercial advantage that they may be more available and may enter or leave export service more readily as production levels change. This might be a serious advantage since the Jones Act fleet is relatively small and the fleet of Jones Act shuttle tankers is much smaller still. The HiLoad system thus offers a new alternative to traditional export configurations for FSOs and FPSOs.

Consideration of these five (5) options, their economics, risks and benefits are the basis for the analyses and discussion in this paper.

DESIGN BASIS

Regardless of past history for offshore production in the deep waters of GoM, some design factors individually or in combination with others will be different for future field developments in the Lower Tertiary Trend. Key among these are:-

Water Depth: 6,000-9,000 ft. is always challenging!

Crude Quality: May be heavier and more sour than previous developments in GoM, e.g. much lower grade oil than the well known West Texas Intermediate (WTI) marker, lower than Mars blend from deepwater locations, and more like Arab Heavy imports.

Gas Production: GORs are much lower than common in GoM, often around 250 scf/bbl, meaning that associated gas volumes are low and a 6- or 8-inch diameter gas export line may become a common, easy to lay practical solution. There is even talk of gas imports being needed as later in field life there may not be enough gas for fuel on the production facility. For purposes of the oil export analyses, this gas export solution is assumed in all cases.

Field Life: Longer than typical GoM, might be 30-50 years or about double typical GoM development field lives.

Well Depths: At around 30,000 ft. through sometimes miles of salt to reach reservoirs that are at pressures of more than 20,000 psi and often at high temperatures, wells take several months to drill and complete, rigs often work at close to their design limits, and investments per well are at levels rarely seen anywhere. Well costs can drive the choice of facility like never before, often outweighing otherwise compelling export economics.

Remoteness: Helicopter trips to shore bases of 250 miles are not uncommon. Distances from facility to sales point for the crude export can be similar or more.

Reservoirs: Limited experience in production from these reservoir formations may mean uncertainties on the expected volumes to be transported, imposing

higher risks in front end investment in export systems and increasing need for flexibility in the export system for adjusting to future actual volumes.

Aggregation: The huge CAPEX for pipelines and the slow development of "critical mass" volumes can combine to make traditional hub and spoke field development systems with pipeline export much more difficult commercially than with traditional patterns in GoM.

Combining the effects of these design factors, it is not difficult to see why arriving at the sanction stage for these mega projects is an exhausting and time consuming process! And that is not to say anything about the $billions of investment and number of years for the execution phase. Once first oil is achieved, the ramp up to full production may take several years in contrast to the faster buildup hitherto, so the build in early revenue potential for export systems may be more economically difficult than before.

In contrast to the demanding nature of the facilities that may be employed to produce oil and gas from the Lower Tertiary Trend, the technologies of export systems are relatively straightforward. Laying 24-inch or even 28-inch pipe in 7,000 foot water depths over the mountainous seabed often found in Walker Ridge and Keathley Canyon will certainly be demanding, but contractors maintain they are able to tackle it, repairs methods have been developed and flow assurance matters are being investigated. The HiLoad system cited as an option with two of the tanker solutions is in the prototype stage after years of development and testing. But close precedents do exist in each of these instances.

The technologies employed in tanker-based export systems are well proven. What is challenging in the US market is the availability of Jones Act tankers and their cost. Until the last year or two, their delivery from US shipyards was not very reliable. That has greatly improved in 2007-2008. The building of tankers in at US shipyards at roughly three times the cost of their Far East counterparts, plus US crews at roughly double international fleet rates, all makes economics difficult. The Jones Act fleet of tankers of the size that might be used for export is small (around 30) and so newbuilds are likely requirements for GoM export service. There are few owners and

operators of Jones Act tonnage. Hence the challenge with tanker based solutions for GoM tends to be more commercial than technical.

We therefore take it for our discussion here that the technologies employed in these five export options are all doable to the extent where any one of them could indeed be sanctioned for construction and operation if an operator chose to do so.

Further, given the cycle time from sanction to first oil of say three to four years, it can be assumed that any one of these five export solutions could be contracted for at sanction time and delivered ready for first oil. Obviously the contracting and managing of whatever export solution is ultimately chosen will still take some doing, but for purposes of the examination of these five options, it is assumed that all can be compared.

CREATING A BASIS FOR COMPARISONS

In order to get away from generalities and arrive at some representative scenarios that provide insights on the choice of export options and to test the influence of volumes, a choice was made of representative production profiles and field developments as follows:

Table 1: Summary of Field Models

Reservoir	Oil Rate, max. bopd	Recoverables, mmbbl	
		1st 16 years	years 17-30
Medium	76,411	268.0	64.8
Large	166,948	703.7	179.5

In case any thought arises about how similar these figures might be to any specific project, these figures are from actual generic investigations about a year ago and do not represent specific prospects.

It became evident that the first half of the field's production had about 80% of the total recoverable and since after 15-16 years it was more and more uncertain how realistic any projections might be, the choice was made for simplicity to make comparisons on the first half – about 16 years of production.

Cost buildups for an ultra deep water pipeline system depend greatly on the location of the field development, the seabed profile, the distance to a tie-in point and available and economic pipeline networks back to shore. For the analyses here a simple assumption was made that the line would be 130 miles long from facility to tie-in point and the ruling factor was an installed cost of $700million for a 24-inch diameter pipeline to serve the "Large" reservoir, and $460million for an 18-inch line to serve the "Medium" reservoir. Obviously these figures will change considerably depending on specific projects, but some representative set of numbers needed to be chosen. More figures are shown in Tables 6 and 7.

The buildup of costs for tanker systems first required an idea of the production that can be transported per tanker and then the number of tankers to serve the volumes for "Large" and "Medium" reservoirs. Simultaneous with that determination, the choice of size of tanker is needed! Draft limitations in GoM ports imply a maximum shuttle tanker capacity of about 550,000 bbl. However there is little crude transportation business as a backup trade for that size of tanker in the Jones Act trade - which led to adoption of the smaller product tanker (often called Handymax) size of about 320,000 bbl capacity, which would have better back up trade possibilities. Many calculations on trip times, weather and port delays and range of destinations led to an average production capacity estimate of 55,000 bopd per tanker. Calculations also showed the smaller tanker size did not detract much from economies of scale.

The number of tankers needed was determined from the production profile for the field development, chartering in tankers in increments of 55,000 bopd as needed for production volumes, e.g. the maximum production rate of 166,948 bopd for the Large reservoir would require three tankers, and when production was at or below 110,000 bopd, then two tankers would be needed and so on. Inevitably there would be surplus capacity in some years, e.g.

130,000 bopd requires 2.27 tankers - so three tankers are provided and there is unused export capacity of about 40,000 bopd.

It was assumed at this early stage in market development in GoM that for these tanker calculations there was no sharing of tankers between one development and another. Tanker operations would be dedicated and so tanker efficiency would be very high, e.g. 95-98%. It is very likely that the sharing of tankers between different future developments in GoM would occur but that was ignored here since there was no guarantee of that potential to spread costs.

For both pipeline and tanker solutions it was next assumed that all aspects of these are obtained in the marketplace on an open competitive contract basis, i.e. none of the equipment is producer built and owned. The argument here is part consistency and part philosophy – some oil companies may or may not wish to invest in and own pipelines or tankers, preferring to sticking to their core businesses, and often a third party transportation contractor is better placed to manage capacity from multiple developments than an operator. The opportunity still exists for an oil company to enter either the pipeline or tanker business based on the economics and risks of the situation. At this point we are not there yet and simply projecting how the economics and risks stack up.

For the pipeline tie in to existing GoM networks, assumptions were made of typical returns of an investment to justify a contractor's decision to build the new segment.

For tanker solutions, estimates were made for time chartering tankers for different periods to suit the reservoir production profile, e.g. one tanker for all of its 25-35 year life in the Jones Act market, a second for perhaps a half of that and a third for maybe a third of its life. In this example the second and third tankers would then be employed later in their lives in the product trade or continue as a shuttle tanker in a different development. Port and fuel costs were then added in as follows:-

Table 2: Tanker Cost Buildup

Total tanker costs, dedicated, no sharing

Term,	TC, $/day	Fuel & Port	Total tanker cost,

years		Charges, est., $/day	$/day
	TC	FP	TC+FP
16	91,372	22,000	113,372
12 to 15	93,126	22,000	115,126
10 to 11	100,000	22,000	122,000
2 to 9	126,457	22,000	148,457

These figures are estimated from a number of sources believed reasonable and competitive in the marketplace at the time of writing (November 2008). They apply for DP2 shuttle tankers with BLS and 320,000 bbl capacity. If conventional product size (i.e. Handymax) tankers are used in conjunction with a HiLoad system, then the time charter rates would go down to be about 70% of the figures above but the port and fuel charges would remain about the same.

The cost of the HiLoad system for these tanker sizes, including all fuel, is taken to be $50,000/day in the comparisons here.

Where a storage vessel is employed, the size of the FSO is taken to be Suezmax, i.e. 1,000,000 bbl capacity. This provides about six days of storage for the highest production rates considered with the “Large” reservoir and much more for the “Medium” reservoir. A case might be made for using an even larger storage tanker since the incremental cost for using a VLCC of twice the capacity is relatively modest and that would allow capacity for tie-ins in future. A number of studies have been made with million barrel capacities for FSOs and FPSOs, perhaps related to that size originally being chosen in the studies behind the Environmental Impact Statement (EIS) that led to the regulatory approval of FPSOs and shuttle tankers for GoM in 2001.

A number of other issues may need to be assessed in the comparisons and can affect the risks and economics:-

Table 3: Other Significant Issues

Issue	Significance

Guaranteed future access throughout field life	Determination that it is feasible to have a pipeline contract for the life of field with no risk of curtailment of capacity by pipeline owner or any regulator at some future date.
Sensitivities to changes in volumes as production proceeds	Oilfields rarely produce exactly as the production profiles here predict! Changes are likely, up or down, and forward or backward in time. Means of dealing with this are desired.
Other key risks, commercial considerations identified by contractors	Examples may be delivery schedules for tankers, long lead item commitments, other risks not thought of.

Major Interruption Risk is a factor that came into focus after the hurricanes of 2005 when production was shut down for many months in many locations throughout the GoM. It is a risk taken here to be an extreme version of "reliability optionality" which is defined here as the ability for an export system to deal with the more routine shut-ins that may occur every year after hurricanes, named storms, process upsets and the like. The long field lives of these Lower Tertiary developments mean a greater exposure than before to extreme events, which coupled with the new realization that deepwater production really may be shut in for months at a time after major hurricanes, raises the specter of interruptions in revenue being far longer than experienced before 2005. This risk is difficult to quantify and might be particularly serious in today's business climate where underwriters are now reluctant - or outright refusing - to offer the business interruption coverage that they offered pre-2005.

If pipeline systems can be designed to have multiple paths ashore, perhaps this risk can be mitigated. For the analyses here we chose a pipeline reliability optionality of 2 (a pipeline with two different routes to shore destinations) and a tanker reliability optionality of 10 (believed practical based on a typical choice of 10 Gulf coast ports). The risk of interruption is obviously much less with tankers as they can always travel to different ports around the GoM and even if 8

or 9 of these GoM ports were shut in, tankers could still deliver to the remaining one or two that were open or to (say) the Philadelphia refiners, if necessary.

Looking now at the economic factors in the comparison of export systems, there are the easy to compute Transportation Components which are based on equipment costs – the "Firm" ones – and there are the Market Components that are much more difficult but nevertheless do exist and may change during over the years, described here as "Fuzzy":

Table 4: Transportation and Market Components: The Firm and The Fuzzy

The fuzzy components can easily add up to be as large as the firm components!

Factor	Economic Projection	Explanation
Transportation Tariff	Firm: generally set at transportation contract time	Total transportation cost from production flange on platform cellar deck to the refinery's storage tank. Needs to allow for ALL export system components, e.g. multiple segments (new and existing) for pipeline delivery, export pumps and riser or hose system costs on the producing platform, platform space and services contributions
Quality Bank	Fuzzy: may change with time over LOF	Loss of value when one grade of crude is commingled with a common stream in a pipeline. A poorer grade means a deduct and then the higher quality stream leaving the pipeline means an adder. However the deduct is usually seriously more than the adder, meaning a net cost element in the overall transportation economics!
Reliability Optionality	Fuzzy: management's best calculation	The value of being able to redirect production from one destination to another in the event of hurricane or other damage. Well known examples would be the BP Texas City Refinery explosion - or the damage suffered in various pipelines and shore stations after the *Katrina* and *Rita* hurricanes in 2005
Market Optionality	Fuzzy: can vary with time	The value to a producer of being able to play the market in selling its production, whether by pipelines to multiple sales points or via tankers that can be redirected at will to different ports for sale.

Engineers understand the Firm but the Fuzzy components drive them nuts! Nevertheless the Fuzzy are commercial realities, cannot be ignored and are susceptible to market projections by independent consultants. Put another way, the Firm components tend to be follow a tight probability curve while the Fuzzy follow a much flatter bell curve with the location of P50 being more difficult to find than with the Firm.

The comparison of export systems gets further muddied by the fact that there are components on a production facility that are related to export and yet which are normally included in the CAPEX estimates for the facility. Thus to rigorously make a true "apples and apples" comparison of everything in each export option, these export related components should be allowed for. Here is an estimate of what they might be:-

Table 5: Export System Requirements in a Facility

Typical facility production profile	Typical max. production rate, bopd	Export mode	Pump requirements	Export line requirements	MAOP, psi	CAPEX $million (1) (2)
Large	167,000	Tanker	Intermittent: 320,000 bbl over 10 hours (32,000 bph), e.g. 10 hours up, 30 hours down, repeat cycle	Catenary hose & reel, about 400 dft. Long x 18 in. dia.	225	AA?
		Pipeline	Continuous, about 8,000 bph	SCR, facility down to PLET on sea floor, 24 in.	4,500	BB?
Medium	75,000	Tanker	Intermittent: 320,000 bbl over 10 hours, e.g. 10 hours up, 70 hours down, repeat cycle	Catenary hose & reel, about 400 ft. Long x 18 in. dia.	225	CC?

	Pipeline	Continuous, about 4,000 bph	SCR, facility down to PLET on sea floor, 18 in.	4,500	DD?

Notes: (i) CAPEX information AAA-DDD needs to include some contribution for prime movers to power the system, plus some contribution for the space and weight carrying capabilities in the facility.

(ii) CAPEX numbers would be translated later to equivalent tariffs in the LT Export comparison tables.

All the factors are now identified to allow economic projections for the five export options and how they are affected by the volumes from the Medium and Large reservoirs.

For simplicity a deterministic calculation is used here to show the directions that emerge. Serious projections for a specific field with all the uncertainties involved obviously would benefit from probabilistic projections. Attempting first to arrive at realistic ranges for each factor would require some serious judgment and experience!

ECONOMIC COMPARISONS

The next two tables summarize the effect of each of the five export options for the “Large” Reservoir and then the same for “Medium” reservoir where economies of scale are less favorable.

Table 6: Comparison of $/bbl Economics for Different Export Options for "Large Reservoir"

703.7 mmbbl recovery in first 16 years Maximum rate of 166,948 bopd

Cost Component		Facility without storage			Facility with Storage		Notes
	Export Option:	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT	
a	New construction tariffs. Tanker figures include time charter as applicable, fuel &	2.58	3.70	3.55	2.47	2.37	(i)

	port costs:						
b	Tariff on existing deepwater pipelines, booster platforms, pipelines to beach:	1.00	0.00	0.00	0.00	0.00	(ii)
c	Equivalent of export system CAPEX in facility:	0.40	0.13	0.13	0.13	0.13	(iii)
d	Quality bank in existing pipelines:	0.80	0.00	0.00	0.00	0.00	(iv)
e	Optionality, no. of destinations:	2 ?	10	10	10	10	(v)
f	Upside on marketing to wider range of destinations	0.00	-0.50	-0.50	-0.50	-0.50	(vi)
g	Guaranteed future access throughout field life	TBD	yes	yes	yes	yes	(vii)
h	Premium for prompt payment on delivery	0.00	-0.30	-0.30	-0.30	-0.30	(viii)
	TOTALS, $/bbl:	4.78	3.03	2.88	1.80	1.70	
	RATIOS:	1.00	0.63	0.60	0.38	0.36	
	SIZE OF THE PRIZE, $BILLION:	0.00	1.23	1.34	2.10	2.17	(ix)
	Discounted at 10%, 16 years, $BILLION:	*0.00*	*0.60*	*0.65*	*1.01*	*1.05*	

Notes:

(i) CAPEX on dedicated new segment pipeline may vary according to location of the LT prospects(!!!) Assume 24 in. line, $700million, 16 yrs, 13.5% on capital, pipeline operation, pigging and inspection (no repair) for about 6% of CAPEX. On FSO, take $317million installed with transfer line, 16 years, 11% and $30,000/day OPEX

(ii) Estimates from various sources.

(iii) Allowances for export pumps, prime mover and space contribution, SCRs or hoses as appropriate.

(iv) Controversial. May vary with characteristics of other production over life of field. Median value chosen.

(v) May include multiple sales point terminals at each port. Minimum optionality of 2 to counter "2005 all over again"

(vi) No GoM market comparable yet: estimate here is from North Sea experience.

(vii) Ability to use full capacity of each pipeline segment, i.e. no possibility of cutbacks from future intervention by an operator or regulator.

(viii) Payment on tanker cargoes in 10 days v. typical 30 days with pipeline contracts.

(ix) "Size of the Prize" equals the $/bbl cost for the highest cost option less the cost of option being compared, multiplied by the volume (i.e. total recoverable) over the 16 year comparison period. It is not discounted.

The Size of the Prize above demonstrates why this paper was written: with $billions at stake, a serious examination of different export options can be well worth the effort and it may even become a factor driving the choice of facility.

Table 7 examines the same comparison to test the effects of smaller volumes on each of the five export options:-

Table 7: Comparison of $/bbl Economics for Different Export Options for "Medium Reservoir"

268.0 mmbbl recovery in first 16 years Maximum rate of 76,411 bopd

Cost Component		Facility without storage			Facility with Storage		Notes
	Export Option:	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT	
a	New construction tariffs. Tanker figures include time charter as applicable, fuel & port costs:	4.54	6.51	6.69	3.28	3.60	(i)
b	Tariff on existing deepwater pipelines, booster platforms, pipelines to beach:	1.00	0.00	0.00	0.00	0.00	(ii)
c	Equivalent of export system CAPEX in facility:	0.40	0.13	0.13	0.13	0.13	(iii)
d	Quality bank in existing pipelines:	0.80	0.00	0.00	0.00	0.00	(iv)
e	Optionality, no. of destinations:	2 ?	10	10	10	10	(v)
f	Upside on marketing to wider range of destinations	0.00	-0.50	-0.50	-0.50	-0.50	(vi)
g	Guaranteed future access throughout field life	TBD	yes	yes	yes	yes	(vii)
h	Premium for prompt payment on delivery	0.00	-0.30	-0.30	-0.30	-0.30	(viii)

TOTALS: RATIOS:	6.74 1.00	5.84 0.87	6.02 0.89	2.61 0.39	2.93 0.43	
SIZE OF THE PRIZE, $BILLION: *Discounted at 10%, 16 years, $BILLION:*	0.00 *0.00*	0.90 *0.44*	0.72 *0.35*	4.13 *2.00*	3.81 *1.84*	(ix)

Notes:

(i) CAPEX on dedicated new segment pipeline may vary according to location of the LT prospects(!!!) Assume 18 in. line, $460million, 16 yrs, 13.5% on capital, pipeline operation, pigging and inspection (no repair) for about 6% of CAPEX. On FSO, take $317million installed with transfer line, 16 years, 11% and $30,000/day OPEX

(ii) Estimates from various sources.

(iii) Allowances for export pumps, prime mover and space contribution, SCRs or hoses as appropriate.

(iv) Controversial. May vary with characteristics of other production over life of field. Median value chosen.

(v) May include multiple sales point terminals at each port. Minimum optionality of 2 to counter "2005 all over again"

(vi) No GoM market comparable yet: estimate here is from North Sea experience.

(vii) Ability to use full capacity of each pipeline segment, i.e. no possibility of cutbacks from future intervention by an operator or regulator.

(viii) Payment on tanker cargoes in 10 days v. typical 30 days with pipeline contracts.

(ix) "Size of the Prize" equals the $/bbl cost for the highest cost option less the cost of option being compared, multiplied by the volume (i.e. total recoverable) over the 16 year comparison period. It is not discounted.

Some patterns emerge on the scalability of the five export options for differing volumes, shown in Tables 8 and 9:

Table 8: Summary: Effect of Reservoir Size on Overall Export Economics, $/bbl With Both "Firm" and the "Fuzzy" Cost Components, i.e. all of a-h in Table 6 or 7.

-	Facility without storage			Facility with Storage	
Export Option:	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT
Medium Reservoir: 268.0 mmbbl recoverable over 16 years, maximum 76,411 bopd	6.74	5.84	6.02	2.61	2.93
Large Reservoir: 703.7 mmbbl	4.78	3.03	2.88	1.80	1.70

recoverable over 16 years, maximum 166,948 bopd					

The "Firm" cost components are relatively straightforward and engineers can compute them with the debate being about design and costs for physical equipment.

However the "Fuzzy" cost components are much more controversial and depend on market behaviors today and in the future. Table 9 is a duplicate of Table 8 but with the Fuzzy cost components eliminated to see the effects of decision making based only on equipment costs:-

Table 9: Summary: Effect of Reservoir Size on Overall Export Economics, $/bbl, Only the "Firm" Cost Components, i.e. only a-c in Tables 6 and 7

	Facility without storage			Facility with Storage	
Export Option:	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT
Medium Reservoir: 268.0 mmbbl recoverable over 16 years, maximum 76,411 bopd	5.94	6.64	6.82	3.41	3.73
Large Reservoir: 703.7 mmbbl recoverable over 16 years, maximum 166,948 bopd	3.98	3.83	3.68	2.60	2.50

CONCLUSIONS

It became clear in this work that careful use of cost parameters and the choice of field development size and location could both make for significant differences in outcomes over more approximate work.

A strict engineering and facilities perspective was not adequate for the analyses – a broader commercial and marketing vision was needed too.

More specific conclusions are made as follows:-

I Facility <u>without</u> storage

1 At the lower volume the pipeline was the highest cost option, but only by 6-10%. The difference was bigger with higher volumes, growing to 36-40% over the two tanker based options.

2 The FSO plus shuttle tanker option and the HiLoad option were very close. The new Hiload system showed a slight advantage but its economic benefit may be within the accuracy of these estimates and more investigation would be desirable on a live project.

3 Eliminating the "Fuzzy", i.e. market components, changed the picture: at lower volumes the pipeline was then 12-16% below the other two options. At the higher volumes the pipeline was still the higher and the other two slightly lower (4-8%).

4 For decision making a closer idea of the Fuzzy components on any specific development is really needed. These factors remain controversial and can be subject to business judgment and even interpretation to suit agendas.

5 At lower volumes the comparisons are close and would need significant investigation and proposals in a live project.

6 From the scenarios here we take it pretty much as a draw in choosing between the HiLoad plus conventional tankers versus the option of a traditional FSO plus shuttle tankers.

7 We would recommend pursuing all three export options in some detail before being able to settle on any one of the three for a particular project.

This document differs from the Conference CD as it corrects the typos on pages 4 and 17 and the 15 slide presentation is now attached

II Facility with storage

8 The major conclusion for the volumes and economic scenarios here is that a facility with storage can enjoy an export cost of around 44-52% of that of a facility without storage. Even if one ignores every one of the Fuzzy cost components, the advantage is less but still serious: in the range of about 55-67% of the without storage option. The lower end of these ranges corresponded to estimates for the larger volume.

9 It is difficult to see a compelling case for deciding between the use of the higher cost shuttle tankers and the lower cost conventional tankers combined with a HiLoad system. The larger volume scenario favored the HiLoad by a few percent and lower the lower volume scenario favored shuttle tankers by a few percent. In the real world more detailed assessments and competitive bidding would be required to resolve the choice for a specific requirement.

Acknowledgement and Disclaimer

The author wishes to thank Devon Energy Corporation for providing the time to prepare this work and in approving its presentation at DOT.

The figures used here and the opinions expressed are these of the author, are believed to be representative of the factors at play but do not imply any corporate position by Devon Energy Corporation. However Devon does endorse the principles put forward here of arriving at some form of careful technical and economic assessment of all export options to enable a prudent business choice on export mode.

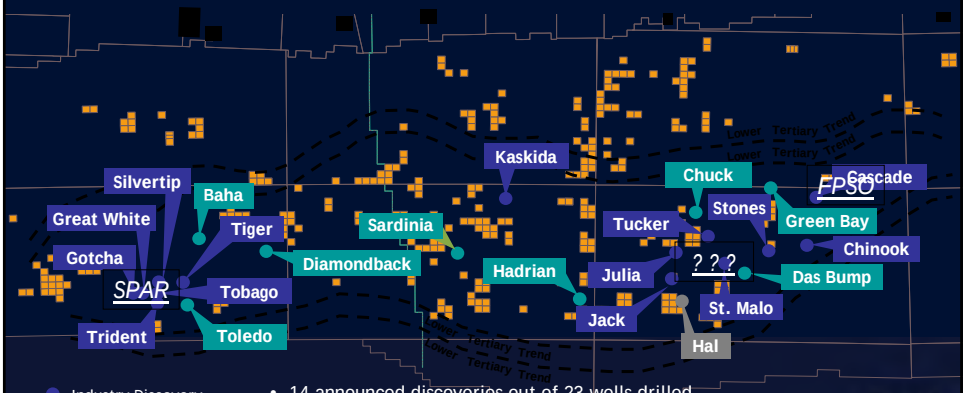
The Lower Tertiary Trend and the Oil Export Economic Prize

Peter Lovie
Devon Energy Corporation

devon

Lower Tertiary Trend - Encouraging Results

Committed to date: one spar, one FPSO
Sanctioned in next twelve months: one more?



- Industry Discovery
- Industry Non-Commercial
- Results Unannounced

- 14 announced discoveries out of 23 wells drilled
- Trend for Alaminos Canyon, Keathley Canyon and Walker Ridge only
- Additional penetrations along trend to the northeast

NYSE: DVN

The Independent's Perspective
Seeking the Right Business Proposition

Devon an E&P company, i.e. no refineries to feed;

Devon owns neither an offshore pipeline company nor a shipping company;

Concept selection process still slow and deliberate, with both Devon and its partners;

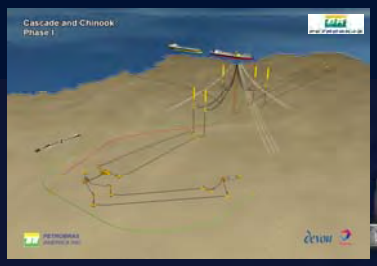
Every incentive to seek out most cost efficient transportation solution for Devon's prospective developments in the Lower Tertiary!

The Two Linked & Ongoing Debates
Facility and Transportation

1. Facility – two main options

(a) Semisubmersible or Spar without storage

(b) FPSO with storage + Disconnectable



NYSE: DVN

“The Coming Shoot-out at the LT Corral”
The Oil Export Economic Prize

2. Transportation – five main options

(a) Pipeline: Long history of success in GoM;

(b) Shuttle Tankers: First use at *Cascade/Chinook* in 2010, common in North Sea;

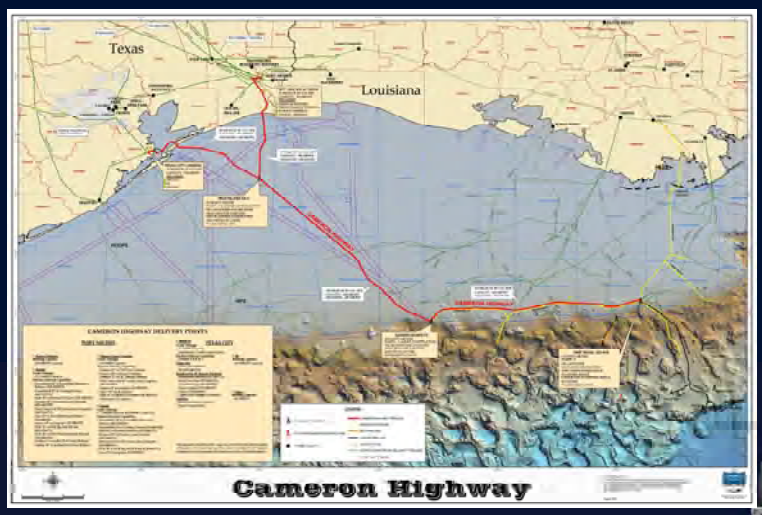
(c) FSO + Shuttle Tankers: Common elsewhere in world, studied for GoM;

(d) One Hiload + Conventional Tankers for FPSO: only new part is HiLoad prototype;

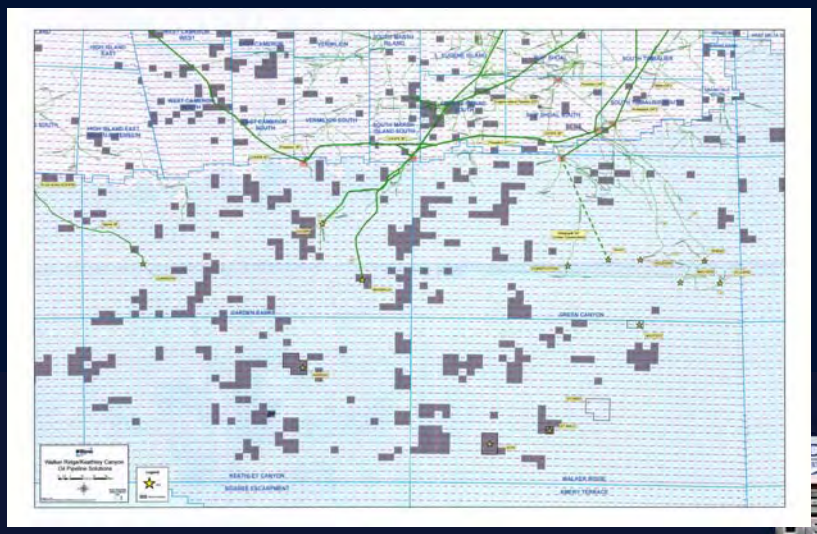
(e) Two HiLoads + conventional tankers for Semi/Spar.

The Pipeline Network
Shore to the Shelf to Deep Water

Ultimately over Mountainous Terrain



Lower Tertiary Discoveries in WR & KC
Existing Pipelines Come Close to Some



7 of 15

Storage: Suezmax, VLCC or ULCC?

1,000,000 to 3,000,000 bbl capacity,
double hull, moored, disconnectable

8 of 15

Shuttle Tankers

Jones Act compliant:
- US built,
- 75+% US owned,
- US crewed

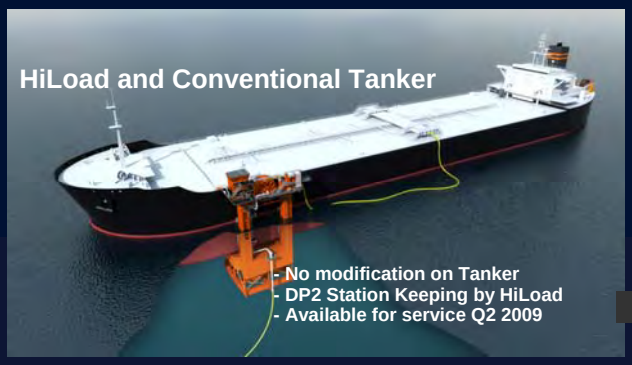
320,000 bbl capacity

Bow Loading System

Added maneuverability for maximum safety:
- Thrusters, DP2

HiLoad & Conventional Tankers

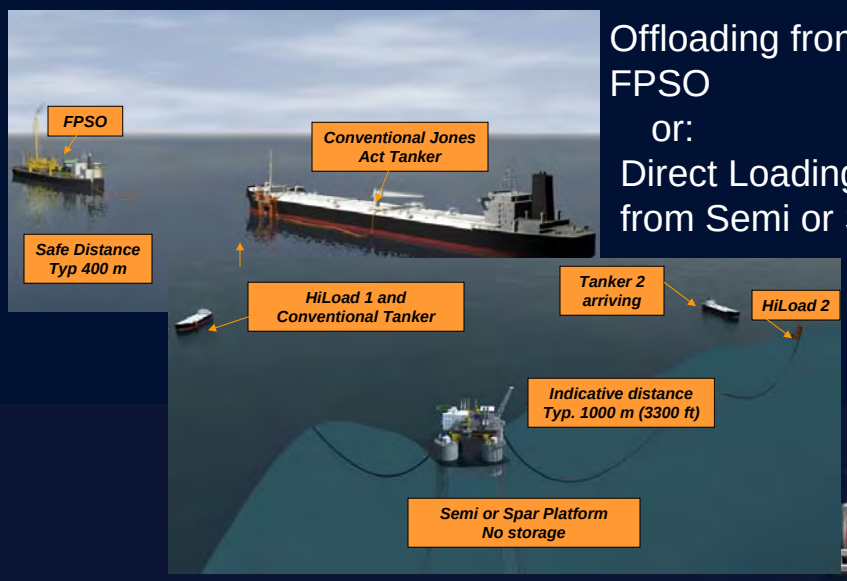
System to offer DP2 maneuverability & safety



Prototype for VLCCs

HiLoad DP No 1

HiLoad + Conventional Tankers:
Systems for Loading from FPSO, Semi or Spar



Offloading from FPSO
or:
Direct Loading from Semi or Spar

Been Good Reasons Why No Shuttle Tankers in GoM

a. Wells often needed intervention, non-FPSO field development solutions available;
b. FPSOs if theoretically workable not the optimum solution so far;
c. Extensive existing efficient network of export infrastructure (pipelines);
d. Shuttle tankers expensive in US GOM: Jones Act means CAPEX about 3x intl, OPEX about 2 x intl, delivery times been questionable;
e. “Economics, Economics, Economics”.

Indicative Comparison of Export Options

Table 8: Summary: Effect of Reservoir Size on Overall Export Economics, $/bbl
With Both "Firm" and the "Fuzzy" Cost Components, i.e. all of a-h in Table 6 or 7.

Export Option:	Facility without storage			Facility with Storage	
	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT
Medium Reservoir: 268.0 mmbbl recoverable over 16 years, maximum 76,411 bopd	6.74	5.84	6.02	2.61	2.93
Large Reservoir: 703.7 mmbbl recoverable over 16 years, maximum 166,948 bopd	4.78	3.03	2.88	1.80	1.70

Table 9: Summary: Effect of Reservoir Size on Overall Export Economics, $/bbl,
Only the "Firm" Cost Components, i.e. only a-c in Tables 6 and 7

Export Option:	Facility without storage			Facility with Storage	
	1 Pipeline	2 FSO+ST	3 HiLoad+DLCT	4 ST	5 HiLoad+CT
Medium Reservoir: 268.0 mmbbl recoverable over 16 years, maximum 76,411 bopd	5.94	6.64	6.82	3.41	3.73
Large Reservoir: 703.7 mmbbl recoverable over 16 years, maximum	3.98	3.83	3.68	2.60	2.50

Conclusions

a. Combination of visions needed in assessing export choices: facilities engineering + broad commercial;

b. Facilities without storage – no compelling winner (3 export choices);

c. Same for facilities with storage (2 export choices);

d. But BIG difference between export economics for: with storage and without: as much as 0.5:1.0

e. Much more information in the manuscript.

Thank You

Questions?

Peter Lovie
Devon Energy Corporation
peter.lovie@dvn.com
713 265 6489

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.1
General Arrangement Drawings

E.1 GENERAL ARRANGEMENT DRAWINGS

General arrangement drawings of the HiLoad DP GoM with minimum 45-foot draft are proprietary. Please contact Remora for more information.

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.2
Structural Drawings

E.2 STRUCTURAL DRAWINGS, HILOAD DP GOM

Structural drawings of the HiLoad DP GoM with minimum 45-foot draft are proprietary. Please contact Remora for more information.

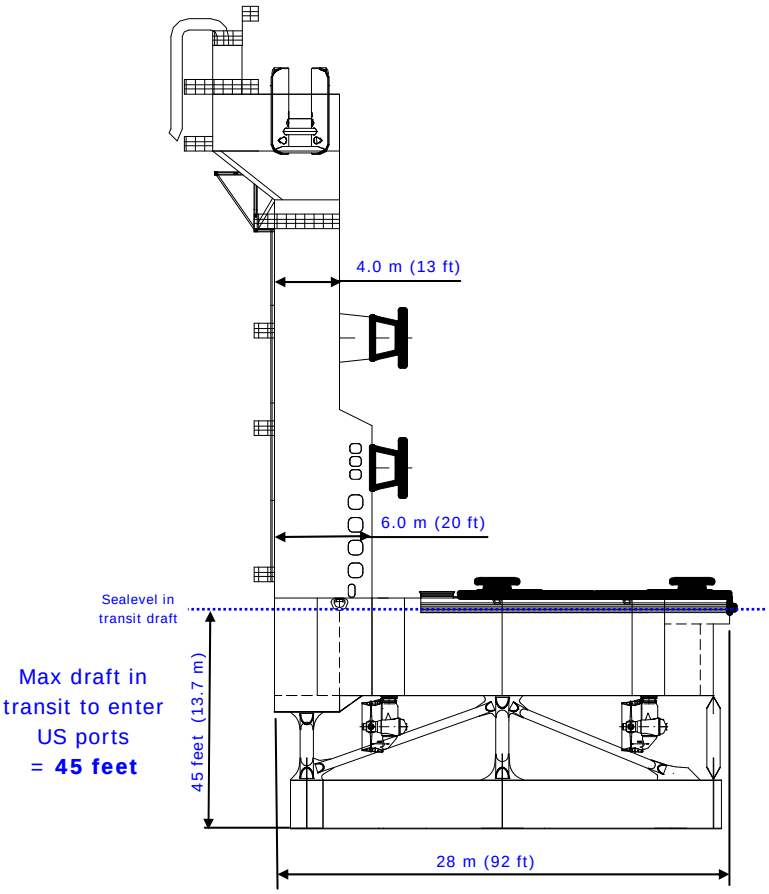
APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

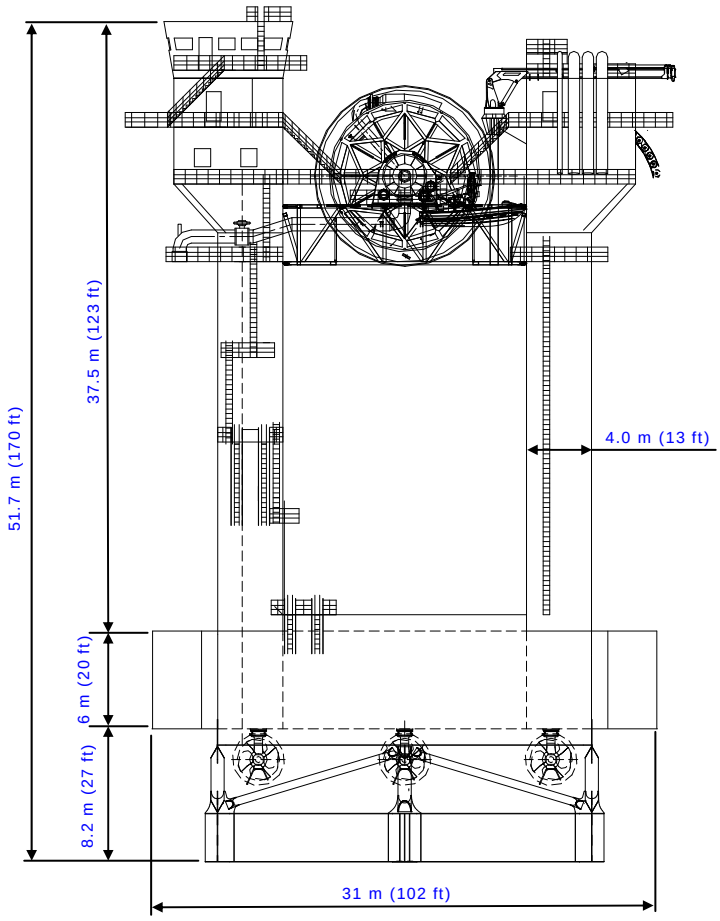
E.3
HiLoad DP GoM Technical Fact Sheet

Technical Fact Sheet

HiLoad® DP GoM - 45 ft

Providing DP station keeping for Handymax and Aframax vessels in Gulf of Mexico operating conditions.





REMORA

Rev 02
11. August 2013

HiLoad® DP GoM

Main Characteristics

Length overall:	28 m (92 ft)
Breadth moulded:	31 m (102 ft)
Overall height:	43.5 m+keel 8.2 m (143+27 ft)
Lightship weight:	4950 t
Gross tonnage:	1650 t
Net tonnage:	490 t
Displacement:	6100 t at max. draft
Bollard pull:	125 ton

Registration

Type:	HiLoad DP Offshore Loading Vessel, Remora design
Owner:	Remora
Classification:	DnV 1A1 Mobile Offshore Support Unit with additional notation: DYNPOS-AUTR

Performance

Fuel:	10 m^3/d in typical operation
Consumption:	0.5 m^3/d in standby
Loading rate:	6600 m^3/h (41.500 Bbl/h)
Max tanker size:	Aframax (115.000 dwt)

Areas of Operation

– Offshore loading terminal
– Import terminal
– Stationkeeping/DP2 system for offshore vessels
– Tug/propulsion applications

Accommodation

– Fully air-conditioned
– 4 beds (4 crew rest + 4 crew on duty)
- Galley
– Seating for 12 persons

Propulsion – Machinery

Main Engines:	3 x 2,800 kW diesel engines CAT C175/60, 1800 rpm or MTU 20V4000P83, 1800 rpm
Shaft Generators:	3 x 550 kW, Leroy
Harbour Generator:	1 x 315 kW CAT 3406C diesel engine, 1800 rpm, w/Leroy shaft generator
Thrusters:	3 x Wärtsilä CS300 (Lips) Azimuth Thrusters (3 x 48.4 ton)
Crane:	1 x 1.0 t at 20 m (5.0 t at 6 m) GMC Sormec marine crane

Capacities and Pumps

Fuel tanks:	191 m^3
Potable water:	160 m^3
Water mist:	1.5 m^3
Lube oil thrusters:	3.5 m^3
Lube oil main engine:	3,0 m^3
Sludge tanks:	3 x 1.9 m^3
Oily bilge tank:	6.0 m^3
Ballast tanks:	1,869 m^3
Ballast pumps:	2 x 3750 m^3/h at 3.3 barg Hamworthy CAD500 deballast pumps
Firewater pumps:	2 x 100 m^3/h at 12 barg
Friction capacity:	3250 ton at 14 m draft

Electronics

Navigation
– radar
– 3 x gyrocompass
– 2 x DGPS

Communication
1 x VHF Telemetry System, GMDSS based
1 x UHF for internal communication
1 x PA/GA DNV compliant
Onboard computer network system with e-mail

Dynamic Positioning System (DP 2)

Complies with DYNPOS AUTR (Class 2)

Reference System:	1 x DGPS, 1 x DARPS, 1 x Artemis, 1 x Fan Beam, 1 x RaDius
Sensors:	3 x gyrocompass, 2x wind sensor

Special Equipment

Loading Hose:	1 off Trelleborg Reeline 20” 120m w/16” tanker rail hose
Loading Hose Reel:	1 off Aker Kværner Pusnes hose reel Ø8m
Oil Spill Detection System:	1 x Flow Monitoring System 2 x Infrared Cameras for Oil Detection
Fire fighting:	Essential rooms: water mist extinguishing system 2 off water/ foam monitors for Hose Reel generally coverage by Hydrants
Life saving:	3 off liferafts, 1 launched by davit, 12 persons capacity each
Fenders:	8 off soft landing fenders similar to those used on quay side
Attachment system:	Rubber friction fenders divided into 6 compartments with heavy duty seals
Tanker fender:	4 off collapsible impact fenders

Head Office:
Remora, P.O. Box 57, 4001 Stavanger, NORWAY
Visiting Address: Kongsgata 10, 4005 Stavanger, NORWAY
Tel: +47 51 85 80 20 · Fax: +47 51 85 80 29

Houston Office:
Remora Inc. 800 Town and Country Blvd, Suite 300,
Houston, TX 77024, USA
Tel: +1 281 598 2460

E-mail: mail@remoratech.com • Web: www.remoratech.com

REMORA

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.4
Oil Spill Detection Systems

E.4 OIL SPILL DETECTION SYSTEMS

The HiLoad DP GoM can be equipped with two independent systems for monitoring of a possible oil spill during the offloading operations. Consideration of such systems has been identified as a recommendation in the HAZID carried out for the RPSEA project (Task 2).

It should be noted that no other offloading system for conventional tankers has such systems implemented today. These systems will mitigate considerably the risk for any major oil spill and environmental consequences during offloading in the GoM compared to traditional offloading operations carried out worldwide. Remora is therefore considering implementing such a system as a standard on any future HiLoad DP vessels.

The two independent systems are:

- **System 1:** Measuring of oil flow between the FPSO/platform and the HiLoad DP GoM
- **System 2:** Monitoring an oil spill by infrared cameras

System 1: Oil Spill Detection – Flow Monitoring

A flow meter will be installed on the HiLoad DP GoM to monitor the received amount of oil from the FPSO/platform. The FPSO/platform will monitor the oil flow sent to the tanker by the crude oil sales meter and any inconsistency or discrepancy in the amount of oil received on the HiLoad DP GoM will trigger an alarm on the HiLoad DP GoM. The officer on watch on the HiLoad DP GoM can then request the FPSO/platform to activate shutdowns of export pumps at the FPSO/platform. Relevant communication is handled by the HiLoad DP GoM integrated telemetry system which is tied into the FPSO/platform's control system. Figure E.4-1 shows the typical arrangement of the OSDS for the HiLoad DP GoM.

System 2: Oil Spill Detection– Infrared Cameras

The HiLoad DP GoM will be equipped with a second OSDS based on infrared camera monitoring system. Remora has selected the SECurus IR camera system including control system and processing algorithms from the supplier Aptomar in Norway. This company has delivered similar systems to a number of installations worldwide.

One camera will monitor the area between the FPSO/platform and the HiLoad DP GoM and one camera will monitor the loading hose from the HiLoad DP GoM to the tanker. The officer on watch will monitor the system on the HiLoad DP GoM. The system will include an image-

processing algorithm for day and night detection of oil spills, by collecting digitized sea surface images from the vessel's radar and thereby estimating the directional wave spectra and the sea surface current on site. Areas possibly containing oil will be identified and an alarm will be initiated so the officer on watch on the HiLoad DP GoM can act accordingly and immediately request shutdowns of export pumps at the FPSO/platform.

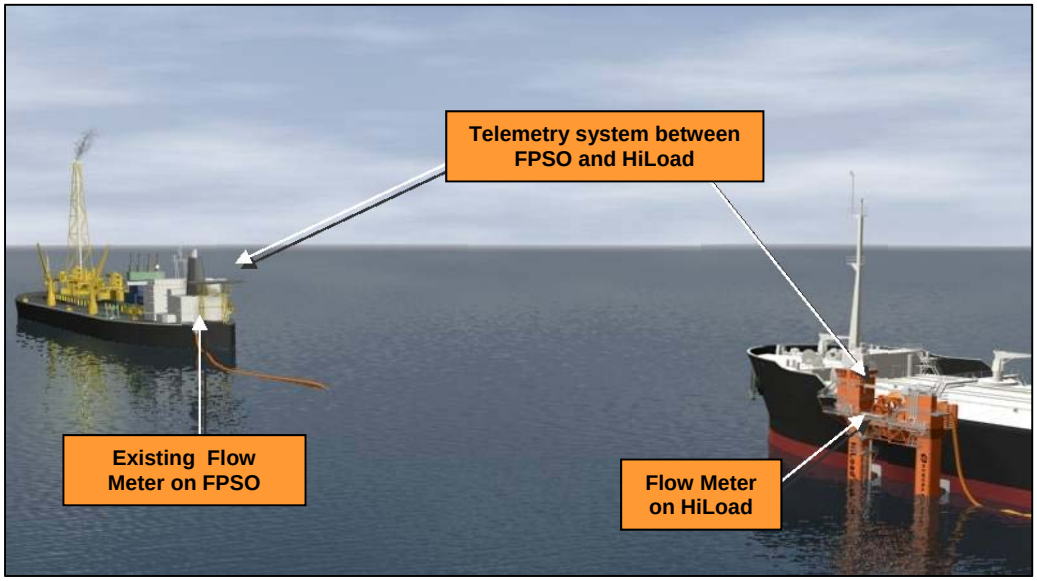


Figure E.4-1: Oil Spill Detection System (OSDS) – Flow Monitoring

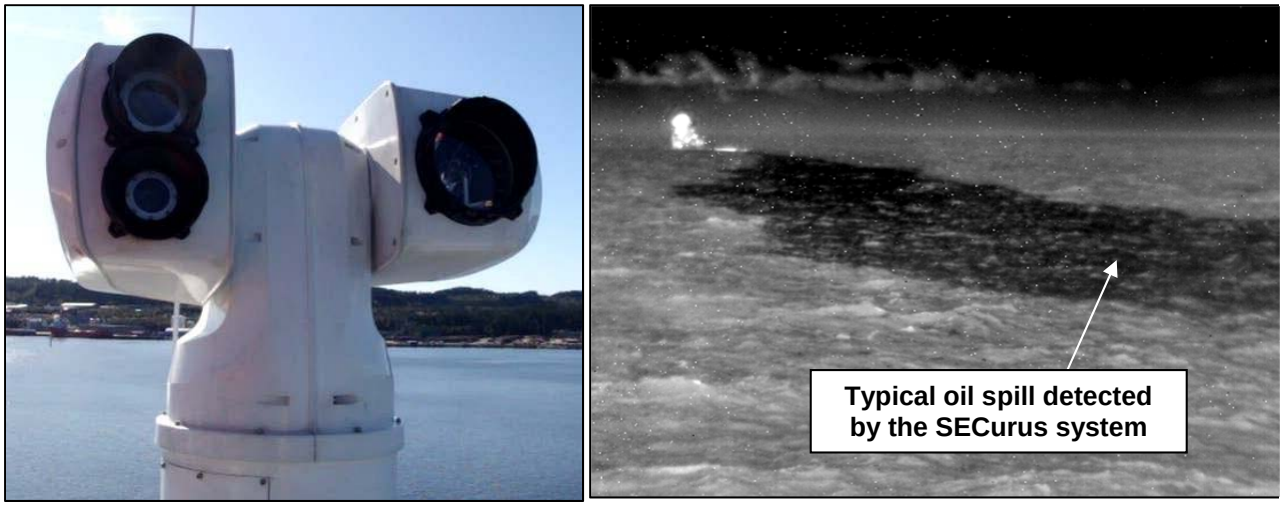


Figure ES.4-2: SECurus IR Camera (left) and oil spill example (right)

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.5
Parking of the HiLoad DP GoM on the Seabed - Assessment

E.5 PARKING OF THE HILOAD DP GOM ON THE SEABED - ASSESSMENT

During the RPSEA Working Project Group 4 (WPG 4) meeting, the question of the feasibility of parking the HiLoad DP GoM on the seabed, for instance in the Houston Ship Channel, was discussed. Remora, in close cooperation with Marin (Task 4 contractor), has conducted a preliminary assessment of such a solution.

To carry out an evaluation of the feasibility to park the HiLoad DP GoM on the seabed, one will need to know a lot about the seabed and possibly prepare it well. The maximum sea state may also dictate operational limitations for vessels parked with such a method. Frequent maintenance to the seabed might also be necessary.

Assuming the conditions make this scenario possible, the loads for the parked HiLoad DP GoM due to a hurricane passage can be analysed:

- The HiLoad DP GoM should not move, so the friction force with the seabed always needs to be larger than the horizontal forces due to wind, waves, and current. This friction force depends on the soil conditions and on the weight of the structure on the seabed. The more ballast the better. This can be tested in a wave basin with model scale equivalent soil conditions. In order to test this, Marin would cooperate with Deltares, a hydraulic institute in the Netherlands, on this subject. Such a test program also could be used to evaluate the loads and set the weather limits for the docking operation.

- To ensure the HiLoad DP GoM does not “tip over” in high wind, wave, and current loads, the moment induced by combined wind, wave drift, and current forces around any tipping point should not exceed the moment induced by the mass. For the mean wind moment, the elevation of the centre of the gravity does not matter in this case.

  When suction with the seabed is ignored, the combined wind, wave drift, and current force should not exceed the weight (kN) x horizontal distance/vertical distance. This horizontal distance is the horizontal distance from the centre of weight to the side of the structure and vertical distance is the distance from the keel to the pressure point of the environmental loads.

  Due to the dimensions of the HiLoad the horizontal distance/vertical distance factor will be much smaller than 1, so the weight of the structure (mass-buoyancy)

* gravity needs to be much larger than the combined wind, wave drift and current force in all cases. Note this also needs to hold after a storm surge.

"Tipping moment" analysis has been carried out and is further described below.

- The suction force should not exceed the amount of ballast weight added to the HiLoad. If it does, it is not possible to float up the HiLoad DP GoM (in a controlled way).

- In most coastal conditions, the storm surge will arrive with high currents before the wind and waves develop. A significant storm surge is needed to ensure the waves do not damage the top of the HiLoad DP GoM base, but it should not be so high as to pose a risk to the airgap with the hose reel, cabin, and bridge on top of the HiLoad DP GoM. It is difficult to forecast storm surge, so wave impacts on the top of the HiLoad DP GoM may have to be evaluated. This can be done with Model Basin tests in the shallow water basin. Run up and airgap also need to be evaluated, but the parked case should not be more limited than the free sailing case, unless the draft with storm surge exceeds the normal sailing draft.

In summary, the "tipping moment" can be determined by simple calculations, assuming no suction force on the seabed and should include an assessment of the largest possible ballast weight. A summary of such calculations is given on the next pages.

The other loads strongly depend on the soil conditions and on the exact details of the storm (amount of storm surge, current velocities, and wave heights) which can vary wildly between different storms.

For wave slamming loads (either on the base or due to airgap problems), model tests are needed. Model tests are also the only reliable way to assess the impact loading of the HiLoad on the seabed during parking. With some assumptions on the storm details, estimates of the wind and current loads, and friction models for different soil conditions, the soil holding capacity can be calculated for different conditions. This analysis also should consider soil scouring in high current conditions.

Further analysis or model testing of "seabed parking" could carried out in a future phase of the HiLoad DP GoM project as further agreed with operators.

“Tipping moment” Calculations

A simplified calculation has been done to evaluate if this solution seems feasible. A calculation based on drag coefficients from the wind tunnel test and regular formulas for drag has been performed. To get a more accurate model, a hydrodynamic panel analysis will have been performed with software like WAMIT, SACS, or similar.

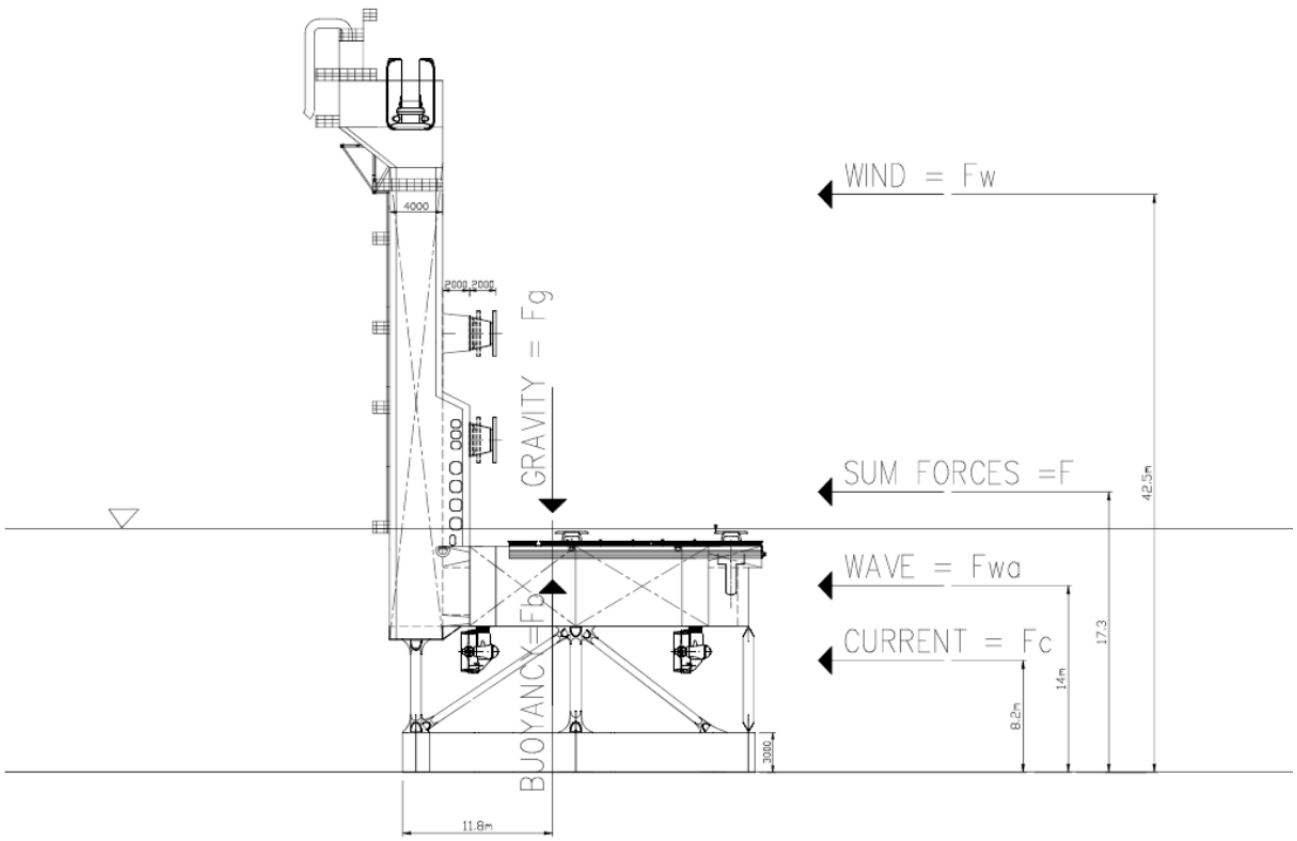


Figure E.5-1: HiLoad Parked on Seabed – Summary of Forces

Figure E.5-1 shows the three forces acting as an overturning moment on the structure. Not considering soil conditions, only gravity force is acting as a righting moment. For the HiLoad to keep standing during a storm, Fg should be higher than F. For calculation of forces, the following formula is used: $F = 0.5 * Cd * \rho * v^2 * A$. Cd is found to be 0.85 for the submerged hull and 1.0 for the structure above the waterline based on speed tests and wind tunnel tests.

Wind

To be conservative, a 100-year wind for the Central GoM was assumed: 1-hour mean wind speed (at 10 meters height) = 49 meters per second (m/s). The wind exposed area is calculated to be 579 square meters (m^2). This gives a force, Fw, of 708 KN with a centre 42.5 meters above seabed.

Current

The assumed high current due to the "channel effect" of the Houston Ship Channel was 6.0 knots. The current exposed area is determined to be 364.4 m^2. This gives a force, Fc, of 1523 KN with a centre 8.2 meters above the seabed.

Wave Drift

- Used "rule" of thumb of 5 kN/m exposed length of structure (conservative)
- Significant wave height squared. Assume Hs = 3.0 meters
- Exposed length of structure: 27.0 meters
- Wave drift load = 5 x 3.02 x 27 0 = Fwa = 1215 kN with a centre 14 meters above the seabed.

Wave force is assumed to act mainly on the pontoon since the effect of the waves decreases with the depth.

The overturning moment, Mo, is calculated to be

1523 kN* 8.2m	=	12488,6 kNm
1215kN*14m	=	17010 kNm
708kN*42,5m	=	30090 kNm
Total Mo	**=**	**59589 kNm**

The righting moment, Mr, is given by the mass of the HiLoad (Fg) minus the buoyancy (Fb) times the distance from the longitudinal center of gravity to the tipping point, which in this case will be the aft end of the keel. For this condition this is 11.8 meters.

Since it is essential to get the HiLoad as heavy as possible, the weight and longitudinal center of gravity is taken from the load condition for draft of 31 meters. In this condition, all ballast tanks are filled and the HiLoad has it maximum weight of 5,604 tons. The hydrostatic table gives a value for displacement of 4,600 ton for a condition where the pontoon is fully submerged. This leaves a vertical force of approximately 1,000 tons to counteract the overturning moment.

Mr = (56040-46000)kN* 11.8m = 118472 kNm
Mr / Mo = 118472/59589 = **2**

The righting moment seems to be larger on an order of **two** compared to the overturning moment, so the reasonable conclusion is that this is a feasible solution for the HiLoad from a "tipping moment" point of view. It is recommended, however, to carry out more sophisticated analysis and optimize the ballast condition for this purpose. Furthermore, the seabed condition, friction force, wave slamming loads, etc, will have to be analysed in a future project phase to conclude the feasibility of this solution.

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.6
Weight Control and Inclination Test

E.6 WEIGHT CONTROL AND INCLINATION TEST

In connection with the construction process of the HiLoad DP1, these values were adjusted and corrected according to weighing of sections, material take off at the yard, and weight certificates from the supplier. The given weight can therefore be taken as a very accurate number. The table below is a comparison done in connection with the inclination test showing the expected and real weight. The difference was only 1.3 tons (0.05%).

Table E.6-1: Weight Comparison from Inclination Test, HiLoad DP1

ITEM	Description	WEIGHT	LCG	TCG	VCG	L-MOM	T-MOM	V-MOM
		tonnes	m	m	m			
1	**HiLoad DP LSW from test 15 March 2009 (Ref.doc.:003832-VAH-J-RA-00001-0001 rev**	**3993,66**	**13,33**	**0,01**	**0,22**	**53219,5**	**35,9**	**870,6**
	Remove expected weights to be added to LSW after 15 March -09	-22,01	3,37	6,10	28,62	-74,1	-134,3	-630,0
	Remove expected fluids incl. In LSW 15 March -09	-69,10	14,21	-0,23	3,14	-982,0	15,9	-217,0
	Add fluids incl. In LSW Febr. -10	68,59	14,23	-0,47	3,17	976,3	-32,4	217,2
	Permanent items added as per weight log Febr. -10	315,11	8,73	-0,42	-0,80	2749,4	-130,9	-252,6
	Permanent items removed as per weight log Febr. -10	-6,42	14,81	0,45	4,57	-95,1	-2,9	-29,3
Sum 1	**Expected lightship weight incl. fixed ballast and loading hose**	**4279,82**	**13,04**	**-0,06**	**-0,01**	**55793,9**	**-248,7**	**-41,1**
2	Add temporary items onboard Febr. -10	0,00	0,00	0,00	0,00	0,0	0,0	0,0
	Add total fluids in hull tanks Febr. -10	10,35	7,00	3,13	4,76	72,5	32,4	49,3
	Add total fluids in small tanks Febr. -10	28,53	13,79	-1,09	4,49	393,3	-31,2	128,0
Sum 2	**Expected displacement at check in Feb. -10**	**4318,70**	**13,03**	**-0,06**	**0,03**	**56259,7**	**-247,6**	**136,2**
3	Fixed ballast plates onboard during inclining test 15 March -09	1536,77	16,75	0,15	-10,26	25746,8	237,0	-15764,1
	Aded fixed ballast plates as per weight log Febr. -10	206,40	9,53	0,16	-9,58	1966,3	32,2	-1976,7
Sum 3	Total fixed ballast plates	1743,17	15,90	0,15	-10,18	27713,1	269,2	-17740,8
Sum 4	**Expected lightship weight excl. fixed ballast plates**	**2575,53**	**11,08**	**-0,20**	**6,94**	**28546,66**	**-516,80**	**17877,02**
5	**Real displacement from check Febr. -10**	**4320,00**	**13,65**	**0,00**	**0,50**	**58959,4**	**0,0**	**2160,0**
	Remove variable loads onboard, not incl. In LSW	-36,11	2,00	-3,11	39,04	-72,2	112,3	-1409,7
	Remove temporary items onboard	0,00	0,00	0,00	0,00	0,0	0,0	0,0
	Total fluids onboard, not incl. In LSW(to be removed)	-39,00	11,50	0,00	5,00	-448,5	0,0	-195,0
Sum 5	**Real lightship weight incl. fixed ballast plates at check in Feb. -10**	**4244,89**	**13,77**	**0,03**	**0,13**	**58438,6**	**112,3**	**555,3**
6	Total fixed ballast plates onboard at check in Feb. -10	1743,17	15,90	0,15	-10,18	27713,1	269,2	-17740,8
Sum 6	**Revised lightship weight excl. fixed ballast plates**	**2501,72**	**12,28**	**-0,06**	**7,31**	**30725,57**	**-156,89**	**18296,11**
Sum 7	Difference between real and expected displacement Febr. -10	1,30	2078,00	190,59	1557,80	2699,63	247,61	2023,82

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.7
Statement from DNV – Operation Area for HiLoad DP

E.7 STATEMENT FROM DNV – OPERATION AREA FOR HILOAD DP

DNV has issued the statement below related to the 3-nautical-mile restriction defined for the prototype, HiLoad DP1, including what additional equipment that will be required to allow operation without restriction inside the GoM.

E-mail from DNV to Remora, August 14, 2013

Hei Knut-Erik,

We have taken a look into the newbuilding documentation to try to find where the 3 nautical miles limitation originates from. As far as we can see, the limitation is not required by class or flag, but has been introduced by Remora as reason for justifying several exemptions from MODU code etc. The limitation has been used as reason for several exemption applications for areas like:

Echo sound
Life raft launching
Lifeboat
Magnetic compass
Navigation lights
Pilot transfer arrangement
Radio equipment
Rescue boat
Sound reception system

In order to expand the operational area to more than 3 nautical miles, or to lift the limitation altogether, these exemptions will have to be re-considered. Some of the exemptions given for Hiload DP no 1 may need further mitigating arrangements and others would need to comply with the requirements.

Service restrictions such as within the GoM may be given and possible exemptions will have to be agreed with flag and for operation in the GoM also BSSE and USCG.

Best regards
for Det Norske Veritas AS
Thomas Trømborg

Principal Surveyor / Naval Architect
GCSNO782 Offshore Units in Operation
Mobile: +47 995 88 168

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.8
Memorandum – Stability of HiLoad DP

E.8 MEMORANDUM – STABILITY OF HILOAD DP

Some of the operators participating in the RPSEA project provided some questions and comments related to the stability calculations for the HiLoad DP vessel. Remora provided their reply to all the questions and comments summarized in a memorandum distributed in the Working Project Group 5 (WPG 5) meeting on August 14, 2013. A copy of this memorandum is included in this appendix.

MEMO - CLARIFICATION OF COMMENTS

STABILITY - HiLoad DP GoM

RPSEA Project No. 10121-4407-01

Date: August 29th 2013
Revision: 02
Prepared by: Knut-Erik Johansen/Svein B. Hellesmark

BACKGROUND

The background for this MEMO is comments and questions raised during the RPSEA project related to the stability of the HiLoad DP GoM vessel during various operating conditions.

This MEMO does include the specific comments or questions and Remora's reply accordingly.

OVERVIEW – STABILITY PRICIPLE AND RULES – HiLoad DP

The HiLoad is not a conventional vessel like a ship or a semisubmersible. The shape and stability principle can not be directly compared to other floating units without taking the specialty of the HiLoad into account. During design and development of the vessel there has therefore been an extensive communication and discussion with the class to clarify the requirements and intentions with the rules and find means to fulfill these requirements with the HiLoad design.

While a ship shaped vessel have its stability by the inertia of the water plane area of the hull and a column stabilized unit have it by the water plane are of the columns and the distance between them, HiLoad is more like a submarine with the COG always below the COB. The small water plane area of the two towers does not contribute to the stability in upright position at all. This is the reason for the big keel structure and the large amount of fixed ballast. When the draft is increased, the COB increases faster than the COG due to the location and shape of the ballast tanks. This means that the stability margin gets larger at larger drafts.

HiLoad have no storage compartments, tanks or deck space for any significant cargo beyond the regular content of the tanks so there is no risk of increasing the COG to dangerous level by mistake. Please note the elevations mentioned in this MEMO are for HiLoad DP No1 and will also be applicable for HiLoad DP GoM unless other are specifically mentioned.

The rules used for the HiLoad is therefore a combination of rules for ships, rules for loading buoys and rules for column stabilized units with basis in the MODU code and DNV stability requirements.
The Operation of HiLoad is divided in three sections as is common also for Column stabilized units.

- Surface position. This is a service condition only used in short periods under full control at shore or offshore in calm weather. In this position the HiLoad has a large water plane area and very high stability margins.

- Draft between 6 and 12 m (17 and 23 m taking the keel into account for HiLoad DP No. 1 and 14.2 and 20.2 m for HiLoad DP GoM) is an intermediate condition between surface position and operation condition. As for a Semisubmersible this is the most critical condition for HiLoad and it should therefore not be operated in this conditions. HiLoad have significant stability margins also at these drafts, but it will not fulfill the requirement of maximum 25 degree heel in worst case of flooding. A reason for operation in this area could be if you wanted to connect to a tanker with less than 6 m draft. Connection to so small vessels is not taken into account in the design. Otherwise there is no reason to stay in this condition.
- Draft between 12 and 31 m (between 20.2 and 39.2 m taking the keel into account for HiLoad DP GoM) is the operational condition of the HiLoad. In this condition the intact stability margin is sufficient and the damage stability criteria are fulfilled for all scenarios.

The 25 degree criterion for the HiLoad is connected to one compartment damage philosophy applied on the HiLoad. In the two first conditions the HiLoad is in a service mode with large margins or in a transient condition for some few minutes. The risk for collision or flooding in this transient condition is assumed to be very small. In normal operation only the two towers are above the water. The pontoon is 9-15 m below the surface and protected by the keel structure below and by filled ballast tanks in the top.

The only damage scenario in this case is therefore flooding by leakage in one compartment in the pontoon or a collision with another vessel in one of the towers (see figure 4, Damage condition). If a collision with a much larger ship should lead to damage and flooding of both towers the HiLoad will not survive, but that is the same risk for any relatively small vessels in case of a collision with a much larger vessel.

A collision in one of the towers will lead to flooding of that compartment and may also lead to flooding of the second compartment in that tower. That compartment is however a ballast tank already partly filled with water dependent on the draft. One of the damage case evaluated is flooding of the tower compartment at maximum draft 31 m (28.2 m for HiLoad DP GoM). In this condition the ballast tank in the tower is full and a flooding of the remaining compartment in the tower is found to be acceptable and within the requirements.

All compartments in the pontoon have water tight integrity so progressive flooding there is no case. This is the reason why DNV concluded that a one compartment damage philosophy is sufficient for the HiLoad and thereby the 25 degree limits on the heel. All safety equipment on HiLoad is documented to be operative at 25 degree heel/trim.

It should also be noted that while regular vessels have a down flooding angle and a second intercept of the heeling moment curve at a relatively small angle (7 degree larger than first intercept, usually when the deck edge reach the water), the HiLoad righting moment angle continues upwards and have no second intercept with the heeling moment curve up to 60 degree. This means that the HiLoad theoretically <u>can not capsize</u>.

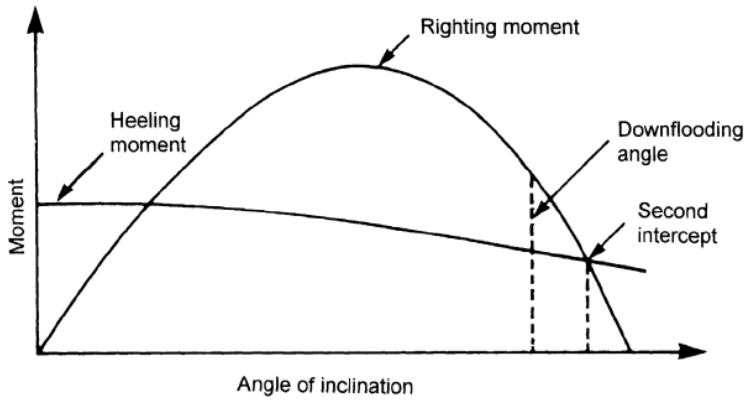


Figure 1 - Heeling and righting moment curves for a regular ship.

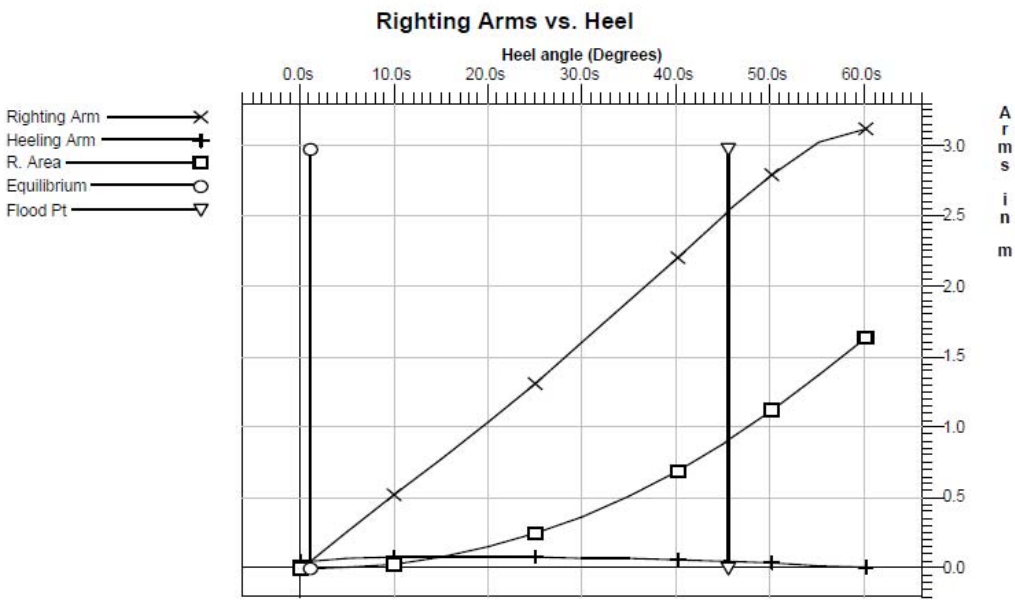


Figure 2 - Typical heeling and righting moment curves for HiLoad

It should also be taken into account that HiLoad DP No. 1 is a prototype design based on several assumptions in the start of the design. The complete stability philosophy of the HiLoad is very simple and based on COB and COG. These parameters can easily be changed in an adjusted design for GoM by increasing the weight and position of the fixed ballast.

Below is also a comparison between DNV offshore rules and MODU code. They both have 25 degree as limit for a one compartment damage scenario and damage penetration in a limited area below and above the waterline. Collision with the pontoon in operation is therefore not a case.

Heading	Criteria	DNV-OS E403 Of April 2004	Modu –code 1989, 1991 and 1994amend
Intact Stability	Static angle of heel Min Angle of intercept Minimum GZ = 0,5 * GM-min* sin θ Minimum GM Area under curves (A+B) = k * (B+C) Areas A, B, & C are evaluated to Angle of first Down flooding Wind speed	NA NA Always positive NA k = 1,3 Less than 1.st flooding Less than 2.nd intercept 100 / 70 knots	NA NA Always positive NA k = 1,3 Less than 1.st flooding Less than 2.nd intercept 100 / 70 knots
Damage Stability Criteria	Static angle of heel due to wind and/or damage Area under curves (A + B) = k * (B + C) Area A, B & C are evaluated from/ to Minimum GZ = 0,5 * GM-min* sin θ Angle of first down flooding Wind speed Damage penetration Watertight integrity Weather tight integrity	17 deg w/ 50 kn.wind 25 deg. 1-comp-dam. without wind k = 1,0 1 intercept + 7 deg GZ = 2 * WHL NA Always positive Less 2. intercept 50 knots 3m*3m*1,5m 5 m above and 3 m below 1st. intecept 1st. intercept + 4 m.	17 deg w/ 50 kn. wind 25 deg. 1-comp-dam. without wind. k = 1,0 1 intercept + 7 deg GZ = 2 * WHL NA Always positive 1.intercept + 7 deg. or less 2. intercept 50 knots 3m*3m*1,5m, 5m above and 3 m below 1st. intercept 1st. intercept + 4 m.

Figure 3 - Rule comparison

COMMENST – RPSEA PRINCIPAL INVESTIGATOR

Comment:

Simultaneous with the port entry issue, the GoM version must have adequate intact and damaged stability for all expected drafts for fundamental safety - which is not. That is not clear from the information available to RPSEA.

Comments on a draft report and at WPG 4 indicate special caution is needed at some drafts and it is not clear what that means and if it is particularly relevant to GoM or not.

Remora's reply:

The HiLoad will stay in transit condition (15 m draft) until it reaches the port. It will then go to surface condition to achieve minimum draft before entering the harbor. In Surface condition, the HiLoad has a large water plane area and large stability margins both for intact and damage stability cases and fulfills all requirements. There is no reason for HiLoad to stay in a transition condition for longer time than required to change between surface condition and operation condition.

To view a video to see how quickly the HiLoad DP is able to de-ballast from 15 m draft to 6 m draft, see YouTube video: http://www.youtube.com/watch?v=ez2ooPj7QqU . This operation was carried out during the Sea Trial with a number of Oil Companies present in order to demonstrate this operation.

COMMENST – OPERATOR 1

Comment:
The better corollary might be a spar, instead of a submarine. The caution when transitioning over the top of the pontoon is likely the heel angle due to the change in the center of buoyancy. It will take significant ballast transfer to minimize this effect.

Remora's reply:
The transitioning over the top of the pontoon is done by giving the HiLoad some degree aft trim before submerging the pontoon. This means that the pontoon is gradually submerged over time and there is no sudden change in the COB, COG or the water plane area. This can also be seen in the above mentioned video from the Sea Trial of the HiLoad DP.

COMMENST - OPERATOR 2

Comment:
First I should disclaim that the following are my thoughts based on my individual contribution to the JIP as a Naval Architects and don't necessarily reflect the Operators' views. Also they are intended to assist the WG, but please don't take them as remarks to the work done as I have not reviewed all the reports and I believe quite a few people have already over looked it closely.

Referring to the document "Stability Analysis" – GF112798-0233-ANL (Rev. 6 dd 06/04/10), the main comment I have is that we would need to clarify which are the limits defined in DNV original approval and the impact on the changes required to sail away for hurricane avoidance. These are my thoughts but I'm afraid they raise more questions rather than help wrapping up the project :

1- It is not clear to me that the analysis takes into account GoM specific conditions. We should keep in mind that DNV original conceptual certification was given under a specific operation philosophy, determining the appropriate set of performance standards to be applied. This is reinforced in the "Open Issues" you sent, where DNV establishes that the unit is to operate within a distance of 3nm from the base unit.

The GoM hurricane avoidance requirement seems to change significantly the original HiLoad operation philosophy and possibly the basis of DNV original certification, with impact on stability, accommodations, supplies, propulsion, navigation, manning, safety, evacuation, etc. In summary, in the case the unit is expected to sail away on her own without assistance DNV might have to look at this again and exemptions given before may be taken away.

Remora's reply:
The stability criteria for the HiLoad is based on regular operation of the unit and is not connected to the restriction of 3nm . Reference first chapter. The restriction is related to four major items on the prototype of the HiLoad. That is MOB boat, Communication equipment, Navigation light and accommodation if required for longer distance travels. Reference is made section 8.1.15 in the updated version of the Final Report for RPSEA (Remora document distributed by PI on August 13th 2013).

Comment:
2- Regulations. The study refers to Modu Code 1989 + Amendments. It probably doesn't have a major impact on stability of the unit but I would expect last Modu Code adopted on 2 December 2009 to be required instead.

Remora's reply:
There is nothing in MODU 2009 that will change the stability requirements for HiLoad. The 1989 rules where used during the design of the first unit since this was done before 2009, but for future units the valid rules at the time of the design will of cause be adapted.

Comment:
3- Buoyance. The 3D view of the model used for stability analysis suggests that the transfer hose and pipes have been modeled too. If this is the case I'm curious how much effective they are to provide additional buoyance to the unit.

Remora's reply:
The pipes have no influence on the model since they are filled with fluid. All hoses is treated as variable loads and applied in the load condition calculations done by the crew on the load computer.

Comment:
4- Downflooding points are considered above 41000 mm AB. According to the calculations in the report, it seems all openings below EL 4000 would be required to be watertight and weathertight above this deck, consequently all openings need to be carefully investigated considering normal operation and emergency procedures.

Remora's reply:
All possible down flooding points are according to the class rules. There is no flooding points below EL 41m and all openings above this elevation is weather tight. Tank ventilation openings are self closing so normal procedure, maintenance and operation is required.

Comment:
5- Intact stability (Section 4). Heel axis should be related to the most critical axes, likely determined by the most stringent downflooding point.
Need to confirm if 0, 45 and 90 deg. as shown in the report indeed cover all critical axis.

Remora's reply:
Heel axis for most critical axes for intact stability is decided by means of wind tunnel tests done by Force Technology in Copenhagen, Denmark. All flooding will lead to a combination of forward trim and heel to either starboard or port side. Aft trim is no case. All down flooding points are therefore taken as a result of the result from these scenarios. The result is also shown in the damage water line drawings for the unit.

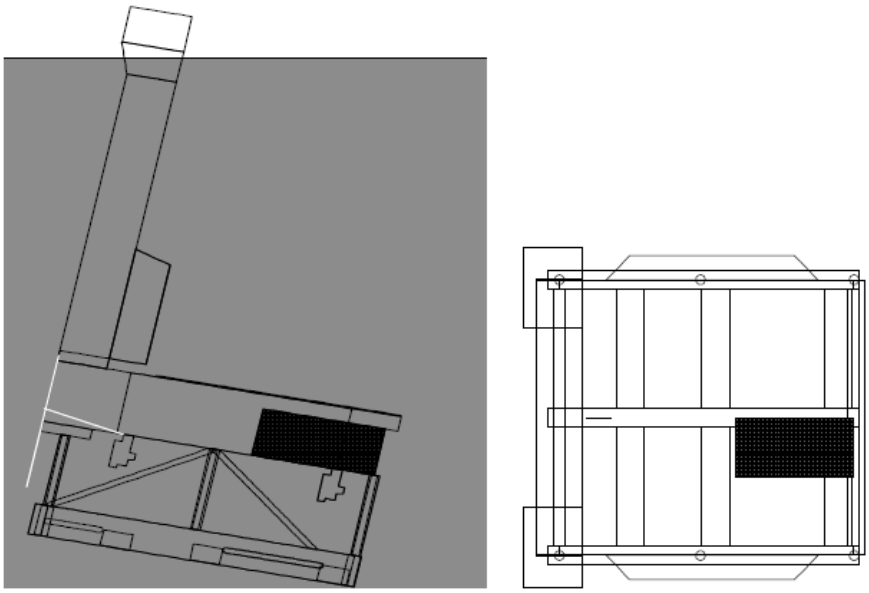


Figure 4 - Typical damage condition.

Comment:
6- Maximum GoM draft. So far it seems damage cases investigated by Remora for 12 m draft do not cross the pontoon level, but in case it needs to be reduced to bring within a port during hurricane, damage stability checks would possibly be required and then sudden change in the inclined water plane inertia in way of the pontoon due to flooding of an empty compartment would need to be investigated.

Remora's reply:
In port, the HiLoad will always be in surface condition. No flooding of any compartment in surface position will lead to sudden change in water plane area since no single compartment is large enough to submerge the pontoon alone.

Comment:
7- Damage stability criteria (Section 5.2). Although the reports refers to Modu Code 1989, the set of criteria presented is actually a modified Page 11 of 13 version:

a) Damage criteria has not been considered, i.e. inclination should not be greater than 17 deg and the righting moment curve should be at least twice the wind heeling moment curve in the 7 deg range between the first and second intercepts.

Remora's reply:
For inclination in damage condition reference is made to the first chapter in this MEMO. With respect to the ratio between heeling and righting moment curve, reference is made to Figure 1 and 2 showing that there is no second intercept with the heeling moment curve. The righting moment is far larger than twice the heeling moment within this range. A regular vessel will have a limited area where the righting moment can stabilize the unit and prevent capsizing due to dynamic behavior. (This shall not be less than 7 degrees).

For the HiLoad, this limitation is not relevant since the righting moment increases for all angles up to a level where progressive flooding will cause the unit to sink. Capsizing is therefore not a case for the HiLoad.

Comment:
b) Only flooding criteria was used, i.e. inclination should not be greater than 25 deg and the 7 deg range between the first and second intercepts.

My question is: Has DNV agreed with the modified downgraded criteria because the unit is restricted to operate within a distance of 3nm from the base unit? In such case, the unit might be required to comply with the full requirement when sailing on its own and the maximum inclination of 17 deg, may not be met. This was also highlighted in the ABS Consulting Hazid, as described in the main report Table 4.2-4.

In summary, I feel the report lacks some background on how stability criteria have been determined and which are their application limitations to avoid any misunderstanding as I don't think we can say the used criteria follows Modu Code 1989.

Remora's reply:
Reference is made section 8.1.15 in the updated version of the Final Report for RPSEA (Remora document distributed by PI on August 13th 2013). The stability requirements are not related to this restriction. The bases for the one compartment damage criterion are explained in the first chapter of this memo. With this conclusion in mind the design fulfils the MODU Code of 1989 and will also fulfill the criteria of MODU Code 2009.

It should also be kept in mind that the damage inclination angle can be reduced by increasing the distance between the COG and COB or reduce the flooding factor of the largest rooms. This can be done either by increasing the fixed ballast weight or reducing the open space in the two forward engine rooms. This has so far not been found required.

Comment:
8- Extent of Damage. Also in Section 5.2, it says "the unit shall be able to withstand flooding of one watertight compartment breached by low energy collision with attendant vessel". In the case the unit is sailing away on its own:

a) Is collision energy still considered "low"? Then we still need to define what is low, although the report suggests this is the 1989 Modu, I could find nothing in the code which refers to "low energy collision". If the unit goes self propelled in open seas to avoid a hurricane it could face higher collision energy levels than at location which the HiLoad could actually sustain for such new collision scenarios.

b) Only one flooded compartment has been considered in the tower. According to Modu code requirement for Column-stabilized units, vertical bulkheads spaced closer than a distance of 1/8 of the column perimeter should be assumed damage. It seems to be the case for the adjacent compartments in the tower. Is there any waiver for this criteria? In case affirmative, which is its limit of application?

Remora's reply:
HiLoad damage case is related to a normal operational risk assessment. It is a relatively small vessel and will of course have limitations with regards to collision with a much larger ship. This will also be valid for any small vessel. The damage condition is defined according to DNV offshore standard for column stabilized units, which is found to be most relevant for the HiLoad design by the class. Damage in these rules is restricted to a level 3m below and 5m above the water line and with a horizontal penetration of 1.5 m. As explained earlier the vertical bulkhead in the tower is only leading into the ballast tank already filled with water and will therefore not be critical for this damage scenario.

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.9
Future Assessment of Loop Current

E.9 FUTURE ASSESSMENT OF LOOP CURRENT

The Project Champion for the RPSEA project provided some relevant input during the WPG 5 meeting related to evaluation of the loop current in the GoM. Their input is given below.

Remora clearly agrees to the given input and proposes that additional analysis and assessment of this topic can be done in cooperation with each specific operator in the future, but not as part of the RPSEA project.

It should be noted that Remora has been working in close cooperation with Marin in The Netherlands and Houston with DP uptime analysis for several projects, including the RPSEA project (refer to Task 4, Section 4.4 of this report). Marin and Remora have jointly developed a DP Analysis Tool for the HiLoad DP that was used for the RPSEA project. This tool will be used for any operator specific analysis carried out in the future.

Input from Project Champion:

1) USGOM loop currents are very site specific. For those locations directly in the axis of loop current, that current can stay on axis on the site for weeks at a time and can range in speeds attaining 3-5 knots on surface. For those locations, the baseline assumption of 95% uptime using average 1.2m/s (2.3 kts) might imply an unrealistic coverage percentile, regardless of tabular date. The averaging total USGOM currents numerically and applying it to all sites specifically, may not be operationally accurate logic. Recommendation is made to further categorize uptimes basis site specific surface loop currents (say in categories of 1 knots, 2 knots, 3 knots, 4 knots, 5 knots) rather than generalize USGOM as a whole rounded off at 2.3 knots. This assumption affects the entire logic or conclusion to arriving at 125T -à 80T in DP2 = 96.5% uptime universally for the region.

2) Loop Current variability between sites in the Gulf is indeed very high. For instance, at Thunderhorse one expects Loop Current / eddy intrusions about 10 to 15 percent of the time. On the other hand, recent work we did for one of our lease areas points to incursions ~25% of the time. There are other areas of the Gulf where discoveries have been made where the incursions rates would be significantly higher than that. As such, you can see that generalizing operability for the Gulf based on the Thunderhorse site would be inaccurate.

3) Assume that the operating threshold is accurately calculated at 1.2m/s, you could make an accurate estimate that Loop Current / eddy generated current only exceeded 1.2m/s at your site about 5% of the time, you would still have interruptions at a higher percentage. If the Loop Current edge is in your vicinity, the accuracy of predicting whether it would meander over your site is not reliable enough to assume that interruption time would simply equal time above 1.2m/s. It's somewhat analogous to the hurricane case. If a hurricane enters the

Gulf, you would discontinue operations long before your Hs threshold was exceeded, because of the consequences of getting caught in the storm. Same thing for the Loop / eddy. That is, you have to worry about being caught in current much higher than 1.2m/s because near the edge of the Loop the current can go from less than a knot to 4+ knots pretty rapidly. In the RPSEA slides it, simply looks at the time above the threshold without considering how you actually have to respond to the event as a whole in an actual operation.

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.10
DP Assurance and DP Operating Philosophy

E.10 DP ASSURANCE AND DP OPERATING PHILOSOPHY

The Project Champion for the RPSEA Project provided valuable input related to DP assurance and DP operational philosophy prior to the WPG 5 meeting. Their input is given below.

Remora confirms that the company will develop DP operational procedures in close cooperation with the specific operator taking into account special requirements for the given client. One example of such implementation is for Remora's client Petrobras for HiLoad DP1 where the DP Acceptance Test was carried out in Norway in July 2013 prior to sail-away to Brazil

Input from Project Champion:

4) DP Assurance is based upon actual reliability and proven redundancy provided, coupled with a clearly identified operational window for the given vessels, and are defined and embraced by vessel operators using:

    a) Certified bollard pull test certificate for DP Mode by an IACS Class Society or a recognized independent third party – to include 2 thruster and 3 thruster pull tests in the actual metocean assumed by project;

    b) Properly written Activity Specific Operating Guideline (ASOG) capturing all variables and requisite actions required, and in the same metocean;

    c) Robust DP Assurance program, including proper DP Operations Manual, experienced DP personnel, robust emergency disconnect (<90 seconds);

    d) Accurate real time metocean measuring data during DP Operations;

5) The overall logic for increasing thrust available to 125T then reducing 1/3 (1 of 3 thrusters) for DP2 redundancy calculation to result at 80T is sound, provided bullet point #4 above is followed; and the test results of the bollard pull are confirmed in reality. We do wish to point out however that standard assumptions of safe working loads on ship to ship min requirements is 100T working tension max on mooring

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.11
HiLoad DP1 Construction Lessons Learned

APPENDIX E.11 – HILOAD DP1 CONSTRUCTION LESSONS LEARNED

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
FFC	**Split Fabrication**		
	The HiLoad DP1 was constructed at Aibel's Shipyard in Haugesund, Norway. The yard made provisions for the pontoon section and the two tower sections to be prefabricated in Poland. Aibel's Shipyard is considered a small but capable fabricator in Norway, with a notable offshore construction track record within the Oil and Gas Industry. The reason for Aibel to arrange for the split construction of the HiLoad DP1 was driven by opportunities to reduce: a. Construction cost b. Overall construction time, as the sections in Norway and Poland could be constructed in parallel.	Module quality and tie-in tolerances for the pontoon section and the two tower sections prefabricated in Poland turned out to be off specification, resulting in time- and cost-consuming remodification work.	For U.S. GoM construction, it is recommended to avoid split fabrication and perform module construction and assembly of modules at one location only. Despite opportunities to arrange for split construction, such as a single fabricator with multiple facilities or fabricators sharing the work among them, Remora does not recommend this approach.
FFC	**Labor Qualification**		
	Small shipyards tend to struggle with assigning qualified personnel to challenging construction projects, often caused due to: a. Lack of experience and know-how b. Key personnel allocated to	During construction of the HiLoad DP1, lack of available, experienced construction personnel was a limiting factor resulting in overall time delays.	**Recommendation:** Fabricators' project team to consist of team members with background experience local offshore fabrication, in terms of execution methods and standards. Key personnel (Project Management Team)

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
	other projects c. Dependence on external support and consultants		to be project nominated.
FFC	**Yard Capabilities/Production Facilities/Location**		
	A proven yard track record and modern fabrication facilities are considered essential for complex construction and outfitting projects. The actual yard location is, to some extent, assumed to have an impact on the overall productivity.	Despite arrangements for module split constructions and preparations for partial sheltered construction (keel and lower pontoon sections), overall productivity can be challenged due to environmental conditions on site. Snow and low temperatures caused delays during construction and outfitting of the HiLoad DP1.	**Opportunity:** High-end fabrication yards in the GoM are assumed to have similar production capabilities as Norway. Despite heat and humidity in the GoM, overall production efficiency is believed to be the same or somewhat better than Norway.
BS	**Three-Dimensional (3D) Construction Modeling**		
	3D design and engineering model tools were used for the HiLoad DP1, however, the construction yards in Norway and Poland did not use this type of tool for fabrication.	The HiLoad DP1 was built without using a 3D yard model tool. Consequently, final installation and fitting of equipment and materials installed were challenged due to: a. Last minute engineering and construction changes b. Limited available space/tight areas within the pontoon	**Recommendation:** Possible utilization of a 3D yard model is assumed to have multiple positive impacts, both for Remora and the construction yard. A 3D yard model will verify that the overall build strategy is developed properly and in sequence of the work. It will reduce risks associated with equipment configuration and lay-out and when/if last minute changes are

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
		and tower sections. During construction of the HiLoad DP1, Remora recommended utilization of such tool, however, the fabrication yard chose to commence construction without.	implemented.
BS	**Build Sequence (Structural)**		
	The structural build sequence is considered essential for successful project execution.	During construction of the HiLoad DP1, the preferred construction sequence was not executed as expected. The yard's structural build sequence was driven by obtaining commercial milestones rather than planning for an optimized overall project. The pontoon section outfitting and system integration was challenged due to incomplete installations prior to mounting of the pontoon top (containing the water ballast sections). Due to the complexity of equipment to be installed and work scope to be conducted within the pontoon section, negligence of the	**Recommendation:** The build sequence will have be determined upon the final design for GoM operations. It must take into account the level of difficulty for each module, the projected construction time, and the delivery schedule for the equipment in each module.

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
		preferred build sequence had an overall time and cost effect on the project.	
FA	**Ballast Arrangement**		
	The HiLoad DP1 is based on steel plates being used as fixed ballast. The fixed ballast is mounted into dedicated ballast compartments located in the lower keel area. Once the HiLoad DP is launched and execution of the inclination test is completed, the verified amount of fixed ballast plates is installed.	To reduce overall launch draft, allowing for possible launch at key side, possible alternatives such as the utilization of Ballast-Crete should be considered.	Ballast-Crete could offer some specific HiLoad DP GoM advantages: a. It would allow for final determination of the proper amount of ballast after launching, resulting in an actual VCG rather than a theoretical VCG. b. Launch draft would be lower than it would be with the ballast already installed. This issue will be evaluated further during final design configuration.
FA	**Towers and Control Room – Outfitting**		
	Outfitting of the HiLoad DP1 control and tower equipment was conducted after tower matting was completed.	Outfitting of the control room and the two towers was a challenge due to: c. Extensive use of crane and lifting support d. Limited access through tower sections leading to the control room e. Amount of equipment to be installed in very	**Recommendation:** To the extent possible, adjust the build strategy to allow for systems and equipment to be pre-installed in the control and tower sections prior to completion of the tower matting (assembly level). Despite the challenges and risks of doing so, possibly causing unforeseen damages to the installed equipment

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
		tight spaces.	during the final assembly, this adjustment is recommended.
FA	**Safety**		
	The HiLoad DP1 fabrication was accomplished in accordance with national as international rules and guidelines defining safe construction at any given time.	Installation and outfitting of the HiLoad DP1 pontoon and tower sections were challenged due to governmental regulations defining the maximum safe entry of personnel into enclosed spaces (maximum 25 persons at the time). Consequently, parallel installation and outfitting of the sections could be accomplished only to the extent possible, causing delays and cost overruns.	**Recommendation:** To the extent possible and to avoid construction limitations with regard to regulations defining maximum safe entry of personnel into enclosed spaces, it is recommended to arrange for pontoon and tower equipment fitting prior to sections being covers/closed. The possibility to do so will depend on several factors, including complexity, equipment to be installed, time to fabricate, prerequisites such as what needs to be installed first, etc.
FA	**Piping**		
	The structural build sequence is considered essential in regard to installation of the integrated piping system.	The HiLoad DP1 pontoon piping system primarily hangs down from the ceiling, which is the lower part of the above-mounted ballast tanks. Due to ballast pipe diameters of 28 inches, the installation required extensive	**Recommendation:** Arrange for fabrication of the HiLoad DP GoM ballast sections “upside-down,” which would allow for pipes and other heavy equipment to be pre-installed at assembly level.

Cat.	Description	Lessons Learned	Opportunity/ Recommendation
		preparations for planning and execution.	
EQ	**Electrical (Cables)**		
	Installation of power and signal cables is considered a challenging element in the HiLoad DP construction.	When assembled, the overall HiLoad DP1 height exceeds 180 feet. The majority of the HiLoad DP1 cabling was conducted after section assembly and tower matting. The yard experienced a number of cable installation challenges while running the power and distribution cables from the silicon controlled rectifier through the two tower sections and into the main engine rooms, causing time delays and, to some extent, replacement due to damaged cable armoring.	**Recommendation:** Cabling that originates and terminates in the same unit can be installed prior to the section units being joined/matted to the next unit. Consequently, cables from the distribution panels to the loads can be pre-installed installed and similarly for the cables from the generators to the switchboards. Cables from the switchboards to a distribution panel in a different unit cannot be installed. Overall, this is expected to reduce overall cable installation time.

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.12
Signal International Statement Letter

SIGNAL
INTERNATIONAL
A Marine & Fabrication Company

August 12, 2013

Geir Ove Saltvedt
Senior Vice President, Technical Division
Remora Technology, Inc.
800 Town & Country Blvd.
Houston, TX 77079

RE: Budgetary Estimate for the Remora Hi-Load DP GoM Offshore Loading Vessel

Gentlemen,

Signal International is pleased to provide the following revised budgetary estimate for building the Remora Hi-Load DP GoM Offshore Loading Vessel.

This estimate is strictly budgetary, based on the Gulf of Mexico design information and parameters provided to date by Remora to meet the GoM service requirements generally spelled out by the RPSEA project initiative. This is not an offer to build. The estimate includes design and fabrication of a complete vessel, including DP systems, Engines, Thrusters, Ship Systems, Structural Steel, and all outfitting commensurate with the vessel's design. This estimate is exclusive of the Remora scope of supply (including Remora Project management, Third Party Engineering, and return). Import duties, license fees and spare parts are not included.

Budgetary Estimate is as follows:

1ea **Remora Hi-Load DP GoM Offshore Loading Vessel: $105,652,610.00 U.S. Dollars**

Said indicative price is for the HiLoad unit delivered dockside at Signal International's Shipyard in Pascagoula, MS, and includes Dock and Sea Trial completion to the satisfaction of the Classification society and the Owners.

Please let me know if you have questions or comments.

Sincerely,

Andrew P. Veith

Andrew P. Veith
Vice President of Engineering

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.13
Estimated Cost for Required Hiload DP Changes

APPENDIX E.13 – ESTIMATED COST FOR REQUIRED HILOAD DP CHANGES

Estimated Cost for Required Changes for HiLoad GoM				
Description	Required Change	HiLoad DP 1	HiLoad DP GoM	Cost Impact USD
Increased Thruster Capasity	Increased Engine Power	SFI 625 Equipment Package GF 112798-0008 3 x 2350 KW CAT 3516/16	3x 2800 KW 3x BOSTEK «Gen-Set» MTU 20V4000P83 motor 2800kWm @ 1800rpm 3x NES generators på 500kW Centalink clucth between motor og generator Geislinger clutch between motor og clutch/propeller Engine coolers Silencer Skid mounted (Budgetary proposal from supplier)	$800.000
	Modified Utility Systems	SFI Groupe 635	Change of exhaust system Chance of Air intake system Review/Change of sea chests Modificatoion of engine foundation Agility Estimate	$150.000
	Larger thrusters	SFI 635 Equipment Package GF 112798-00083 x Wartsila LCT S275-S/WN-K 3 x 40t	3x Watrsila 3 CS 300 3x50t with 3 m propeller Price indication - Wartsila	$1.700.000
Increased Fuel Tank Capacity	Modification of existing ballast tanks (2) converted into fuel tanks	Capacity: 104 m^3	Capacity: 191 m3 Increase of tank volume Modification of transfer system Agility Estimate	$50.000
Installation of Pot Water system	Pot Water	N/A	Implementation of Pot Water Distribution system 160 m3 Coating of tanks New filling lines Fresh water monitoring system (to be evaluated) Agility Estimate	$150.000
Accomondation for Crew	Recreation / living quarters to be implemented in tower section. Implementation according to HAZID Specific recommendation 15 and 26	Container based recreation module	Recreation / Living quarter four up to 4 persons implemented in superstructure Estimate based upon HiLoad DP no. 1 recreation module to be installed	$1.800.000
Lowering of tower structure	4 m tower reduction	N/A	Tower reduction corresponds 20 MT weight reduction Pro rata reduction in tower construction cost	-$390.000
	Modify and optimize keel structure to refelct tower reduction	N/A	No or minor cost impact due to modified keel structure and lay-out	$0
	Fixed Ballast	Fixed Ballast 1750 ton	To be analysed	$0
Oil Spill Monitoring System	Implementation of recommendation from Hazid Specific item 14	N/A	Implementation of flow meter and oil spill detection by use of infrared cameras. Price indication Optimar, Norway	$1.000.000
Estimated Cost Impact				**$5.260.000**

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.14
Delivery

APPENDIX E.14 - DELIVERY

DESCRIPTION	Signal Int	Remora	Totals Combined
Delivery			
Load out by use of SPMT and Signal Int "Dual Carrier"	$1 000 000	$0	$1 000 000
Weightning	$100 000	$0	$100 000
Inclination Test	$100 000	$0	$100 000
Commissioning	$400 000	$0	$250 000
Commissioning Consumables	$100 000	$0	$100 000
Tug assistance during load out and inclination test (4 days) 2 tugs	$40 000	$0	$40 000
Third party assistance during load out	$200 000	$0	$200 000
Sea Trial	$500 000	$0	$500 000
Tug assistance during sea trial (14 days) 2 tugs	$140 000	$0	$140 000
Delivery and Handover to Owner	$250 000	$0	$250 000
Total	**$2 930 000**		**$2 930 000**

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.15
Breakdown of Estimated Remora Project Management Cost

APPENDIX E.15 – BREAKDOWN OF ESTIMATED REMORA PROJECT MANAGEMENT COST

DESCRIPTION	Month Working	Man Hours/ Month	USD Rate/ Hours	USD Total
Remora Project Management Activities - project life				
Project Manager / Consultant	$30	$160	$150	$720 000
Planner	$12	$160	$95	$182 400
Project Engineers (Mechanical/Electrical/Instrumentation)	$30	$500	$120	$1 800 000
Document Control	$12	$160	$80	$153 600
Secretary	$30	$160	$85	$408 000
Project Controls Manager	$30	$160	$90	$432 000
QA/HSE	$12	$16	$90	$17 280
Commissioning Manager	$6	$160	$145	$139 200
Indirect Cost (office, phone, insurance etc.)				$400 000
Total				**$4 252 480**

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.16
Equipment

APPENDIX E.16 - EQUIPMENT

DESCRIPTION	Signal Int	Remora	Totals Combined
Delivery			
SFI Group - 2 Hull and Structure	$1 300 000	$0	$1 300 000
Fenders and Seals			
SFI Group 3 - Oil Transfer System	$7 700 000	$0	$7 700 000
Swivel, Turret, 160 m Loading Hose, Valves			
SFI Group 4 - HiLoad Equipment	$5 300 000	$0	$5 300 000
DP System			
SFI Group 5 - Equipment for Crew	$700 000	$0	$700 000
HVAC			
SFI Group 6 - Machinery and Main Components	$6 900 000	$0	$6 900 000
Thrustors, Motors, Converters, Umbilical			
SFI Group 7 - System for Main Components	$1 000 000	$0	$1 000 000
Valve system			
SFI Group 8 - Common Systems	$1 100 000	$0	$1 100 000
Power System			
SFI Group 9 - Integrated Control System	$800 000	$0	$800 000
Total Actual Cost 2007	$24 800 000	$0	$24 800 000
Price Escalation 2013 according to Assumptions	$5 200 000		
Estimated Equipment Cost 2013	**$30 000 000**		

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.17
List of Documents Shared With Signal International

APPENDIX E.17 – LIST OF DOCUMENTS SHARED WITH SIGNAL INT.

DOC. NUMBER	TYPE	TITLE
GF112798-0175-ARD	ARD	Tank Plan, GA
GF112798-1236-ARD	ARD	Isometric View, Ballast System
GF112798-0001-GAD	GAD	General Arrangement Main Dimensions
GF112798-0003-GAD	GAD	General Arrangement Floor Plan & AFT View
GF112798-0004-GAD	GAD	02-LAY
GF112798-0005-GAD	GAD	General Arrangement Pontoon Deck & Side View
GF112798-N-0001-SAD	SAD	Main Steel, Perspective View, from above
GF112798-N-0002-SAD	SAD	Main Steel, Perspective View, from beneath
GF112798-N-0004-SAD	SAD	Main Steel, Pontoon
GF112798-N-0008-SAD	SAD	Main Steel, Pontoon, Frames 0 & 1
GF112798-N-0016-SAD	SAD	Main Steel, Pontoon, BLKHD. 11500 & 13500 off CL
GF112798-N-0033-SAD	SAD	Main Steel, Tower, Ring Stiffeners
GF112798-N-0036-SAD	SAD	Main Steel, Tower
RT1001-112-RE	RE	Technical Description, HiLoad DP including 18 appendixes
		Video 14, Fabrication
		Video 16, Loadout in Poland
		Video 17, Lifting of Pontoon Section
		Video 22, Matting of Pontoon and Tower sections
		Video 27, Loadout yard Norway

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.18
Basis and Assumptions for Cost Estimate

APPENDIX E.18 – BASIS AND ASSUMPTIONS FOR COST ESTIMATE

Description	Reference	Assumptions	Comments
Economics	Appendix E.12	N/A	The HiLoad DP Cost Estimate has been jointly developed between Remora and Signal Int. No provisions have been made for duties, taxes, license fees or spares
Drawings and Documentation	Appendix E.17	The HiLoad DP GoM Cost Estimate is based on the HiLoad DP no.1 build unit with inclusion of GoM required changes.	List of documents submitted to Signal Int. internal review
Validity of Cost Estimate - Contingency	N/A	No inclusions have been made for cost contingencies within the cost estimate.	A +- 10% cost estimate accuracy within an 80 % confidence level is assumed realistic. Cost Estimate Contingencies may be taken into account as final scope of work is cleared
Equipment and Material	Appendix E.16	HiLoad DP installed equipment assumed identical with equipment to be utilized on HiLoad DP GoM (modified for GoM operations)	Actual HiLoad DP material and equipment quantity/cost used as reference in the Cost Estimate

Description	Reference	Assumptions	Comments
Price Escalation	www.bls.gov www.ssb.no	Escalation in consumer prices based on: • US Product Price Index Commodity • Norsk Konsumprisindex Escalation in material prices 2007-2013 (averaged): • +20,5 %	Price indications on equipment obtained from various vendors e.g., engine/thruster suppliers. Feedback from the suppliers supports the assumption made.
Weight	Task 17, Appendix E.6	HiLoad DP1 calculated and distributed weights used.	Deviation: A comparison was done in connection with the inclination test of the HiLoad DP1 showing the expected and real weight. The difference was 1.3 t

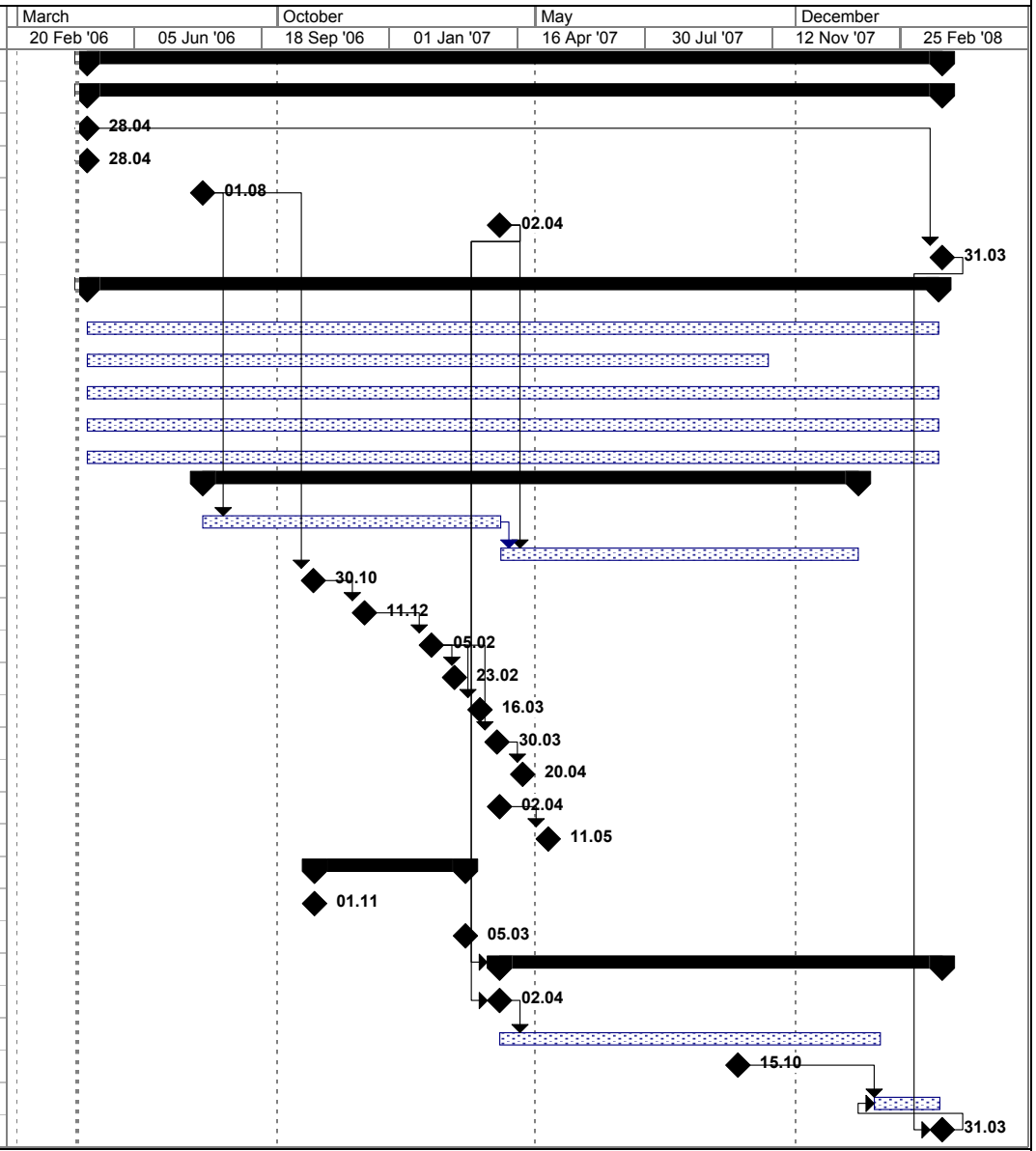
APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.19
HiLoad DP1 Planned Time Schedule

Remora - Hi-Load

GRENLAND FRAMNÆS

ID	Task Name	Duration	Start	Finish
1	**Remora - Hi-Load**	**100,2 wks**	**Fri 28.04.06**	**Mon 31.03.08**
2	**Milestones**	**100,2 wks**	**Fri 28.04.06**	**Mon 31.03.08**
3	Contract Award	0 hrs	Fri 28.04.06	Fri 28.04.06
4	Fabrication contract Award	0 hrs	Fri 28.04.06	Fri 28.04.06
5	Start Engineering	0 wks	Tue 01.08.06	Tue 01.08.06
6	Commence Fabrication	0 hrs	Mon 02.04.07	Mon 02.04.07
7	Delivery Hi-Load	0 hrs	Mon 31.03.08	Mon 31.03.08
8	**Project Management**	**100 wks**	**Fri 28.04.06**	**Thu 27.03.08**
9	Project Management	100 wks	Fri 28.04.06	Thu 27.03.08
10	Eng. Management	80 wks	Fri 28.04.06	Thu 08.11.07
11	Doc. Control	100 wks	Fri 28.04.06	Thu 27.03.08
12	Interface coordination	100 wks	Fri 28.04.06	Thu 27.03.08
13	Planning	100 wks	Fri 28.04.06	Thu 27.03.08
14	**Engineering**	**77 wks**	**Tue 01.08.06**	**Mon 21.01.08**
15	Detail Engineering	35 wks	Tue 01.08.06	Mon 02.04.07
16	Follow on engineering	42 wks	Tue 03.04.07	Mon 21.01.08
17	Design Freeze	0 wks	Mon 30.10.06	Mon 30.10.06
18	Layout freeze	0 wks	Mon 11.12.06	Mon 11.12.06
19	Preliminary MTO Steel for fabrication	0 wks	Mon 05.02.07	Mon 05.02.07
20	Preliminary MTO Steel and Piping for fabrication	0 wks	Fri 23.02.07	Fri 23.02.07
21	Issue primary of Steel dwg to Fabrication yard	0 wks	Fri 16.03.07	Fri 16.03.07
22	Issue of primary Piping dwg to Fabrication yard	0 wks	Fri 30.03.07	Fri 30.03.07
23	Issue Utility Piping dwg	0 wks	Fri 20.04.07	Fri 20.04.07
24	Issue Instrument and Electrical MTO	0 wks	Mon 02.04.07	Mon 02.04.07
25	Issue detail E&I dwg	0 wks	Fri 11.05.07	Fri 11.05.07
26	**Procurement**	**17,6 wks**	**Wed 01.11.06**	**Mon 05.03.07**
27	Issue technical specifications for Long lead equipment	0 wks	Wed 01.11.06	Wed 01.11.06
28	Issue technical specifications for Yard Purchase equipmei	0 wks	Mon 05.03.07	Mon 05.03.07
29	**Fabrication - Hi-Load**	**52 wks**	**Mon 02.04.07**	**Mon 31.03.08**
30	Start Fabrication	0 wks	Mon 02.04.07	Mon 02.04.07
31	Fabrication	45 wks	Mon 02.04.07	Fri 08.02.08
32	Receive main Equipment	0 wks	Mon 15.10.07	Mon 15.10.07
33	MC/FAT Module	8 wks	Mon 04.02.08	Fri 28.03.08
34	Delivery FCA fabrication Yard	0 wks	Mon 31.03.08	Mon 31.03.08



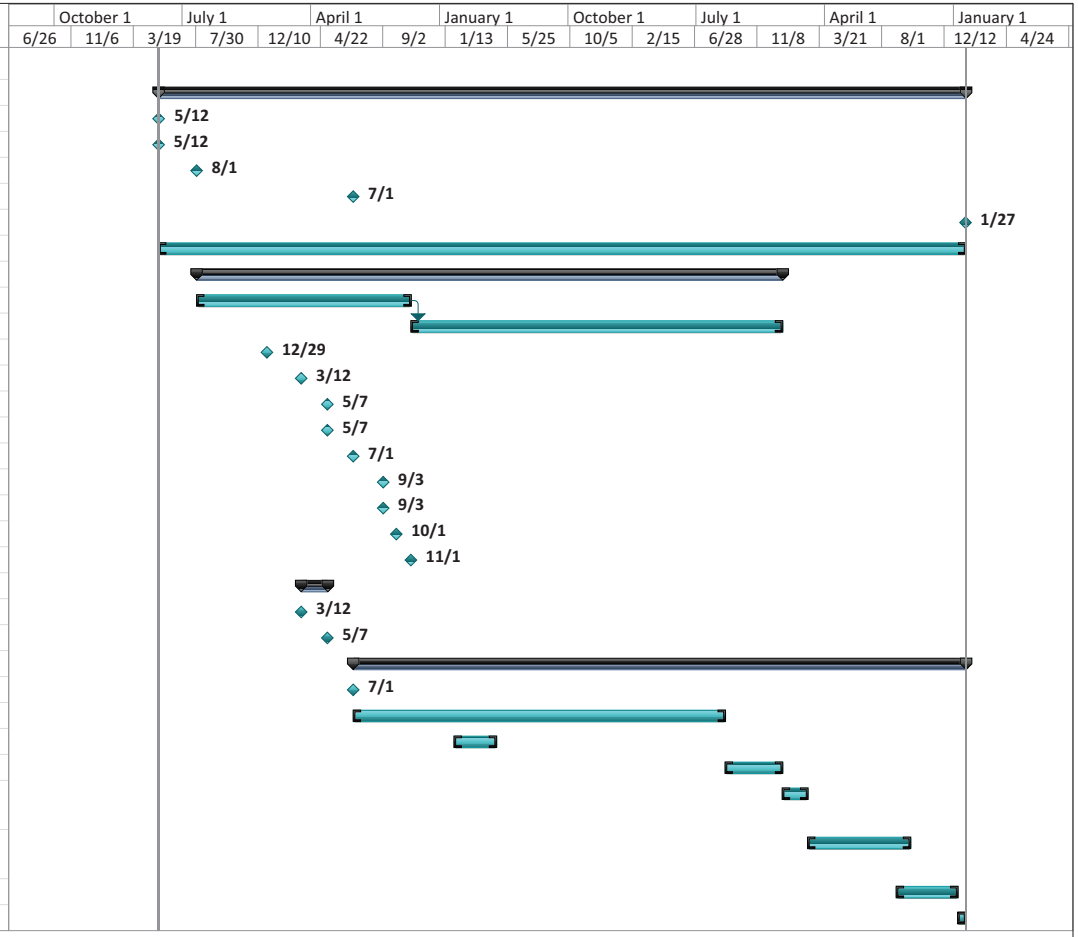
Project: 200621
Date: Wed 19.04.06

Task | Progress | Summary | Deadline
Split | Milestone | Project Summary

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.20
HiLoad DP1 Executed Time Schedule

ID	Task Name	Duration	Start	Finish
1	**HiLoad DP no.1 Executed Time Schedule**			
2	**Milestones**	**1230 days**	**Fri 5/12/06**	**Thu 1/27/11**
3	Contract Award	0 days	Fri 5/12/06	Fri 5/12/06
4	Fabrication contract awarded	0 days	Fri 5/12/06	Fri 5/12/06
5	Start Engineering	0 days	Tue 8/1/06	Tue 8/1/06
6	Commence Fabrication	0 days	Sun 7/1/07	Sun 7/1/07
7	Delivery Hi-Load	0 days	Thu 1/27/11	Thu 1/27/11
8	**Project Management**	**1230 days**	**Fri 5/12/06**	**Thu 1/27/11**
9	**Engineering**	**894 days**	**Tue 8/1/06**	**Fri 1/1/10**
10	Detail Engineering	328 days	Tue 8/1/06	Thu 11/1/07
11	Follow on Engineering	567 days	Thu 11/1/07	Fri 1/1/10
12	Design Freeze	0 days	Fri 12/29/06	Fri 12/29/06
13	Layout Freeze	0 days	Mon 3/12/07	Mon 3/12/07
14	Preliminary MTO Steel for Fabrication	0 days	Mon 5/7/07	Mon 5/7/07
15	Preliminary MTO Steel and Piping for Fabrication	0 days	Mon 5/7/07	Mon 5/7/07
16	Issue Primary of Steel dwg to Fabrication Yard	0 days	Sun 7/1/07	Sun 7/1/07
17	Issue Primary of Piping dwg to Fabrication Yard	0 days	Mon 9/3/07	Mon 9/3/07
18	Issue Utility Piping dwg	0 days	Mon 9/3/07	Mon 9/3/07
19	Issue Instrument and Electrical MTO	0 days	Mon 10/1/07	Mon 10/1/07
20	Issue Detail E&I dwg	0 days	Thu 11/1/07	Thu 11/1/07
21	**Procurement**	**41 days**	**Mon 3/12/07**	**Mon 5/7/07**
22	Issue Technical Specifications for Long Lead Equipment	0 days	Mon 3/12/07	Mon 3/12/07
23	Issue Technical Specifications for Yard Purchase Equipment	0 days	Mon 5/7/07	Mon 5/7/07
24	**Fabrication Hi-Load**	**935 days**	**Sun 7/1/07**	**Thu 1/27/11**
25	Start Fabrication	0 days	Sun 7/1/07	Sun 7/1/07
26	Fabrication	568 days	Sun 7/1/07	Tue 9/1/09
27	Receive Main Equipment	65 days	Fri 2/1/08	Thu 5/1/08
28	Partly MC/FAT Module	89 days	Tue 9/1/09	Fri 1/1/10
29	Yard Discussions, Early delivery Prior to Project Completion, Due to Non Compliance	39 days	Fri 1/1/10	Wed 2/24/10
30	Remodification Work Performed by Remora and New Selected Yard, Eide Marine	158 days	Wed 2/24/10	Fri 10/1/10
31	Sea Trials	94 days	Wed 9/1/10	Mon 1/10/11
32	Customer Sea Trials	14 days	Mon 1/10/11	Thu 1/27/11



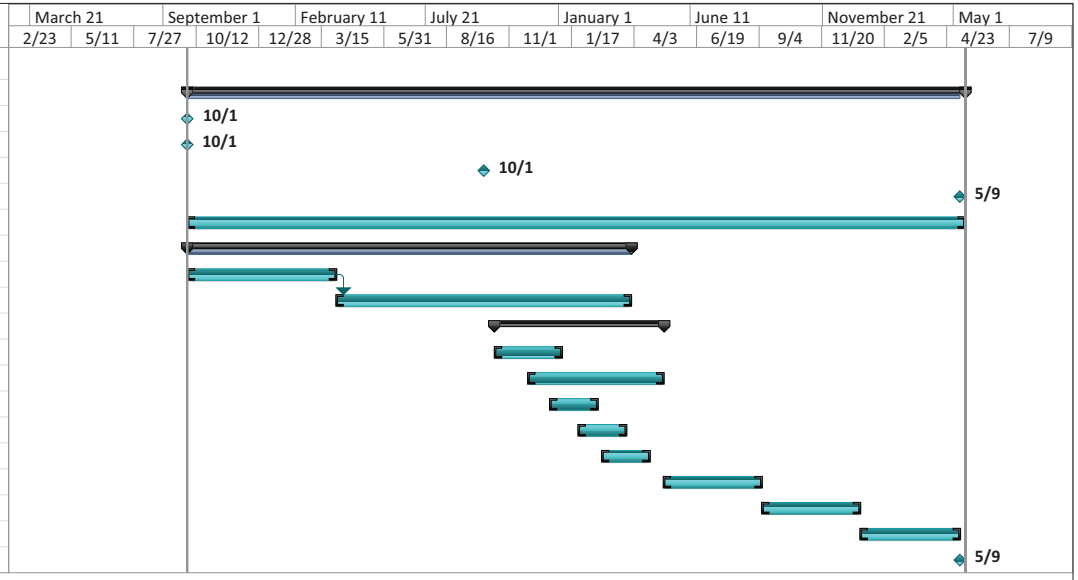
Project: HiLoad DP no. 1 Executed
Date: Mon 8/12/13

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

APPENDIX E:
TASKS 15-19 – SUPPORTING INFORMATION

E.21
HiLoad GoM Planned Time Schedule

ID	Task Name	Duration	Start	Finish
1	**HiLoad DP GoM Planned Time Schedule**			
2	**Milestones**	**684 days**	**Wed 10/1/14**	**Mon 5/15/17**
3	Fabrication Contract Award	0 days	Wed 10/1/14	Wed 10/1/14
4	Start Engineering	0 days	Wed 10/1/14	Wed 10/1/14
5	Commence Fabrication	0 days	Thu 10/1/15	Thu 10/1/15
6	Delivery Hi-Load	0 days	Tue 5/9/17	Tue 5/9/17
7	**Project Management**	**684 days**	**Wed 10/1/14**	**Mon 5/15/17**
8	**Engineering**	**391 days**	**Wed 10/1/14**	**Wed 3/30/16**
9	Functional Design	132 days	Wed 10/1/14	Thu 4/2/15
10	Detail Engineering (3D Modelling)	260 days	Thu 4/2/15	Wed 3/30/16
11	**Fabrication Hi-Load**	**149 days**	**Wed 10/14/15**	**Mon 5/9/16**
12	Unit 5	60 days	Wed 10/14/15	Tue 1/5/16
13	Unit 4	120 days	Tue 11/24/15	Mon 5/9/16
14	Unit 2	44 days	Mon 12/21/15	Thu 2/18/16
15	Unit 3	44 days	Mon 1/25/16	Thu 3/24/16
16	Unit 1	44 days	Tue 2/23/16	Fri 4/22/16
17	**Assembly**	**88 days**	**Mon 5/9/16**	**Wed 9/7/16**
18	**Integration**	**88 days**	**Wed 9/7/16**	**Fri 1/6/17**
19	**Comissioning - Sea Trials**	**88 days**	**Fri 1/6/17**	**Tue 5/9/17**
20	**Delivery**	**0 days**	**Tue 5/9/17**	**Tue 5/9/17**



Project: HiLoad DP GoM Planned
Date: Mon 8/12/13

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			