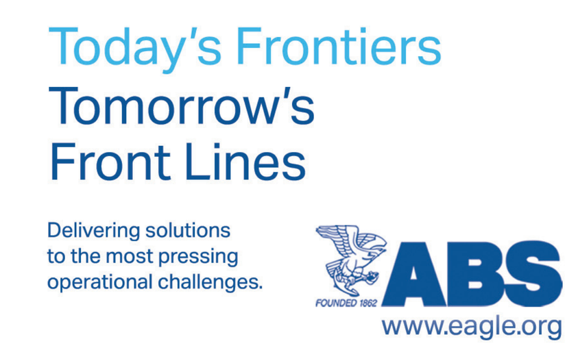


2014 SURVEY OF ARCTIC & COLD REGION TECHNOLOGY FOR OFFSHORE FIELD DEVELOPMENT

CHALLENGES & SOLUTIONS

FEBRUARY 2014

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INTECSEA WorleyParsons Group

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Information Accuracy: We have attempted to use correct and current, as of press time, information for the Arctic and for the associated oil & gas development technologies, and solutions described herein. No installed, sanctioned, or pending projects were intentionally excluded. We have summarized the capability and operating experience by acting as a neutral party and integrator of information. Information has been collected from public sources, company brochures, personal interviews, phone interviews, press releases, industry magazines, vendor-supplied information, and web sites. No guarantee is made that information is accurate or all-inclusive. Neither INTECSEA, Inc. nor *Offshore Magazine* guarantees or assumes any responsibility or liability for any party's use of the information presented. If any information is found to be incorrect, not current, or has been omitted, please send comments to: *arctic@intecsea.com*.

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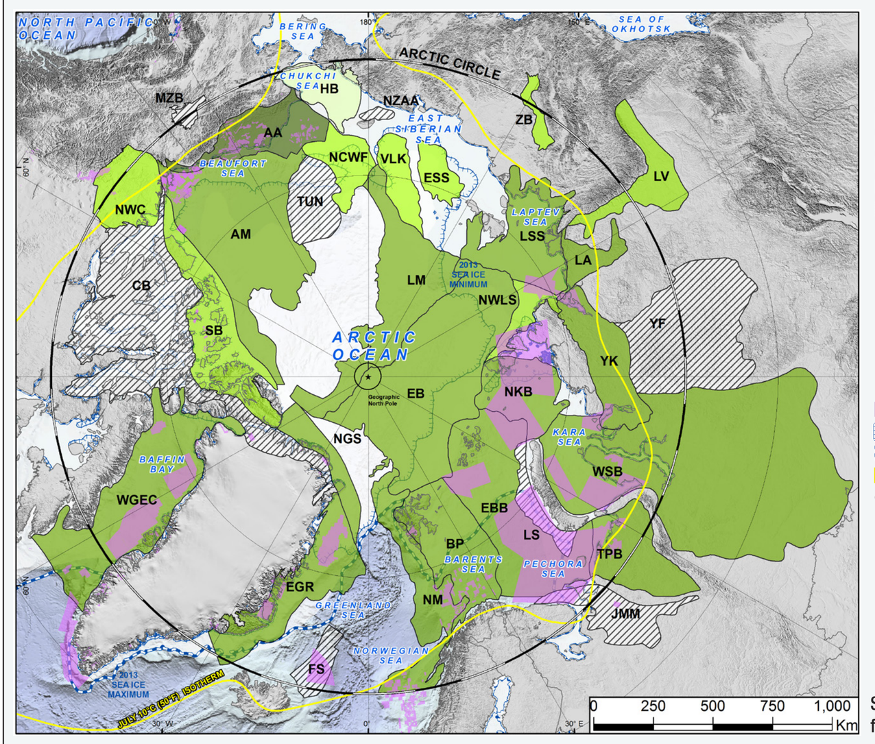
TABLE 1 – ESTIMATED OIL & GAS IN-PLACE IN THE ARCTIC

Sorted from largest to smallest prize in MMBOE for each geological province

PROVINCE CODE	GEOLOGICAL PROVINCE	OIL (MMBO)	TOTAL GAS (BCFG)	NGL (MMBNGL)	BOE (MMBOE)
WSB	West Siberian Basin	3,659.88	651,498.56	20,328.69	132,571.66
AA	Arctic Alaska	29,960.94	221,397.60	5,904.97	72,765.52
EBB	East Barents Basin	7,406.49	317,557.97	1,422.28	61,755.10
EGR	East Greenland Rift Basins	8,902.13	86,180.06	8,121.57	31,387.04
YK	Yenisey-Khatanga Basin	5,583.74	99,964.26	2,675.15	24,919.61
AM	Amerasia Basin	9,723.58	56,891.21	541.69	19,747.14
WGEC	West Greenland-East Canada	7,274.40	51,818.16	1,152.59	17,063.35
LSS	Laptev Sea Shelf	3,115.57	32,562.84	867.16	9,409.87
NM	Norwegian Margin	1,437.29	32,281.01	504.73	7,322.19
BP	Barents Platform	2,055.51	26,218.67	278.71	6,704.00
EB	Eurasia Basin	1,342.15	19,475.43	520.26	5,108.31
NKB	North Kara Basins and Platforms	1,807.26	14,973.58	390.22	4,693.07
TPB	Timan-Pechora Basin	1,667.21	9,062.59	202.80	3,380.44
NGS	North Greenland Sheared Margin	1,349.80	10,207.24	273.09	3,324.09
LM	Lomonosov-Makarov	1,106.78	7,156.25	191.55	2,491.04
SB	Sverdrup Basin	851.11	8,596.36	191.20	2,475.04
LA	Lena-Anabar Basin	1,912.89	2,106.75	56.41	2,320.43
NCWF	North Chukchi-Wrangel Foreland Basin	85.99	6,065.76	106.57	1,203.52
VLK	Vilkitskii Basin	98.03	5,741.87	101.63	1,156.63
NWLS	Northwest Laptev Sea Shelf	172.24	4,488.12	119.63	1,039.90
LV	Lena-Vilyui Basin	376.86	1,335.20	35.66	635.06
ZB	Zyryanka Basin	47.82	1,505.99	40.14	338.95
ESS	East Siberian Sea Basin	19.73	618.83	10.91	133.78
HB	Hope Basin	2.47	648.17	11.37	121.87
NWC	Northwest Canada Interior Basins	23.34	305.34	15.24	89.47
MZB	Mezen' Basin	NQA(1)	NQA	NQA	NQA
NZAA	Novaya Zemlya Basins and Admiralty Arch	NQA	NQA	NQA	NQA
TUN	Tunguska Basin	NQA	NQA	NQA	NQA
CB	Chuckhi Borderland	NQA	NQA	NQA	NQA
YF	Yukon Flats (part of Central Alaska Province)	NQA	NQA	NQA	NQA
LS	Long Strait	NQA	NQA	NQA	NQA
JMM	Jan Mayen Microcontinent	NQA	NQA	NQA	NQA
FS	Franklinian Shelf	NQA	NQA	NQA	NQA
Totals		**89,983.21**	**1,668,657.84**	**44,064.24**	**412,157.09**

SOURCE: USGS (http://pubs.usgs.gov/fs/2008/3049/) Note: 1) NQA - Not Quantitatively Assessed

MAP 2 – ESTIMATED OIL IN-PLACE IN THE ARCTIC



SOURCE: USGS Note: See Table 1 for Geologic Province Codes.

MAP 3 – ESTIMATED GAS IN-PLACE IN THE ARCTIC

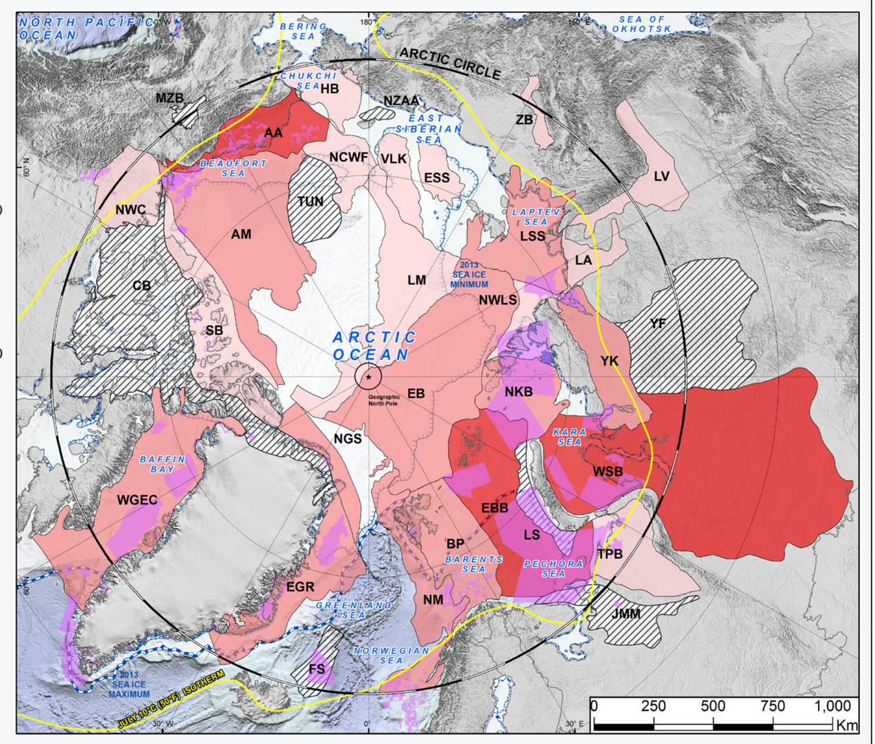


TABLE 6 – INDUSTRY ACRONYMS & ABBREVIATIONS

COURTESY OF INTECSEA WorleyParsons Group

AMSR-E	Advanced Microwave Scanning Radiometer-Earth
BCFG	Billion Cubic Feet of Gas
BOE	Barrels of Oil Equivalent
BOEM	Bureau of Ocean Energy Management, Regulation, and Enforcement
CIDS	Concrete Island Drilling System
CIRCAC	Cook Inlet Regional Citizens Advisory Council
CNG	Compressed Natural Gas
CRI	Caisson Retained Island
E & P	Exploration and Production
EER	Escape, Evacuation, and Rescue
FPSO	Floating Production, Storage, and Offloading
FSO	Floating Storage and Offloading
FWS	Full Well Stream (unprocessed, three-phase fluids from wells)
GBS	Gravity Based Structure
HMDC	Hibernia Management and Development Company
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MAC	Mobil Arctic Caisson
MBO	Thousand Barrels of Oil
MBOPD	Thousand Barrels of Oil per Day
MBPD	Thousand Barrels per Day
MMBNGL	Million Barrels of Natural Gas Liquids
MMBO	Million Barrels of Oil
MMBOE	Million Barrels of Oil Equivalent
MMS	Minerals Management Service
MMSCFD	Million Standard Cubic Feet per Day (Gas)
MSCFD	Thousand Standard Cubic Feet per Day (Gas)
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NGL	Natural Gas Liquids
OLS	Offshore Loading System
SCR	Steel Catenary Riser
SDC	Steel Drilling Caisson
SPM	Single Point Mooring
SSDC	Single Steel Drilling Caisson
TBD	To be Determined
USGS	United States Geological Survey
WI	Water Injection

TABLE 3 – FIELD DEVELOPMENT CONCEPT SELECTION MATRIX

COURTESY OF INTECSEA WorleyParsons Group

LEGEND: G = Field Proven; Y = Qualified; R = Concept; NO = Does Not Meet Requirements; N/A = Not Applicable

Column groups: MAJOR CAPABILITY (Exploration, Production, Production Storage); Water Depth Rating; Ice Environment; Design for Icebergs; Disconnectable (3); INSTALLATION METHOD (Topsides Floatover, Derrick Barge Lift, Deck/Hull Mating at Fabrication Yard); TREE TYPE (Wet Tree, Dry Tree); LOCATION APPL. (Nearby Infrastructure, Remote); ENVIR. CONDITIONS (Calm, Significant Seas (4)); RISERS (Steel Catenary Riser (SCR), Flexible Riser, Top Tensioned Riser, Internal Steel Riser); EXPORT/DISPOSAL METHODS – OIL/CONDENSATE (Oil Export Pipeline, Shuttling Application, Oil to Wire (Convert to Electricity)) and GAS (Gas Export Pipeline, LNG (Liquified Natural Gas), CNG (Compressed Natural Gas), Gas to Wire (Convert to Electricity), Fuel Gas, Gas Reinjection)

	Concept	Exploration	Production	Production Storage	Water Depth Rating	Ice Environment	Design for Icebergs	Disconnectable (3)	Topsides Floatover	Derrick Barge Lift	Deck/Hull Mating at Fabrication Yard	Wet Tree	Dry Tree	Nearby Infrastructure	Remote	Calm	Significant Seas (4)	Steel Catenary Riser (SCR)	Flexible Riser	Top Tensioned Riser	Internal Steel Riser	Oil Export Pipeline	Shuttling Application	Oil to Wire	Gas Export Pipeline	LNG	CNG	Gas to Wire	Fuel Gas	Gas Reinjection
1.0	**BOTTOM FOUNDED STRUCTURES**				SEE CHART 1	SEE TABLE 5																								
1.1	Ice Island	G	NO	NO			NO	NO	Y	Y	N/A	NO	G	G	G	G	G	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.2	Rock/Gravel/Sand Island	G	G	NO			Y	NO	G	G	N/A	NO	G	G	G	G	G	N/A	N/A	N/A	G	G	R	R	G	Y	R	R	G	G
1.3	Ballasted Barge/Vessel	G	Y	G			R	NO	N/A	N/A	G	NO	Y	G	G	G	G	N/A	N/A	N/A	G	R	R	R	R	Y	R	R	Y	R
1.4	Ballasted Barge/Vessel + Berm	G	Y	G			R	NO	N/A	N/A	G	NO	Y	G	G	G	G	N/A	N/A	N/A	G	R	R	R	R	Y	R	R	Y	R
1.5	Piled Barge	Y	Y	Y			R	NO	N/A	N/A	G	NO	Y	Y	Y	G	G	N/A	N/A	N/A	Y	R	R	R	R	Y	R	R	G	R
1.6	Caisson Retained Island	G	G	Y			R	NO	G	G	N/A	NO	G	G	G	G	G	N/A	N/A	N/A	Y	Y	G	R	Y	Y	R	R	G	G
1.7	Concrete GBS	G	G	G			G	NO	G	G	G	NO	G	G	G	G	G	N/A	N/A	N/A	G	G	G	R	G	Y	R	R	G	G
1.8	Steel GBS	Y	G	G			Y	NO	Y	Y	Y	NO	Y	Y	Y	G	G	N/A	N/A	N/A	G	Y	Y	R	Y	Y	R	R	Y	Y
2.0	**FIXED JACKET/MOBILE JACK-UP**																													
2.1	Mobile Offshore Prod. Unit	G(1)	Y	NO			NO	R	N/A	N/A	G	G	NO	G	NO	G	G	N/A	Y	N/A	N/A	Y	Y	R	Y	R	R	R	G	Y
2.2	Jacket	NO	G	NO			NO	NO	G	G	N/A	NO	G	G	NO	G	G	G	G	N/A	G	G	Y	R	G	R	R	R	G	Y
2.3	Monopod	NO	G	NO			NO	NO	G	G	N/A	NO	G	G	NO	G	G	N/A	G	N/A	G	G	Y	R	G	R	R	R	G	Y
3.0	**FLOATING STRUCTURES**																													
3.1	FPSO (Ship Shaped Vessel)	G(1)	G	G			G(2)	G	N/A	N/A	G	G	NO	G	G	G	G	Y	G	N/A	N/A	Y	G	R	Y	Y	R	R	G	G
3.2	FPSO (Round Shaped)	NO	Y	Y			G(2)	Y(5)	N/A	N/A	G	Y	NO	G	G	G	G	Y	G	N/A	N/A	Y	Y	R	Y	R	R	R	G	Y
3.3	Semi-Submersible	G(1)	G	R			G(2)	Y(5)	N/A	N/A	G	G	NO	G	NO	G	G	G	G	G	N/A	G	Y	R	G	R	R	R	G	G
3.4	Tension Leg Platform	NO	R	R			G(2)	Y(5)	N/A	N/A	G	G	G	G	G	G	G	G	G	G	N/A	G	Y	R	G	R	R	R	G	G
3.5	SPAR	NO	R	Y			G(2)	Y(5)	N/A	N/A	G	G	G	G	Y	G	G	G	G	G	N/A	G	Y	R	G	R	R	R	G	G
4.0	**SUBSEA FACILITIES**																													
4.1	Flowline	N/A	G	N/A			G	N/A	N/A	N/A	N/A	N/A	N/A	G	G	G	G	N/A	N/A	N/A	N/A	G	G	G	G	G	Y	G	G	G
4.2	Pipeline	N/A	G	N/A			G	N/A	N/A	N/A	N/A	N/A	N/A	G	G	G	G	N/A	N/A	N/A	N/A	G	G	G	G	G	Y	G	G	G
4.3	Subsea (Glory Hole)	N/A	G	N/A			G	N/A	N/A	N/A	N/A	G	NO	G	G	G	G	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	G	G
4.4	Subsea Protective Structure	Y	Y	N/A			R	N/A	N/A	N/A	N/A	G	NO	R	R	Y	Y	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	G	G
4.5	Subsea Drill Rig	R	R	N/A			NO	N/A	N/A	N/A	N/A	R	NO	R	R	R	R	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5.0	**OTHER**																													
5.1	Extended Reach Drilling	G	G	N/A			G	N/A	N/A	N/A	N/A	R	G	G	G	G	G	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes: 1) During Open Water Season 2) Iceberg Management and/or Disconnect 3) If not disconnectable, then must be designed for all ice loads 4) As appropriate for location 5) Disconnectable, however there may be issues with moving off station in an ice environment

KEY CHALLENGES FOR ARCTIC MODULARIZATION (ALASKAN EXAMPLE)

Engineering & Design
- Metocean data for Sealift from Gulf of Mexico to Alaska North Slope
- Designed for Land Transport and setting of module
- Arctic enclosure for operations
- Modules designed for -50 degrees Fahrenheit (-45.6 Celsius)

Construction
- Modules fabricated in Gulf of Mexico for sea transport to Alaska
- Modules 1,200 s.t. (1,088.6 mt) to 3,800 s.t. (3,447.3 mt)
- Low temperature materials are required

Operations
- Oil production facilities
- Harsh Arctic environment
- Remote access to facilities, weather window restrictions

Figs. 1 and 2 – Arctic Ice Lift on Sea Ice Road

Figures 1, 2, and 4 Courtesy of WorleyParsons; Figure 3 Courtesy of Crowley Marine

Fig. 3 – Arctic Sea Lift Ocean Transport

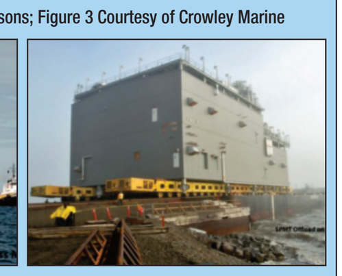


Fig. 4 – Arctic Sea Lift North Slope Offload

TRANSPORT OPTIONS

One of the major challenges for Operators is getting the oil and gas to the markets. There are basically 3 transport options:
1) Oil or Gas Pipeline,
2) Icebreaking Oil Shuttle Tanker,
3) Icebreaking LNG Vessel.

The stern working double acting shuttle tanker with ice breaking capability is a rather new proven technology which greatly reduces transport costs. Double acting or dual direction shuttle tankers break ice stern first and make ocean transit bow first. This allows the designers to maximize the hull form efficiency in each environment.

Fig. 1 – Arctic DAS™ Dual Direction Icebreaking Shuttle Tanker

Courtesy of Aker Arctic Technology Inc.

Fig. 2 – World's first Arctic oil export terminal at Varandey, Russia that uses DAS™ pod driven, Sovcomflot tankers.

Courtesy of Aker Arctic Technology Inc.

Fig. 3 – Sakhalin Gas Export via LNG Transport Ship

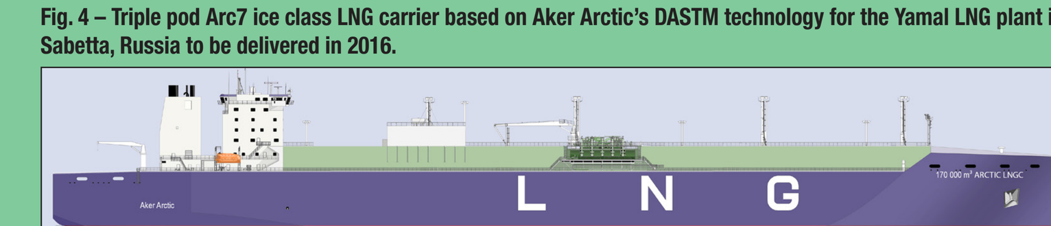
Courtesy of Photographic Services, Shell International Limited

TABLE 4 – LISTING OF ARCTIC RATED SHUTTLE TANKERS

NO	OWNER	TANKER NAME	VESSEL TONNAGE	YEAR BUILT	ICE CAPABILITY CLASS	ICE CAPABILITY ICE CLASS	ICE CAPABILITY METERS
1	Murmansk Shipping Company	Indiga	16,168 dwt	1976	RMRS	ULA1	1.0
2	Murmansk Shipping Company	Varzuga	16,038 dwt	1977	RMRS	ULA1	1.0
3	Palmali Shipping Services	Bozdag	19,800 dwt	2002	RMRS	Arc 5 (UL)	0.5
4	Palmali Shipping Services	Ginaldag	19,800 dwt	2002	RMRS	Arc 5 (UL)	0.5
5	Neste Oil Shipping	Tempera	106,000 dwt	2002	LR	1ASuper	1.0
6	Neste Oil Shipping	Mastera	106,000 dwt	2003	LR	1ASuper	1.0
7	Sovcomflot	Kapitan Gotsky	70,000 dwt	2008	RMRS	Arc 6	1.5
8	Sovcomflot	Vasily Dinkov	70,000 dwt	2008	RMRS	Arc 6	1.5
9	Sovcomflot	Timofey Guzhenko	70,000 dwt	2009	RMRS	Arc 6	1.5
10	Sovcomflot Varandey	Kirill Lavrov	70,000 dwt	2010	RMRS	Arc 6	1.3
11	Sovcomflot Varandey	Mikhail Ulyanov	70,000 dwt	2010	RMRS	Arc 6	1.3
12	Norilsk Nickel	Enisey	18,902 dwt	2011	DNV	ICE-15	1.5

SOURCE: Aker Arctic and Public Data DNV - Det Norske Veritas LR - Lloyd's Register RMRS - Russian Maritime Register of Shipping dwt - Deadweight tonnage

Fig. 4 – Triple pod Arc7 ice class LNG carrier based on Aker Arctic's DASTM technology for the Yamal LNG plant in Sabetta, Russia to be delivered in 2016.

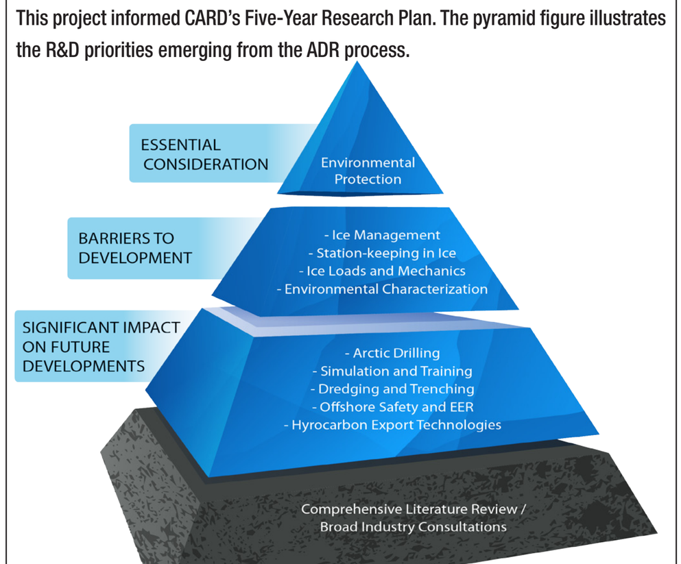


Courtesy of Aker Arctic Technology Inc.

ARCTIC DEVELOPMENT ROADMAP –

The Arctic Development Roadmap (ADR) developed by the Centre for Arctic Resource Development (CARD) identified, organized and prioritized key R&D issues requiring work to advance knowledge, technology, methodology and training needed for Arctic oil and gas development. Based on in-depth reviews of previous gap analyses and current technology, as well as broad consultation with industry, issues were ranked according to: current state of knowledge and technology, impact of further R&D, extent of applicability, relevance to the industry and anticipated timeframe to achieve result.

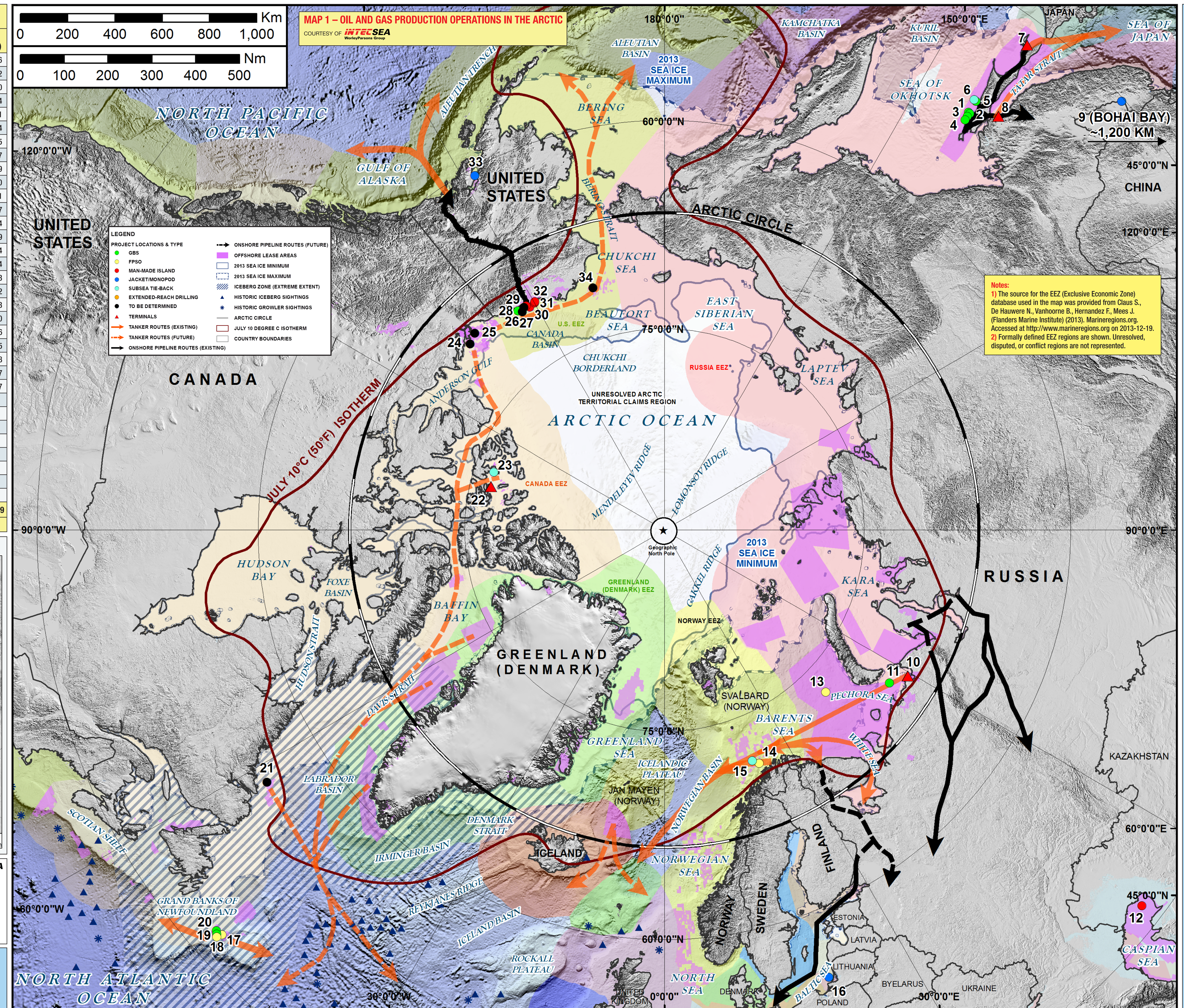
This project informed CARD's Five-Year Research Plan. The pyramid figure illustrates the R&D priorities emerging from the ADR process.



Courtesy of the Centre for Arctic Resource Development

MAP 1 – OIL AND GAS PRODUCTION OPERATIONS IN THE ARCTIC

COURTESY OF INTECSEA WorleyParsons Group



CHALLENGES IN THE ARCTIC

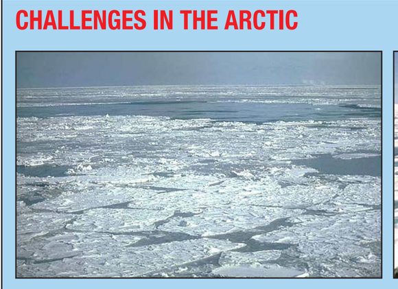


Fig. 1 – First Year Ice Courtesy of NASA

Fig. 2 – Multi Year Ice Courtesy of NASA

Fig. 3 – Icebergs Courtesy of NASA

Fig. 4 – Frost Heave & Thaw Subsidence Courtesy of INTECSEA

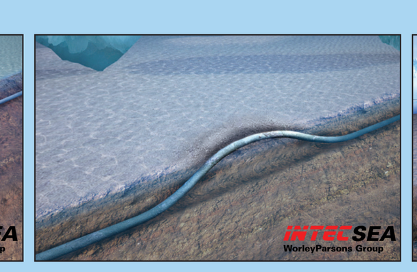


Fig. 5 – Upheaval Buckling Courtesy of INTECSEA

Fig. 6 – Ice Scour Courtesy of INTECSEA

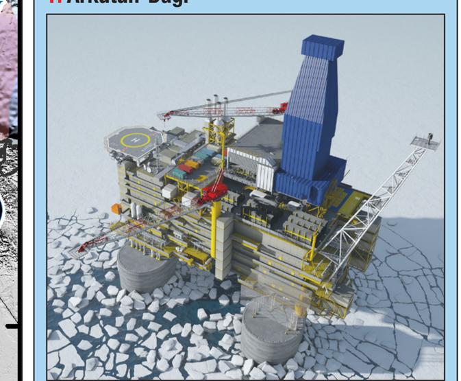
Fig. 7 – Strudel Scour Courtesy of INTECSEA

Fig. 8 – EER (Escape, Evacuation & Rescue) Courtesy of ARKTOS

Fig. 9 – Permafrost, Winterization & Expansion Courtesy of WorleyParsons

ARCTIC PRODUCTION FACILITIES

1. Arkutun-Dagi

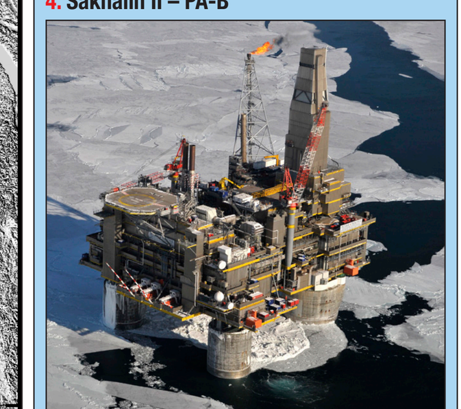


Courtesy of WorleyParsons

3. Sakhalin II – PA-A (MolikPaq)

Courtesy of Sakhalin Energy

4. Sakhalin II – PA-B



Courtesy of Sakhalin Energy

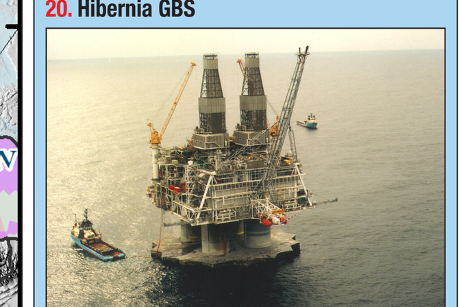
5. Sakhalin II – LUN-A

Courtesy of Sakhalin Energy

17. Sea Rose FPSO for White Rose Field

Courtesy of Husky Energy

20. Hibernia GBS



Courtesy of HMDC

30. Northstar

Courtesy of BP Alaska

32. Ooguruk

Courtesy of Pioneer Natural Resources

33. Cook Inlet, Alaska – Monopod Platform

Courtesy of Cook Inlet RCAC

TABLE 2 – ARCTIC PRODUCTION FACILITIES AND TERMINALS (AS OF JANUARY 2014)

COURTESY OF INTECSEA WorleyParsons Group

Column groups: GENERAL PROJECT INFORMATION; LOCATION INFORMATION; DEVELOPMENT INFORMATION; STORAGE & EXPORT INFO.; ICE ENVIRONMENT

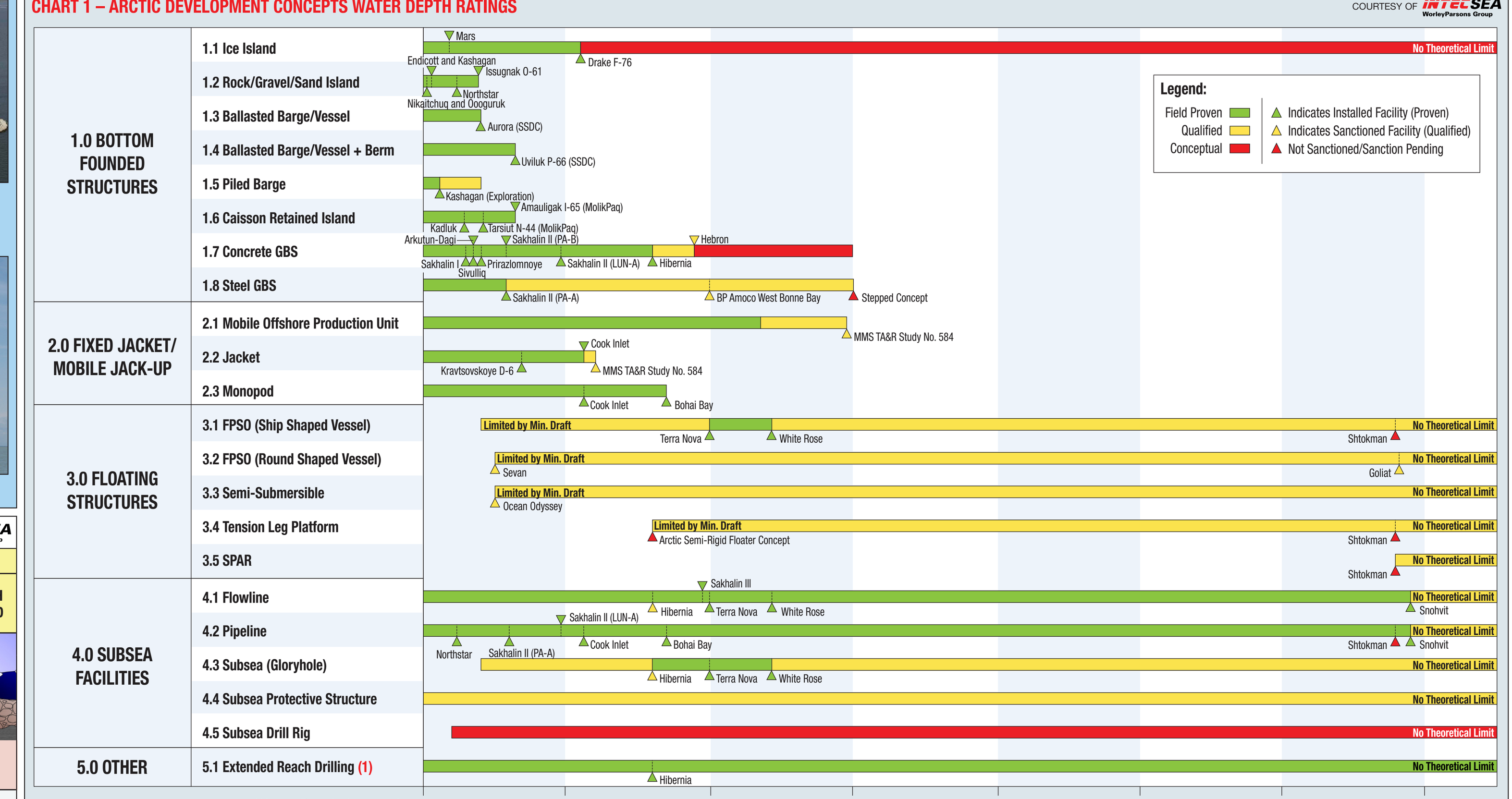
LOCATION NO.	PROJECT	LEASE OPERATOR	FIELD(S)	EXPLORATION WELL DRILLING SYSTEM	FIRST PROD. YEAR	LOCATION	MAXIMUM WATER DEPTH	PRODUCTION VESSEL/STRUCTURE	TIE-BACK	PEAK PRODUCTION/ THROUGHPUT	NUMBER OF WELLS	OIL STORAGE	EXPORT TECHNOLOGY	FIRST-YEAR	MULTI-YEAR	ICEBERGS	ICE PROTECTION
	SAKHALIN, RUSSIA																
1	Sakhalin I - Arkutun Dagi	Exxon Neftegaz	Arkutun Dagi	Sakhalinmorneftegas' OKHA drilling rig	2014	Sea of Okhotsk, Sakhalin Island, Russia	115 ft (35m)	Concrete GBS	Dry trees and FWS pipeline export to shore	90 MBOPD 60 MSCFD	45	N/A	Pipelines	●			Pipeline burial in water depth less than 30 m
2	Sakhalin I - Orlan (previously CIDS)	Exxon Neftegaz	Chayvo	Semi-submerible floaters and/or jack-up drilling rigs	2008	Sea of Okhotsk, Sakhalin Island, Russia	50 ft (15m)	Block-type GBS	Dry trees and FWS pipeline export to shore	94 MBOPD	20	N/A	Pipelines	●			Pipeline burial
3	Sakhalin II – PA-A (MolikPaq)	Sakhalin Energy	Piltun Astokhskoye	Semi-submerible floaters and/or jack-up drilling rigs	1999 Tanker, 2008 Pipeline	Sea of Okhotsk, Sakhalin Island, Russia	98 ft (30m)	Steel GBS	Dry trees, offshore separation, and oil & gas pipeline export to shore	90 MBOPD 72 MMSCFD	32	N/A	Currently pipelines	●			Pipeline burial in water depth less than 30 m
4	Sakhalin II - PA-B	Sakhalin Energy	Piltun Astokhskoye	Semi-submerible floaters and/or jack-up drilling rigs	2007	Sea of Okhotsk, Sakhalin Island, Russia	98 ft (30m)	Multi-column GBS	Dry trees, offshore separation, and oil & gas pipeline export to shore	70 MBOPD 100 MMSCFD	45	N/A	Pipelines	●			Pipeline burial
5	Sakhalin II - LUN-A	Sakhalin Energy	Lunskoye	Semi-submerible floaters and/or jack-up drilling rigs	2008	Sea of Okhotsk, Sakhalin Island, Russia	157 ft (48m)	Multi-column GBS	Dry trees, offshore primary separation, and FWS pipelines to shore	50 MBOPD 1,800 MMSCFD	27	N/A	Pipelines	●			Pipeline burial in water depth less than 30 m
6	Sakhalin III - Kirinskoye Development	Gazprom	Kirinskoye field ABC1+C2	Semi-submerible floaters and/or jack-up drilling rigs	2014	Sea of Okhotsk, Sakhalin Island, Russia	300 ft (90m)	Subsea equipment	Subsea trees and 17 mile (27.5 km) tie-back to shore	435 MMSCFD	6	N/A	Pipelines	●			Pipeline burial in water depth less than 30 m
7	Sakhalin II Prigorodnoye (LNG & Oil Export Terminal)	Sakhalin Energy	Piltun-Astokhskoye, Lunskoye	N/A	2009	Aniva Bay, Sea of Japan, Sakhalin Island, Russia	66 ft (20 m)	Onshore LNG plant, LNG tanker loading dock, oil tanker SPM	Overland pipelines	9.6 million tons LNG per year	N/A	1,200 MBO & 7,000,000 cubic ft LNG storage	LNG tanker loading jetty & Oil Tanker Loading Unit (tower)	●			Pipeline burial
8	Sakhalin I - De-Kastri (Oil Export Terminal)	Exxon Neftegaz	Chayvo, Odopto, Arkutun Dagi	N/A	2006	Tatar Strait, Sakhalin Island, Russia	72 ft (22 m)	Ice resistant, SPM loading tower	48-inch (1.2 m), 3 mile (5.6 km) subsea pipeline	250 MBOPD	N/A	1,300 MBO	SPM tower loading of double hull tankers	●			Pipeline burial
	BOHAI BAY, CHINA																
9	Bohai Bay Area Developments	Various	---	Various	1999	Bohai Bay of South China Sea, China	279 ft max 66 ft average (85m max) (20m average)	Open-legged platforms and monopile platforms, some with ice cones	Dry trees and pipelines to shore	---	Var-ies	N/A	Pipelines to shore	○			Pipeline burial
	PECHORA SEA, RUSSIA																
10	Varandey (Oil Export Terminal)	Lukoil/ ConocoPhillips	Yuzhno Khylchuyu	Onshore wells	2008	Pechora Sea Shelf, Pechora Sea	56 ft (17 m)	Steel piled loading structure with loading arm	2 x 32-inch (50 x 812 mm), 13.7 mile (22 km) subsea pipelines	240 MBOPD	N/A	2,044 MBO	Icebreaking (double-acting) shuttle tankers to FSO at Murmansk	●	○		Pipeline burial
11	Prirazlomnoye	Sevmorneftegaz	Prirazlomnoye	Not Published	2014	Pechora Sea Shelf, Pechora Sea	62 ft to 66 ft (19m to 20 m)	Block-type GBS	Dry trees and crane boom loading arms	120 MBOPD	40	710 MBO	Offloading - GBS to ice-strengthened shuttle tankers	●	○		GBS
	NORTH CASPIAN SEA, KAZAKHSTAN																
12	Kashagan	North Caspian Operating Company	Kashagan	6,000 tones ice-resistant Sunkar barge	2013	North Caspian Sea, Kazakhstan	10 ft - 20 ft (3m - 6m)	Rock-filled, sheetpile cofferdam island and gravel island production sites and satellite drillsites	Dry trees, FWS flowlines to offshore processing facilities, oil export pipeline to shore	1,500 MBOPD	---	N/A	Pipelines	●			Pipeline burial
	BARENTS SEA, RUSSIA																
13	Shtokman	Shtokman Development AG	Shtokman Phase 1, 2 and 3	Deepsea Delta semi-submersible drilling unit	2022	Barents Sea Shelf, Barents Sea	1,050 ft to 1,115 ft (320m to 340m)	FPSO	Subsea trees, flexible risers & pipeline export to shore	6,800 MMSCFD	88	N/A	Pipelines	○		●	Ice management vessels & pipeline burial in shallow water section of export route
	BARENTS SEA, NORWAY																
14	Goliat	Eni Norge AS	Kobbe & Realgrunnen	Eirik Raude semi-submersible drilling unit	Q3, 2014	Norwegian Barents Sea	1,312 ft (400m)	Sevan 1000 FPSO	Subsea trees and flexible risers	100 MBOPD	22	1,000 MBO	Offloading - FPSO to shuttle tankers				N/A
15	Snohvit	Statoil	Snohvit 3, Albatross, & Askeladd	West Vanguard semi-submersible drilling unit	2007	Norwegian Barents Sea	820 ft to 1,132 ft (250m to 345m)	Subsea tie-back to shore	Subsea trees & pipelines to shore	1,643 MMSCFD 15 MBCPD 7 MBPD LPG	21	N/A	Pipelines to shore				N/A
	BALTIC SEA, RUSSIA																
16	Kravtsovskoye D-6	Lukoil	Kravtsovskoye	Not Published	2004	Baltic Sea Shelf, Baltic Sea	82 ft to 115 ft (25m to 35 m)	2 each-Open leg jacket platforms	Dry trees and pipeline export to shore	0.6 million tonnes oil per year	27	N/A	Pipelines	●			Pipeline burial in shallow water
	GRAND BANKS, EAST COAST CANADA																
17	White Rose	Husky Energy	Jeanne d'Arc Basin - White Rose, North Amethyst, South WR Ext, West WR Ext	Sedco 706 semi-submersible	2005	Grand Banks, Newfoundland, Canada	403 ft (122m)	FPSO	Subsea wells & flexible flowlines/risers	120 MBOPD	22	700 - 850 MBO	Tandem offloading - FPSO to ice-strengthened shuttle tankers	○		●	Glory holes, iceberg management & sacrificial, quick-disconnect flowlines
18	Terra Nova	Petro Canada	Jeanne d'Arc Basin - Graben & East Flank	Sedco 710 semi-submersible	2002	Grand Banks, Newfoundland, Canada	295 ft - 328 ft (90m - 100m)	FPSO	Subsea wells & flexible flowlines/risers	150 MBOPD	36	960 MBO	Tandem offloading - FPSO to ice-strengthened shuttle tankers	○		●	Glory holes, iceberg management & sacrificial, quick-disconnect flowlines
19	Hebron	ExxonMobil	Jeanne d'Arc Basin - Hebron, West Ben Nevis, & Ben Nevis	Sedco 706 semi-submersible	2017	Grand Banks, Newfoundland, Canada	312 ft (95m)	Block-type GBS	Dry trees and OLS	150 MBOPD	52	1,450 MBO	Offloading - GBS to ice-strengthened shuttle tankers	○		●	Iceberg management & sacrificial, quick-disconnect OLS pipelines
20	Hibernia	Hibernia Management & Development Company (HMDC)/ ExxonMobil	Jeanne d'Arc Basin - Hibernia & Ben Nevis-Avalon	Glomar Atlantic drillship	1997	Grand Banks, Newfoundland, Canada	262 ft (80m)	Block-type GBS	Dry prodution trees, planned subsea water injection wells and flexible flowlines/risers, and OLS	220 MBOPD	80	1,300 MBO	Offloading - GBS to ice-strengthened shuttle tankers	○		●	Iceberg management & sacrificial, quick-disconnect OLS pipelines & WI flowlines and planned WI well glory holes
	LABRADOR, EAST COAST CANADA																
21	Bjarni/ North Bjarni	Suncor	Bjarni/ North Bjarni	Pelican (Drill Ship)	2019	Labrador Shelf	459 ft - 492 ft (140m - 150m)	TBD	TBD	---	---	---	TBD	●		●	---
	ARCTIC ISLANDS, CANADA																
22	Bent Horn (Oil Export Terminal)	Panarctic Oils	Bent Horn	Onshore wells	1985 through 1996	Cameron Island, Canada	N/A	Onshore oil production with summer tanker loading terminal	N/A	0.55 MBOPD	N/A	Onshore crude oil storage tank	Flexible hose to icebreaking tanker MV Arctic	●	●		N/A
23	Drake Point	Suncor	Drake Point, Hecla	Floating winter ice pad	TBD	Melville Island, Canada	180 ft (55 m)	Subsea equipment	Subsea trees & pipelines to shore	---	---	---	---	●	●		---
	BEAUFORT SEA, CANADA																
24	Amauligak	ConocoPhillips	Amauligak	Kulluk floating drilling platform (cone-shaped) & Mobil Arctic Caisson (MAC) "Molikpaq"	TBD	Canadian Beaufort Sea	87 ft (26.5m) to 105 ft (32m)	TBD	TBD	---	---	---	---	●	●		---
25	Tarsuit	Gulf Canada	Tarsuit	Concrete Caisson (Tarsuit Island) & Mobil Arctic Caisson (MAC) "MolikPaq"	TBD	Canadian Beaufort Sea	69 ft (21m)	---	---	---	---	---	---	●	●		---
	BEAUFORT SEA, ALASKA																
26	Sivulliq	Shell (Expired UNOCAL Lease)	Sivulliq	Kulluk floating drilling platform , Global CIDS (UNOCAL Hammerhead)	TBD	Beaufort Sea, North Slope Alaska	110 ft (34m)	Conical-type GBS	Dry trees, offshore processing, and oil pipeline export to shore	---	---	N/A	Pipelines	●	●		---
27	Kuvlum	Shell (expired ARCO Alaska lease)	Kuvlum	Beaudrill Kulluk drilling platform, cone-shaped	TBD	Beaufort Sea, North Slope Alaska	110 ft (34m)	TBD	---	---	---	---	Pipelines	●	●		---
28	Liberty	BP Exploration Alaska	Liberty	Gravel Island (Shell Tern Island)	TBD	Beaufort Sea, North Slope Alaska	20 ft (6m)	Gravel Island	TBD	---	TBD	N/A	Pipelines	●	●		N/A
29	Endicott	BP Exploration Alaska	Endicott	Winter ice pad	1987	Beaufort Sea, North Slope Alaska	14 ft (4.3m)	Gravel island connected to shore by a causeway	Dry trees, offshore processing, and export oil pipeline to shore	115 MBOPD	101	N/A	Pipelines	●	●		Gravel causeway
30	Northstar	BP Exploration Alaska	Northstar	Gravel island (Shell Seal Island)	2001	Beaufort Sea, North Slope Alaska	38 ft (12m)	Gravel island w/concrete mat & rock armor	Dry trees, offshore processing, and oil pipeline export to shore	80 MBOPD	36	N/A	Pipelines	●	●		Pipeline burial
31	Nikaitchuq	Eni Petroleum	Nikaitchuq	Winter ice pad	2011	Beaufort Sea, North Slope Alaska	7 ft (2m)	Gravel island w/gravel bag armor	Dry trees and FWS pipeline export to shore	28 MBOPD	52-80	N/A	Pipelines	●	●		Pipeline burial
32	Ooguruk (4)	Pioneer Natural Resources (4)	Ooguruk	Winter ice pad	2008	Beaufort Sea, North Slope Alaska	5 ft (2m)	Gravel island w/ gravel bag armor	Dry trees and FWS pipeline export to shore	20 MBOPD	40	N/A	Pipelines	●	●		Pipeline burial
	COOK INLET, ALASKA																
33	Cook Inlet Area Developments	UNOCAL, Cross Timbers, ConocoPhillips, Forest Oil, Shell	Granite Point, McArthur River, North Cook Inlet, Redoubt Shoal, Middle Ground Shoals, Trading Bay	Ocean Ranger semi-submersible; jack-up rigs	1958-2000	Cook Inlet, Alaska	45 to 183 ft (14 to 56m)	16 each, Large diameter, 4-leg platforms + 1 each monopod platform	Dry trees and pipeline export to shore	20 MBOPD 570 MMSCFD	Var-ies	N/A	Pipelines	●			J-tubes in platform jackets
	CHUKCHI SEA, ALASKA																
34	Burger	Shell & Western E&P Inc.	Burger	Nobel Discoverer Drillship	TBD	Chukchi Sea Alaska	131 to 164 ft (40 to 50m)	TBD	TBD	---	---	---	TBD	●	●		TBD

(---) Information Not Available (N/A) Not Applicable (TBD) To Be Determined ○ Moderate Ice Conditions ● More Significant Ice Conditions

Notes: 1) See Map 1 for Locations of the Facilities and Terminals 2) Location numbers highlighted in red indicate an available photo shown to the upper left 3) Platform concept has not been selected but FPSO is most likey 4) Ooguruk Assets are in the process of being sold to Caelus Energy Alaska

CHART 1 – ARCTIC DEVELOPMENT CONCEPTS WATER DEPTH RATINGS

COURTESY OF INTECSEA WorleyParsons Group



Note: 1) Limited by total distance drilled

TABLE 5 – EXPLORATION & FIELD DEVELOPMENT CONCEPTS

COURTESY OF INTECSEA WorleyParsons Group

Note: 1) May be technically feasible by avoiding iceberg impact through ice management or emergency disconnection procedures

LEGEND: ● (green) Field Proven; ● (yellow) Conceptual and/or Considered Technically Feasible; ● (red) Not Considered Technically Feasible

1.0 BOTTOM FOUNDED STRUCTURES

	1.1 ICE ISLAND	1.2 ROCK/GRAVEL/ SAND ISLAND	1.3 BALLASTED BARGE/VESSEL	1.4 BALLASTED BARGE/ VESSEL + BERM	1.5 PILED BARGE	1.6 CAISSON RETAINED ISLAND	1.7 CONCRETE GBS	1.8 STEEL GBS
Courtesy	Courtesy of: Repsol Alaska	Courtesy of: BP Alaska	Courtesy of: BOEM	Courtesy of: Canadian Marine Drilling Ltd.	Courtesy of: Parker Drilling	Courtesy of: Sakhalin Energy	Courtesy of HMDC	Courtesy of: CJK Engineering Ltd
ICE ENVIRONMENT								
First Year Ice	Green	Green	Green	Green	Green	Green	Green	Green
Multi-Year Ice	Yellow	Green	Green	Green	Green	Green	Green	Green
Icebergs	Red	Green	Red	Red	Red	Yellow	Green	Green

2.0 FIXED JACKET/MOBILE JACK-UP and 3.0 FLOATING STRUCTURES

	2.1 MOBILE OFFSHORE PRODUCTION UNIT (MOPU)	2.2 JACKET	2.3 MONOPOD	3.1 FPSO (SHIP SHAPED) (TERRA NOVA)	3.2 FPSO (ROUND SHAPED)	3.3 SEMI - SUBMERSIBLE	3.4 TENSION LEG PLATFORM	3.5 SPAR
Courtesy	Courtesy of: GustoMSC	Courtesy of: Government of Alaska, Div. of Oil & Gas	Courtesy of: Cook Inlet RCAC	Courtesy of: Suncor	Courtesy of: Sevan Marine ASA	Courtesy of: SBM Offshore	Courtesy of: CJK Engineering Ltd.	Courtesy of: Technip
ICE ENVIRONMENT								
First Year Ice	Green	Green	Green	Green	Green	Green	Green	Yellow
Multi-Year Ice	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow
Icebergs	Yellow (1)	Red	Red	Yellow (1)	Yellow (1)	Yellow (1)	Yellow	Yellow (1)

4.0 SUBSEA FACILITIES and 5.0 OTHER

	4.1 ALL SUBSEA (SS TIEBACK TO BEACH)	4.1 INSULATED FLOWLINES & BREAK-AWAY COUPLINGS	4.2 TRENCHED & BURIED PIPELINE	4.3 SUBSEA (GLORY HOLE)	4.4 SINGLE SUBSEA WELLHEAD PROTECTIVE STRUCTURE	4.4 MULTIPLE SUBSEA WELLHEAD PROTECTIVE STRUCTURE	4.5 SUBSEA DRILL RIG	5.1 EXTENDED REACH DRILLING FROM LAND
Courtesy	Courtesy of: FMC Technologies	Courtesy of: FMC Technologies	Courtesy of: INTECSEA	Courtesy of: INTECSEA	Courtesy of: SPT Offshore	Courtesy of: FMC Technologies	Courtesy of: Seabed Rig AS	Courtesy of: INTECSEA
ICE ENVIRONMENT								
First Year Ice	Yellow	Green	Green	Green	Yellow	Yellow	Yellow	Green
Multi-Year Ice	Yellow	Green	Green	Green	Yellow	Yellow	Yellow	Green
Icebergs	Yellow	Green	Green	Green	Yellow	Yellow	Yellow	Green