2011 SURVEY OF ARCTIC & COLD REGION TECHNOLOGY FOR OFFSHORE FIELD DEVELOPMENT

CHALLENGES & SOLUTIONS

FEBRUARY 2011

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INTECSEA WorleyParsons Group

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TABLE 6 – INDUSTRY ACRONYMS & ABBREVIATIONS

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

EXTENT OF ARCTIC SEA ICE (Figures 1, 2, and 3)

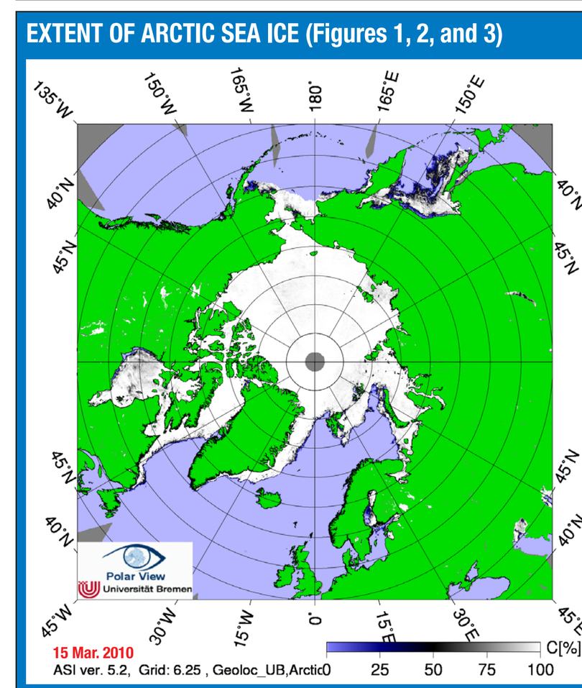


Fig. 1 – Maximum Ice Coverage (15 Mar. 2010)

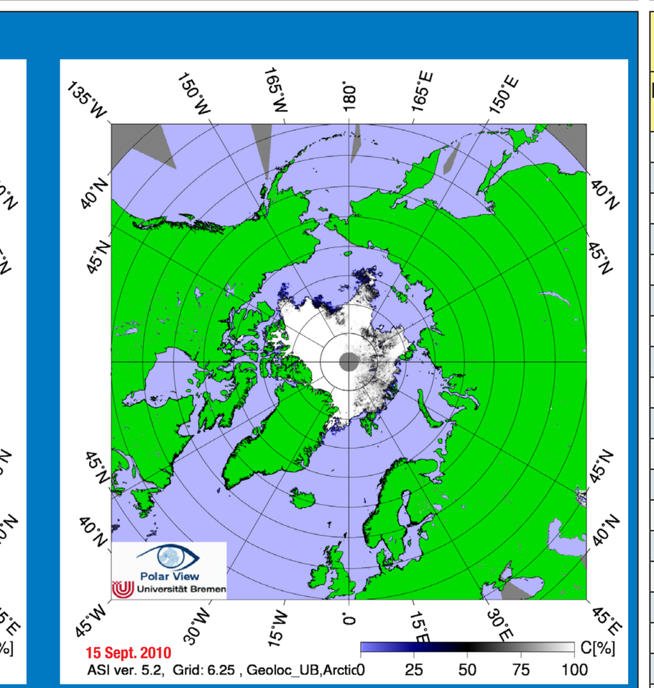


Fig. 2 – Minimum Ice Coverage (15 Sept. 2010)

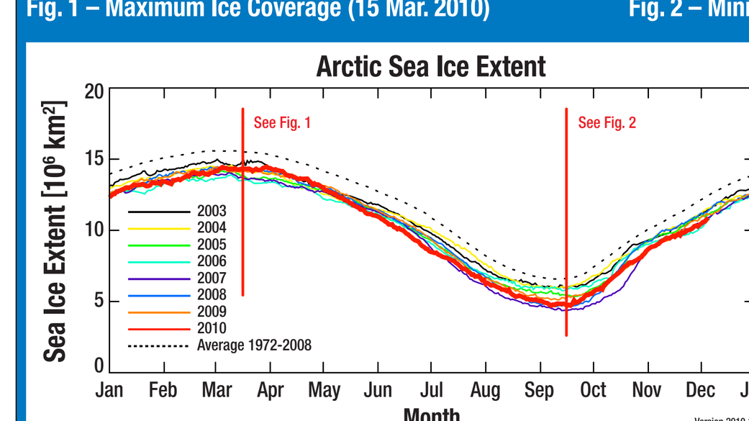


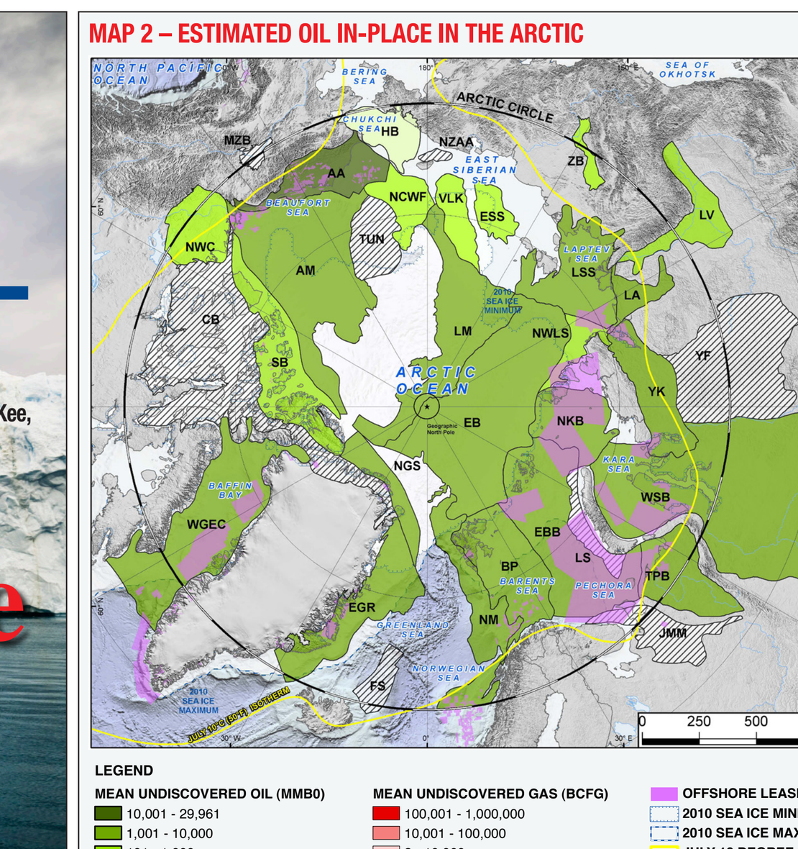
Fig. 3 – Arctic Annual Ice Coverage

SOURCE: Figures 1, 2, and 3: Courtesy of Institute of Environment Physics, University of Bremen

NOTES

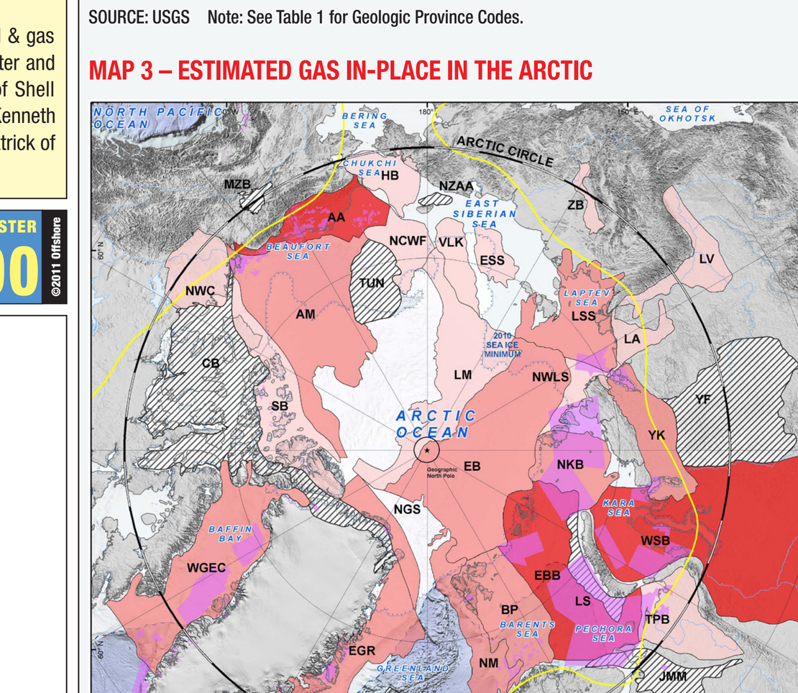
Figures 1 & 2 – The sea ice extent maps are based on data from AMSR-E (Advanced Microwave Scanning Radiometer-Earth Observing System, on NASA satellite Aqua). AMSR-E measures the microwave emission of the Earth's surface. Since the open ocean and the sea ice have different emission characteristics, the ice concentration can be derived. The ice concentration is shown on the maps, ranging from 0% (open water, shown in pale blue) to 100% (fully ice covered, shown in white); intermediate values are shown in shades of grey. The sea ice extent is defined as the total area with an ice concentration above 15%. **Figure 3** – This graph shows the time series of the daily Arctic sea ice extent since 2003. Each year is shown in a different color. The average annual cycle of the years 1972-2008 are shown as a black dashed line.

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



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

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

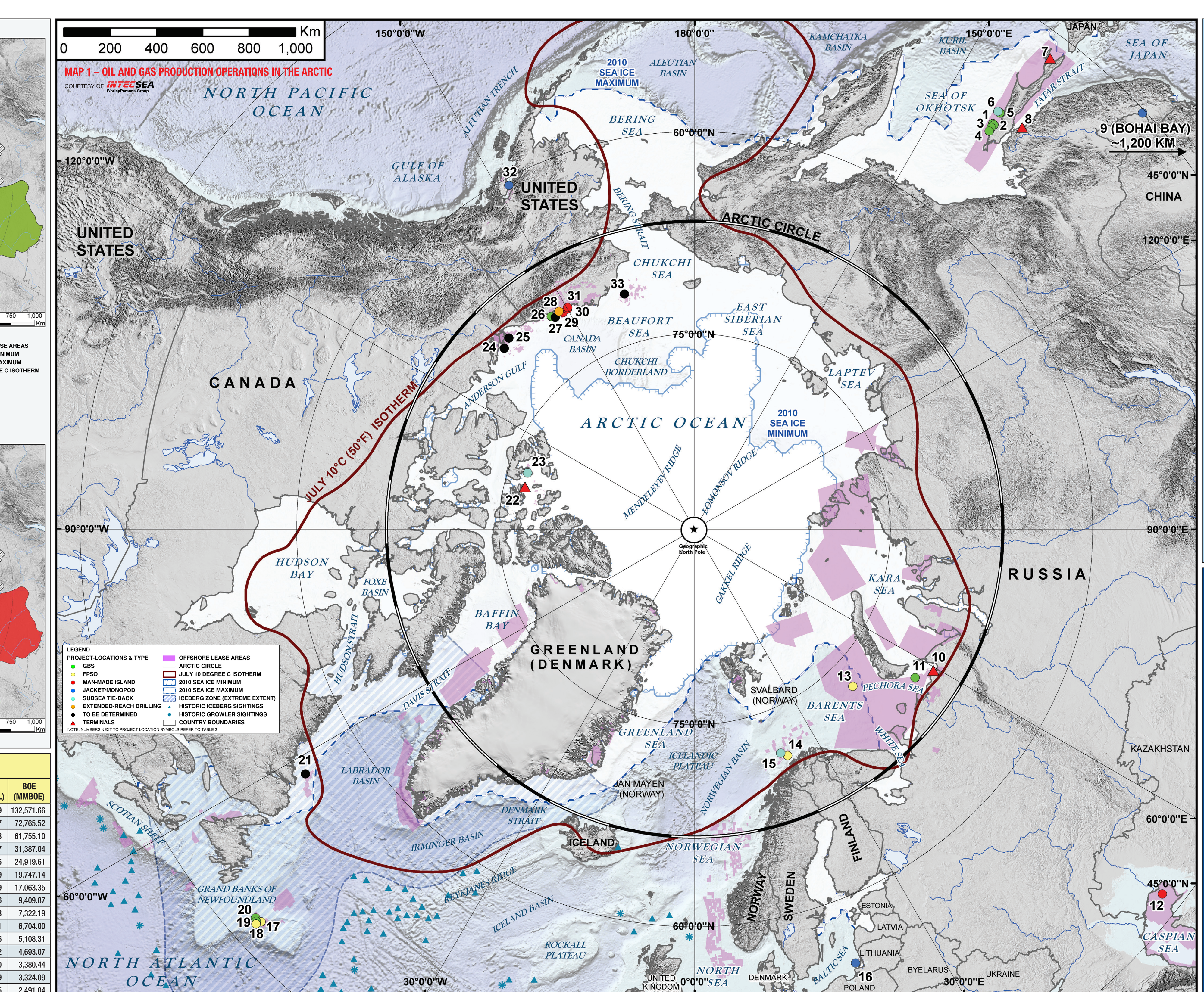
Sorted from largest to smallest prize in MMBOE for each geological province

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

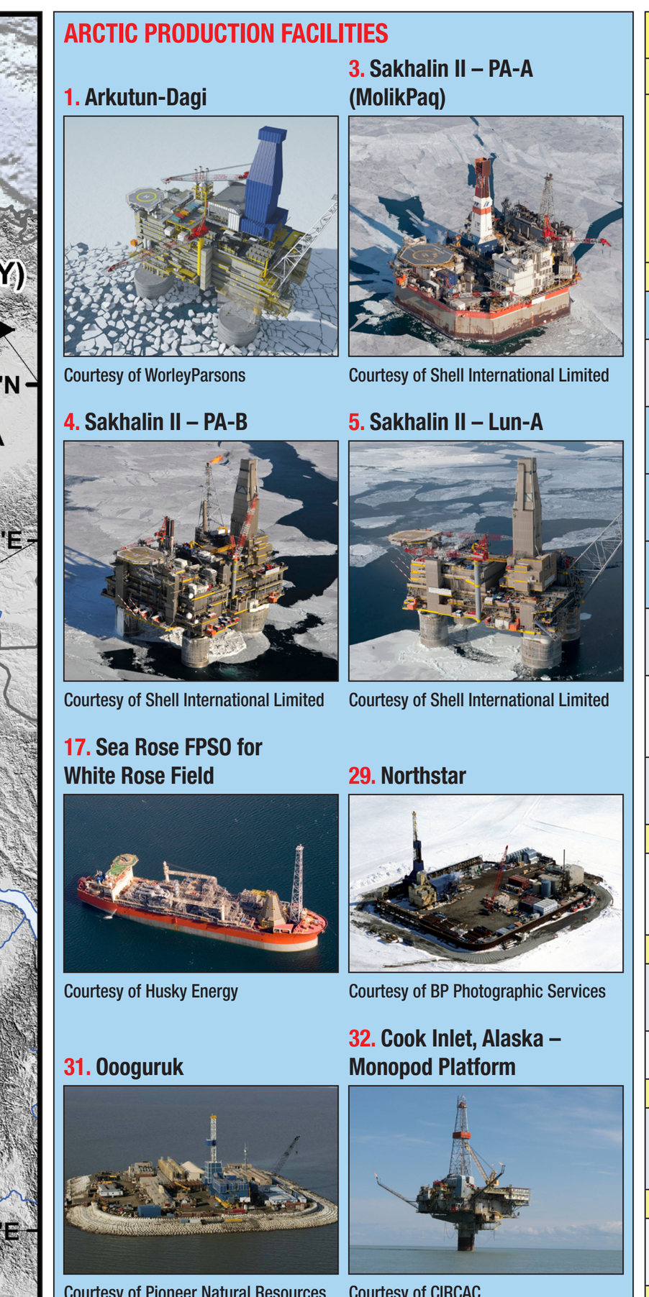
SOURCE: USGS (http://pubs.usgs.gov/fs/2008/3049/) Note: 1) NQA - Not Quantitatively Assessed

MAP 1 – OIL AND GAS PRODUCTION OPERATIONS IN THE ARCTIC

COURTESY OF INTECSEA WorleyParsons Group



ARCTIC PRODUCTION FACILITIES



1. Arkutun-Dagi – Courtesy of WorleyParsons
3. Sakhalin II – PA-A (MolikPaq) – Courtesy of Shell International Limited
4. Sakhalin II – PA-B – Courtesy of Shell International Limited
5. Sakhalin II – Lun-A – Courtesy of Shell International Limited
17. Sea Rose FPSO for White Rose Field – Courtesy of Husky Energy
29. Northstar – Courtesy of BP Photographic Services
31. Oooguruk – Courtesy of Pioneer Natural Resources
32. Cook Inlet, Alaska – Monopod Platform – Courtesy of CIRCAC

KEY CHALLENGES FOR ARCTIC TOPSIDES

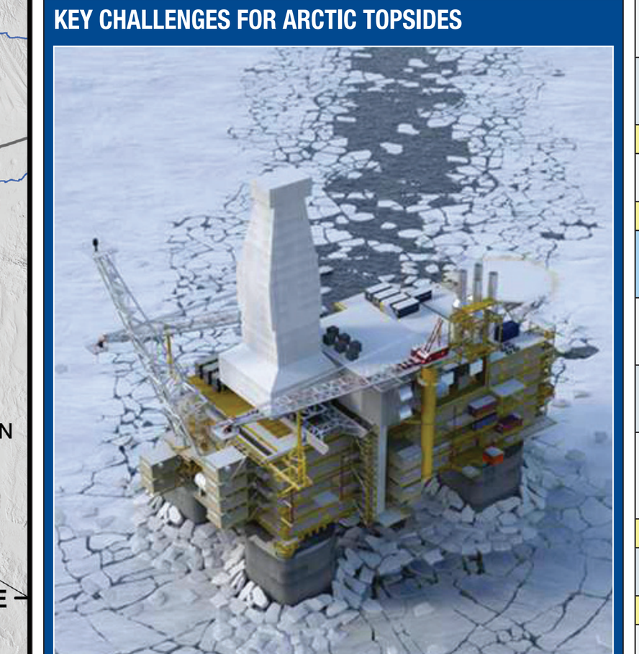


Fig 1. – Arkutun-Dagi Topsides Drilling and Production Platform on Frozen Sea of Okhotsk (see Loc. 1).

Image Courtesy of WorleyParsons

Engineering & Design
- Metocean, Seismic, Ice considerations
- Off-loading system interruptions, Emergency shutdown and Offshore supply strategy
- Extreme weather protection - Icing due to sea spray, Effective Winterization (insulation, heating, power demand)
- Weight management – Effect of Ice weight on Topsides and Sea Ice loads to be considered
- Ice compliant floatable escape and evacuation system
- Ice compliant disconnect and reconnect systems for FPSOs
- Environmentally compliant produced/drains water treatment and disposal

Construction
- Construction and commissioning issues using Topsides Floatover technique
- Offshore Operations Limitations for Construction Vessels
- Logistics – Handling and transport issues, Ice breakers
- Metallurgy and Interface management

Operation
- Operation in hostile environment
- Transportation of personnel to/from installation
- Harsh weather evacuation and safety systems for broken and fast ice
- Reliable, Available and Maintainable production facility in Icy conditions
- Platform Re-Supply logistics challenges

Courtesy of WorleyParsons

TABLE 2 – ARCTIC PRODUCTION FACILITIES AND TERMINALS

COURTESY OF INTECSEA WorleyParsons Group

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
	GENERAL PROJECT INFORMATION					LOCATION INFORMATION		DEVELOPMENT INFORMATION				STORAGE & EXPORT INFO.		ICE ENVIRONMENT			
SAKHALIN, RUSSIA																	
1	Arkutun-Dagi	Exxon Neftegaz	Arkutun Dagi	Sakhalinmorneftegas' OKHA drilling rig	2015	Sea of Okhotsk, Sakhalin Island, Russia	60 ft (18m)	Multi-column 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 - MolikPaq (PA-A)	Sakhalin Energy	Piltun Astoskhskoye	Semi-submerible floaters and/or jack-up drilling rigs	1999 Tanker, 2008 Pipeline	Sea of Okhotsk, Sakhalin Island, Russia	98 ft (30m)	Block-type 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 Astoskhskoye	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	TBD	---	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/Conoco Phillips	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	2,700 MBO	Icebreaking (double-acting) shuttle tankers to FSO at Murmansk	●	○		Pipeline burial
11	Prirazlomnoye	Sevmorneftegaz	Prirazlomnoye	Not Published	2011	Pechora Sea Shelf, Pechora Sea	62 ft to 66 ft (19m to 20 m)	Block-type GBS	Dry trees and crane boom loading arms	100 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	2014	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	Sevmorneftegas, Gazprom, Total, Statoil Hydro	Shtokman	Deepsea Delta semi-submersible drilling unit	2016	Barents Sea Shelf, Barents Sea	1,050 ft to 1,115 ft (320m to 340m)	FPSO/SPAR	Subsea trees, dry trees & pipeline export to shore	2,300 MMSCFD	156	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	2013	Norwegian Barents Sea	1,119 ft (341m)	Sevan 1000 FPSO	Subsea trees and flexible risers	94 MBOPD	22	---	Offloading - FPSO to shuttle tankers				N/A
15	Snohvit	Statoil	Snohvit 3, Albatross, & Askeladd	West Vanguard semi-submersible drilling unit	2006	Norwegian Barents Sea	820 ft to 1,132 ft (250m to 345m)	Subsea tie-back to shore	Subsea trees & pipelines to shore	556 MMSCFD 15 MBCPD 5 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	---	27	N/A	Pipelines	●			Pipeline burial in shallow water
GRAND BANKS, EAST COAST CANADA																	
17	White Rose	Husky Energy	Jeanne d'Arc Basin - South Avalon Pool	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	266 ft - 295 ft (90m - 100m)	FPSO	Subsea wells & flexible flowlines/risers	150 MBOPD	44	900 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	1.5 - 1.9 MMBO	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	64	1.3 MMBO	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)	TBD	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	BeauDril Kulluk drillship (cone-shaped drillship)/ & Mobil Arctic Caisson (MAC) "Molikpaq"	TBD	Canadian Beaufort Sea	87ft (26.5m) to 105ft (32m)	---	---	---	---	---	---	●	●		---
25	Tarsuit	Gulf Canada	Tarsuit	Concrete Caisson (Tarsiut Island) & Mobil Arctic Caisson (MAC) "Molikpaq"	TBD	Canadian Beaufort Sea	69ft (21m)	---	---	---	---	---	---	●	●		---
BEAUFORT SEA, ALASKA																	
26	Sivulliq	Shell (Expired UNOCAL Lease)	Sivulliq	Shell Frontier Discoverer drillship, 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	BeauDril Kulluk drillship, cone-shaped drillship	TBD	Beaufort Sea, North Slope Alaska	110 ft (34m)	TBD	---	---	---	---	Pipelines	●	●		---
28	Liberty	BP Exploration Alaska	Liberty	Gravel Island (Shell Tern Island)	2011 / TBD	Beaufort Sea, North Slope Alaska	20 ft (6m)	"Ultra" extended reach drilling from Endicott causeway	Dry trees, existing offshore processing and pipeline	---	6	N/A	Pipelines	●	●		N/A
29	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
30	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	26 MBOPD	52-80	N/A	Pipelines	●	●		Pipeline burial
31	Oooguruk	Pioneer Natural Resources	Oooguruk	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																	
32	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																	
33	Burger	Shell & Western E&P Inc.	Burger	Explorer III 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

CHART 2 – ICE COVERAGE BY REGION

(Arctic & Northern Hemisphere Cold Climates, Excluding the Southern Ocean Around Antarctica)

LEGEND: Winter Ice Cover; Open Water; Potential for Ice Cover or Open Water depending on severity of winter from year to year; Winter Ice Cover with Polynya; Arrows represent iceberg information, only

COURTESY OF INTECSEA WorleyParsons Group

REGION	MONTH (JAN. – DEC.)
RUSSIA	
1 East Siberian Sea	Winter Ice – Winter Ice
2 Sea of Okhotsk	Winter Ice – Open Water
3 Tatar Strait	Winter Ice – Open Water
4 Laptev Sea	Winter Ice – E. Polynya – Icebergs – Winter Ice
5 Kara Sea	Winter Ice – Icebergs
6 Pechora Sea	Winter Ice – Iceberg Potential – Open Water
7 Barents Sea	Icebergs – Open Water
8 White Sea	Open Water
9 Baltic Sea & Gulf of Finland	Winter Ice – Open Water
RUSSIA/UKRAINE	
1 Sea of Azov	Winter Ice – Open Water
CHINA	
1 Bohai Bay	Winter Ice – Open Water
CASPIAN SEA	
1 North Caspian Sea	Winter Ice – Open Water – Winter Ice
NORWAY	
1 Western Barents Sea	Open Water – Icebergs
2 Norwegian Sea	Open Water
EASTERN GREENLAND	
1 Greenland Sea	Winter Ice – Icebergs – Winter Ice
2 Denmark Strait	Winter Ice – Open Water – Winter Ice
WESTERN GREENLAND	
1 Western Labrador Sea	Icebergs – Open Water
2 Davis Strait	Winter Ice – Icebergs – Open Water – Winter Ice
3 Baffin Bay	Winter Ice – Open Water
EASTERN CANADA	
1 Grand Banks	Icebergs (Highest Concentration) – Open Water
2 North Atlantic	Icebergs (Highest Concentration)
3 Canadian High Arctic	Winter Ice – Icebergs – Winter Ice
ALASKA AND NORTHWESTERN CANADA	
1 Beaufort Sea (CAN)	Winter Ice – Open Water – Winter Ice
2 Beaufort Sea (US)	Winter Ice – Open Water – Winter Ice
3 Cook Inlet	Winter Ice – Open Water – Winter Ice
4 Chukchi Sea (US)	Winter Ice – Near-Shore Polynya – Open Water – Winter Ice
5 Bering Sea	Winter Ice – Open Water – Winter Ice

Notes: 1) Arctic Ocean info omitted for clarity. Peripheral oceans and seas are included. 2) Refer to Table 2 for project-specific ice conditions.

OIL & GAS EXPORT SOLUTIONS FOR THE ARCTIC

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. Stern working double acting shuttle tankers 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.

TABLE 7 – LISTING OF ARCTIC RATED SHUTTLE TANKERS

	VESSEL NAME	SERVICE	DEADWEIGHT TONNAGE	ICE CAPABILITY m	CLASS	ICE CLASS(3)	YEAR BUILT	BUILDER	CONCEPT DESIGN	BOW LOADING
1	BOZDAG		19,800	0.5	RMRS	Arc 5 (UL)	2002	AS(1)	AS	APL SAL
2	GINALDAG		19,800	0.5	RMRS	Arc 5 (UL)	2002	AS	AS	APL SAL
3	TEMPERA	Primorsk - Finland	106,000	1.0	LR	1ASuper	2002	SHI(1)	Aker Arctic	none
4	MASTERA	Primorsk - Finland	106,000	1.0	LR	1ASuper	2003	SHI	Aker Arctic	none
5	VASILY DINKOV	Varandei - Murmansk	70,000	1.5	RMRS	Arc 6	2008	SHI	Aker Arctic	Aker Pusnes
6	KAPITAN GOTSKY	Varandei - Murmansk	70,000	1.5	RMRS	Arc 6	2008	SHI	Aker Arctic	Aker Pusnes
7	TIMOFEY GUZHENKO	Varandei - Murmansk	70,000	1.5	RMRS	Arc 6	2009	SHI	Aker Arctic	Aker Pusnes
8	MIKHAIL ULYANOV	Prirazlomnoye - Murmansk	70,000	1.3	RMRS	Arc 6	2010	AS	Aker Arctic	Aker Pusnes
9	KIRILL LAVROV	Prirazlomnoye - Murmansk	70,000	1.3	RMRS	Arc 6	2010	AS	Aker Arctic	Aker Pusnes

Courtesy of Aker Arctic Technology Inc. Notes: 1) SHI-Samsung Heavy Industries 2) AS-Admiralty Shipyards 3) For Ice Class by Classification Societies: www.bsis-ice.de/material/table_iceclasses.pdf

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

Courtesy of Aker Arctic Technology Inc.

Fig. 2 – Proposed Aker Arctic DAS™ Arctic LNG Carrier (200,000 m³) Using the Stern Working Principal

Courtesy of Aker Arctic Technology Inc.

Fig. 3 – Sakhalin Gas Export via LNG Transport Ship

Courtesy of Shell International Limited

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)); 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
BOTTOM FOUNDED STRUCTURES																													
1 Ice Island	G	NO	NO	SEE CHART 1	SEE CHART 2	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
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
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
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
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
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
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
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
FIXED JACKET/MOBILE JACK-UP																													
1 Jack-up	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 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
3 Monopile	NO	G	NO			NO	NO	G	G	N/A	NO	G	G	NO	G	G	N/A	N/A	N/A	G	G	Y	R	G	R	R	R	G	Y
FLOATING STRUCTURES																													
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
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 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
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
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
SUBSEA FACILITIES																													
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
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
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 Subsea (Caisson)	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
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
OTHER																													
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

TABLE 4 – FIELD DEVELOPMENT CHALLENGES AND SOLUTIONS

COURTESY OF INTECSEA WorleyParsons Group

Notes:
1) "2010 Worldwide Survey of Subsea Processing: Separation, Compression, and Pumping Systems", March 2010, INTECSEA Inc., Offshore Magazine, Available Online (www.offshore-mag.com).

2) Floaters may be technically feasible by avoiding iceberg impact through ice management or emergency disconnection procedures.

SOLUTIONS: PLATFORM DESIGN – 1 Design for Ice Loads, 2 Disconnect & Avoidance, 3 Refrigerated Well Casing; ICE MANAGEMENT – 4 Use Ice Breakers, 5 Ice Monitoring, 6 Iceberg Towing; SUBSEA PROTECTION – 7 Glory Holes, 8 Steel Silo, 9 Protective Structure; PIPELINE DESIGN – 10 Trenching & Backfill, 11 Insulate, 12 Strain Based Design; CONSTRUCTION SOLUTIONS – 13 Early Regulatory and Permitting Planning, 14 Support Bases; OPERATIONAL SOLUTIONS – 15 Disconnect and Avoidance, 16 Subsea Processing (1), 17 Automation, 18 Multiple Drill Rigs, 19 EER Research & Development, 20 Development of Under Ice Inspection Technologies

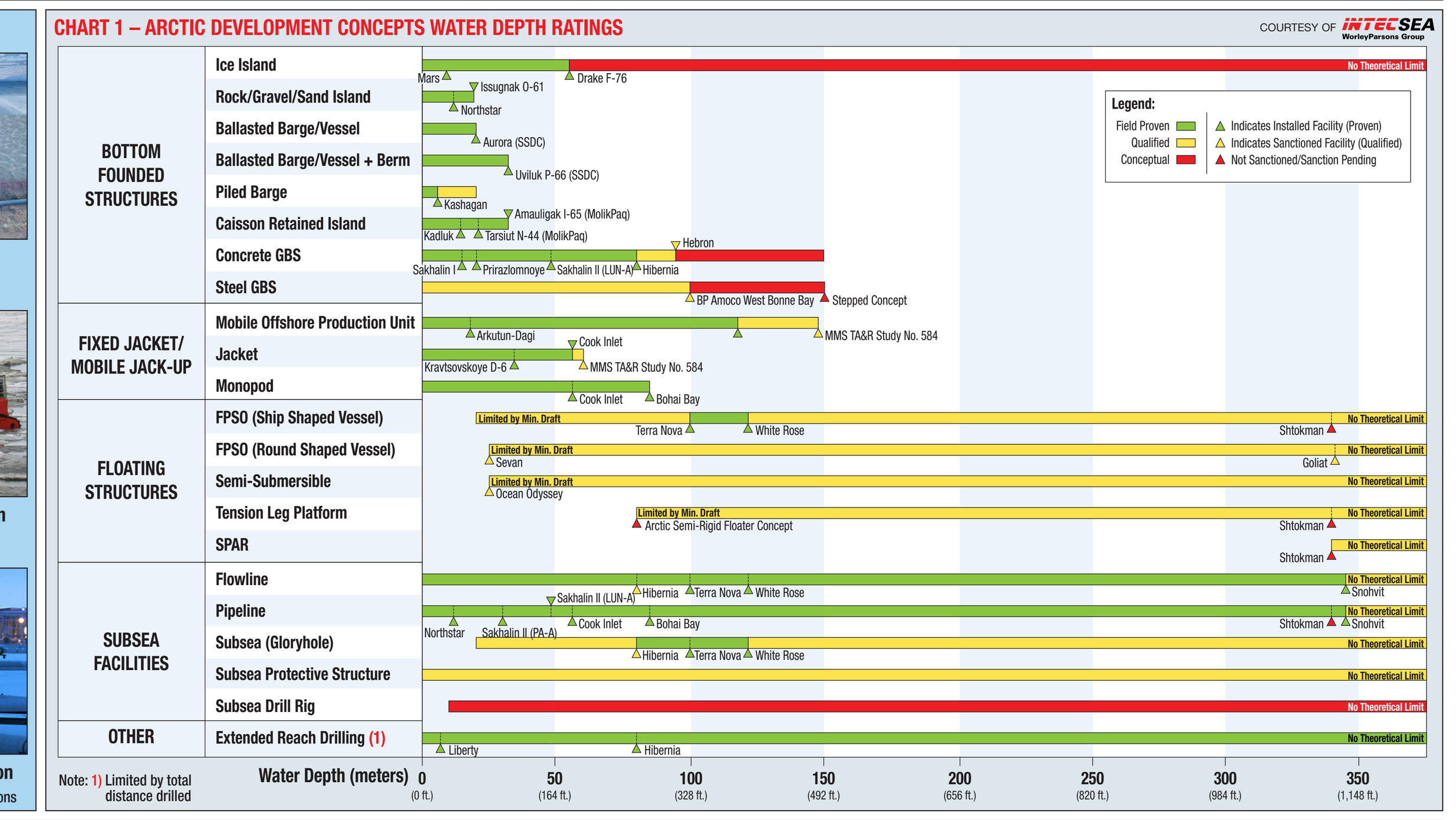
CHALLENGES		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ICE CONDITIONS	1 First Year Ice	●	●		●	●		●	●	●											
	2 Multi-Year Ice	●	●		●	●		●	●	●						●					
	3 Icebergs	●	●(2)		●	●	●	●	●	●						●					
DESIGN ISSUES	4 Permafrost (Thaw Settlement)			●								●	●								
	5 Ice Gouge						●	●	●	●	●		●								
	6 Strudel Scour								●	●	●										
	7 Frost Heave										●	●	●								
	8 Upheaval Buckling										●		●								
CONSTRUCTION ISSUES	9 Regulatory and Permitting				●	●	●							●							
	10 Construction Season													●							
	11 Remote Location														●						
OPERATIONAL ISSUES	12 Long Distance Tiebacks																●				
	13 Relief Well Capabilities																		●		
	14 Escape, Evacuation and Rescue (EER)	●																		●	
	15 Inspection and Intervention																	●			●

CHALLENGES IN THE ARCTIC (See Table 4)

Fig. 1 – First Year Ice – Courtesy 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

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

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

COURTESY OF INTECSEA WorleyParsons Group

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

Group	Concept	Courtesy	First Year Ice	Multi-Year Ice	Icebergs
BOTTOM FOUNDED STRUCTURES	ICE ISLAND	Courtesy of: BOEMRE	Green	Green	Green
	ROCK/GRAVEL/ SAND ISLAND	Courtesy of: BP Photographic Services	Green	Green	Green
	BALLASTED BARGE/VESSEL	Courtesy of: BOEMRE	Green	Green	Red
	BALLASTED BARGE/ VESSEL + BERM	Courtesy of: Canadian Marine Drilling Ltd.	Green	Green	Red
	PILED BARGE	Courtesy of: Parker Drilling	Green	Green	Red
	CAISSON RETAINED ISLAND	Courtesy of: Shell International Ltd.	Green	Green	Yellow
	CONCRETE GBS	Courtesy of: Shell International Ltd.	Green	Green	Green
	STEEL GBS	Courtesy of: CJK Engineering Ltd.	Green	Green	Green
FIXED JACKET/MOBILE JACK-UP	MOBILE OFFSHORE PRODUCTION UNIT (MOPU)	Courtesy of: Encana Corp.	Green	Red	Yellow (1)
	JACKET	Courtesy of: Gov't of Alaska, Div. of Oil & Gas	Green	Red	Red
	MONOPOD	Courtesy of: CIRCAC	Green	Red	Red
FLOATING STRUCTURES	FPSO (SHIP SHAPED)	Courtesy of: Husky Energy	Green	Yellow	Yellow (1)
	FPSO (ROUND SHAPED)	Courtesy of: Sevan Marine ASA	Green	Yellow	Yellow (1)
	SEMI - SUBMERSIBLE	Courtesy of: SBM Atlantia, Inc.	Green	Yellow	Yellow (1)
	TENSION LEG PLATFORM	Courtesy of: CJK Engineering Ltd.	Yellow	Yellow	Yellow
	SPAR	Courtesy of: Technip	Yellow	Yellow	Yellow (1)
SUBSEA FACILITIES	ALL SUBSEA (SS TIEBACK TO BEACH)	Courtesy of: FMC Technologies	Green	Yellow	Yellow
	INSULATED FLOWLINES & BREAKAWAY COUPLINGS	Courtesy of: FMC Technologies	Green	Green	Green
	TRENCHED & BURIED PIPELINE	Courtesy of: BP Northstar	Green	Green	Green
	GLORY HOLE	Courtesy of: FMC Technologies	Green	Green	Green
	SINGLE SUBSEA WELLHEAD PROTECTIVE STRUCTURE	Courtesy of: SPT Offshore	Yellow	Yellow	Yellow
	MULTIPLE SUBSEA WELLHEAD PROTECTIVE STRUCTURE	Courtesy of: FMC Technologies	Yellow	Yellow	Yellow
	SUBSEA DILL RIG	Courtesy of: Seabed Rig AS	Yellow	Yellow	Yellow
OTHER	EXTENDED REACH DRILLING		Green	Green	Green