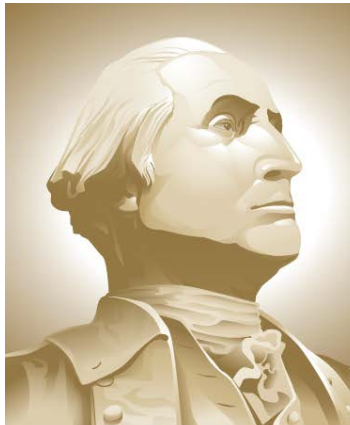


VTRA 2015 US-KM-CA-LN-348 Case and VTRA 2015 Base Case Comparison



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VCU

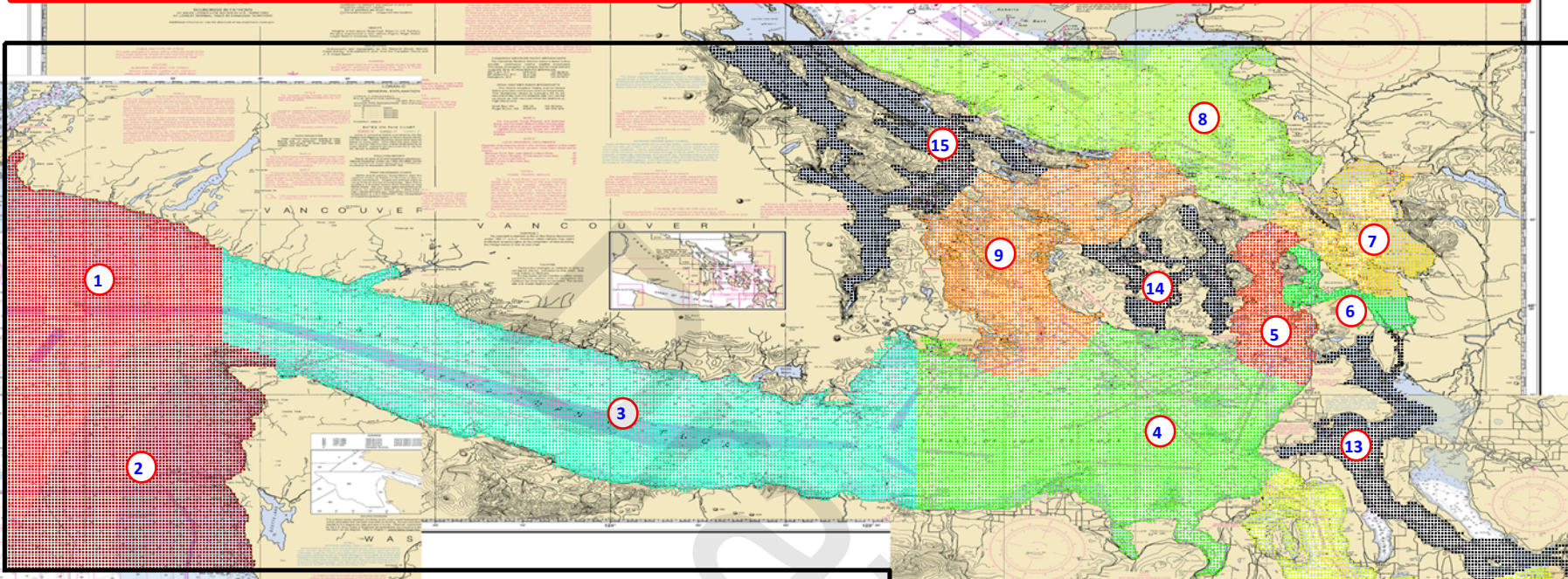
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

August 9th – 10th, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

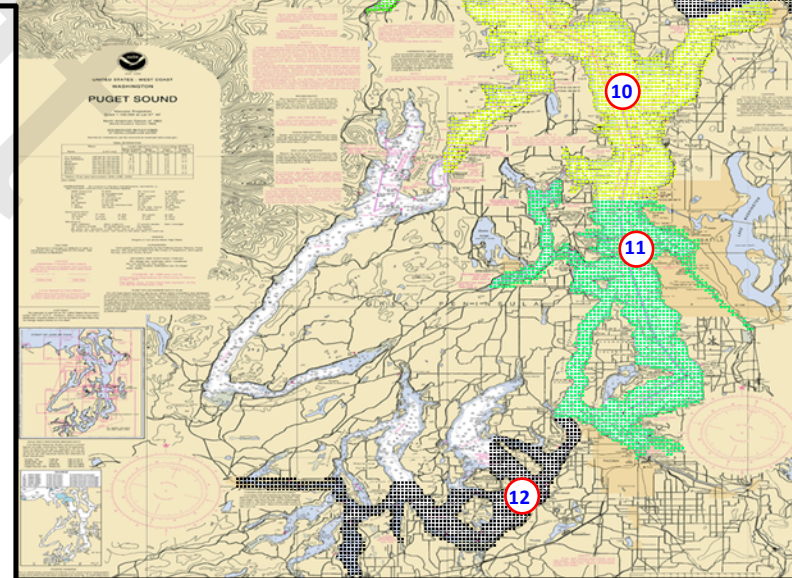


DEFINITION OF 15 WATERWAY ZONES

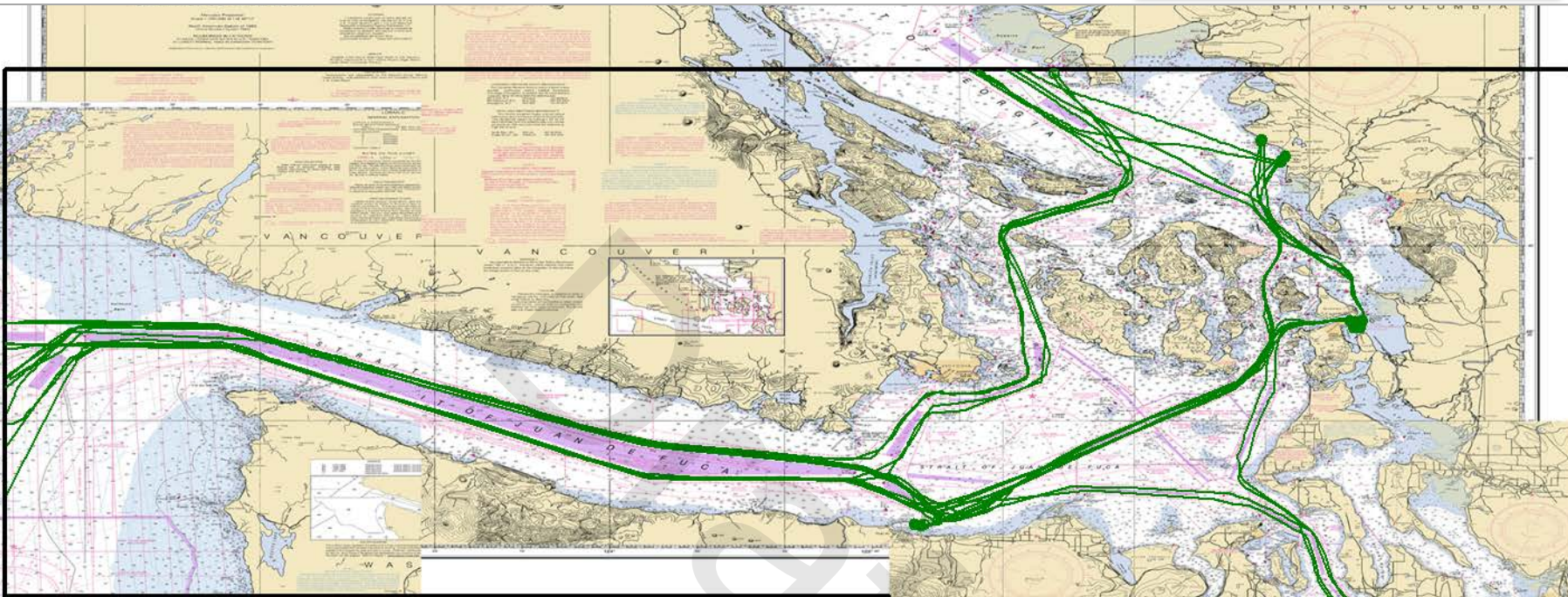


VTRA 2015 Waterway Zones

- | | |
|-----------------|---------------------------|
| 1. Buoy J | 9. Haro/Boun. |
| 2. ATBA | 10. PS North |
| 3. WSJF | 11. PS South |
| 4. ESJF | 12. Tacoma |
| 5. Rosario | 13. Sar/Skagit |
| 6. Guemes | 14. SJ Islands |
| 7. Saddlebag | 15. Southern Gulf Islands |
| 8. Georgia Str. | |



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



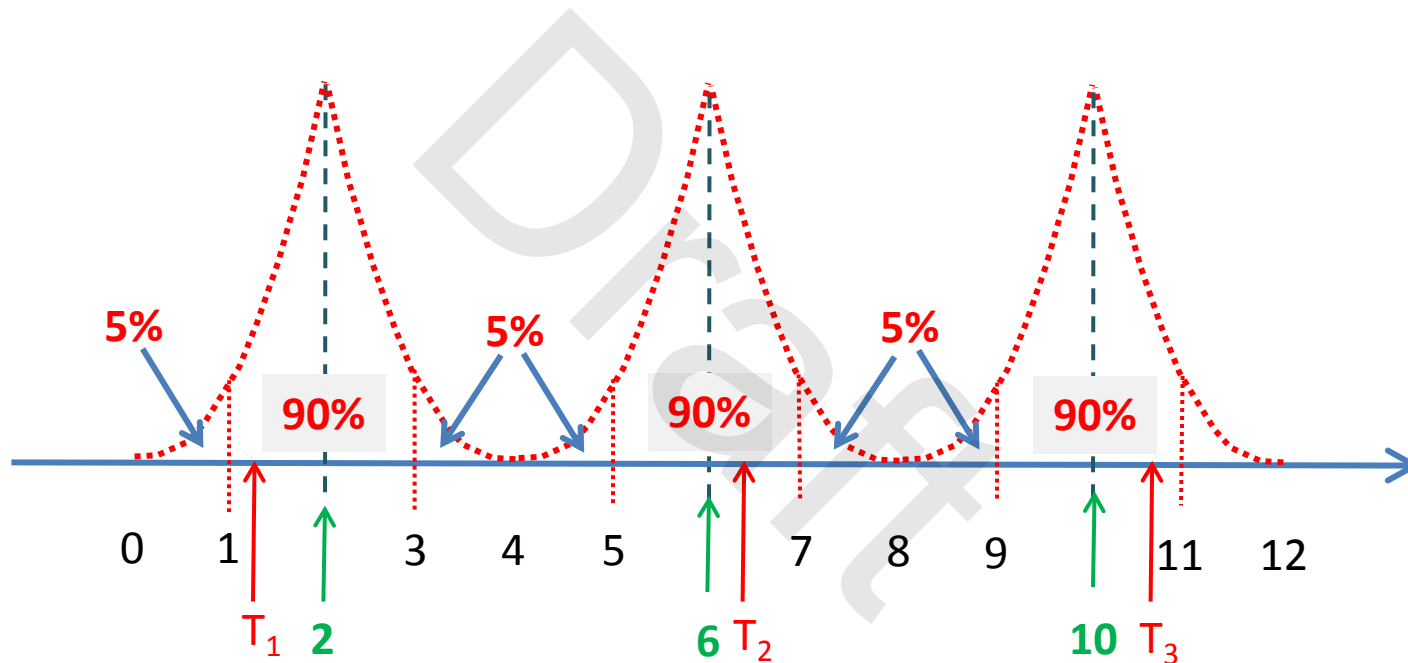
VTRA 2015 Routes for What-If Case: US - KM - CA - LN - 2248

	VTRA 2015
TOTAL WHATIF - LNG PROJECTS (without Bunkering)	650
TOTAL WHATIF - CA PROJECTS (without Bunkering)	1020
TOTAL WHATIF - KM (without Bunkering)	348
TOTAL WHATIF - US PROJECTS (without Bunkering)	230
SUBTOTAL WHAT-IF (without Bunkering)	2248
TOTAL BUNKERING SUPPORT - LNG PROJECTS	29
TOTAL BUNKERING SUPPORT - CA PROJECTS	111
TOTAL BUNKERING SUPPORT - KM	17
TOTAL BUNKERING SUPPORT - US PROJECTS	49
SUBTOTAL Bunkering Support	206
TOTAL WHAT-IF FOCUS VESSELS	2454

DISCLAIMER:

1. The VTRA 2015 Model **does not** contain a model for the Potential Consequences of an Accident with an LNG Tanker.
2. LNG Tankers for the purposes of the VTRA 2015 study are minimally modeled for traffic impact **as Cargo Focus Vessels only.**
3. Hence, risk metrics evaluated for any of the VTRA 2015 Cases that include LNG tankers **ought to be considered lower bounds** of those risk metrics.

VTTRA 2015 – What If FV Scheduled Random Arrival Pattern Model (See Example Graph below)



VTTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

VTTRA 2015 Random Arrival Pattern (3 Random Times in 12 days)

By Waterway Zone Risk Comparison

Oil Spill Size Category:

ALL SPILL SIZES

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV

100.0% of VTRA 2015 Base Case Total Annual Potential Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)

1.2%

78.2%

61.3%

Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)

VTRA '15 Case: BASE CASE

GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY ALL SPILL SIZES

Factor x Average

Oil Outflow

> 100.00

> 10.00

10.00

3.70

2.95

2.51

2.20

1.95

1.75

1.59

1.44

1.31

1.20

1.09

1.00

0.81

0.65

0.51

0.39

0.28

0.18

0.09

0.00

7/30/2016

© GW-VCU : DRAFT

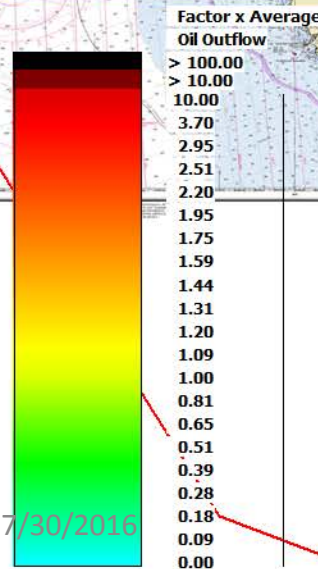
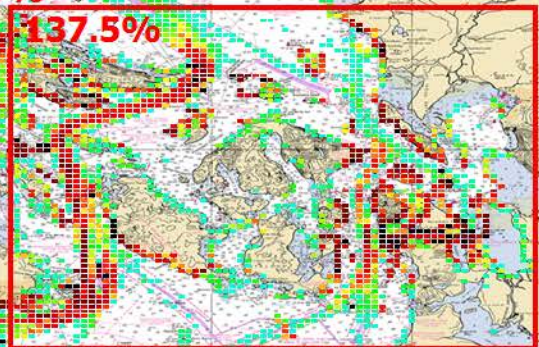
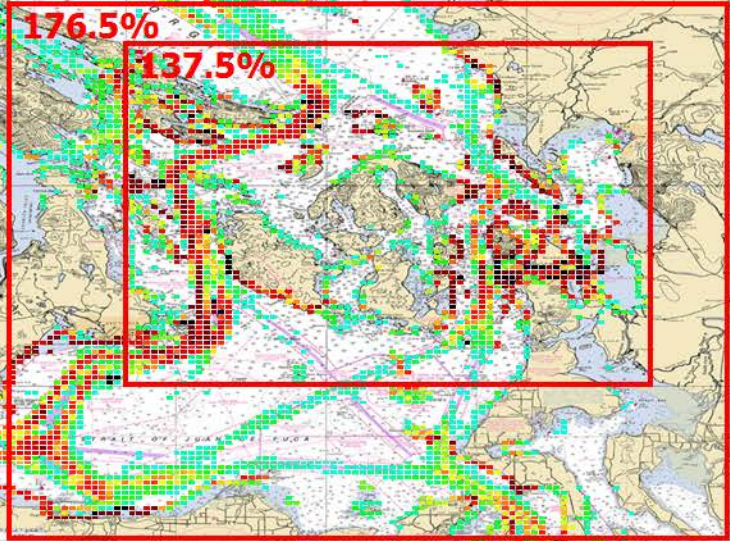
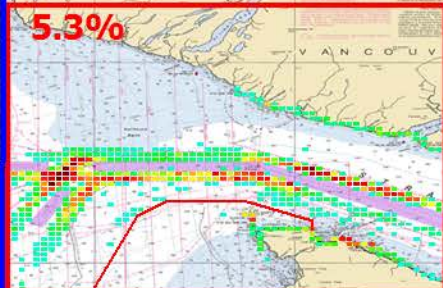
7/28/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

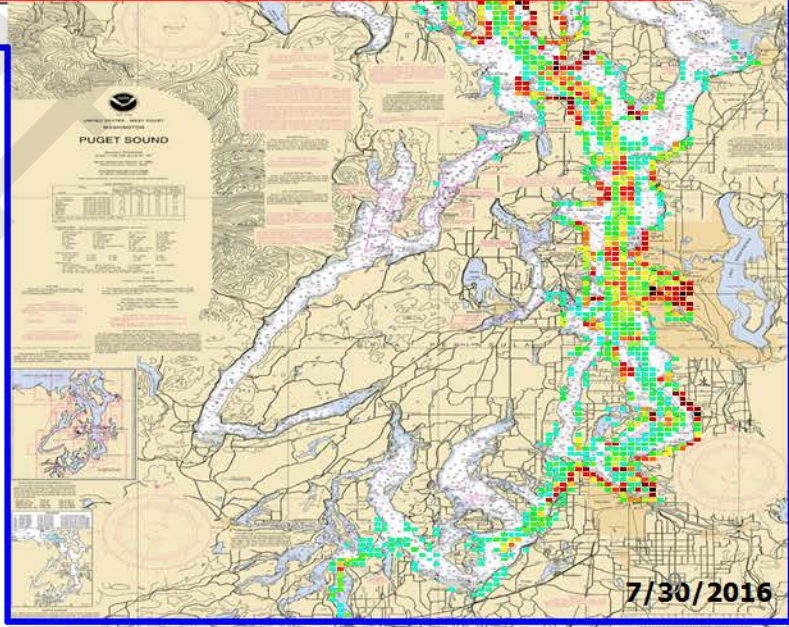
VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV

203.9% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

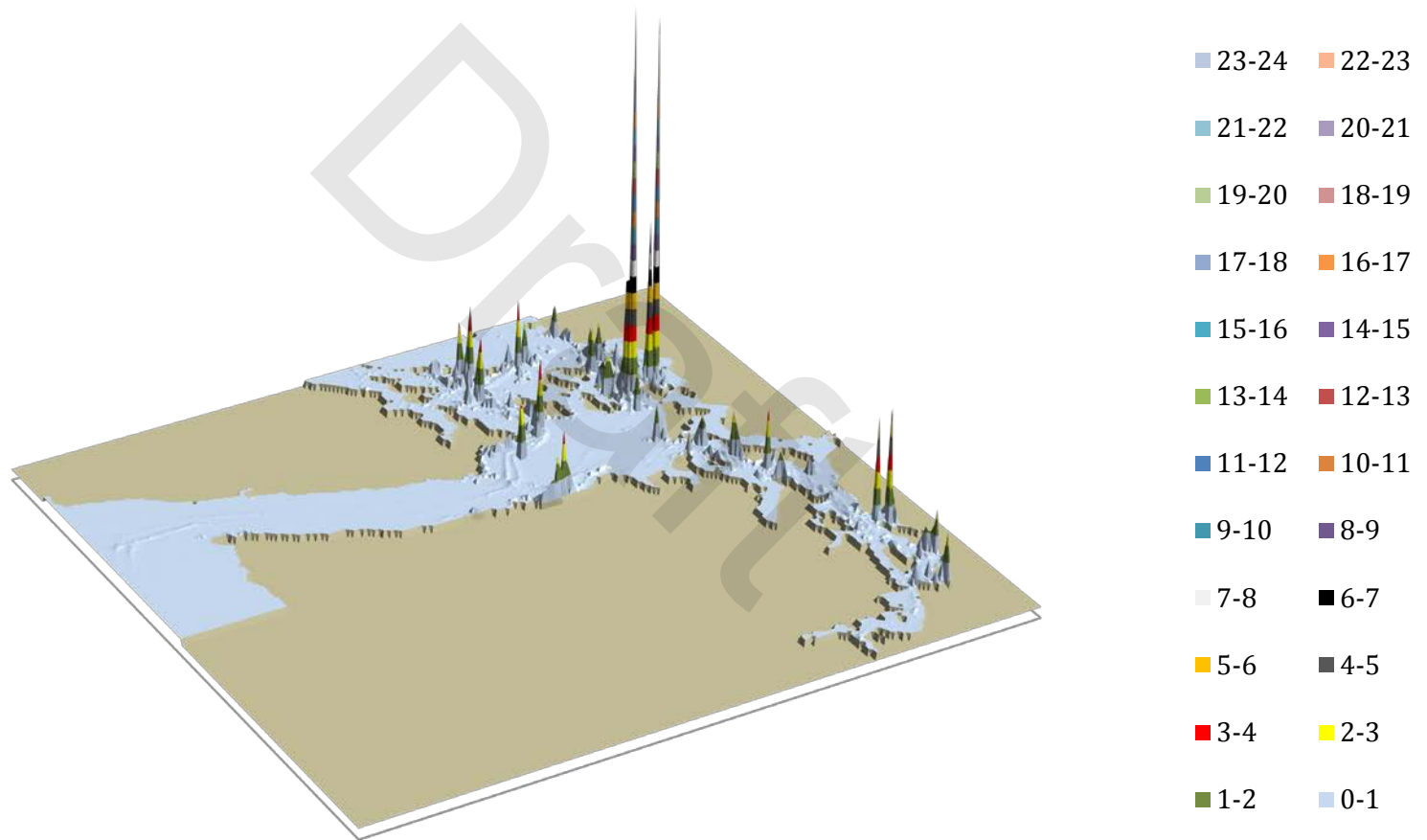
ALL SPILL SIZES (including accid. with zero oil loss)



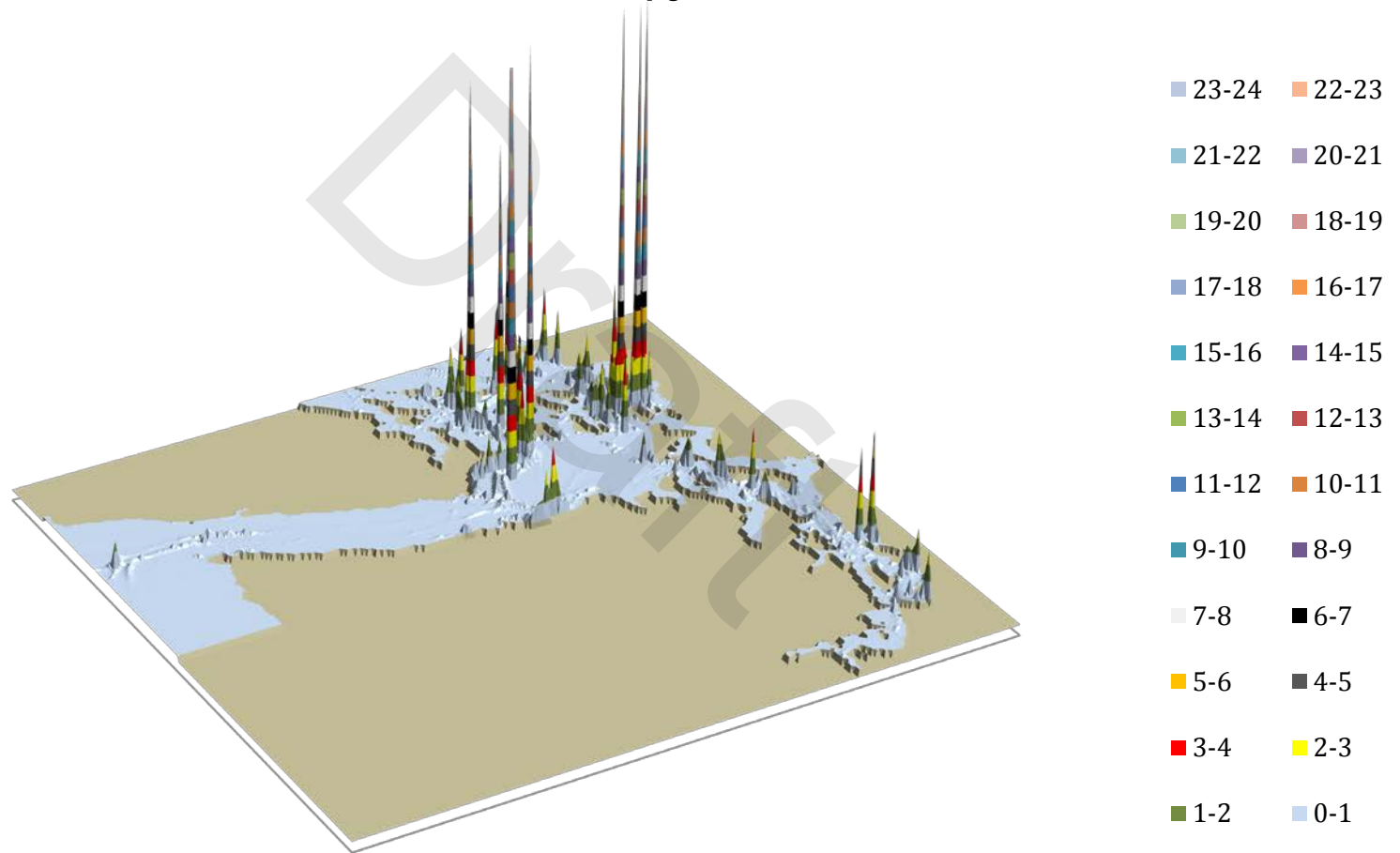
VTRA '15 Case:
US - KM - CA - LN - 348
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY **ALL SPILL SIZES**



VTRA '15: Base Case 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 100% of Base Case POL

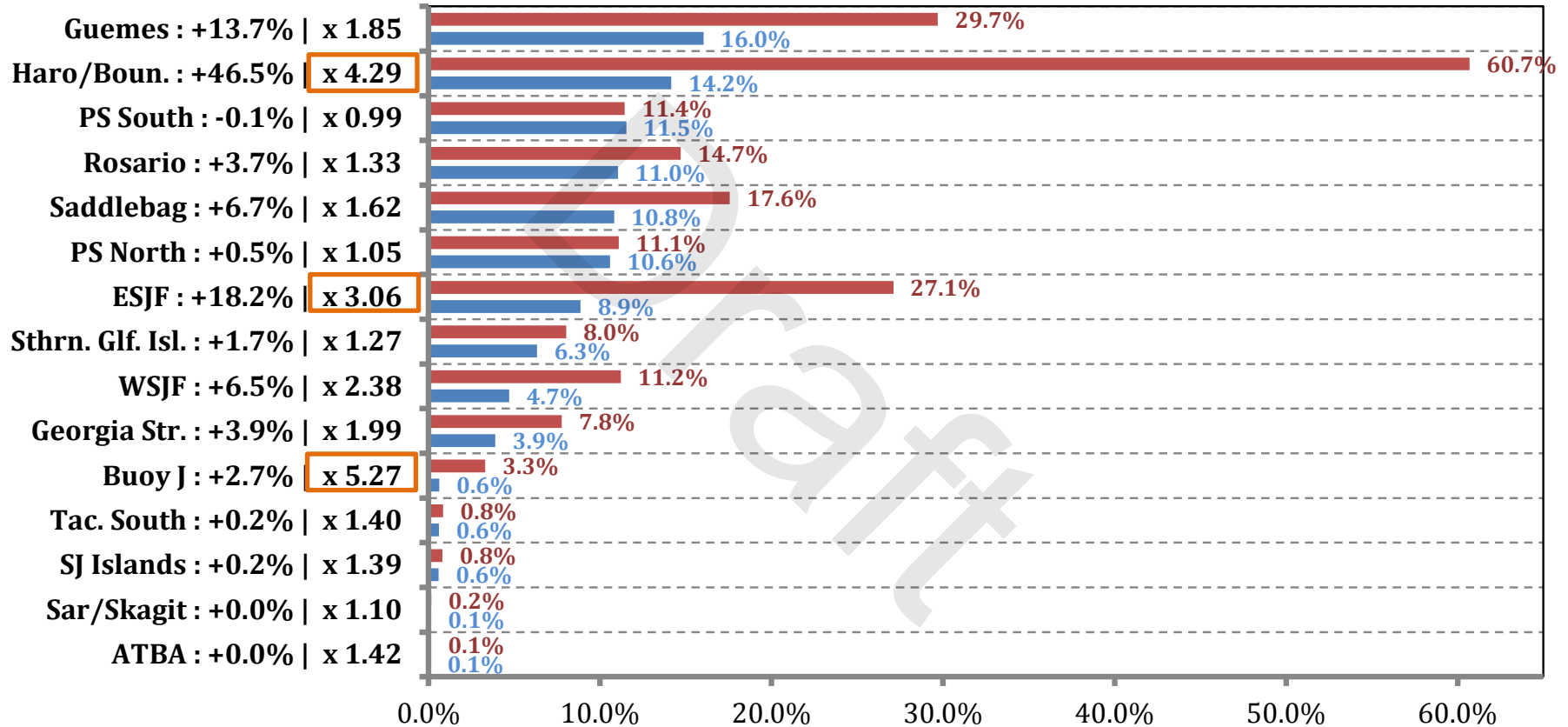


US - KM - CA - LN - 2248 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 204% of Base Case POL



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

% Base Case Pot. Oil (C + G + A) Loss - ALL_FV

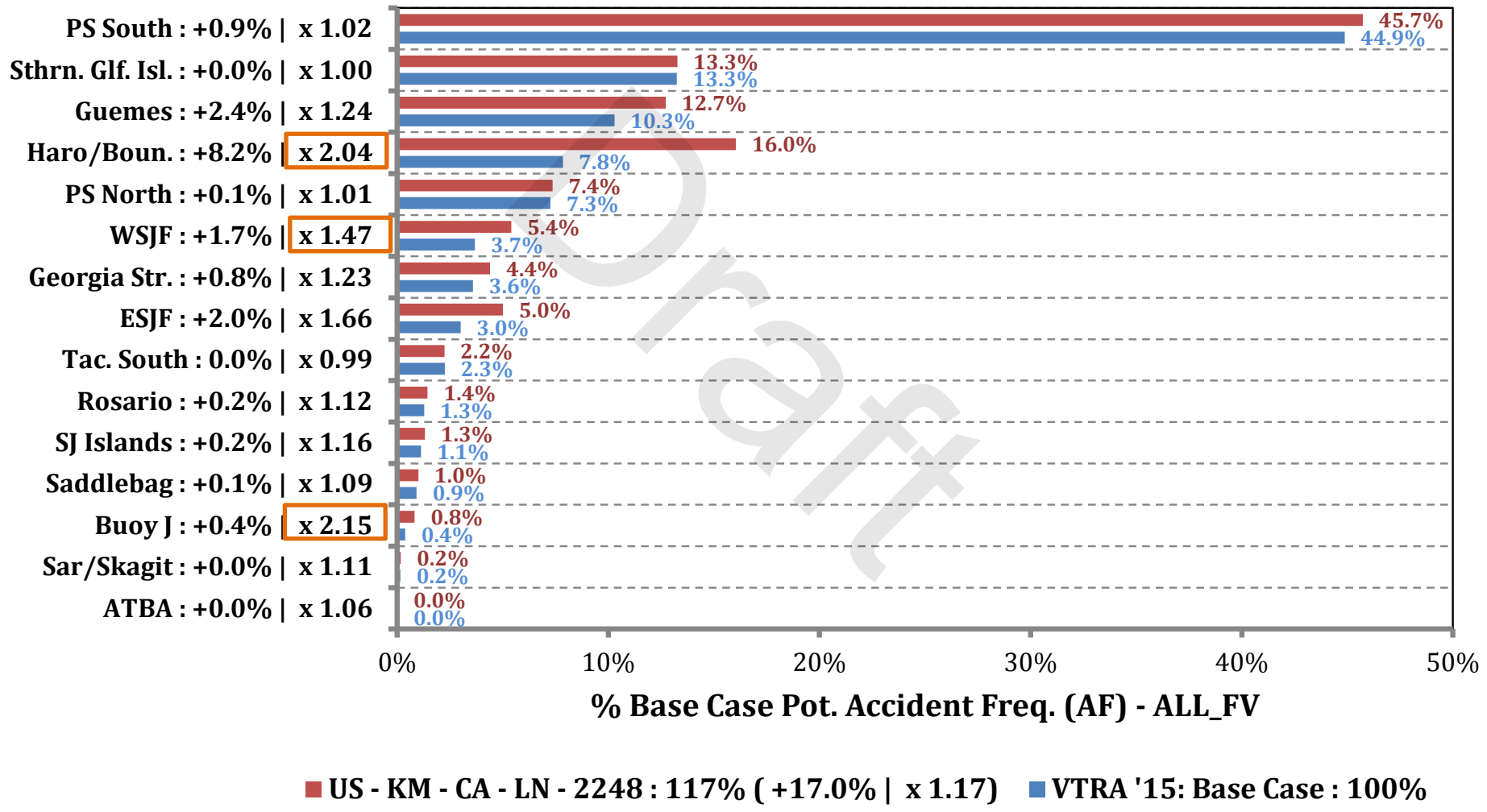


■ US - KM - CA - LN - 2248 : 205% (+104.5% | x 2.05) ■ VTRA '15: Base Case : 100%

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



% Base Case Pot. Accident (C+G+A) Frequency - ALL_FV



By Waterway Zone Risk Comparison

Oil Spill Size Category:
2500 m³ or more

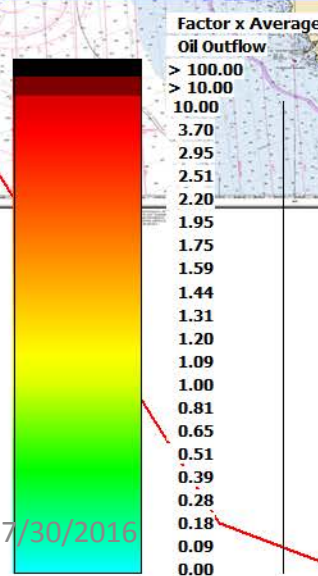
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV

42.0% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³

37.3%
31.5%

0.7%



VTRA '15:
BASE CASE
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m³ or more**

≈ 0.50% Probability of Spill Occurrence in 10 years

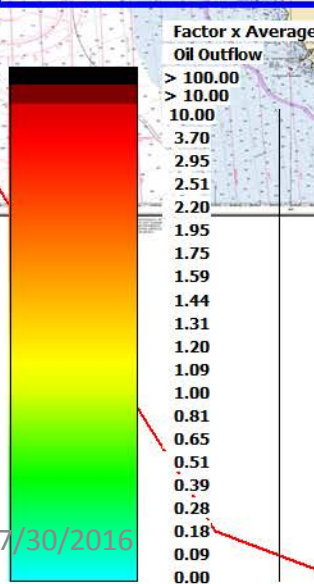
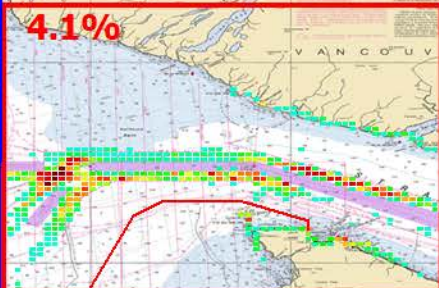
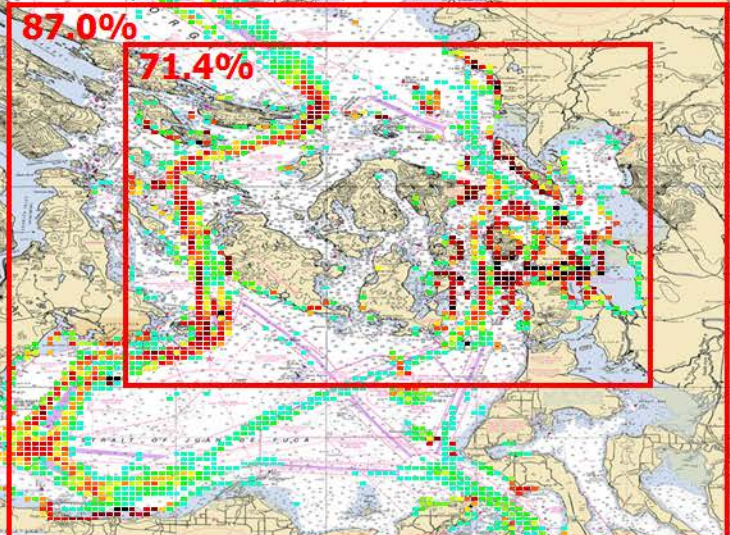
Average of ≈ 6,798 m³ Per Potential Spill (≈ 5,846 Metric. Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV

96.2% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

SPILL SIZES LARGER THAN 2,500 m³



VTRA '15 Case:
US - KM - CA - LN - 348
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE 2,500 m³ or more

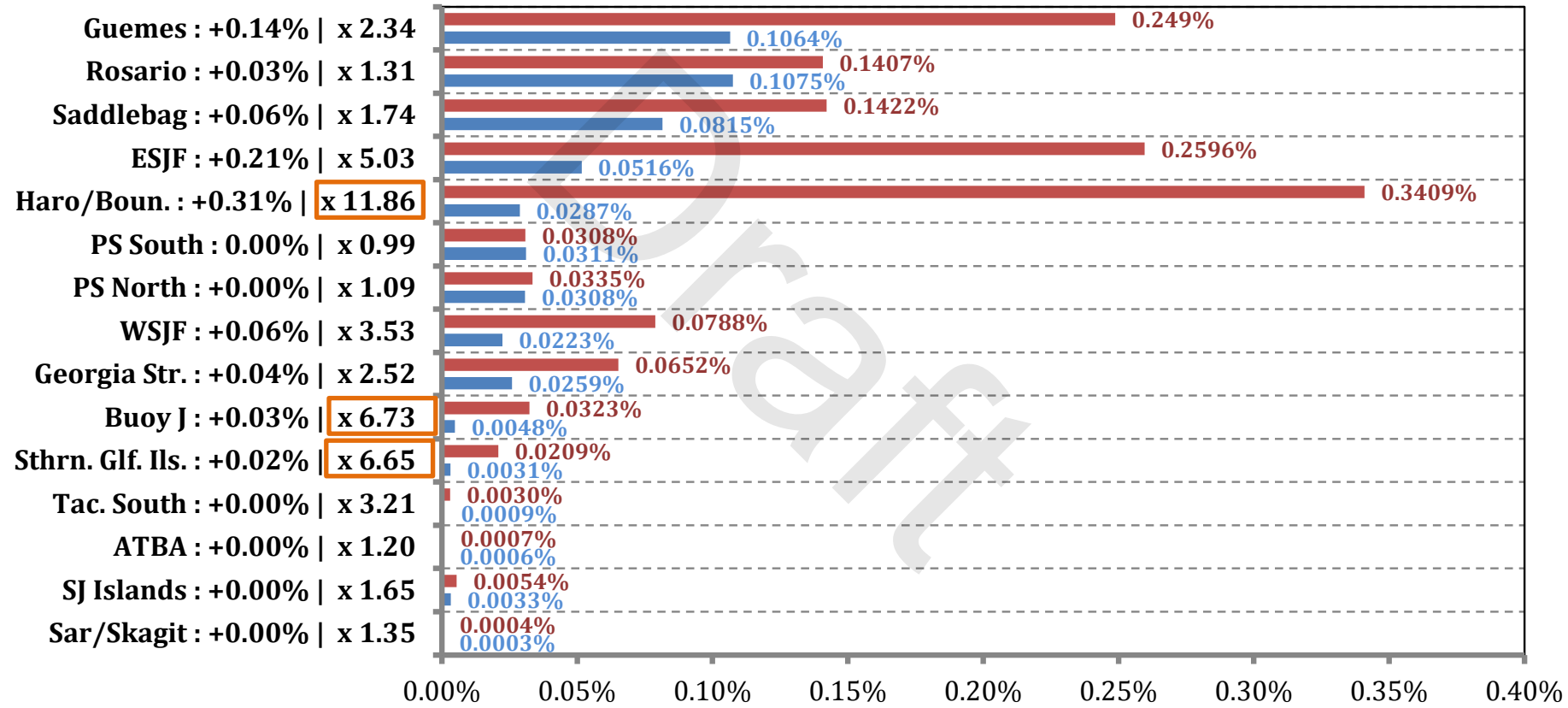
≈ 1.39% Probability of Spill Occurrence in 10 years

Average of ≈ 5,544 m³ Per Potential Spill (≈ 4,768 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more

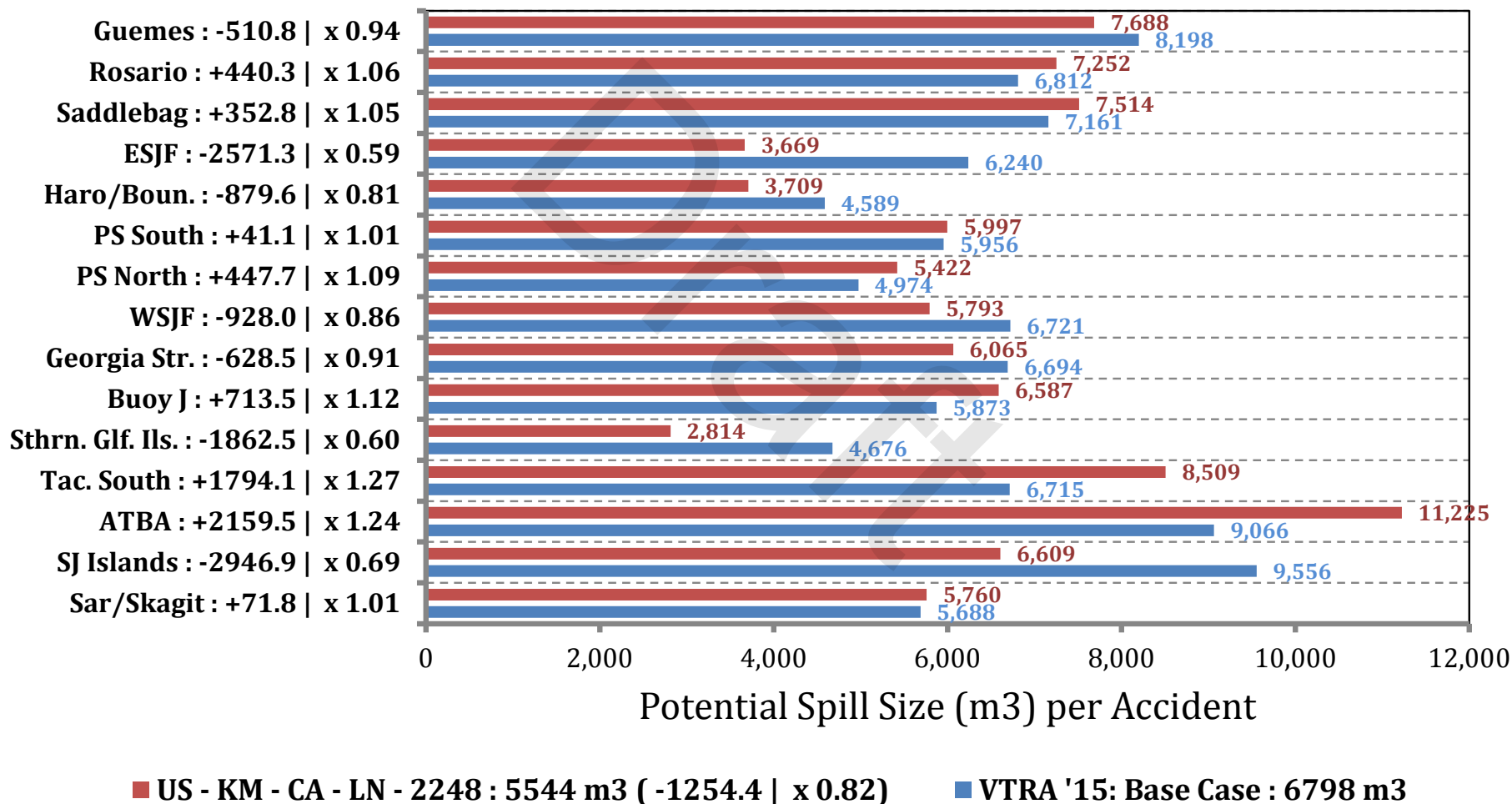


Prob. Estimate At Least One Accident in 10 Years

■ US - KM - CA - LN - 2248 : 1.39% (+0.90% | x 2.80) ■ VTRA '15: Base Case : 0.50%

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



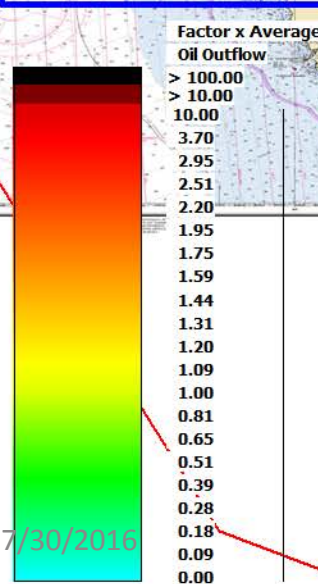
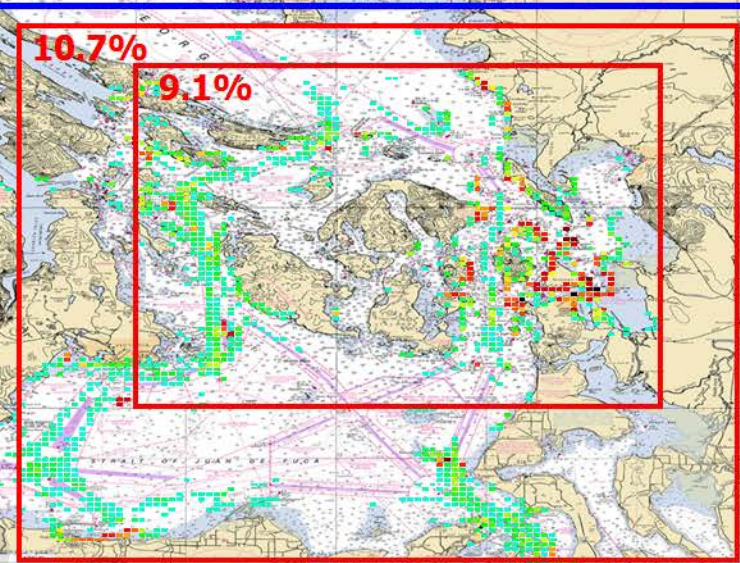
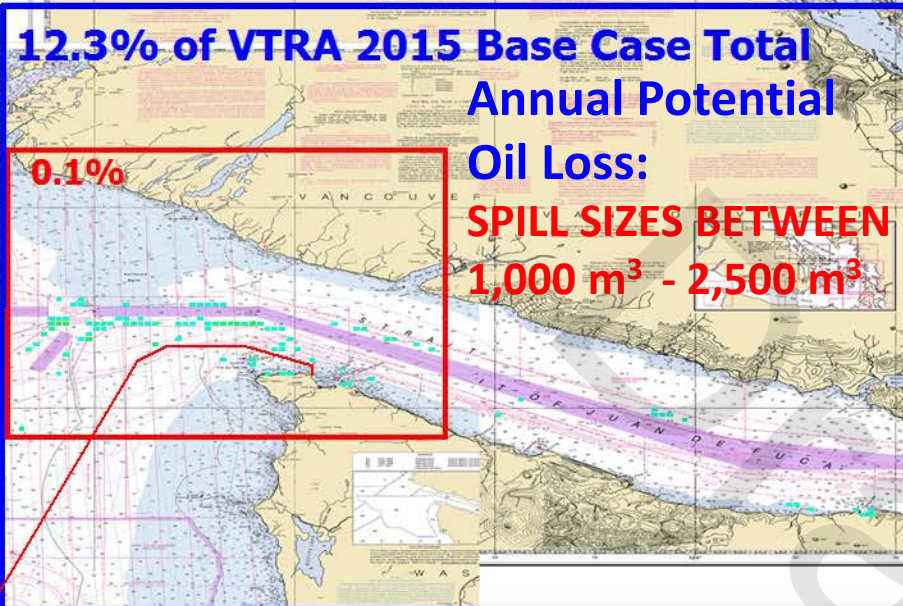
By Waterway Zone Risk Comparison

Oil Spill Size Category:

1000 m³ - 2500 m³

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV



VTRA '15:
BASE CASE

GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN 1,000 m³ - 2,500 m³**

≈ 0.61% Probability of Spill Occurrence in 10 years

Average of ≈ 1,619 m³ Per Potential Spill (≈ 1,392 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV

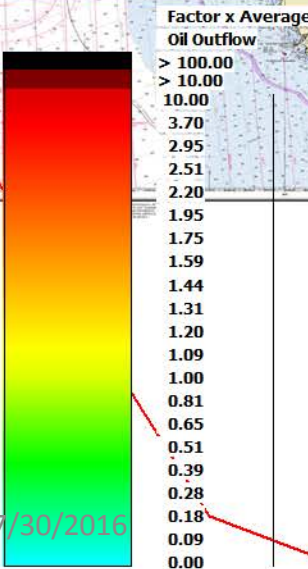
20.2% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

0.3%

SPILL SIZES BETWEEN 1,000 m³ - 2,500 m³

18.3%

15.8%



VTRA '15 Case: US - KM - CA - LN - 348
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN 1,000 m³ - 2,500 m³**

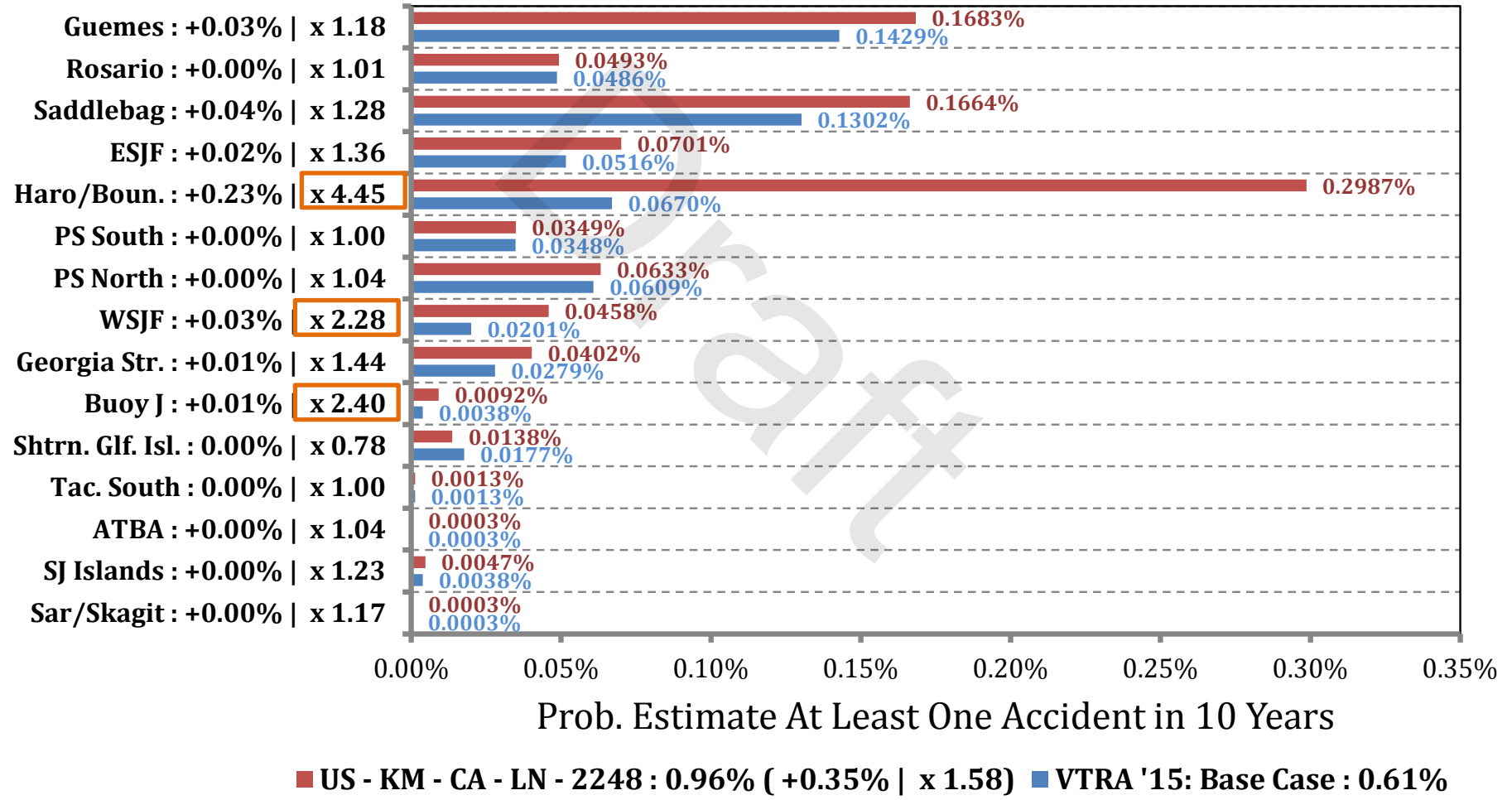
≈ 0.96% Probability of Spill Occurrence in 10 years

Average of ≈ 1,692 m³ Per Potential Spill (≈ 1,455 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

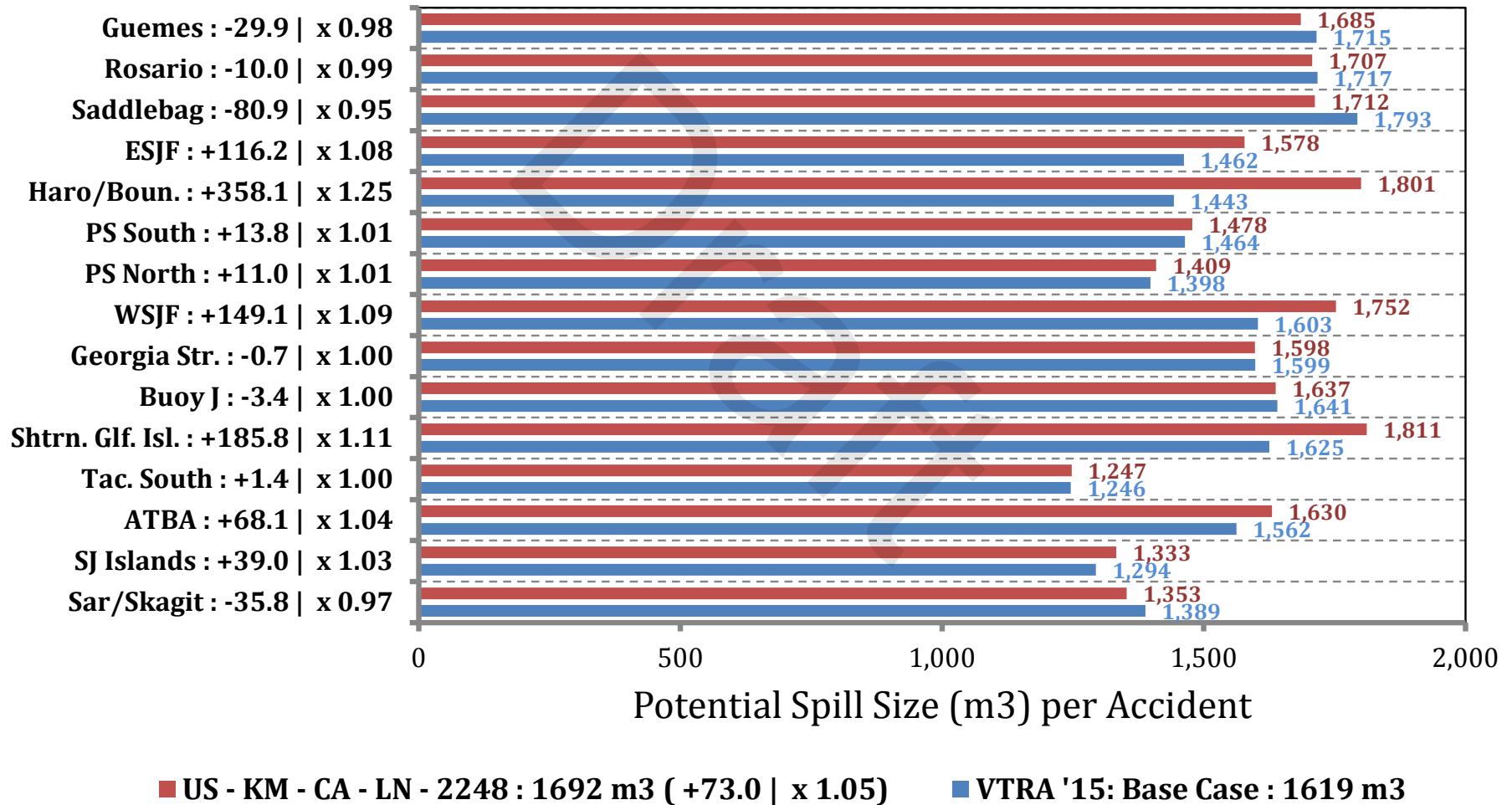


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 1000 - 2500 m³



By Waterway Zone Risk Comparison

Oil Spill Size Category:

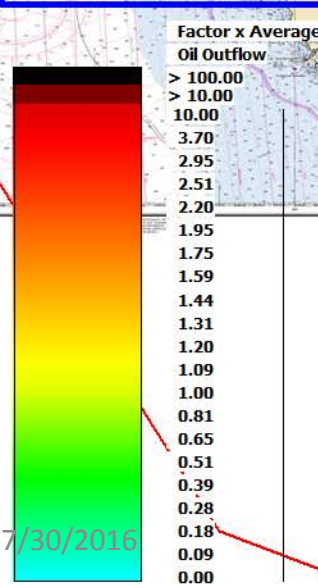
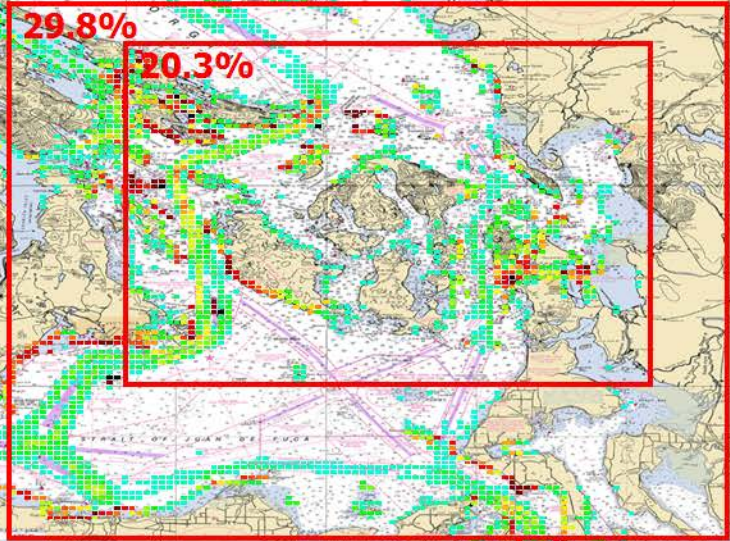
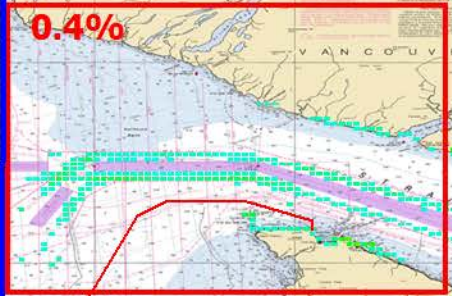
$1 \text{ m}^3 - 1000 \text{ m}^3$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV

45.3% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

Oil Loss: SPILL SIZES BETWEEN 1 m³ - 1,000 m³



VTRA '15: BASE CASE
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 1 m³ - 1000 m³

≈ 54.1% Probability of Spill Occurrence in 10 years

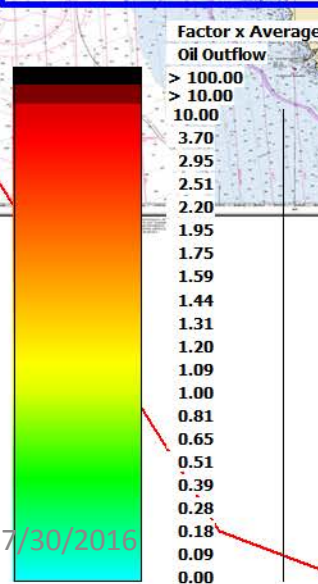
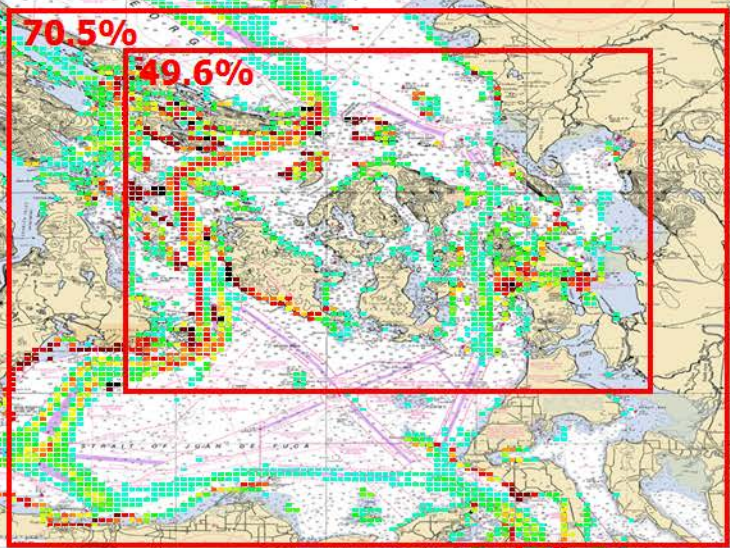
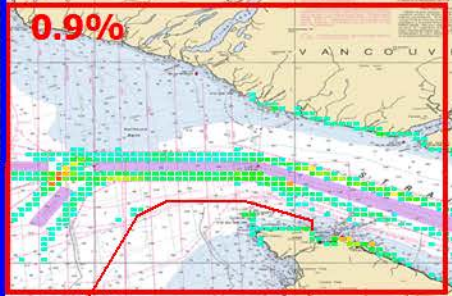
Average of ≈ 47 m³ Per Potential Spill (≈ 295 Barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV

86.8% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

Oil Loss: SPILL SIZES BETWEEN 1 m³ - 1,000 m³



VTRA '15 Case: US - KM - CA - LN - 348
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 1 m³ - 1000 m³

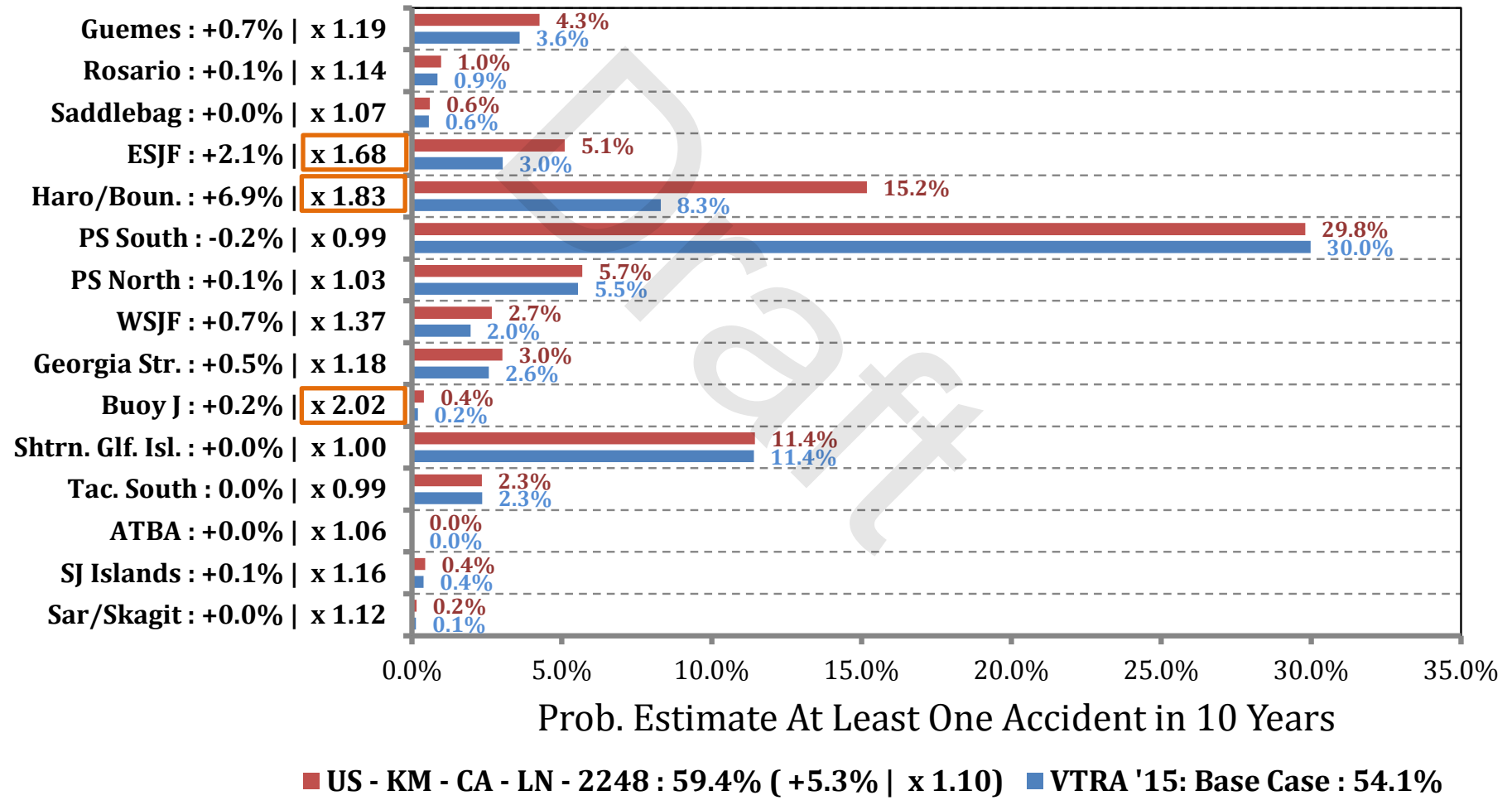
≈ 59.4% Probability of Spill Occurrence in 10 years

Average of ≈ 78 m³ Per Potential Spill (≈ 491 Barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

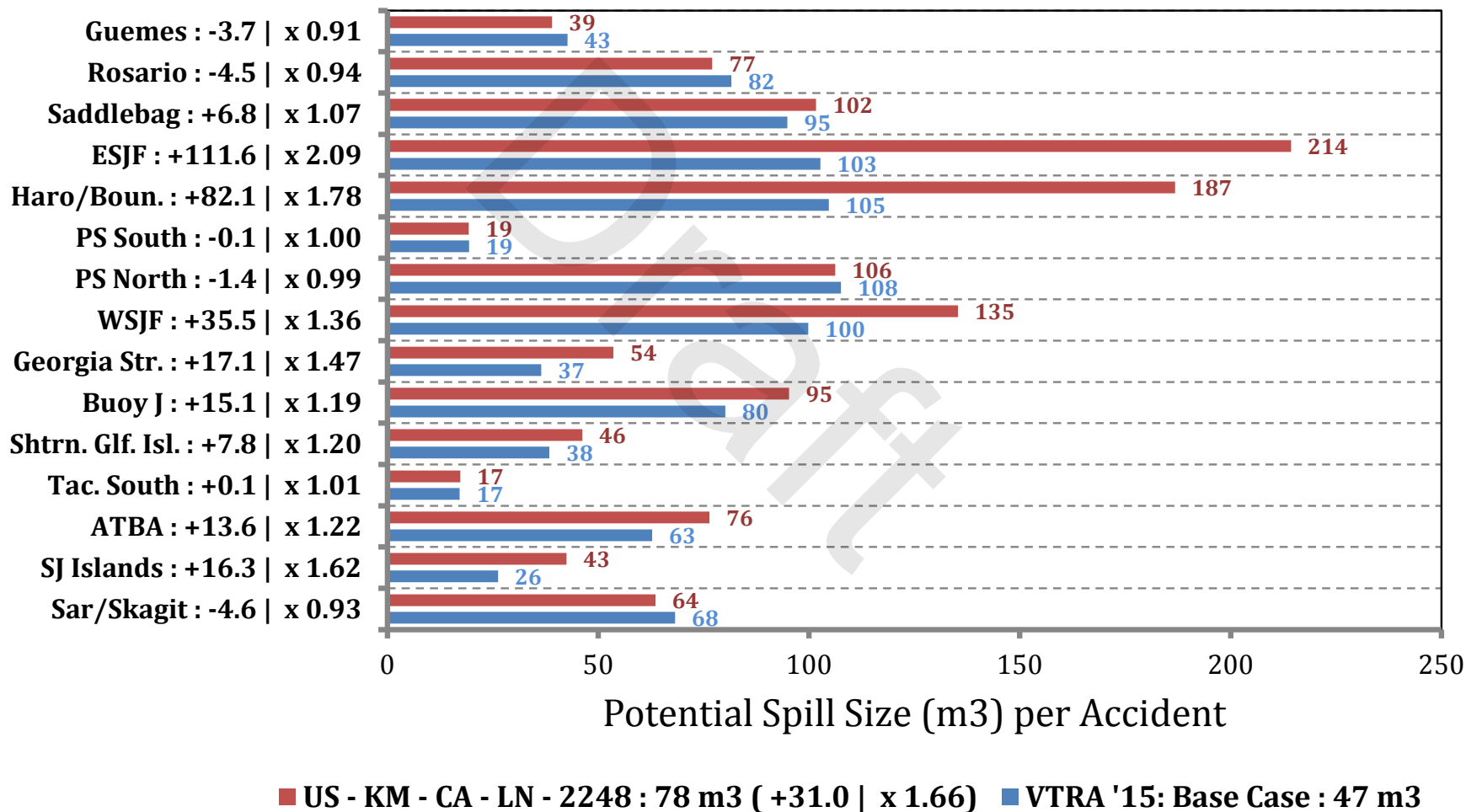


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1 - 1000 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 1 - 1000 m³



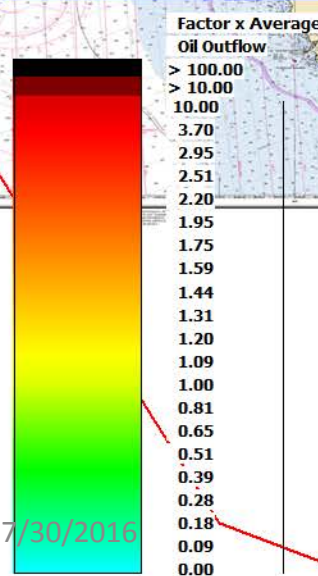
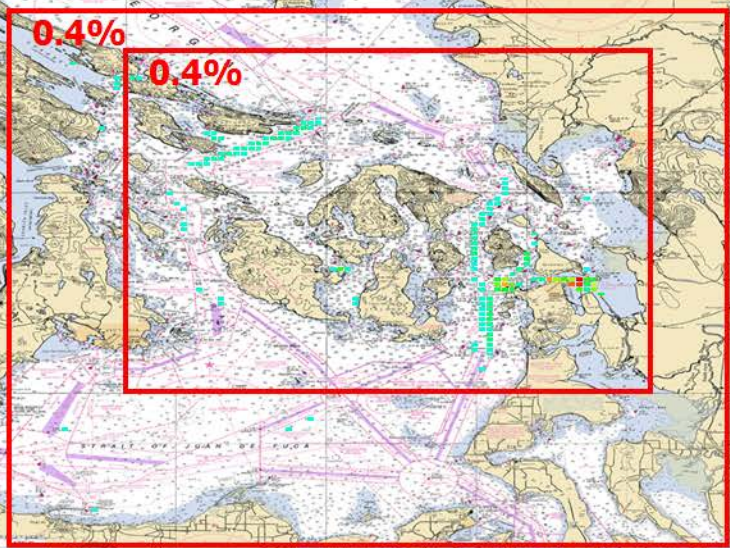
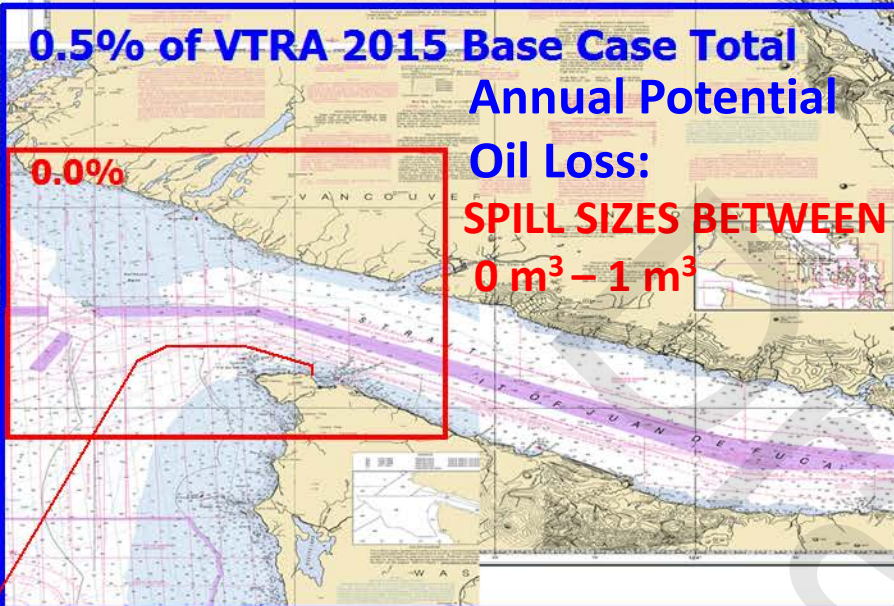
By Waterway Zone Risk Comparison

Oil Spill Size Category:

$0 \text{ m}^3 - 1 \text{ m}^3$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV



VTRA '15:
BASE CASE
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN $0\text{ m}^3 - 1\text{ m}^3$

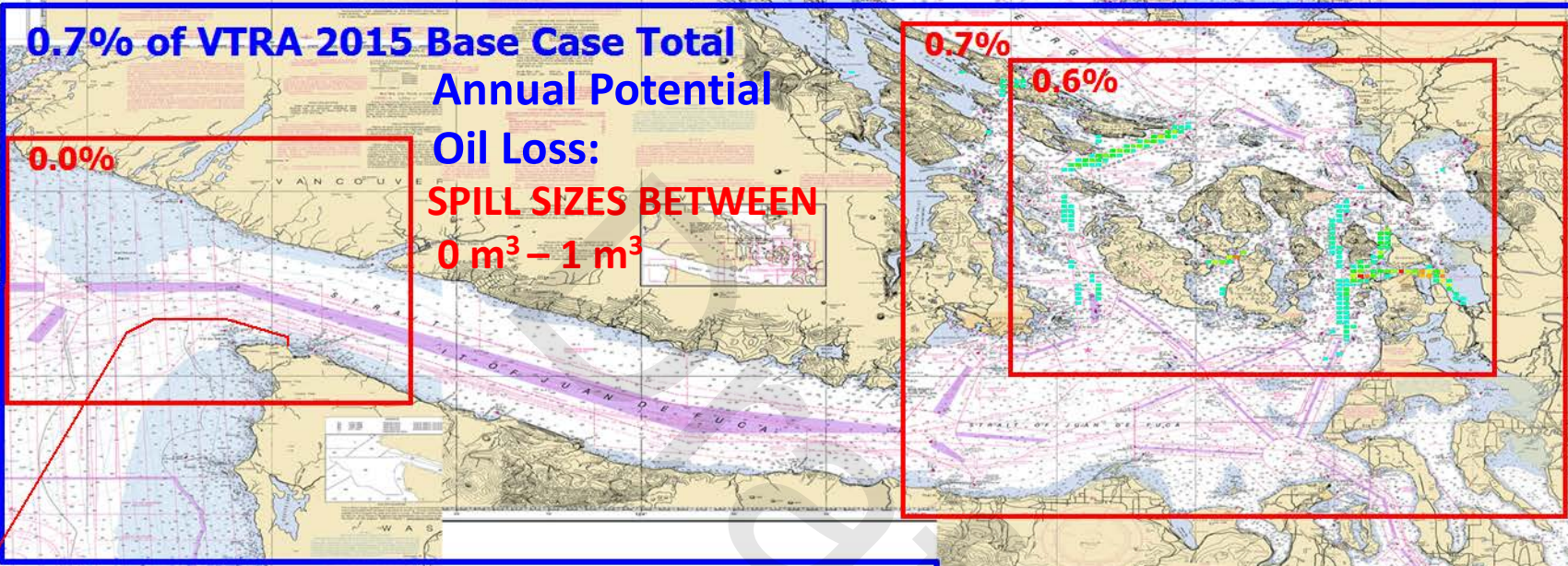
≈ 100% Probability
of Spill Occurrence
in 10 years

Average of ≈ 0.01 m^3
Per Potential Spill
(≈ 2.3 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

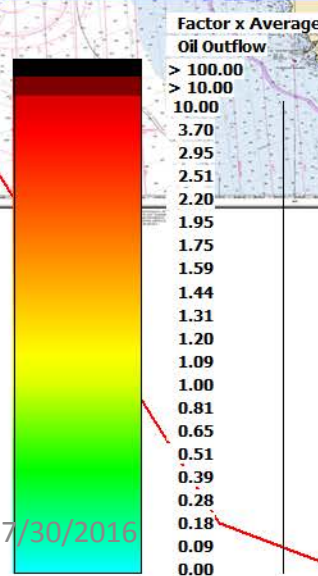


VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV



0.7% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES BETWEEN
0 m³ - 1 m³

0.7%
0.6%



VTRA '15 Case:
US - KM - CA - LN - 348
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 100% Probability
of Spill Occurrence
in 10 years

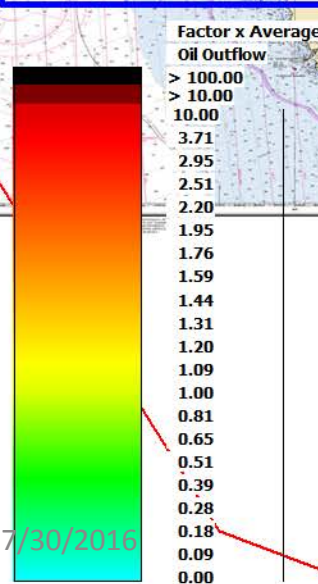
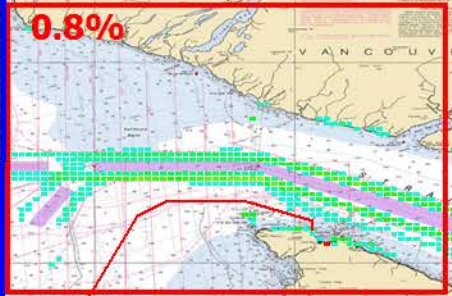
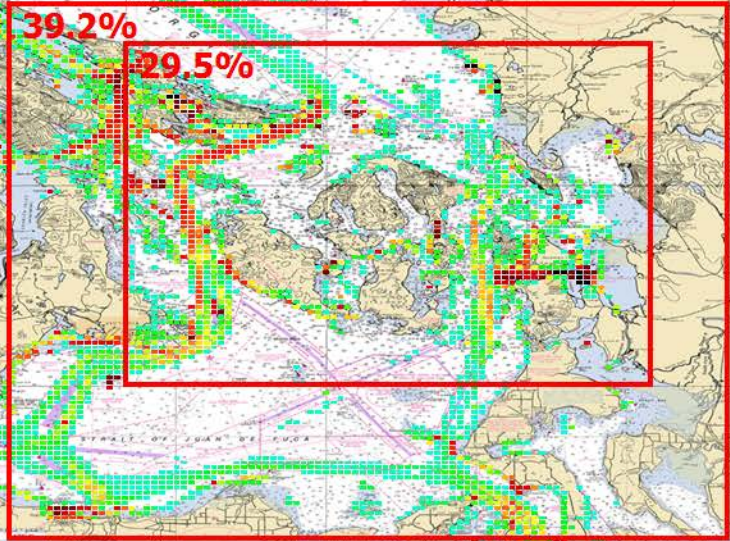
Average of ≈ 0.01 m³
Per Potential Spill
(≈ 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV

98.2% of VTRA 2015 Base Case Total Potential Annual # Accidents:

SPILL SIZES BETWEEN $0\text{ m}^3 - 1\text{ m}^3$



VTRA '15 Case:
BASE CASE
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN $0\text{ m}^3 - 1\text{ m}^3$

≈ 100% Probability
of Spill Occurrence
in 10 years

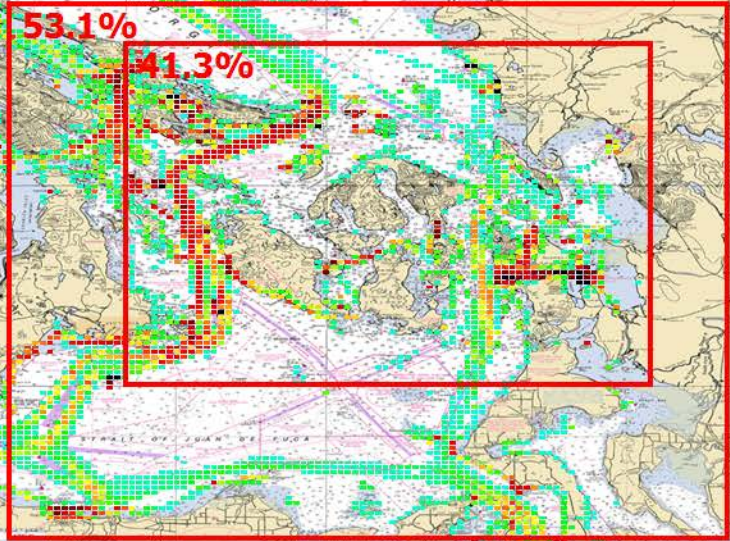
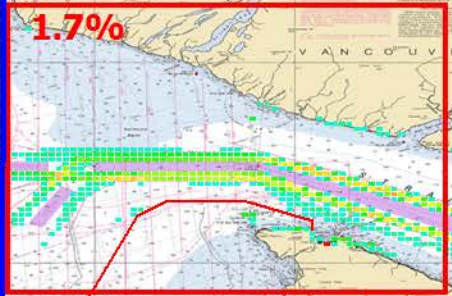
Average of ≈ 0.01 m^3
Per Potential Spill
(≈ 2.3 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: US-KM-CA-LN-2248 - ALL FV

115.0% of VTRA 2015 Base Case Total Potential Annual # Accidents:

**# Accidents:
SPILL SIZES BETWEEN
0 m³ - 1 m³**



53.1%



**VTRA '15 Case:
US - KM - CA - LN - 348
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³**

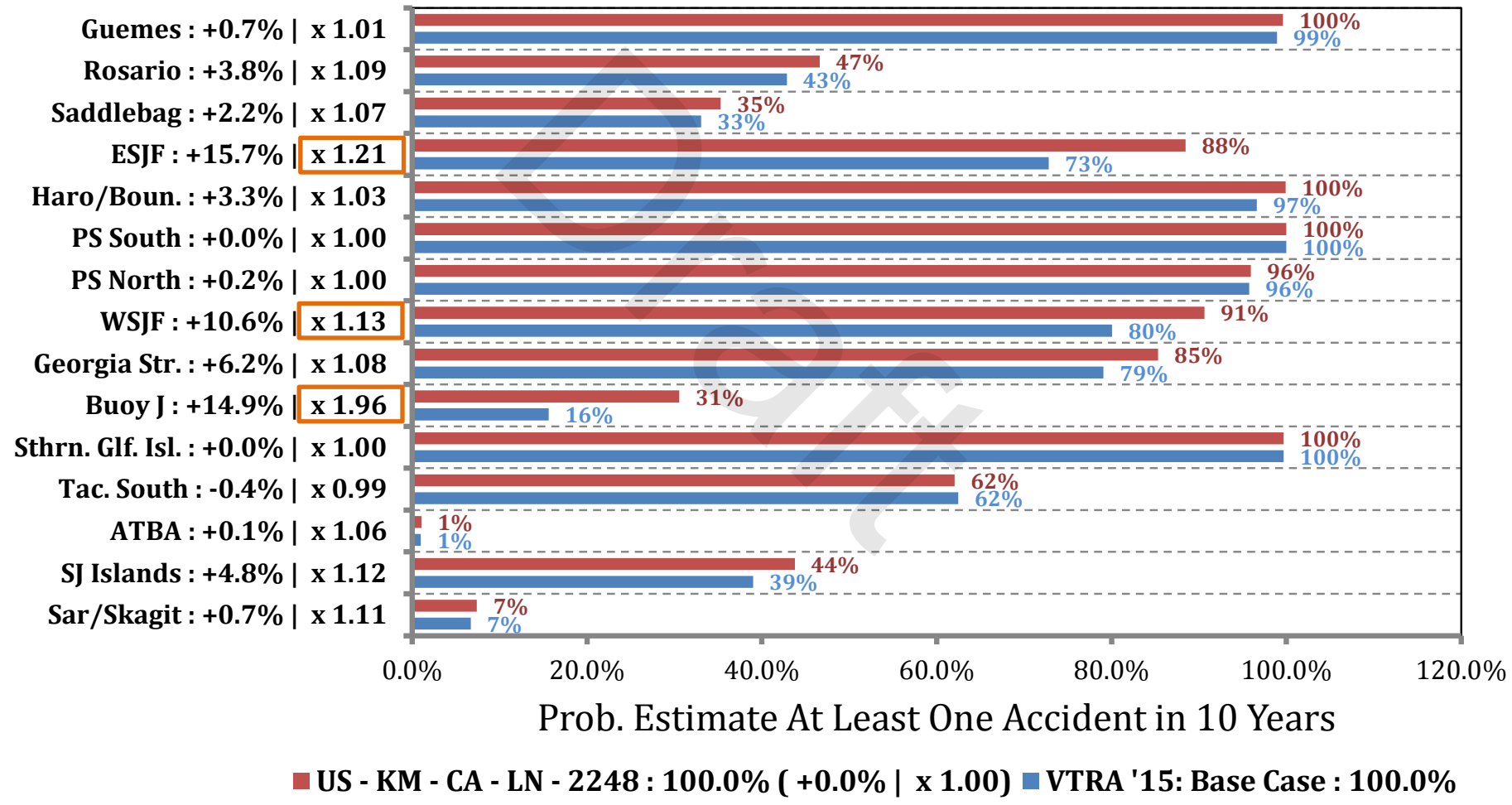
≈ 100% Probability
of Spill Occurrence
in 10 years

Average of ≈ 0.01 m³
Per Potential Spill
(= 3.0 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

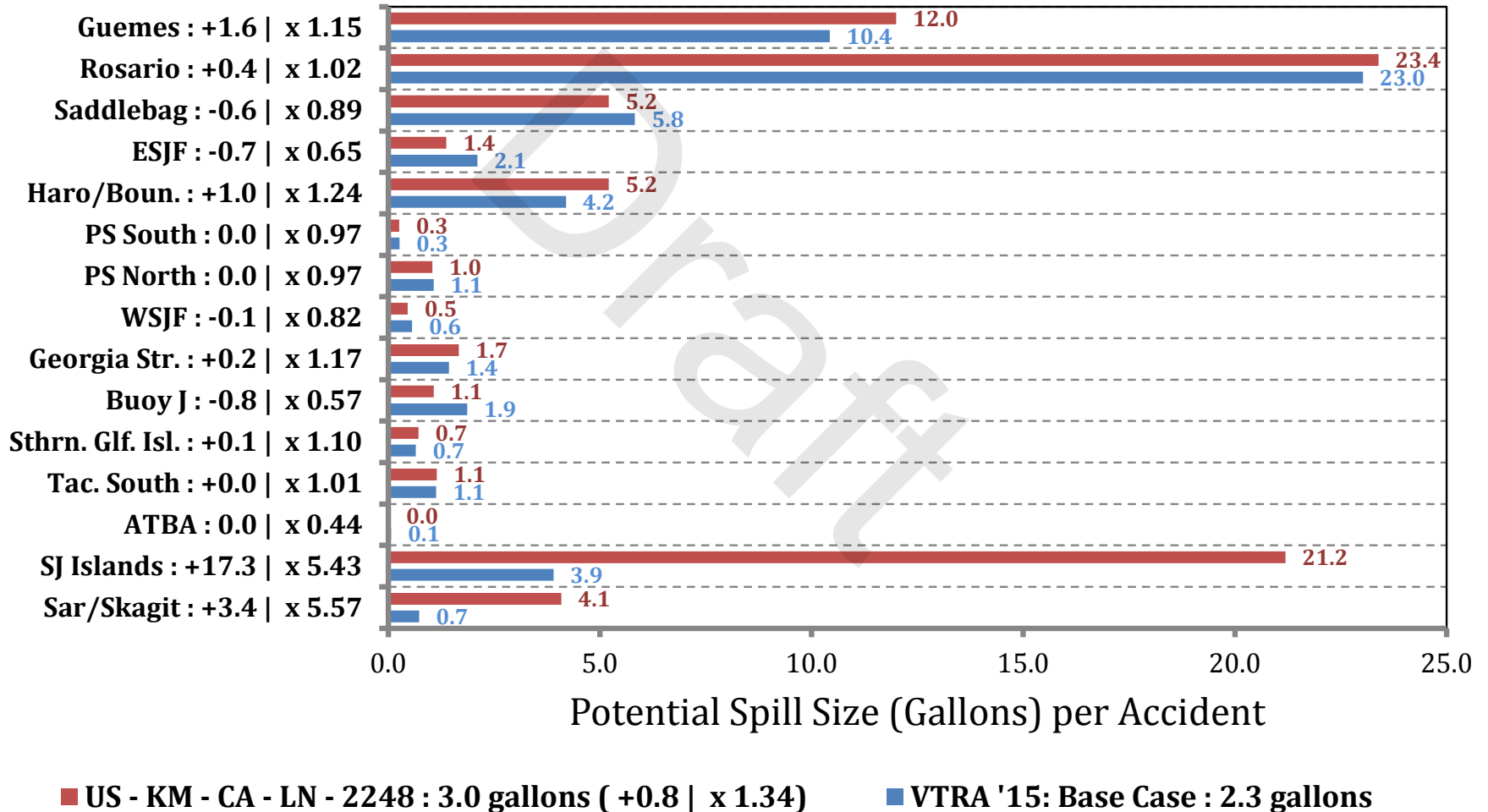


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

Potential Spill Size (Gallons) per Accident - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



Summary Risk Comparison

Oil Spill Size Category:
All Spill Sizes

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Summary Risk Comparison

		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	TOTAL_OIL
VTRA '15 BASE CASE	Base Case % Potential Annual Oil Loss	42.0%	12.3%	45.3%	0.5%	100.0%
	Base Case % Potential Annual Accident Frequency	0.01%	0.01%	1.8%	98.2%	100.0%
	Average potential spill size per accident (in m ³)	6,798	1,619	46.9	0.01	1.8
	Probability of at least one accident in 1 year by spill size	0.05%	0.06%	7.5%	98.7%	98.8%
	Probability of at least one accident in 10 year by spill size	0.50%	0.61%	54.2%	100.0%	100.0%
	Probability of at least one accident in 25 years by spill size	1.24%	1.52%	85.8%	100.0%	100.0%
		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	TOTAL_OIL
US - KM - CA - LN 2248	Base Case % Potential Annual Oil Loss	96.4% (+54.37% x2.29)	20.2% (+7.99% x1.65)	86.9% (+41.64% x1.92)	0.7% (+0.26% x1.56)	204.3% (+104.3% x2.04)
	Base Case % Potential Annual Accident Frequency	0.03% (+0.02% x2.81)	0.02% (+0.01% x1.58)	2.0% (+0.28% x1.16)	114.9% (+16.7% x1.17)	117.0% (+17.0% x1.17)
	Average potential spill size per accident (in m ³)	5545 (-1253 x0.82)	1692 (+73 x1.05)	77.8 (+30.9 x1.66)	0.01 (+0.00 x1.34)	3.2 (+1.4 x1.75)
	Probability of at least one accident in 1 year by spill size	0.14% (+0.09% x2.81)	0.10% (+0.04% x1.58)	8.6% (+1.12% x1.15)	99.4% (+0.67% x1.01)	99.4% (+0.63% x1.01)
	Probability of at least one accident in 10 year by spill size	1.40% (+0.90% x2.80)	0.96% (+0.35% x1.58)	59.5% (+5.27% x1.10)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)
	Probability of at least one accident in 25 years by spill size	3.45% (+2.21% x2.78)	2.39% (+0.87% x1.57)	89.5% (+3.73% x1.04)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)