

Paired Comparison of following VTRA 2015 Cases:

1. '15 Base Case to USKCA1600 and
2. USKCA1600 to USKCA1600 – 3RMM



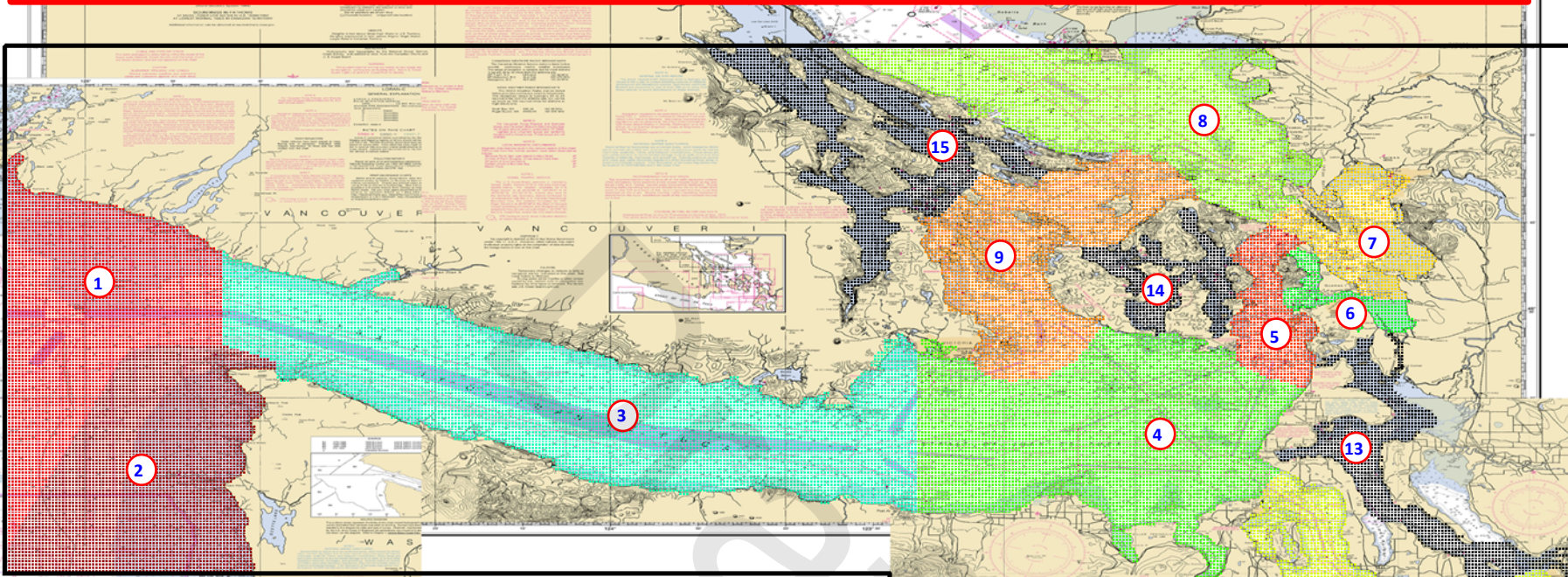
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

September, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

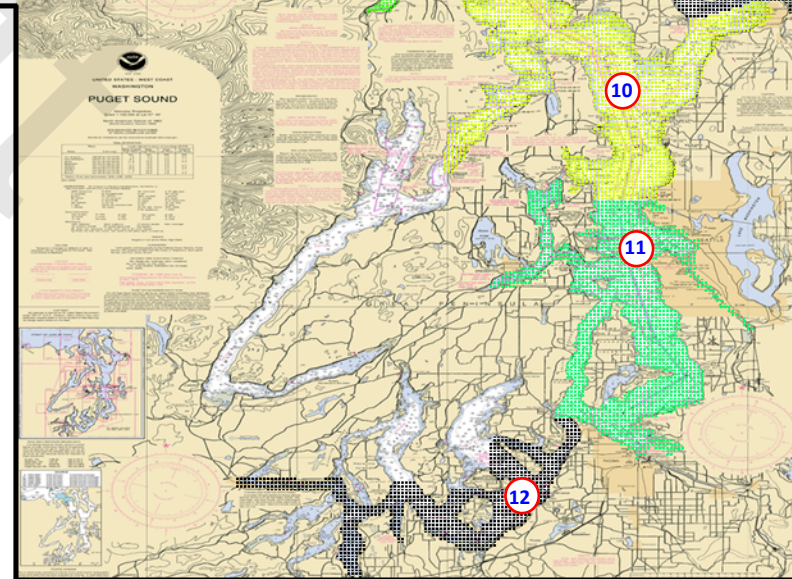


DEFINITION OF 15 WATERWAY ZONES

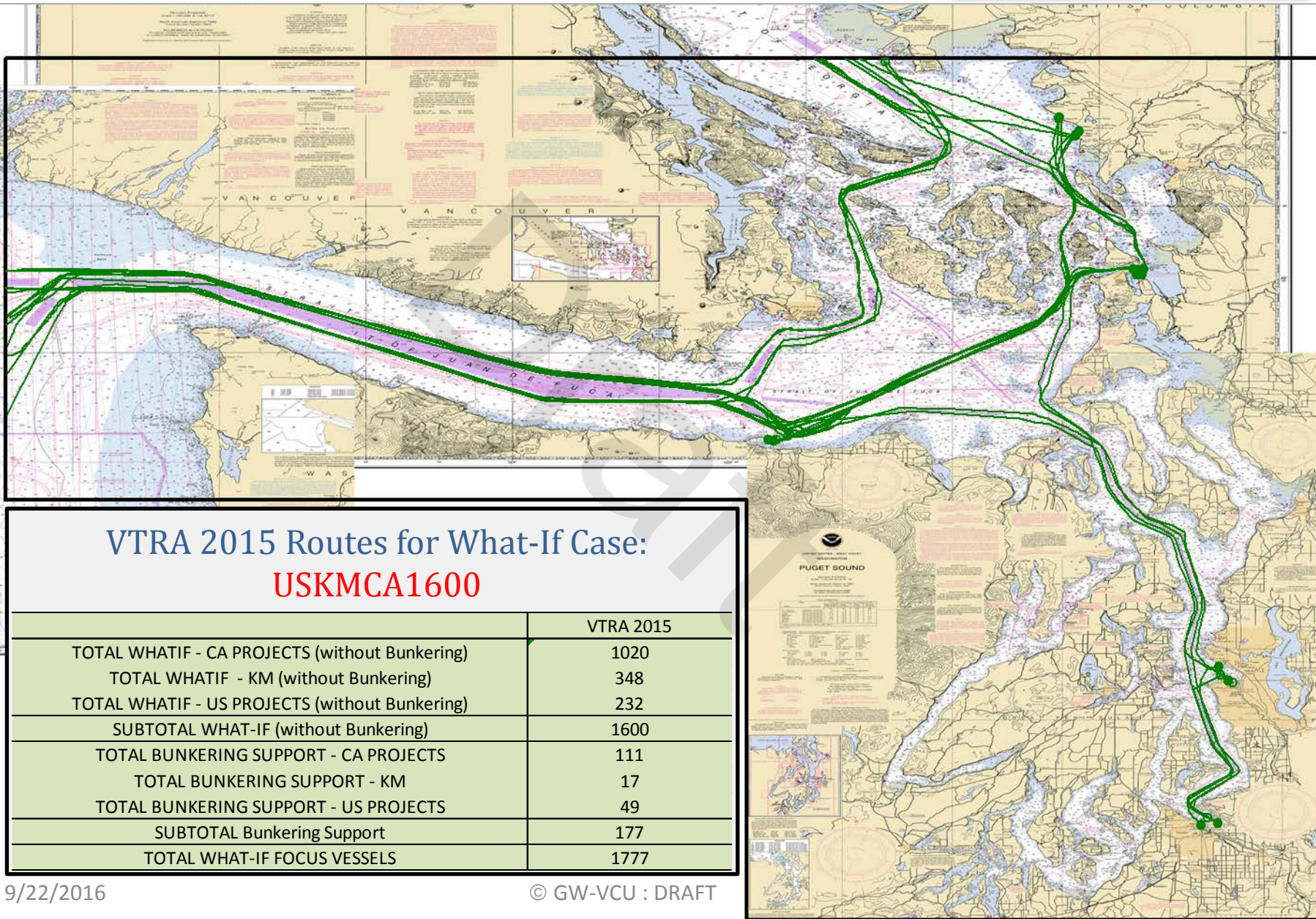


VTRA 2015 Waterway Zones

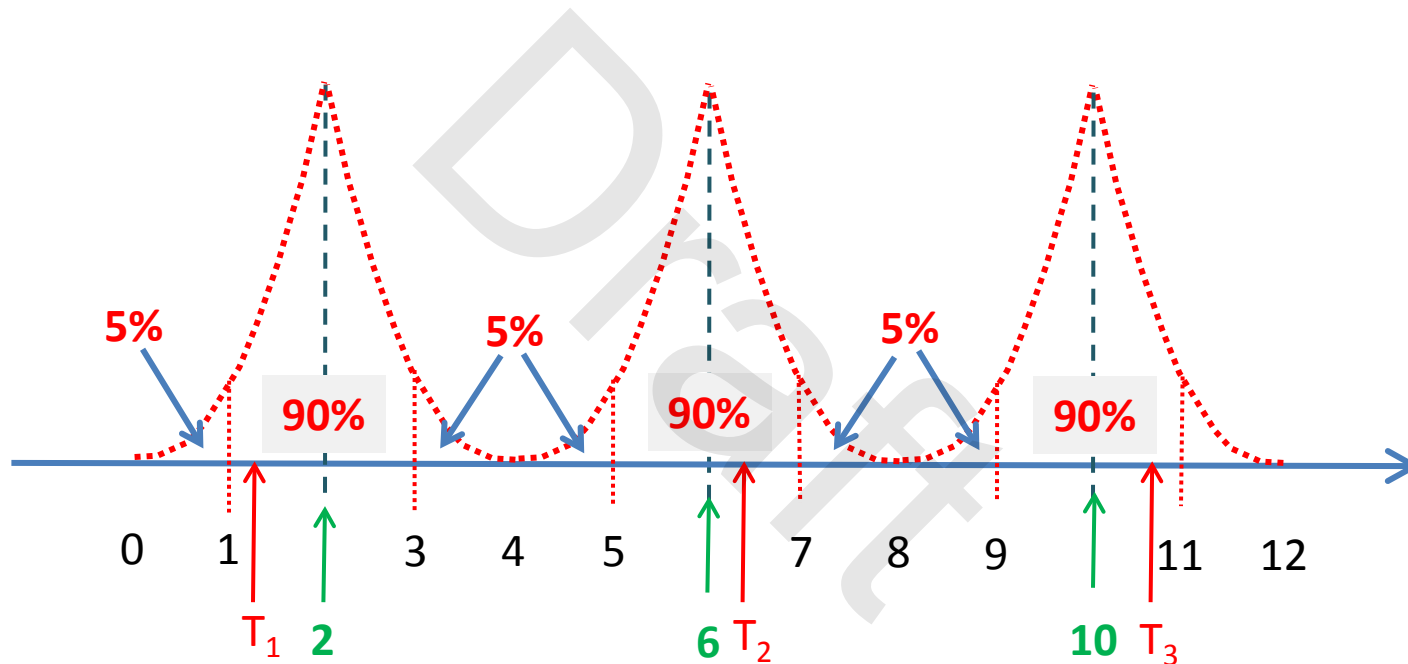
- | | |
|-----------------|---------------------------|
| 1. Buoy J | 9. Haro/Boun. |
| 2. ATBA | 10. PS North |
| 3. WSJF | 11. PS South |
| 4. ESJF | 12. Tacoma |
| 5. Rosario | 13. Sar/Skagit |
| 6. Guemes | 14. SJ Islands |
| 7. Saddlebag | 15. Southern Gulf Islands |
| 8. Georgia Str. | |



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



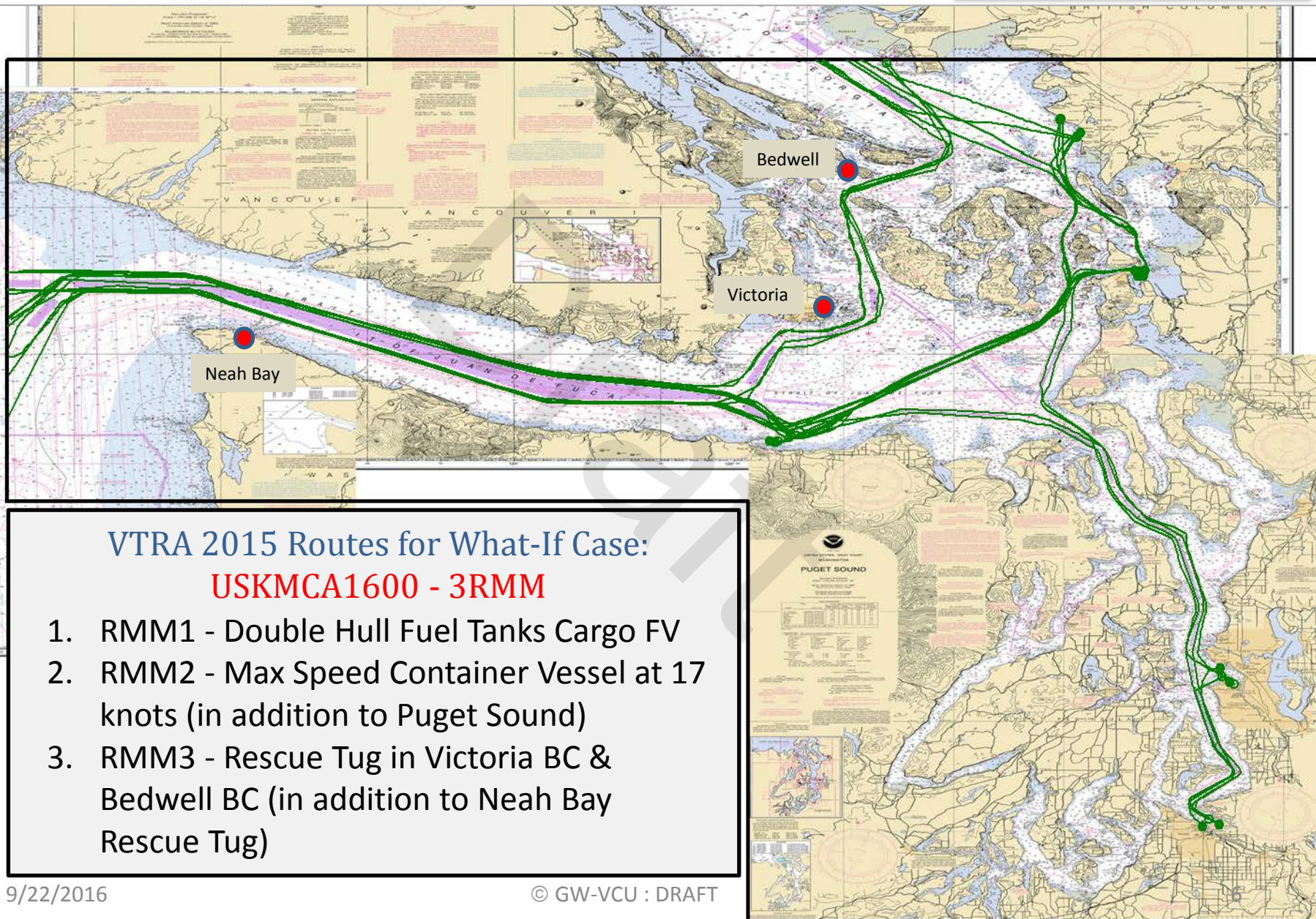
VTRA 2015 – What If FV Scheduled Random Arrival Pattern Model (See Example Graph below)



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

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

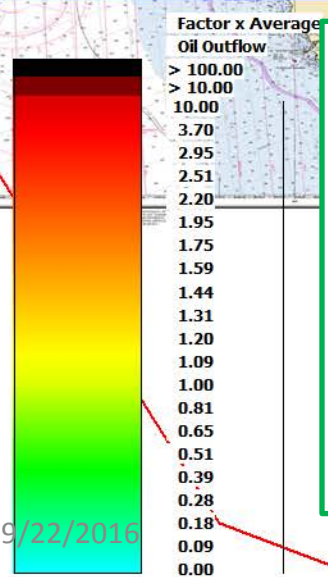
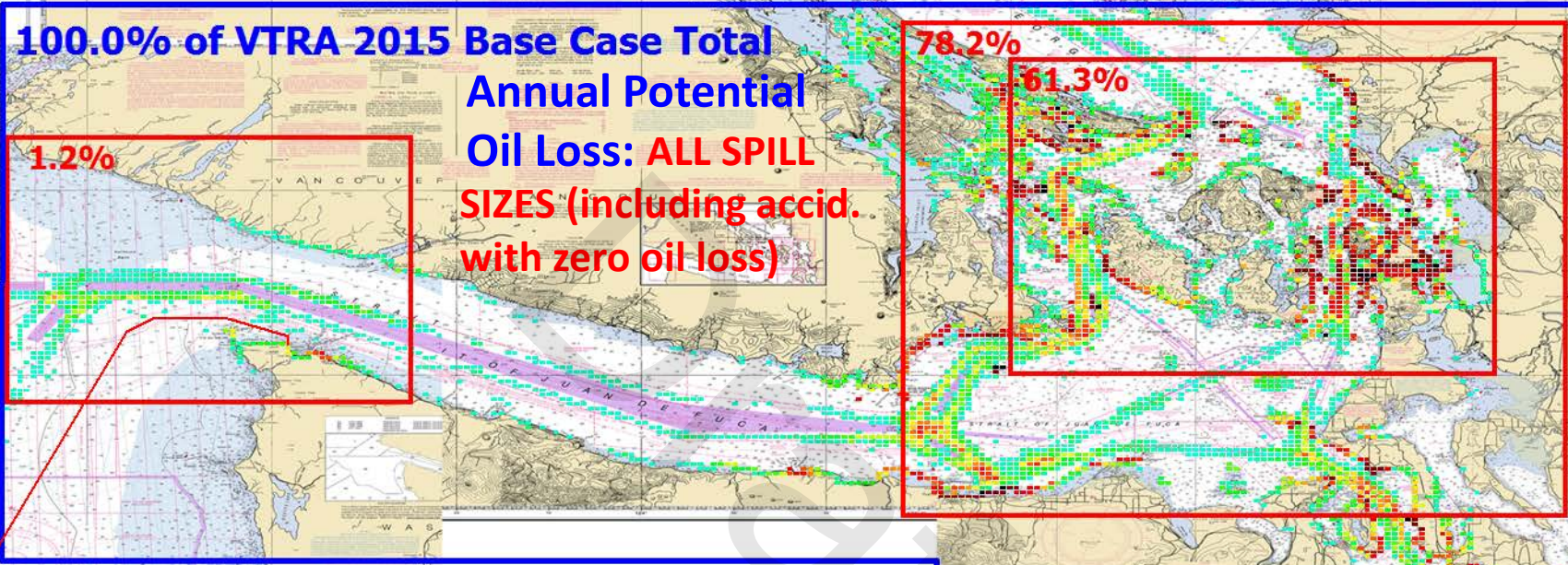


By Waterway Zone Risk Comparison

Oil Spill Size Category:
ALL SPILL SIZES

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

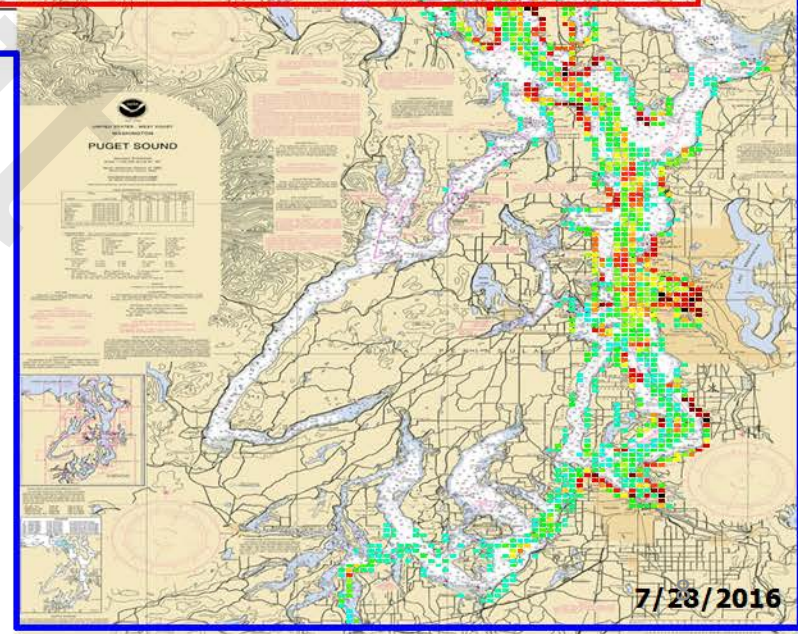
VTRA 2015 BASE CASE - ALL FV



VTRA '15 Case:
BASE CASE

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

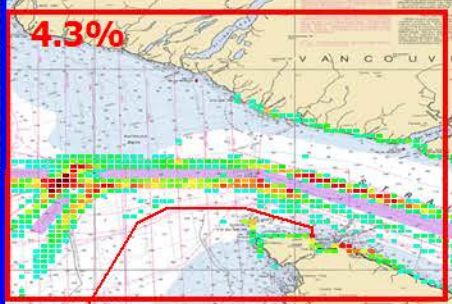
ALL SPILL SIZES



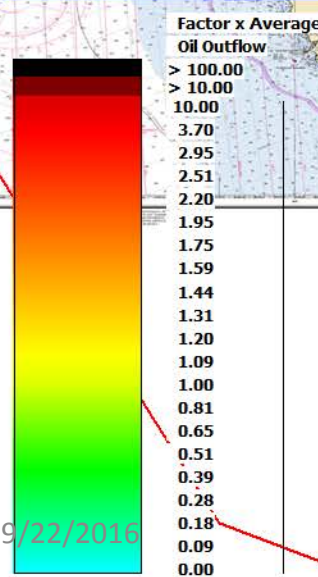
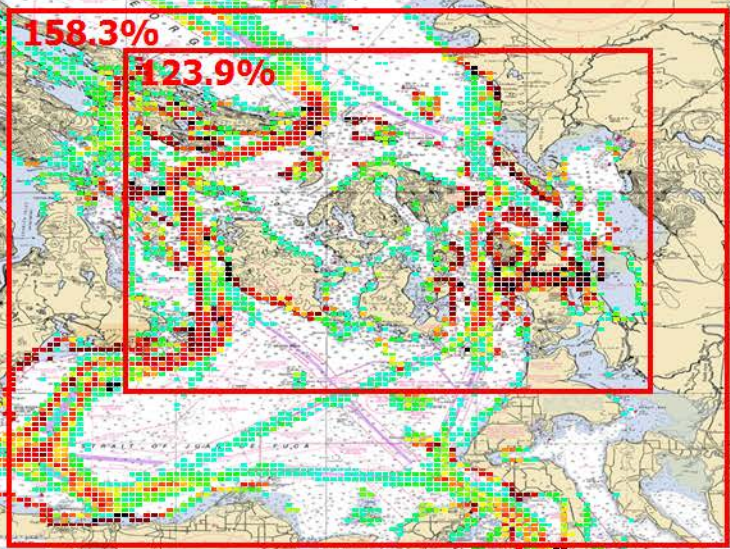
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600 - ALL FV

184.1% of VTRA 2015 Base Case Total Annual Potential Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)

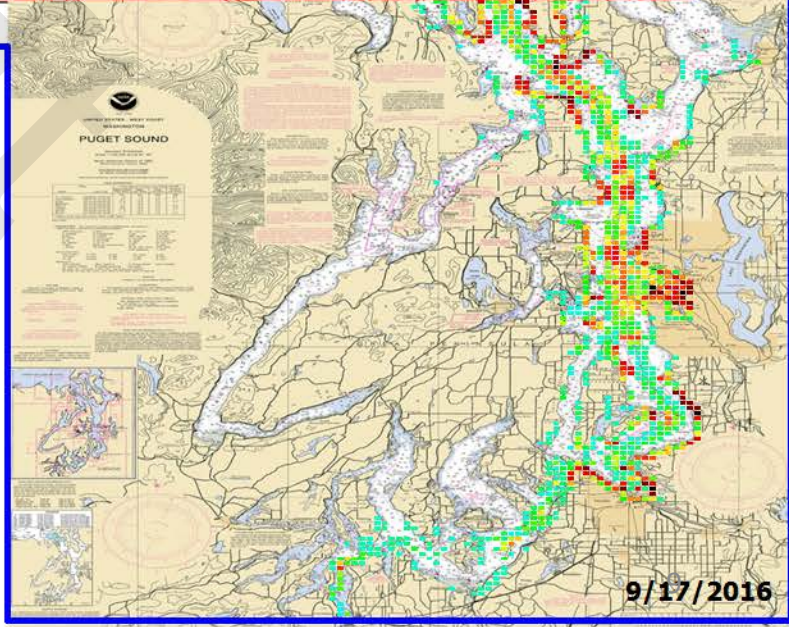


Oil Loss: ALL SPILL SIZES (including accid. with zero oil loss)



VTRA '15 Case: USKMCA1600

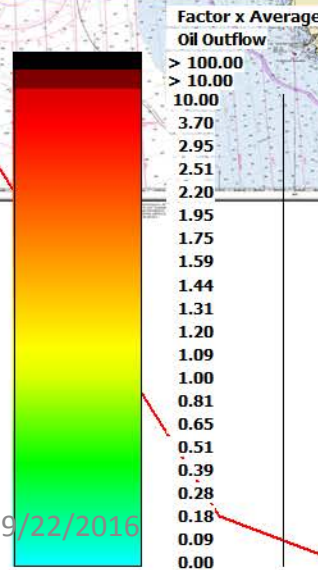
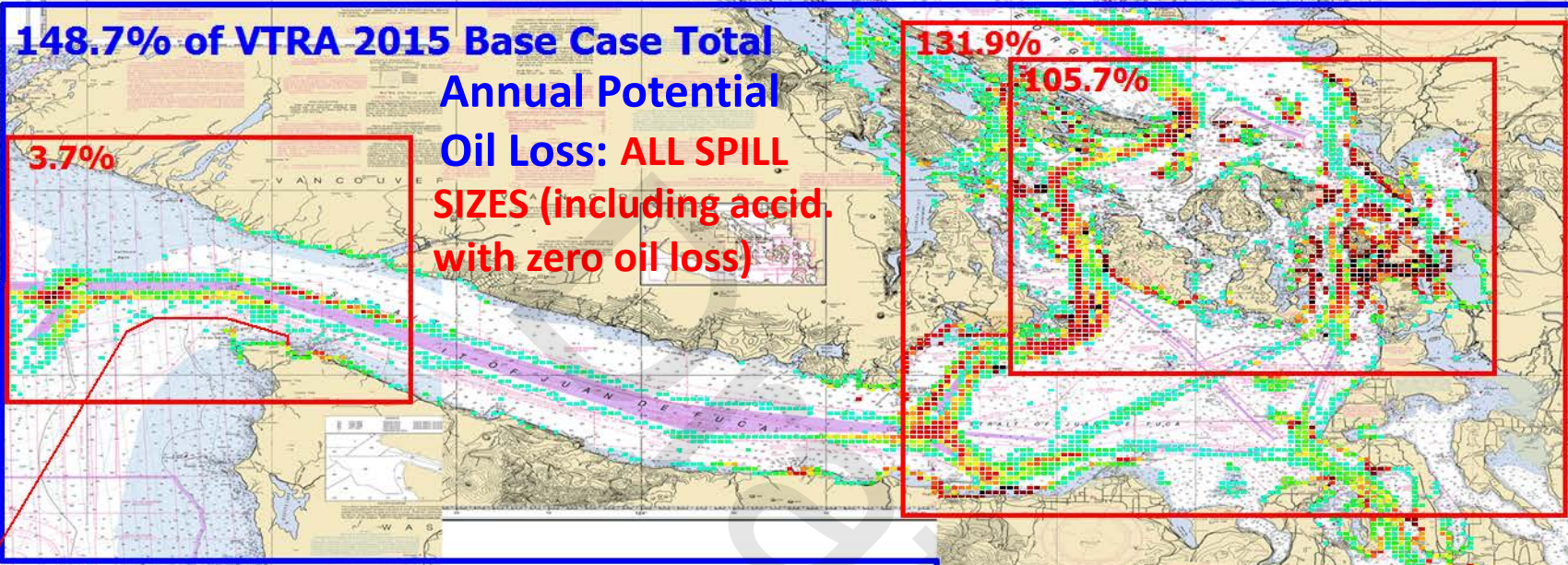
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS IN SPILL SIZE CATEGORY ALL SPILL SIZES



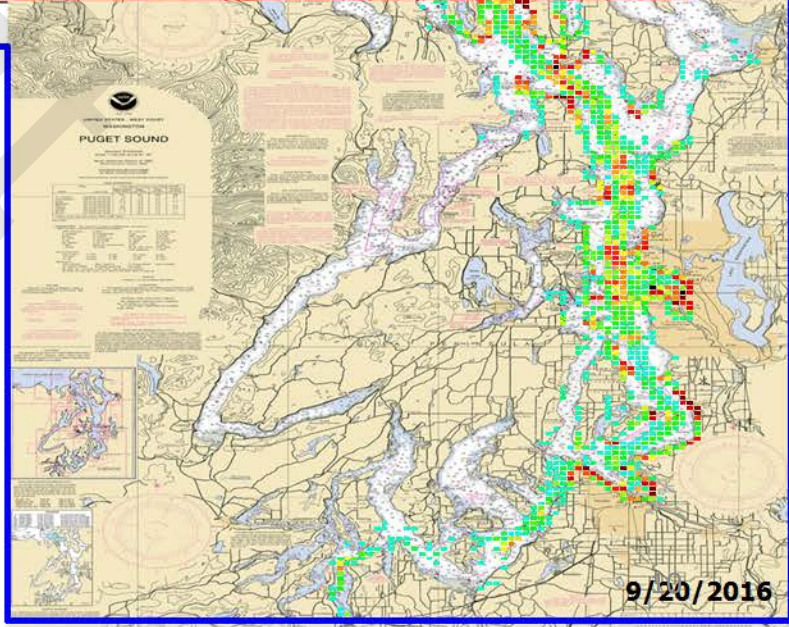
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



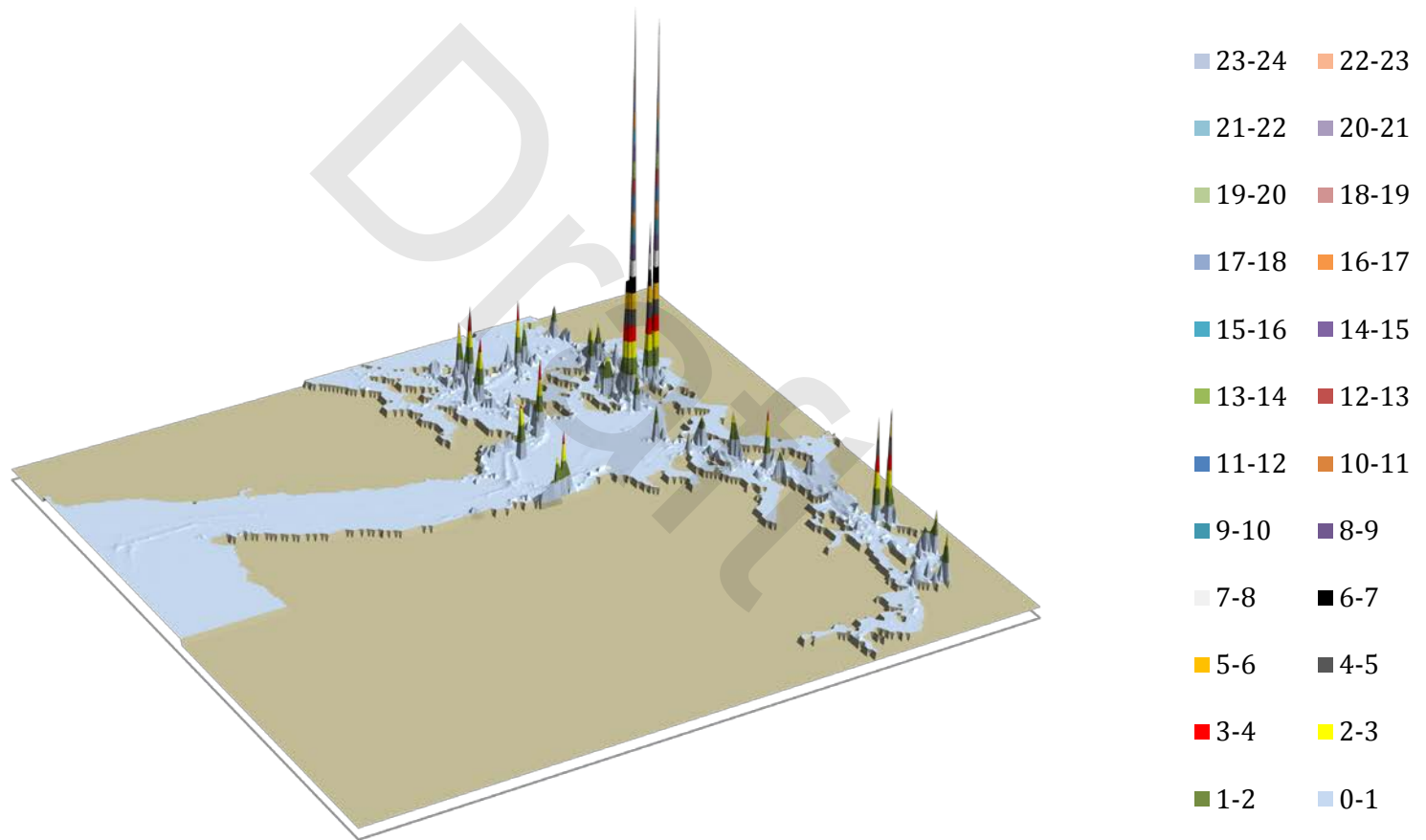
VTRA 2015 Case: USKMCA1600-3RMM - ALL FV



VTRA '15 Case:
USKMCA1600 - 3RMM
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
OIL LOSS OF ACCIDENTS
IN SPILL SIZE CATEGORY
ALL SPILL SIZES



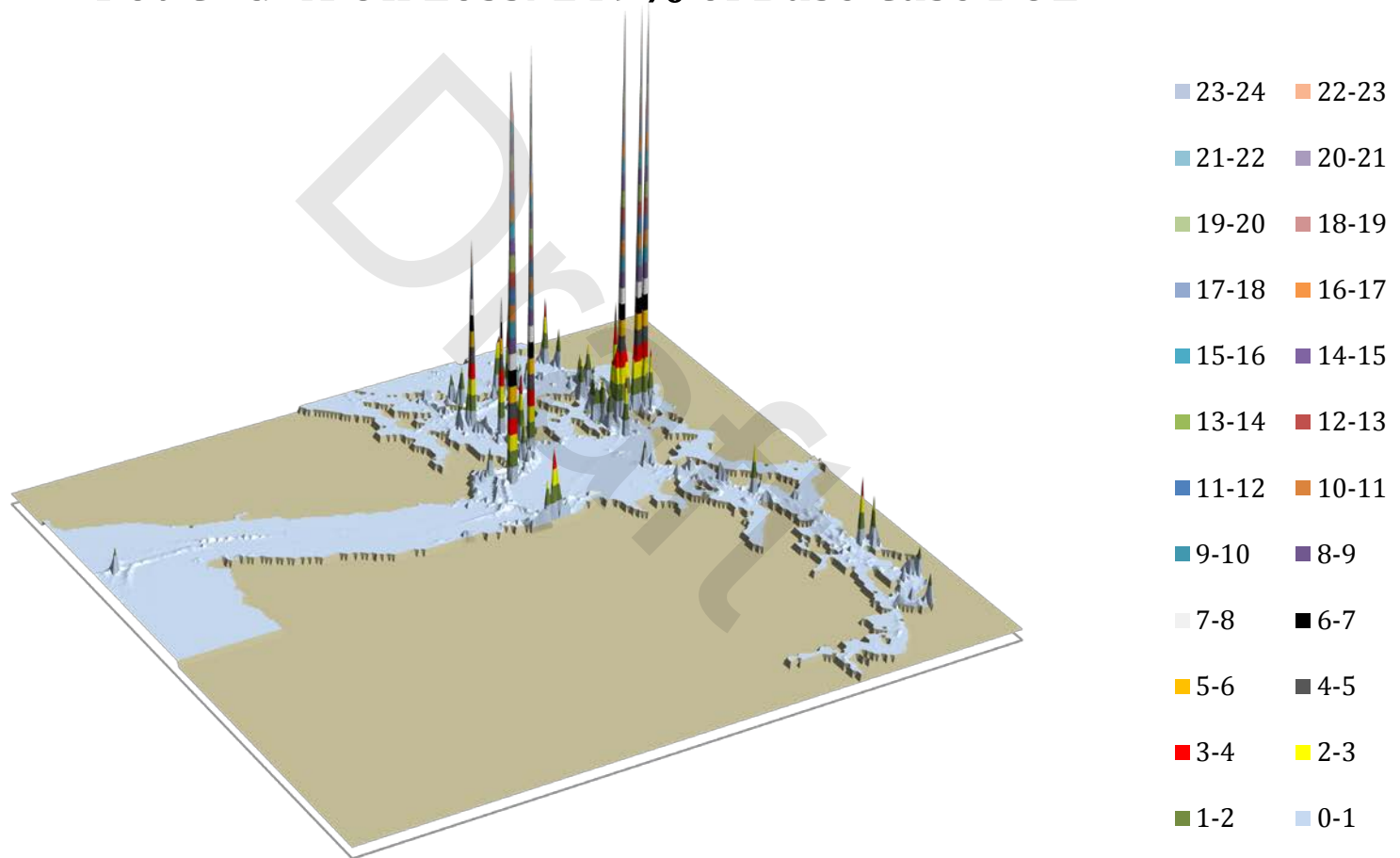
VTRA '15: Base Case 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 100% of Base Case POL



USKMCA1600 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 184% of Base Case POL



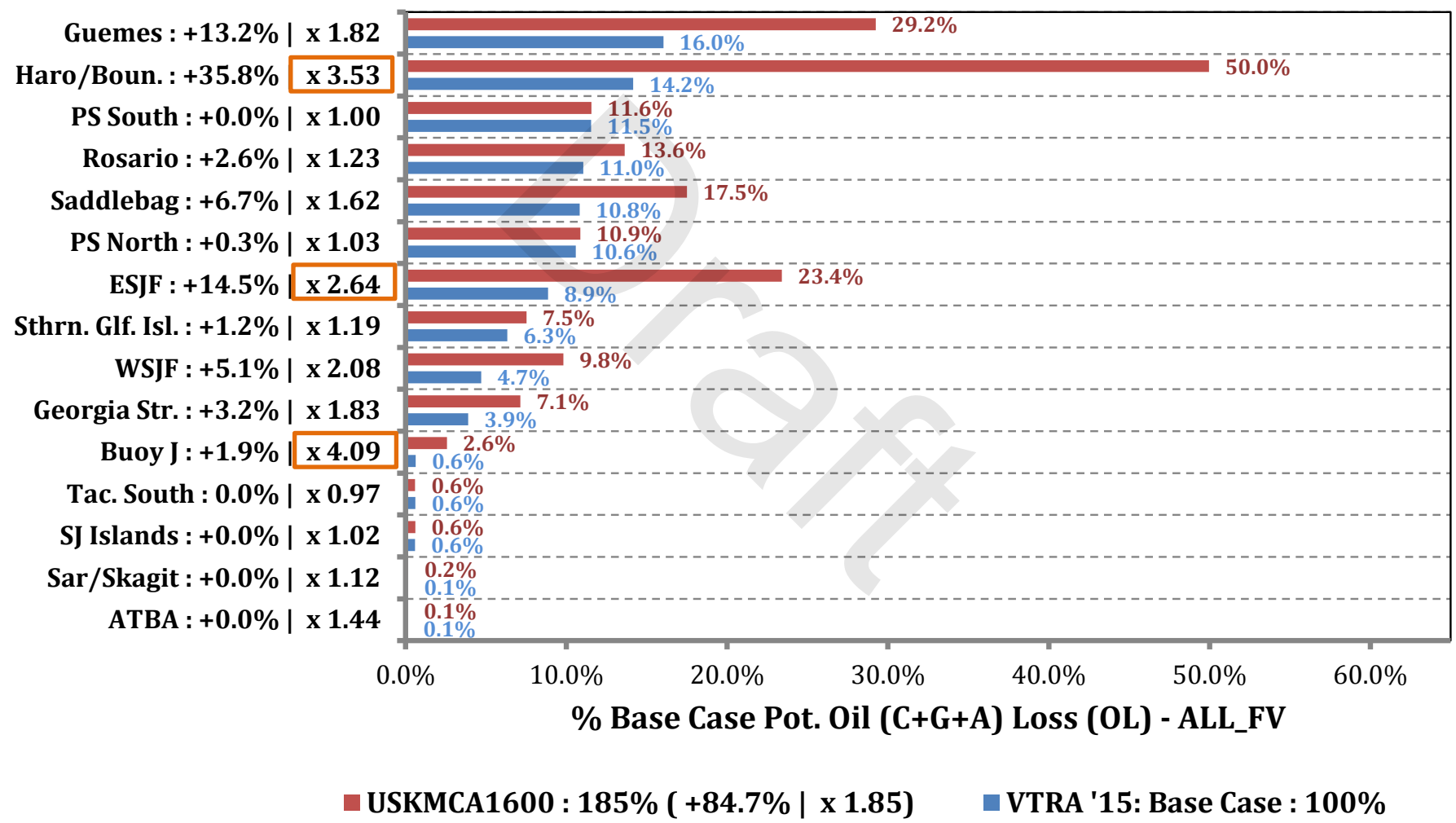
USKMCA1600 - 3RMM 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 149% of Base Case POL



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

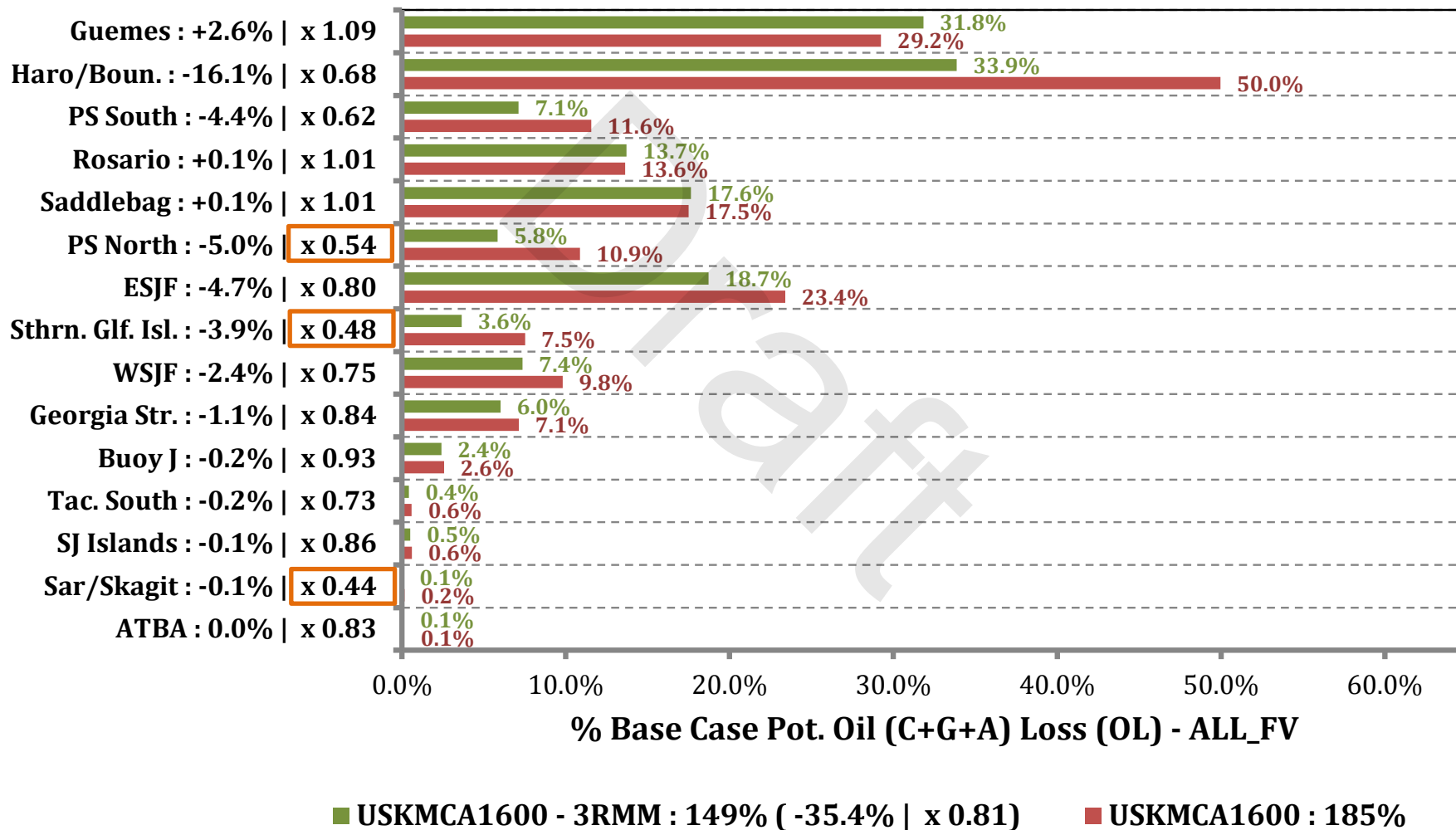


% Base Case Pot. Oil (C + G + A) Loss - ALL_FV



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

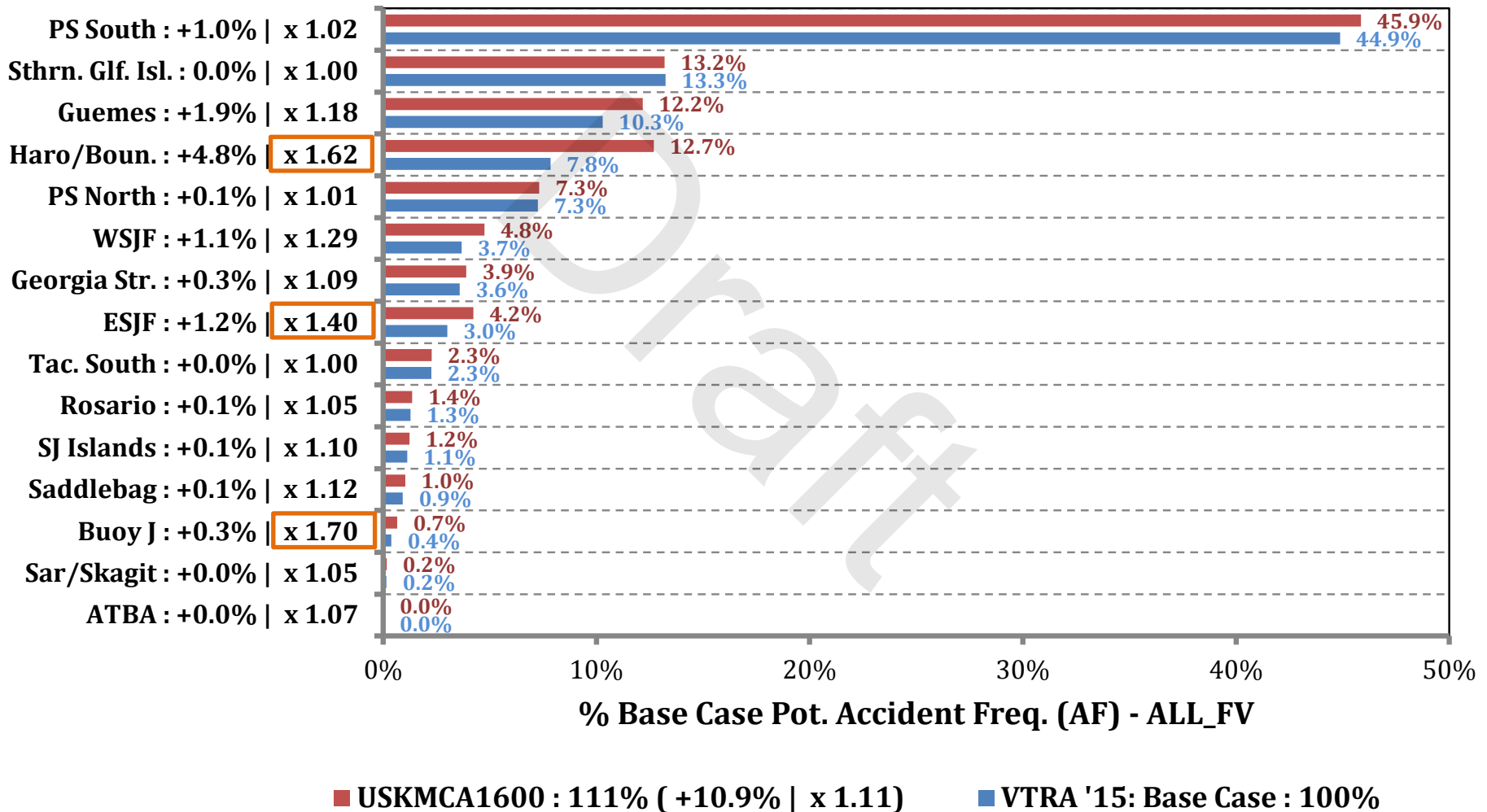
% Base Case Pot. Oil (C + G + A) Loss - ALL_FV



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



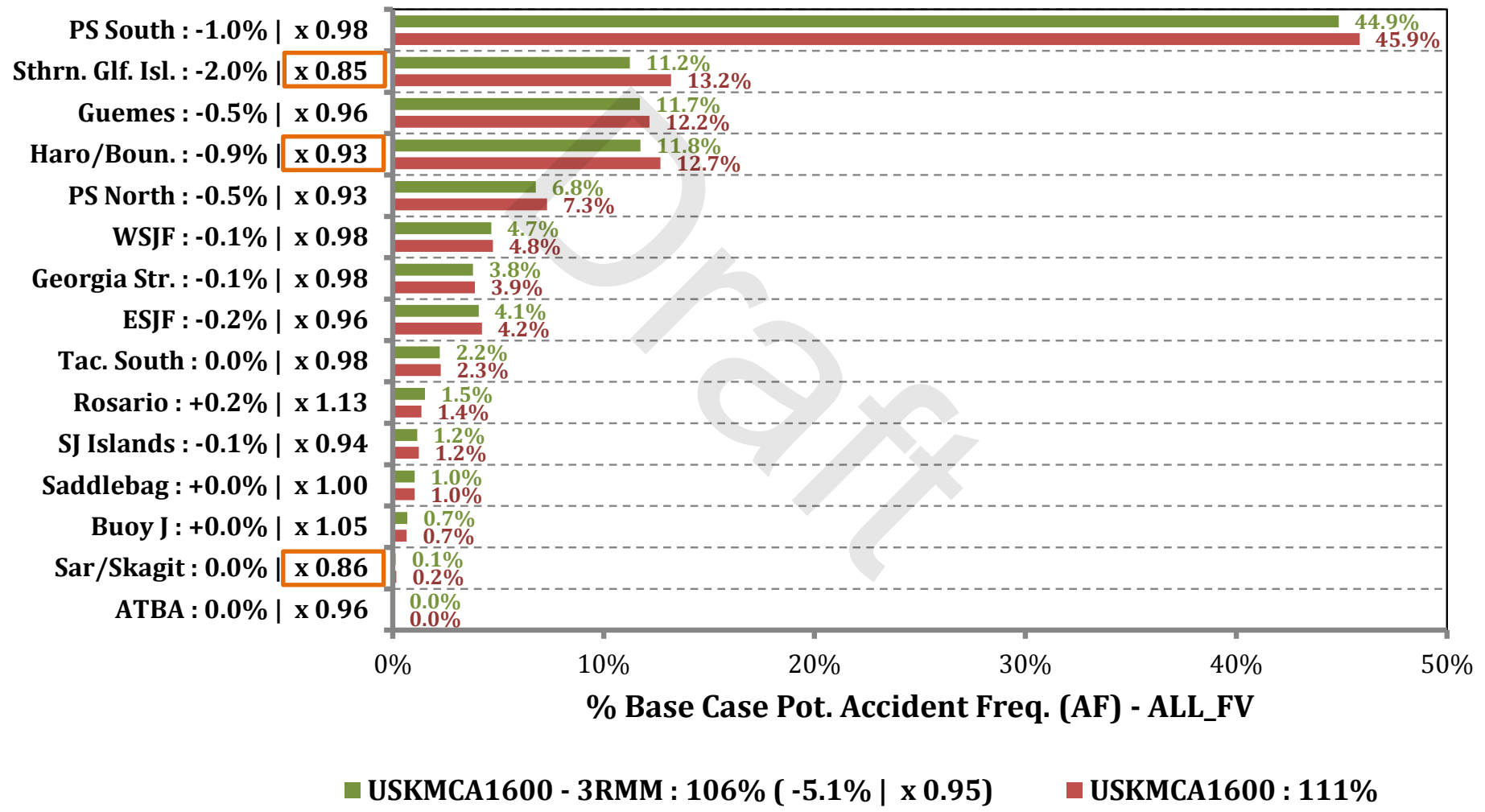
% Base Case Pot. Accident (C+G+A) Frequency - ALL_FV



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



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

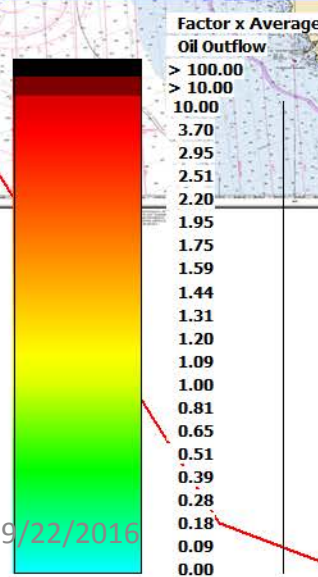
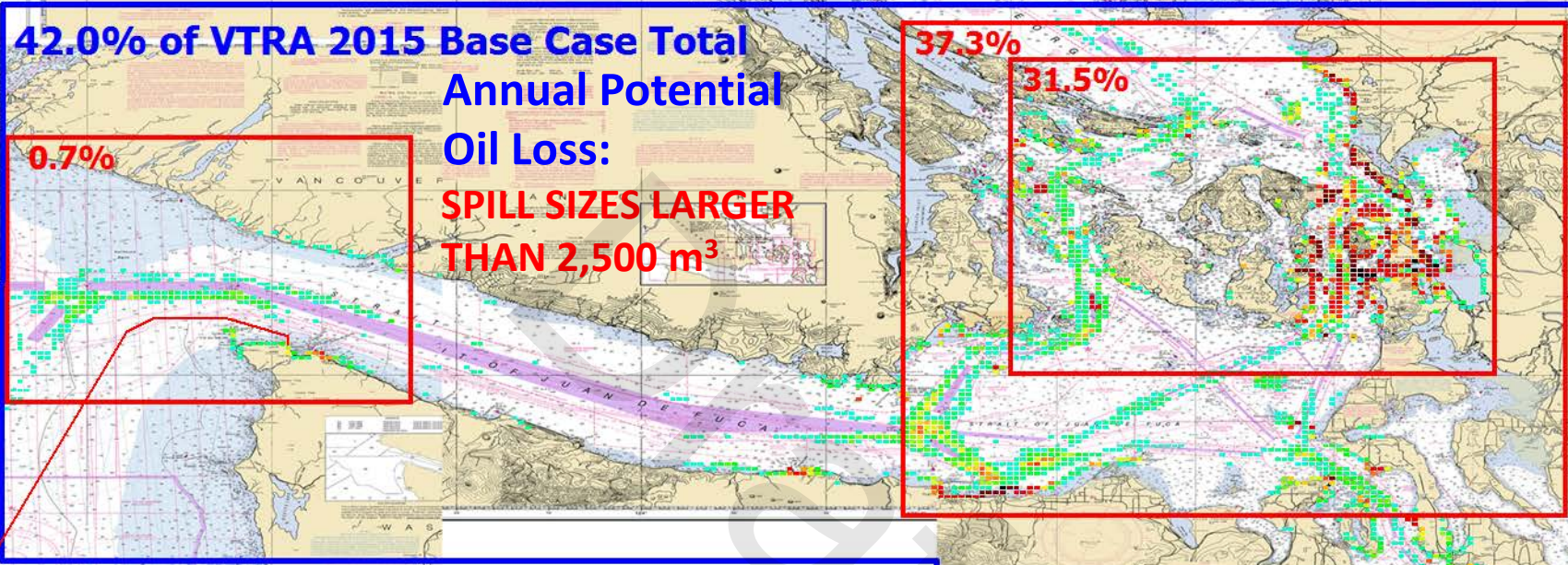


By Waterway Zone Risk Comparison

Oil Spill Size Category:
2500 m³ or more

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV



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: USKMCA1600 - ALL FV

91.0% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³

83.1%
67.7%

3.3%



VTRA '15 Case: USKMCA1600
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m³ or more**

≈ 1.35% Probability of Spill Occurrence in 10 years

Average of ≈ 5,412 m³ Per Potential Spill (≈ 4,654 Metric Tons)

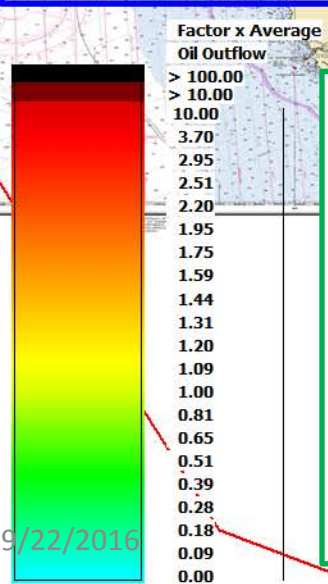
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600-3RMM - ALL FV

91.4% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³

83.8%
68.4%

3.1%



VTRA '15 Case:
USKMCA1600 - 3RMM
 GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m³ or more**

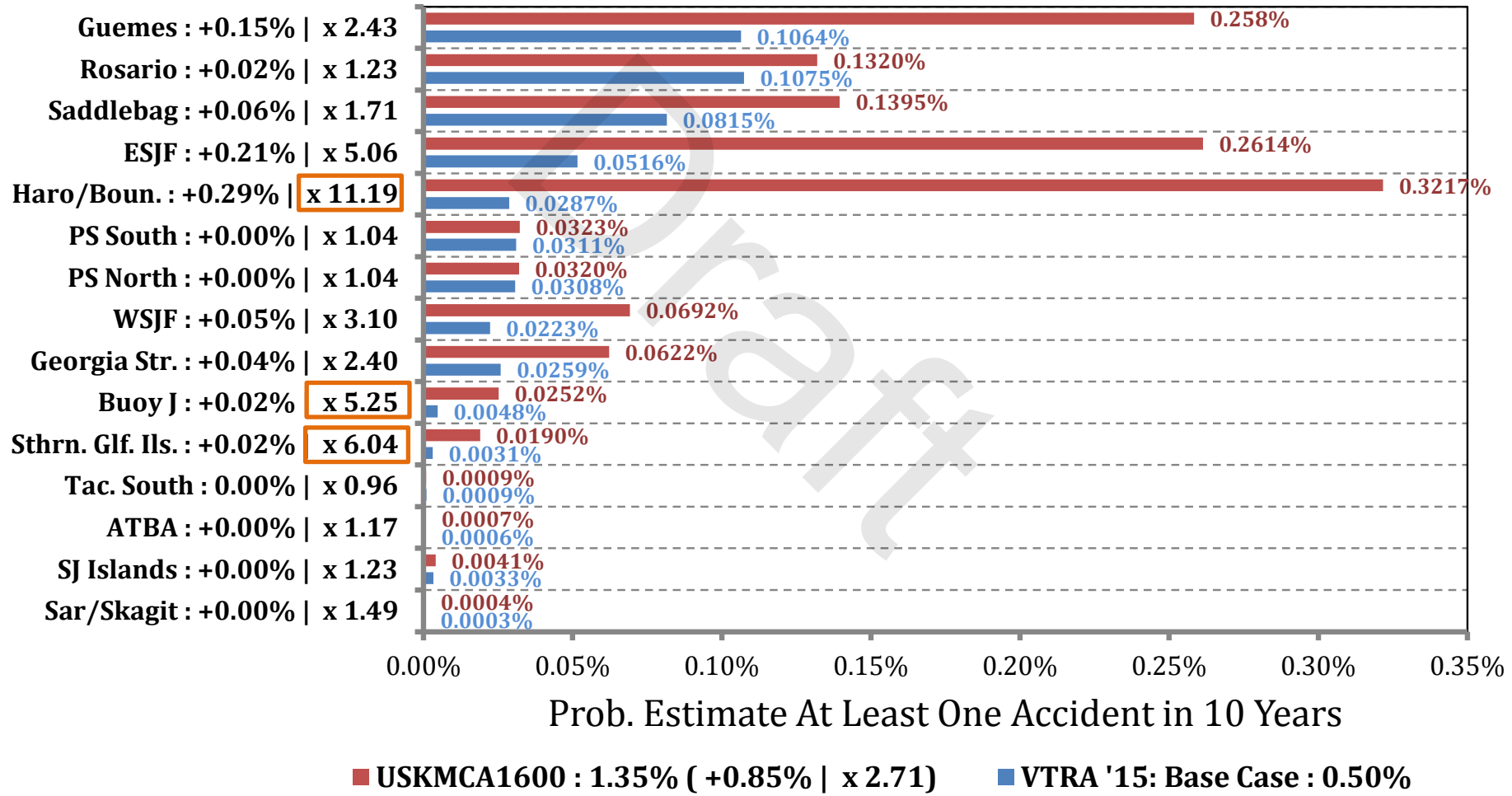
≈ 1.33% Probability of Spill Occurrence in 10 years

Average of ≈ 5,518 m³ Per Potential Spill (≈ 4,745 Metric. Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



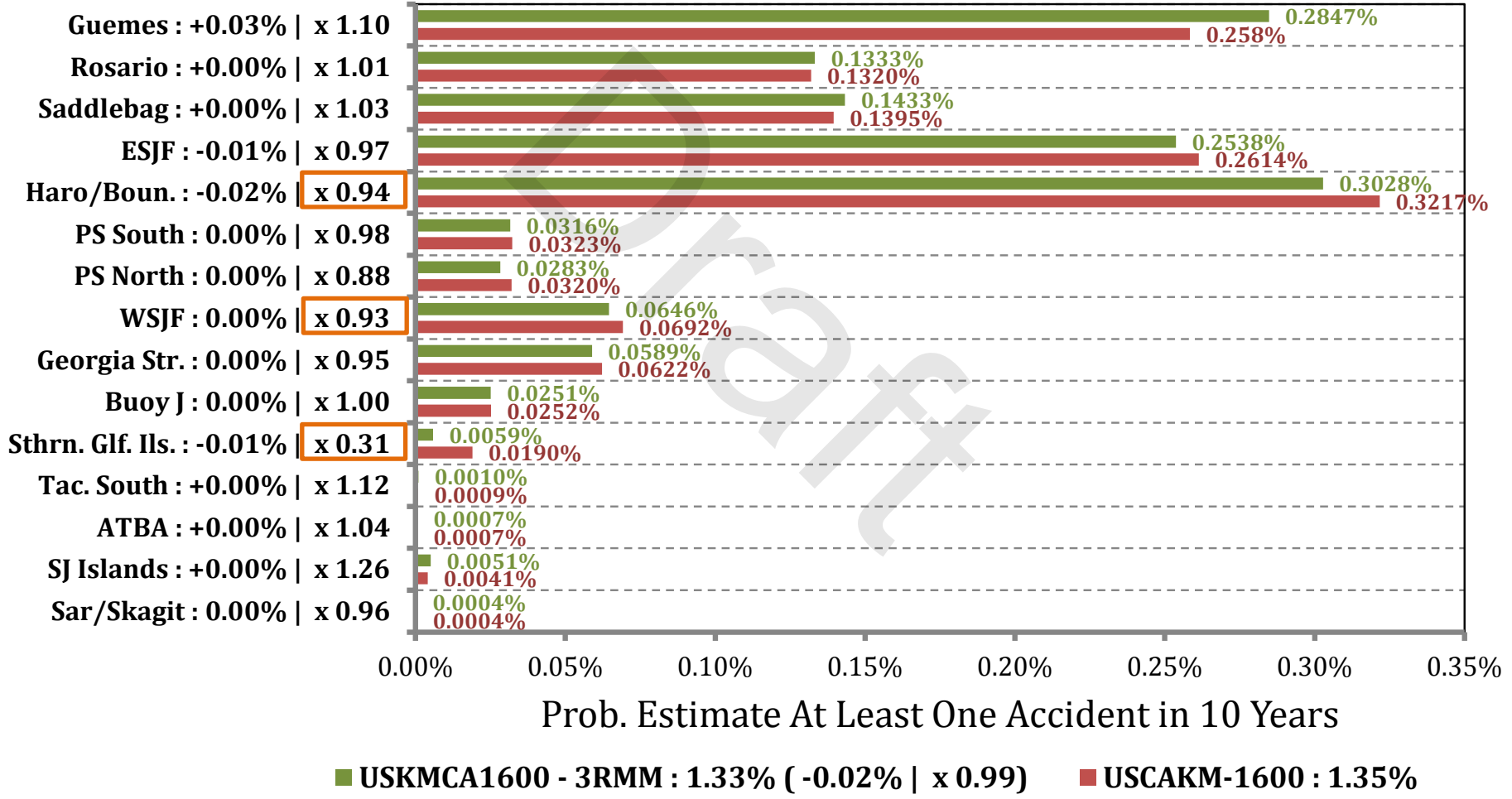
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



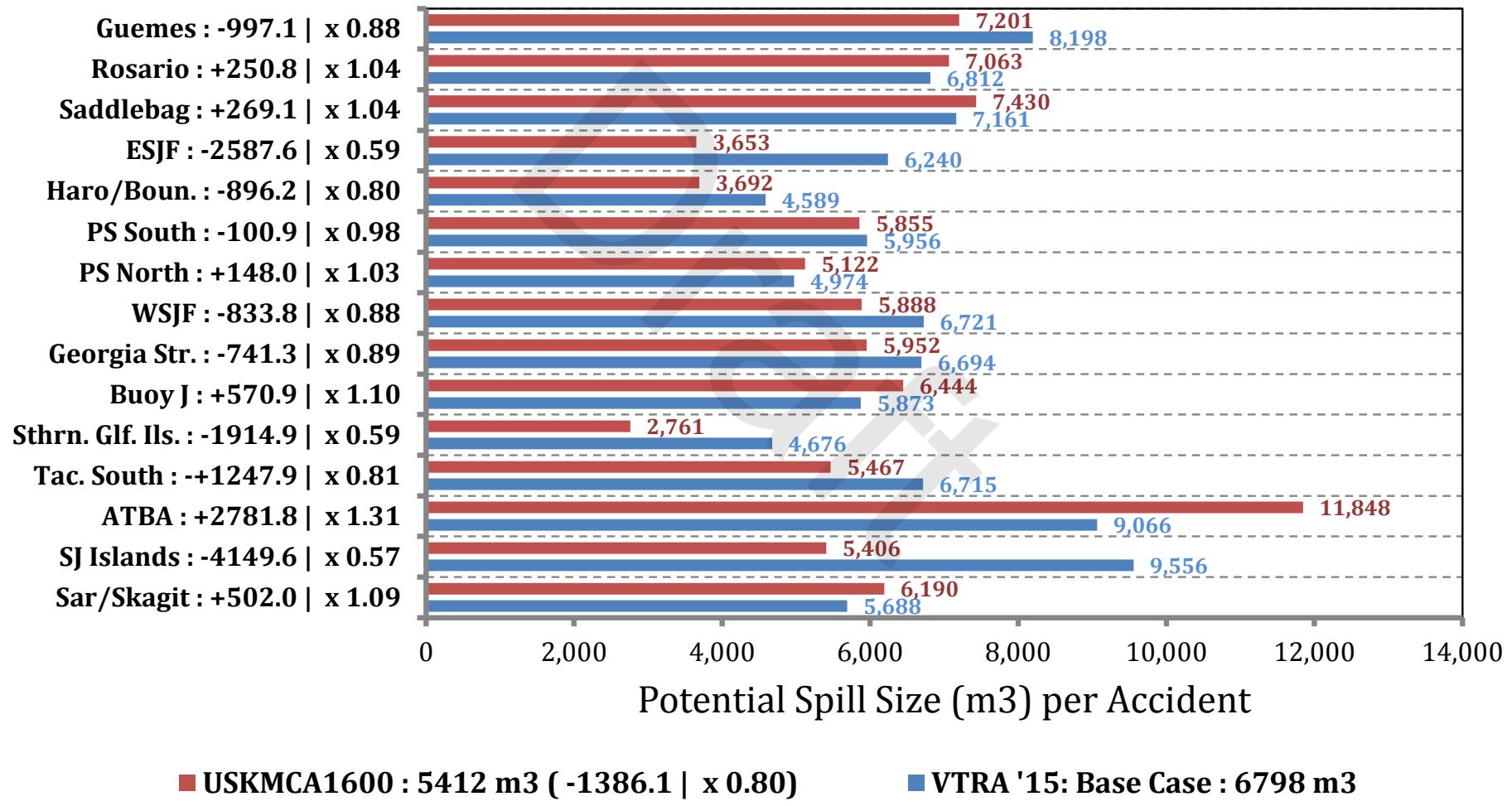
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

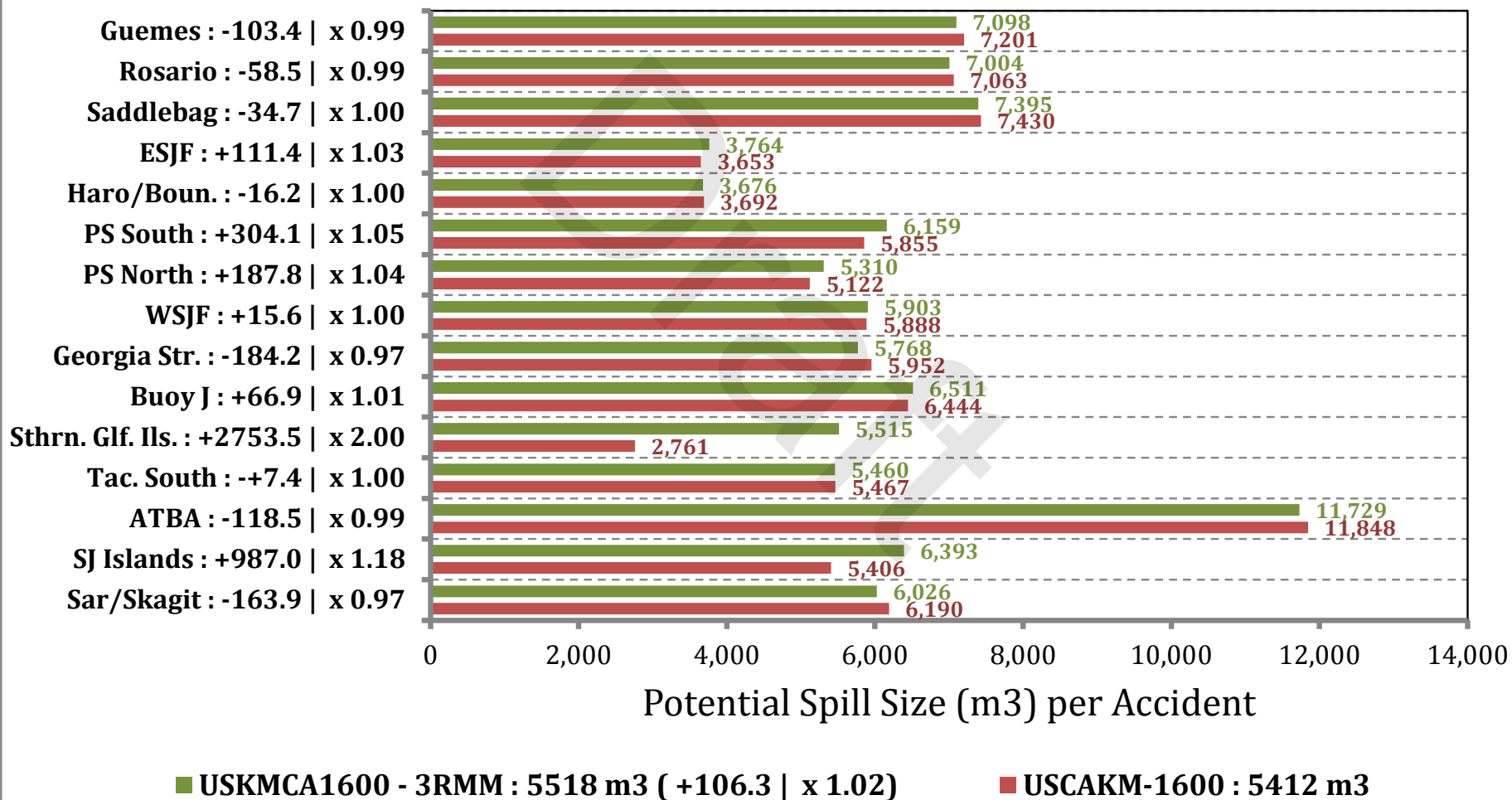


Potential Spill Size (m3) per Accident - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



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

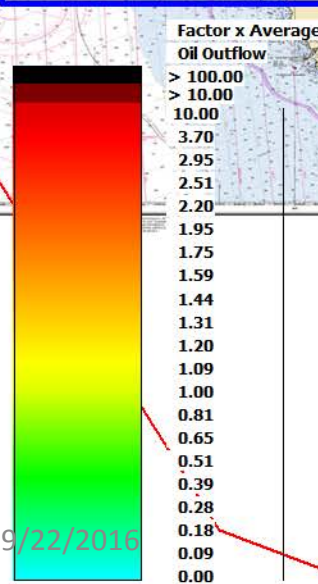


VTRA 2015 BASE CASE - ALL FV

12.3% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES BETWEEN 1,000 m³ - 2,500 m³

10.7%
9.1%

0.1%



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)

9/22/2016

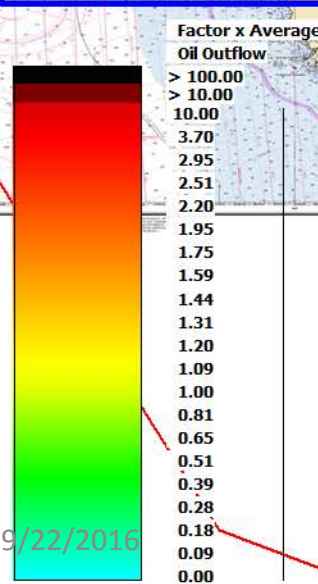
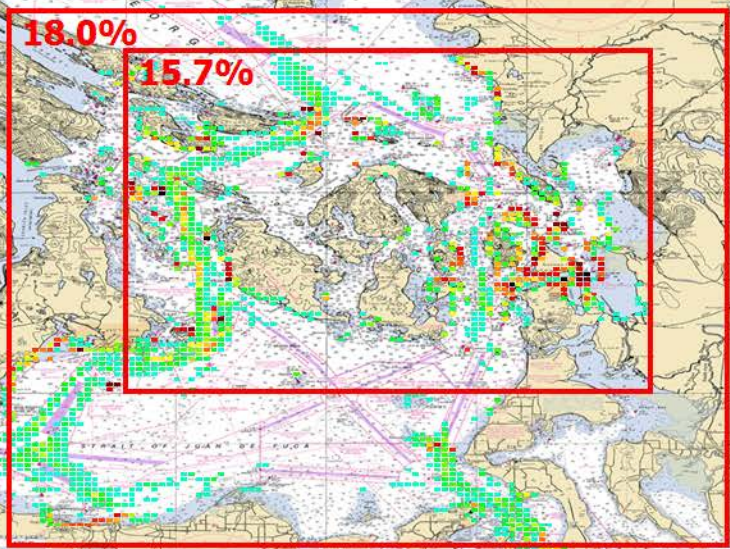
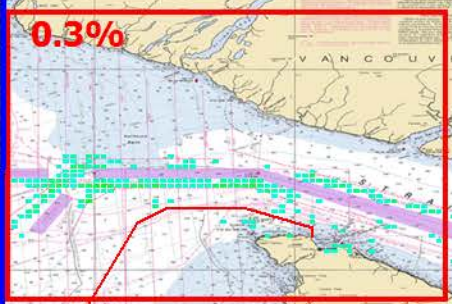
7/28/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600 - ALL FV

19.9% of VTRA 2015 Base Case Total Annual Potential Oil Loss:

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



VTRA '15 Case: USKMCA - 1600
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 1,000 m³ - 2,500 m³

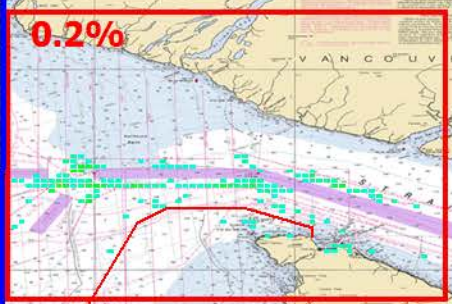
≈ 0.95% Probability of Spill Occurrence in 10 years

Average of ≈ 1,694 m³ Per Potential Spill (≈ 1,457 Metric Tons)

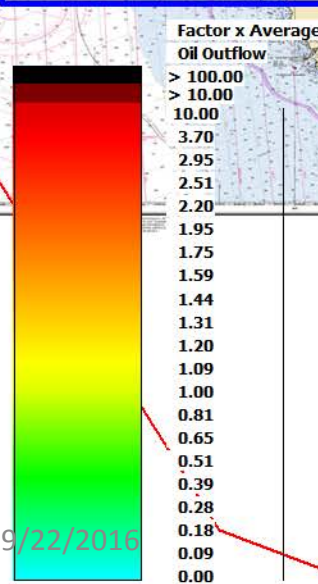
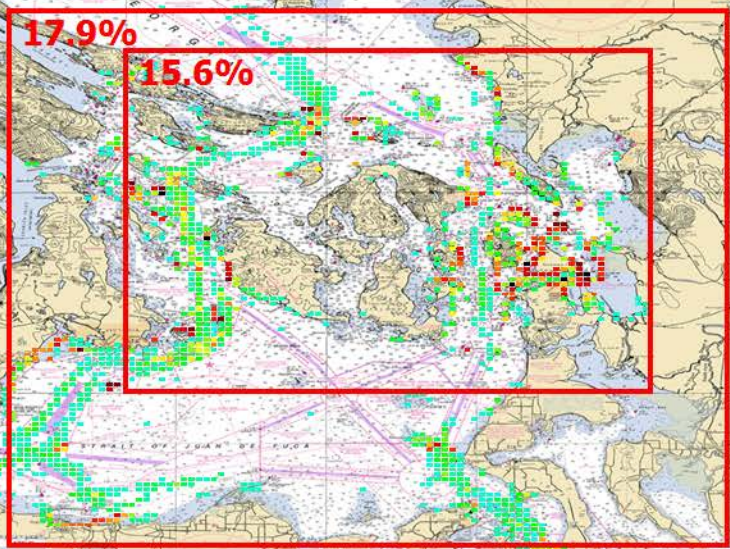
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600-3RMM - ALL FV

19.6% of VTRA 2015 Base Case Total Annual Potential Oil Loss:



Oil Loss:
SPILL SIZES BETWEEN
1,000 m³ - 2,500 m³



VTRA '15 Case:
USKMCA1600 - 3RMM
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **BETWEEN** **1,000 m³ - 2,500 m³**

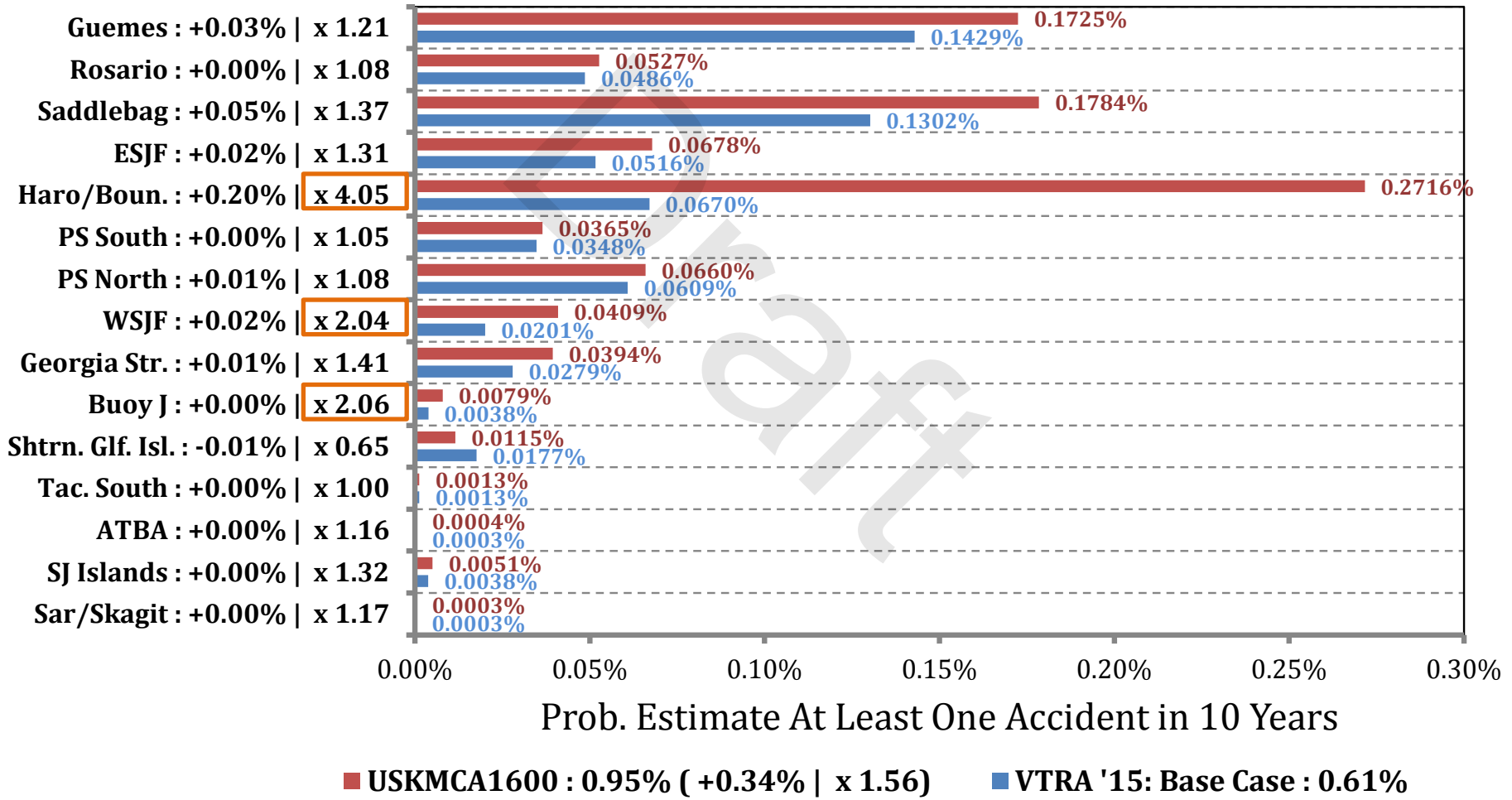
≈ 0.93% Probability of Spill Occurrence in 10 years

Average of ≈ 1,694 m³ Per Potential Spill (≈ 1,457 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



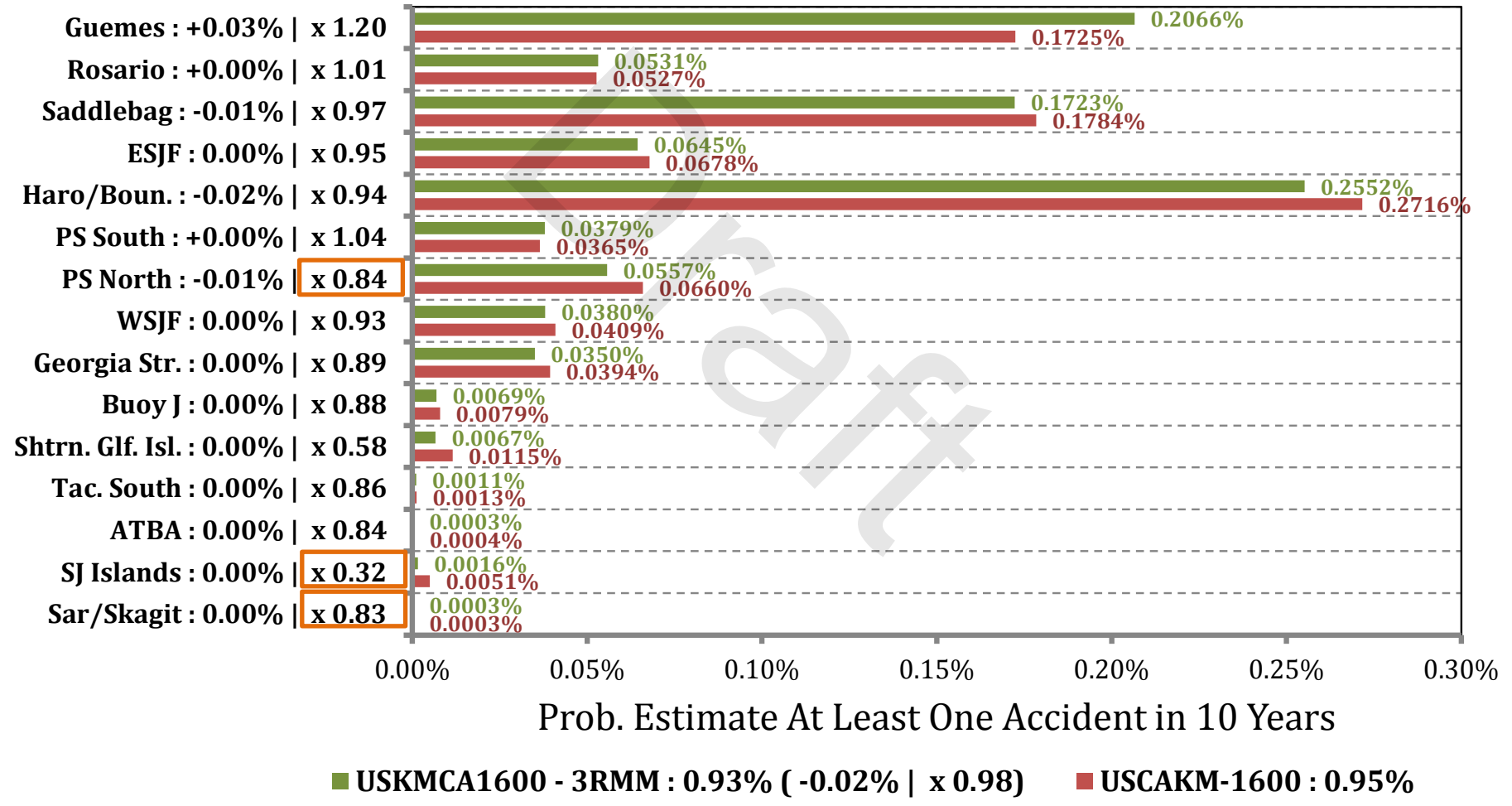
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



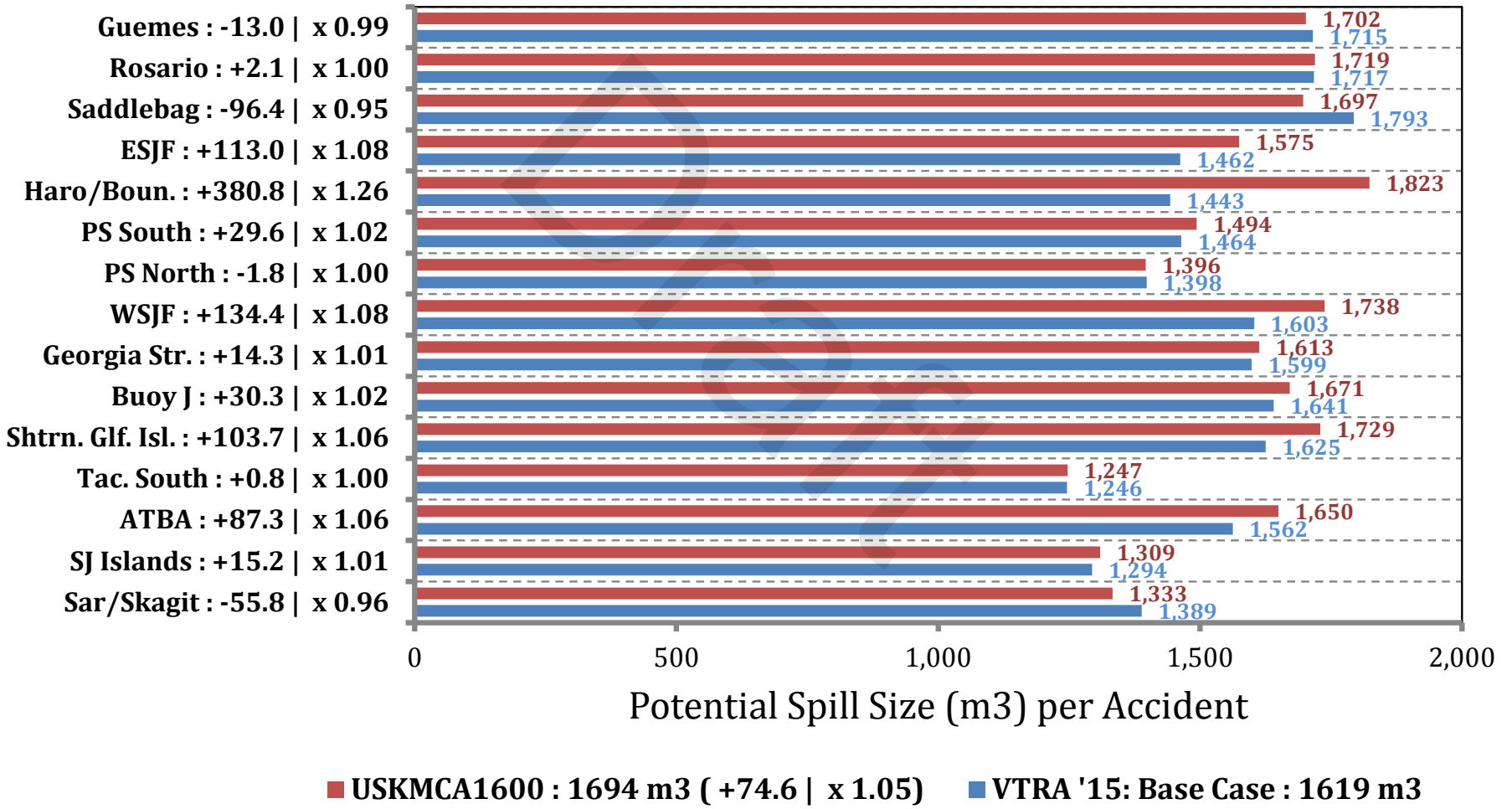
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



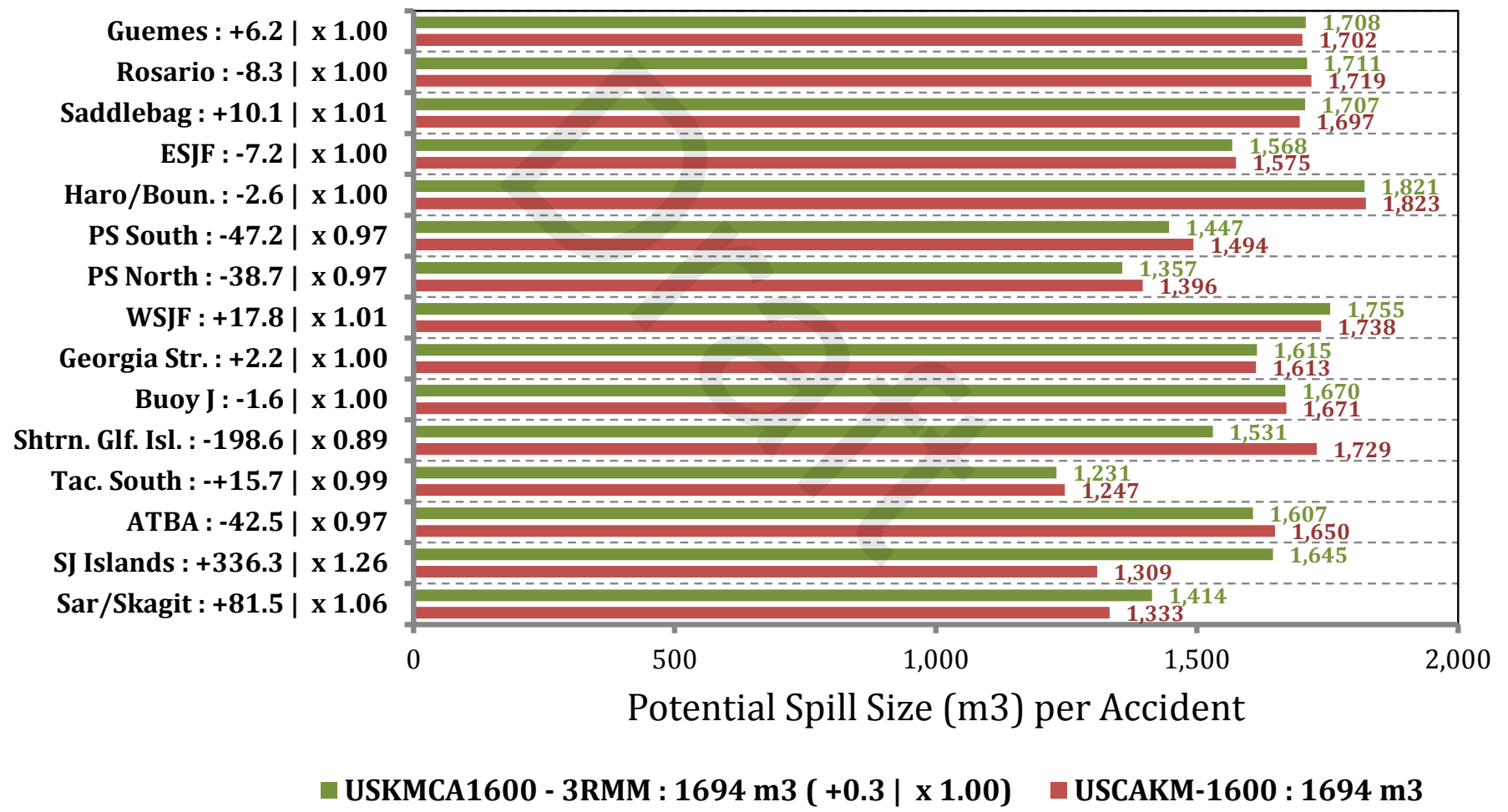
Potential Spill Size (m³) per Accident - ALL_FV - Oil Spill Size Category: 1000 - 2500 m³



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



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



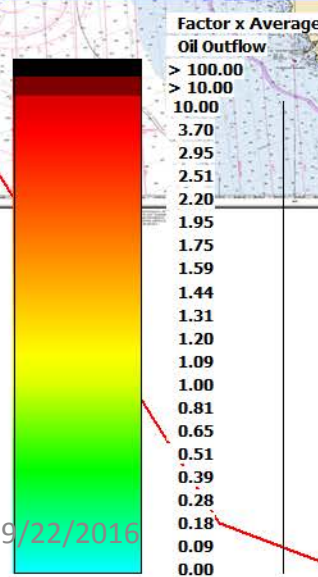
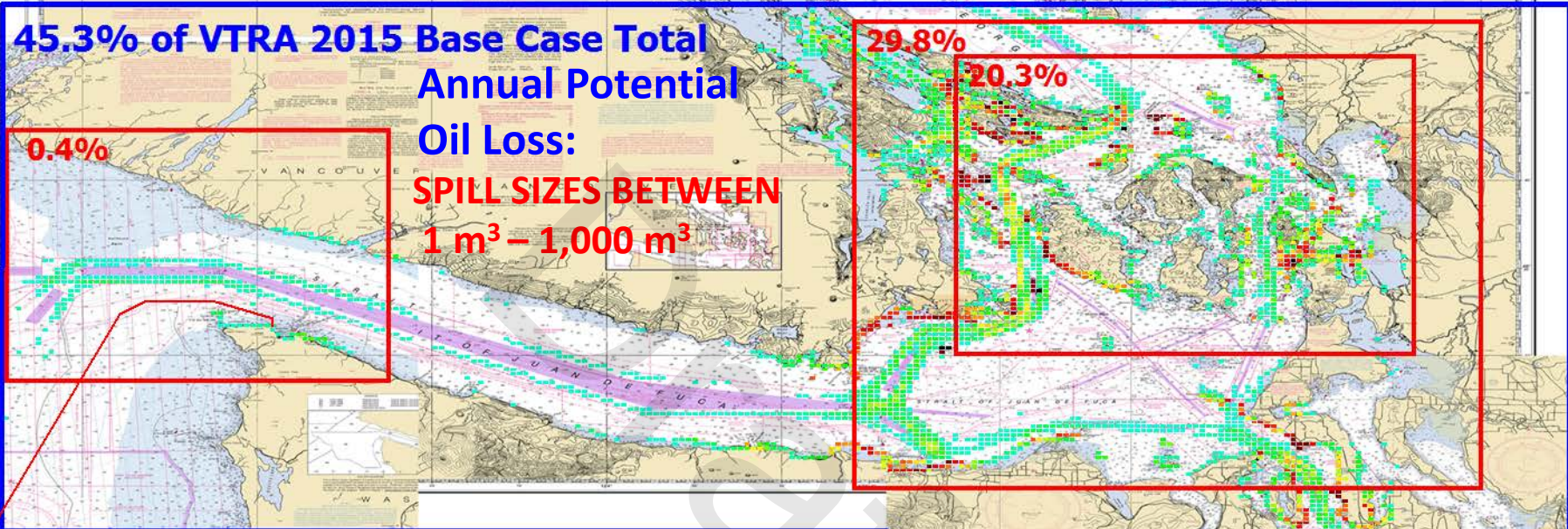
By Waterway Zone Risk Comparison

Oil Spill Size Category:

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV



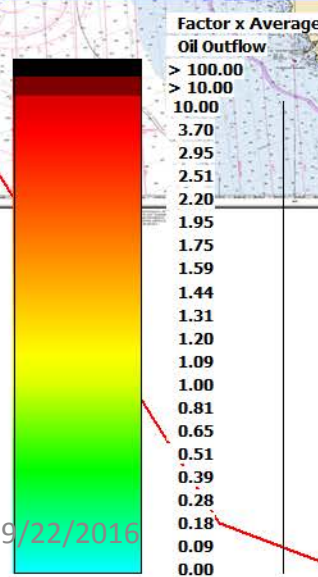
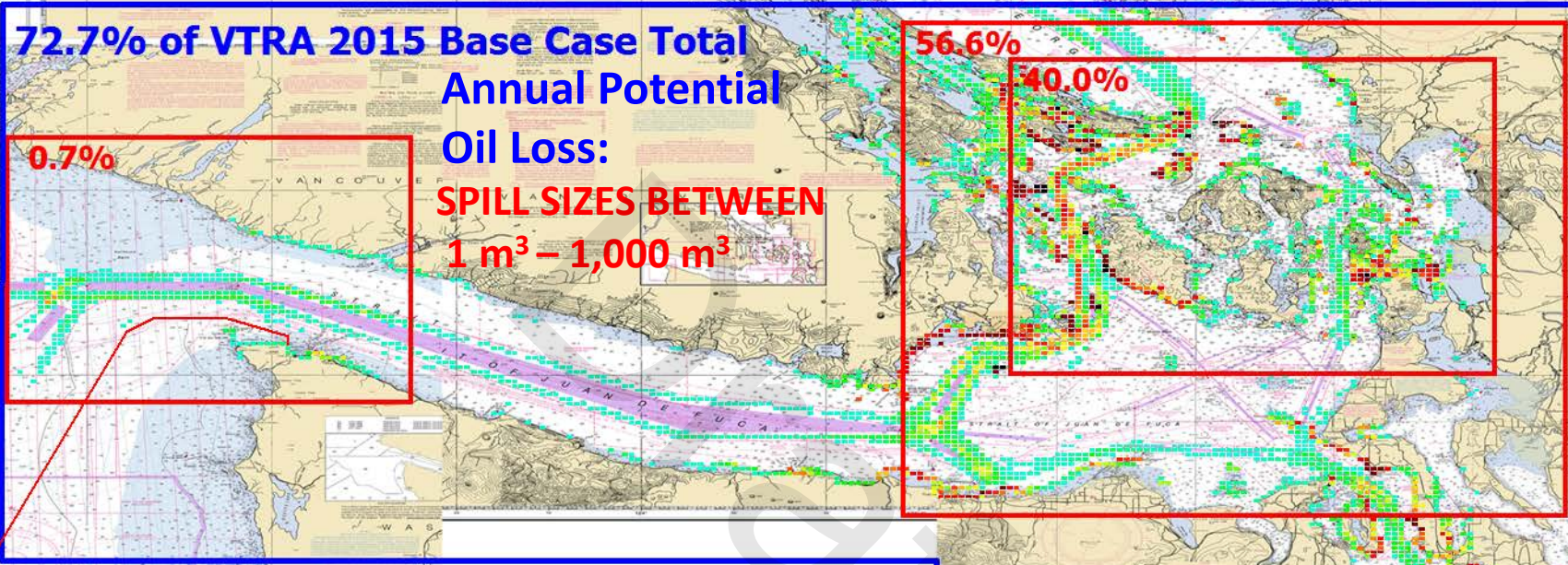
VTRA '15:
BASE CASE
 GEOGRAPHIC PROFILE
 OF ANNUAL
 POTENTIAL OIL LOSS
 OF ACCIDENTS
 WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 54.2% 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: USKMCA1600 - ALL FV



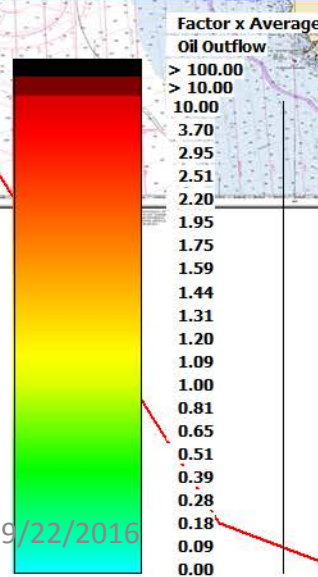
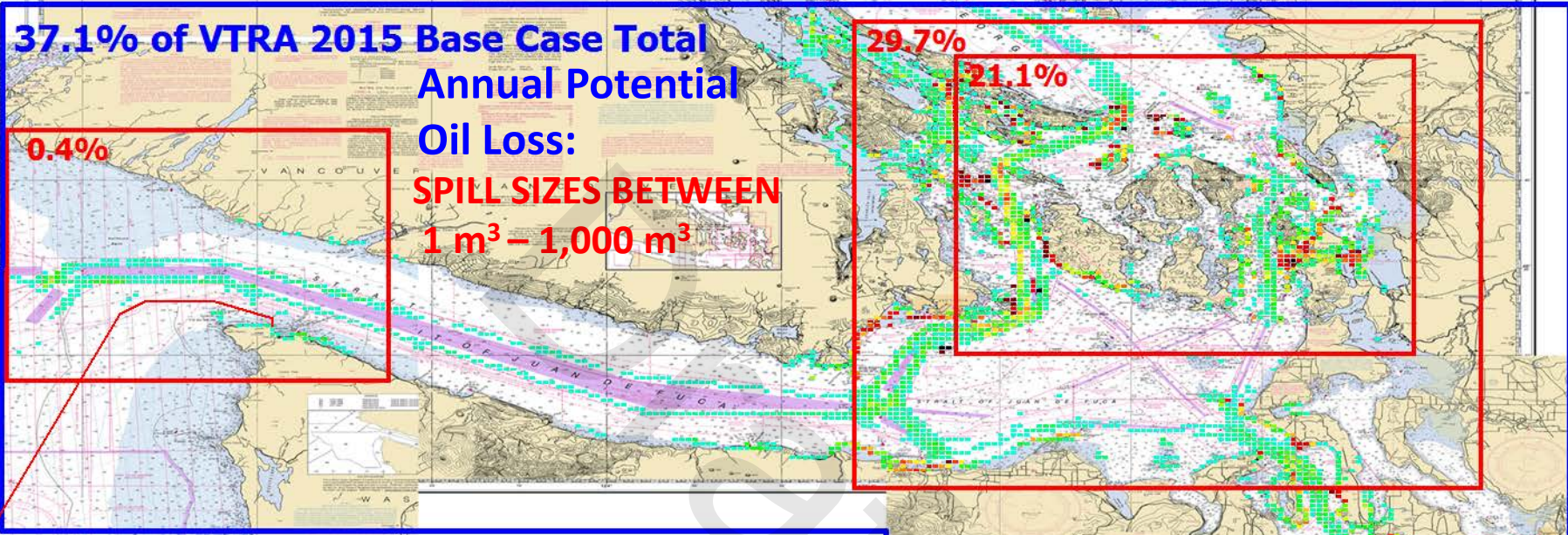
**VTRA '15 Case:
USKMCA - 1600**
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 57.2% Probability
of Spill Occurrence
in 10 years

Average of ≈ 69 m³
Per Potential Spill
(≈ 436 Barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600-3RMM - ALL FV



VTRA '15 Case:
USKMCA1600 - 3RMM
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

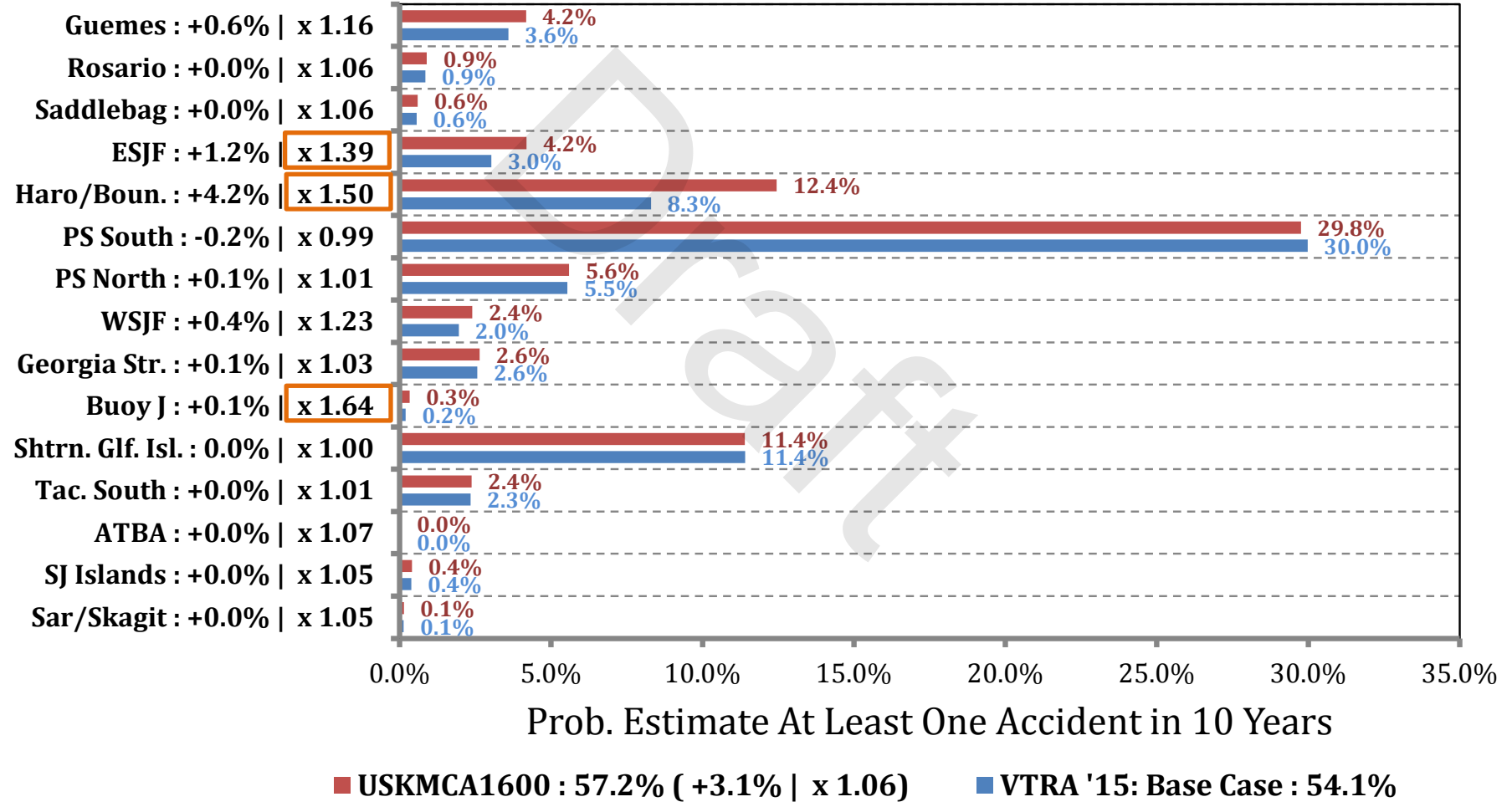
≈ 50.7% Probability
of Spill Occurrence
in 10 years

Average of ≈ 42 m³
Per Potential Spill
(≈ 265 Barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

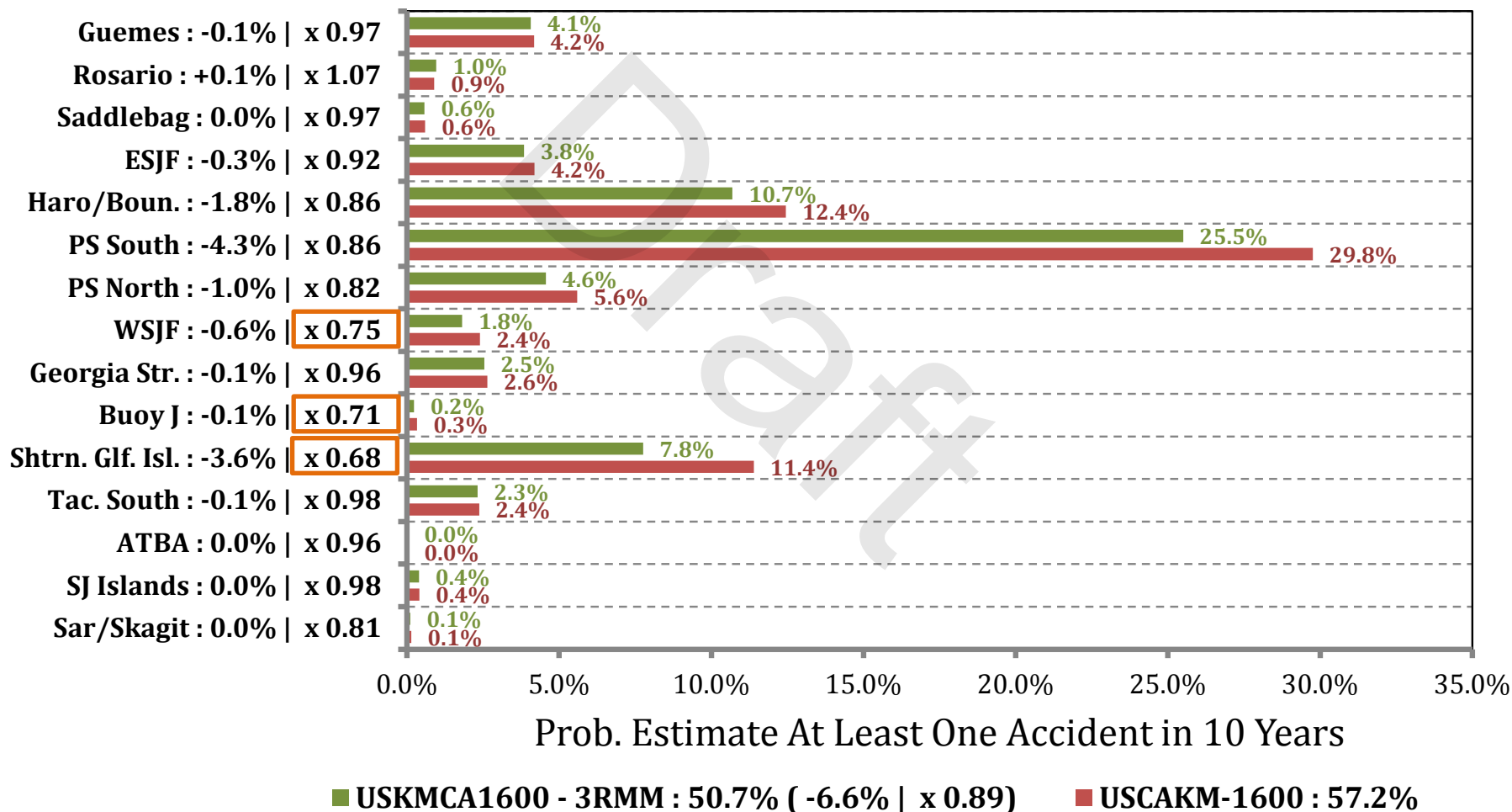


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1 - 1000 m3



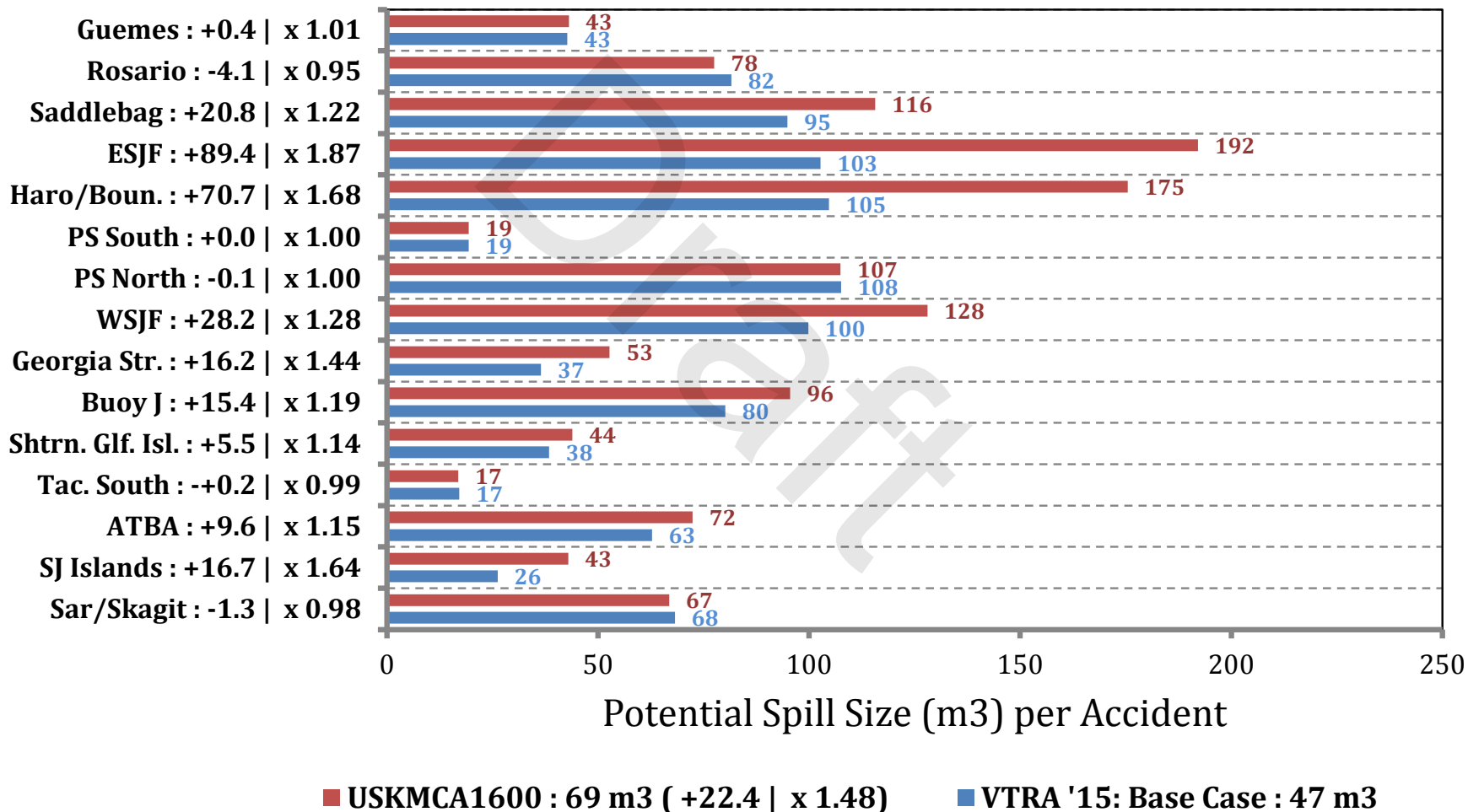
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



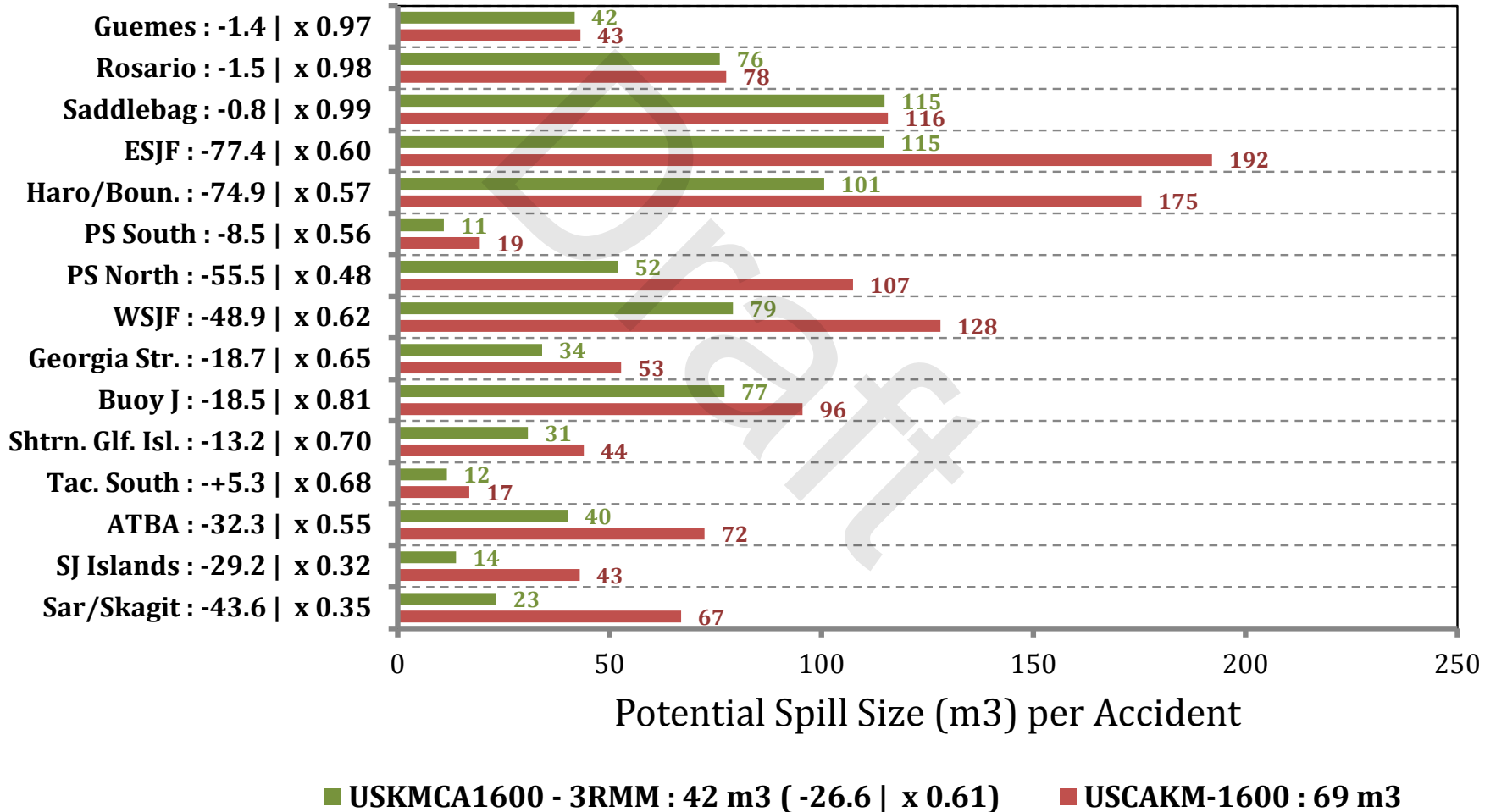
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



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

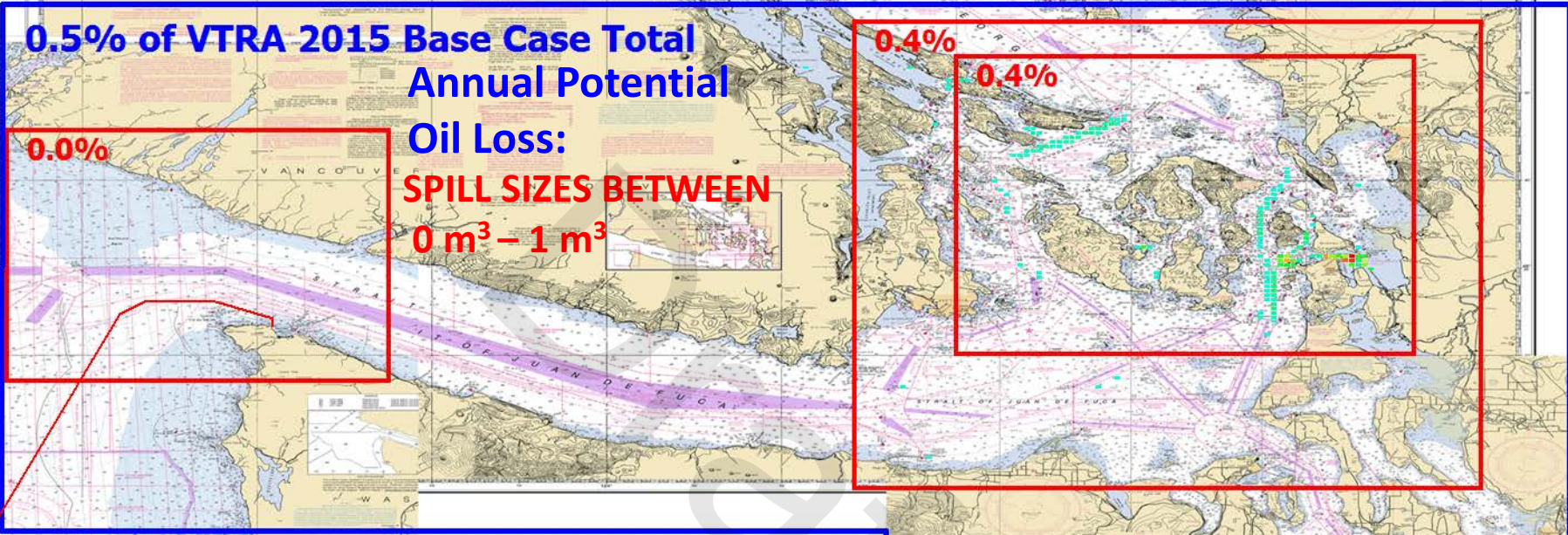
Oil Spill Size Category:

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

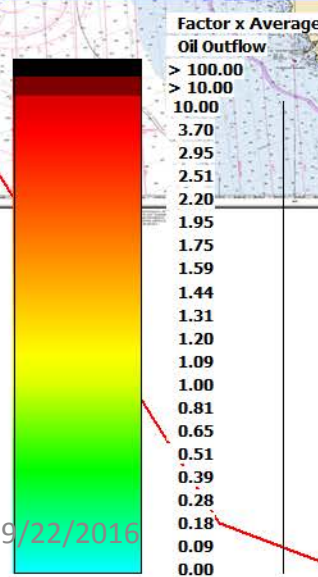


VTRA 2015 BASE CASE - ALL FV



0.5% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES BETWEEN
 $0\text{ m}^3 - 1\text{ m}^3$

0.4%
0.4%



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)

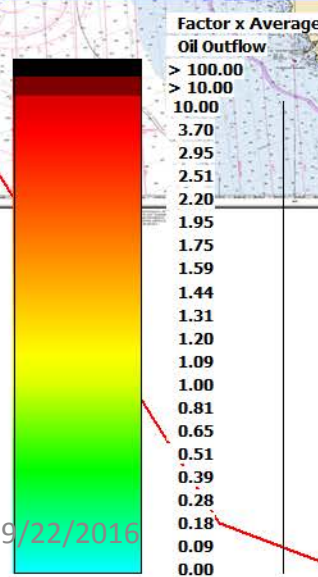
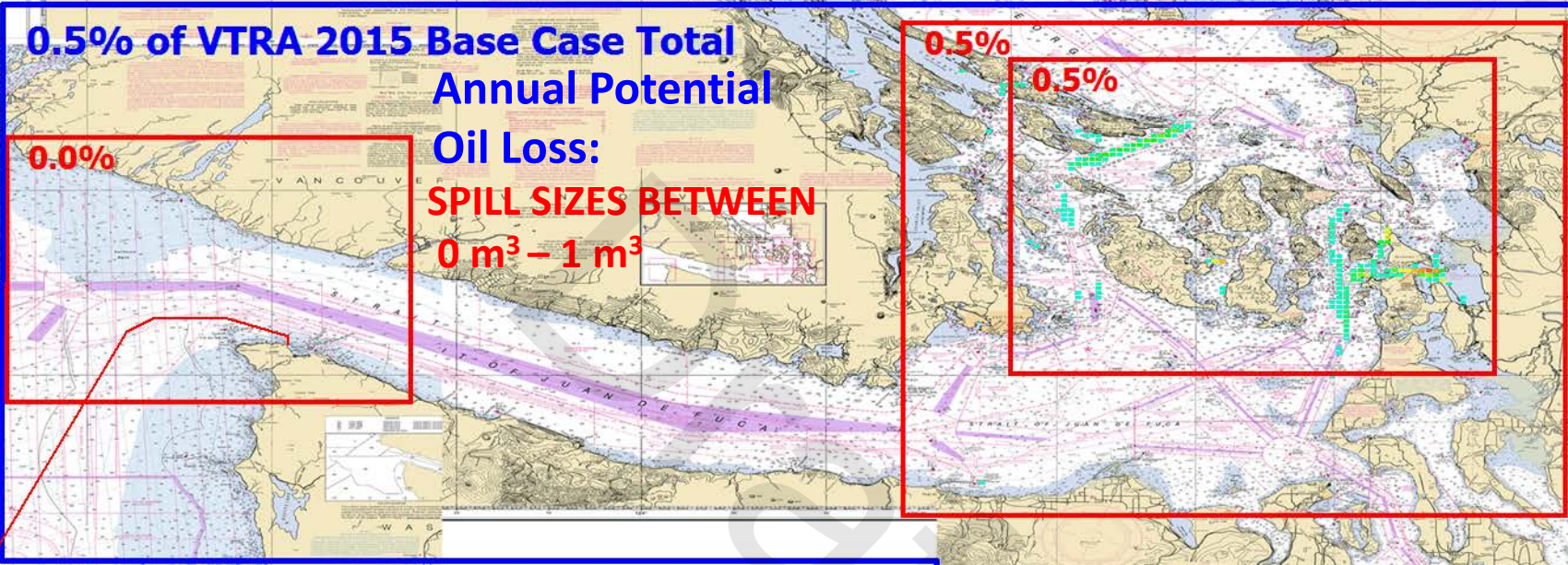
9/22/2016

7/28/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 Case: USKMCA1600 - ALL FV



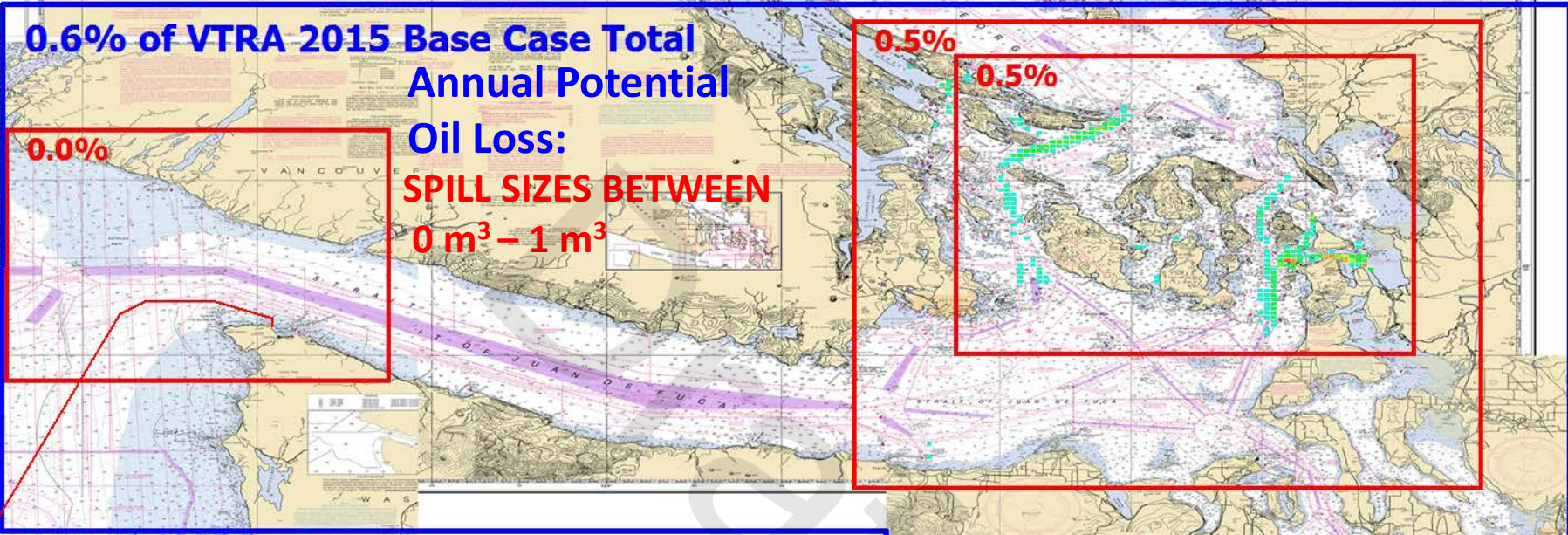
VTRA '15 Case:
USKMCA1600
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 100% Probability
of Spill Occurrence
in 10 years

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

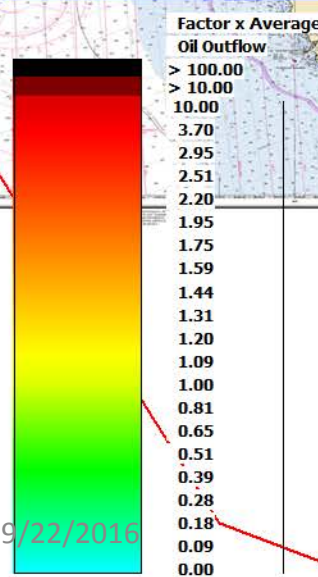
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 Case: USKMCA1600-3RMM - ALL FV



0.6% of VTRA 2015 Base Case Total Annual Potential Oil Loss:
SPILL SIZES BETWEEN
0 m³ - 1 m³

0.5%
0.5%



VTRA '15 Case:
USKMCA1600 - 3RMM
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
(≈ 2.5 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 BASE CASE - ALL FV

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

0.8%

**# Accidents:
SPILL SIZES BETWEEN
 $0\text{ m}^3 - 1\text{ m}^3$**

39.2%
29.5%



**VTRA '15 Case:
BASE CASE
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
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: USKMCA1600 - ALL FV

109.0% of VTRA 2015 Base Case Total Potential Annual # Accidents:

1.4%

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

47.6%

36.8%



VTRA '15 Case: USKMCA1600
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL # ACCIDENTS WITH SPILL SIZE BETWEEN $0\text{ m}^3 - 1\text{ m}^3$

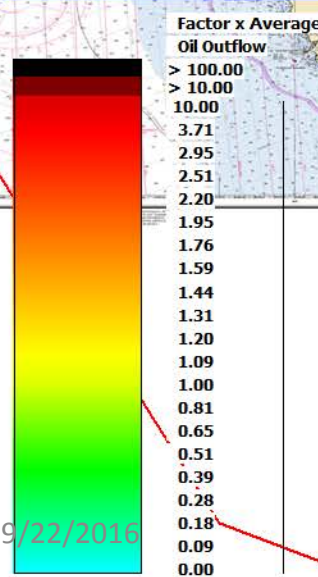
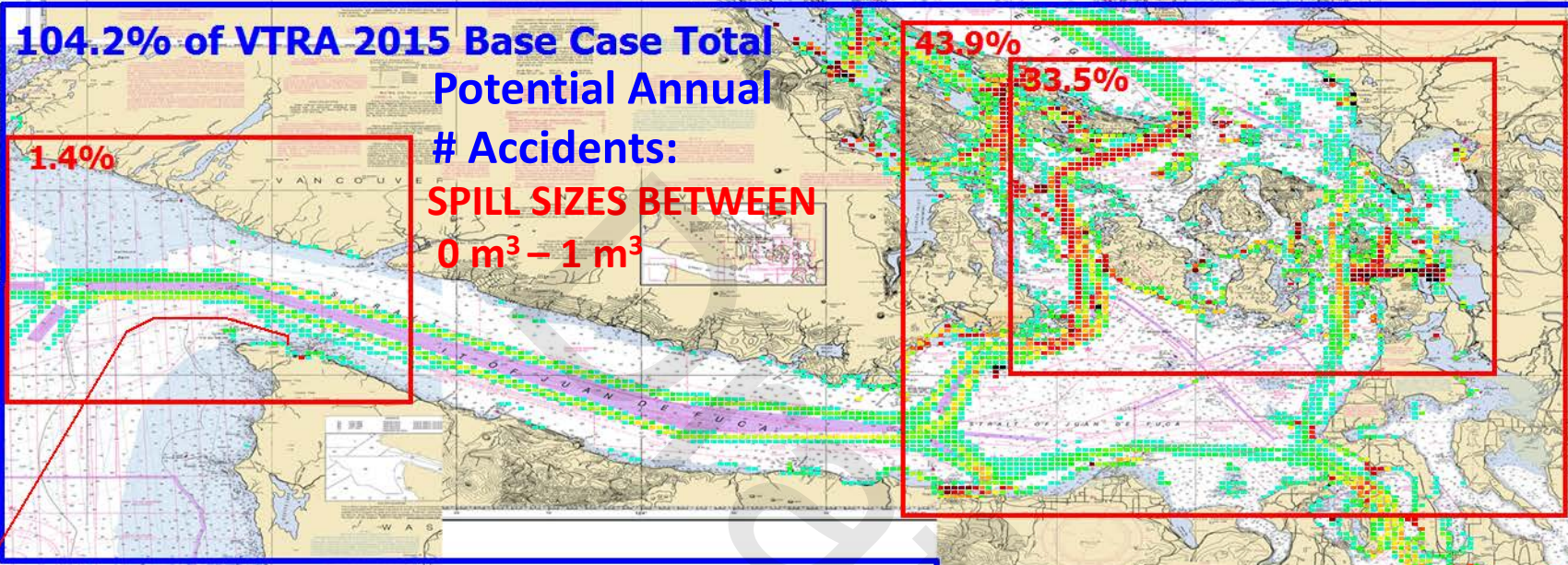
≈ 100% Probability of Spill Occurrence in 10 years

Average of ≈ 0.01 m^3 Per Potential Spill (= 2.4 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 Case: USKMCA1600-3RMM - ALL FV



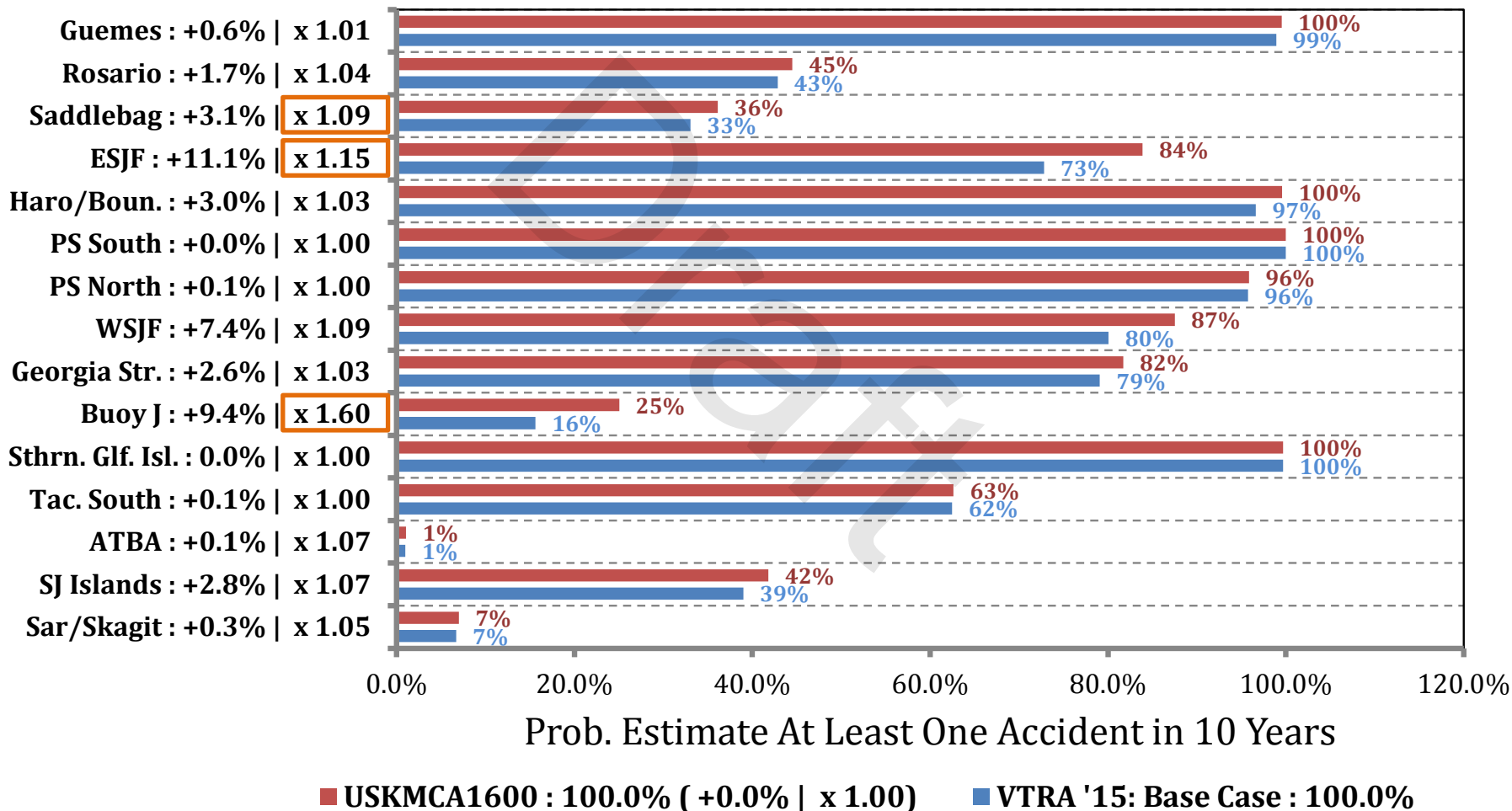
VTRA '15 Case:
USKMCA1600 - 3RMM
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 100% Probability
of Spill Occurrence
in 10 years

Average of ≈ 0.01 m³
Per Potential Spill
(≈ 2.8 gallons)

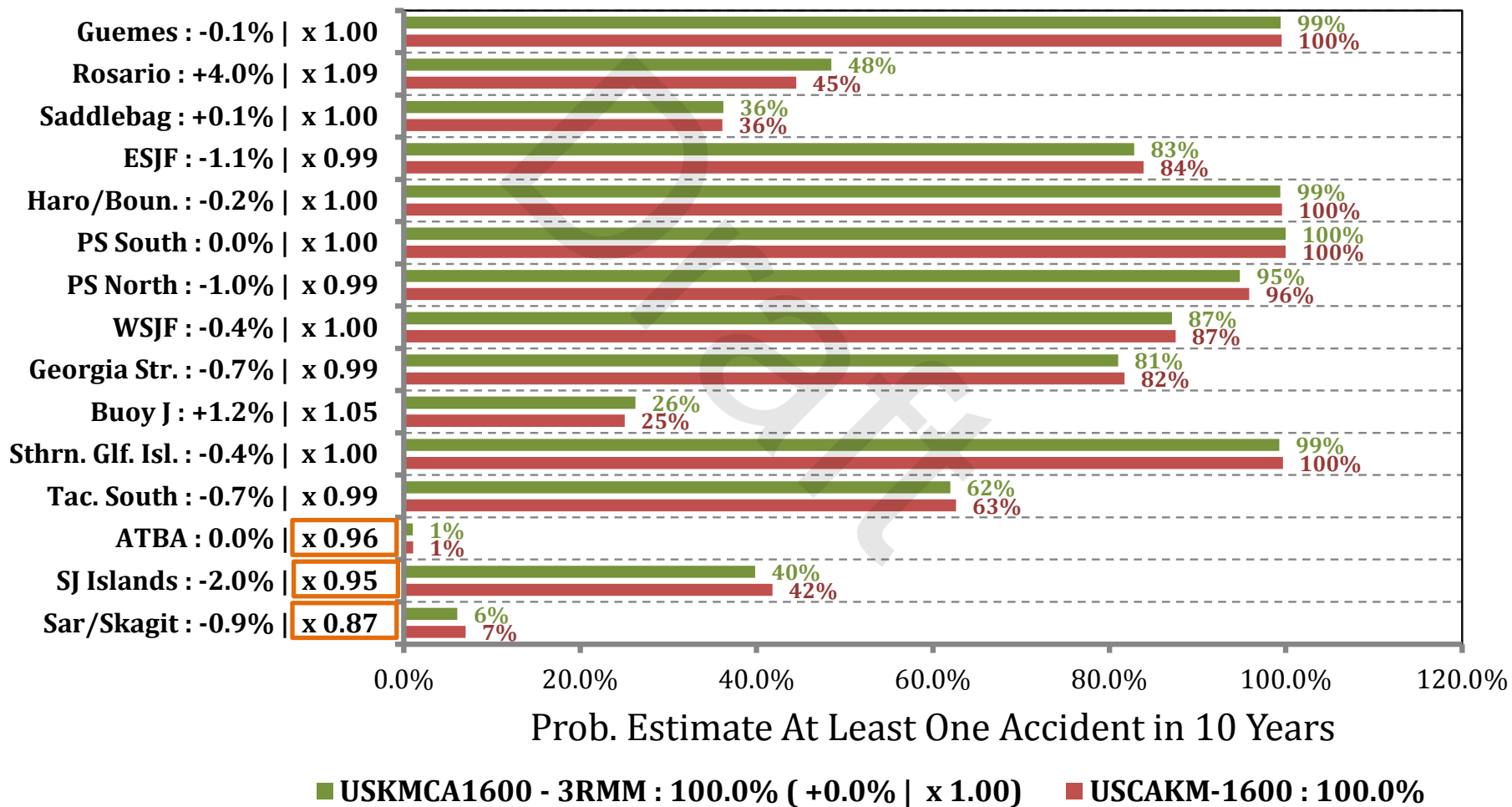
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

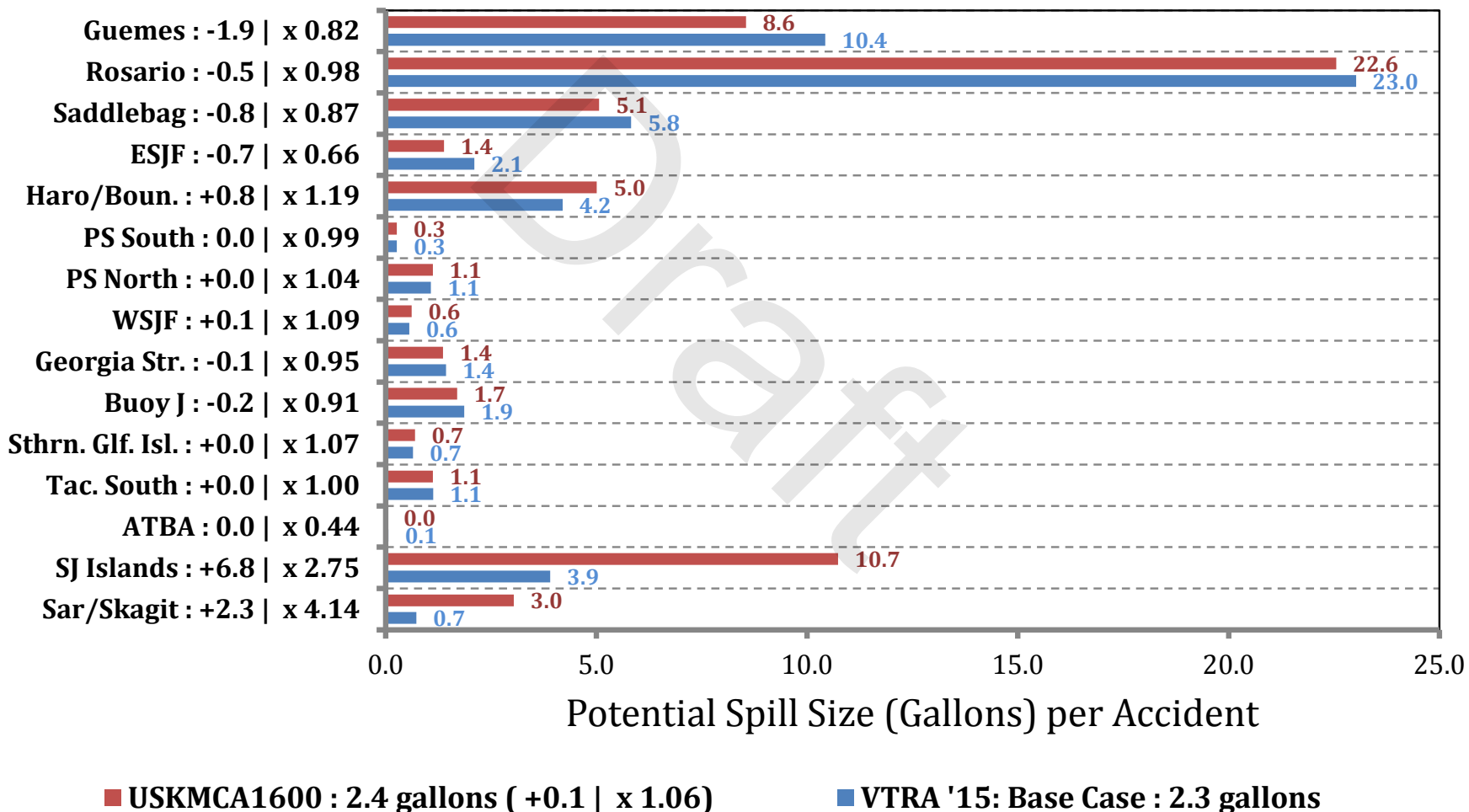
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

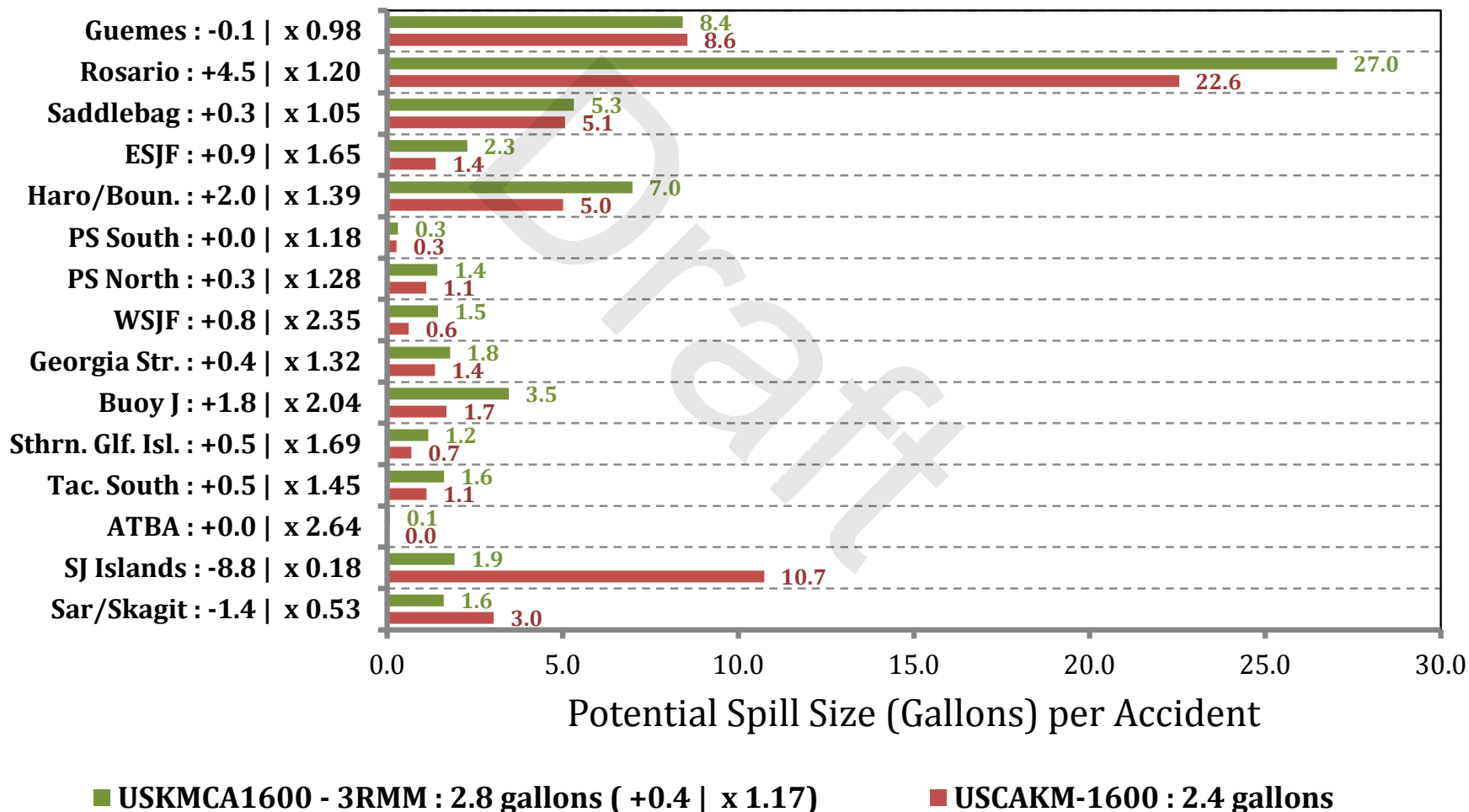


Potential Spill Size (Gallons) per Accident - ALL_FV - Oil Spill Size Category: 0 - 264 Gallons



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 Base Case to USKMCA1600

		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
USKMCA1600	Base Case % Potential Annual Oil Loss	91.1% (+49.11% x2.17)	20.0% (+7.71% x1.63)	72.8% (+27.54% x1.61)	0.5% (+0.08% x1.17)	184.4% (+84.4% x1.84)
	Base Case % Potential Annual Accident Frequency	0.03% (+0.02% x2.72)	0.02% (+0.01% x1.56)	1.9% (+0.16% x1.09)	108.9% (+10.7% x1.11)	110.9% (+10.9% x1.11)
	Average potential spill size per accident (in m ³)	5413 (-1385 x0.80)	1693 (+75 x1.05)	69.2 (+22.3 x1.48)	0.01 (+0.00 x1.06)	3.0 (+1.2 x1.66)
	Probability of at least one accident in 1 year by spill size	0.14% (+0.09% x2.72)	0.10% (+0.03% x1.56)	8.2% (+0.64% x1.09)	99.2% (+0.48% x1.00)	99.3% (+0.45% x1.00)
	Probability of at least one accident in 10 year by spill size	1.35% (+0.85% x2.71)	0.95% (+0.34% x1.55)	57.3% (+3.09% x1.06)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)
	Probability of at least one accident in 25 years by spill size	3.35% (+2.10% x2.70)	2.36% (+0.84% x1.55)	88.1% (+2.27% x1.03)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Summary Risk Comparison USKMCA1600 to USKMCA1600-3RMM

		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	TOTAL_OIL
USACAKM1600	Base Case % Potential Annual Oil Loss	91.0%	19.9%	72.7%	0.5%	184.1%
	Base Case % Potential Annual Accident Frequency	0.03%	0.02%	1.9%	108.9%	110.9%
	Average potential spill size per accident (in m^3)	5,413	1,693	69.2	0.01	3.0
	Probability of at least one accident in 1 year by spill size	0.14%	0.10%	8.2%	99.2%	99.3%
	Probability of at least one accident in 10 year by spill size	1.35%	0.95%	57.3%	100.0%	100.0%
	Probability of at least one accident in 25 years by spill size	3.35%	2.36%	88.1%	100.0%	100.0%
		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	TOTAL_OIL
USACAKM1600 - 3RMM	Base Case % Potential Annual Oil Loss	91.4% (+0.4% x1.00)	19.6% (-0.36% x0.98)	37.1% (-35.58% x0.51)	0.6% (+0.06% x1.12)	148.7% (-35.4% x0.81)
	Base Case % Potential Annual Accident Frequency	0.03% (0.00% x0.99)	0.02% (0.00% x0.98)	1.6% (-0.32% x0.83)	104.1% (-4.8% x0.96)	105.7% (-5.2% x0.95)
	Average potential spill size per accident (in m^3)	5519 (+106 x1.02)	1694 (+0 x1.00)	42.5 (-26.7 x0.61)	0.01 (+0.00 x1.17)	2.6 (-0.5 x0.85)
	Probability of at least one accident in 1 year by spill size	0.13% (0.00% x0.99)	0.09% (0.00% x0.98)	6.8% (-1.32% x0.84)	99.0% (-0.19% x1.00)	99.1% (-0.19% x1.00)
	Probability of at least one accident in 10 year by spill size	1.33% (-0.02% x0.99)	0.93% (-0.02% x0.98)	50.7% (-6.57% x0.89)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)
	Probability of at least one accident in 25 years by spill size	3.30% (-0.05% x0.99)	2.31% (-0.04% x0.98)	83.0% (-5.13% x0.94)	100.0% (0.00% x1.00)	100.0% (0.00% x1.00)