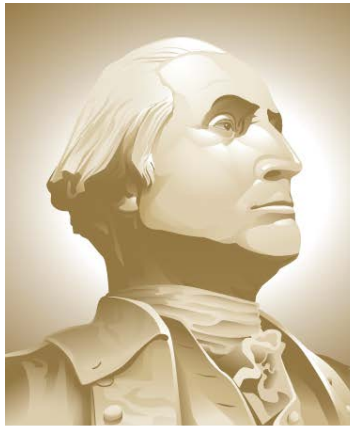


VTRA 2015 Case S : KM – 668 and VTRA 2015 Calibration Case Comparison



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VCU

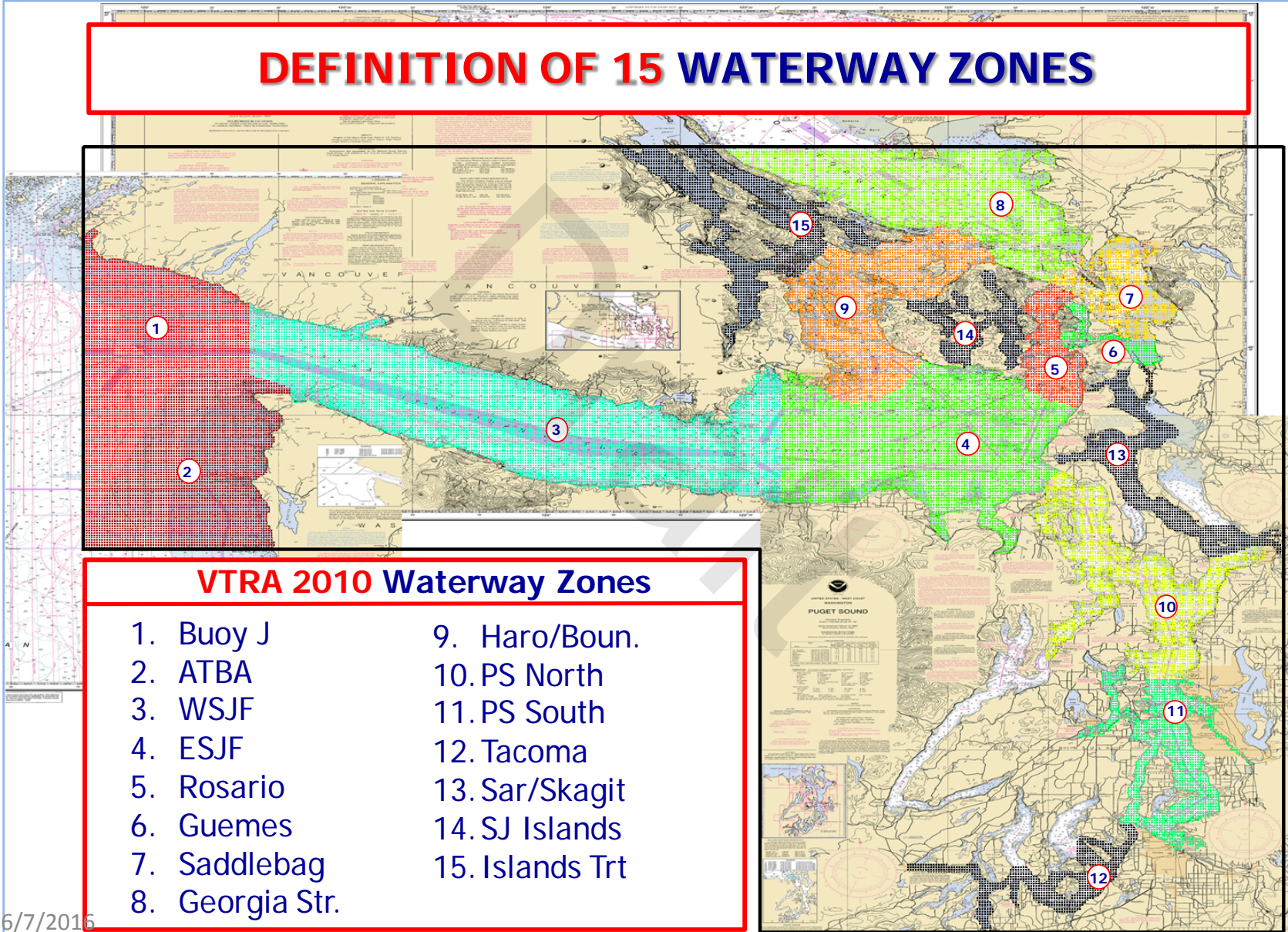
Jason R.W. Merrick (VCU) and J. Rene van Dorp (GW)

June 1st - 2nd, 2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



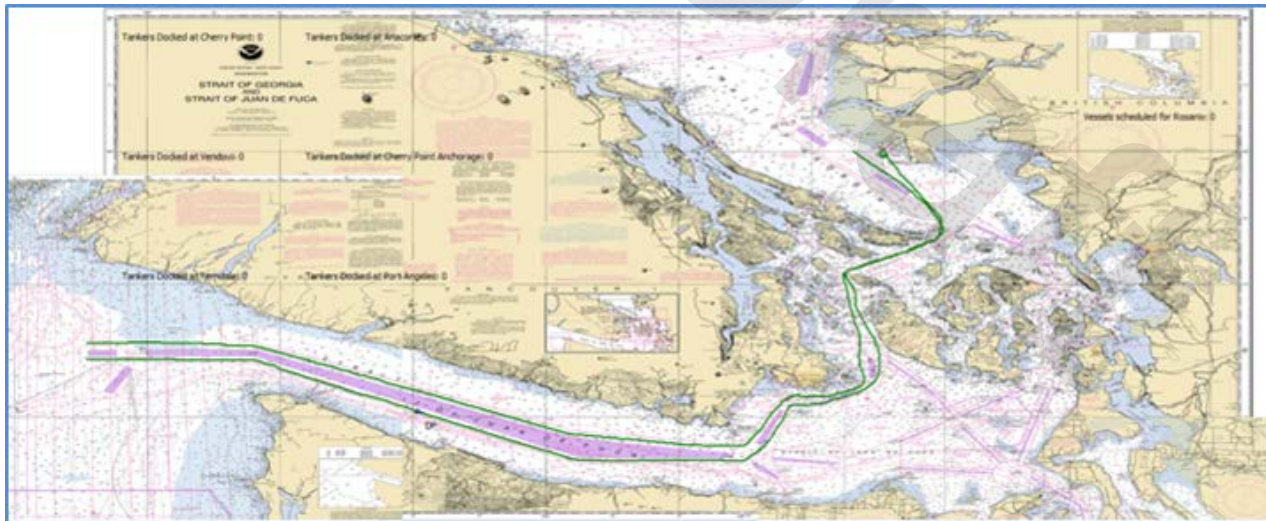
DEFINITION OF 15 WATERWAY ZONES



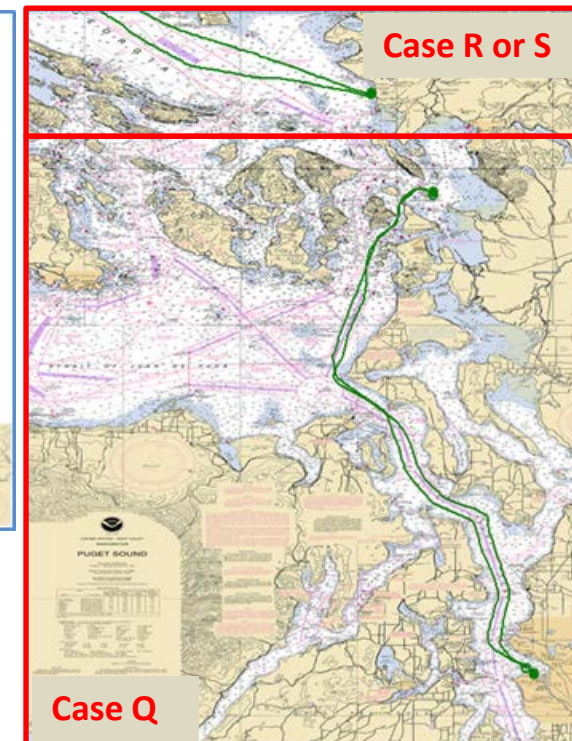
VTRA '15 S : DP - 668 Update

CASE S	VTRA 2010 OLD Case S	VTRA 2015 Updated Case S
Container Ships	67	368
Bulk Carriers	348	300
Subtotal	415	668
Bunkering Support	40	60

Container and Bulk Carrier Routes



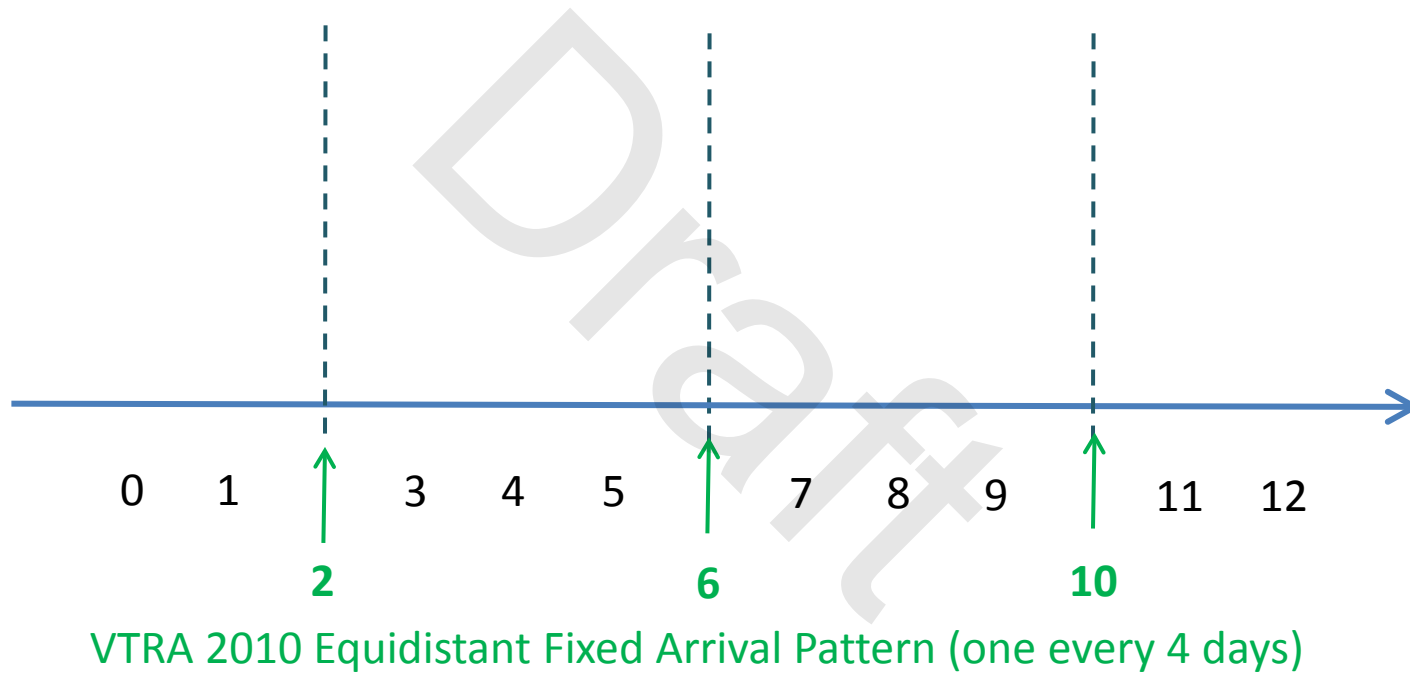
Bunker Routes



+ Update on Arrival Process

NOT SELECTED

VTRA 2010 – What If FV Scheduled Arrival Pattern Model



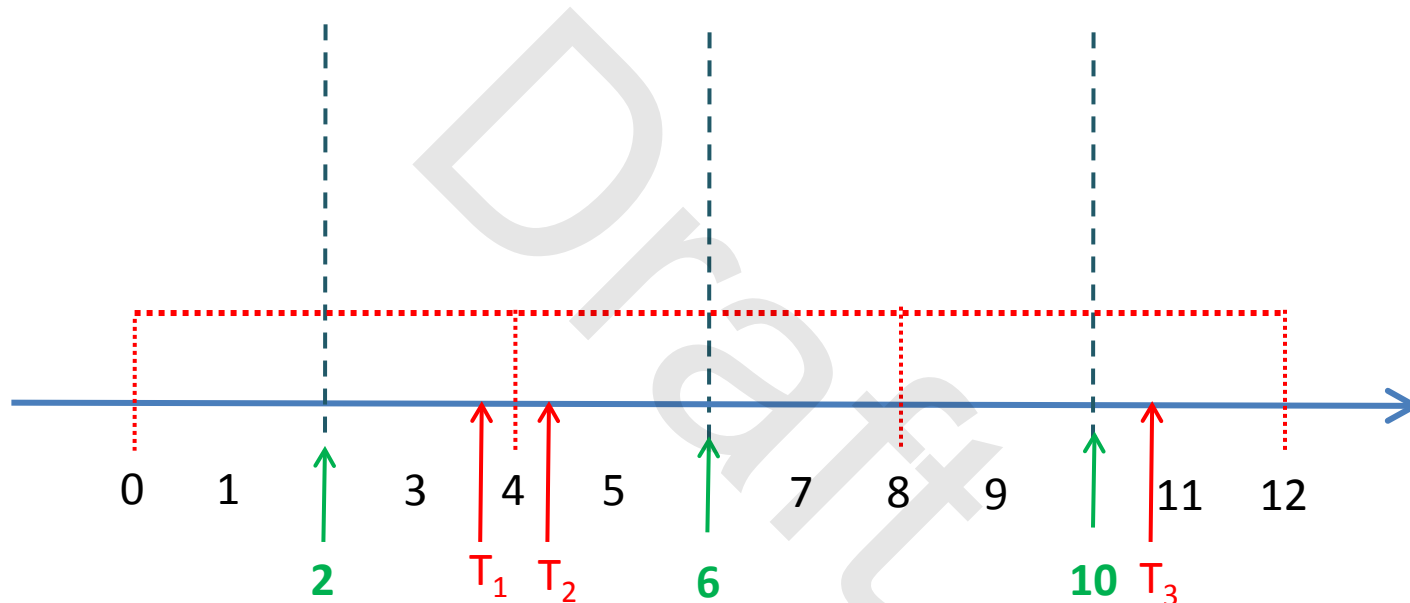
% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 415: 1.04

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 668: 1.14

NOT SELECTED

VTRA 2015 – What If FV

Complete Random Arrival Pattern Model



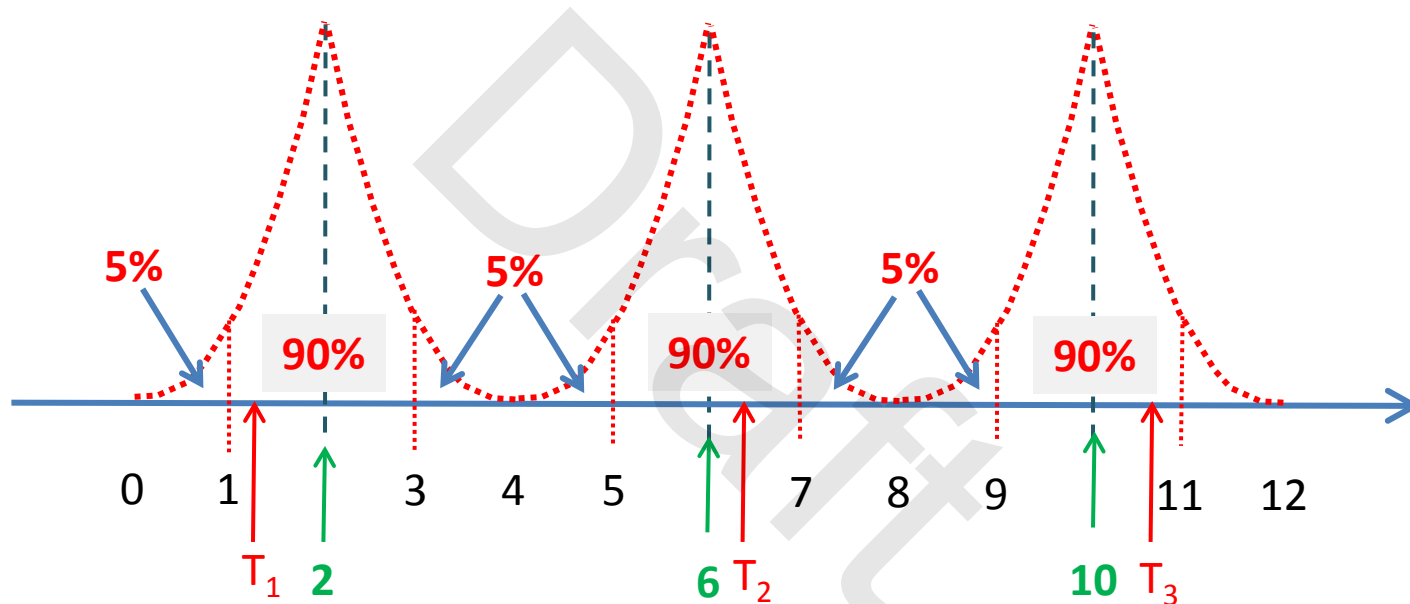
VTRA 2010 Equidistant Fixed Arrival Pattern (one every 4 days)

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

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 415: 1.04

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 668: 1.17

SELECTED VTRA 2015 – What If FV Scheduled Random Arrival Pattern Model



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

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

% OF VTRA '10 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 415: 1.04

% OF VTRA '15 BASE CASE POTENTIAL TOTAL OIL LOSS: CASE S: DP – 348: 1.15

By Waterway Zone Risk Comparison

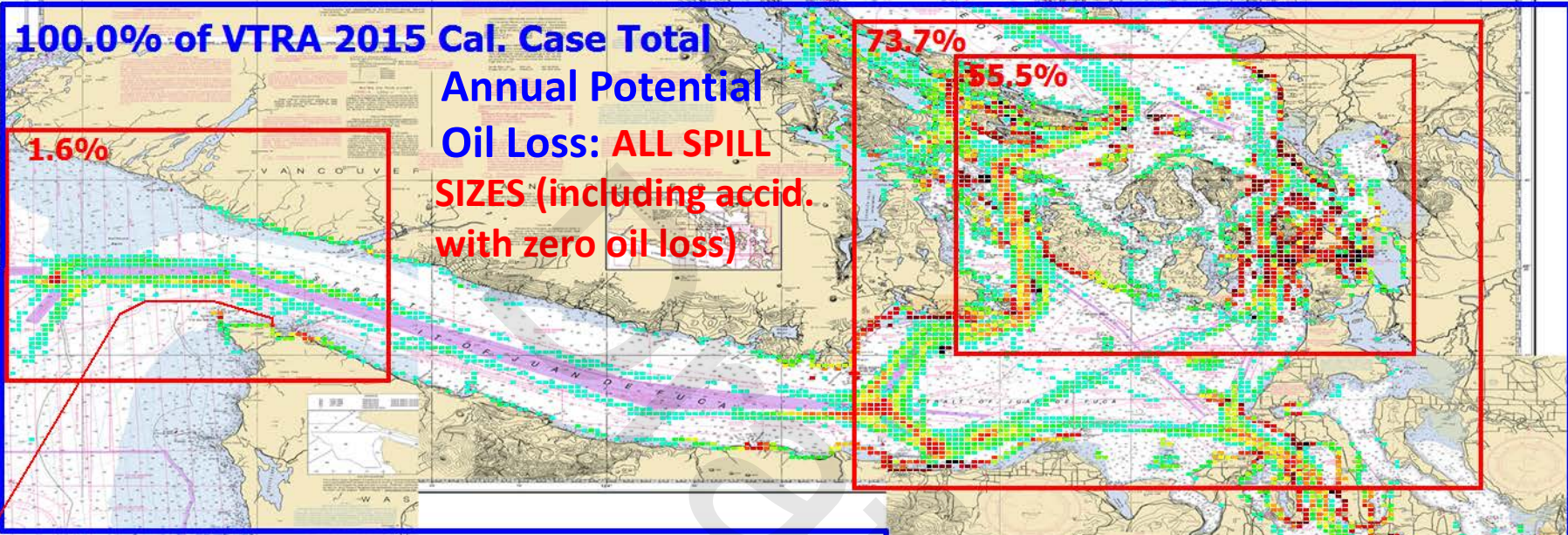
Oil Spill Size Category:

ALL SPILL SIZES

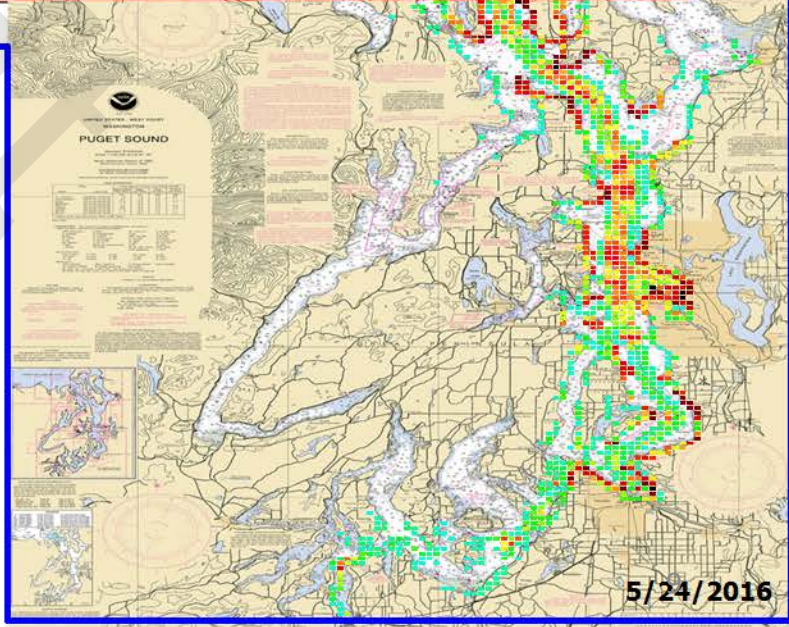
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 CALIBRATION CASE - ALL FV



VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
OIL LOSS OF ACCIDENTS
IN SPILL SIZE CATEGORY
ALL SPILL SIZES



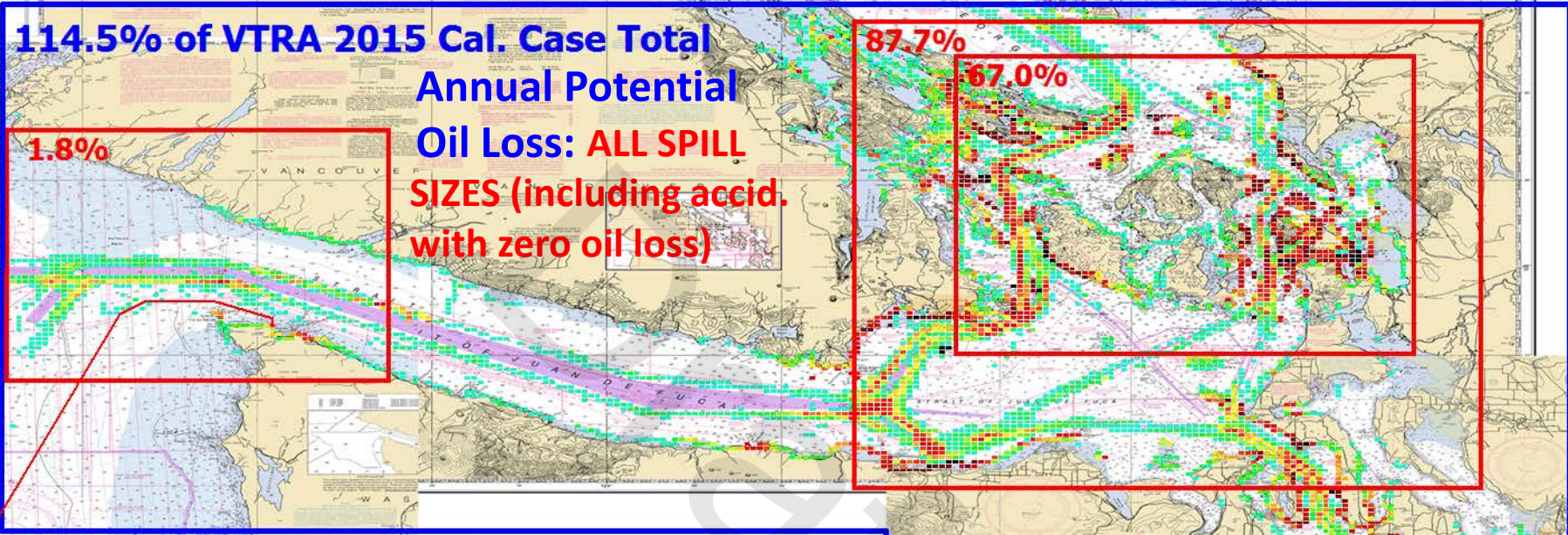
6/7/2016

5/24/2016

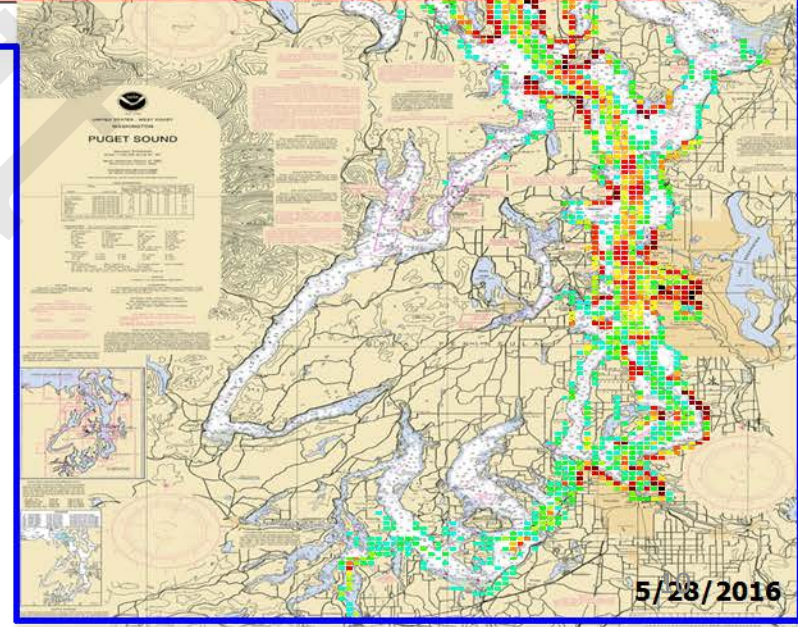
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



S: VTRA 2010 - Delta Port - Cont. 368 and Bulk 300 - ALL FV



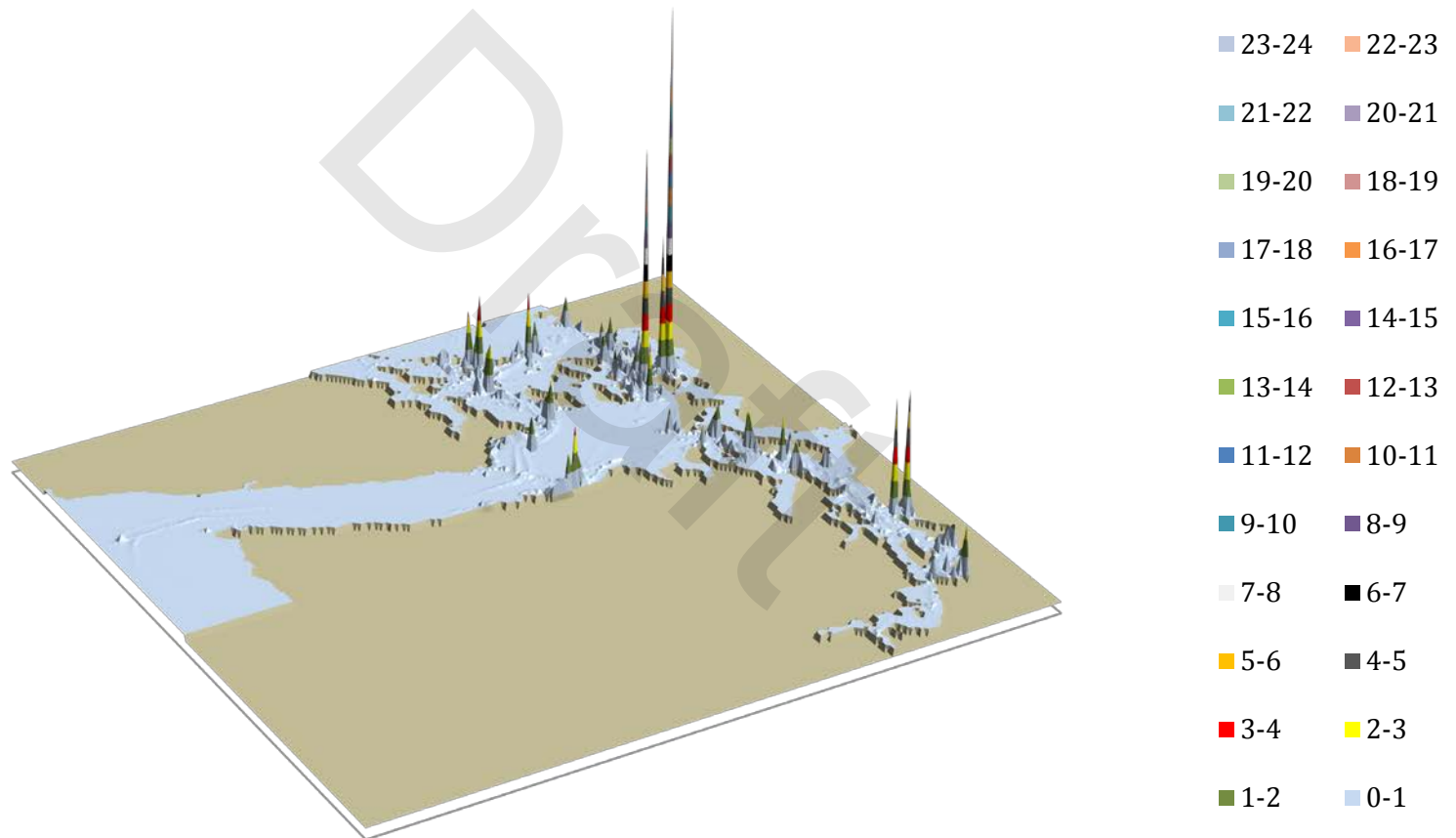
VTRA '15 Case S: DP - 668
GEOGRAPHIC PROFILE
OF POTENTIAL ANNUAL
OIL LOSS OF ACCIDENTS
IN SPILL SIZE CATEGORY
ALL SPILL SIZES



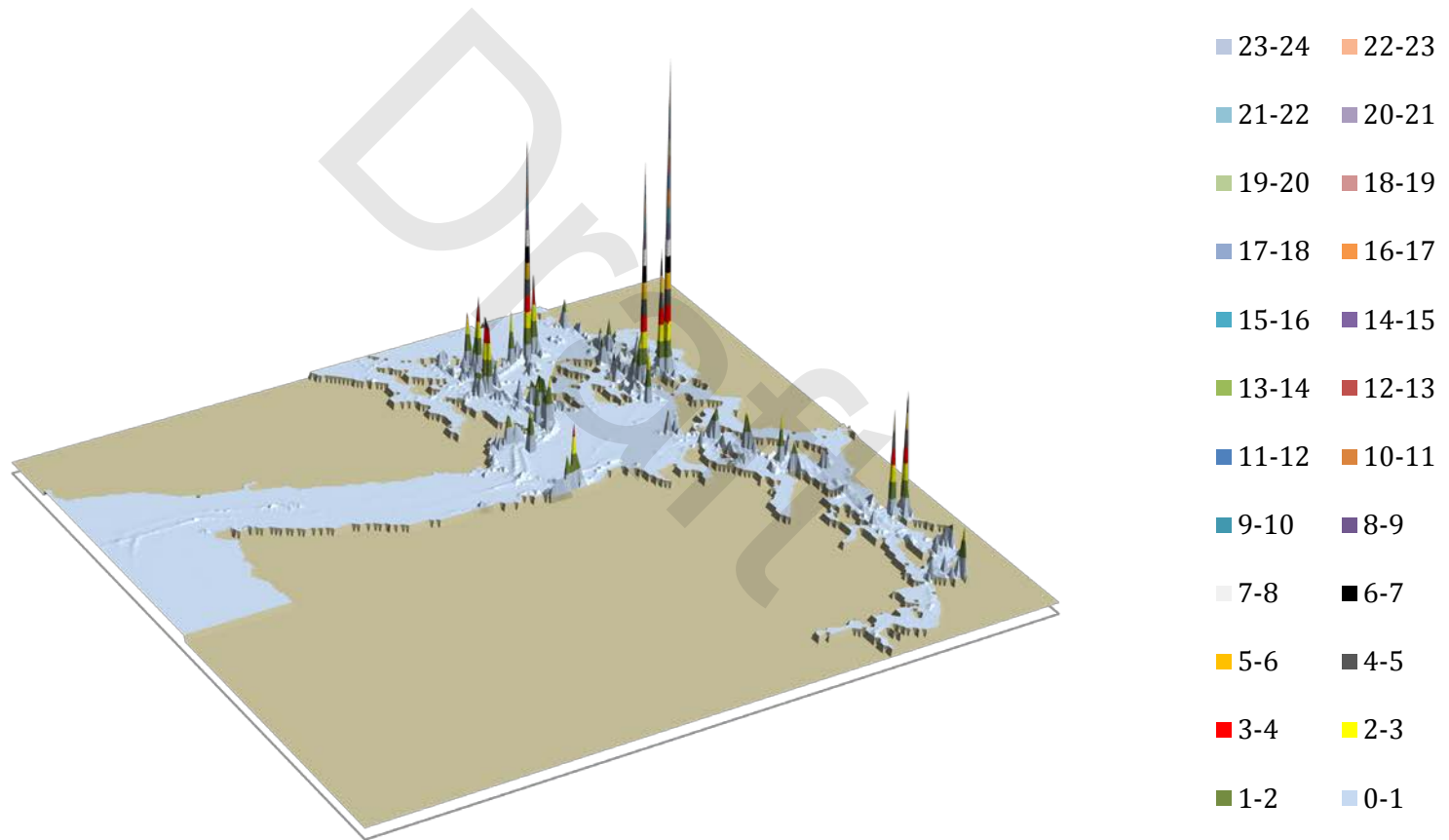
6/7/2016

5/28/2016

VTRA '15: Call. Case 3D Risk Profile All FV - Pot.Grou+Coll.+All.Oil Loss: 100% of Cal. Case POL



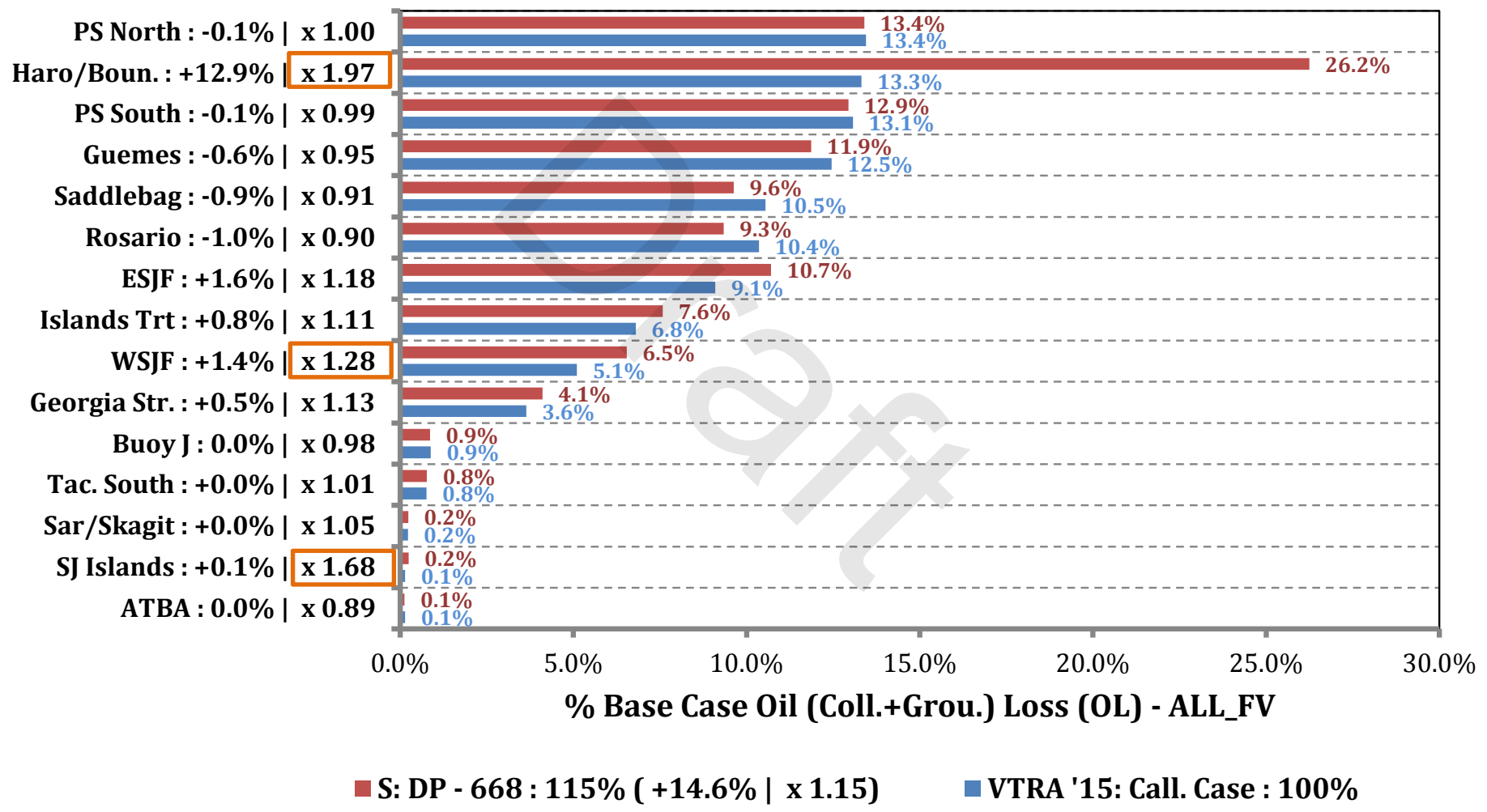
S: DP - 668 3D Risk Profile All FV - Pot.Grou+Coll+All.Oil Loss: 115% of Cal. Case POL



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

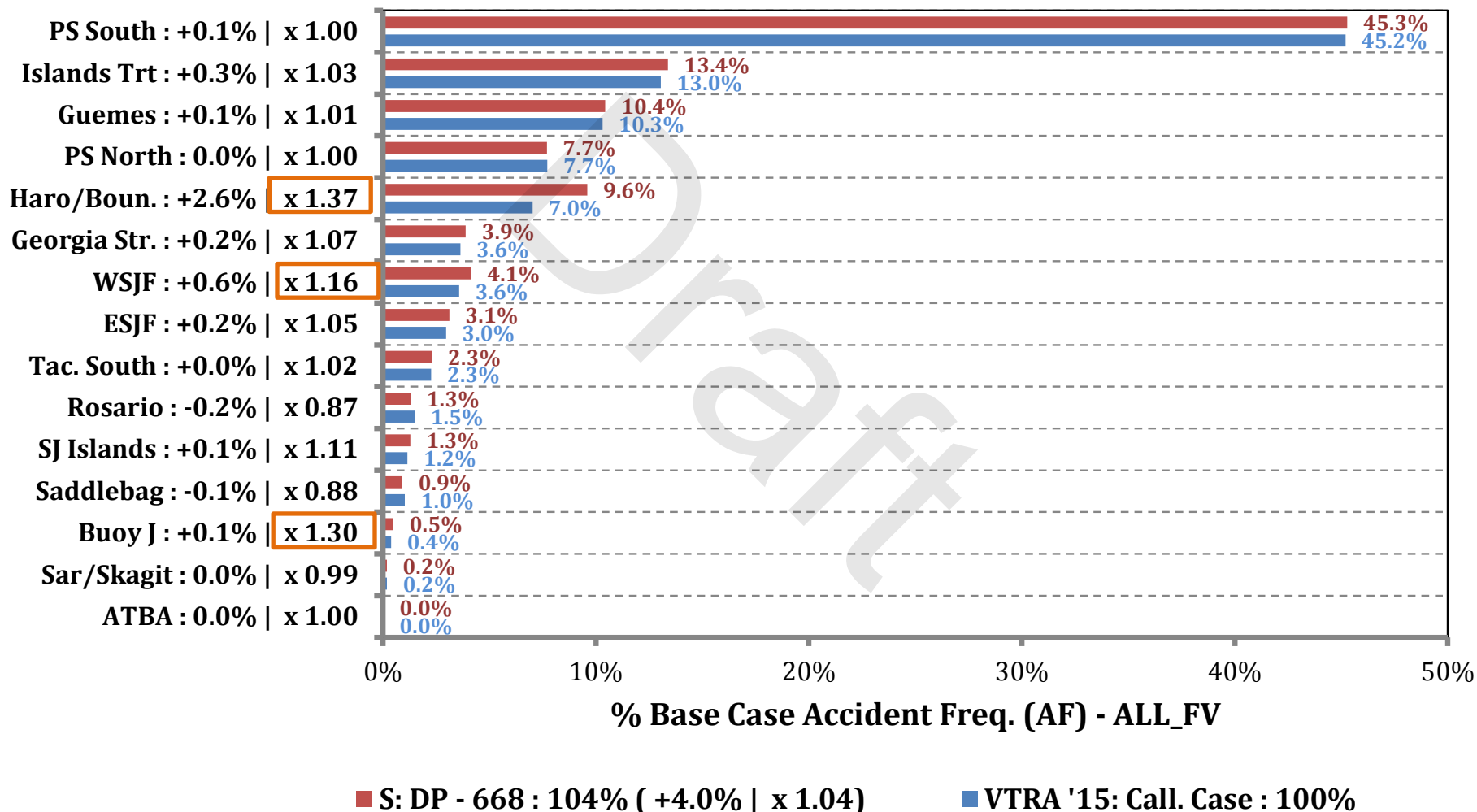


% Base Case Oil (Coll. + Grou. + All.) Loss - ALL_FV



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



By Waterway Zone Risk Comparison

Oil Spill Size Category:
2500 m³ or more

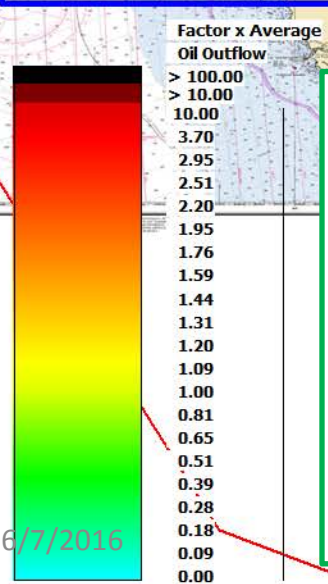
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

39.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:
SPILL SIZES LARGER THAN 2,500 m³

33.9%
27.2%

1.0%



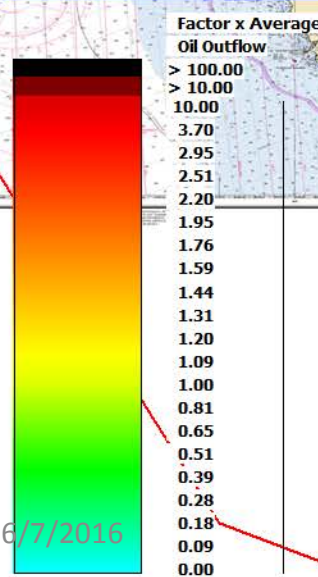
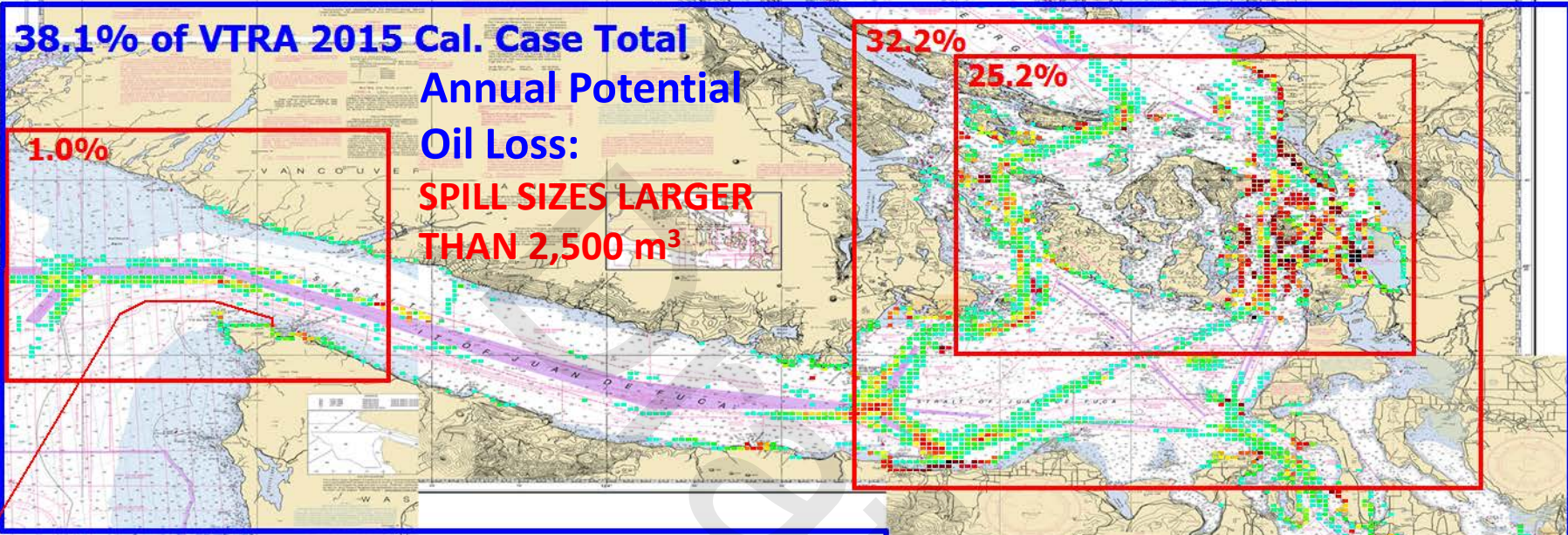
VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF POTENTIAL
ANNUAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
2,500 m³ or more

≈ 0.47% Probability
of Spill Occurrence
in 10 years

Average of ≈ 5,746 m³
Per Potential Spill
(≈ 4,942 Metric. Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

S: VTRA 2010 - Delta Port - Cont. 368 and Bulk 300 - ALL FV



VTRA '15 Case S: DP - 668
GEOGRAPHIC PROFILE OF POTENTIAL ANNUAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE **2,500 m³ or more**

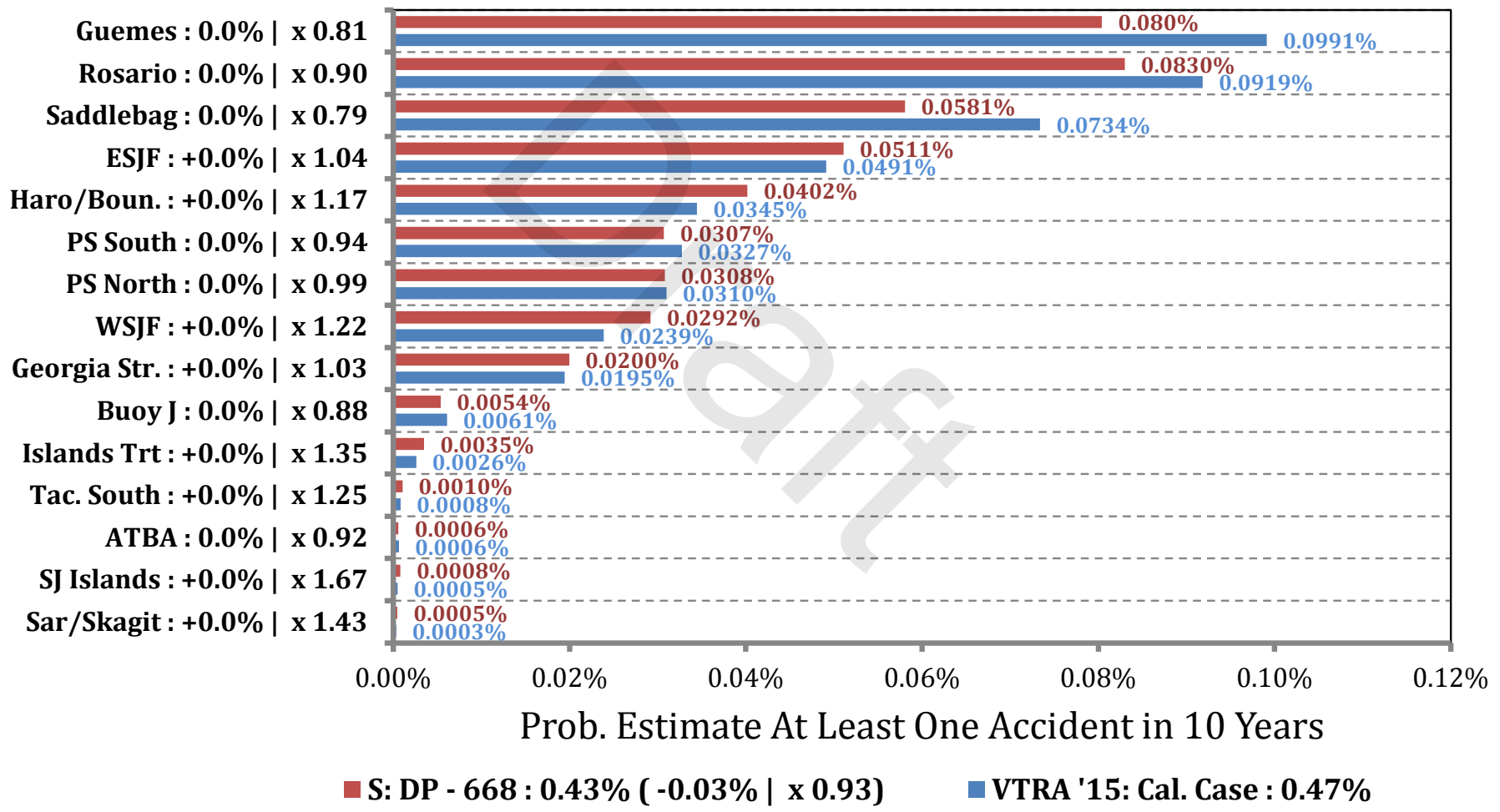
≈ 0.43% Probability of Spill Occurrence in 10 years

Average of ≈ 5,586 m³ Per Potential Spill (≈ 4,804 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

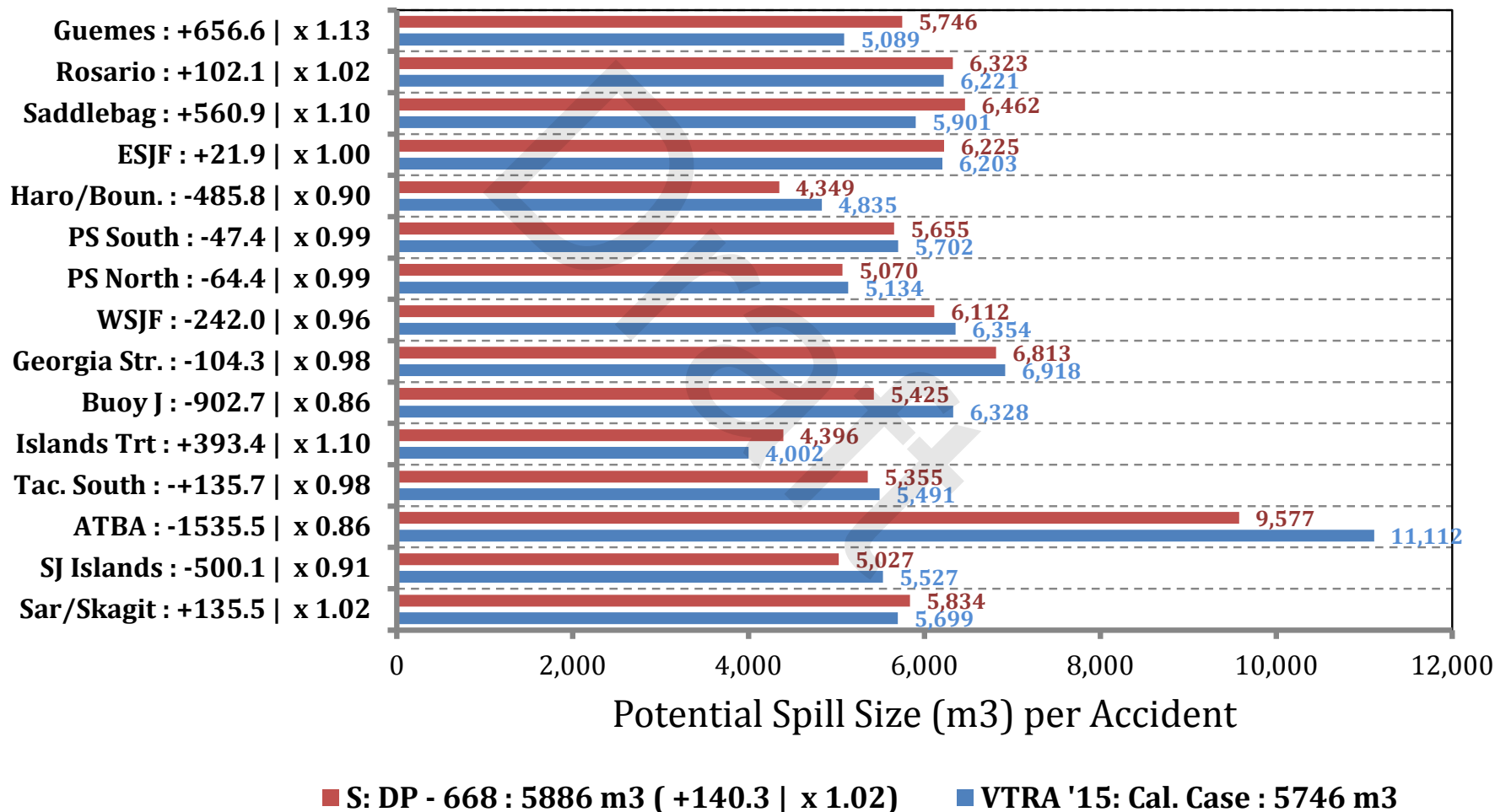


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 2500 cubic meters or more



VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



By Waterway Zone Risk Comparison

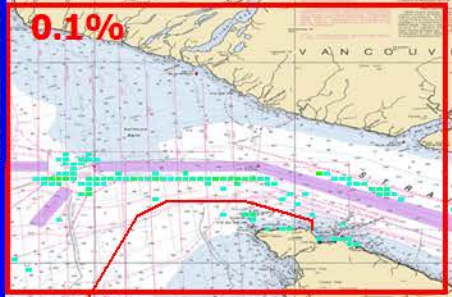
Oil Spill Size Category:

1000 m³ - 2500 m³

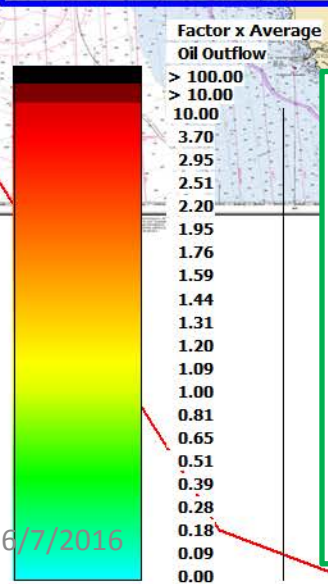
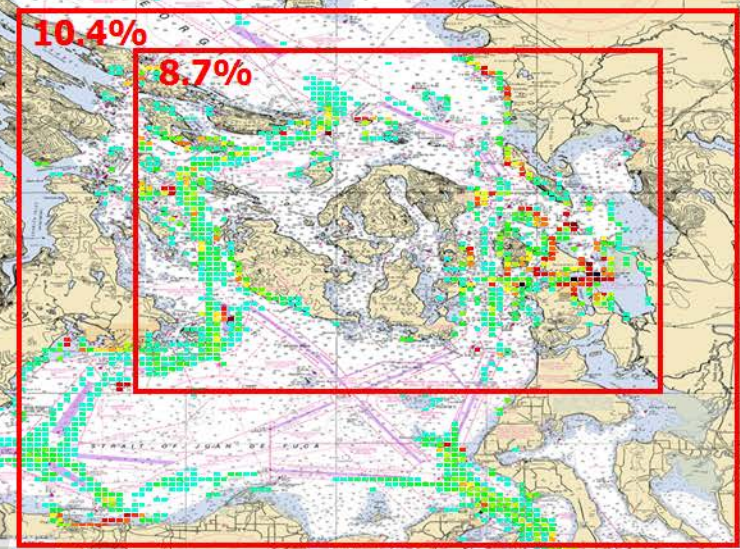
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

12.2% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:



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



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

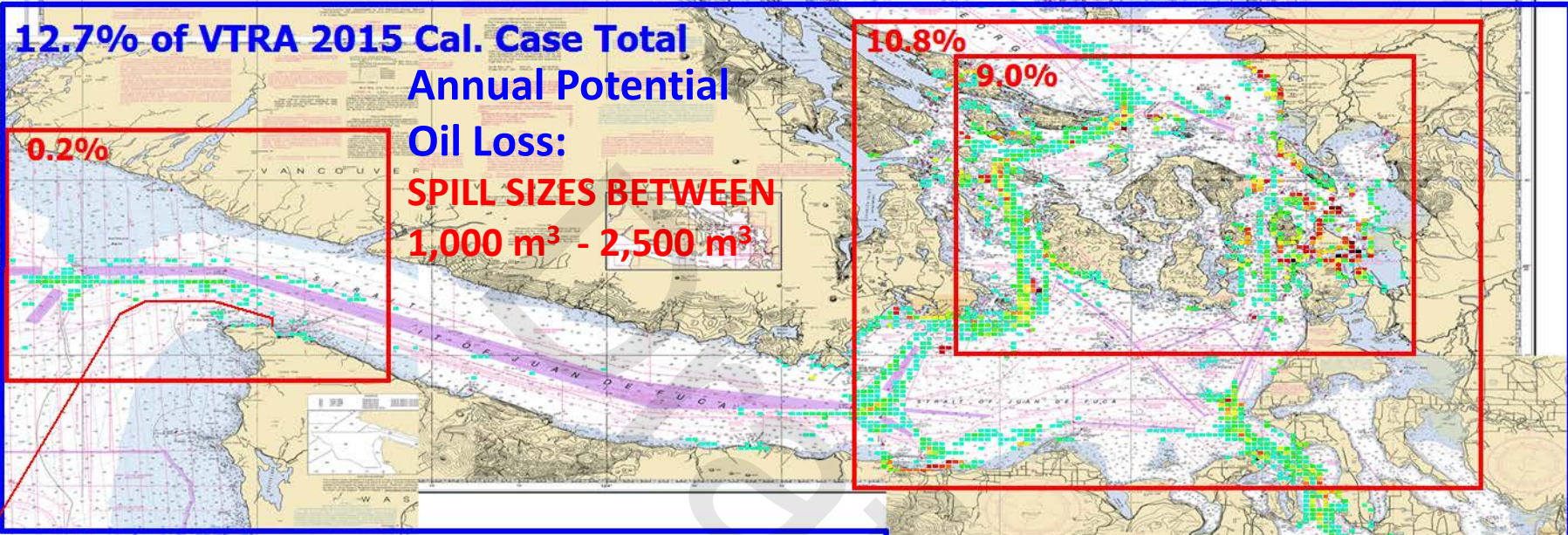
≈ 0.50% Probability
of Spill Occurrence
in 10 years

Average of ≈ 1,628 m³
Per Potential Spill
(≈ 1,400 Metric Tons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



S: VTRA 2010 - Delta Port - Cont. 368 and Bulk 300 - ALL FV



VTRA '15 Case S: DP - 668
GEOGRAPHIC PROFILE
OF POTENTIAL
ANNUAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE BETWEEN
1,000 m³ - 2,500 m³

≈ 0.53% Probability
of Spill Occurrence
in 10 years

Average of ≈ 1,618 m³
Per Potential Spill
(≈ 1,391 Metric Tons)

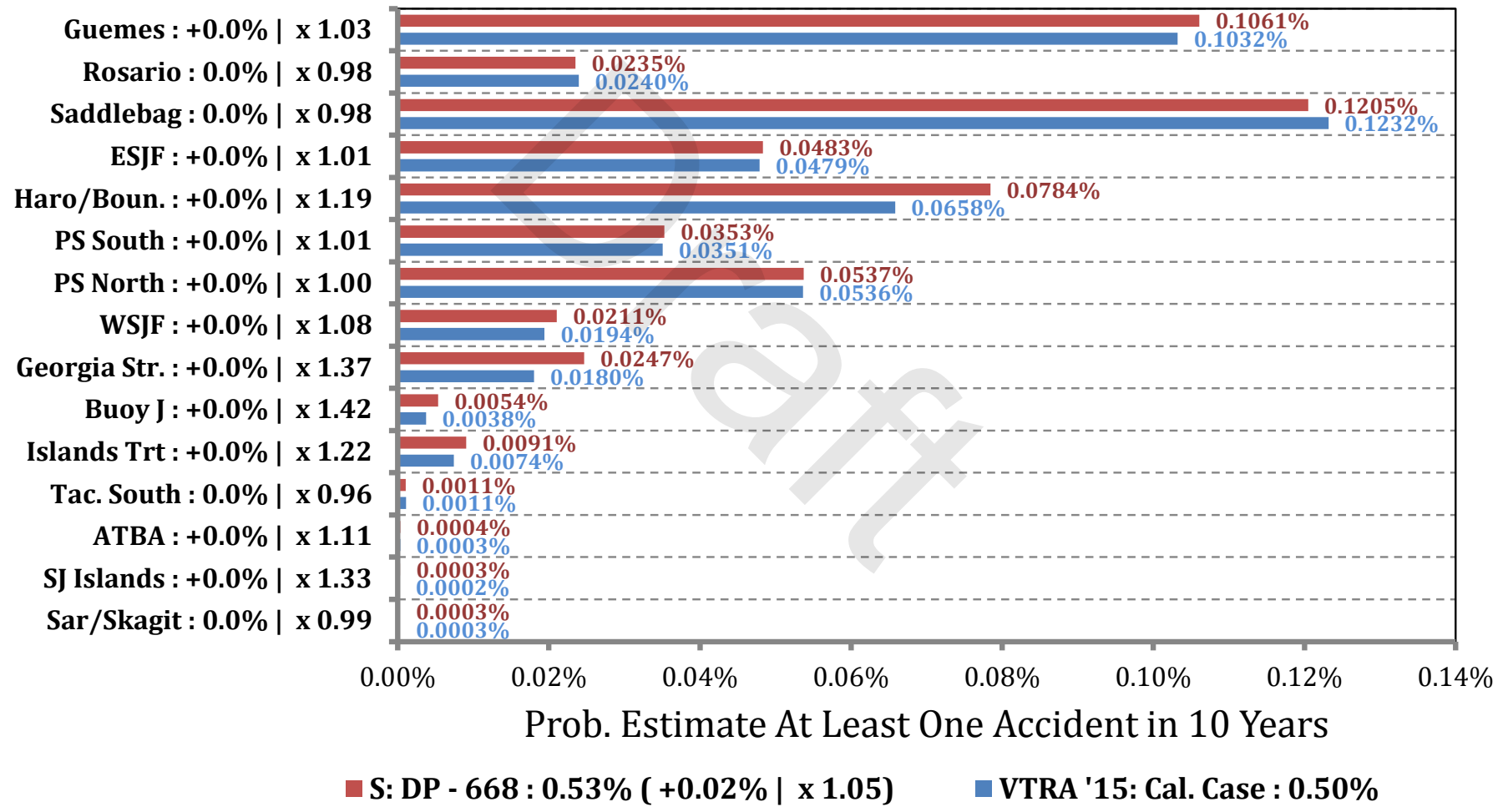
6/7/2016

5/28/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



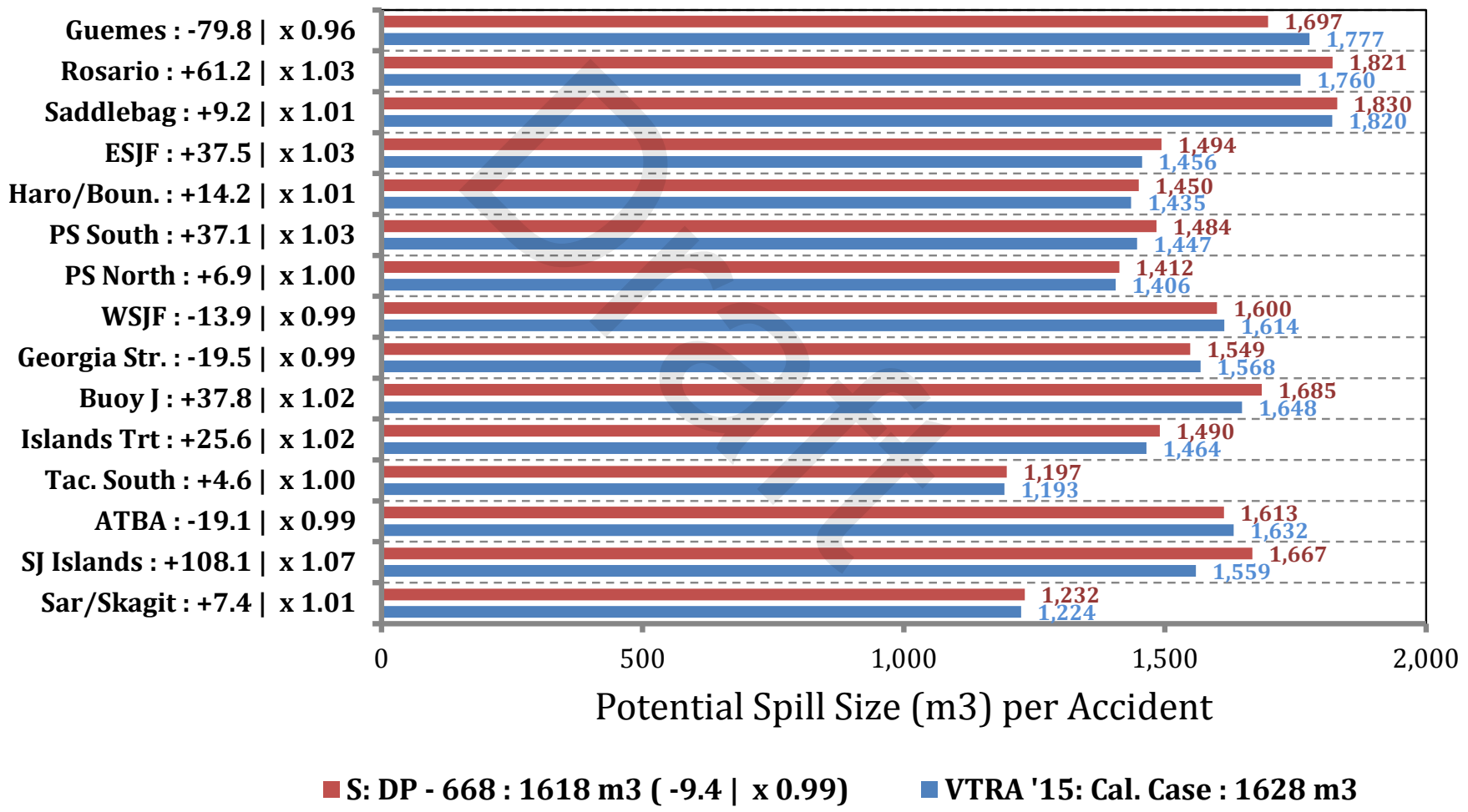
Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1000 - 2500 m3



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

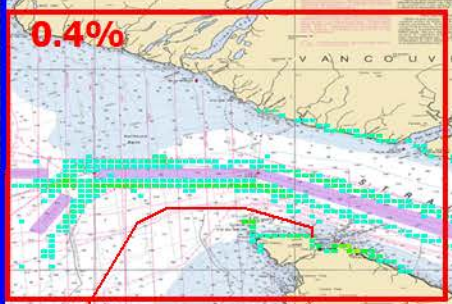
Oil Spill Size Category:

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

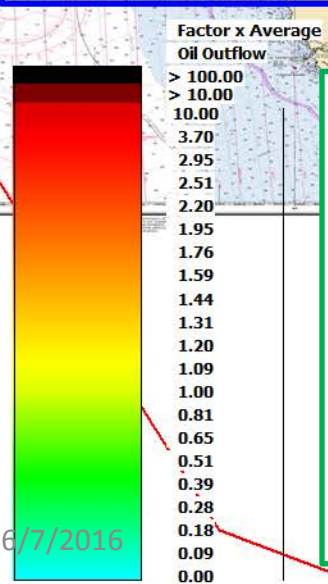
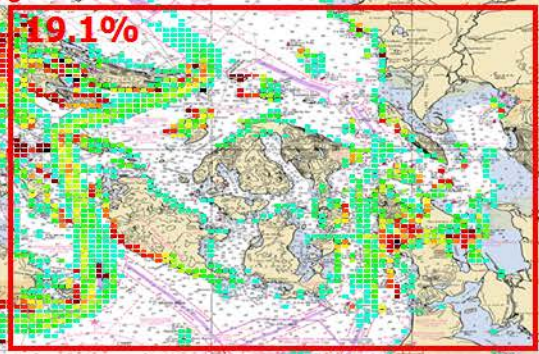
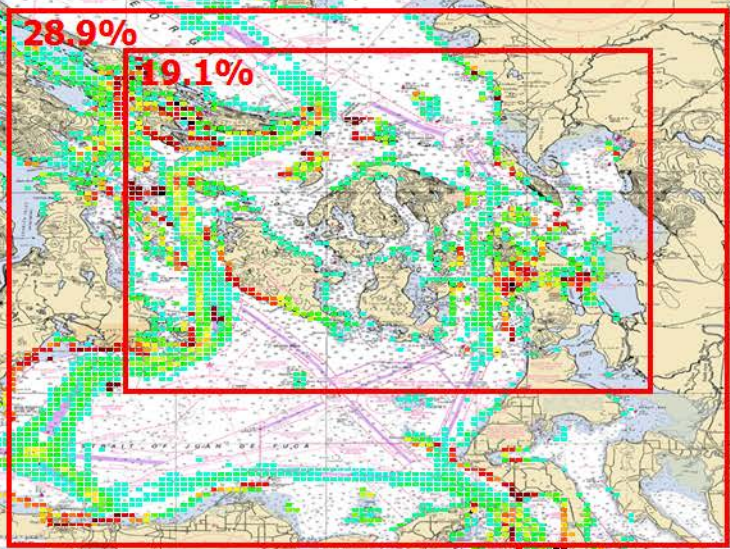
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

47.4% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:



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



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

≈ 53.1% Probability
of Spill Occurrence
in 10 years

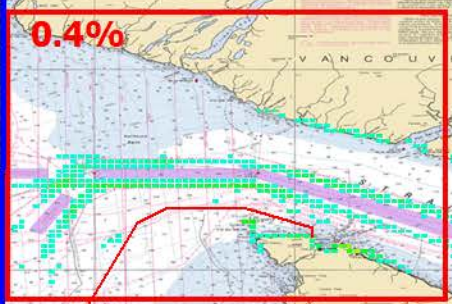
Average of ≈ 42 m³
Per Potential Spill
(≈ 265 barrels)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

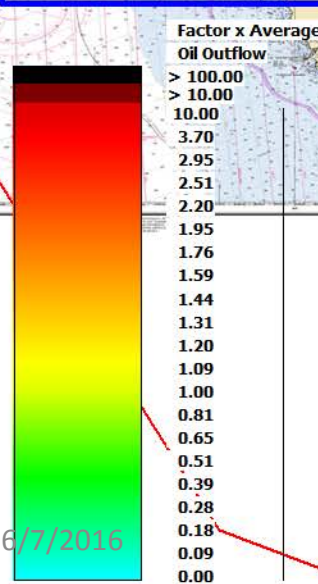
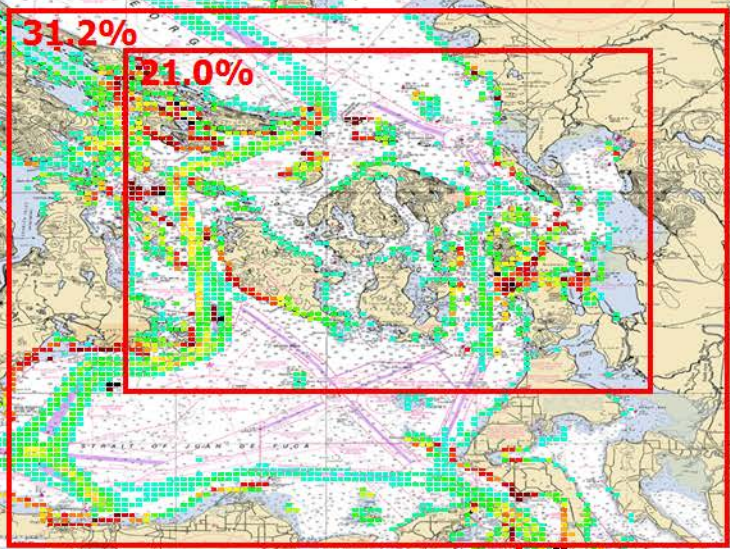


R: VTRA 2015 - Kinder Morgan 348 - ALL FV

49.8% of VTRA 2015 Cal. Case Total Annual Potential Oil Loss:



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



VTRA '15 Case S: DP - 668
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 1 m³ - 1000 m³

≈ 55.0% Probability
of Spill Occurrence
in 10 years

Average of ≈ 53 m³
Per Potential Spill
(≈ 334 Barrels)

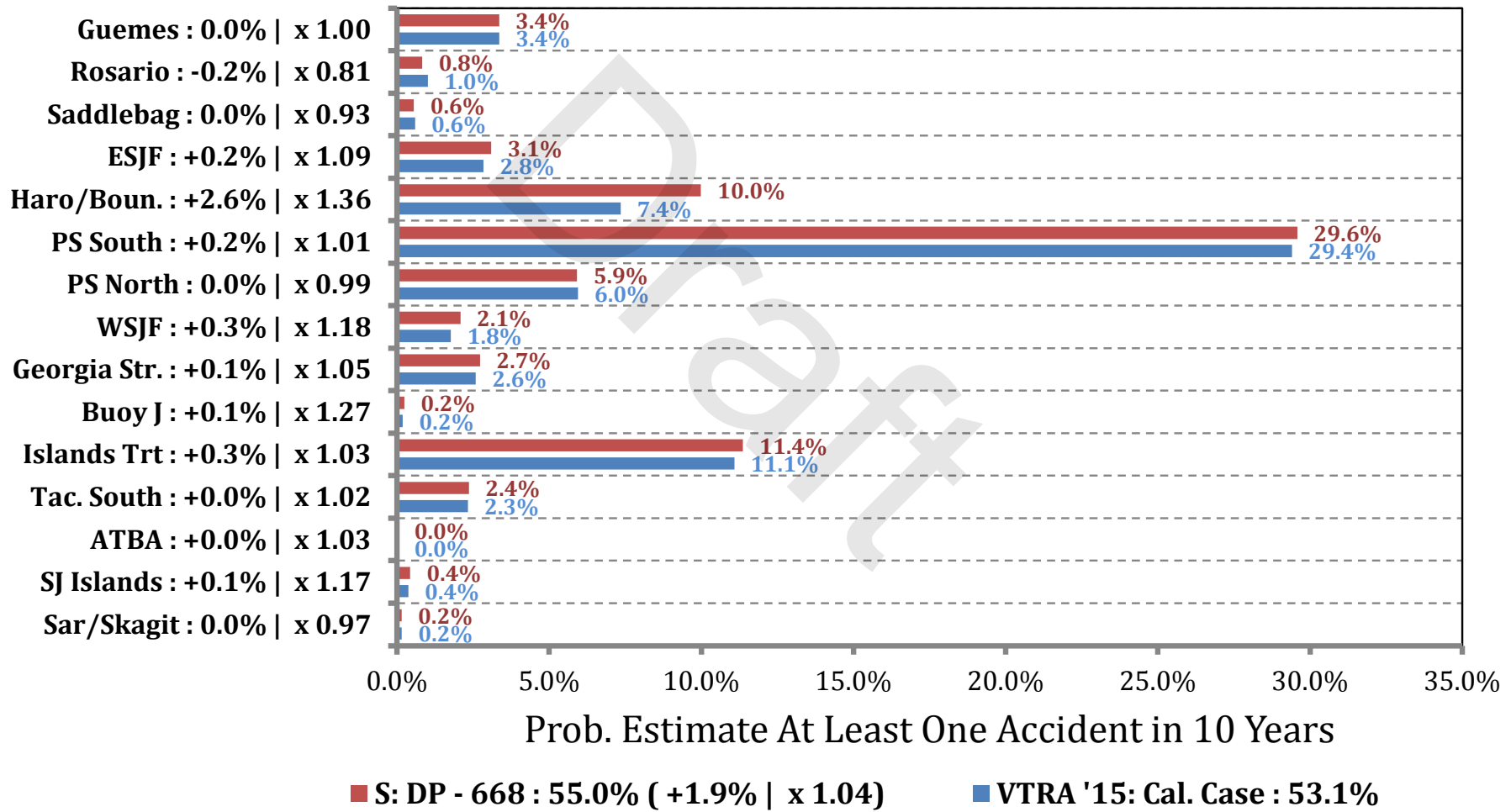
6/7/2016

5/27/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

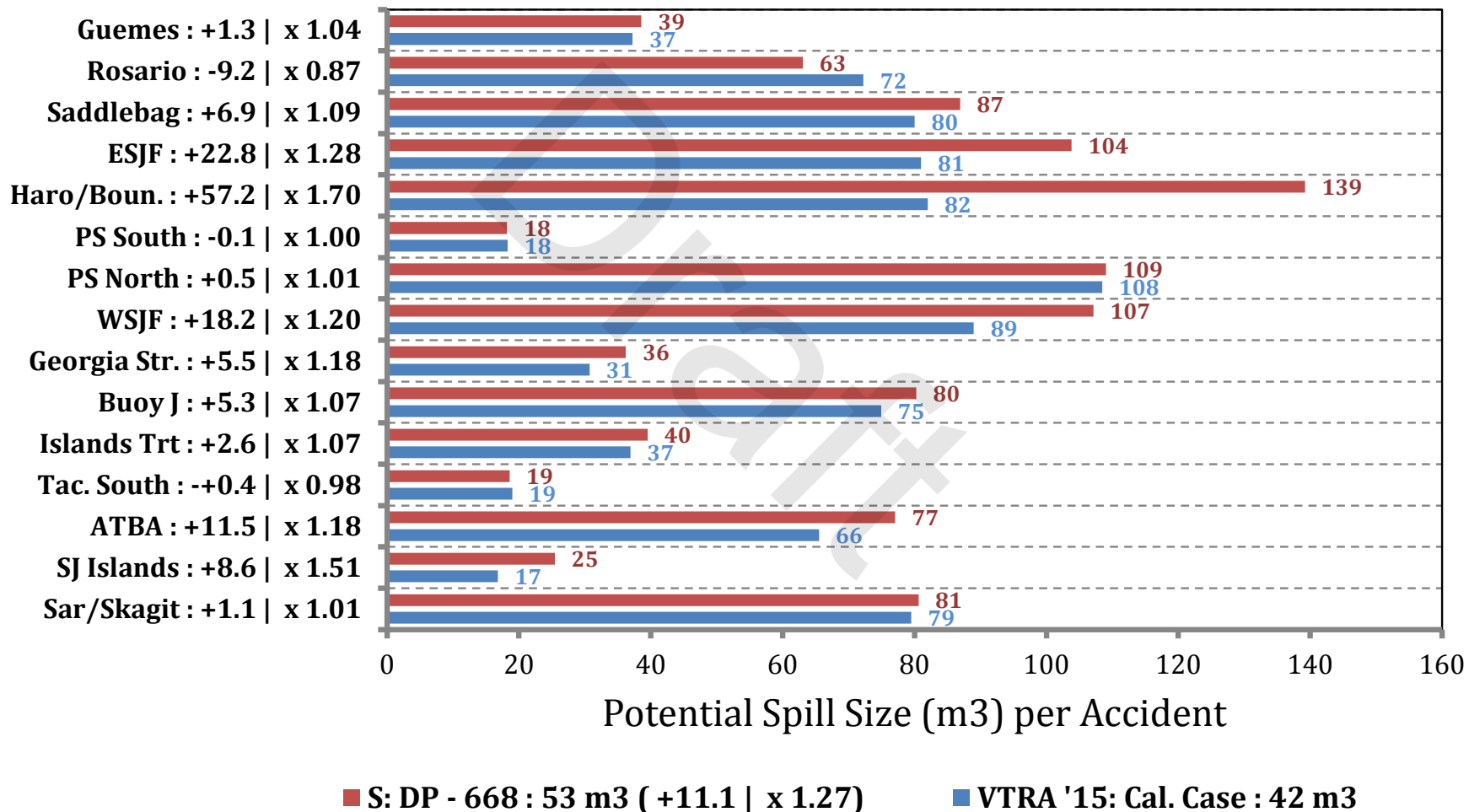


Prob. Estimate At Least One Accident in 10 Years - ALL_FV - Oil Spill Size Category: 1 - 1000 m3



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

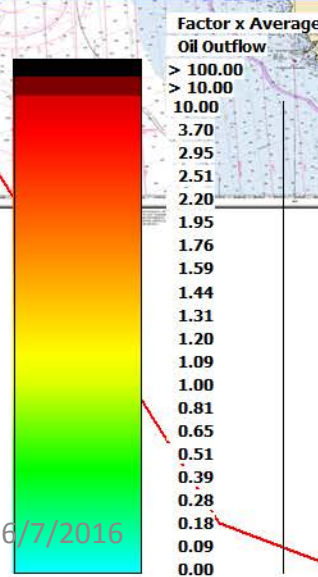
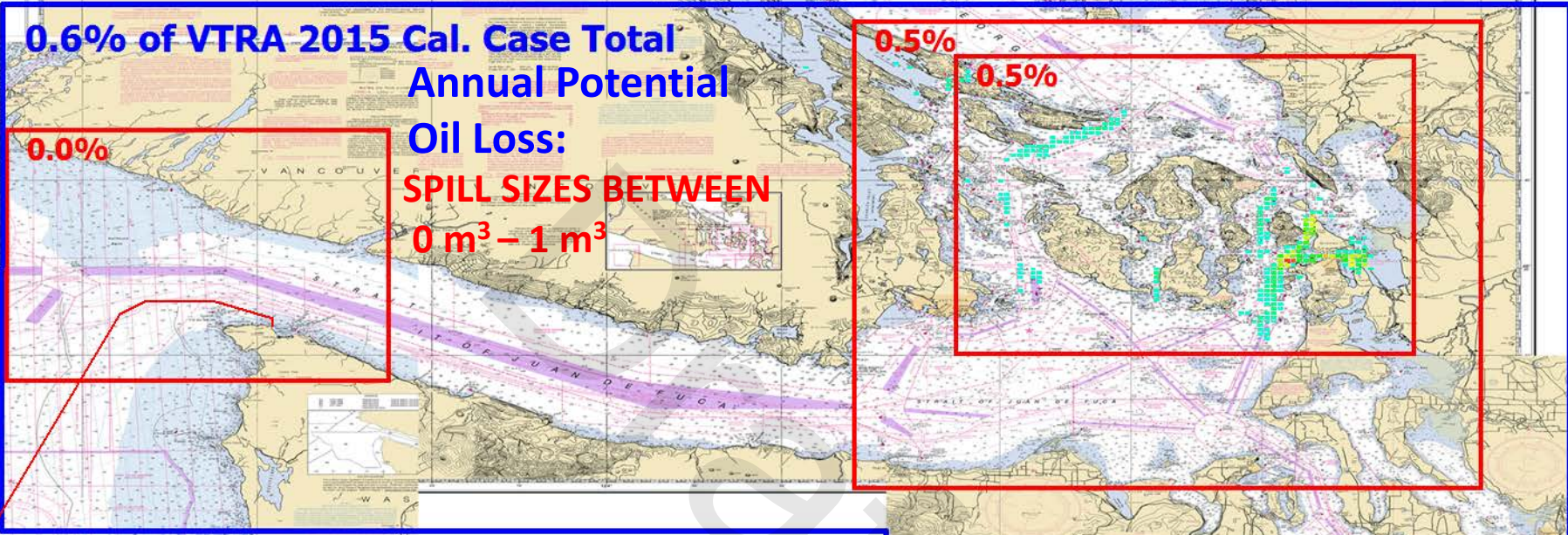
Oil Spill Size Category:

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

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



VTRA 2015 CALIBRATION CASE - ALL FV



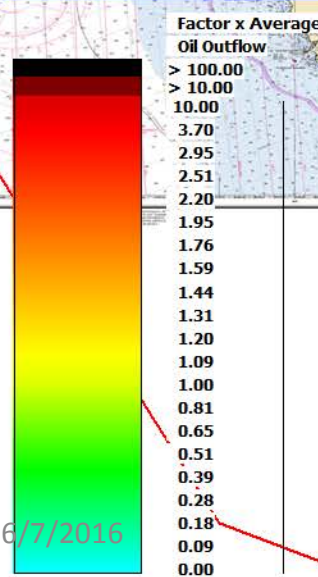
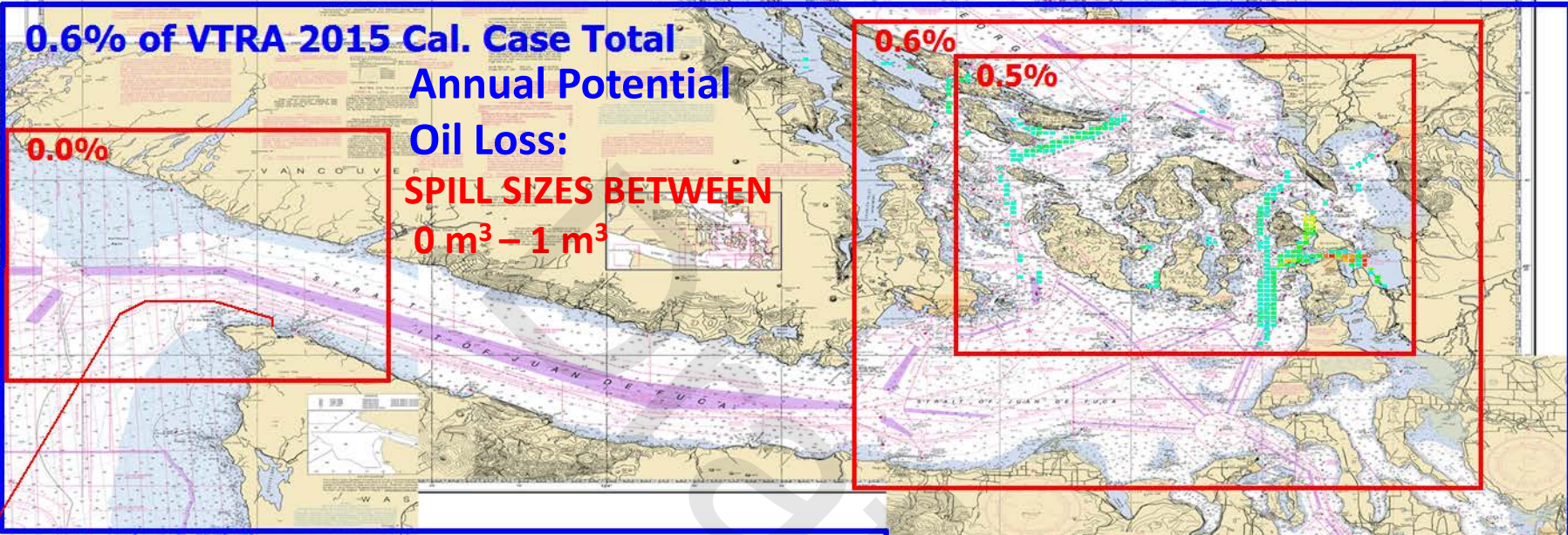
VTRA '15: Cal. Case
GEOGRAPHIC PROFILE
OF ANNUAL
POTENTIAL OIL LOSS
OF ACCIDENTS
WITH SPILL SIZE
BETWEEN 0 m³ - 1 m³

≈ 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

S: VTRA 2010 - Delta Port - Cont. 368 and Bulk 300 - ALL FV



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

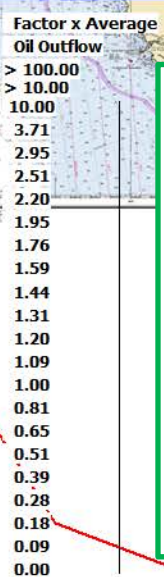
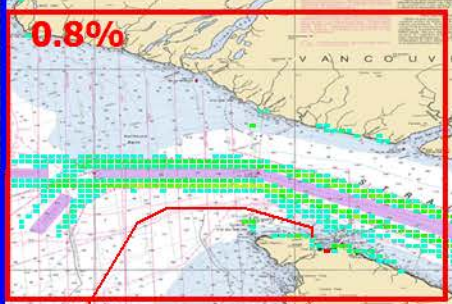
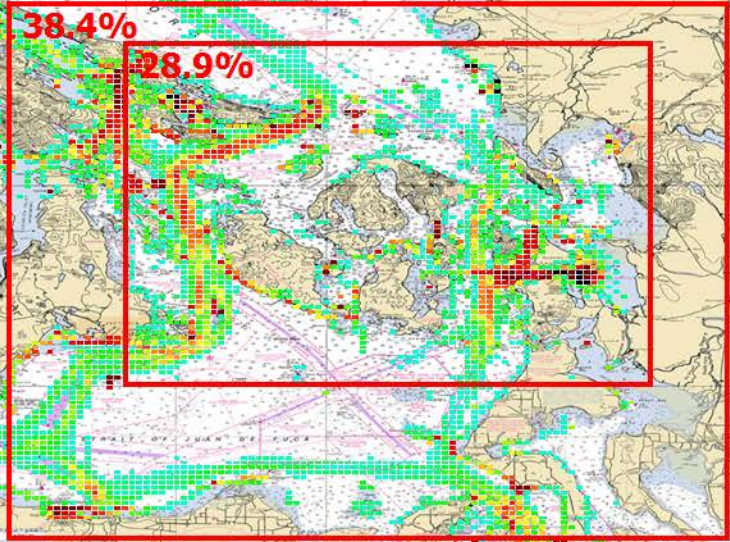
Average of ≈ 0.01 m^3 Per Potential Spill (= 2.5 gallons)

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

VTRA 2015 CALIBRATION CASE - ALL FV

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

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



VTRA '15 Case S: DP - 668
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

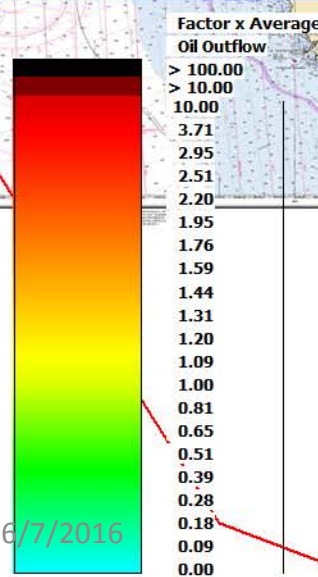
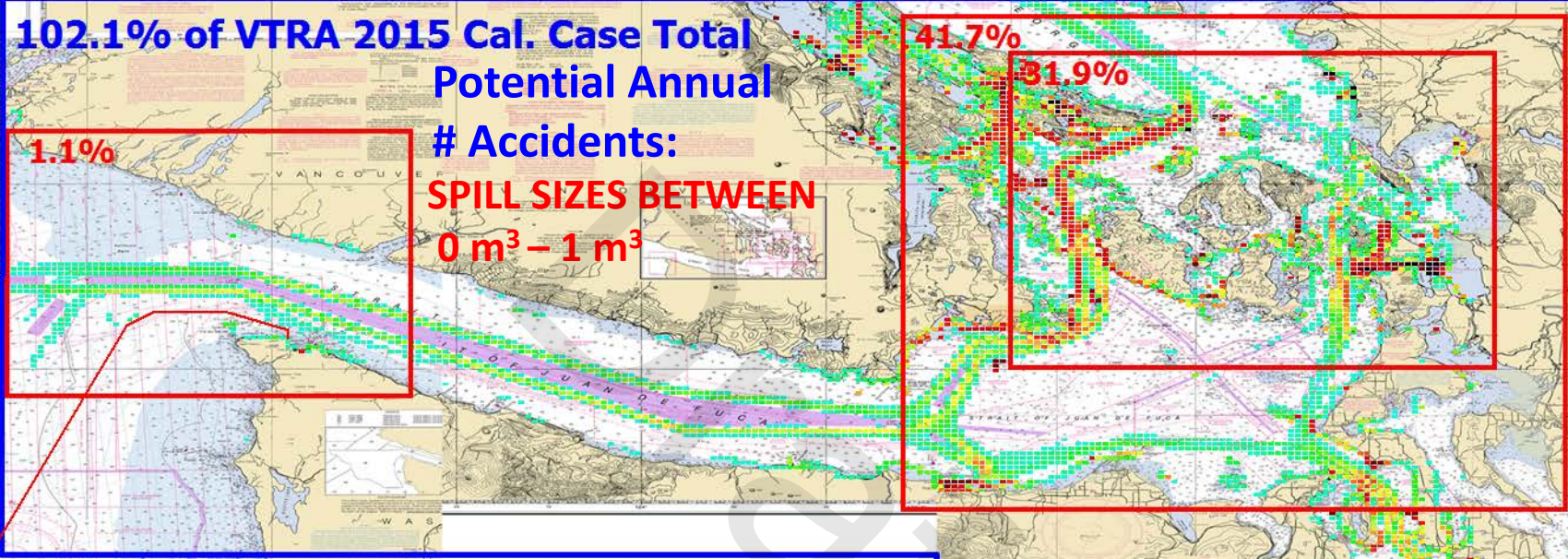
Average of ≈ 0.01 m^3 Per Potential Spill (≈ 2.4 gallons)

6/7/2016

5/24/2016

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

S: VTRA 2010 - Delta Port - Cont. 368 and Bulk 300 - ALL FV



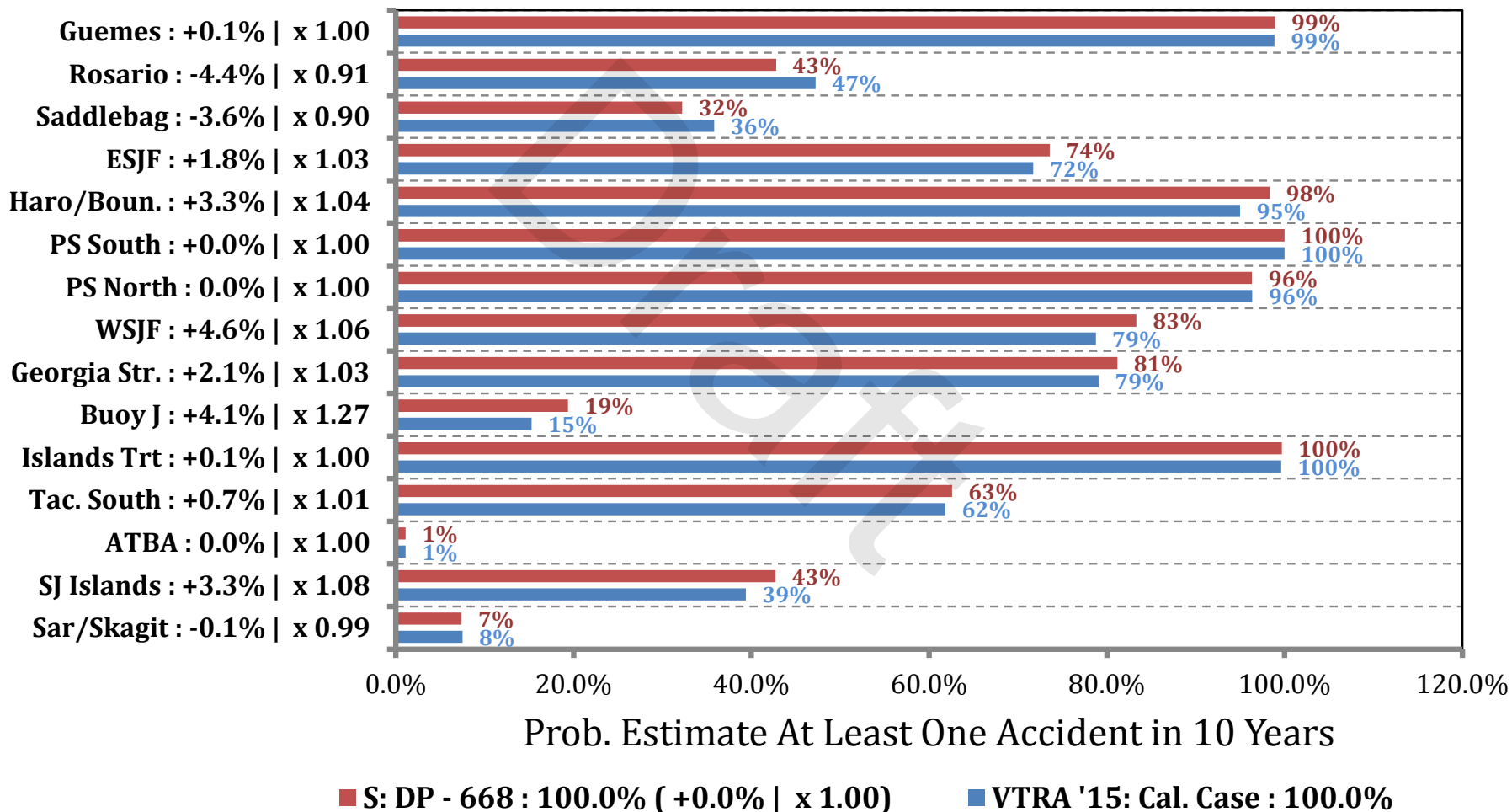
VTRA '15 Case R: KM - 348
GEOGRAPHIC PROFILE OF ANNUAL POTENTIAL OIL LOSS OF ACCIDENTS WITH SPILL SIZE BETWEEN 0 m³ - 1 m³

≈ 100% Probability of Spill Occurrence in 10 years

Average of ≈ 0.01 m³ Per Potential Spill (= 2.5 gallons)

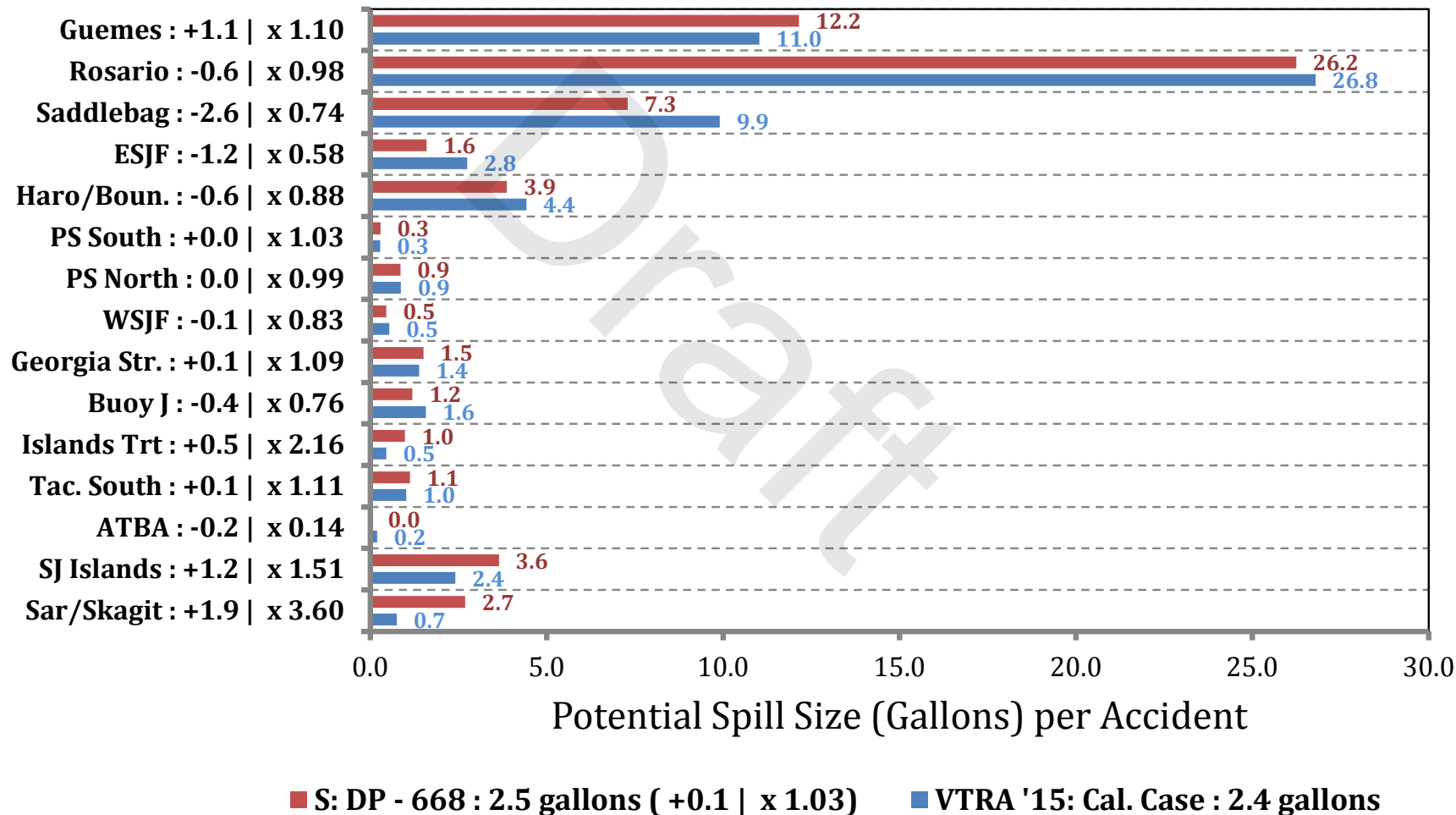
VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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



By Waterway Zone Risk Comparison

Oil Spill Size Category:
All Spill Sizes

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



Summary Relative Risk and Absolute Risk Comparison

		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	ANY SIZE
VTRA '15 CAL. CASE	Base Case % Potential Annual Oil Loss	39.8%	12.2%	47.4%	0.6%	100.0%
	Base Case % Potential Annual Accident Frequency	0.01%	0.01%	1.7%	98.2%	100.0%
	Average potential spill size per accident (in m ³)	5,745	1,627	42.0	0.01	1.5
	Probability of at least one accident in 1 year by spill size	0.05%	0.05%	7.3%	98.7%	98.8%
	Probability of at least one accident in 10 years by spill size	0.47%	0.50%	53.2%	100.0%	100.0%
	Probability of at least one accident in 25 years by spill size	1.16%	1.25%	85.0%	100.0%	100.0%
		OIL_2500_MORE	OIL_1000_2500	OIL_1_1000	OIL_0_1	ANY SIZE
VTRA '15 CASE S: DP -668	Base Case % Potential Annual Oil Loss	38.1% (-1.7% x0.96)	12.7% (+0.5% x1.04)	63.0% (+15.7% x1.33)	0.6% (+0.04% x1.07)	114.5% (+14.5% x1.15)
	Base Case % Potential Annual Accident Frequency	0.01% (0.00% x0.93)	0.01% (+0.00% x1.05)	1.8% (+0.1% x1.05)	102.1% (+3.9% x1.04)	104.0% (+4.0% x1.04)
	Average potential spill size per accident (in m ³)	5886 (+141.2 x1.02)	1618 (-9.3 x0.99)	53.0 (+11.1 x1.26)	0.01 (+0.0 x1.03)	1.7 (+0.2 x1.10)
	Probability of at least one accident in 1 year by spill size	0.04% (0.00% x0.93)	0.05% (+0.00% x1.05)	7.7% (+0.4% x1.05)	98.9% (+0.2% x1.00)	99.0% (+0.2% x1.00)
	Probability of at least one accident in 10 years by spill size	0.43% (-0.03% x0.93)	0.53% (+0.02% x1.05)	55.1% (+1.9% x1.03)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)
	Probability of at least one accident in 25 years by spill size	1.08% (-0.08% x0.93)	1.31% (+0.06% x1.05)	86.5% (+1.4% x1.02)	100.0% (0.0% x1.00)	100.0% (0.0% x1.00)