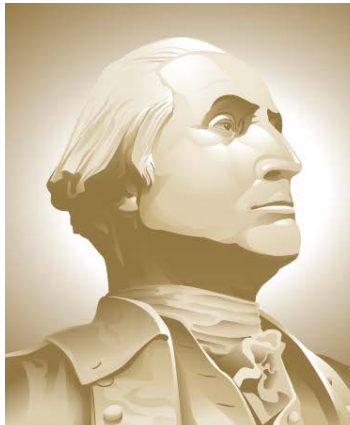


## VTRA 2015 KM -348 Case and VTRA 2015 Base Case Comparison



**THE GEORGE  
WASHINGTON  
UNIVERSITY**

WASHINGTON, DC

**VCU**

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

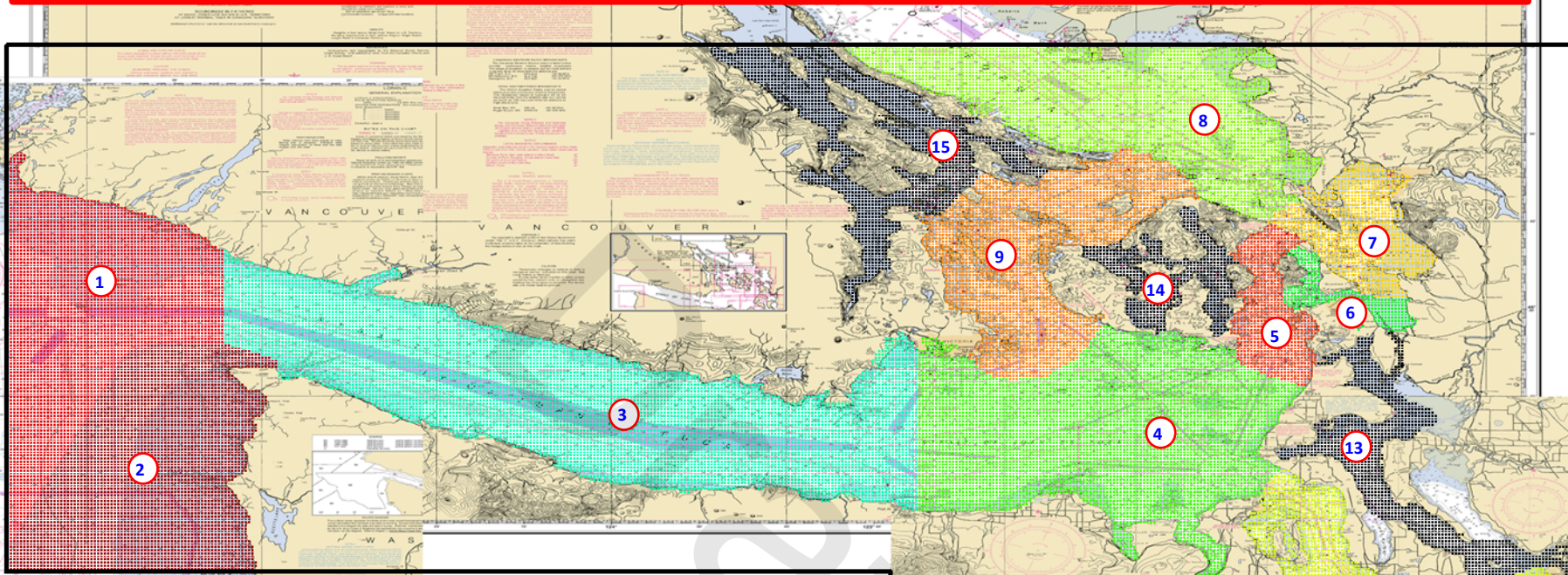
August 9<sup>th</sup> – 10<sup>th</sup>, 2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



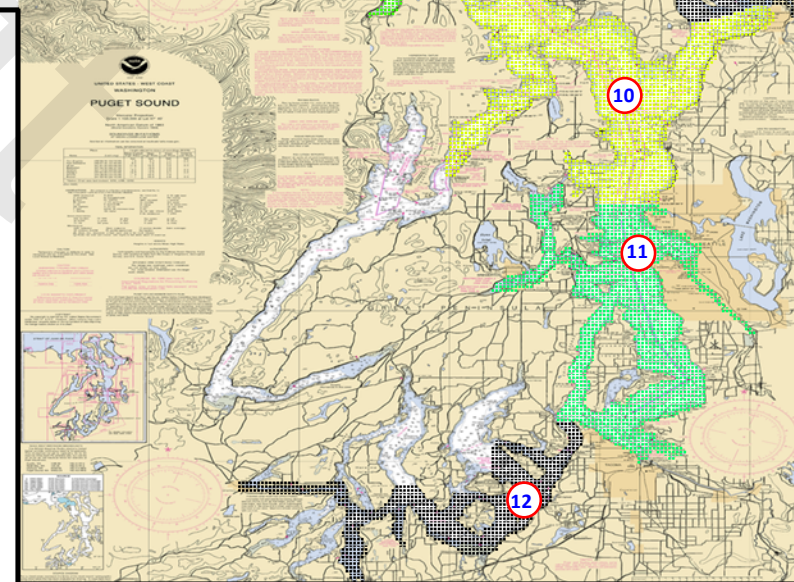


# DEFINITION OF 15 WATERWAY ZONES



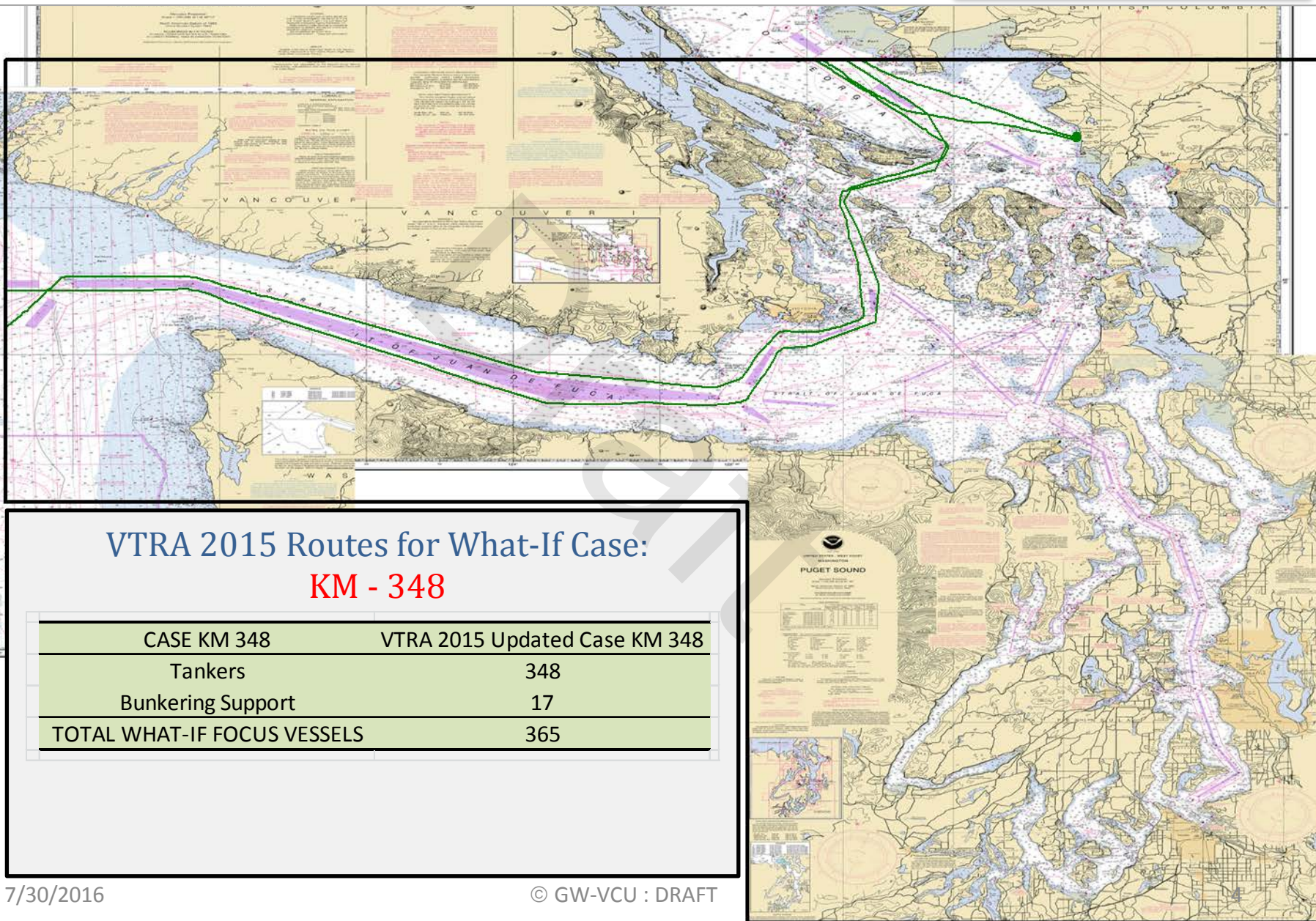
## VTRA 2015 Waterway Zones

- |                 |                           |
|-----------------|---------------------------|
| 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. |                           |

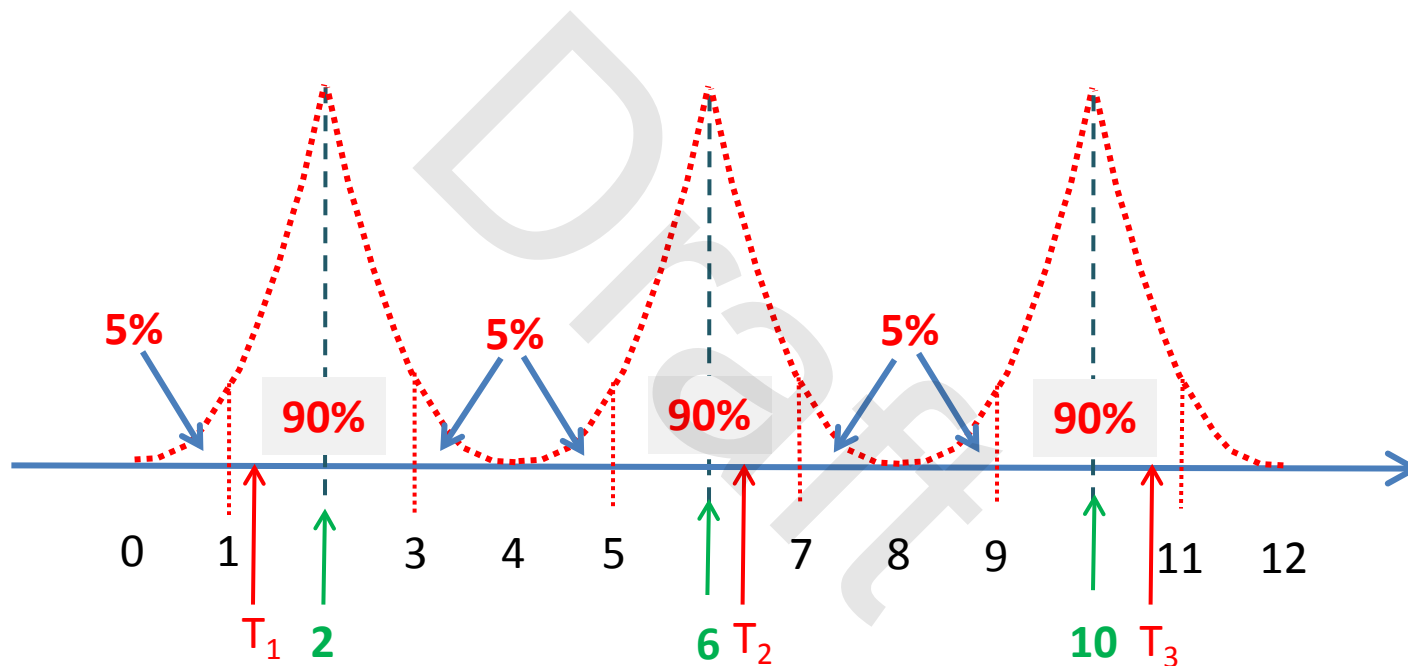




# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015



## 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)**

78.2%

61.3%

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

### VTRA '15 Case: BASE CASE

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

7/30/2016

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# VESSEL TRAFFIC RISK ASSESSMENT (VTTRA) 2015

**VTTRA 2015 Case: KM-348 - ALL FV**

**121.0% of VTTRA 2015 Base Case Total  
Annual Potential  
Oil Loss: ALL SPILL  
SIZES (including accid.  
with zero oil loss)**

2.8%

97.8%

73.0%

**VTTRA '15 Case:  
KM - 348**

**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

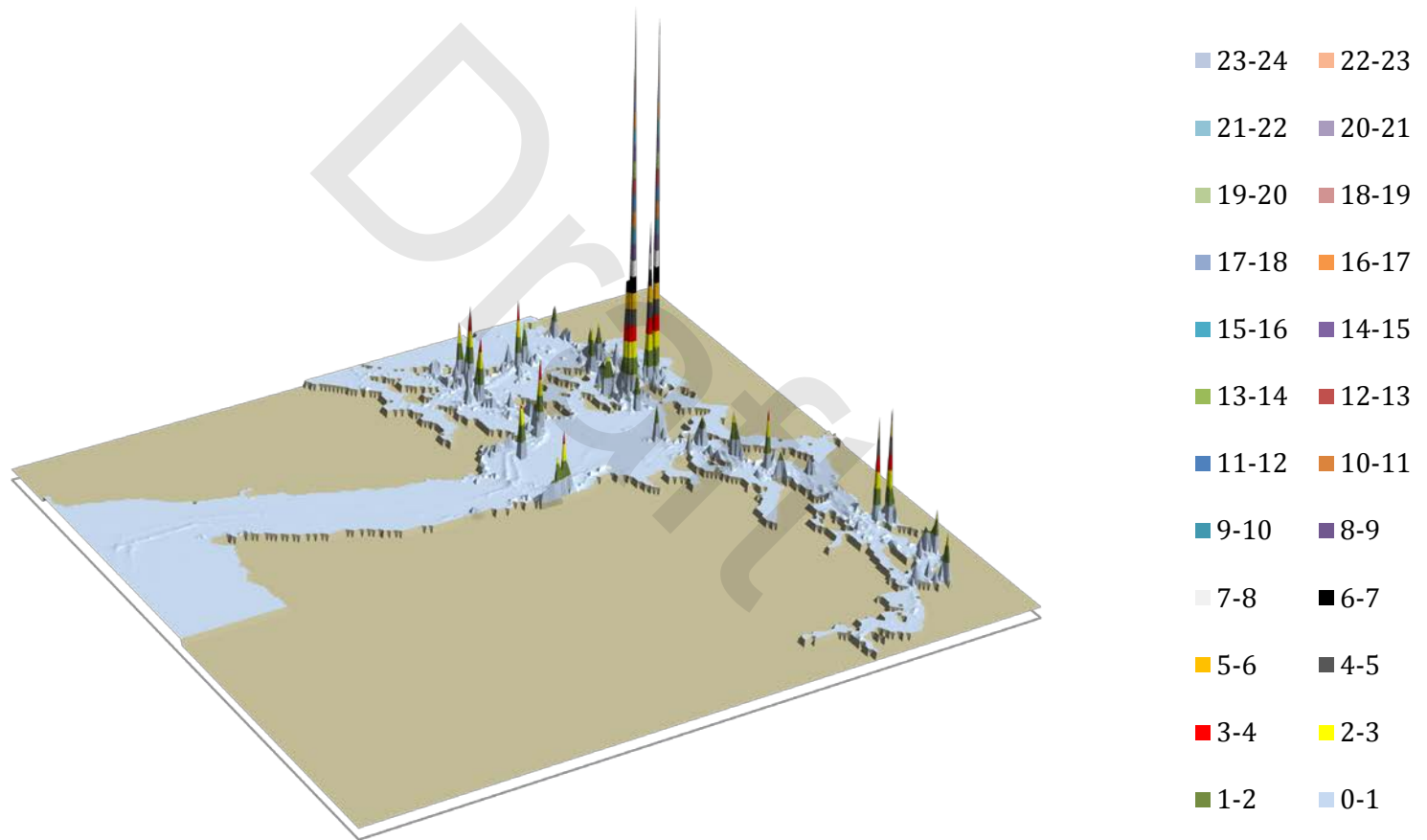
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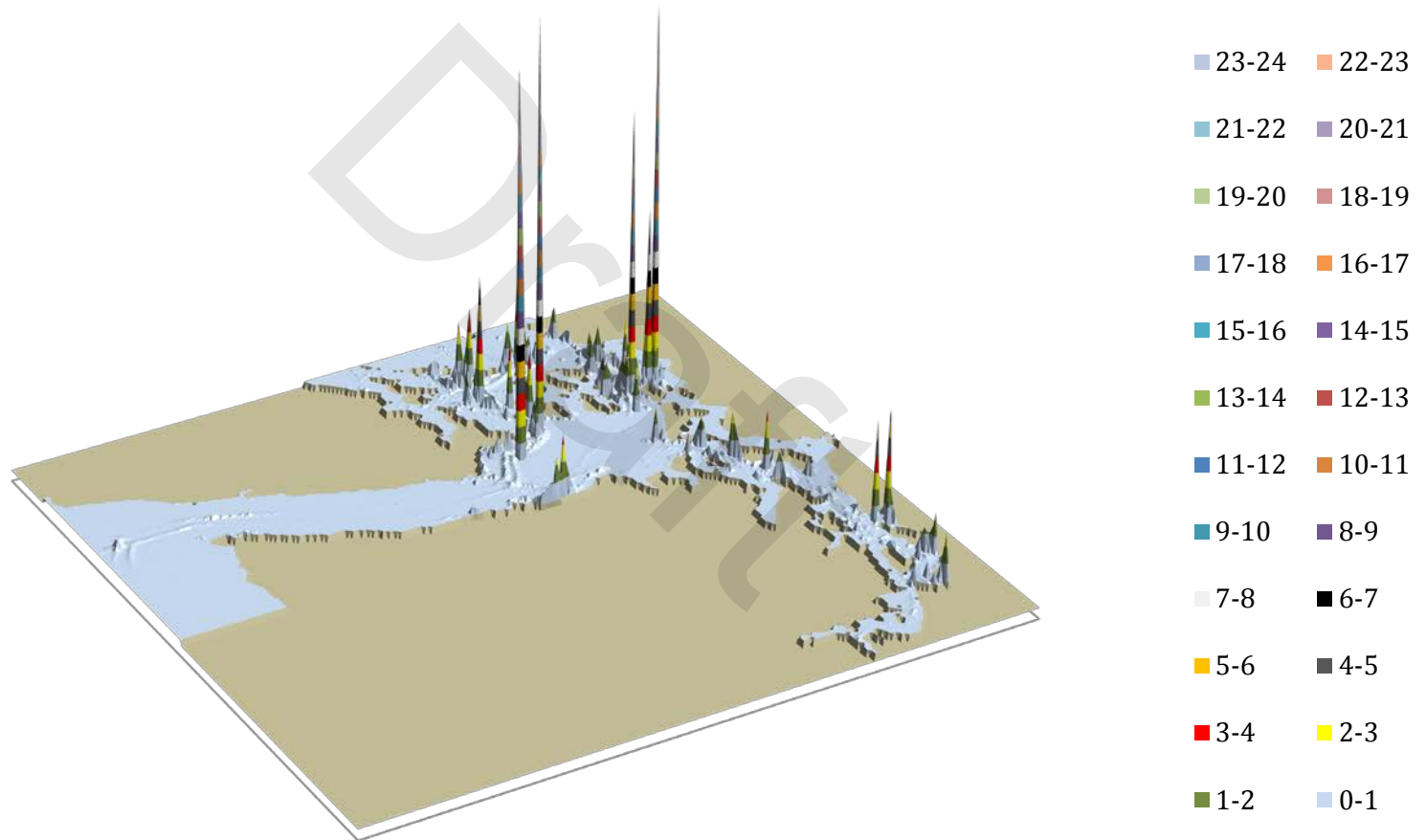
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## VTRA '15: Base Case 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 100% of Base Case POL



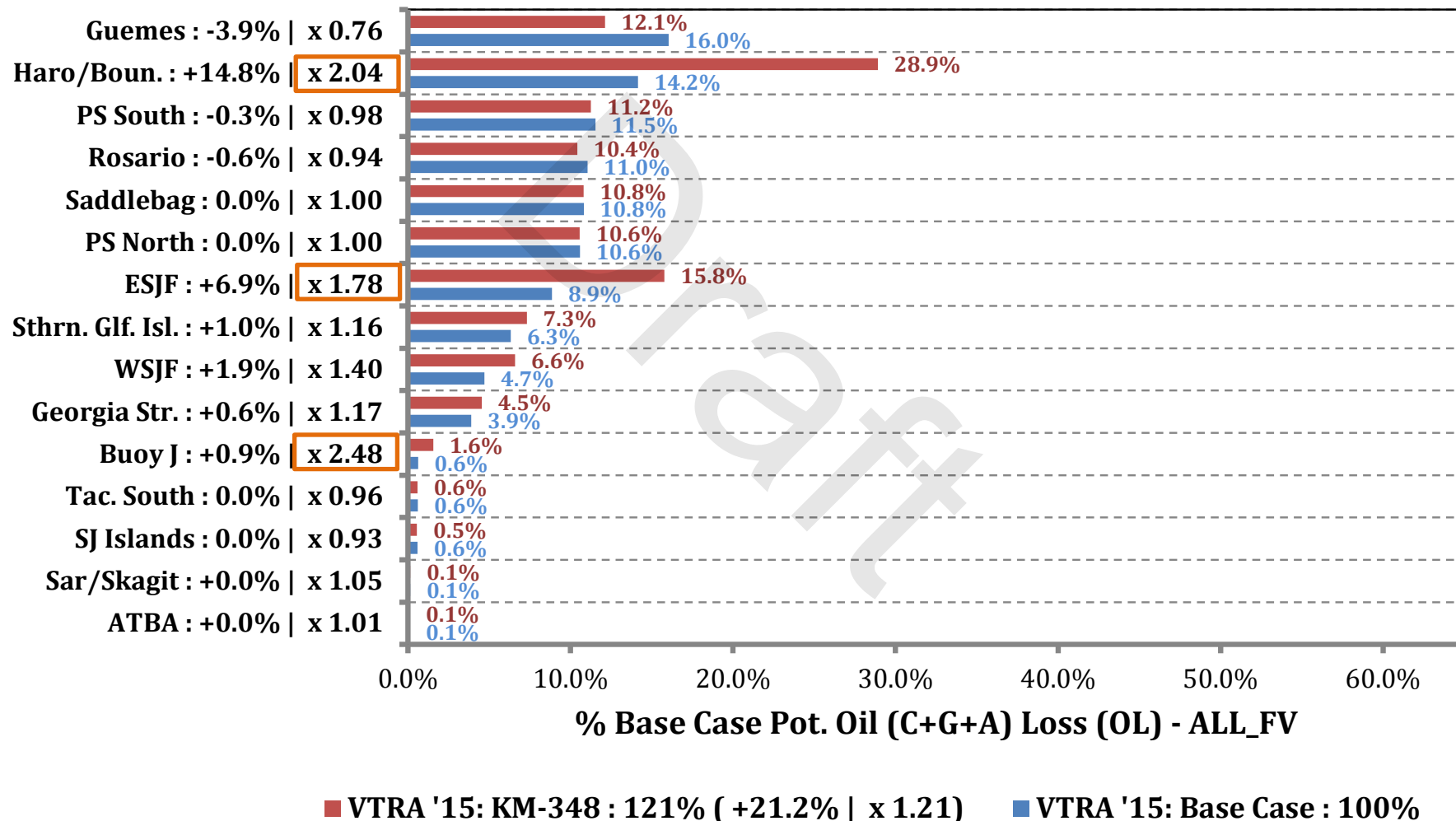
## VTRA '15: KM-348 3D Risk Profile All FV - Pot.C+G+A.Oil Loss: 121% of Base Case POL





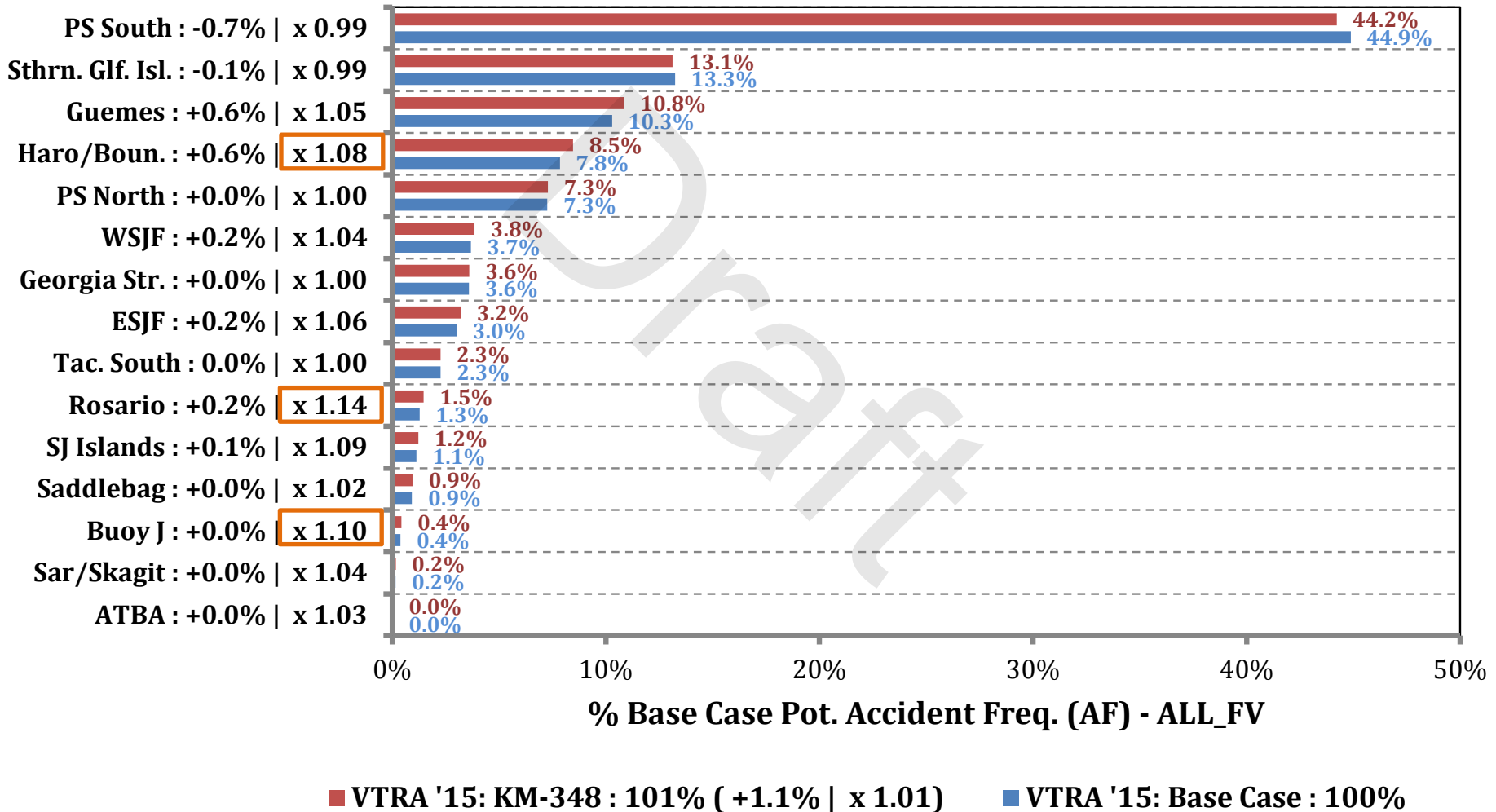
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## % Base Case Pot. Oil (C + G + A) Loss - ALL\_FV



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## % Base Case Pot. Accident (C+G+A) Frequency - ALL\_FV





# By Waterway Zone Risk Comparison

Oil Spill Size Category:  
**2500 m<sup>3</sup> 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 m<sup>3</sup>**

**0.7%**

**37.3%**

**31.5%**

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

### VTRA '15: BASE CASE

GEOGRAPHIC PROFILE  
OF POTENTIAL  
ANNUAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE

**2,500 m<sup>3</sup> or more**

≈ 0.50% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 6,798 m<sup>3</sup>  
Per Potential Spill  
(≈ 5,846 Metric. Tons)

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# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 Case: KM-348 - ALL FV

57.4% of VTRA 2015 Base Case Total  
Annual Potential  
Oil Loss:

**SPILL SIZES LARGER  
THAN 2,500 m<sup>3</sup>**

2.2%

51.1%

38.5%

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

### VTRA '15 Case: KM - 348

GEOGRAPHIC PROFILE  
OF POTENTIAL  
ANNUAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE  
**2,500 m<sup>3</sup> or more**

≈ 0.97% Probability  
of Spill Occurrence  
in 10 years

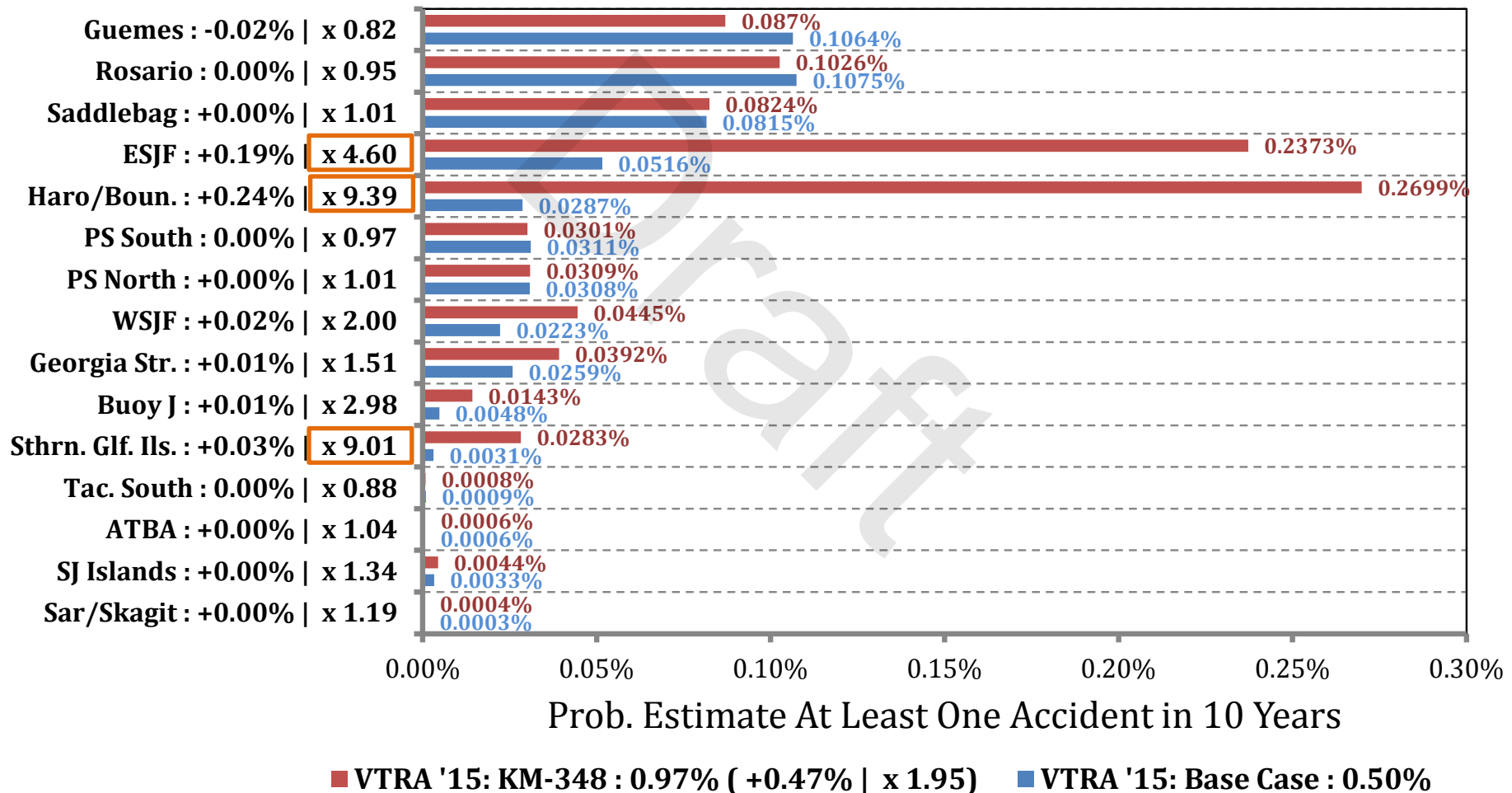
Average of ≈ 4,770 m<sup>3</sup>  
Per Potential Spill  
(≈ 4,102 Metric Tons)

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# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

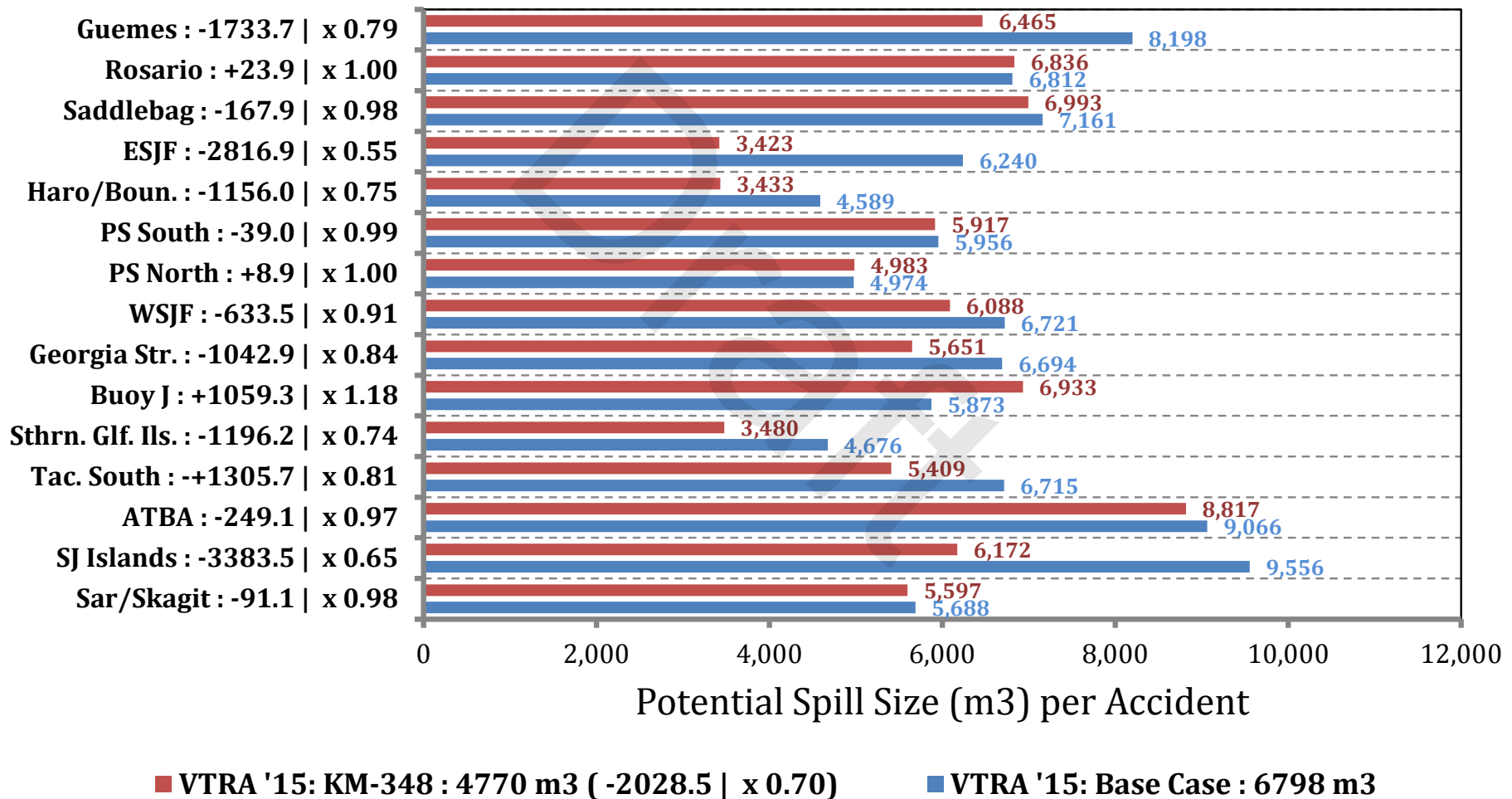
Prob. Estimate At Least One Accident in 10 Years -  
ALL\_FV - Oil Spill Size Category: 2500 cubic meters or more





# 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:

**$1000 \text{ m}^3 - 2500 \text{ m}^3$**



# 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 m<sup>3</sup> - 2,500 m<sup>3</sup>**

**10.7%**

**9.1%**

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

### VTRA '15: BASE CASE

GEOGRAPHIC PROFILE  
OF POTENTIAL  
ANNUAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE **BETWEEN**  
**1,000 m<sup>3</sup> - 2,500 m<sup>3</sup>**

≈ 0.61% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 1,619 m<sup>3</sup>  
Per Potential Spill  
(≈ 1,392 Metric Tons)

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# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 Case: KM-348 - ALL FV

**17.7% of VTRA 2015 Base Case Total Annual Potential Oil Loss:**

**Oil Loss:**  
**SPILL SIZES BETWEEN**  
**1,000 m<sup>3</sup> - 2,500 m<sup>3</sup>**

**0.2%**

**16.0%**

**13.8%**

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

**VTRA '15 Case:**  
**KM - 348**

**GEOGRAPHIC PROFILE**  
**OF POTENTIAL**  
**ANNUAL OIL LOSS**  
**OF ACCIDENTS**  
**WITH SPILL SIZE BETWEEN**  
**1,000 m<sup>3</sup> - 2,500 m<sup>3</sup>**

≈ 0.83% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 1,708 m<sup>3</sup>  
Per Potential Spill  
(≈ 1,469 Metric Tons)

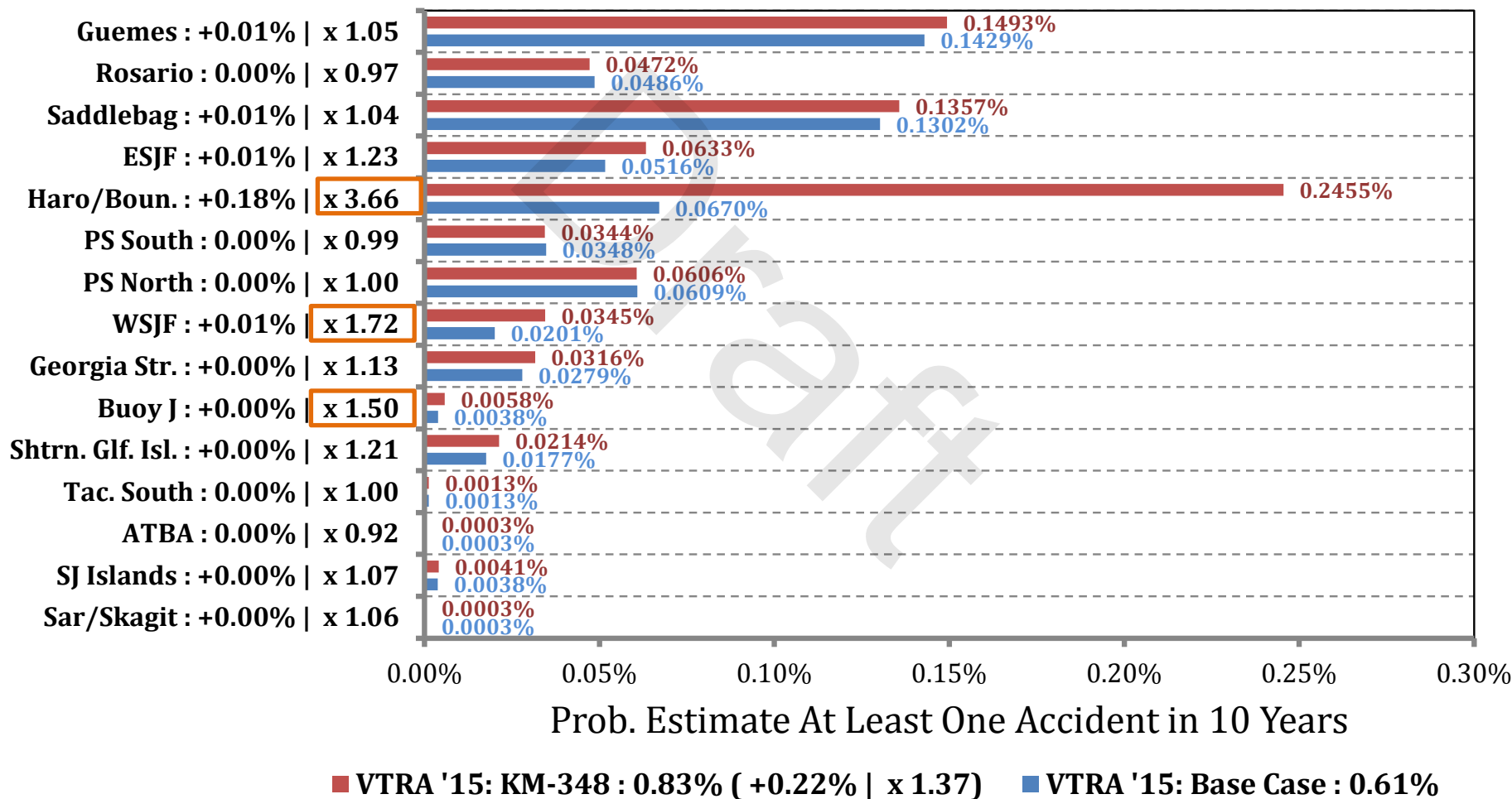
7/30/2016

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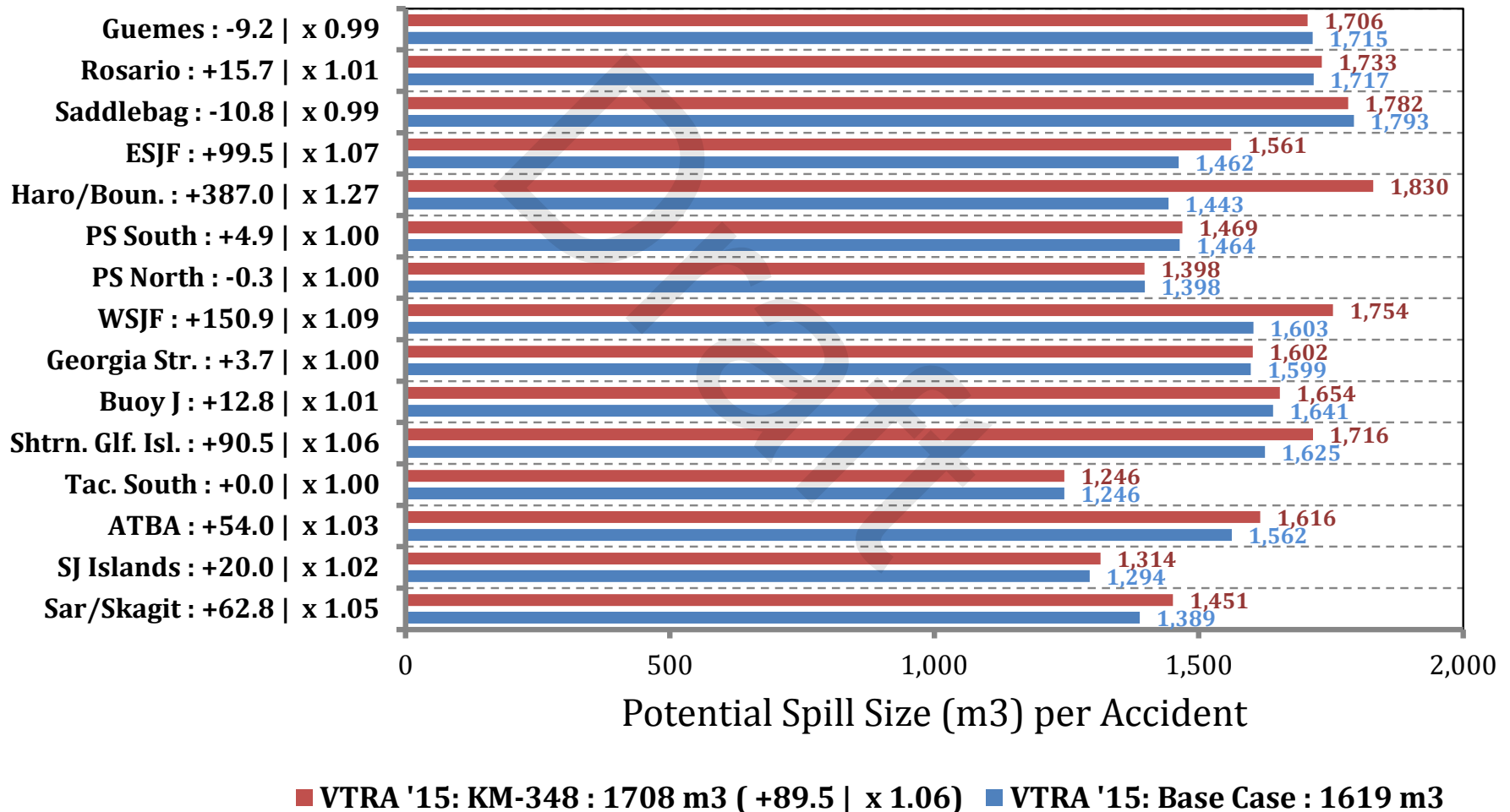
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

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 (VTTRA) 2015

## VTTRA 2015 BASE CASE - ALL FV

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

**SPIR SIZEE BETWEEN  
1 m<sup>3</sup> – 1,000 m<sup>3</sup>**

0.4%

29.8%

20.3%

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

### VTTRA '15: BASE CASE

GEOGRAPHIC PROFILE  
OF ANNUAL  
POTENTIAL OIL LOSS  
OF ACCIDENTS  
WITH SPIR SIZE

**BETWEEN 1 m<sup>3</sup> - 1000 m<sup>3</sup>**

≈ 54.2% Probability  
of Spill Occurrence  
in 10 years

Average of ≈ 47 m<sup>3</sup>  
Per Potential Spill  
(≈ 295 Barrels)

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# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 Case: KM-348 - ALL FV

45.5% of VTRA 2015 Base Case Total  
Annual Potential

Oil Loss:

**SPILL SIZES BETWEEN  
 $1 \text{ m}^3 - 1,000 \text{ m}^3$**

0.4%

30.3%

20.3%

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

## VTRA '15 Case: KM - 348

GEOGRAPHIC PROFILE  
OF ANNUAL  
POTENTIAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE

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

≈ 54.1% Probability  
of Spill Occurrence  
in 10 years

Average of ≈  $47 \text{ m}^3$   
Per Potential Spill  
(≈ 298 Barrels)

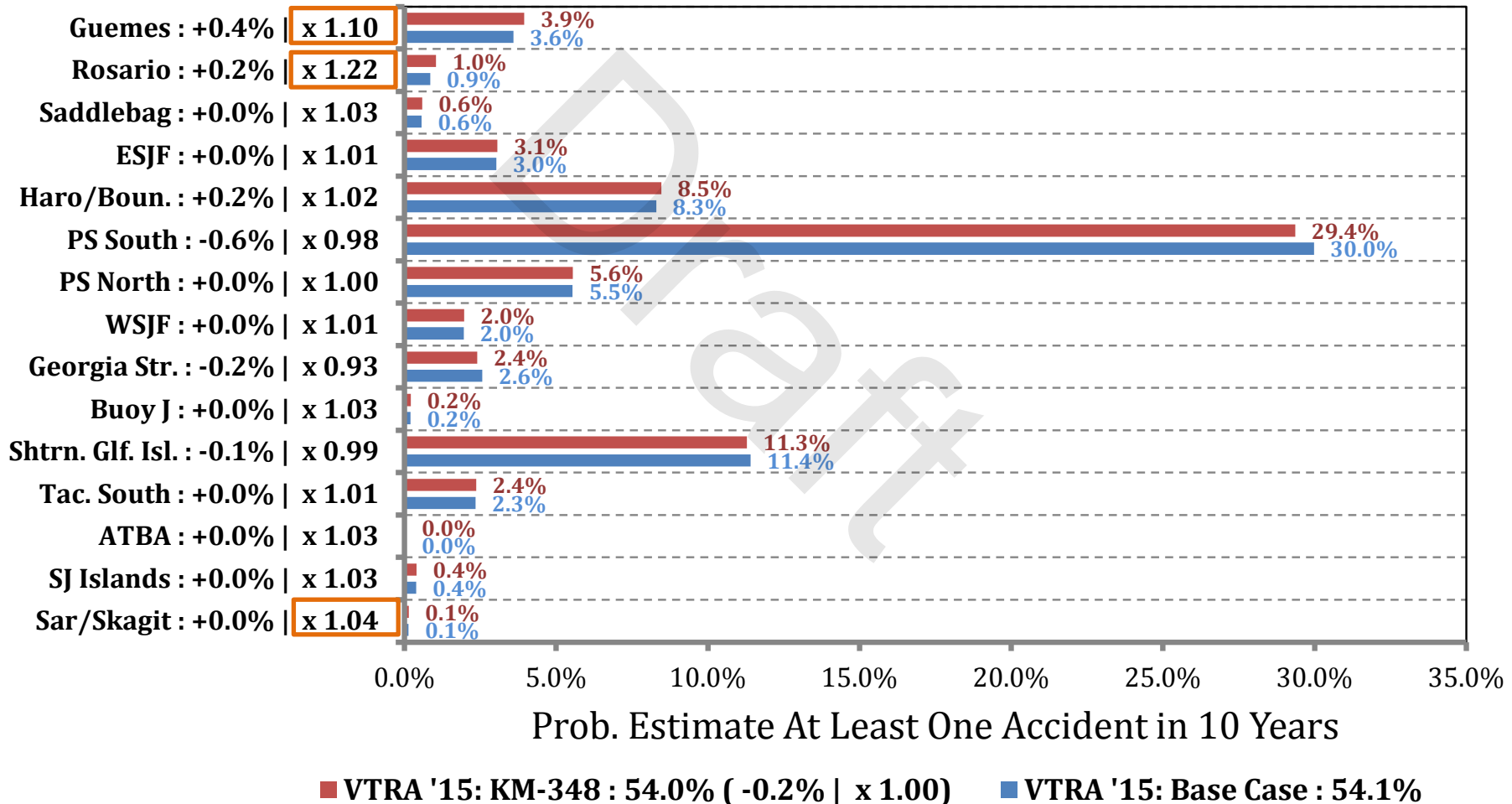
7/30/2016

7/30/2016



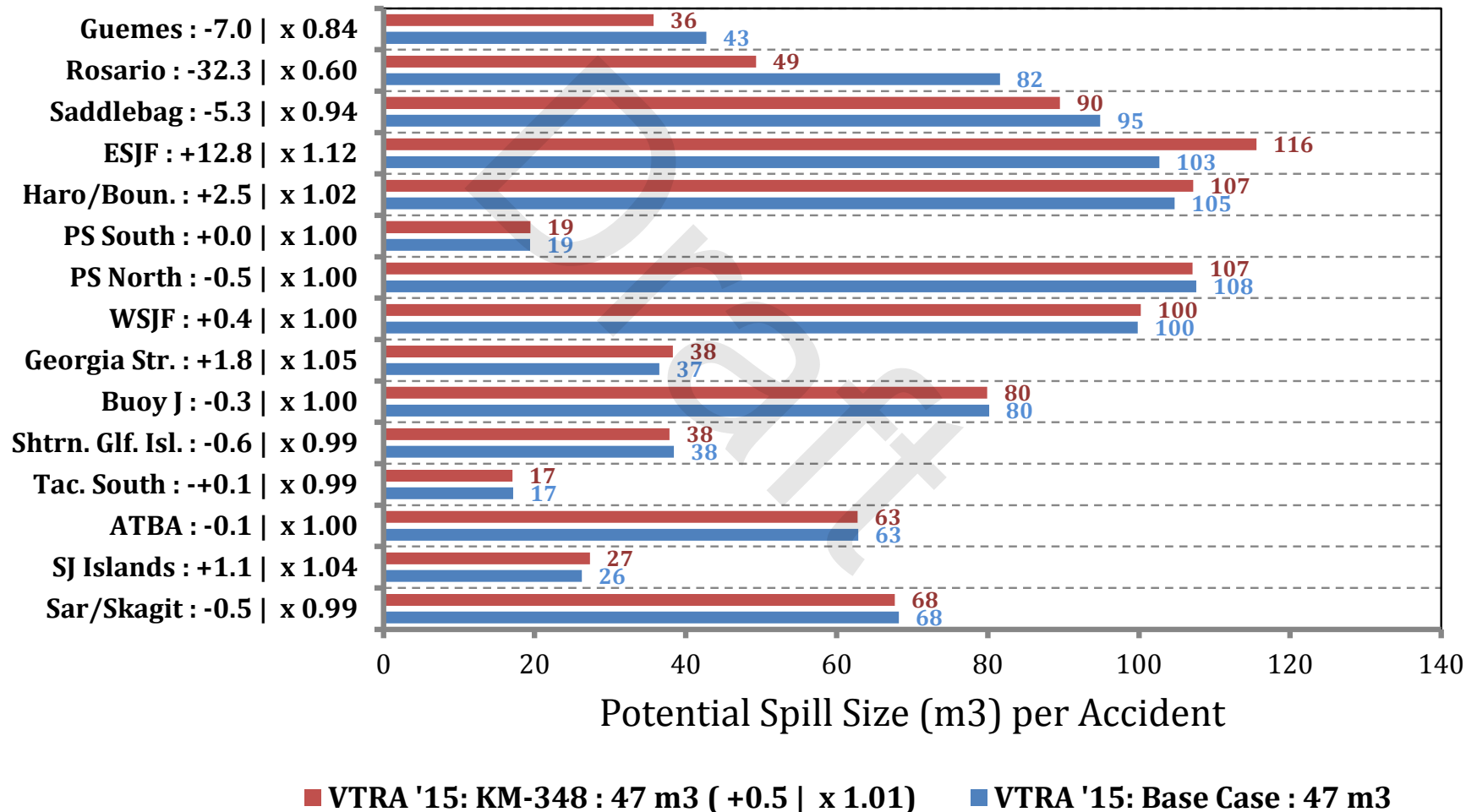
# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## 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 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%**

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

**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 ≈  $0.01 \text{ m}^3$   
Per Potential Spill  
(≈ 2.3 gallons)

7/30/2016

7/28/2016



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 Case: KM-348 - 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%**

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

**VTRA '15 Case:  
KM - 348**

**GEOGRAPHIC PROFILE  
OF ANNUAL  
POTENTIAL OIL LOSS  
OF ACCIDENTS  
WITH SPILL SIZE**

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

**$\approx 100\%$  Probability  
of Spill Occurrence  
in 10 years**

**Average of  $\approx 0.01 \text{ m}^3$   
Per Potential Spill  
(  $\approx 2.4$  gallons)**

7/30/2016

7/30/2016





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

0.8%

39.2%

29.5%

Factor x Average  
Oil Outflow

> 100.00  
> 10.00  
10.00  
3.71  
2.95  
2.51  
2.20  
1.95  
1.76  
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

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 ≈  $0.01 \text{ m}^3$   
Per Potential Spill  
(≈ 2.3 gallons)

7/30/2016

7/28/2016



# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

## VTRA 2015 Case: KM-348 - ALL FV

99.5% of VTRA 2015 Base Case Total  
Potential Annual

# Accidents:

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

0.9%

40.8%

30.9%

Factor x Average  
Oil Outflow

> 100.00  
> 10.00  
10.00  
3.71  
2.95  
2.51  
2.20  
1.95  
1.76  
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

VTRA '15 Case:  
KM - 348

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

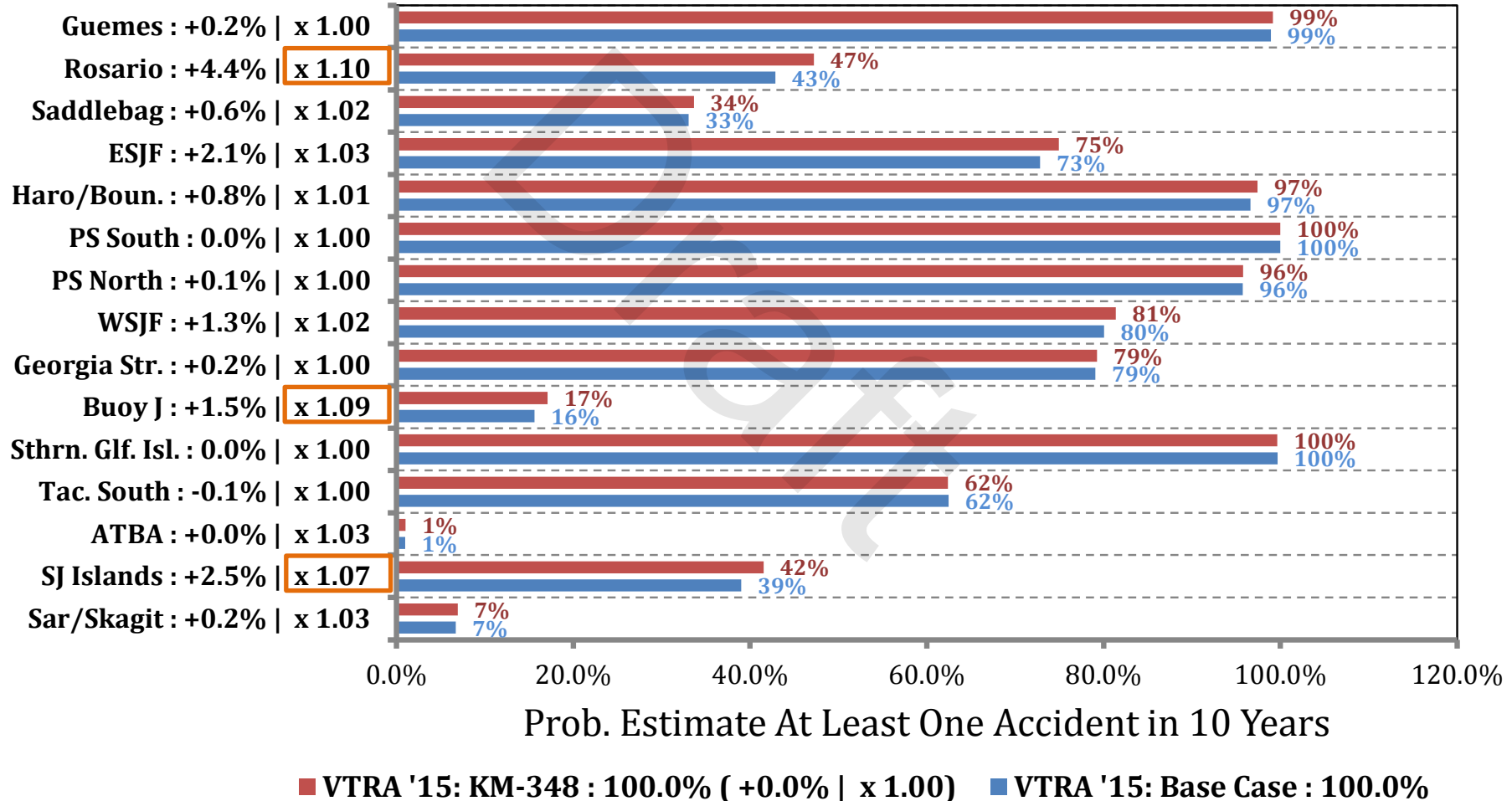
Average of  $\approx 0.01 \text{ m}^3$   
Per Potential Spill  
(= 2.2 gallons)

7/30/2016

7/30/2016

# VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2015

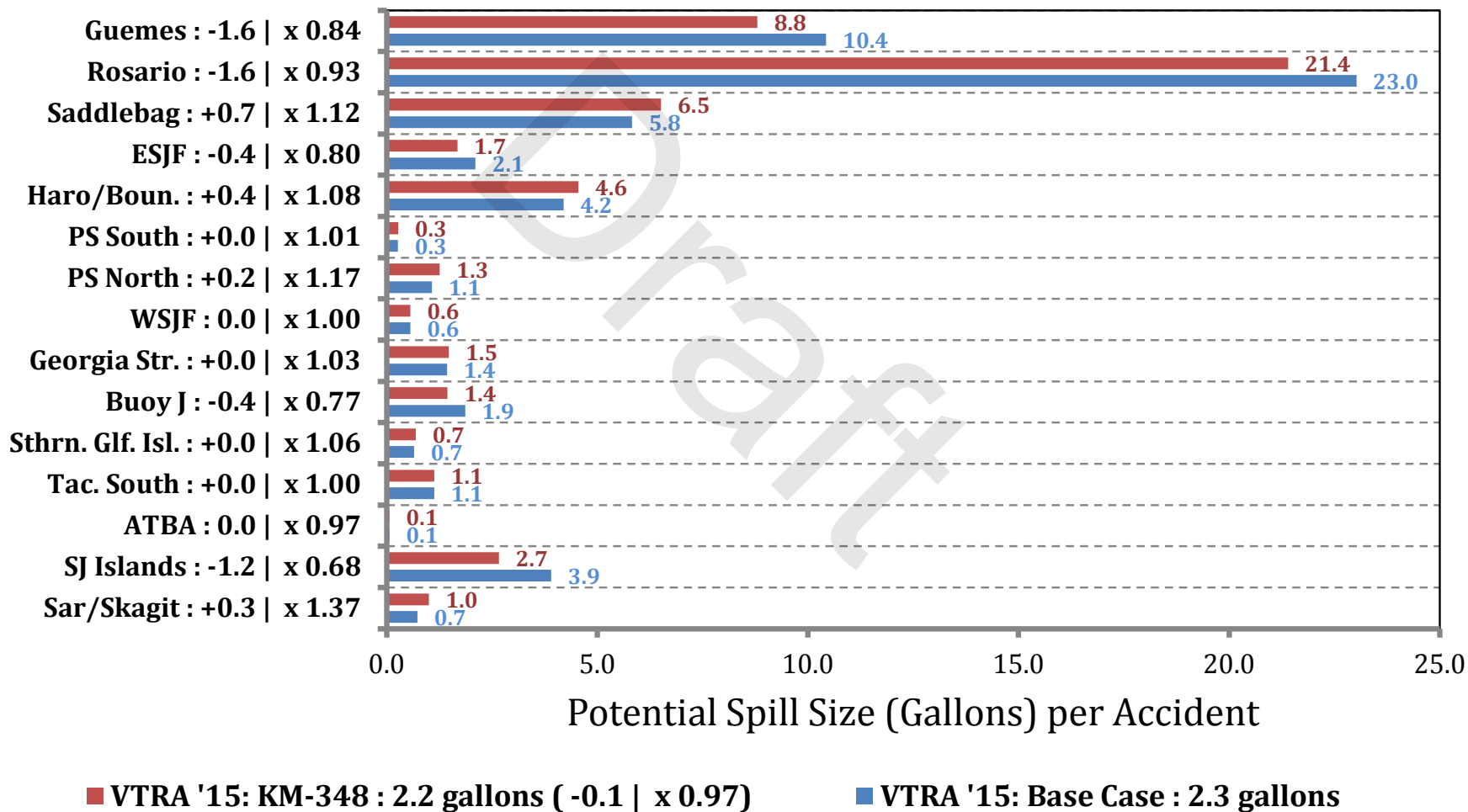
## Prob. Estimate At Least One Accident in 10 Years - ALL\_FV - Oil Spill Size Category: 0 - 264 Gallons





# 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 <sup>3</sup> )	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
VTRA '15 KM - 348	Base Case % Potential Annual Oil Loss	57.5% ( +15.46%   x1.37 )	17.7% ( +5.42%   x1.44 )	45.6% ( +0.31%   x1.01 )	0.5% ( -0.01%   x0.98 )	121.2% ( +21.2%   x1.21 )
	Base Case % Potential Annual Accident Frequency	0.02% ( +0.01%   x1.95 )	0.02% ( +0.01%   x1.37 )	1.8% ( -0.01%   x1.00 )	99.3% ( +1.1%   x1.01 )	101.1% ( +1.1%   x1.01 )
	Average potential spill size per accident (in m <sup>3</sup> )	4771 ( -2028   x0.70 )	1708 ( +89   x1.06 )	47.4 ( +0.5   x1.01 )	0.01 ( 0.00   x0.97 )	2.2 ( +0.4   x1.20 )
	Probability of at least one accident in 1 year by spill size	0.10% ( +0.05%   x1.95 )	0.08% ( +0.02%   x1.37 )	7.5% ( -0.03%   x1.00 )	98.8% ( +0.06%   x1.00 )	98.9% ( +0.06%   x1.00 )
	Probability of at least one accident in 10 year by spill size	0.97% ( +0.47%   x1.95 )	0.83% ( +0.22%   x1.36 )	54.1% ( -0.15%   x1.00 )	100.0% ( 0.00%   x1.00 )	100.0% ( 0.00%   x1.00 )
	Probability of at least one accident in 25 years by spill size	2.41% ( +1.16%   x1.94 )	2.07% ( +0.55%   x1.36 )	85.7% ( -0.12%   x1.00 )	100.0% ( 0.00%   x1.00 )	100.0% ( 0.00%   x1.00 )