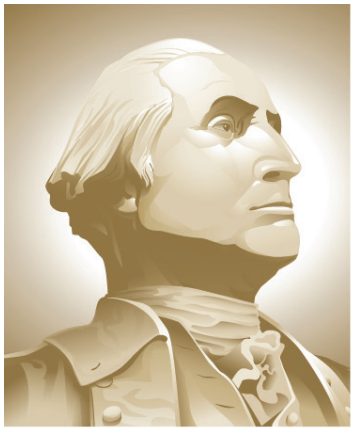
DRAFT VTRA 2010 TRAFFIC DENSITIES BY NON – FOCUS VESSEL (FV), CARGO – FV and TANK FV



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GWU Personnel: Dr. J. Rene van Dorp

VCU Personnel: Dr. Jason R. W. Merrick

DECEMBER 5, 2013

Table. Focus Vessel (FV) Classification for the 26 VTOSS vessel type classification used in the GW/VCU MTS simulation model.

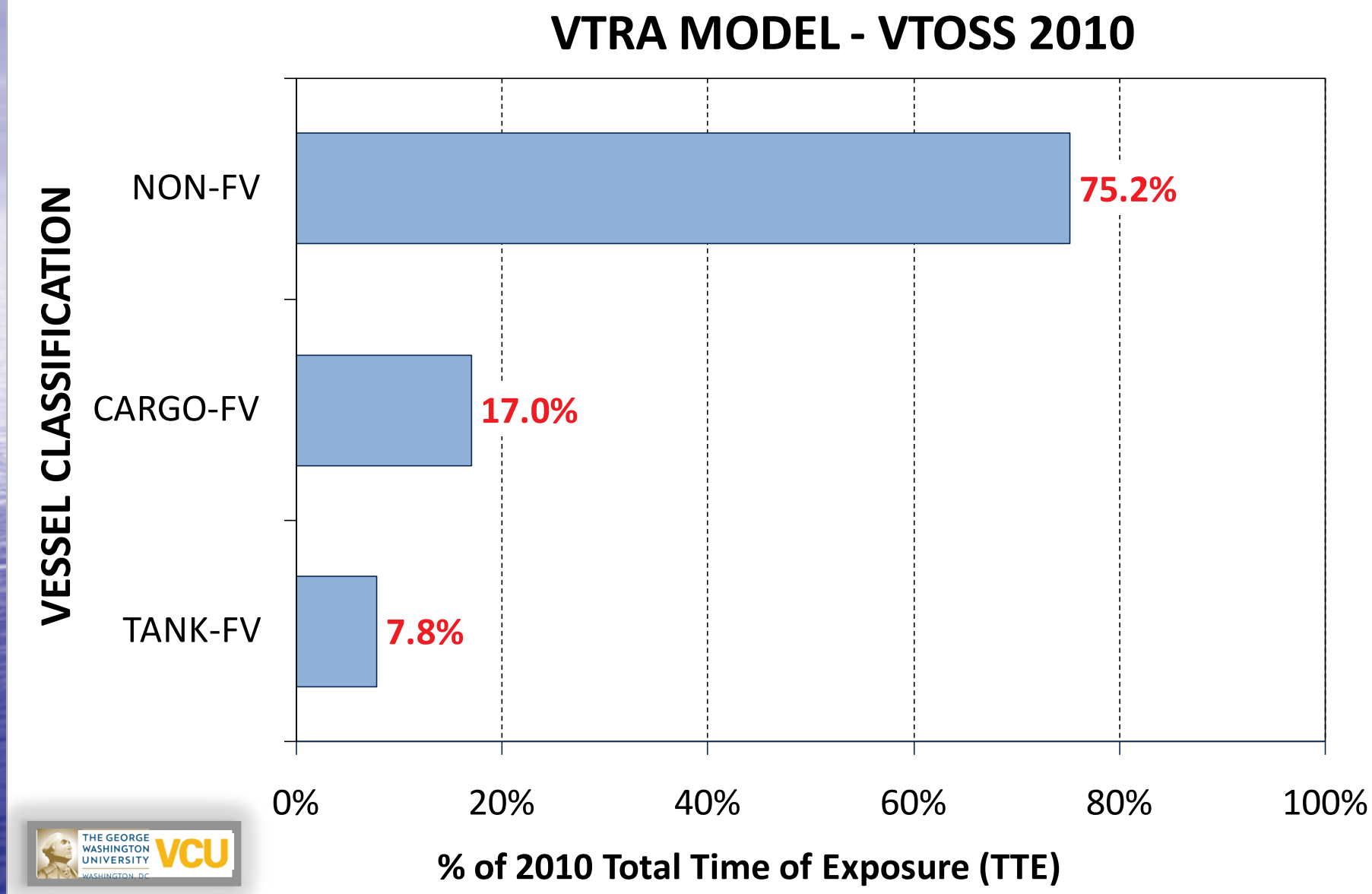
NON – FV : Those vessels that are only considered as Interacting Vessels (IV) with Focus Vessels (FV) in this study

CARGO – FV : Bulk Carriers, Container Vessels, Other Cargo Vessels

TANK – FV : Oil Barge, Oil Tankers, Chem-Carrier, ATB

Note: Focus Vessels (FV's) are also considered as Interacting Vessels (IV's) when interacting with another Focus Vessel.

#	VESSEL TYPE	FOCUS VESSEL?	#	VESSEL TYPE	FOCUS VESSEL?
1	BULKCARRIER	CARGO - FV	14	PASSENGERSHIP	NO
2	CHEMICALCARRIER	TANK - FV	15	REFRIGERATEDCARGO	CARGO-FV
3	CONTAINERSHIP	CARGO - FV	16	RESEARCHSHIP	NO
4	DECKSHIPCARGO	CARGO - FV	17	ROROCARGOSHIP	CARGO-FV
5	FERRY	NO	18	ROROCARGOCONTSHIP	CARGO-FV
6	FERRYNONLOCAL	NO	19	SUPPLYOFFSHORE	NO
7	FISHINGFACTORY	NO	20	TUGTOWBARGE	NO
8	FISHINGVESSEL	NO	21	UNKNOWN	NO
9	LIQGASCARRIER	TANK - FV	22	USCOASTGUARD	NO
10	NAVYVESSEL	NO	23	VEHICLECARRIER	CARGO-FV
11	OILTANKER	TANK - FV	24	YACHT	NO
12	OTHERSPECIALCARGO	CARGO - FV	25	ATB	TANK - FV
13	OTHERSPECIFICSERV	NO	26	OIL BARGE	TANK - FV


VTRA MODEL - VTOSS 2010
VESSEL CLASSIFICATION
NON-FV
CARGO-FV
TANK-FV
75.2%
17.0%
7.8%
0%
20%
40%
60%
80%
100%
% of 2010 Total Time of Exposure (TTE)

100% of Total Traffic Density

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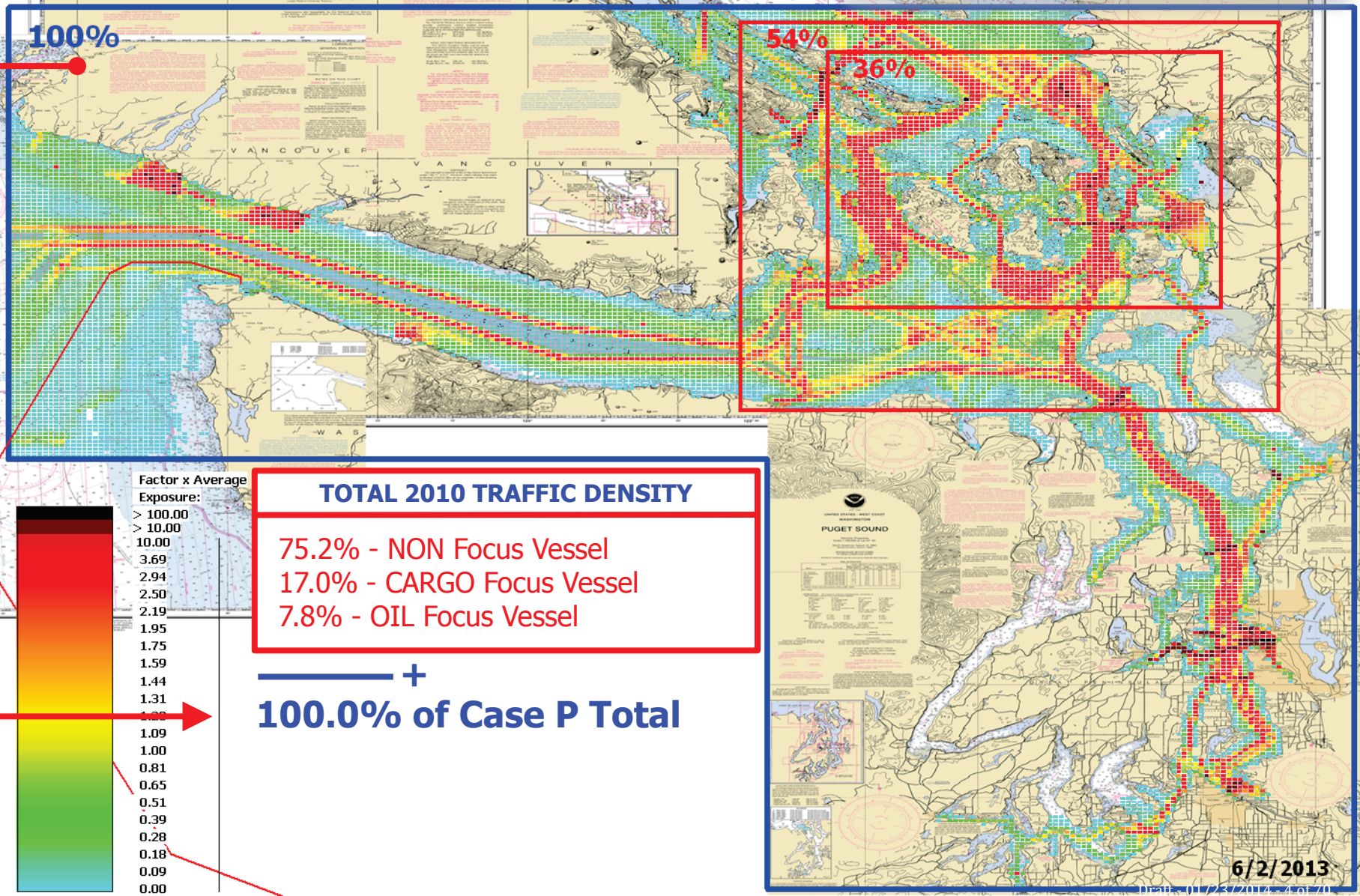
P: VTRA 2010 - Total Density



TOTAL 2010 TRAFFIC DENSITY

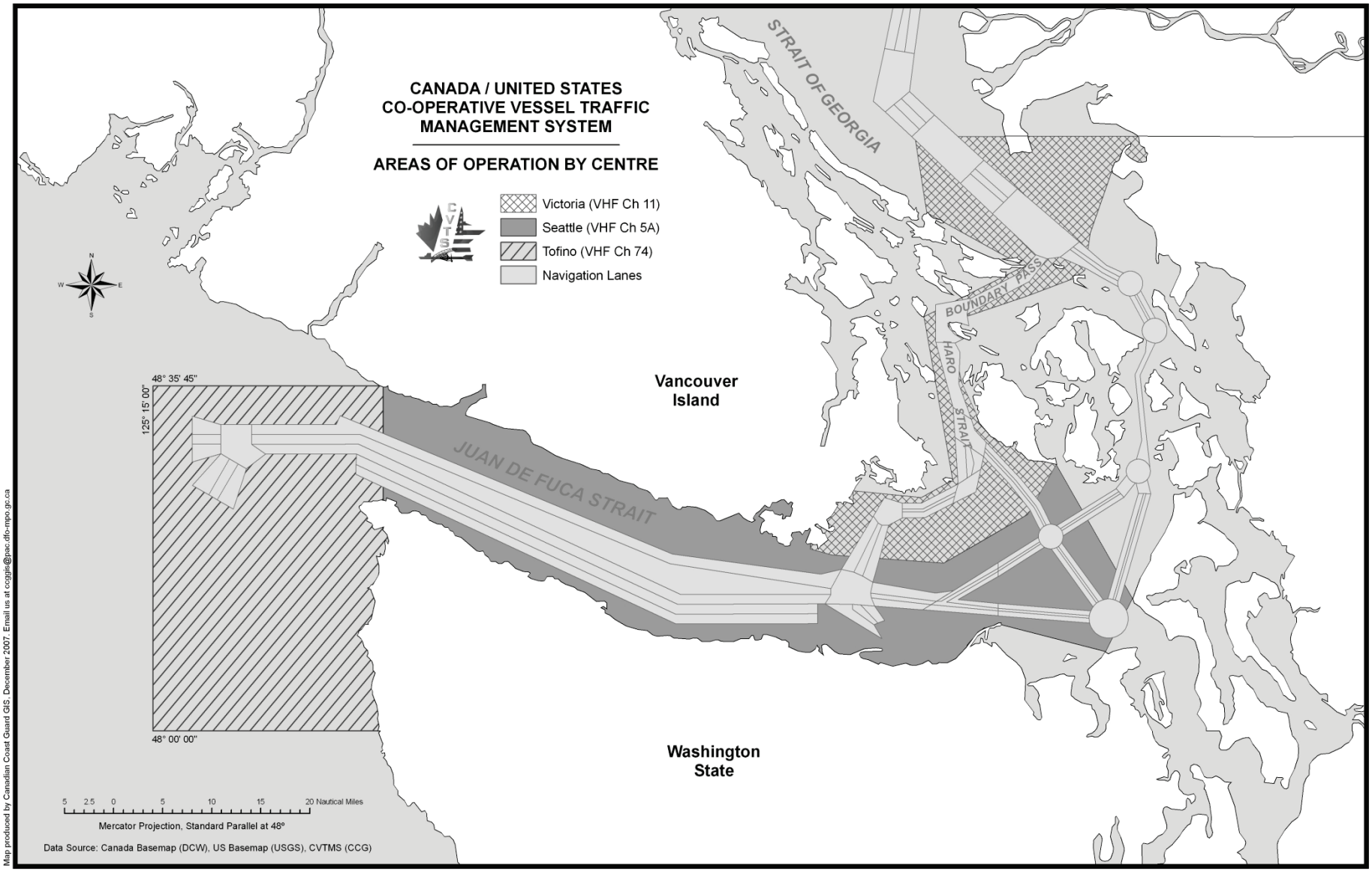
75.2% - NON Focus Vessel
17.0% - CARGO Focus Vessel
7.8% - OIL Focus Vessel

\+

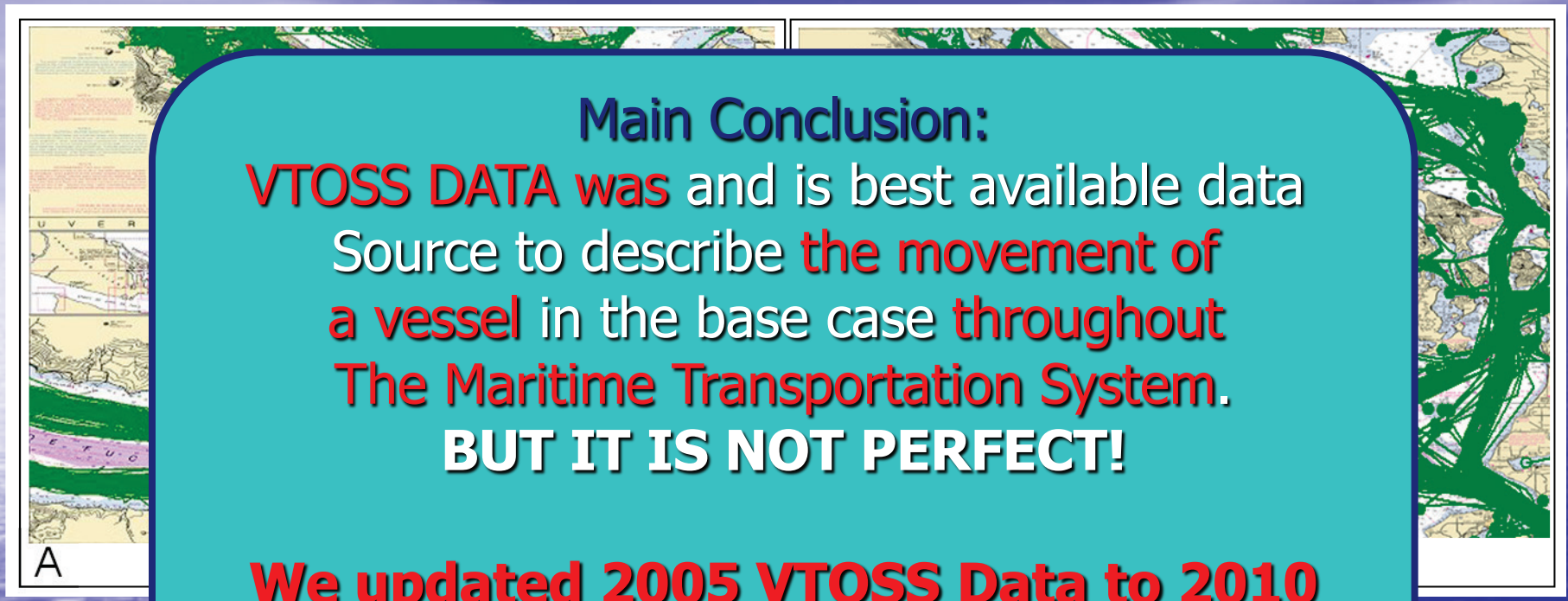
100.0% of Case P Total

6/2/2013

The Vessel Traffic Operation Support System (VTOSS)



From this VTOSS Database routes and input files were constructed that describe vessel movements arrivals to routes:



Main Conclusion:

VTOSS DATA was and is best available data Source to describe the movement of a vessel in the base case throughout The Maritime Transportation System.

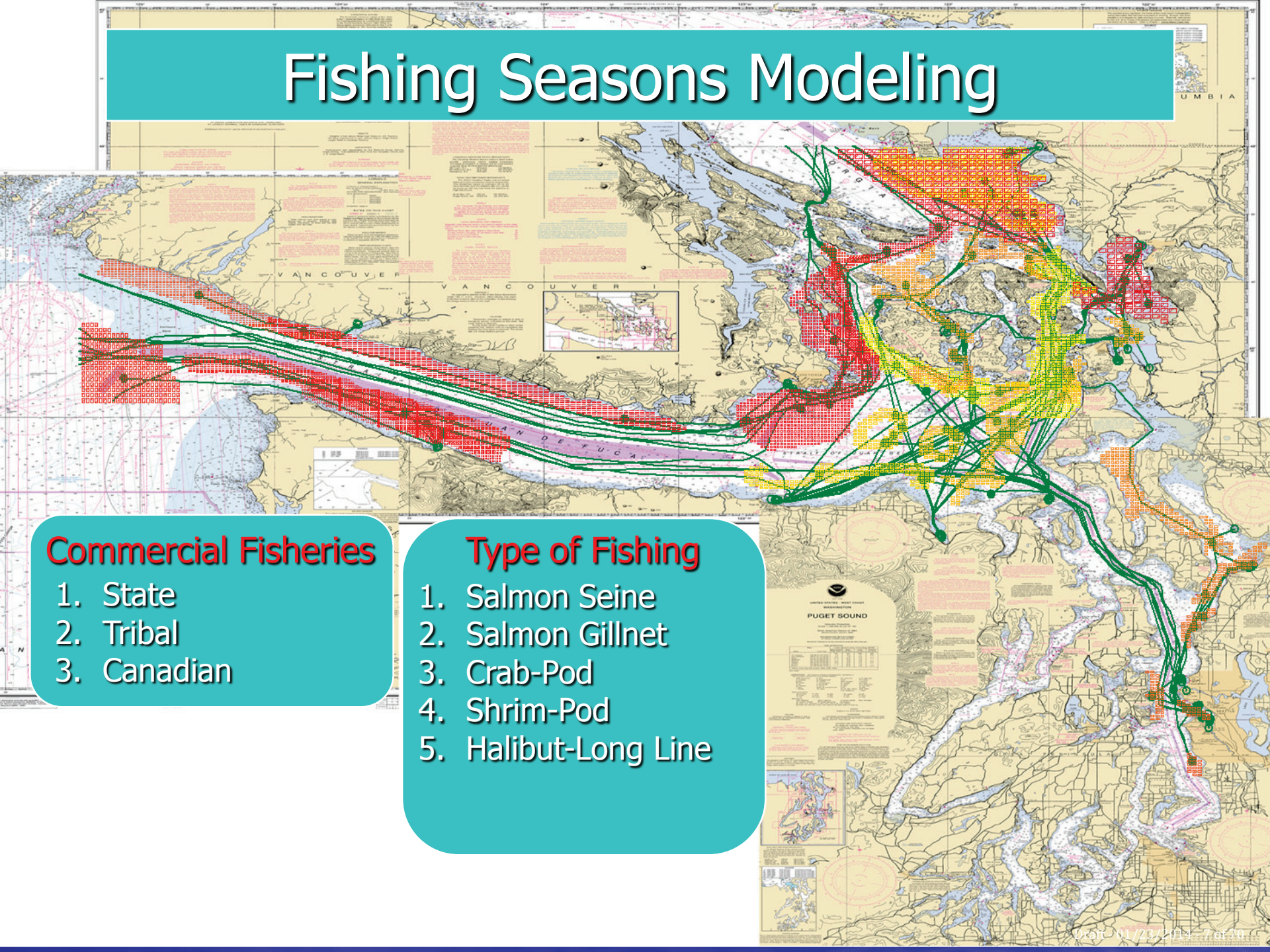
BUT IT IS NOT PERFECT!

We updated 2005 VTOSS Data to 2010 And Validated it with AIS 2010 data

Vessel Name										Beam	Draft
ITB BALTIMORE	CAL									32.23	12.8
ITB BALTIMORE	SEAT								9.9	32.23	12.8
ITB BALTIMORE	CHERRY								179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	3/25/05 6:26 AM	9.18	3012560	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	3/26/05 10:41 PM	1.17	3001714	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	4/6/05 9:10 PM	10.47	3012560	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	4/8/05 2:14 PM	1.20	3001714	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CALIF	CHERRY PT	4/19/05 3:21 PM	10.58	3012560	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8
ITB BALTIMORE	CHERRY PT	CALIF	4/21/05 1:10 AM	0.90	3001714	Product	ITB	48067 DB/SS	10357	179.9	32.23	12.8

VTS responding traffic moves over route segments according to their arrivals in the VTOSS database

Fishing Seasons Modeling



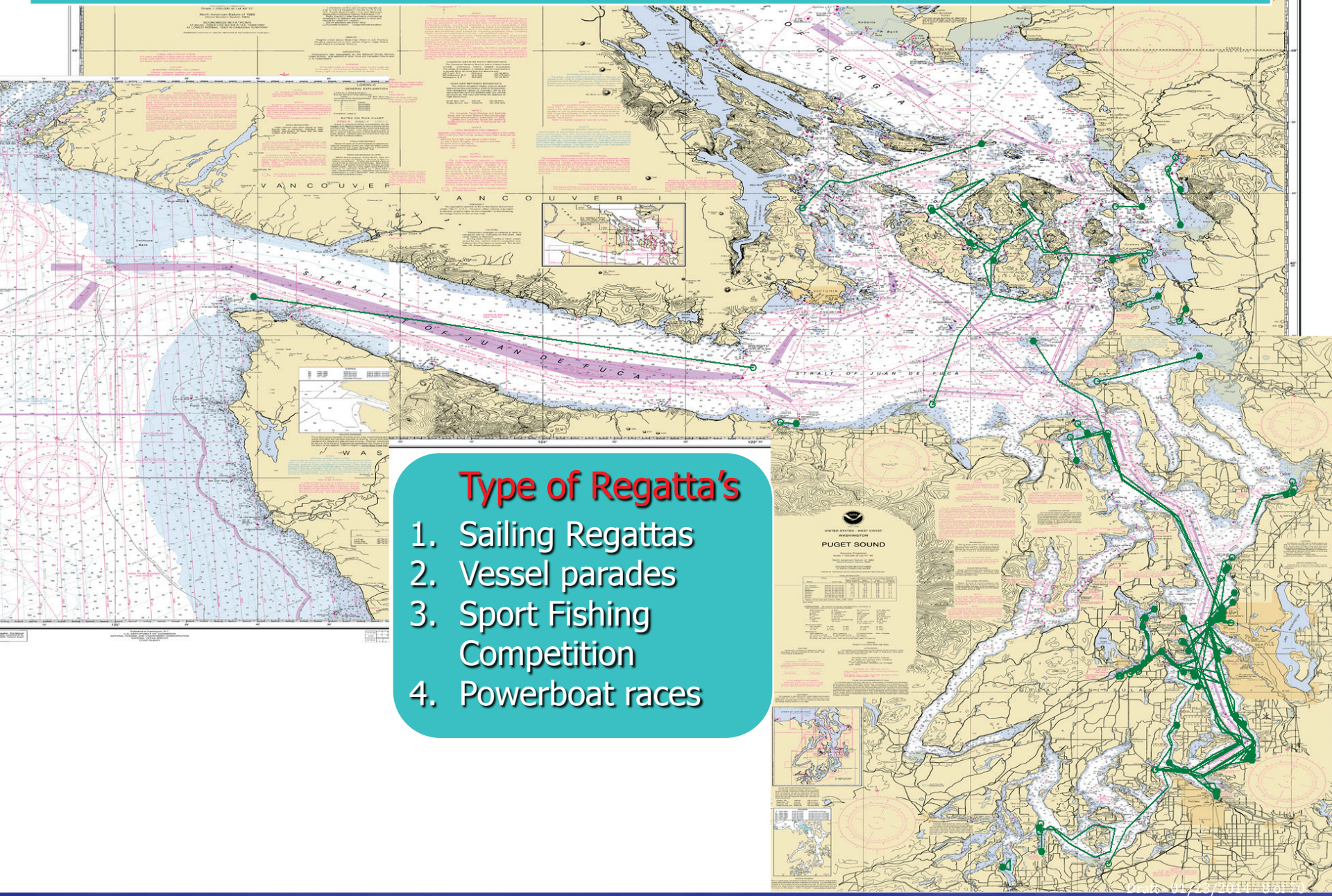
Commercial Fisheries

1. State
2. Tribal
3. Canadian

Type of Fishing

1. Salmon Seine
2. Salmon Gillnet
3. Crab-Pod
4. Shrim-Pod
5. Halibut-Long Line

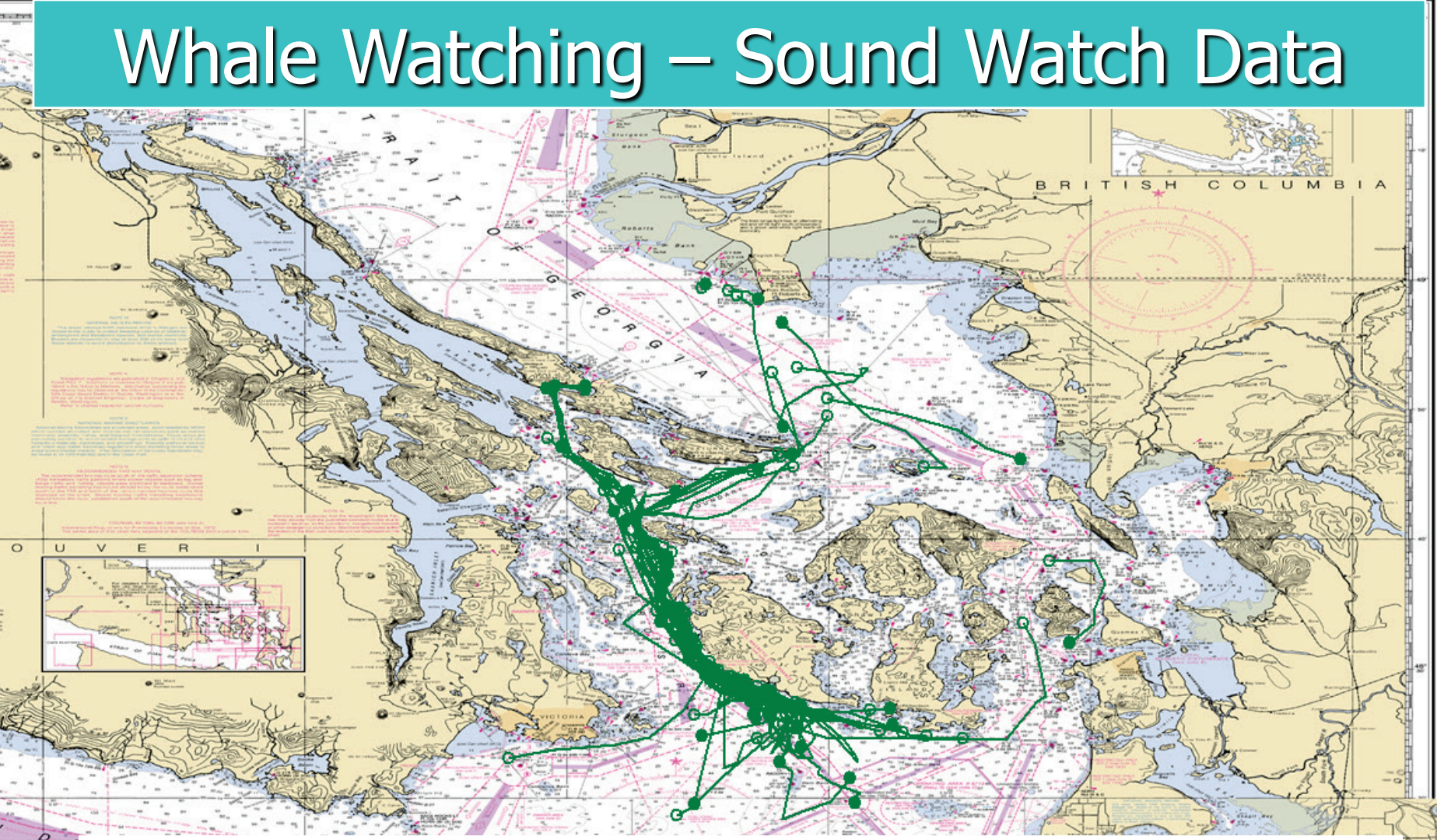
USCG Permitted Non-Commercial Traffic



Type of Regatta's

1. Sailing Regattas
2. Vessel parades
3. Sport Fishing Competition
4. Powerboat races

Whale Watching – Sound Watch Data



The movements of whale watching vessels are determined by the movements of the orca pods. The Sound Watch data gives the location of the orcas and then the number of vessels within a 2 mile radius of them. We move the orcas in the simulation and then add a swarm whale watching vessels around them. The number of vessels in the swarm is varied over time according to the counts in the Sound Watch data.

75.2% of Total Traffic Density

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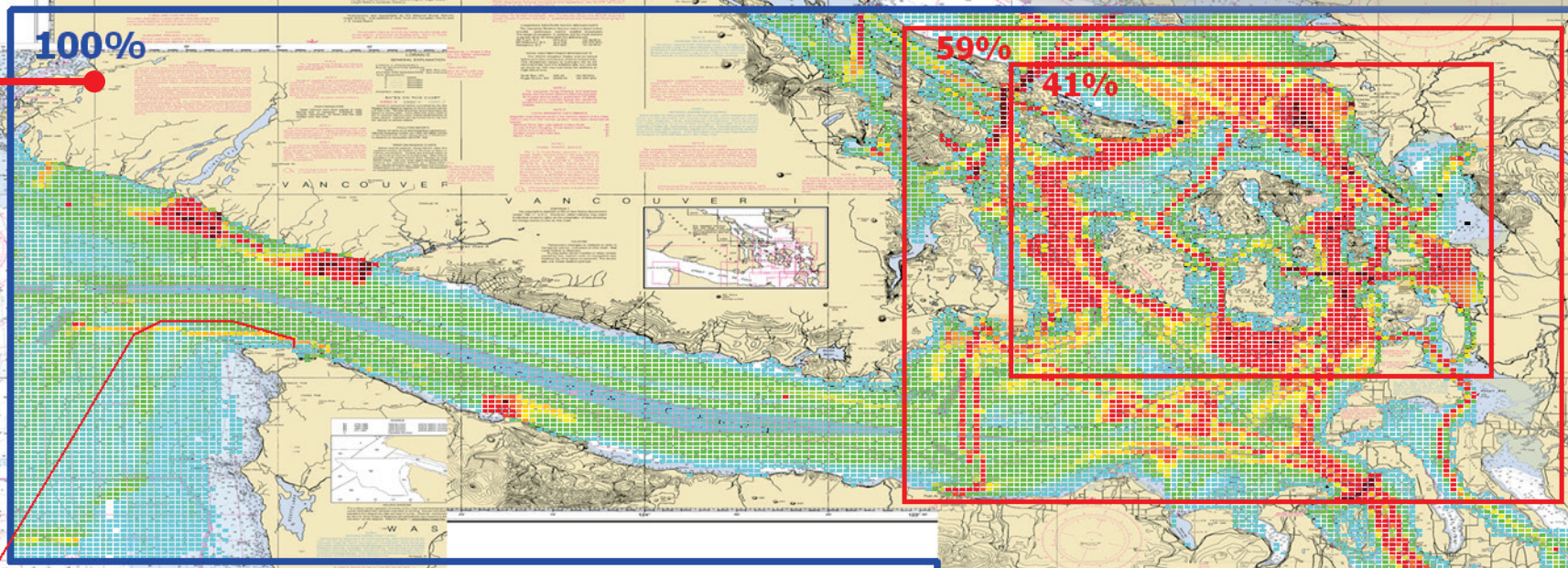
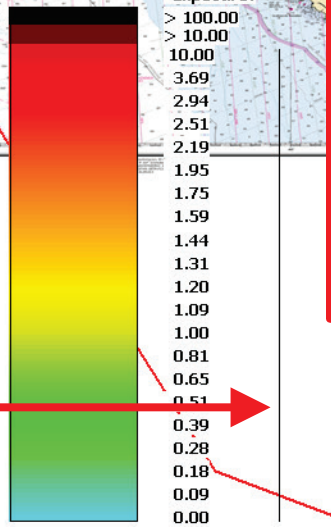
P: VTRA 2010 - NON Focus Vessel Density



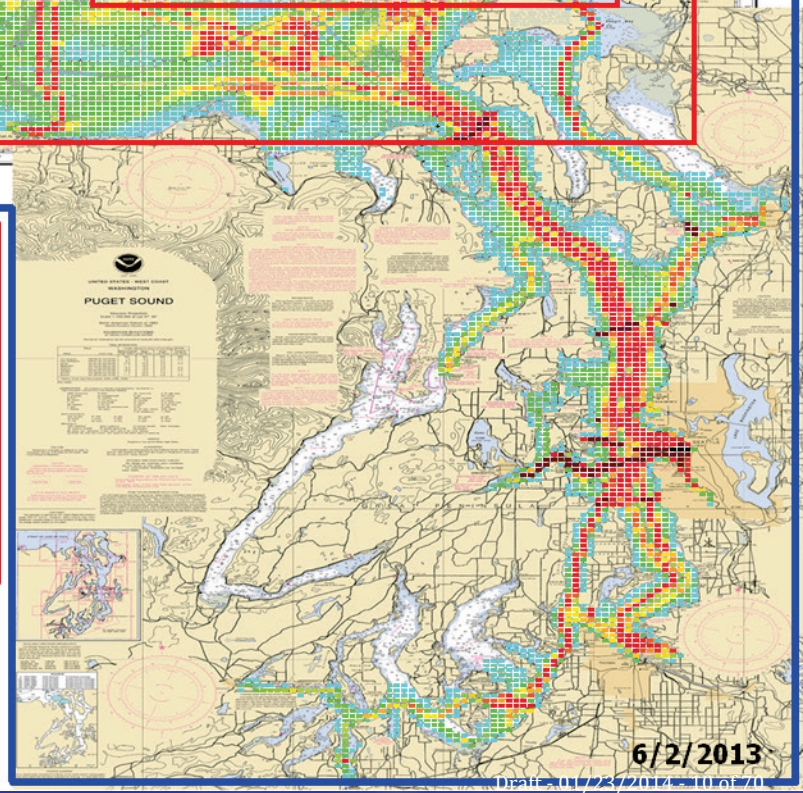


2010 NON FV – 75.2% of 2010 Total

41.3% - FISHINGVESSEL	02.1% - LOG_BARGE
18.1% - FERRY	01.7% - TUGTOWBARGE
06.8% - BULKCARGOBARGE	01.5% - USCOASTGUARD
06.0% - UNLADENBARGE	01.1% - FISHINGFACTORY
04.0% - YACHT	00.8% - RESEARCHSHIP
03.9% - NAVYVESSEL	00.7% - OTHERSPECIFICSERV
03.3% - TUGNOTOW	00.6% - CONTAINERBARGE
02.8% - FERRYNONLOCAL	00.2% - SUPPLYOFFSHORE
02.7% - PASSENGERSHIP	00.2% - CHEMICALBARGE
02.2% - WOODCHIPBARGE	00.0% - DERRICKBARGE

+

100.0% of Case P Total



6/2/2013

17.0% of Total Traffic Density

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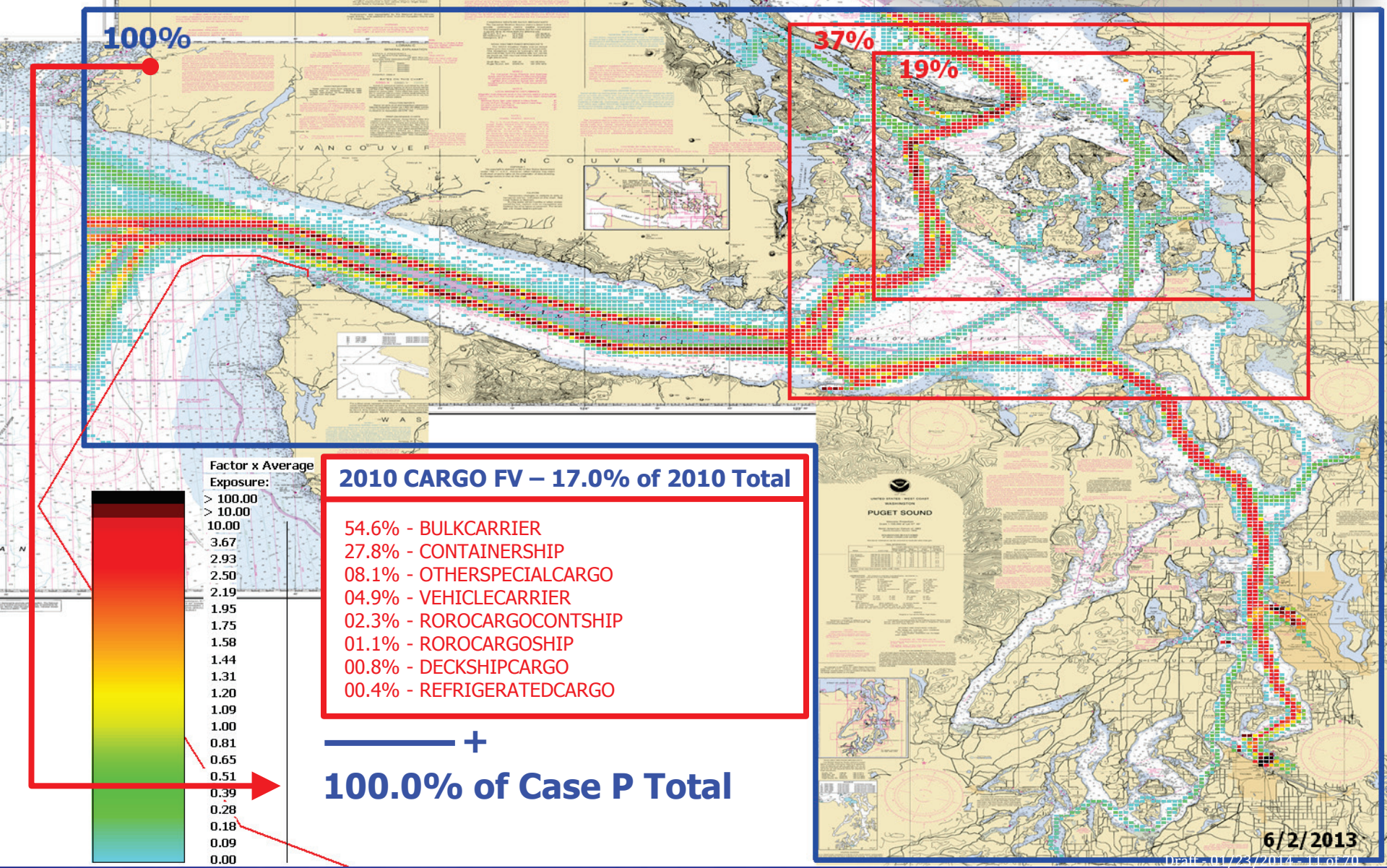
P: VTRA 2010 - CARGO Focus Vessel Density



2010 CARGO FV – 17.0% of 2010 Total

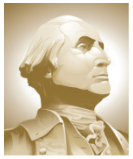
54.6% - BULKCARRIER
27.8% - CONTAINERSHIP
08.1% - OTHERSPECIALCARGO
04.9% - VEHICLECARRIER
02.3% - ROROCARGOCONTSHIP
01.1% - ROROCARGOSHIP
00.8% - DECKSHIPCARGO
00.4% - REFRIGERATEDCARGO

\+

100.0% of Case P Total

6/2/2013

7.8% of Total Traffic Density



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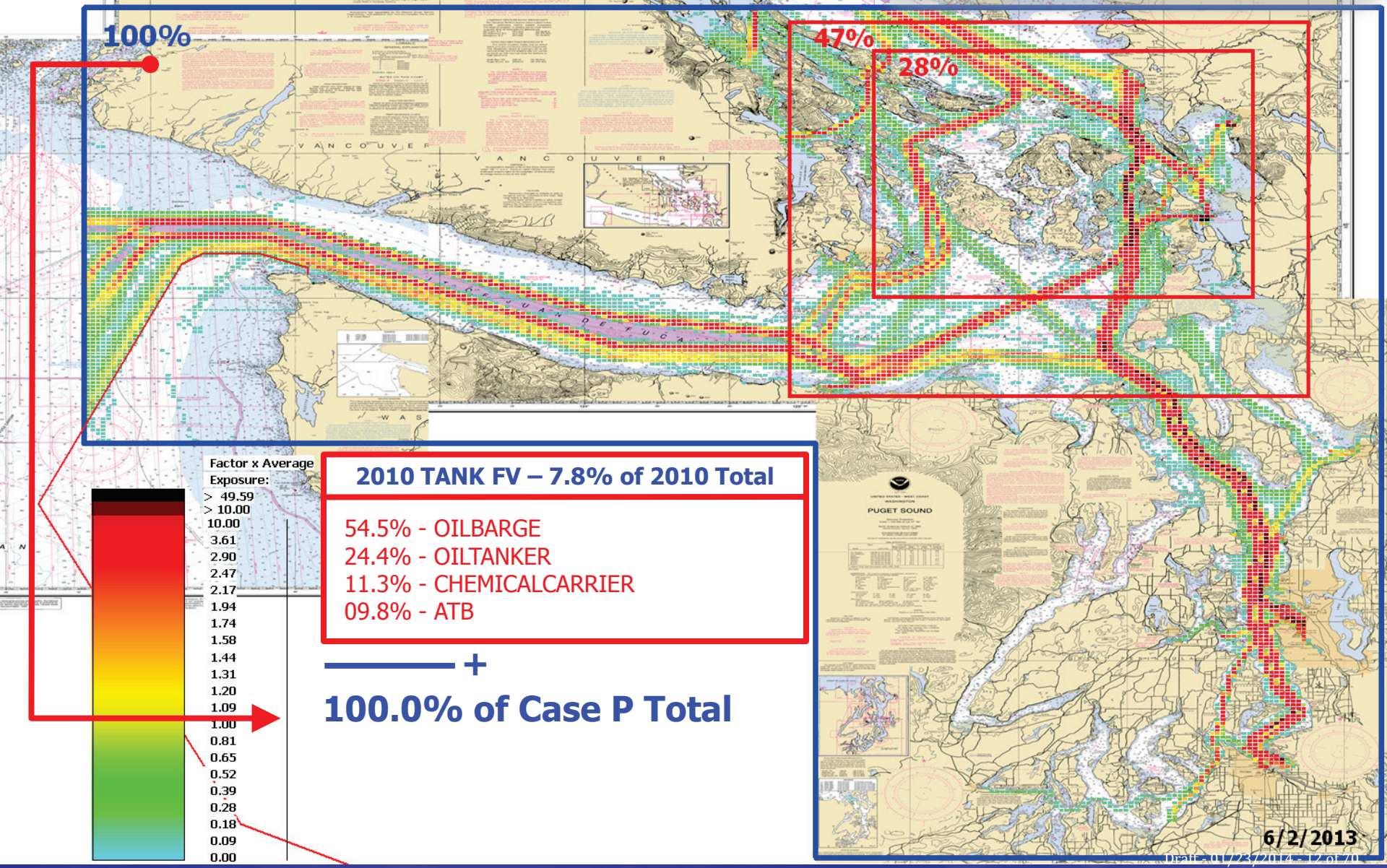
P: VTRA 2010 - Tank Focus Vessel Density



2010 TANK FV – 7.8% of 2010 Total

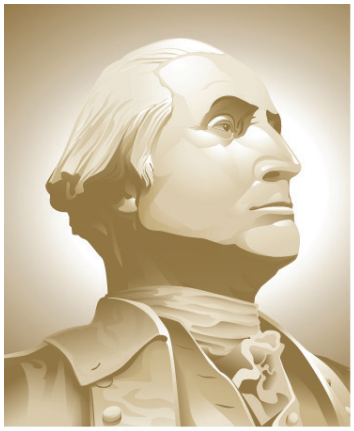
54.5% - OILBARGE
24.4% - OILTANKER
11.3% - CHEMICALCARRIER
09.8% - ATB

——— +

100.0% of Case P Total

6/2/2013

VTRA 2010 TRAFFIC DENSITIES BY CARGO – FV and TANK- FV A WATERWAY BY LOCATION ANALYSIS



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CASE T: Gateway, Kinder Morgan, Delta Port

GWU Personnel: Dr. J. Rene van Dorp

VCU Personnel: Dr. Jason R. W. Merrick

AUGUST 26, 2013

PRELIMINARY

Table. Focus Vessel (FV) Classification for the 26 VTOSS vessel type classification used in the GW/VCU MTS simulation model.

NON – FV : Those vessels that Interacting Vessels (IV) with Focus Vessels (FV)

BASE CASE CARGO – FV : Bulk Carriers, Container Vessels, Other Cargo Vessels that travel in VTRA 2010 Base Case

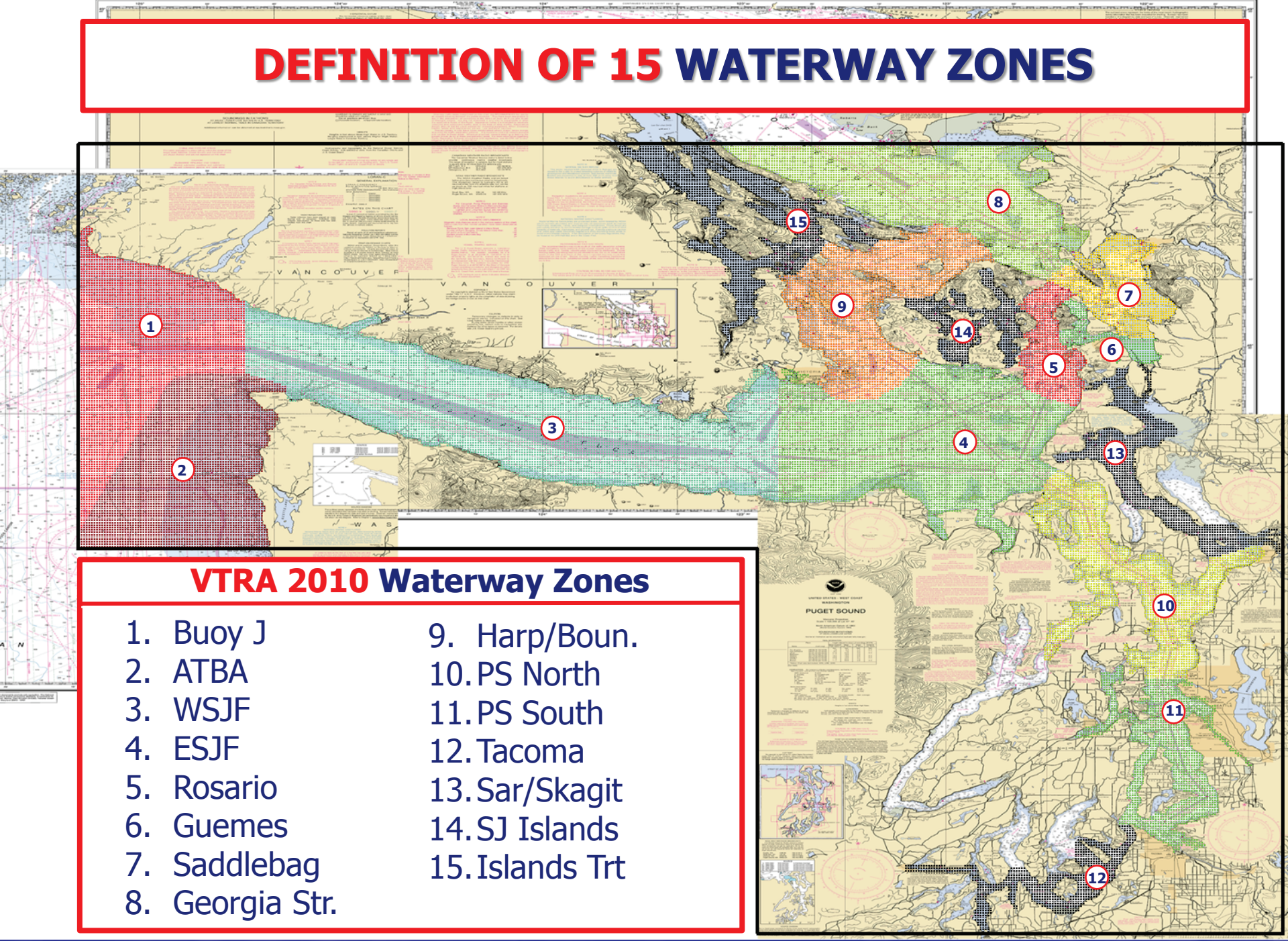
BASE CASE TANK – FV : Oil Barge, Oil Tankers, Chemical Carrier, ATB 's that travel in VTRA 2010 Base Case

WHAT IF – FV : CARGO AND TANK FV'S added to VTRA 2010 Base Case to model What-If Scenario

Note: Focus Vessels (FV's) are also considered as Interacting Vessels (IV's) when interacting with another Focus Vessel.

#	VESSEL TYPE	FOCUS VESSEL?	#	VESSEL TYPE	FOCUS VESSEL?
1	BULKCARRIER	CARGO - FV	14	PASSENGERSHIP	NO
2	CHEMICALCARRIER	TANK - FV	15	REFRIGERATEDCARGO	CARGO-FV
3	CONTAINERSHIP	CARGO - FV	16	RESEARCHSHIP	NO
4	DECKSHIPCARGO	CARGO - FV	17	ROROCARGOSHIP	CARGO-FV
5	FERRY	NO	18	ROROCARGOCONTSHIP	CARGO-FV
6	FERRYNONLOCAL	NO	19	SUPPLYOFFSHORE	NO
7	FISHINGFACTORY	NO	20	TUGTOWBARGE	NO
8	FISHINGVESSEL	NO	21	UNKNOWN	NO
9	LIQGASCARRIER	TANK - FV	22	USCOASTGUARD	NO
10	NAVYVESSEL	NO	23	VEHICLECARRIER	CARGO-FV
11	OILTANKER	TANK - FV	24	YACHT	NO
12	OTHERSPECIALCARGO	CARGO - FV	25	ATB	TANK - FV
13	OTHERSPECIFICSERV	NO	26	OIL BARGE	TANK - FV

DEFINITION OF 15 WATERWAY ZONES



VTRA 2010 Waterway Zones

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

IMPORTANT:

THE OPERATIVE WORD IN PRESENTING THESE ANALYSIS RESULTS IS THE USE OF THE WORD

POTENTIAL

TO INDICATE THAT THESE ANALYSIS RESULTS DO NOT FOLLOW FROM AN HISTORICAL DATA ANALYSIS, BUT THROUGH THE USE OF AN ANALYSIS TOOL THAT EVALUATES SUCH **POTENTIAL**.

THE 2010 YEAR IS CONSIDERED **THE BASE CASE YEAR** AND A BASE CASE YEAR POTENTIAL IS EVALUATED.

NEXT, **WHAT-IF SCENARIOS** ARE DEVELOPED FROM THE BASE CASE BY ADDING ADDITIONAL HYPOTHETICAL TRAFFIC AND A WHAT-IF POTENTIAL IS EVALUATED AND COMPARED **RELATIVE TO THE BASE CASE** TO INFORM **RISK MANAGEMENT.**

CASE T: GW 487, KM 348, DP 348 and 67:

BASE CASE 2010 TRAFFIC WITH FOLLOWING WHAT-IF FOCUS VESSELS

487 Gateway Bulk Carriers + Bunkering Barges

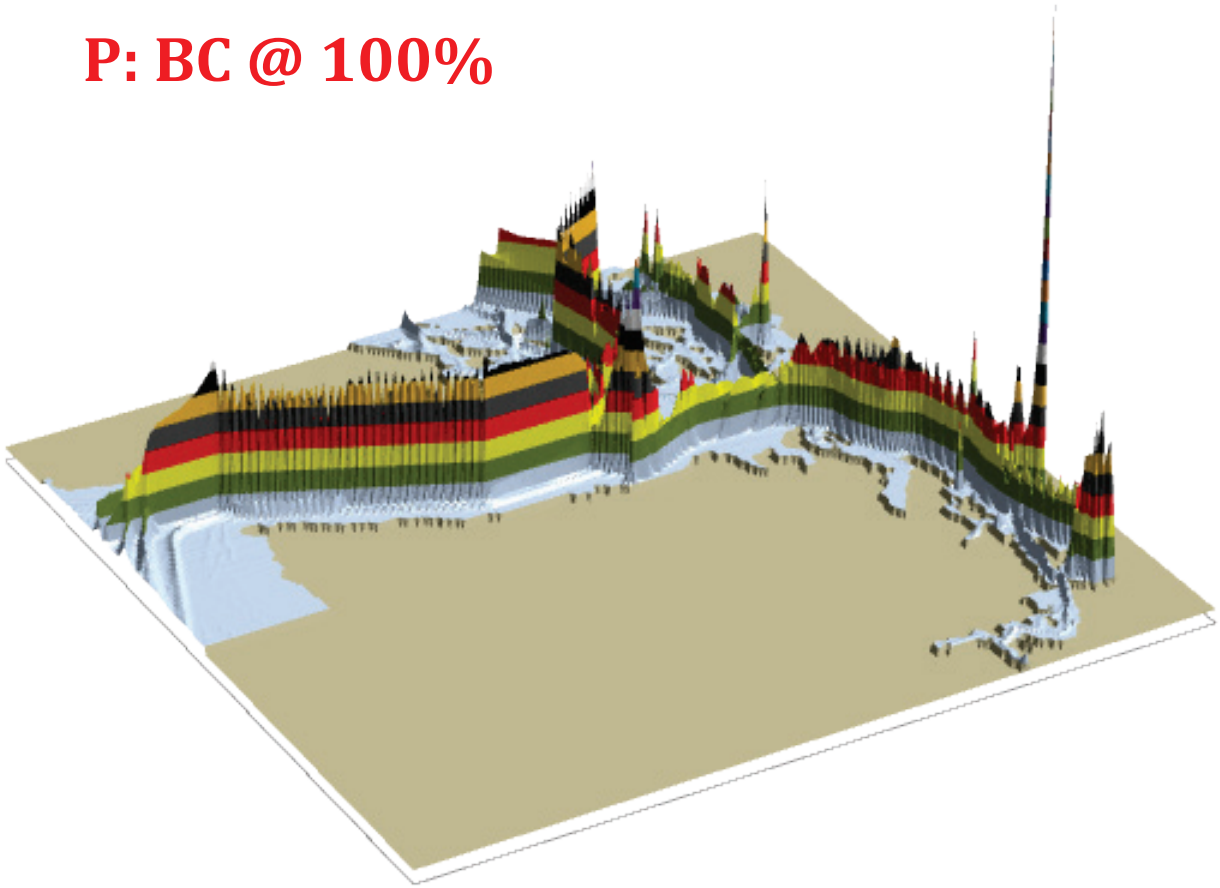
348 Kinder Morgan Tankers + Bunkering Barges

348 Delta Port Bulk Carriers + Bunkering Barges

67 Delta Port Container Ships+ Bunkering Barges

P: Base Case 3D Risk Profile
All FV - Vessel Time Exposure: 100% of Base Case VTE

P: BC @ 100%



23-24
22-23
21-22
20-21
19-20
18-19
17-18
16-17
15-16
14-15
13-14
12-13
11-12
10-11
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1

P: ALL FV Traffic Density

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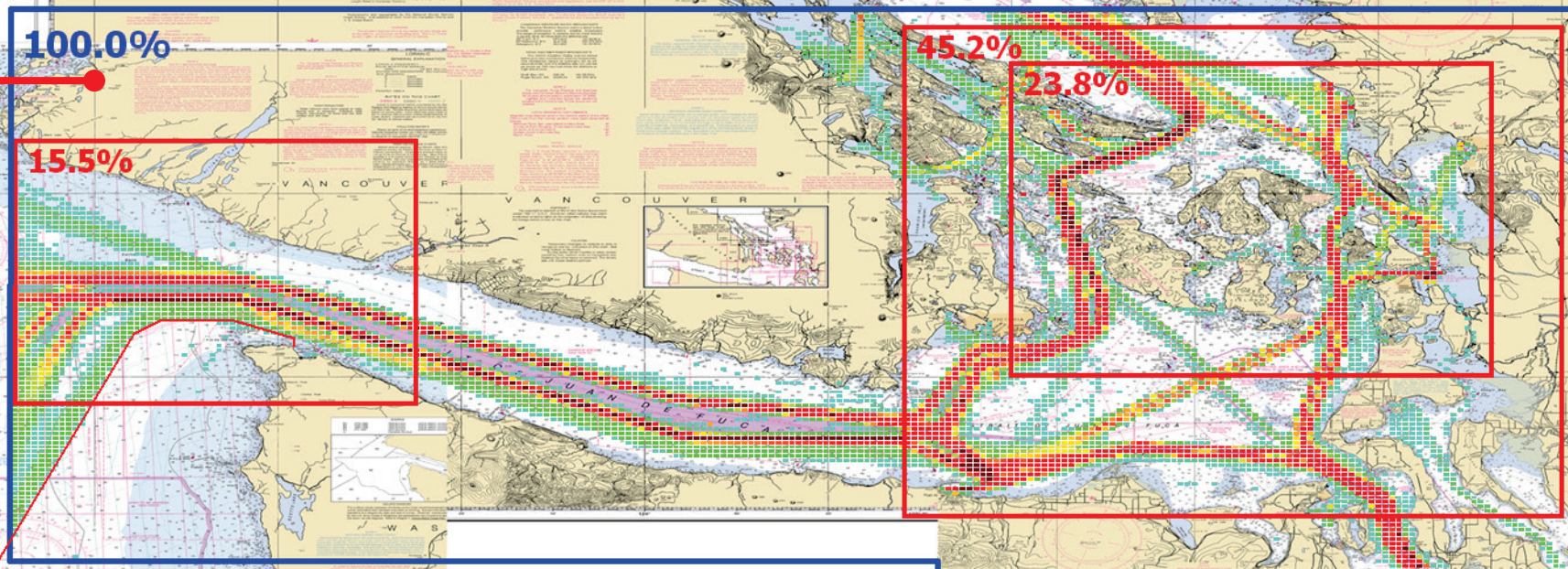
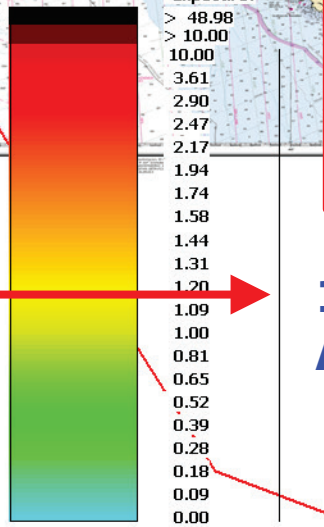
P: VTRA 2010 - BASE CASE - All FV



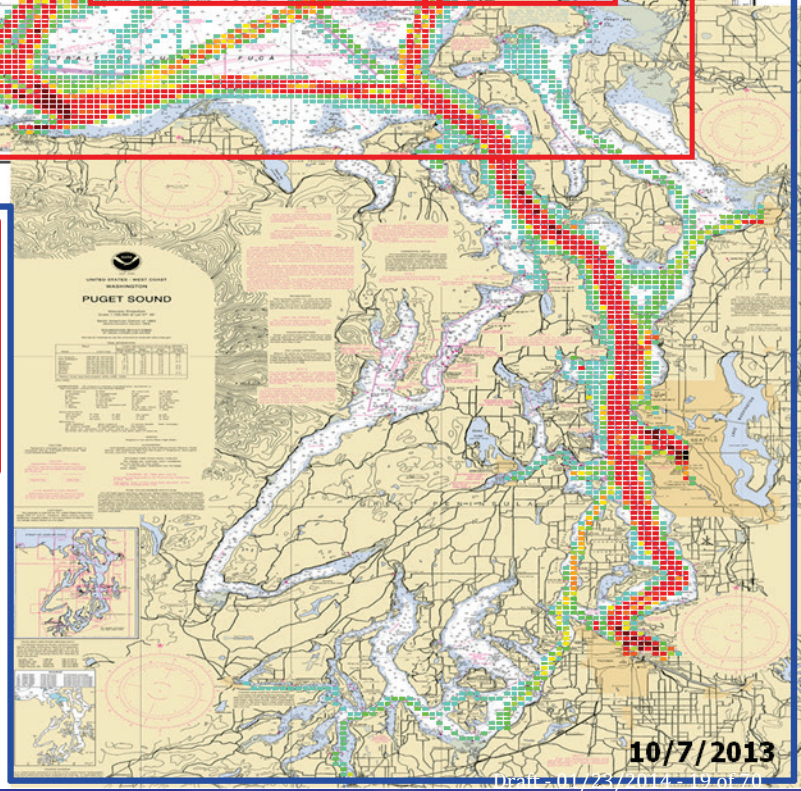


CASE P – ALL FV TRAFFIC DENSITY

65.7% - CARGO Focus Vessel
34.3% - OIL Focus Vessel
00.0% - WHAT-IF Focus Vessel

\+

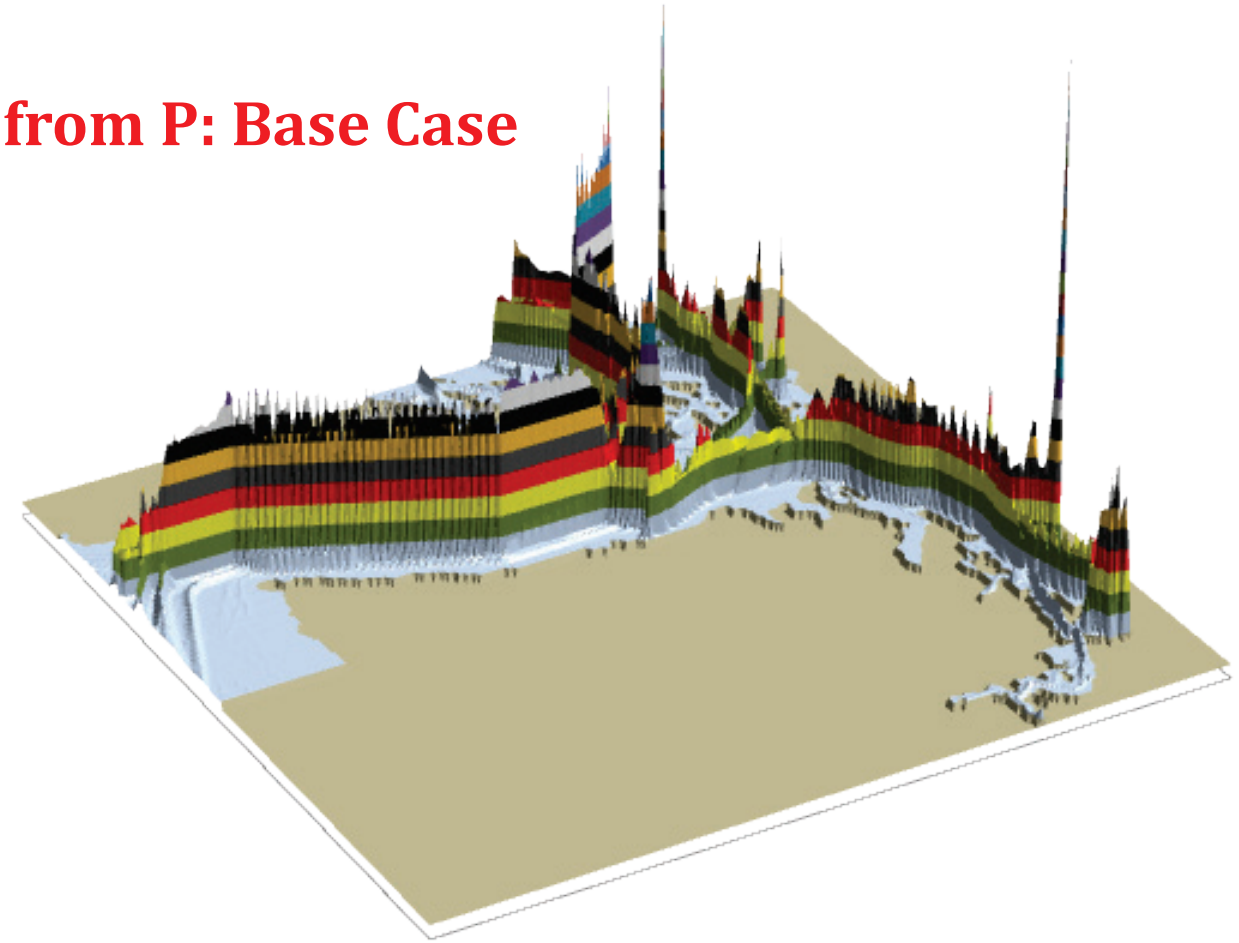
100.0% of 2010 Base Case ALL FV - VTE



10/7/2013

T: GW - KM - DP 3D Risk Profile
All FV - Vessel Time Exposure: 125% of Base Case VTE

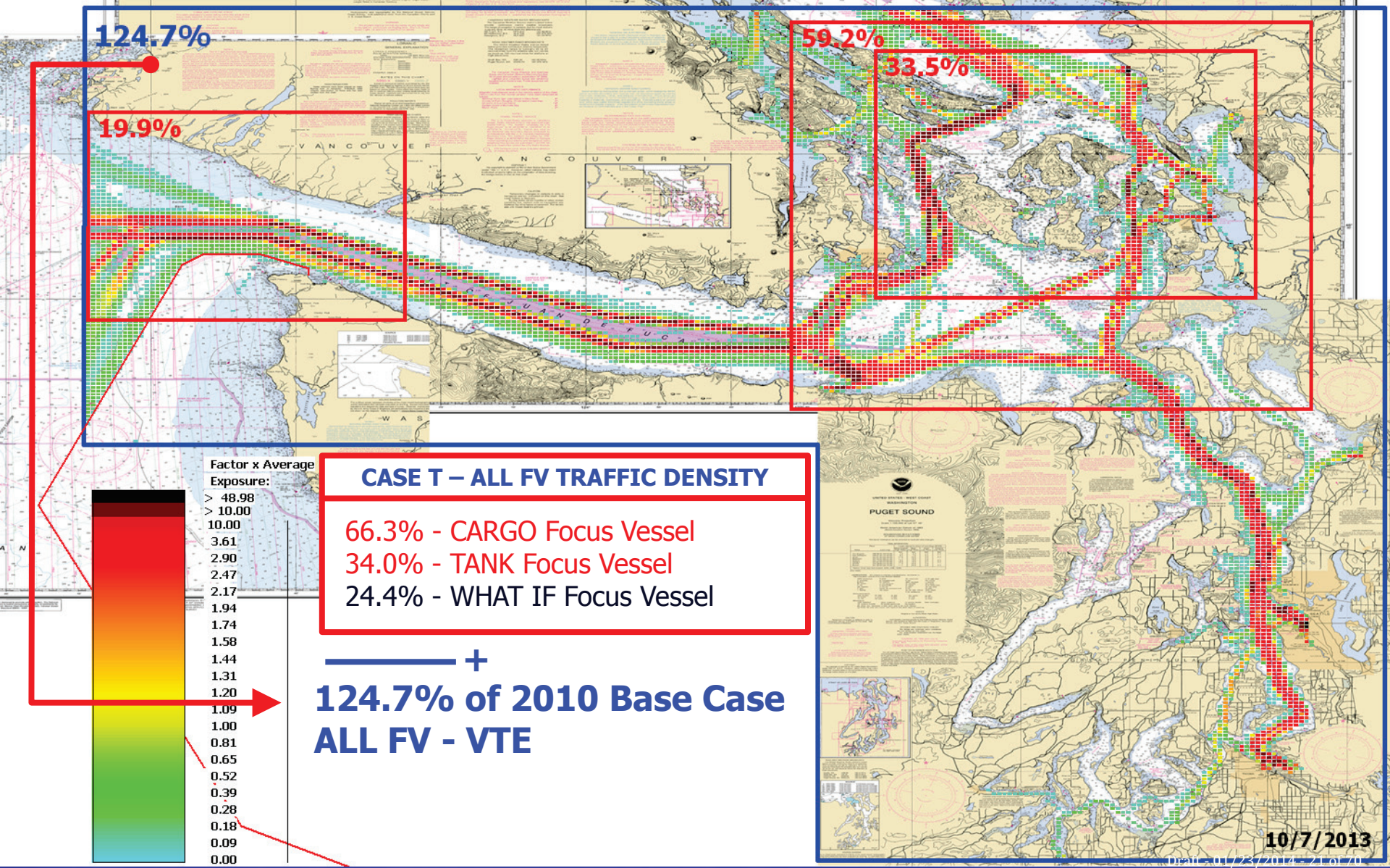
+25% from P: Base Case



T: ALL FV Traffic Density

THE GEORGE WASHINGTON UNIVERSITY VCU WASHINGTON, DC

T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348 - All FV



CASE T – ALL FV TRAFFIC DENSITY

66.3% - CARGO Focus Vessel
34.0% - TANK Focus Vessel
24.4% - WHAT IF Focus Vessel

\+

124.7% of 2010 Base Case
ALL FV - VTE

10/7/2013

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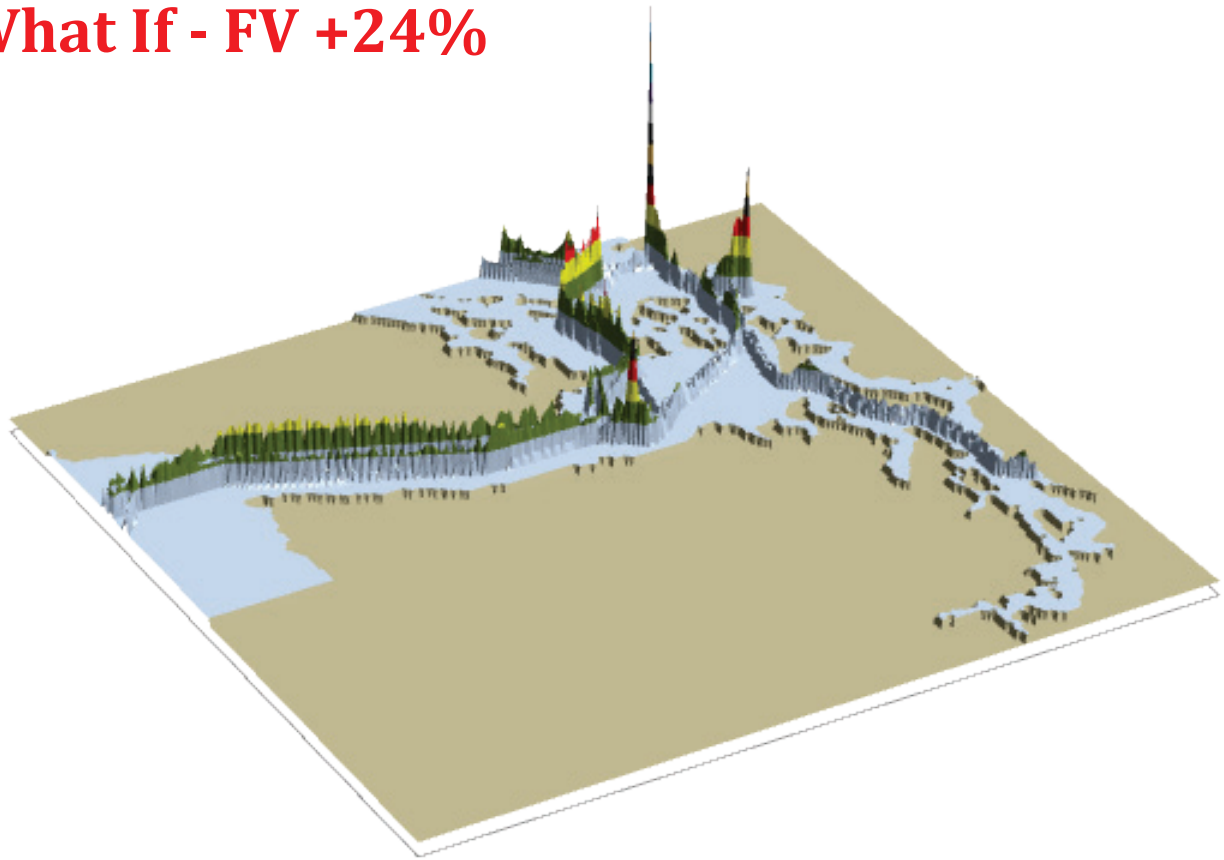
T: GW - KM - DP 3D Risk Profile
What-If FV - Vessel Time Exp.: 24% of Base Case VTE

What If - FV +24%



23-24	22-23
21-22	20-21
19-20	18-19
17-18	16-17
15-16	14-15
13-14	12-13
11-12	10-11
9-10	8-9
7-8	6-7
5-6	4-5
3-4	2-3
1-2	0-1

T: WHAT-IF FOCUS VESSEL
Traffic Density

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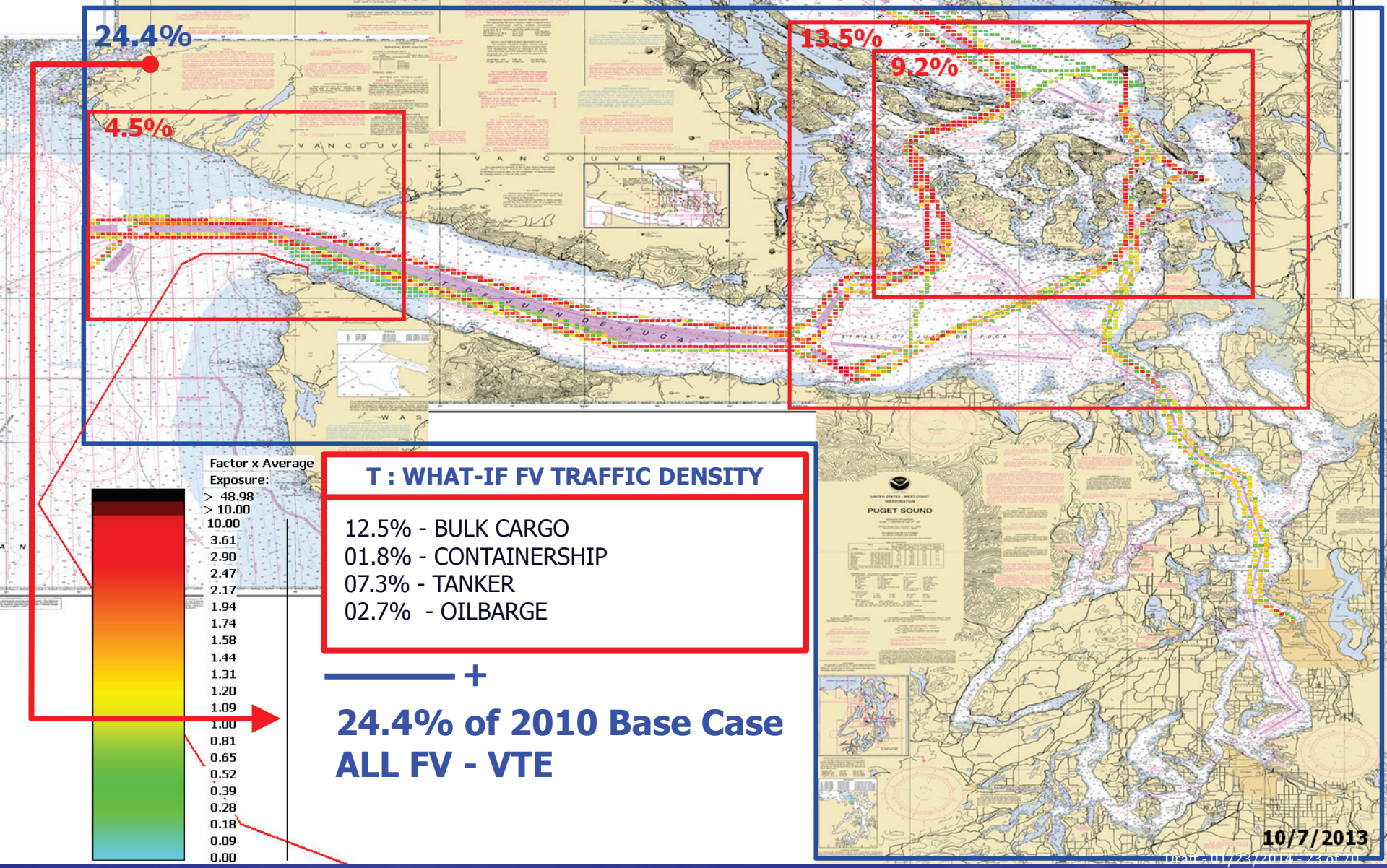
T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348



T : WHAT-IF FV TRAFFIC DENSITY

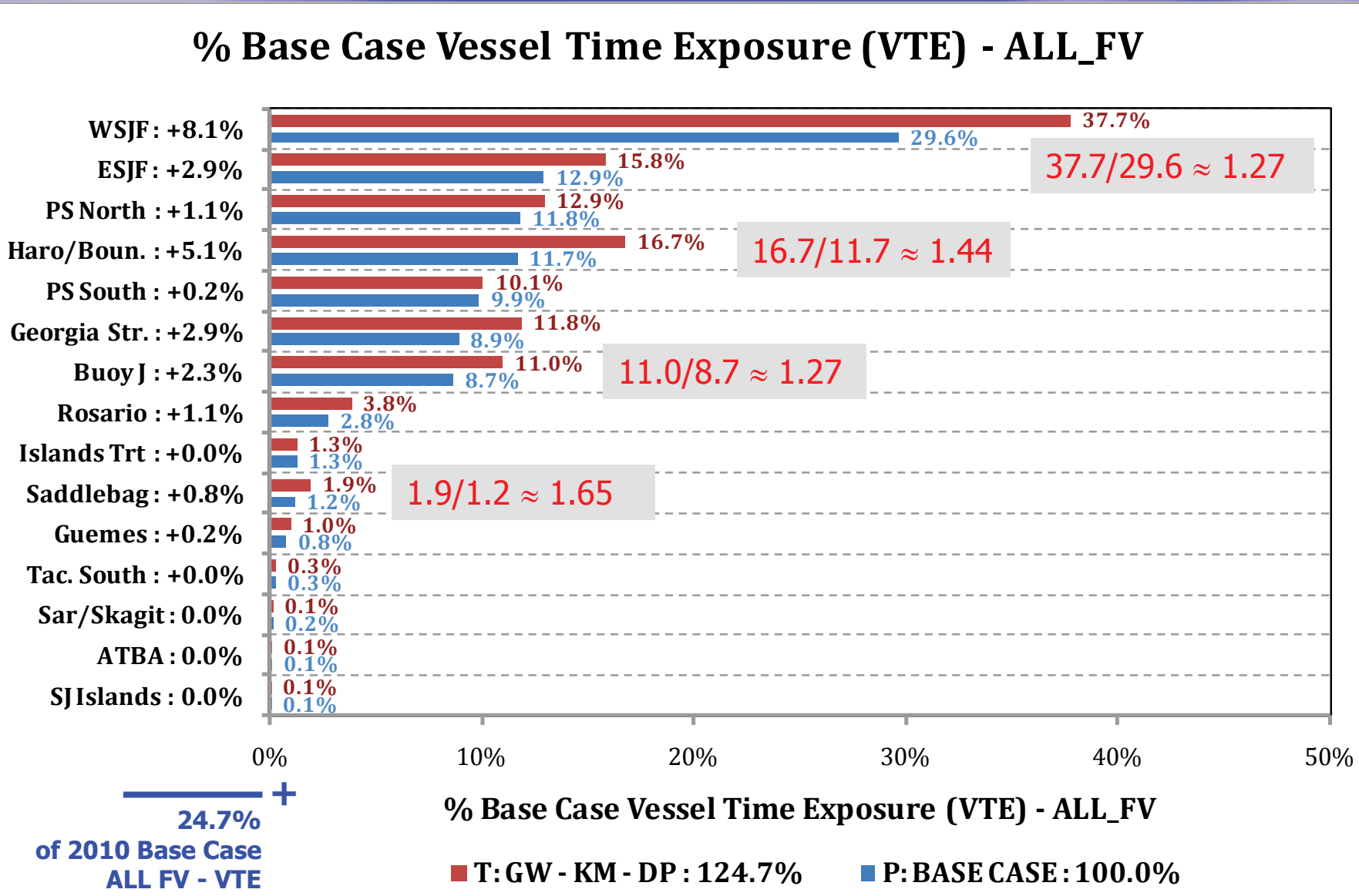
12.5% - BULK CARGO
01.8% - CONTAINERSHIP
07.3% - TANKER
02.7% - OILBARGE

\+

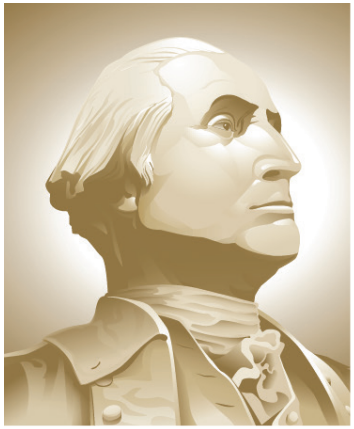
24.4% of 2010 Base Case
ALL FV - VTE

10/7/2013

WATERWAY LOCATION
VESSEL TIME EXPOSURE ANALYSIS – ALL FOCUS VESSELS



VTRA 2010 POTENTIAL COLLISION FREQUENCY BY ALL FV, CARGO – FV, TANK- FV AND WHAT-IF FV



THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON, DC

VCU

CASE T: Gateway, Kinder Morgan, Delta Port

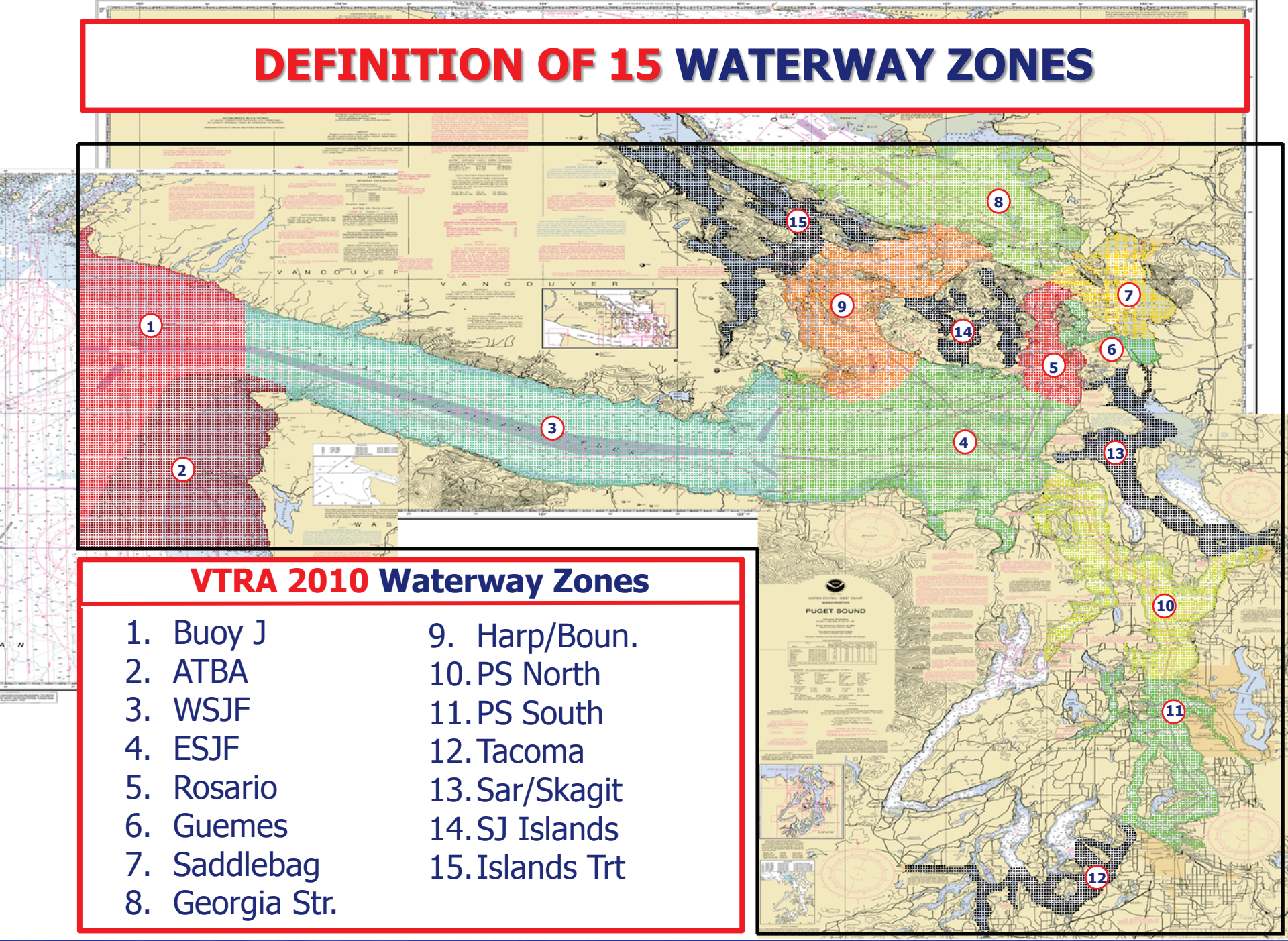
GWU Personnel: Dr. J. Rene van Dorp

VCU Personnel: Dr. Jason R. W. Merrick

AUGUST 26, 2013

PRELIMINARY

DEFINITION OF 15 WATERWAY ZONES



VTRA 2010 Waterway Zones

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2. ATBA
3. WSJF
4. ESJF
5. Rosario
6. Guemes
7. Saddlebag
8. Georgia Str.
9. Harp/Boun.
10. PS North
11. PS South
12. Tacoma
13. Sar/Skagit
14. SJ Islands
15. Islands Trt

VESSEL TRAFFIC RISK ASSESSMENT (VTRA) 2010

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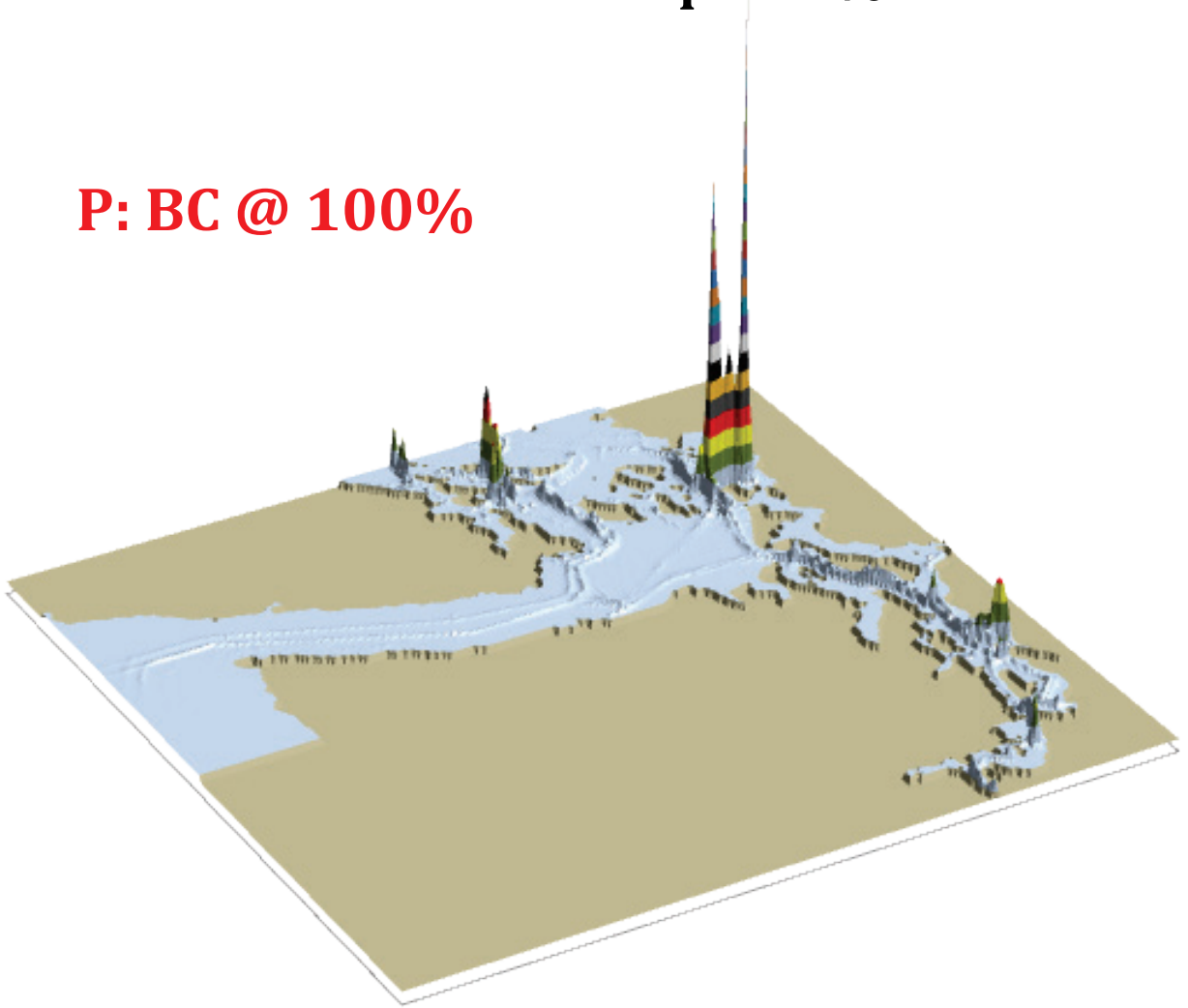
P: Base Case 3D Risk Profile
All FV - Pot. Coll. Acc. Freq.: 100% of Base Case PCF

P: BC @ 100%



25-26
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P: ALL FV POTENTIAL COLL. FREQUENCY (PCF)

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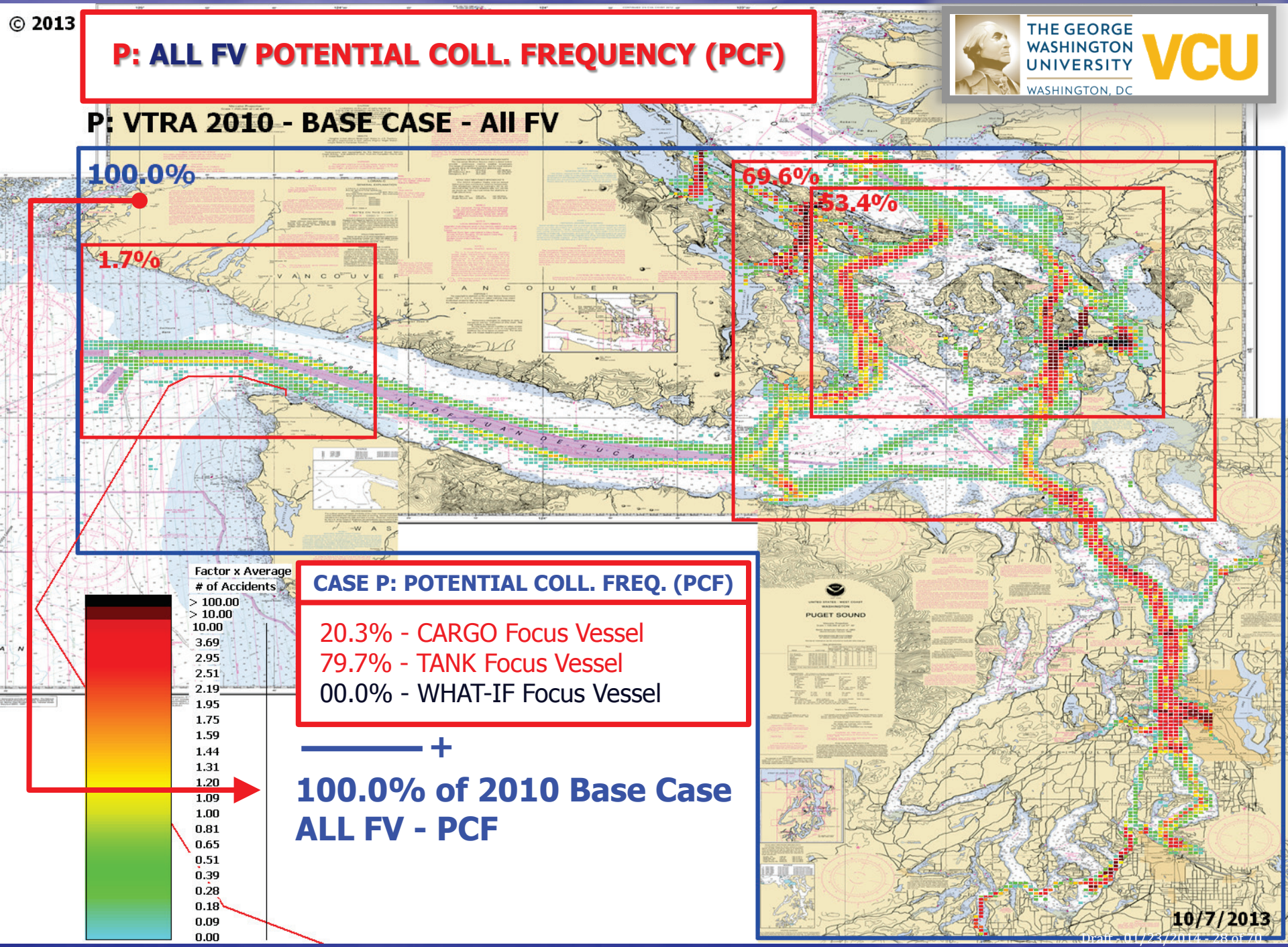
P: VTRA 2010 - BASE CASE - All FV



CASE P: POTENTIAL COLL. FREQ. (PCF)

20.3% - CARGO Focus Vessel
79.7% - TANK Focus Vessel
00.0% - WHAT-IF Focus Vessel

\+

100.0% of 2010 Base Case
ALL FV - PCF

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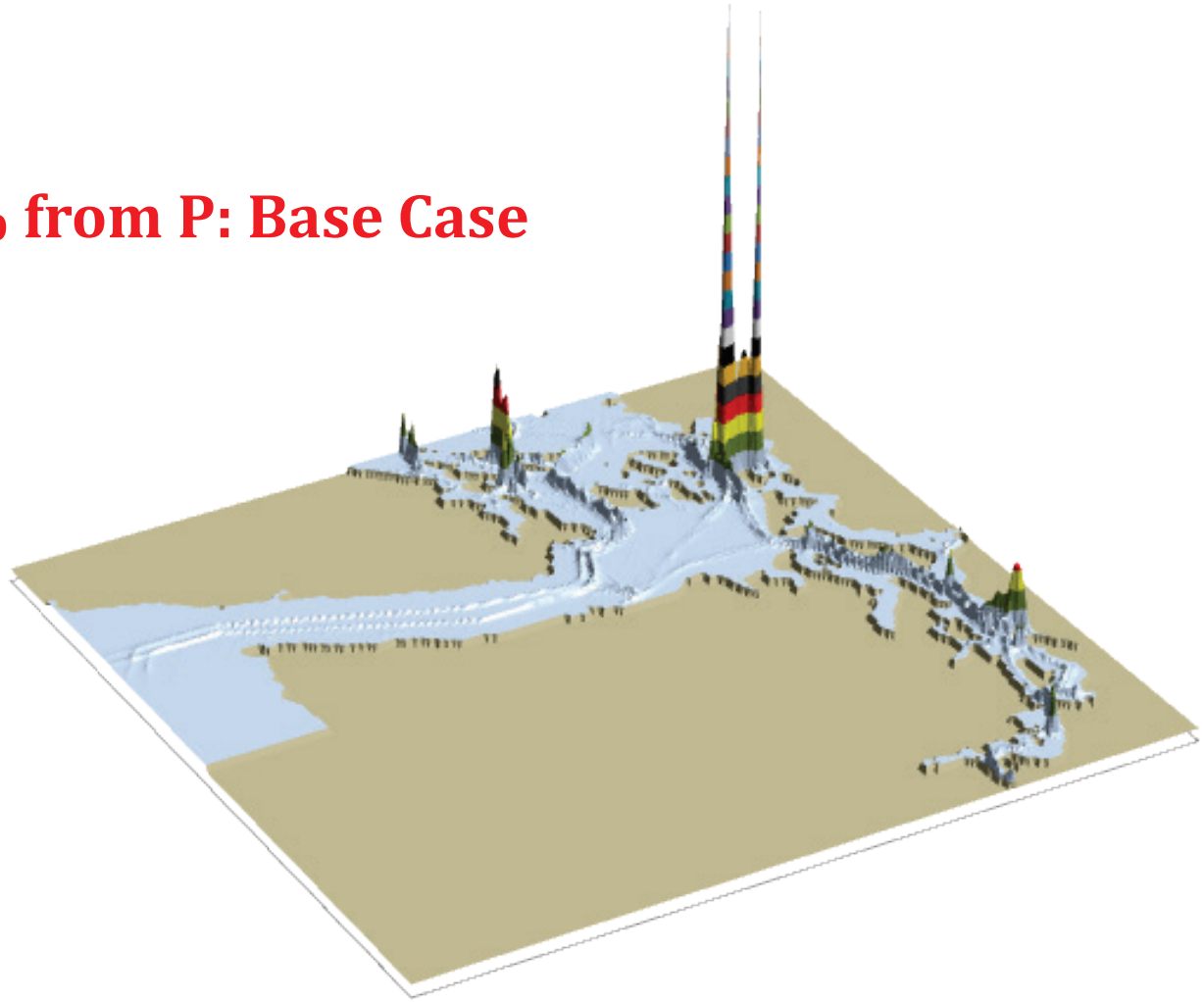
T: GW - KM - DP 3D Risk Profile
All FV - Pot. Coll. Acc. Freq.: 121% of Base Case PCF

+21% from P: Base Case



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1-2	0-1

T: ALL FV POTENTIAL COLL. FREQUENCY (PCF)

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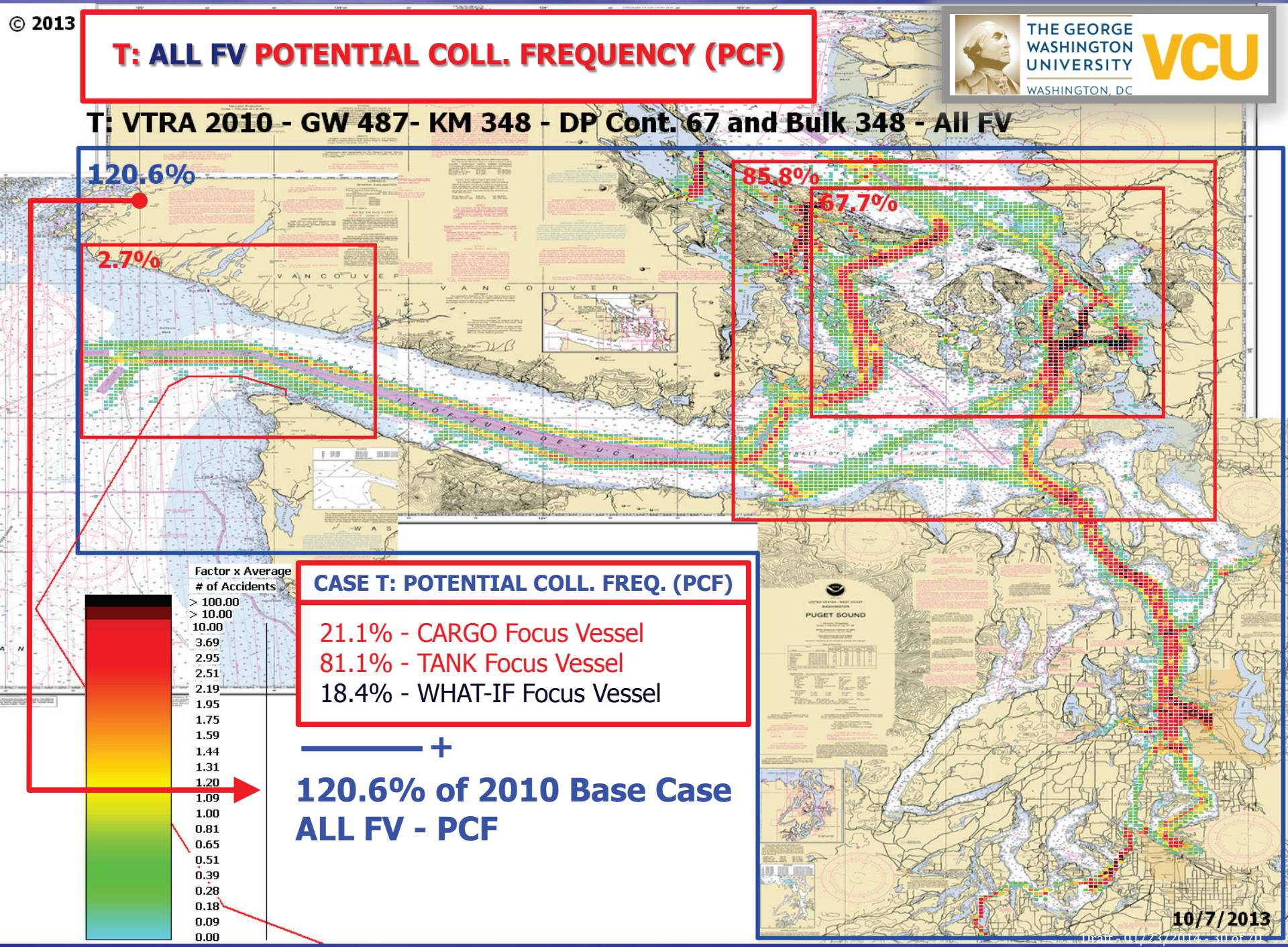
T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348 - All FV



CASE T: POTENTIAL COLL. FREQ. (PCF)

21.1% - CARGO Focus Vessel
81.1% - TANK Focus Vessel
18.4% - WHAT-IF Focus Vessel

+

120.6% of 2010 Base Case ALL FV - PCF

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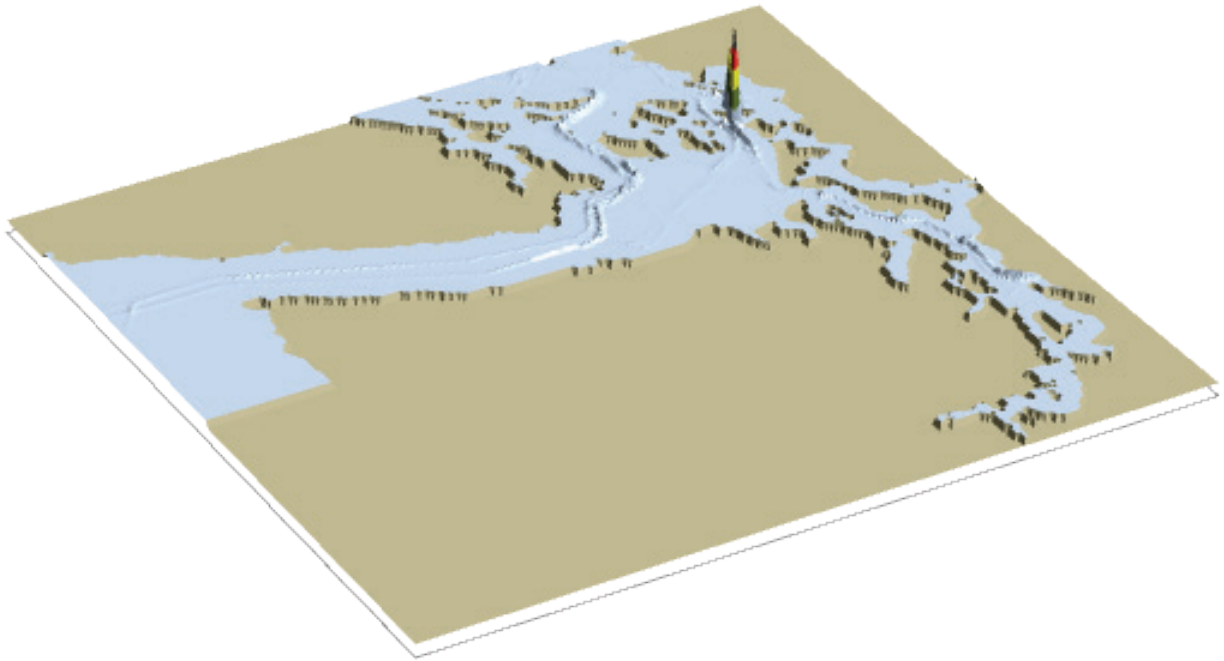
T: GW - KM - DP 3D Risk Profile
What If FV - Pot. Coll. Acc. Fr.: 18% of Base Case PCF

What If - FV +18%



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T: WHAT-IF FV POTENTIAL COLLISION FREQUENCY (PCF)

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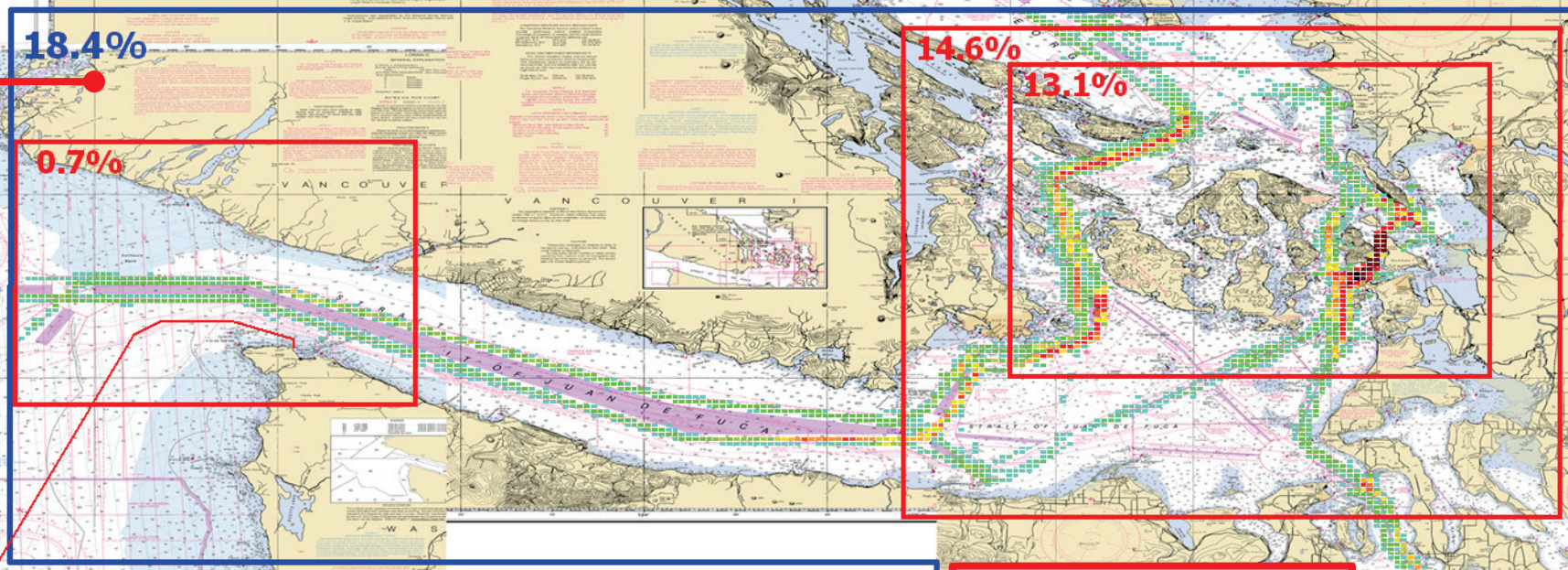
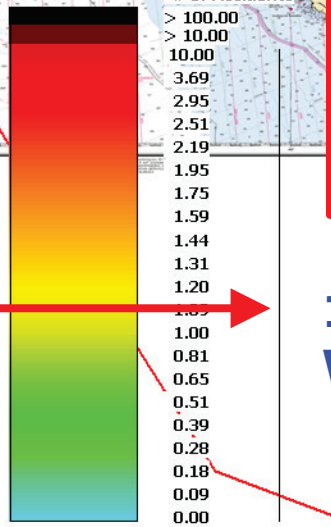
T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348





T: POTENTIAL COLL. FREQ. (PCF)

03.6% - BULK CARGO
00.7% - CONTAINERSHIP
03.1% - TANKER
10.9% - OILBARGE

+

18.4% of 2010 Base Case WHAT-IF FV - PCF

T: 88.4% OF 18.4% PCF BY INTERACTING VESSEL TYPE

8.8% - FISHINGVESSEL
1.9% - BULKCARRIER
1.6% - FERRY
1.1% - OILTANKER
0.8% - BULKCARGOBARGE
0.5% - FERRYNONLOCAL
0.5% - UNLADENBARGE
0.4% - CONTAINERSHIP
0.3% - NAVYVESSEL
0.3% - OILBARGE

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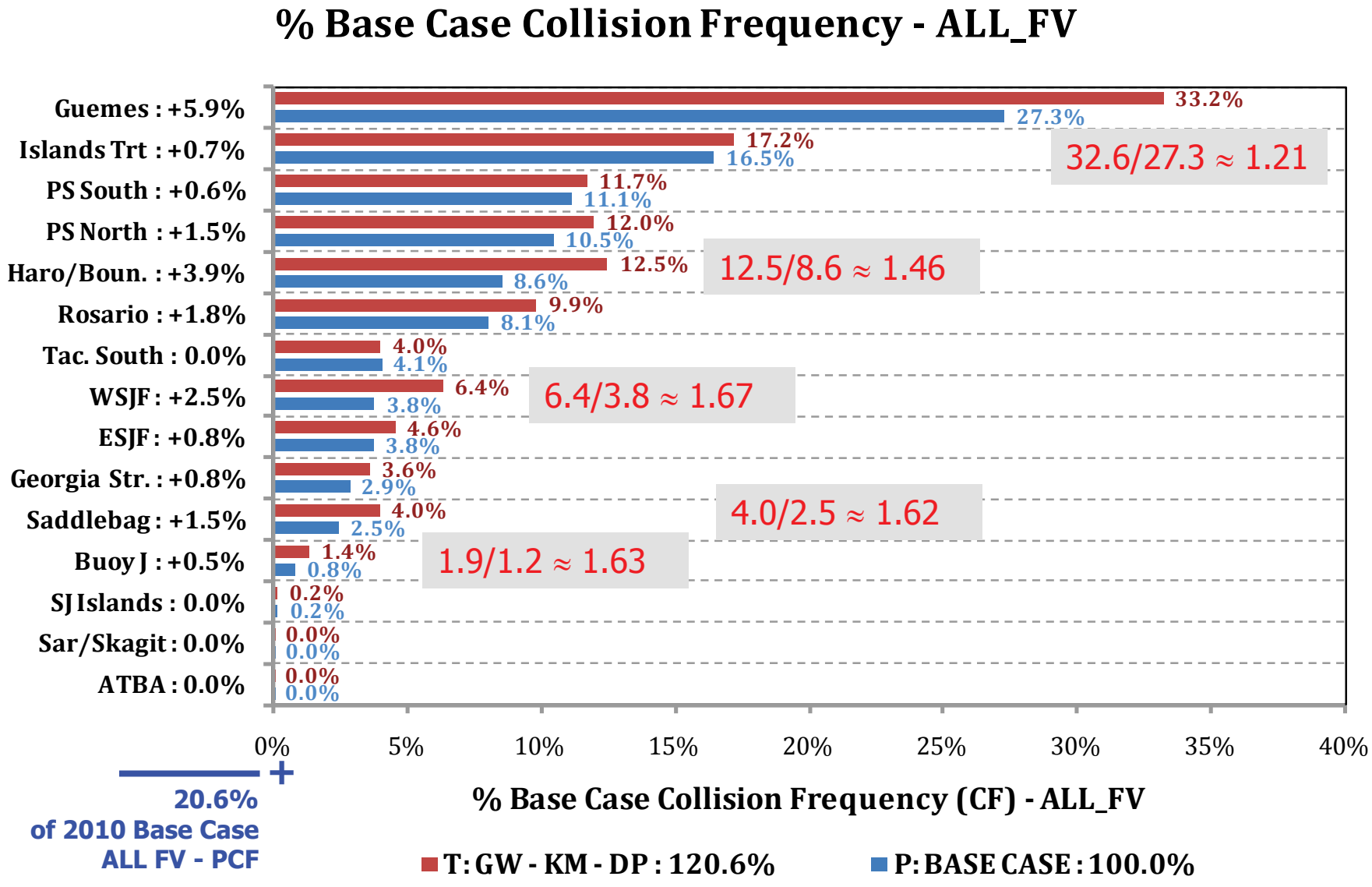
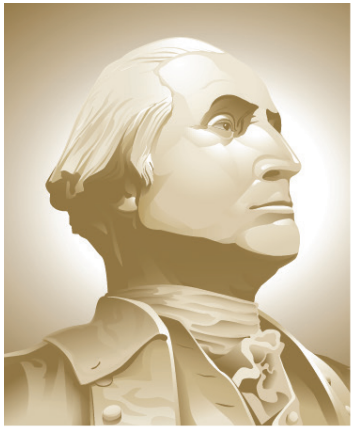
WATERWAY LOCATION
Potential Collision Freq. Comparison – ALL FV



VTRA 2010 POTENTIAL COLLISION LOSSES BY ALL FV, CARGO – FV, TANK- FV AND WHAT-IF FV



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CASE T: Gateway, Kinder Morgan, Delta Port

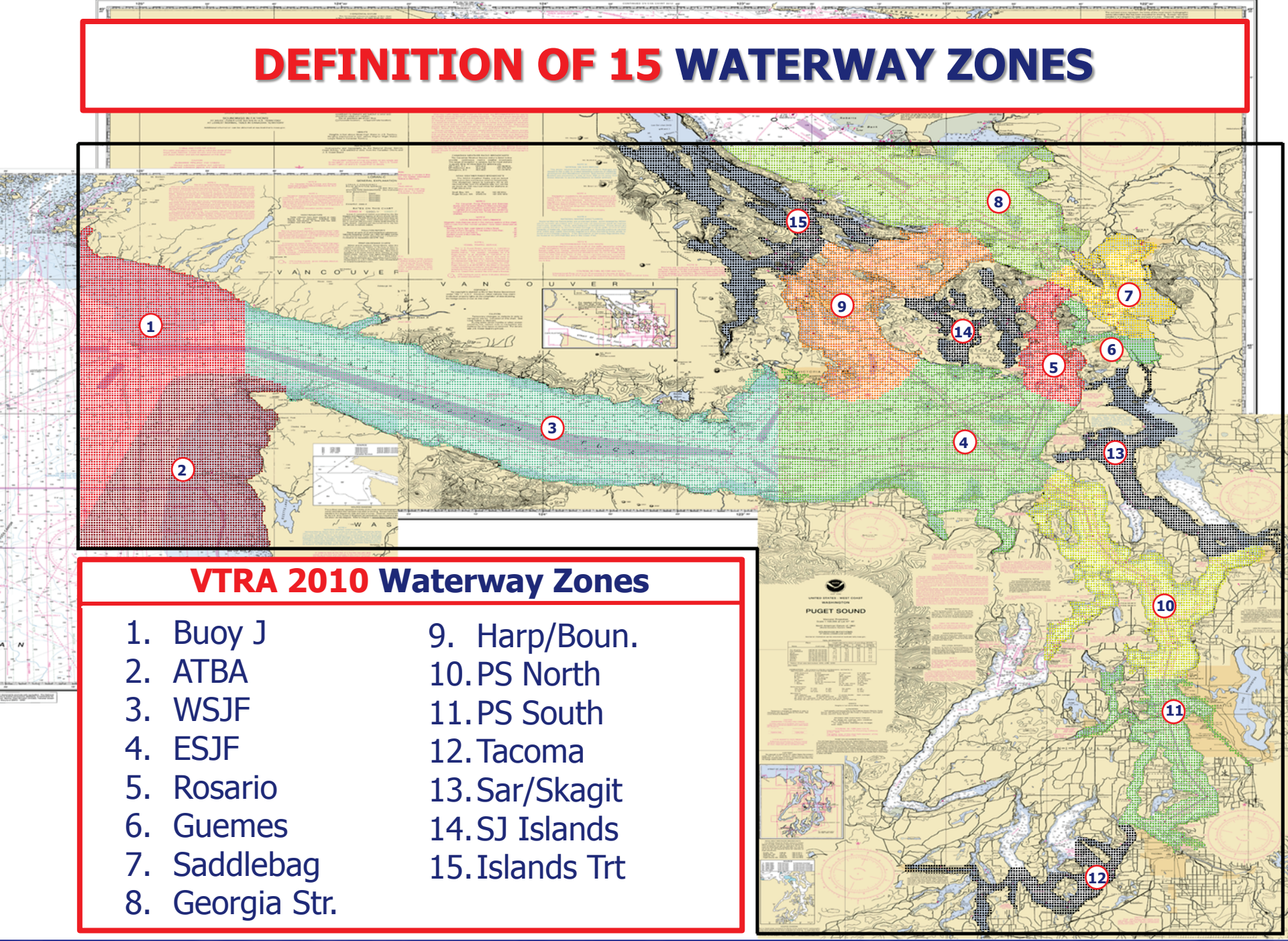
GWU Personnel: Dr. J. Rene van Dorp

VCU Personnel: Dr. Jason R. W. Merrick

AUGUST 26, 2013

PRELIMINARY

DEFINITION OF 15 WATERWAY ZONES



VTRA 2010 Waterway Zones

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

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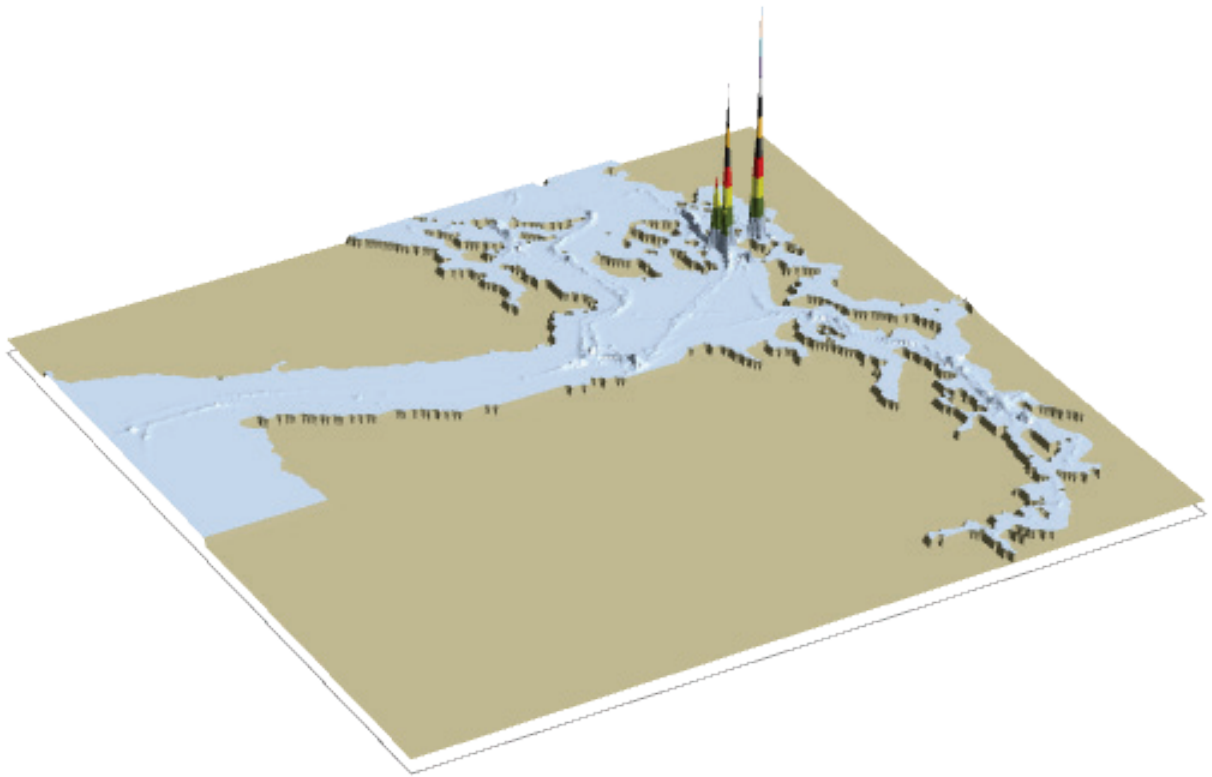
P: Base Case 3D Risk Profile
All FV - Pot. Collision Oil Loss: 100% of Base Case PCO

P: BC @ 100%



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P: ALL FV POTENTIAL COLLISION OIL (FUEL + CARGO) LOSS (PCO)

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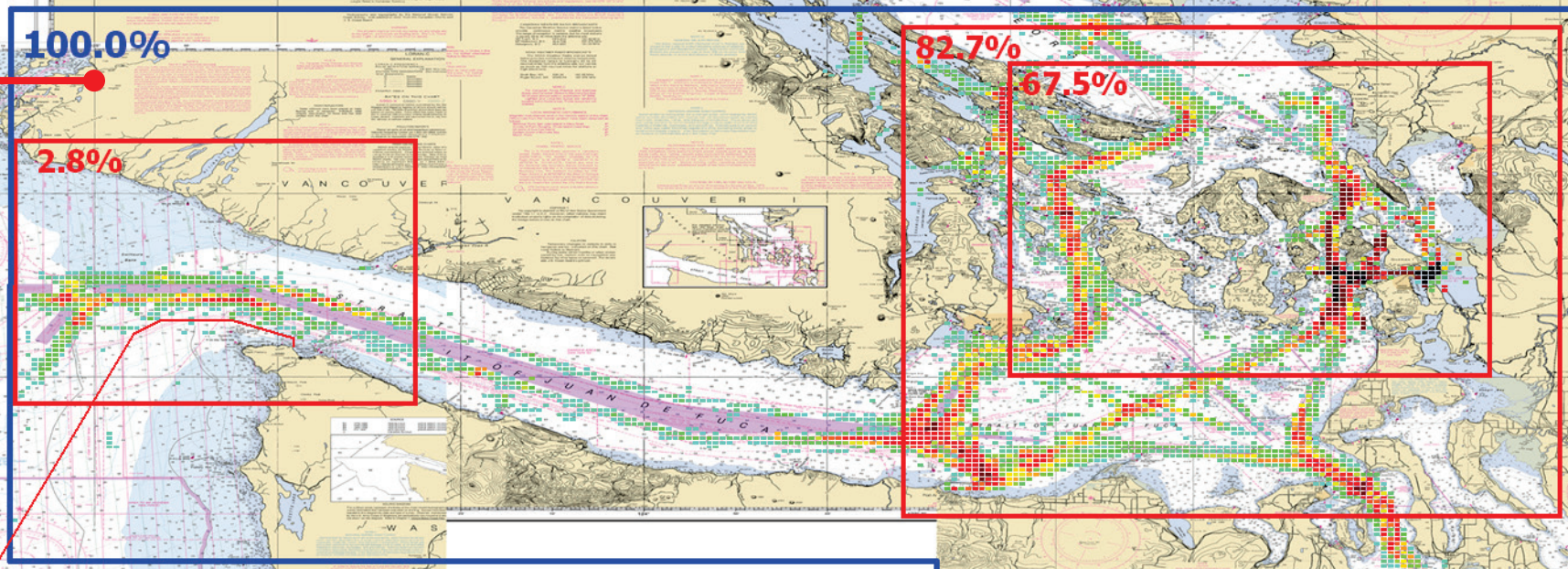
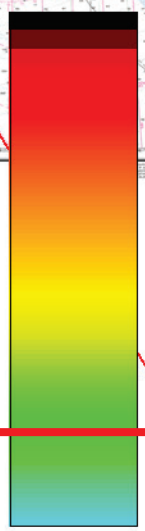
P: VTRA 2010 - BASE CASE - All FV





Factor x Average Oil Outflow

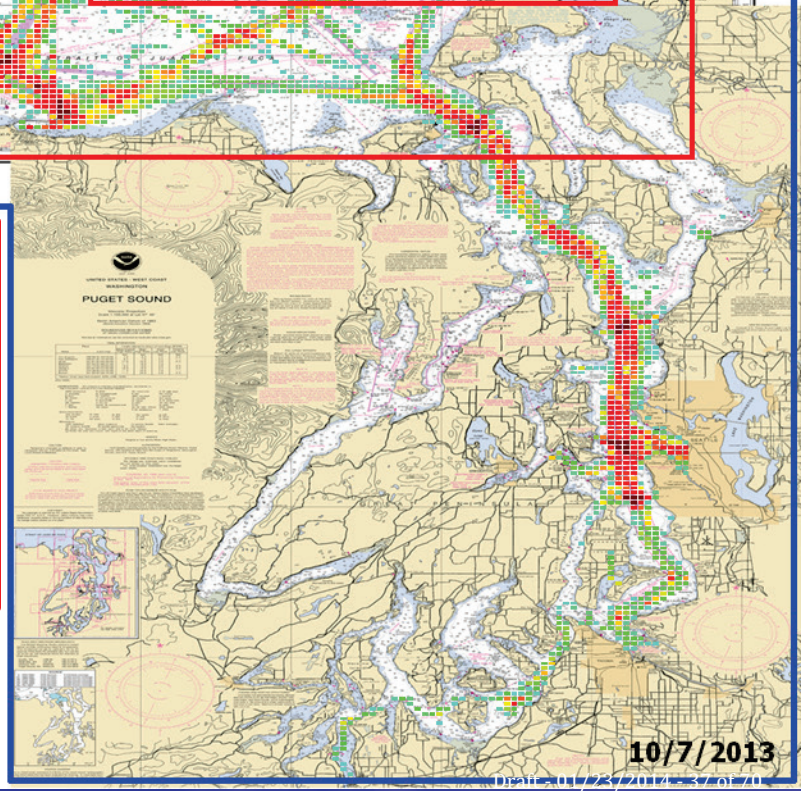
> 100.00
> 10.00
10.00
3.70
2.95
2.51
2.20
1.95
1.76
1.59
1.44
1.31
1.20
1.09
1.00
0.81
0.65
0.51
0.28
0.18
0.09
0.00

P: POTENTIAL COLL. OIL LOSS (PCO)

03.0% - BULK CARGO
04.1% - CONTAINERSHIP
01.4% - OTHER CARGO
21.4% - OIL BARGE
54.2% - TANKER
13.3% - CHEMICAL CARRIER
02.6% - ATB
00.0% - WHAT-IF FV

\+

100.0% of 2010 Base Case
ALL FV – PCO



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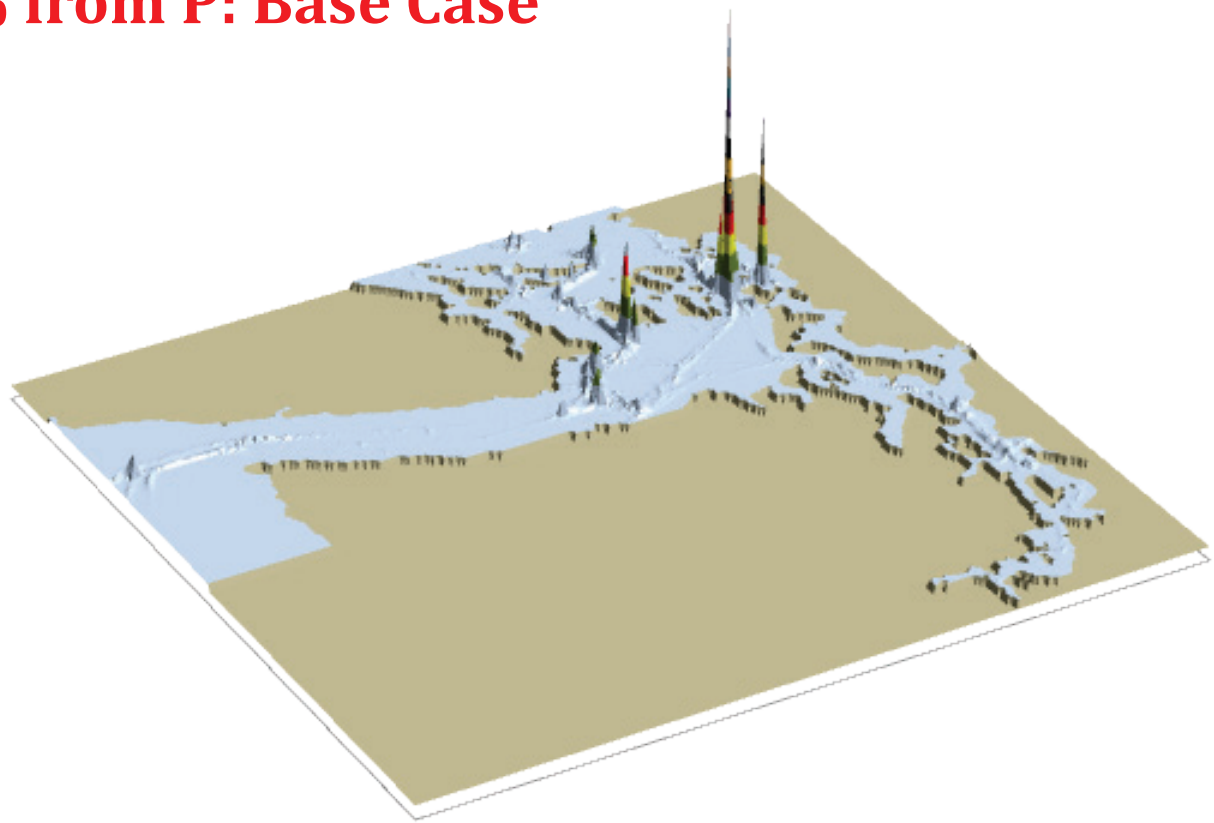
VCU

T: GW - KM - DP 3D Risk Profile
All FV - Pot. Collision Oil Loss: 189% of Base Case PCO

+89% from P: Base Case



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T: ALL FV POTENTIAL COLLISION OIL (FUEL + CARGO) LOSS (PCO)

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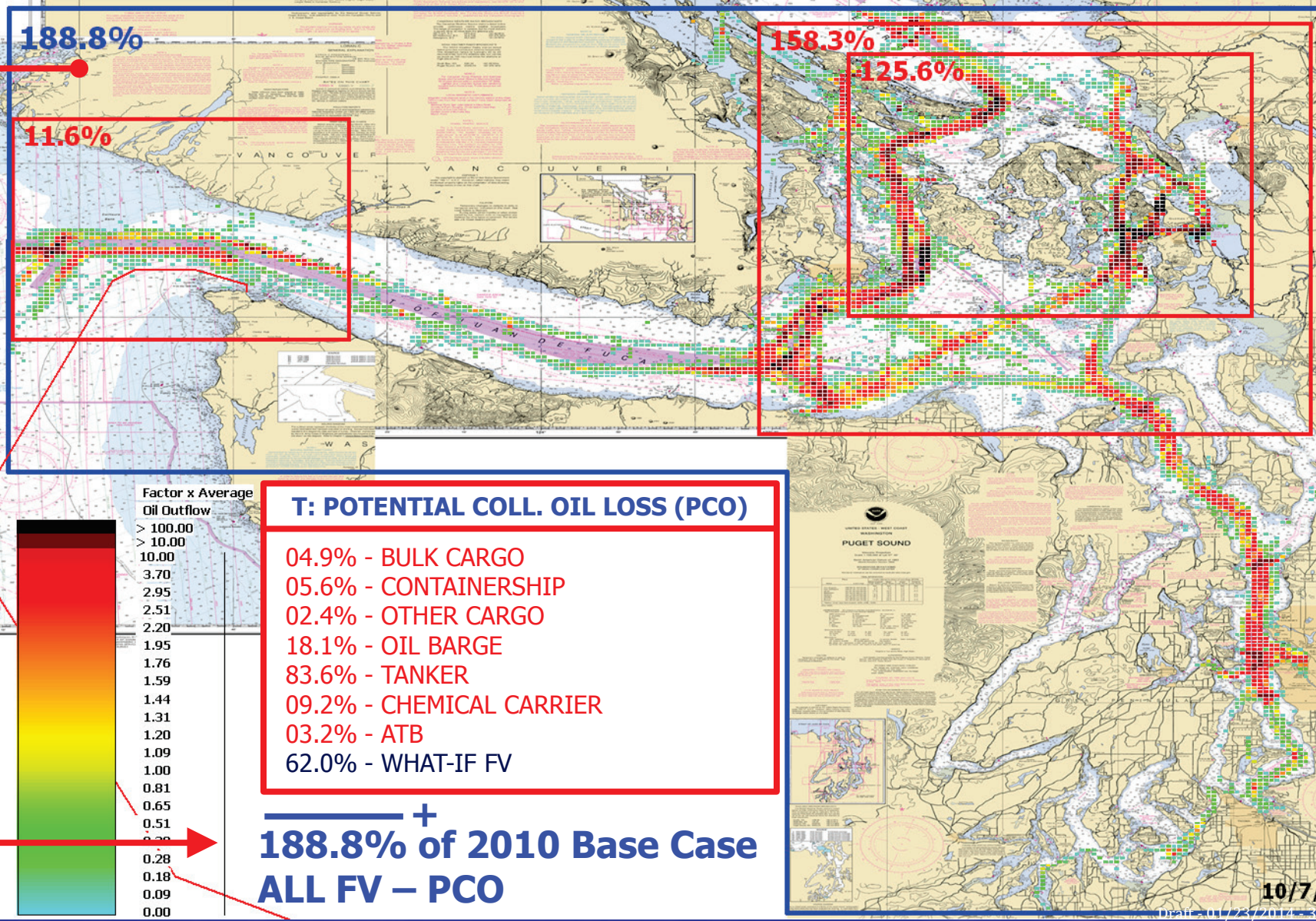
VCU

T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348 - All FV



T: POTENTIAL COLL. OIL LOSS (PCO)

04.9% - BULK CARGO
05.6% - CONTAINERSHIP
02.4% - OTHER CARGO
18.1% - OIL BARGE
83.6% - TANKER
09.2% - CHEMICAL CARRIER
03.2% - ATB
62.0% - WHAT-IF FV

\+

188.8% of 2010 Base Case
ALL FV – PCO

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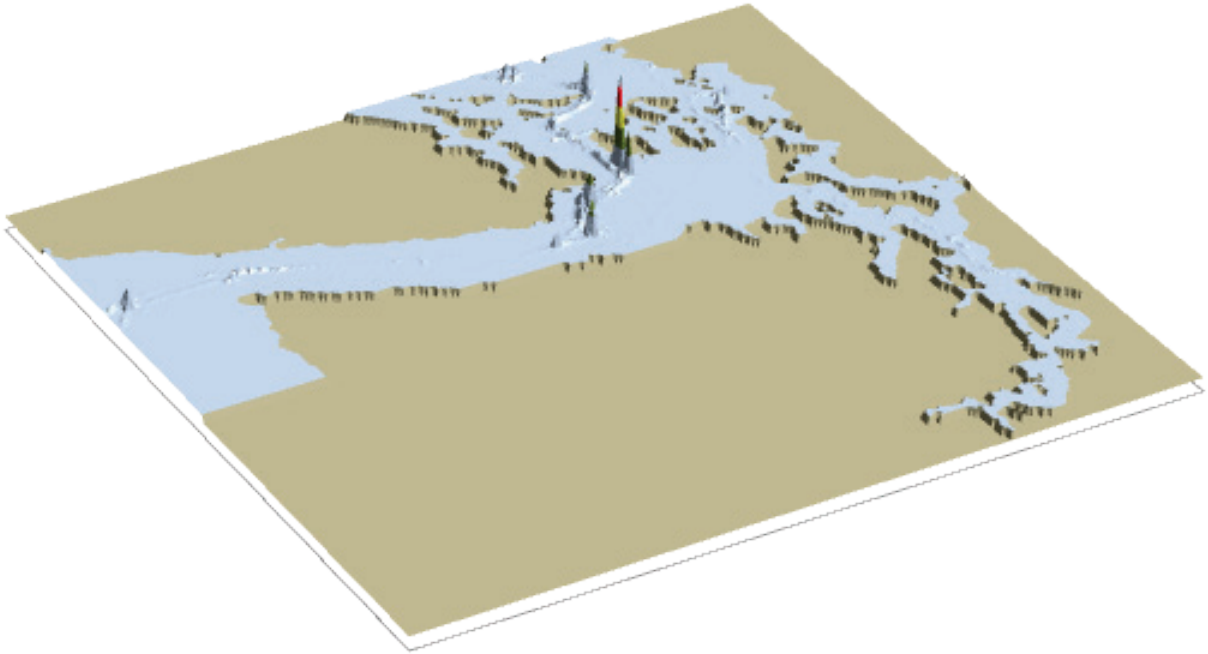
T: GW - KM - DP 3D Risk Profile
What If FV - Pot. Coll. Oil Loss: 62% of Base Case PCO

+62% from P: Base Case



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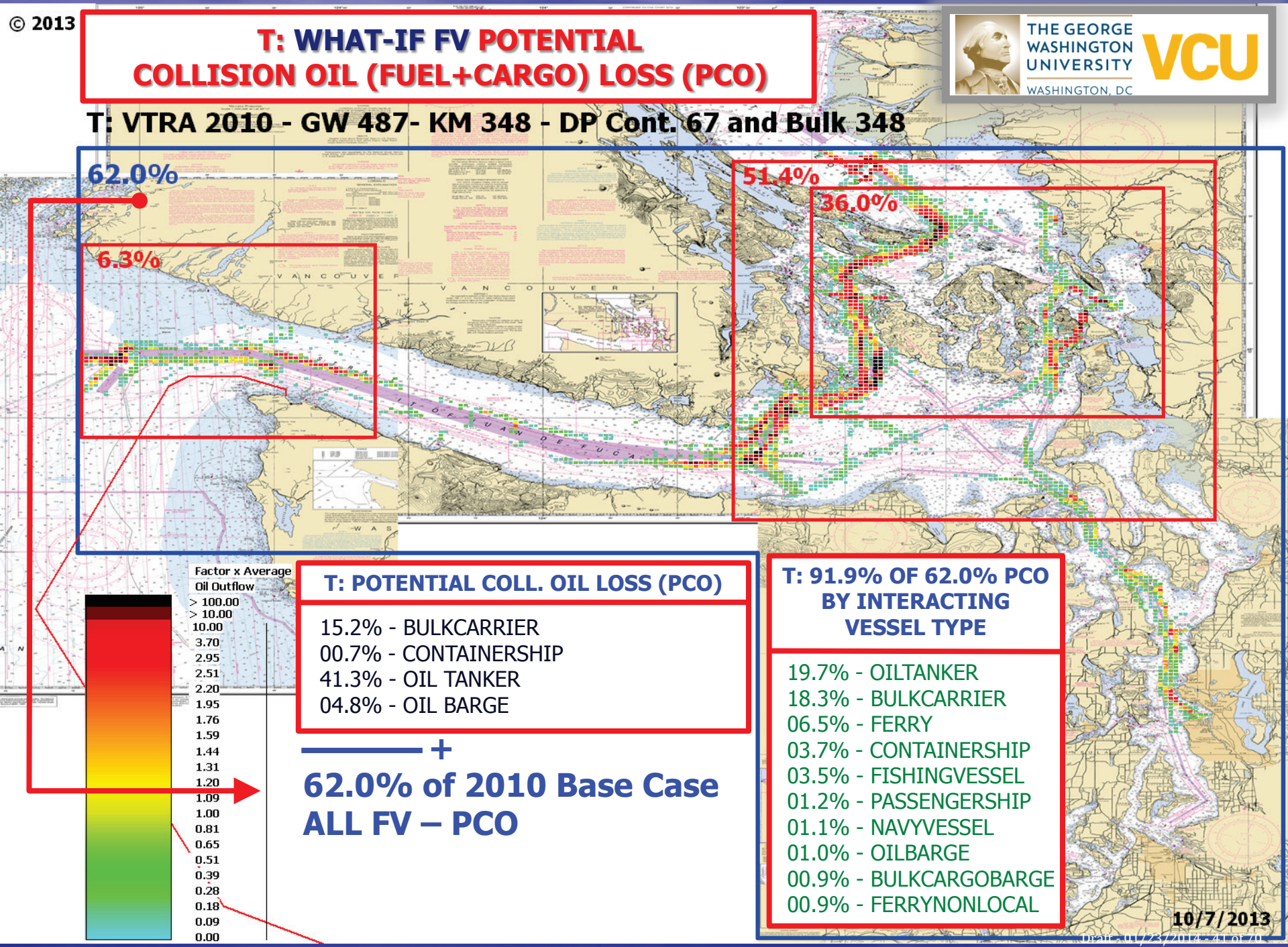
T: WHAT-IF FV POTENTIAL COLLISION OIL (FUEL+CARGO) LOSS (PCO)

THE GEORGE WASHINGTON UNIVERSITY WASHINGTON, DC VCU

T: VTRA 2010 - GW 487- KM 348 - DP Cont. 67 and Bulk 348



T: POTENTIAL COLL. OIL LOSS (PCO)

15.2% - BULKCARRIER
00.7% - CONTAINERSHIP
41.3% - OIL TANKER
04.8% - OIL BARGE

\+

62.0% of 2010 Base Case ALL FV – PCO

T: 91.9% OF 62.0% PCO BY INTERACTING VESSEL TYPE

19.7% - OILTANKER
18.3% - BULKCARRIER
06.5% - FERRY
03.7% - CONTAINERSHIP
03.5% - FISHINGVESSEL
01.2% - PASSENGERSHIP
01.1% - NAVYVESSEL
01.0% - OILBARGE
00.9% - BULKCARGOBARGE
00.9% - FERRYNONLOCAL

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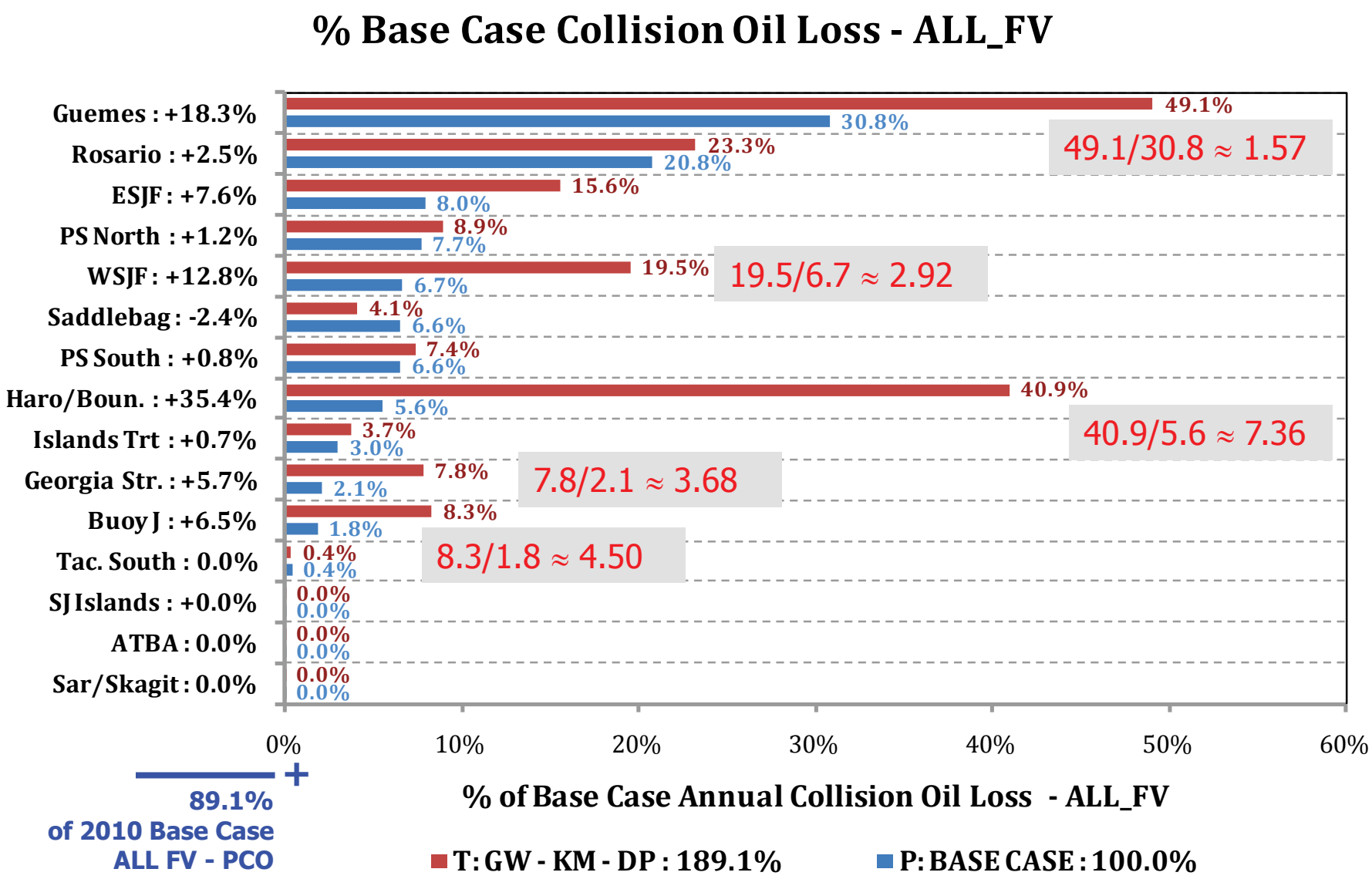
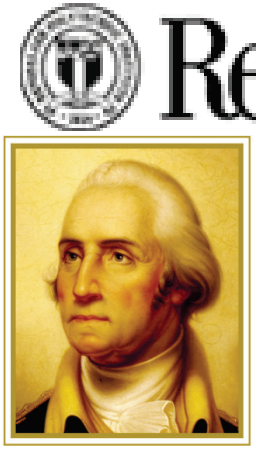
WATERWAY LOCATION
Potential Collision Oil Loss Comparison – ALL FV



Towards the Development of a Comprehensive Vessel Traffic Risk Management Tool



Rensselaer

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VCU

TU Delft

Delft University of Technology

GWU Personnel: Dr. J. Rene van Dorp, Dr. Jack Harrald, Dr. Greg Shaw, Adil Caner Sener, Christian Salmon

VCU Personnel: Dr. Jason R. W. Merrick, Christina Werner

RPI Personnel: Dr. Martha Grabowski, Zhi Zhou, Michael Steward, Brittany Steward, Huawei Song, Zhuyu You

TU Delft Personnel: Giel van de Wiel

Puget Sound Harbor Safer Committee Presentation April 2012

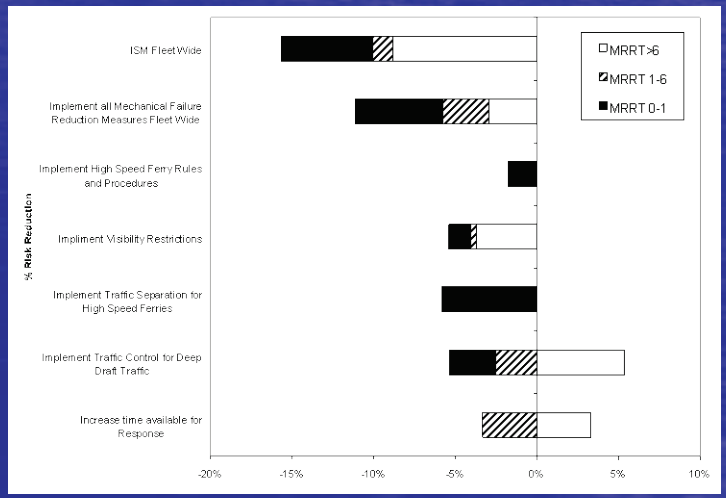
Previous Work

- Prince William Sound Risk Assessment
  - Site of the Exxon Valdez Disaster
  - Objective—reduce oil spill risk
  - Model used system simulation, data analysis and expert judgment
  - Capable of modeling systemic effects of proposed interventions
  - Multi-million dollar investments made to reduce risk of further oil spills

Merrick, J. R. W., J. R. van Dorp, T. Mazzuchi, J. Harrald, J. Spahn, M. Grabowski. 2002. The Prince William Sound Risk Assessment. *Interfaces* **32**(6) 25-40.

Previous Work

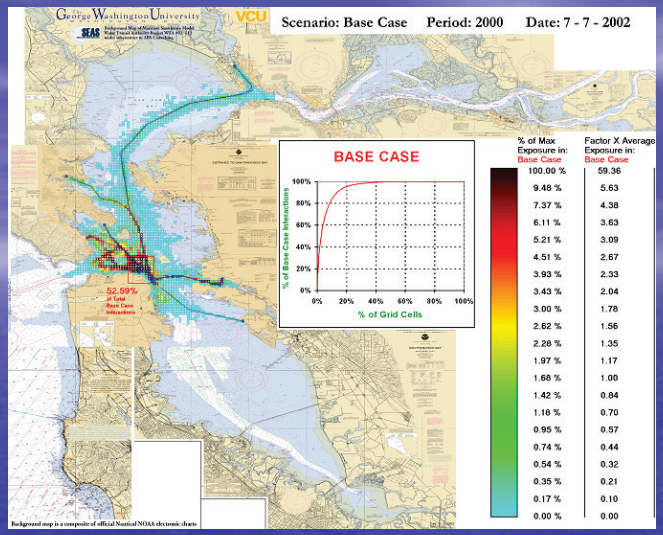
- **Washington State Ferries Risk Assessment**
  - Largest ferry system in the United States
  - Objective—Subchapter W determination, reduce risk alternatives to lifeboats
  - Simulation/expert judgment model improved based on NRC review of PWS study
  - Legislature approved funding of Safety Management System, training and emergency preparedness exercises

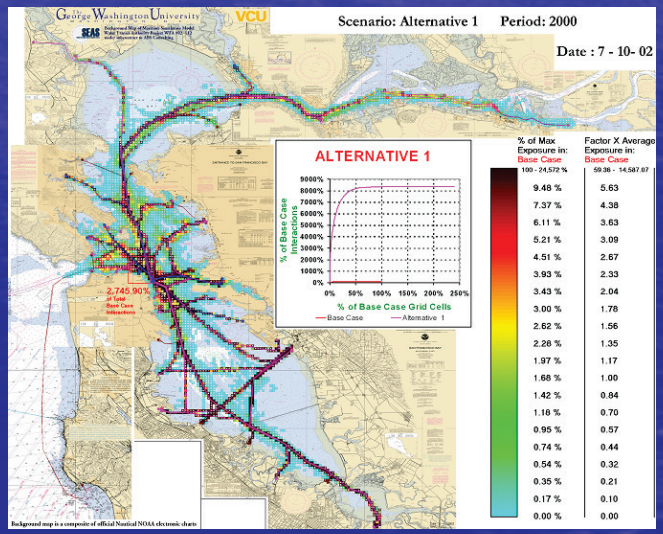


van Dorp, J. R., J. R. W. Merrick, J. Harrald, T. Mazzuchi, M. Grabowski. 2001. A Risk Management Procedure for the Washington State Ferries. *Risk Analysis* **21**(1) 127-142.

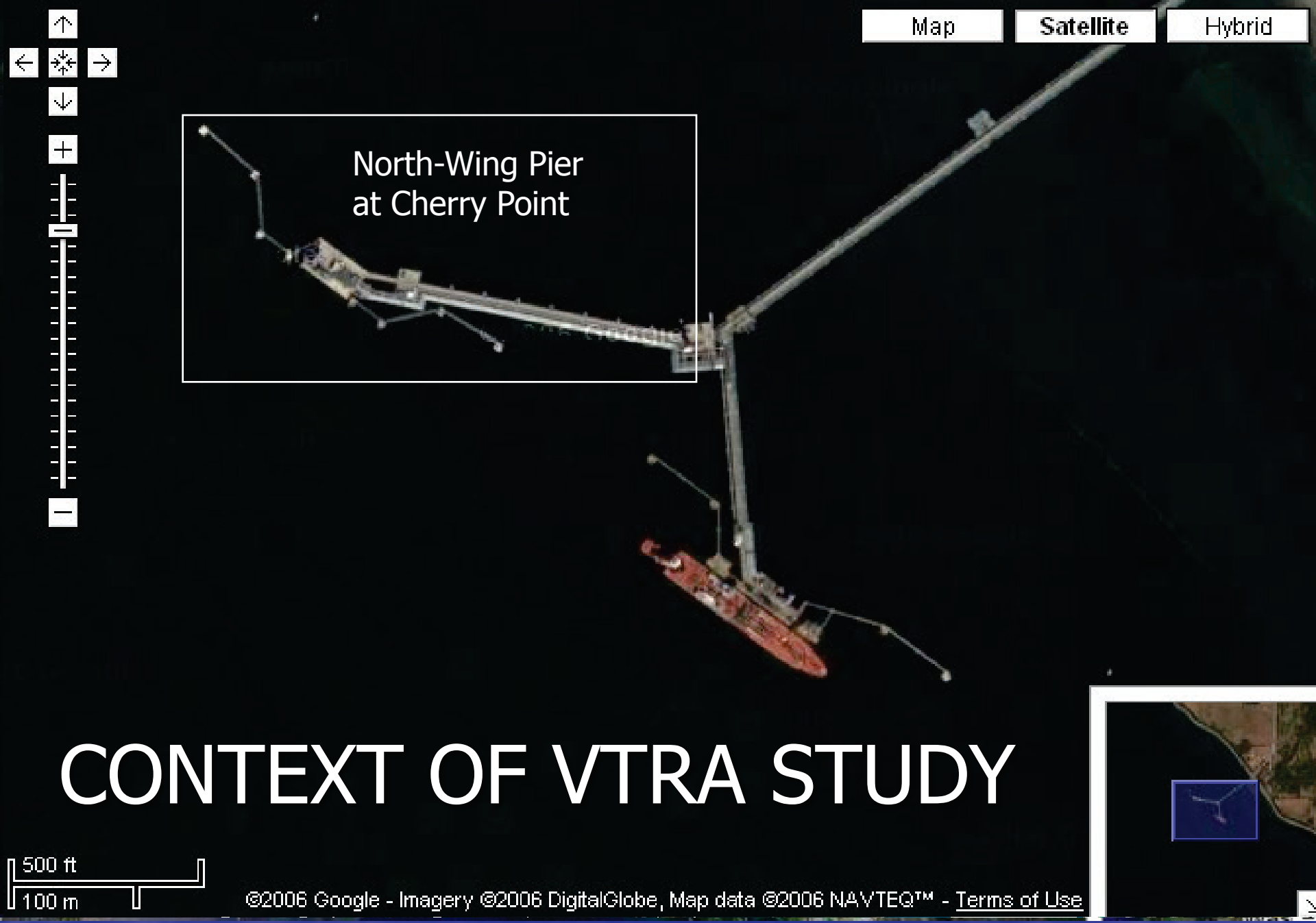
Previous Work

- San Francisco Bay Exposure Assessment
  - California legislature examining the effects of major expansion of ferry services
  - Objective—fulfill environmental impact requirement
  - Simulation model tested the impact of proposed expansion on vessel interactions
  - Legislature considering implementing proposed expansions



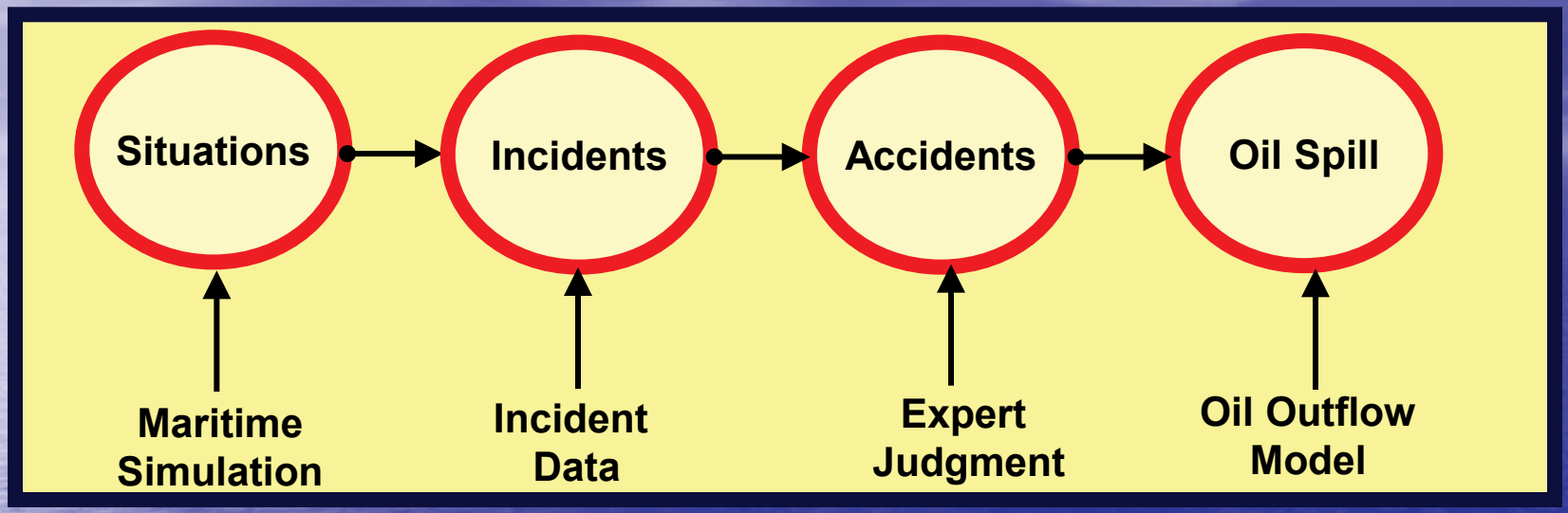


Merrick, J. R. W., J. R. van Dorp, J. P. Blackford, G. L. Shaw, J. Harrald, T.A. Mazzuchi. 2003. Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model. *Reliability Engineering and System Safety* **81**(2) 119-132.



CONTEXT OF VTRA STUDY

An Oil Spill is a series of cascading events referred to as a Causal Chain



$$R = \{< s_i, l_i, x_i >\}_c$$

Complete Set

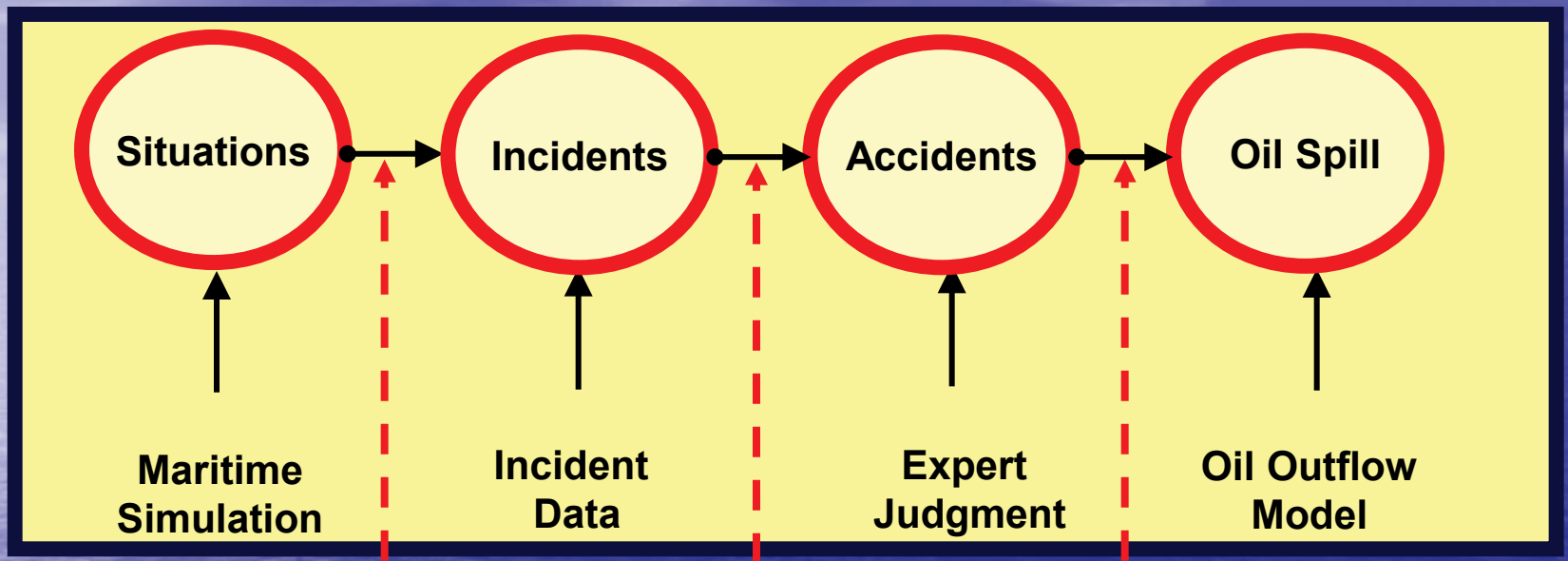
Scenario i

Likelihood i

Consequence i

Use Kaplan's (1997) definition of system risk in:
"The Words of Risk Analysis", Risk Analysis 17 (4), 407-417

Risk Management of a Causal Chain

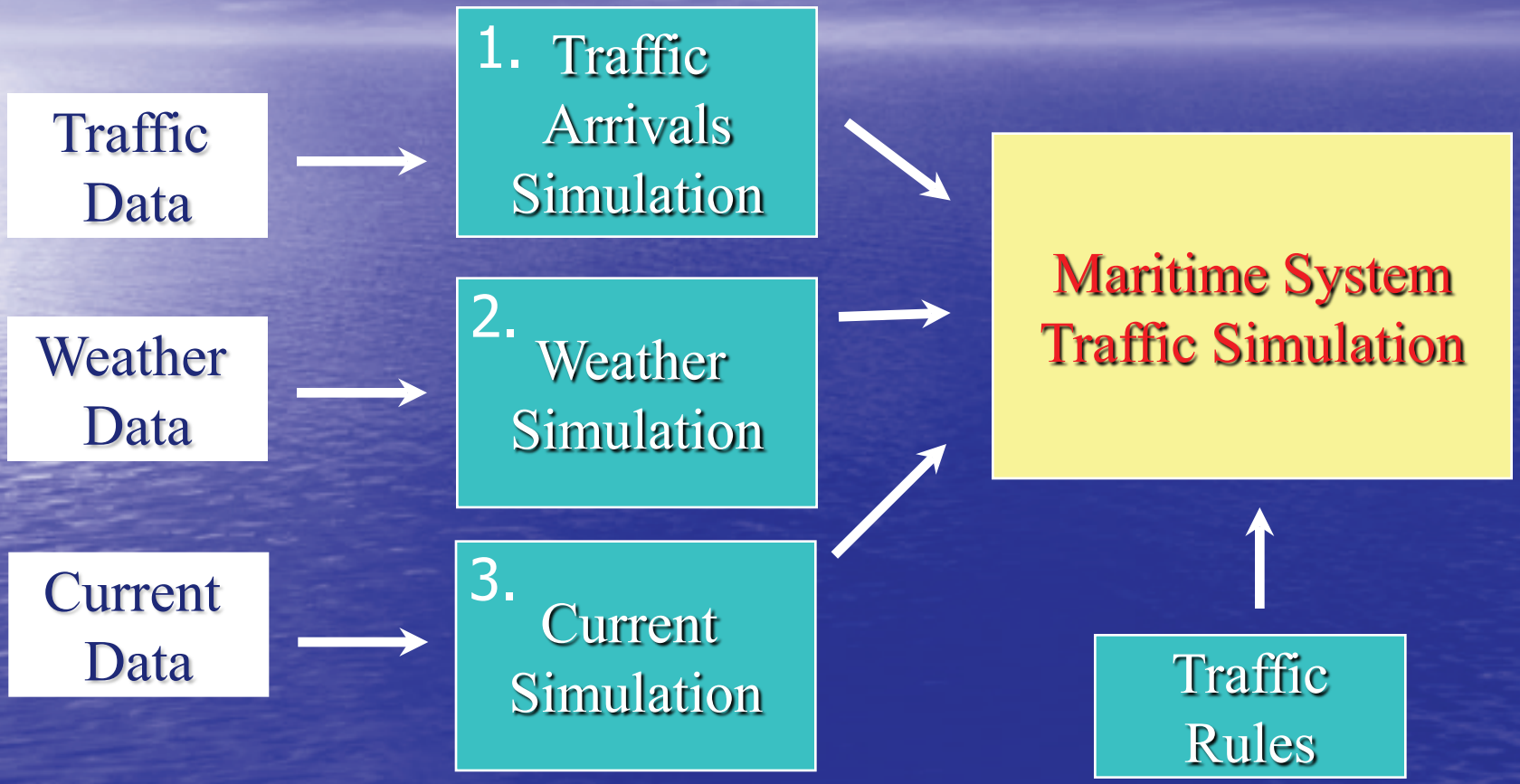


RISK MANAGEMENT QUESTIONS

Kaplan's (1997) Risk Definition

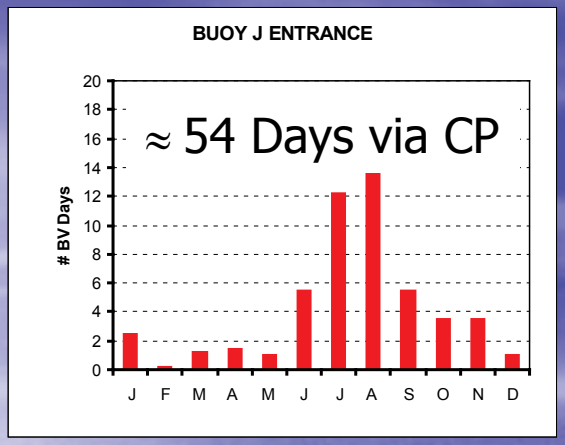
$$R = \{< s_i, l_i, x_i >\}_c$$

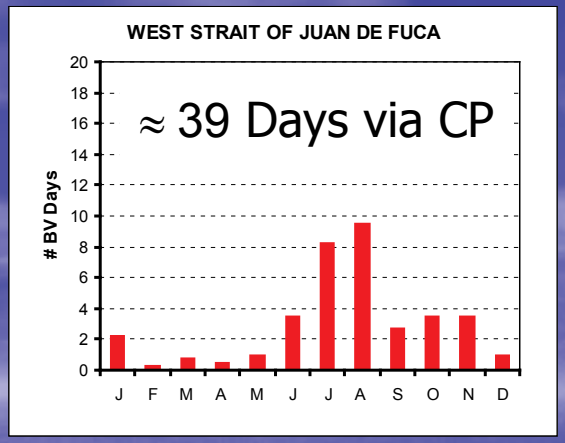
Step 1a: Model Maritime Traffic Simulation (MTS) Model

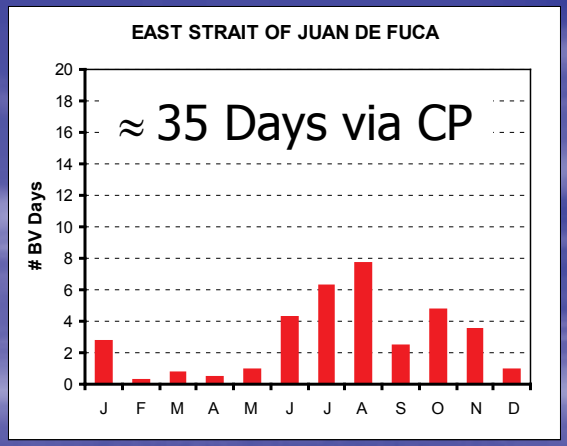


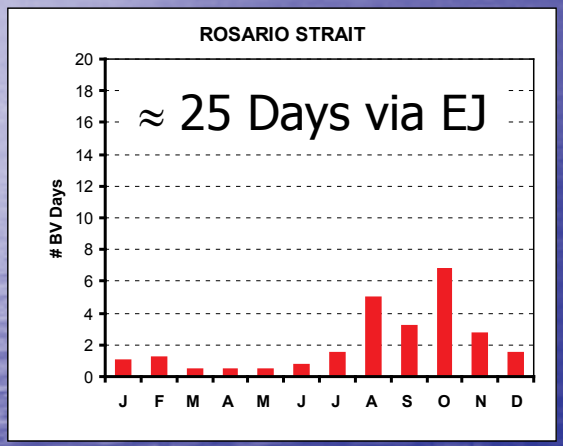
Required close cooperation with the USCG VTS and Puget Sound Harbor Safety Committee for data + validation

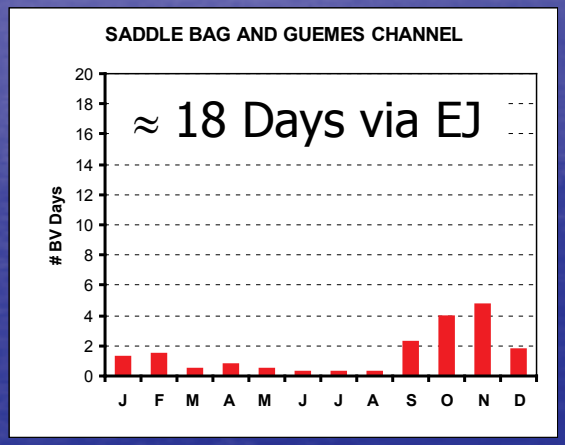
Bad Visibility Days by Month

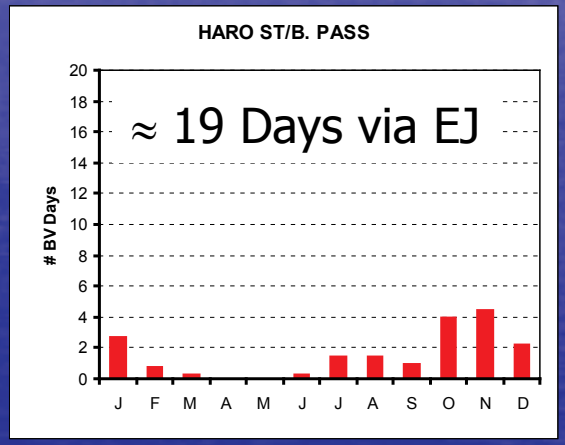


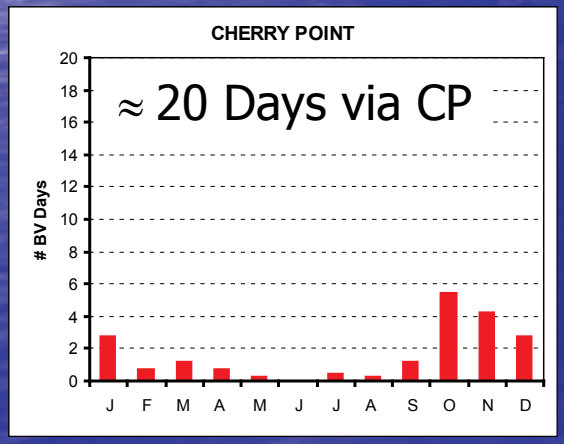


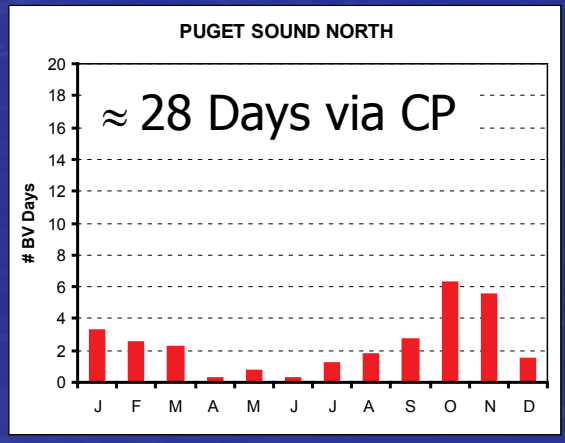


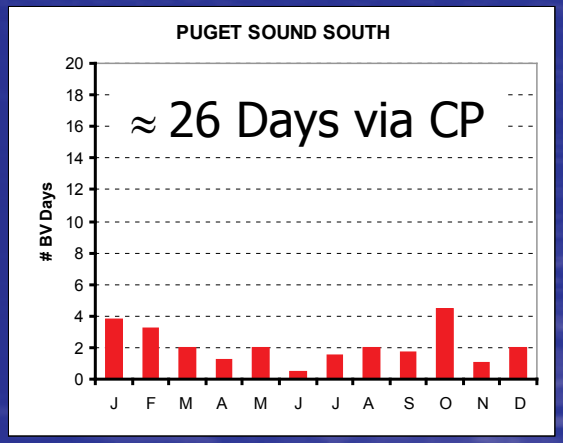


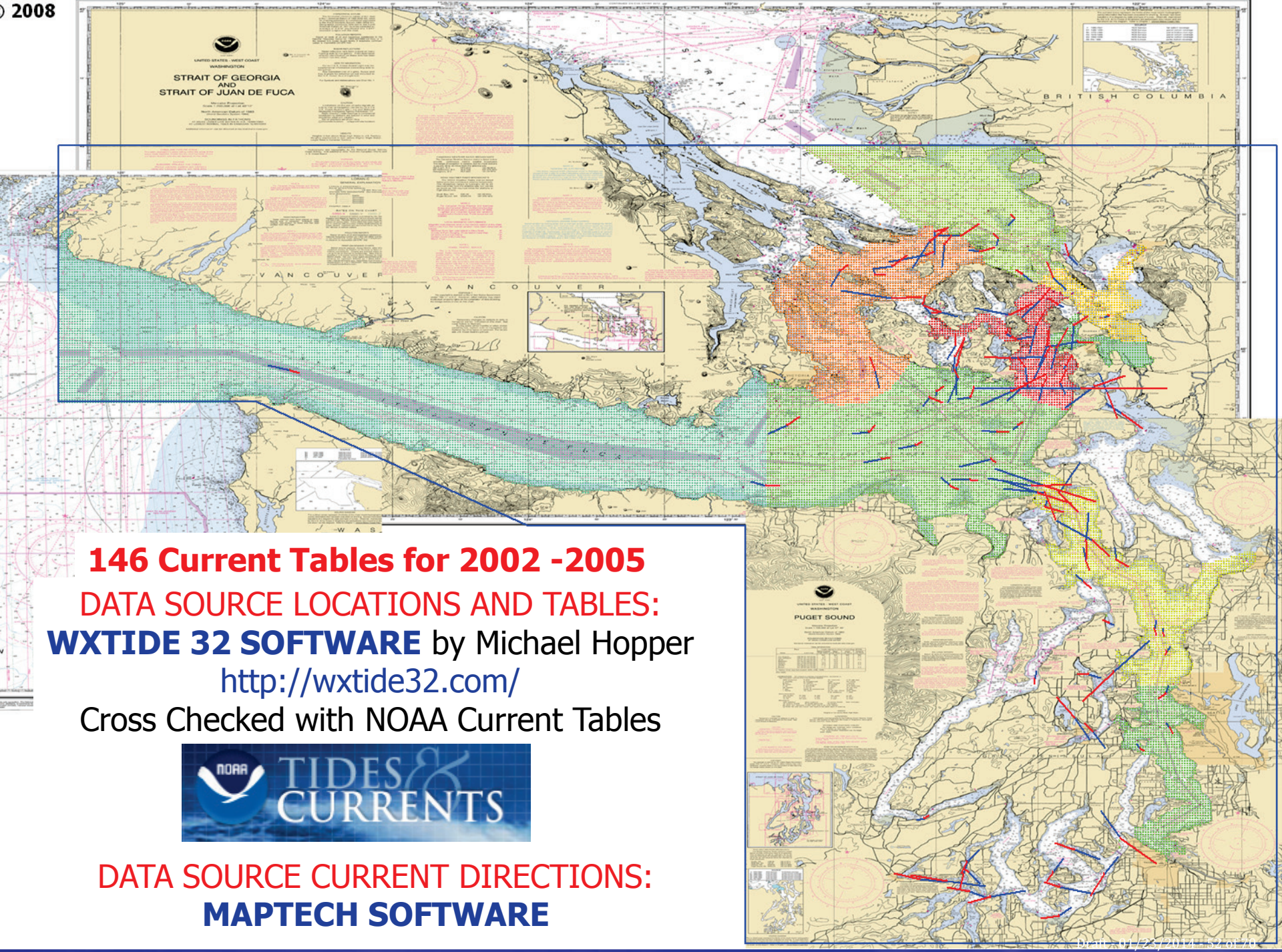












146 Current Tables for 2002 -2005

DATA SOURCE LOCATIONS AND TABLES:

WXTIDE 32 SOFTWARE by Michael Hopper

http://wxtide32.com/

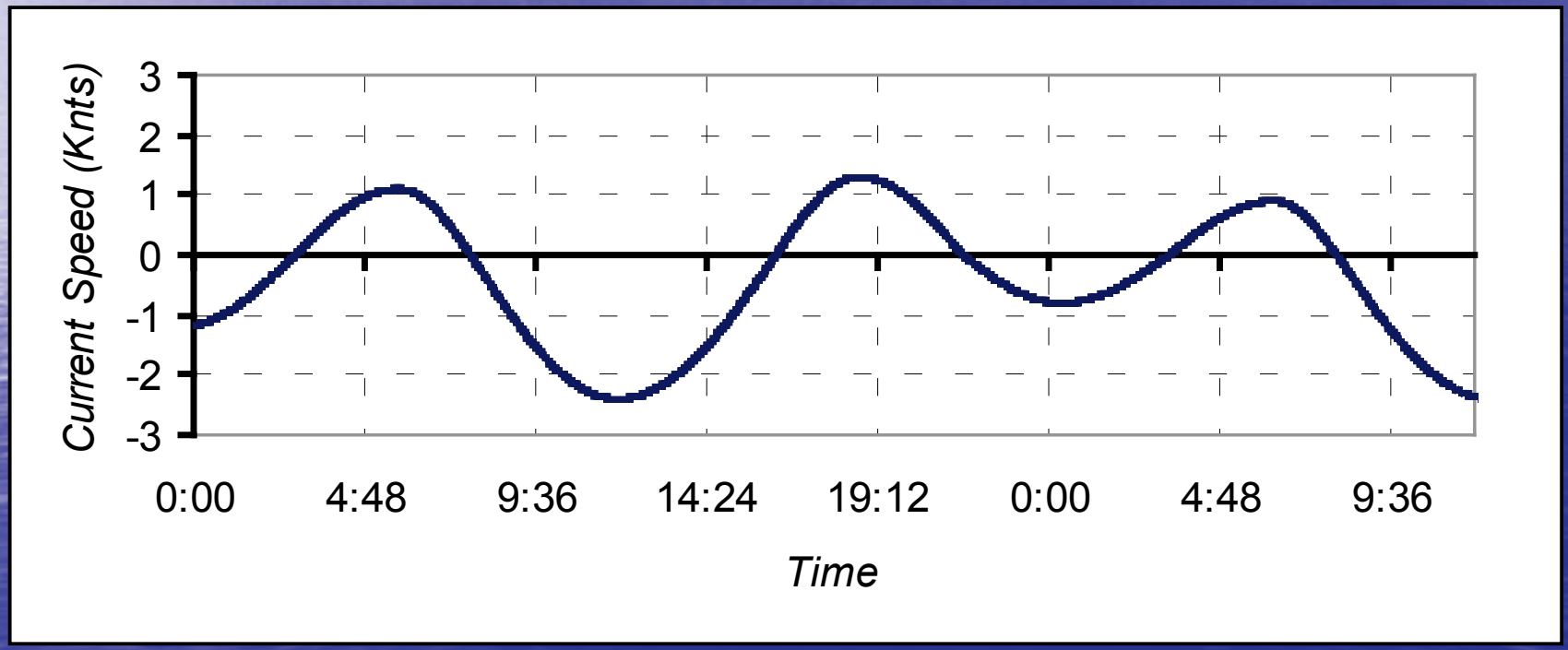
Cross Checked with NOAA Current Tables

NOAA TIDES & CURRENTS

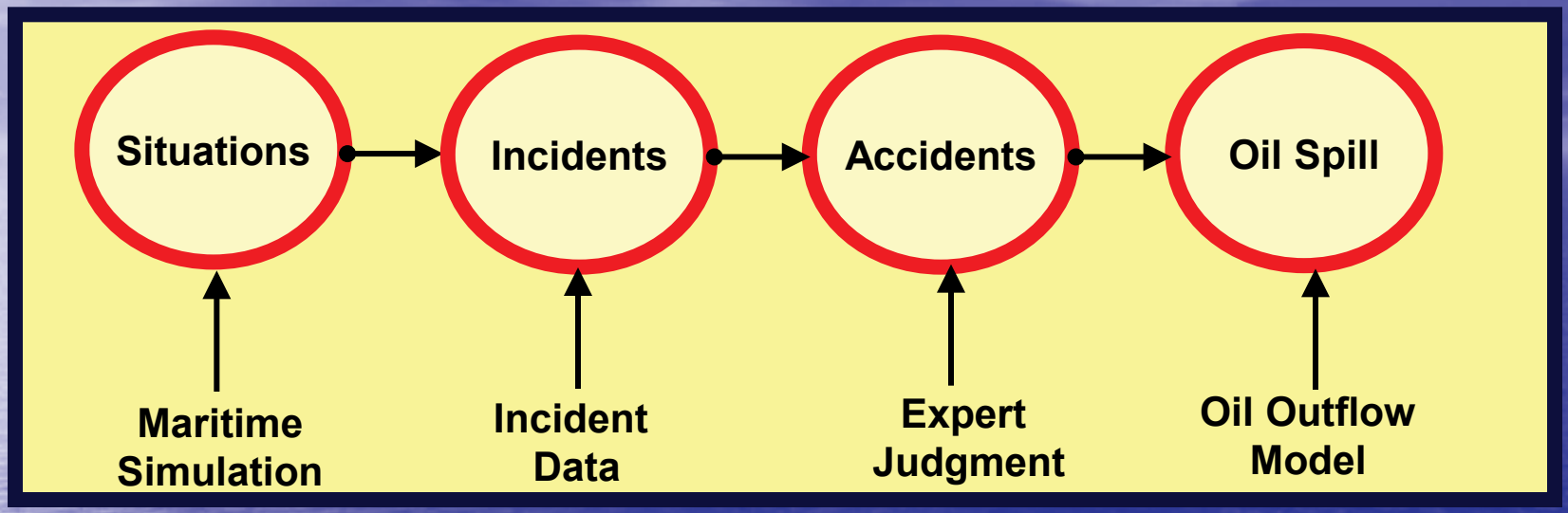
DATA SOURCE CURRENT DIRECTIONS:

MAPTECH SOFTWARE

Modeled Harmonic Curve betweem Eb, Slack, Flood, Eb, Slack, Flood, etc.



An Oil Spill is a series of cascading events referred to as a Causal Chain



$$R = \{< s_i, l_i, x_i >\}_c$$

Complete Set

Scenario i

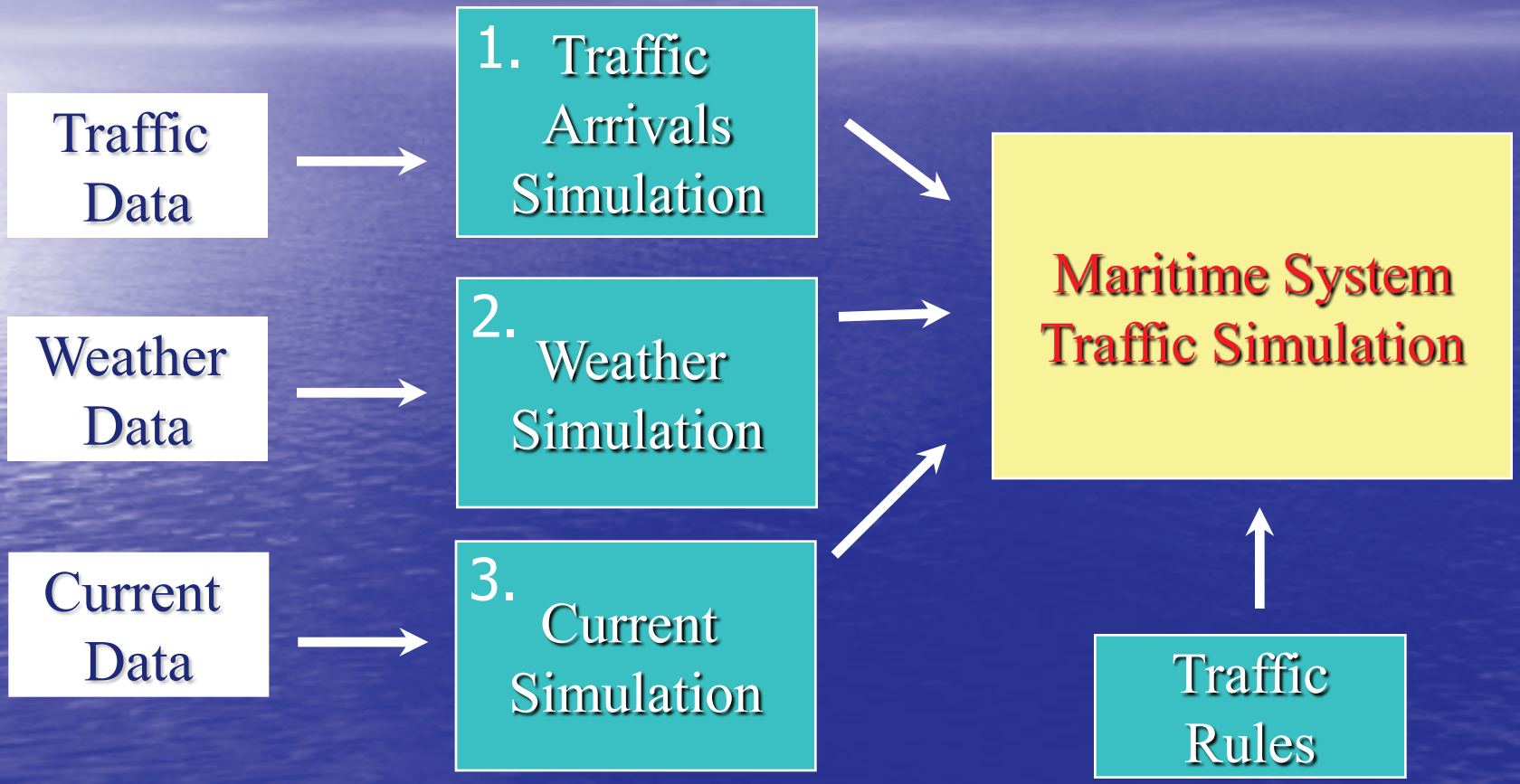
Likelihood i

Consequence i

Use Kaplan's (1997) definition of system risk in:
"The Words of Risk Analysis", Risk Analysis 17 (4), 407-417

Step 1b: Generate Accident Scenarios

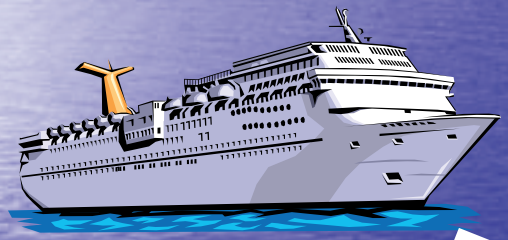
Using The Maritime System Simulation Model



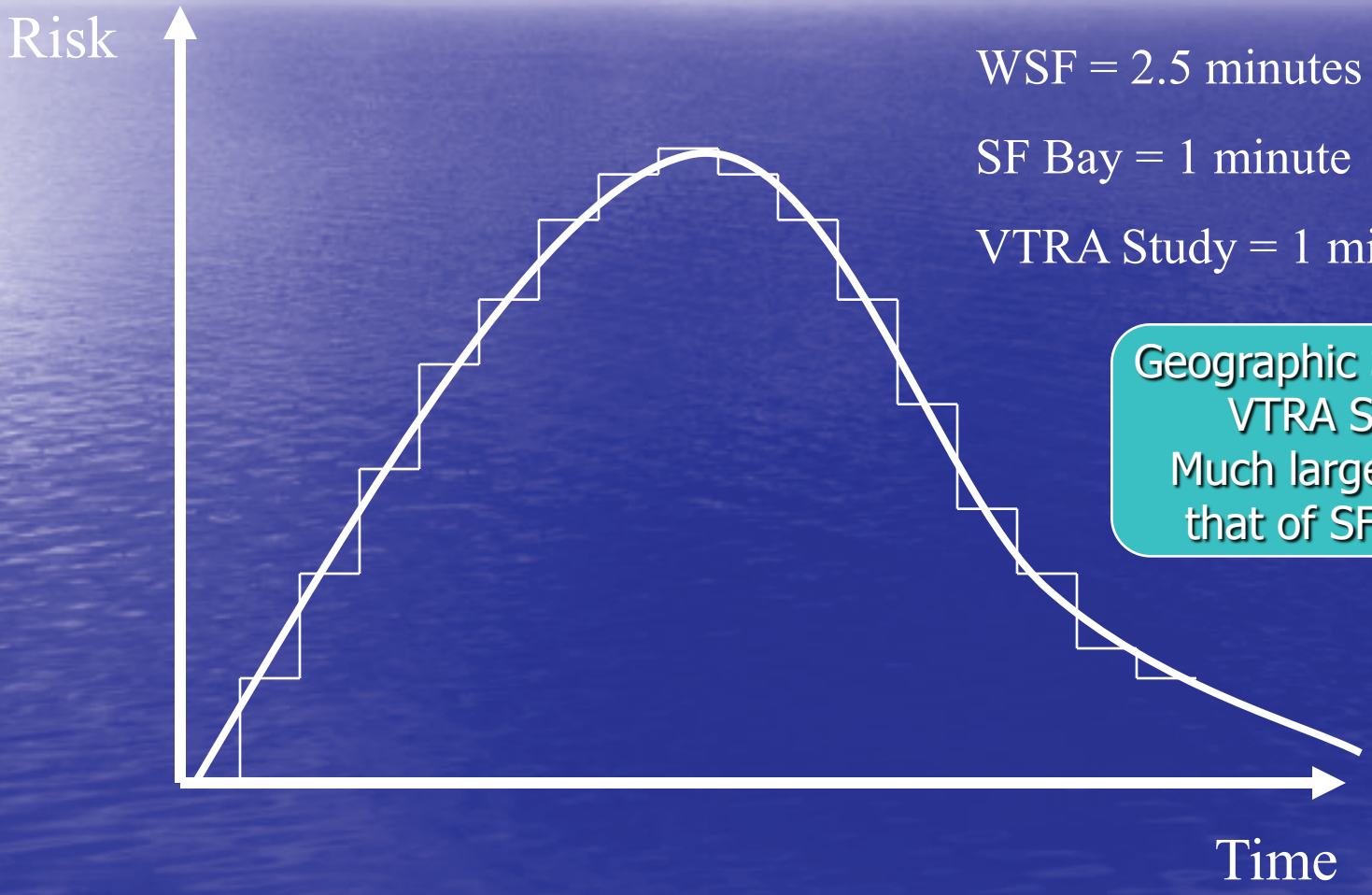
Required close cooperation with the USCG VTS and Puget Sound Harbor Safety Committee for data + validation

Count Accident Scenarios

Interacting Vessels



Risk During Interactions



PWS = 5 minutes

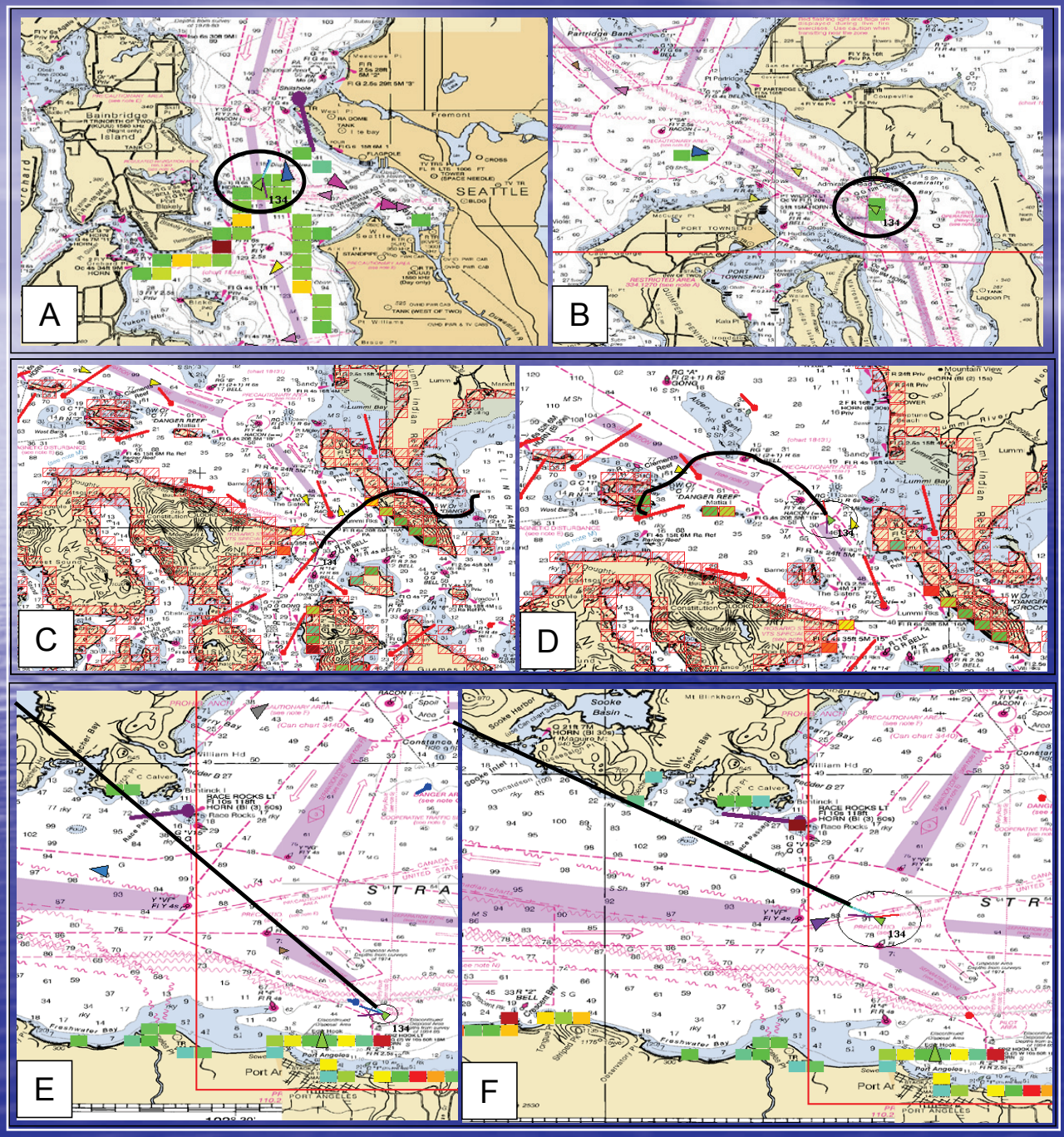
WSF = 2.5 minutes

SF Bay = 1 minute

VTRA Study = 1 minute

Geographic Scope of VTRA Study Much larger than that of SF Study

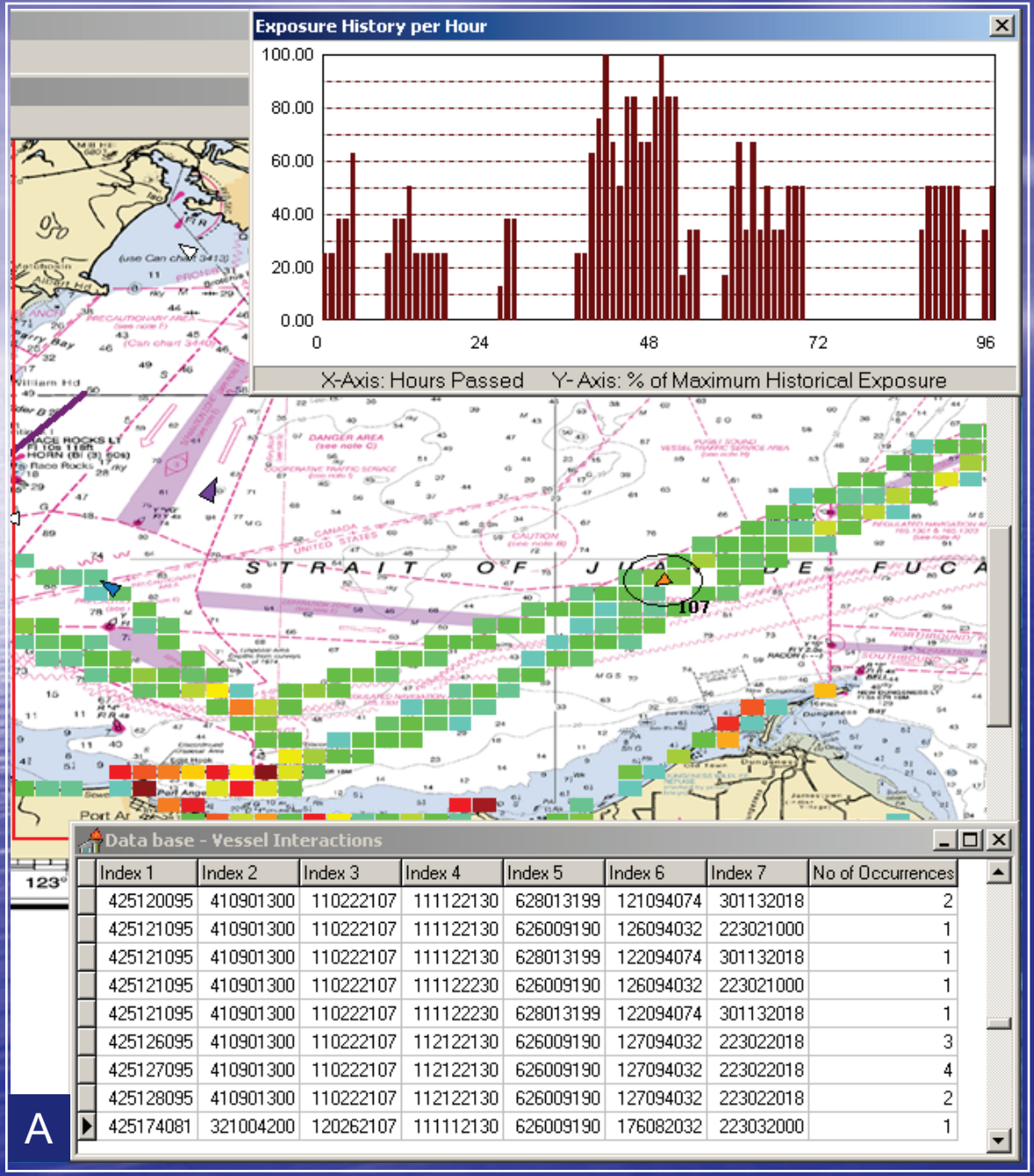
Generating Accident Scenarios:



Counting Collision Accident Scenario's

Counting Drift Grounding Accident Scenario's

Counting Powered Grounding Accident Scenario's




```
type INTERACTION = record
       lex_number_1      :longint;
       lex_number_2      :longint;
       lex_number_3      :longint;
       lex_number_4      :longint;
       lex_number_5      :longint;
       lex_number_6      :longint;
       lex_number_7      :longint;

       {Index 1 - VOI Location Info}
       Interaction_Type  :longint; {400000000}
       VOI               :longint; { 26000000}
       VOI_X             :Longint; {   500000}
       VOI_Y             :Longint; {      500}

       {Index 2 - VOI Attributes}
       VOI_Location      :Longint; {900000000}
       VOI_Inbound_Outbound:Longint; { 20000000}
       VOI_Speed         :Longint; {  3000000}
       VOI_DP            :longint; {    12500}
       IV_Cargo          :Longint; {       20}
       IV_Barge_Type     :Longint; {        5}

       {Index 3 - VOI Attributes}
       VOI_Cargo         :Longint; {20000000}
       VOI_Tethered_State:Longint; {  200000}
       VOI_Barge_Type    :Longint; {   50000}
       VOI_Hook_Up       :Longint; {    4000}
       VOI_ID            :longint; {     999}

       {Index 4 - Environment Info}
       Visibility        :longint; {20000000}
       wind_Direction    :longint; { 2000000}
       Wind_Speed        :longint; {  400000}
       Current           :Longint; {   30000}
       Current_Direction :Longint; {    3000}
       N_Vessels         :Longint; {     300}
       Escort_State      :Longint; {      20}

       {Index 5 - Shore Interaction Location}
       Shore_X           :Longint; {500000000}
       Shore_Y           :Longint; {  500000}
       Time_to_Shore     :Longint; {     300}

       {Index 6 - Interacting Vessel Location}
       IV_X              :Longint; {500000000}
       IV_Y              :Longint; {  500000}
       IV_DP             :Longint; {     125}

       {Index 7 - Interacting Vessel Info}
       IV_TrafficScenario :Longint; {400000000}
       IV_TrafficType    :longint; { 25000000}
       IV_Speed          :Longint; {  300000}
       IV_ProxVessel     :Longint; {    2000}
       IV_InterAngle     :Longint; {     180}
     end;
```

Accident Attributes Model

LOCATION	DIRECTION	CARGO	ESCORTS	TETHERED
Cherry Point Area	Inbound	Unladen	2 Escorts	tethered
Puget Sound South	Outbound	Laden	1 Escort	untethered
Strait of Juan de Fuca East			No Escorts	
Strait of Juan de Fuca West				
Puget Sound North				
Saddle Bag Area				
Rosario Strait				
Haro Strait\Boundary Pass				
Guemes Channel				

VESSEL TYPE	TRAFFIC PROXIMITY	TRAFFIC SCENARIO
Tug without Barge	1 to 5 miles	Crossing Astern
Tug ATB's or ITB's	Less than 1 mile	Meeting
Tug Pushing Ahead		Overtaking
Container		Crossing the Bow
Tanker		
Bulk carrier		
Freighter		
Passenger vessel		
Service vessel		
Public vessel		
Fishing Vessel		
Tug Towing Astern		
Recreational Vessel		

VISIBILITY	WD	WIND SPEED	CURRENT	CUR_DIR
More than 0.5 mile	Along Vessel	Less than 10 knots	Almost Slack	Along Vessel - Opposite
Less than 0.5 mile	Abeam Vessel	20 knots	Max Eb or Max Flood	Along Vessel - Same Dir.
		30 knots		Abeam Vessel
		More than 40 knots		

Organizations Participating in Expert Judgment Elicitations

- 1. Puget Sound Pilots
- 2. ATC
- 3. US and Canadian Tug Companies operating in the VTRA study area:
  US-Based: Foss, Crowley, Olympic Tug and Barge (US), K-Sea, Sea Coast, Sause Bros.
  Canadian Based: Seaspan, Island Tug and Barge
- 4. The Washington State Ferries
- 5. Seattle sector US Coast guard VTS.

9 QUESTIONNAIRES	38 EXPERTS - Numbers indicate years sailing experience in VTRA Study area	CUMULATIVE EXPERIENCE (YRS)	7 SESSIONS
Bradley-Terry Pair Wise Comparison Location Questionnaire	7 PILOTS (42,34,32,25,16,16) 6 TUG OPERATORS (39, 30, 30, 30, 15, 12) 4 FERRY OPERATORS (31, 30, 25, 8) 2 PORT CAPTAINS (27, 25) 1 VTS WATCH (25)	186 156 94 52 25	Dec-06 Feb-07
Bradley-Terry Pair Wise Comparison Traffic Sc	7 PILOTS (42,34,32,25,16,16)	186	Dec-06 Feb-07
Brad 1st			06 07
Brad 2nd			07 07 07
Brad Tug			07 07 07
Tan Acc Give			07 7
Tan Acc Give Given Given Hu Given Near By Vessel Failure			07 7
Tug Pair Wise Situation Accident Probability Questionnaires Given Propulsion Failure	7 TUG OPERATORS (53, 21, 20, 32 30, 28, 18) 2 PORT CAPTAINS (32, 30)	202 52	Aug-07 Sep-07 Dec-07
Tug Pair Wise Situation Collision Accident Probability Questionnaires Given Steering Failure, Given Navigational Aid Failure Given Human Error Given Near By Vessel Failure	7 TUG OPERATORS (53, 21, 20, 32 30, 28, 18) 2 PORT CAPTAINS (32, 30)	202 52	Aug-07 Sep-07 Dec-07

Summary of Expert Judgment Data Source

- A total of 9 questionnaires
- 38 experts over 7 separate elicitation sessions dispersed over a 1 year period.
- Combined numbers of years sailing experience exceeds 922 years.

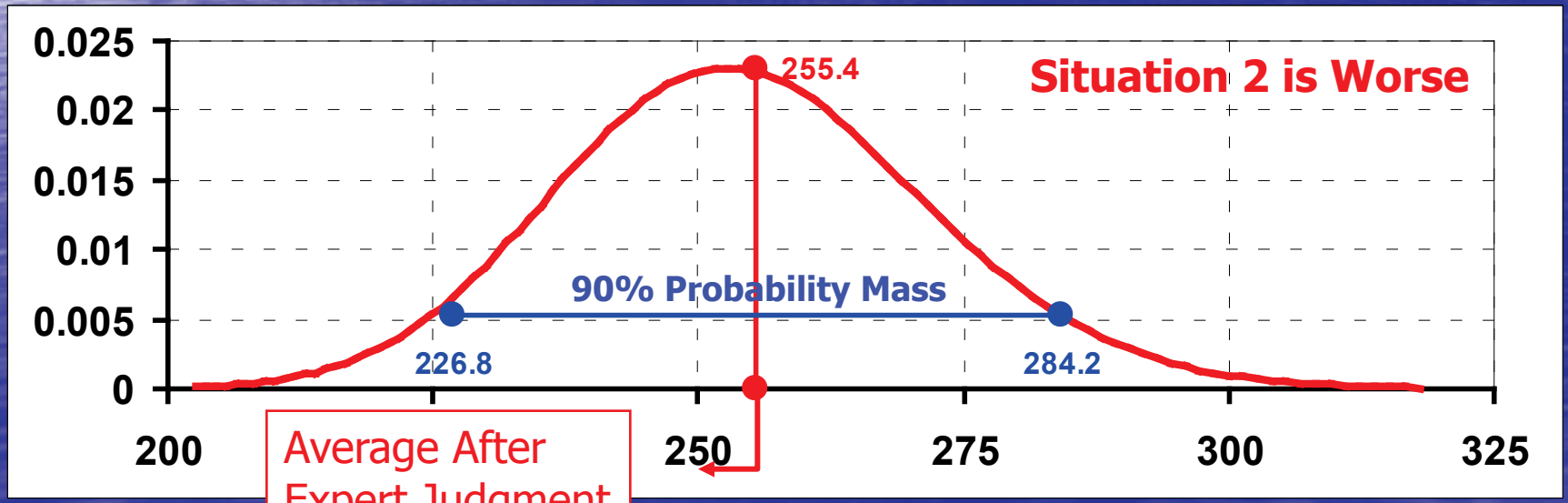
Conduct Expert Judgment Elicitations via Questionnaires

Q30

Situation 1	TANKER DESCRIPTION	Situation 2
Strait of Juan de Fuca East	**Location**	-
Inbound	**Direction**	-
Laden	**Cargo**	-
1 Escort	**Escorts**	-
Untethered	**Tethering**	-
	INTERACTING VESSEL	
Shallow Draft Pass. Vessel	**Vessel Type**	-
Crossing the Bow	**Traffic Scenario**	-
Less than 1 mile	**Traffic Proximity**	-
	WATERWAY CONDITIONS	
More than 0.5 mile Visibility	**Visibility**	Less than 0.5 mile Visibility
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Opposite Direction	**Current Direction**	-
More? : ____	**9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9**	**____ : More?**
Situation 1 is worse	**<==========X==========>**	**Situation 2 is worse**

Example of potential experts: USCG VTS Operators, Puget Sound Pilots, Tanker Captains and First Mates, Tug Captains and First Mates, etc.

Situation 1	TANKER DESCRIPTION	Situation 2
Rosario Strait	**Location**	Guemes Channel
Inbound	**Direction**	-
Laden	**Cargo**	-
1 Escort	**Escorts**	No Escorts
One Tethered	**Tethering**	Untethered
	INTERACTING VESSEL	
Shallow Draft Pass. Vessel	**Vessel Type**	-
Crossing the Bow	**Traffic Scenario**	-
Less than 1 mile	**Traffic Proximity**	-
	WATERWAY CONDITIONS	
More than 0.5 mile Visibility	**Visibility**	-
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Same Direction	**Current Direction**	-

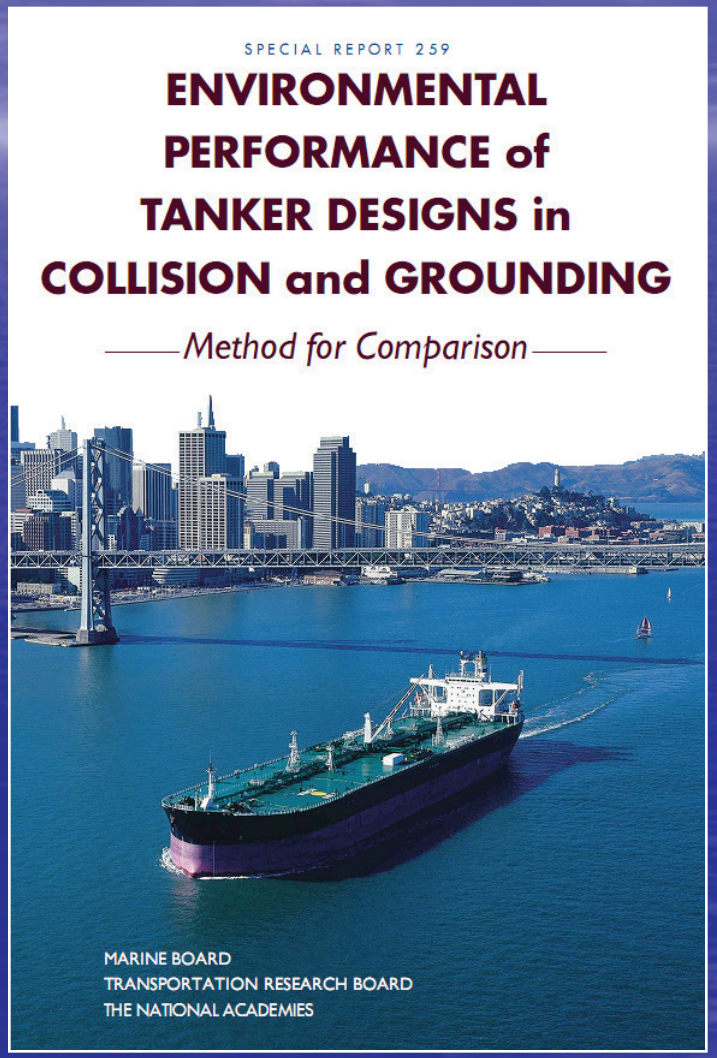


NATIONAL RESEACH COUNCIL SPECIAL REPORT 259

"Given the status of previous efforts to establish a methodology for comparing the environmental performance of alternative tanker designs, **the committee concluded that the development of a new approach was warranted**."

"The committee ran a total of 80,000 accident scenarios: 10,000 collision and 10,000 grounding events for each of two designs (single-hull and double-hull) of the two different sizes (150,000 and 40,000 DWT)."

Quoted from: NRC Special Report 259



Step 1
Damage calculation

A SR 259 Collision Scenario

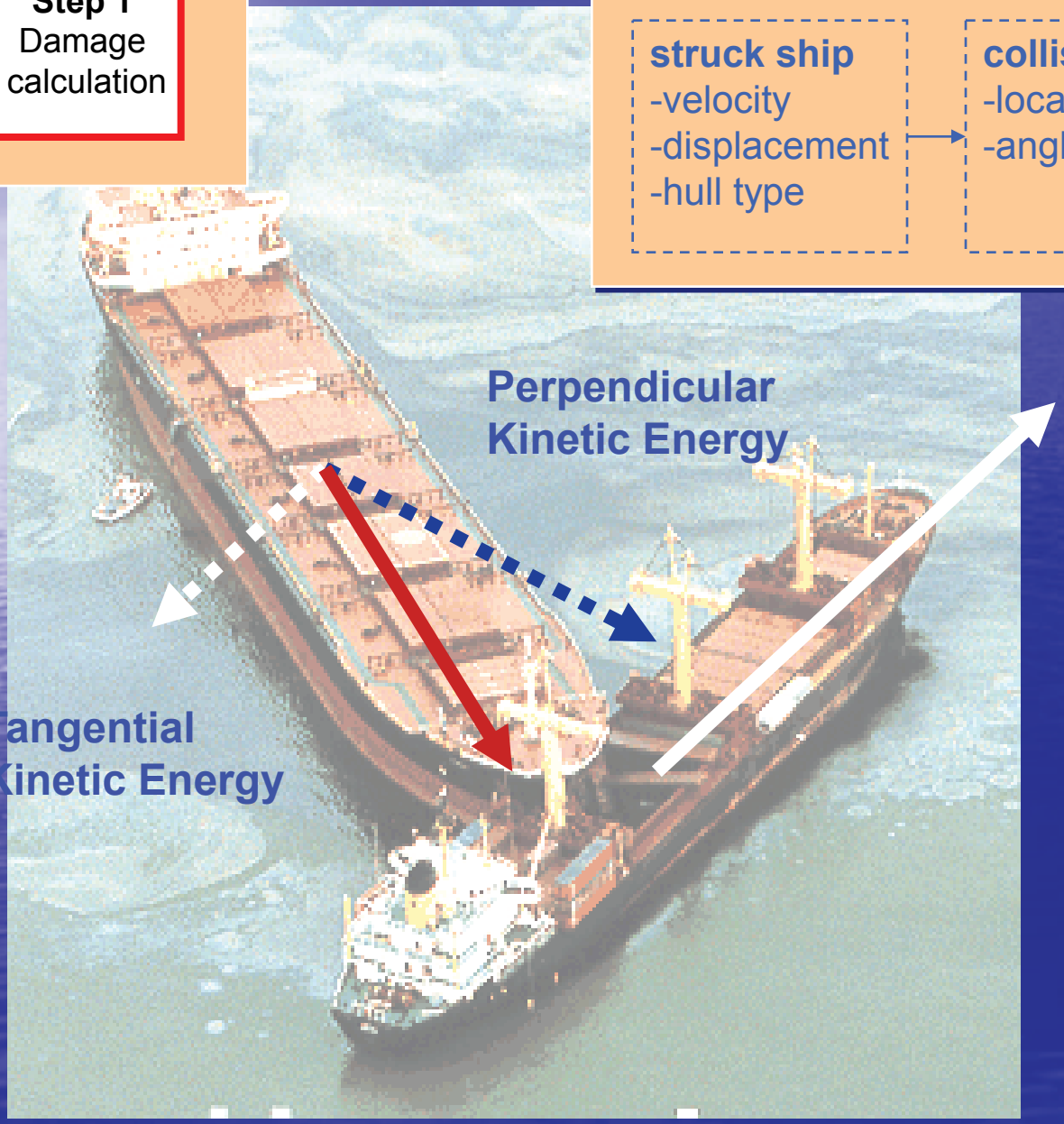
struck ship
-velocity
-displacement
-hull type

→

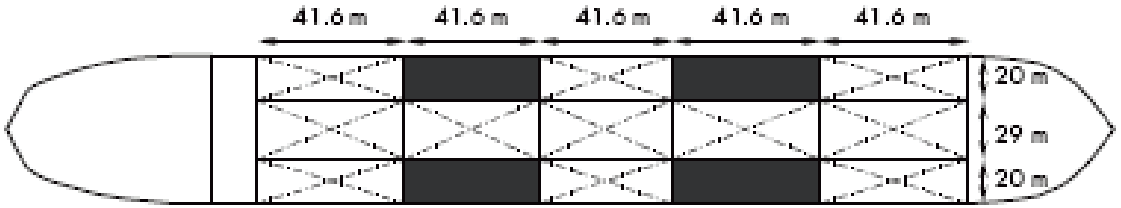
collision
-location
-angle

←

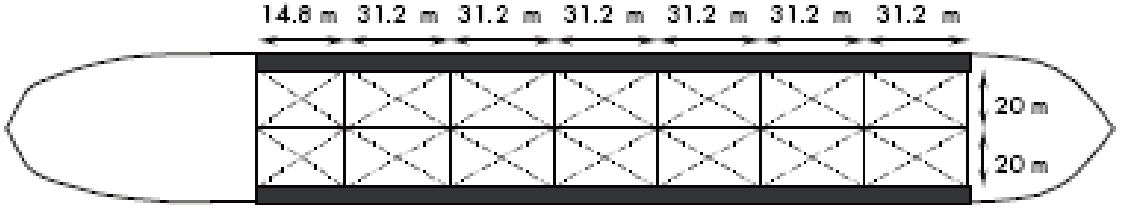
striking ship
-velocity
-displacement
-bow angle



Tanker Configurations 150 kT

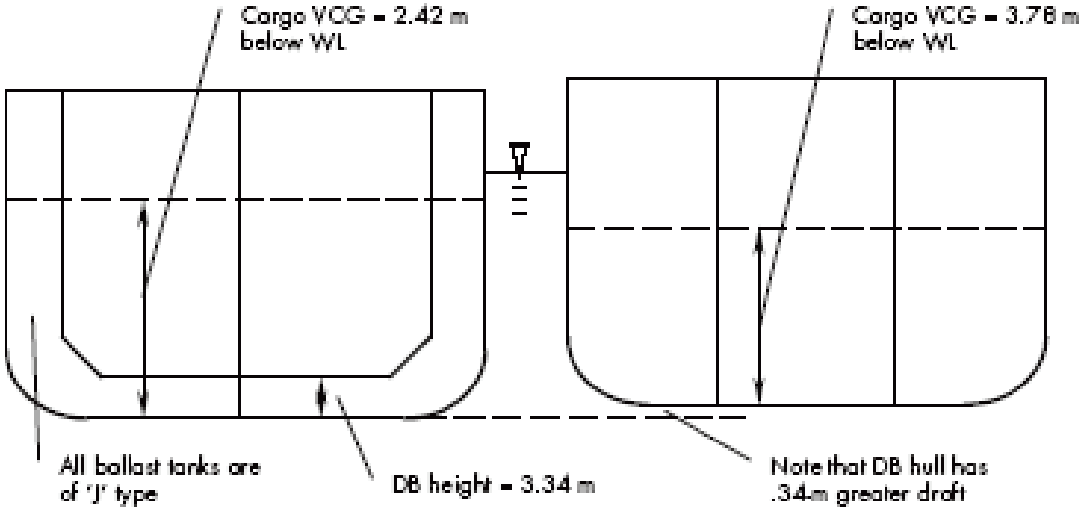


Single Hull



Double Hull

Taken From NRC 259 Report



Special Thanks To:

- US Coast Guard Sector Seattle for being responsive to our countless data request during the enhancement and improvement of our MTS risk simulation methodology and recommending us to the Puget Sound Harbor Safety Committee.
- Puget Sound Harbor Safety Committee who served as a host for bimonthly meetings and provide us access to Seattle Maritime Community.
- The Seattle Maritime Community as a whole who unselfishly met with us and provided access to experts both for ship rides but also for their participation in many expert judgment elicitation sessions during which these experts donated their time for the safety improvement in their Maritime Domain.

THANK YOU!!!!

- Without their help, efficient and timely response to our repeated questions and data requests we would not have been able to further enhance and improve our MTS Risk Simulation Methodology.

QUESTIONS?


Rensselaer
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON DC
VCU
TU Delft
Delft University of Technology