Future Scenario - Definition

Presentation by: J. Rene van Dorp

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VCU

GWU Personnel: Dr. J. Rene van Dorp

VCU Personnel: Dr. Jason R. W. Merrick

MARCH 15, 2013

2010 VTRA STUDY – FUTURE PROJECT + FOCUS VESSELS

BASE CASE: VTRA UPDATED WITH VTOSS 2010

FOCUS VESSEL	VESSEL TYPE
1	Oil Tanker
2	ATB
3	Oil Barge
4	Bulk Carrier
5	Container Vessels

FUTURE	SCENARIO
1	GATEWAY
2	KINDER MORGAN
3	DELTA\WEST SH\ NEPTUNE
4	OTHER TRENDS

SUGGESTED APPROACH TOWARDS FUTURE SCENARIO DEFINITION:

- **Keep interacting vessels at VTOSS 2010 levels, limit to FV changes**
- **Each Scenario may result in Focus Vessel increases**
- **Each Scenario may result in Focus Vessel decreases**

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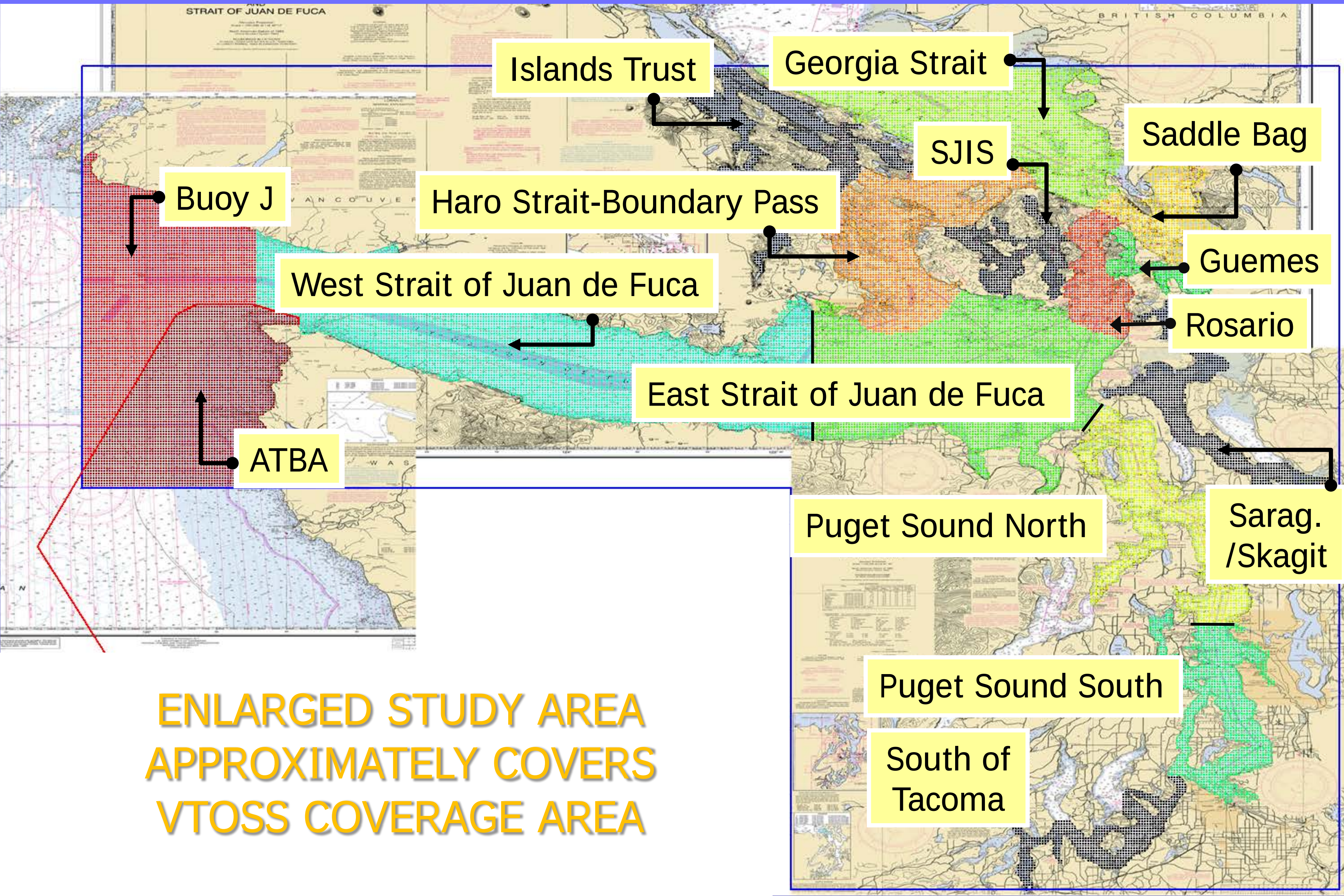
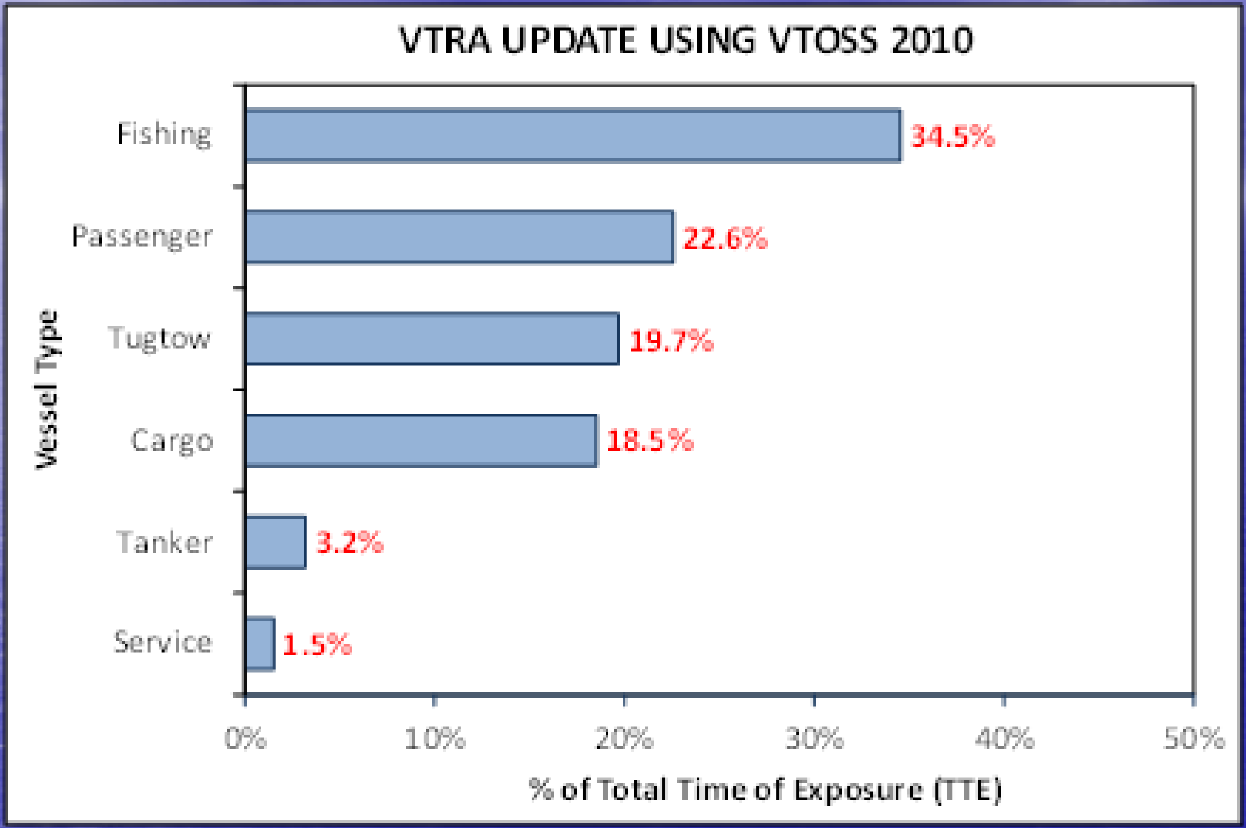
VTRA STUDY AREA - 15 DEFINED LOCATIONS



ENLARGED STUDY AREA APPROXIMATELY COVERS VTOSS COVERAGE AREA

2010 VTRA STUDY AREA – 15 WATERWAY LOCATIONS



Larger Traffic – Modeled in VTRA Model using VTOSS 2010 data

VTS Participating Traffic: Seattle, Tofino and Victoria

Smaller Traffic – Modeled in VTRA Model using other data

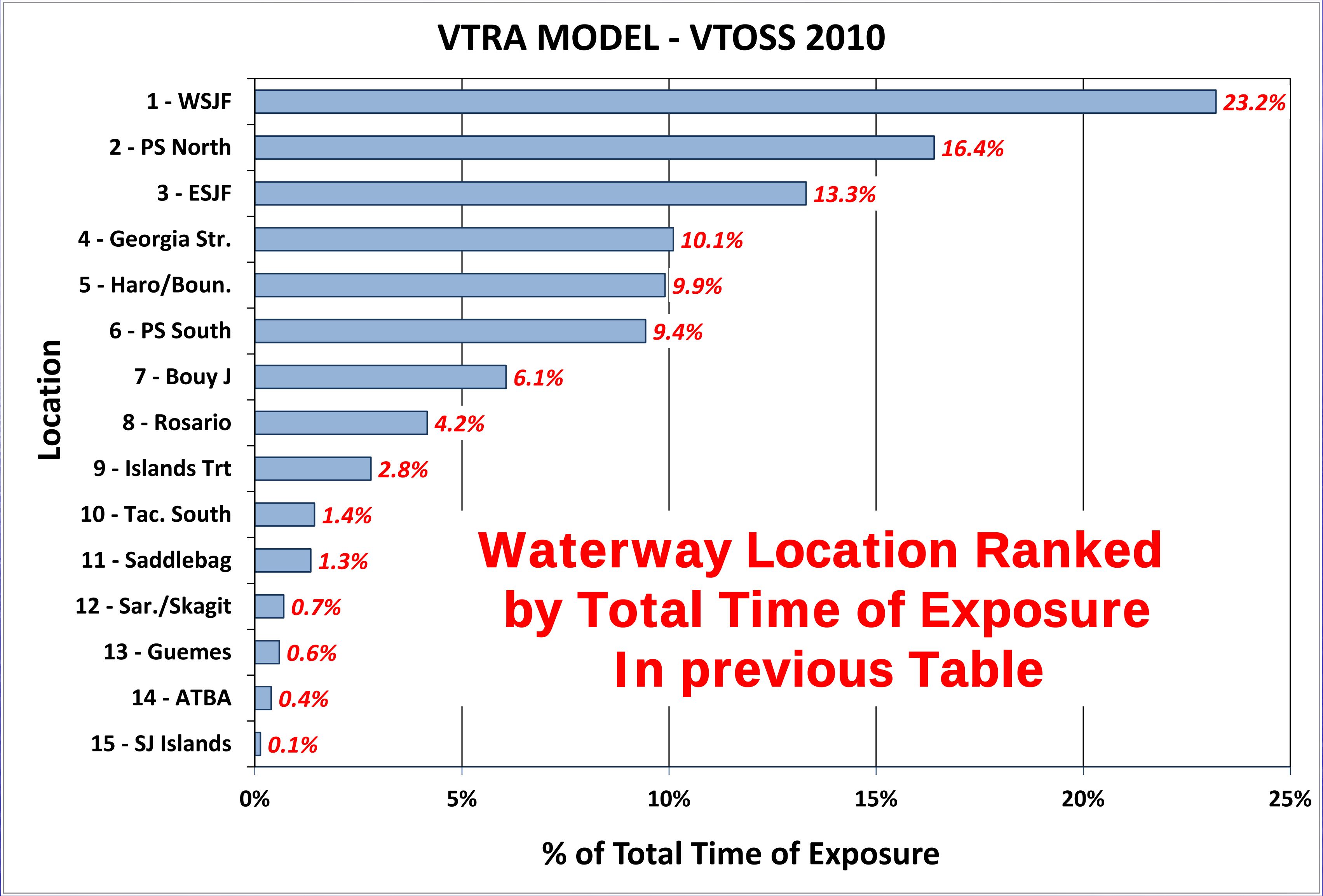
State, Tribal, Canadian fisheries, Permitted Regatta Events, Whale Watching Activities

2010 VTRA STUDY AREA – 15 WATERWAY LOCATIONS

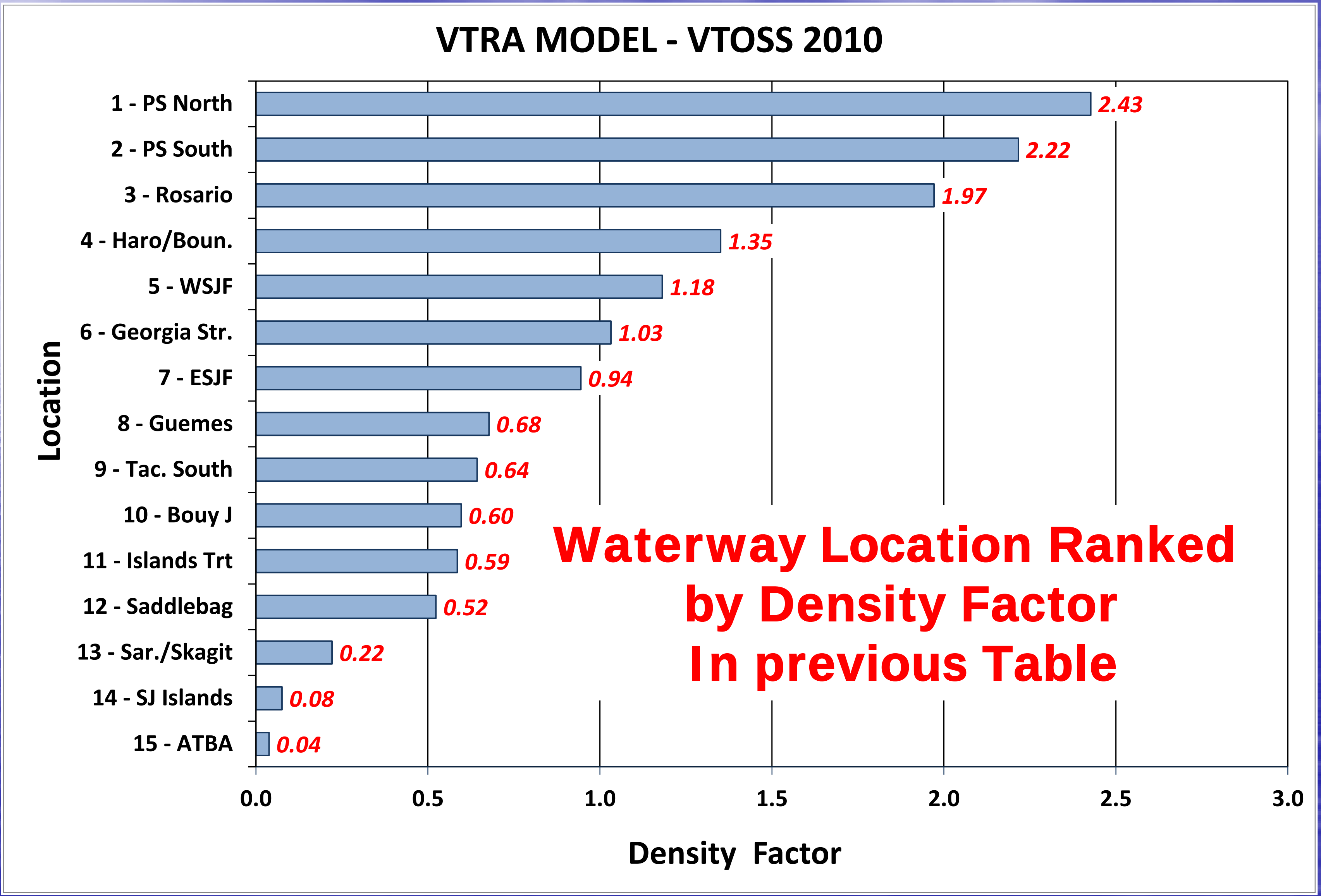
With eye towards larger potential oil spills restrict in Table below to Tanker, Cargo, Tug-Tow

LOCATION	# Grid Cells	% Area	# Days Vessel is Moving per year	Average # of Vessels	% of Total Time of Exposure	Density Factor (DF)
WSJF	2857	19.6%	2683.7	7.4	23.2%	1.18
PS North	983	6.8%	1896.7	5.2	16.4%	2.43
ESJF	2049	14.1%	1538.9	4.2	13.3%	0.94
Georgia Str.	1424	9.8%	1168.3	3.2	10.1%	1.03
Haro/Boun.	1066	7.3%	1145.1	3.1	9.9%	1.35
PS South	619	4.3%	1090.9	3.0	9.4%	2.22
Bouy J	1478	10.2%	701.5	1.9	6.1%	0.60
Rosario	307	2.1%	481.2	1.3	4.2%	1.97
Islands Trt	696	4.8%	324.0	0.9	2.8%	0.59
Tac. South	326	2.2%	166.7	0.5	1.4%	0.64
Saddlebag	375	2.6%	156.0	0.4	1.3%	0.52
Sar./Skagit	459	3.2%	80.8	0.2	0.7%	0.22
Guemes	127	0.9%	68.4	0.2	0.6%	0.68
ATBA	1520	10.5%	45.9	0.1	0.4%	0.04
SJ Islands	259	1.8%	15.6	0.0	0.1%	0.08
Total	**13246**	**100.0%**	**11563.8**	**31.7**	**100.0%**	**1.0**

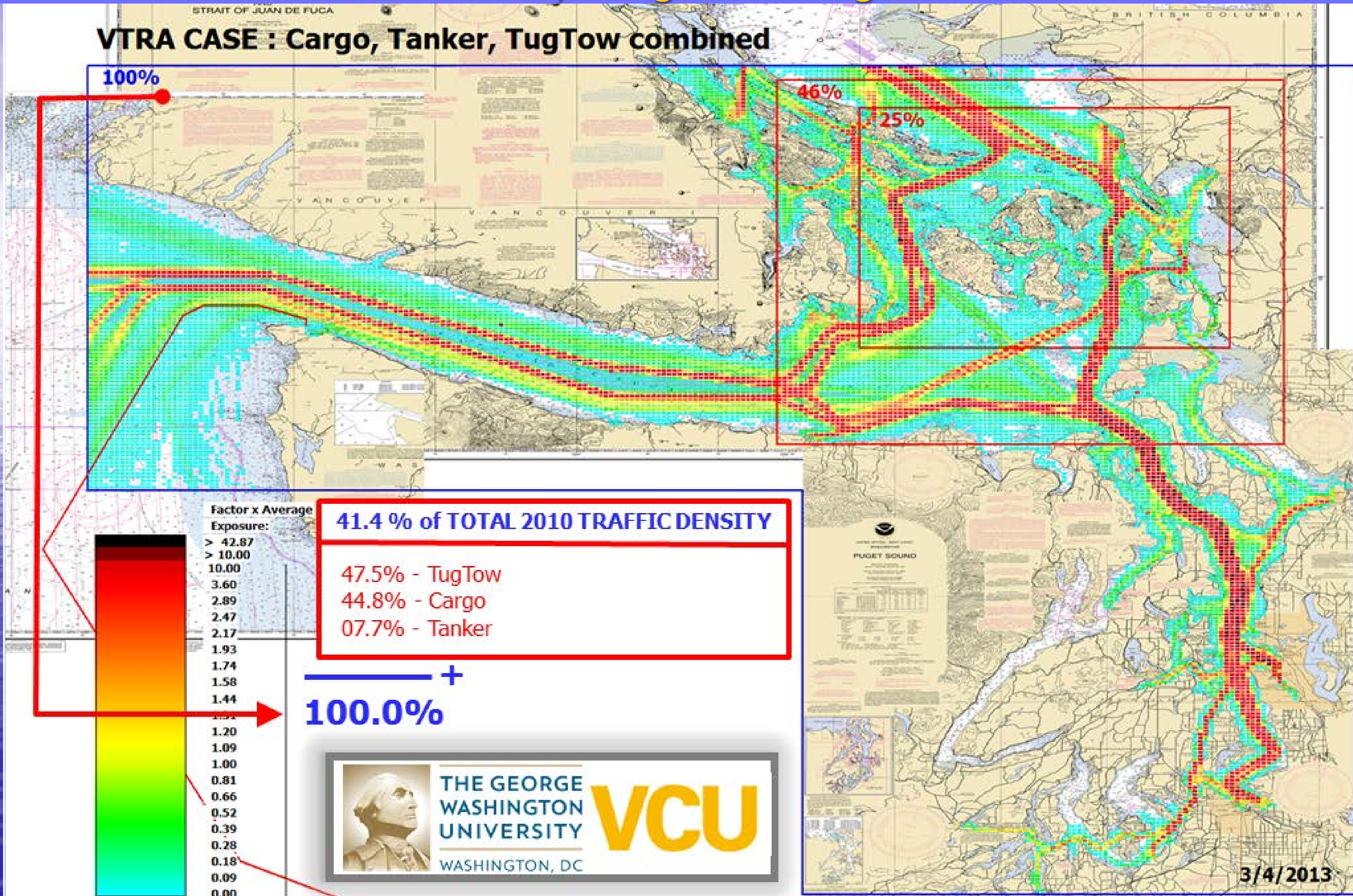
2010 VTRA STUDY AREA – 15 WATERWAY LOCATIONS



2010 VTRA STUDY AREA – 15 WATERWAY LOCATIONS



2010 VTRA STUDY – EXPOSURE GEOGRAPHIC PROFILE
Tanker, Cargo and Tug-Tow



Towards the Development of a Comprehensive Vessel Traffic Risk Management Tool

Presentation by: J. Rene van Dorp

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

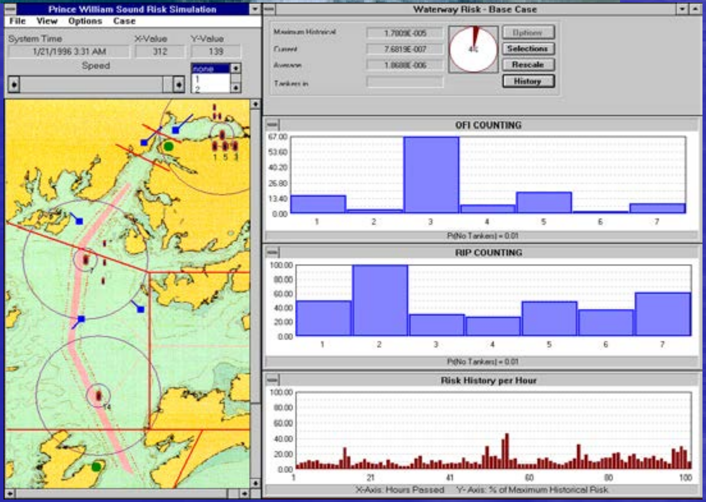
RPI Personnel: Dr. Martha Grabowski, Zhi Zhou, Michael Steward, Brittany Steward, Huawei Song, Zhuyu You

TU Delft Personnel: Giel van de Wiel

Puget Sound Harbor Safer Committee Presentation April 2012

Previous Work

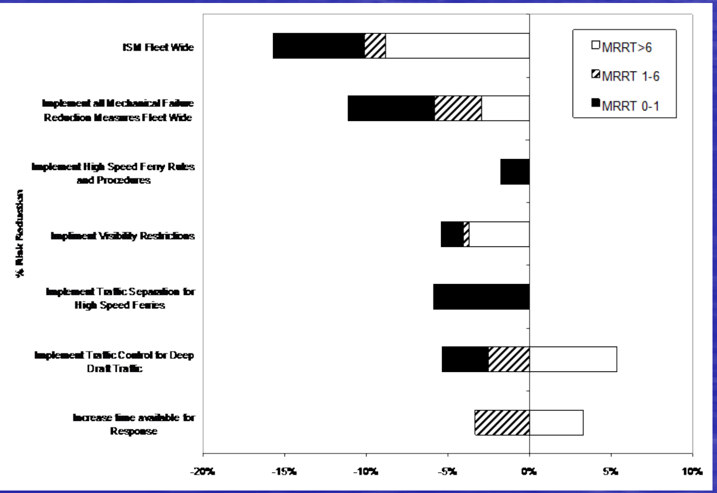
- Prince William Sound Risk Assessment
  - Site of the Exxon Valdez Disaster
  - Objective—reduce oil spill risk
  - Model used system simulation, data analysis and expert judgment
  - Capable of modeling systemic effects of proposed interventions
  - Multi-million dollar investments made to reduce risk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

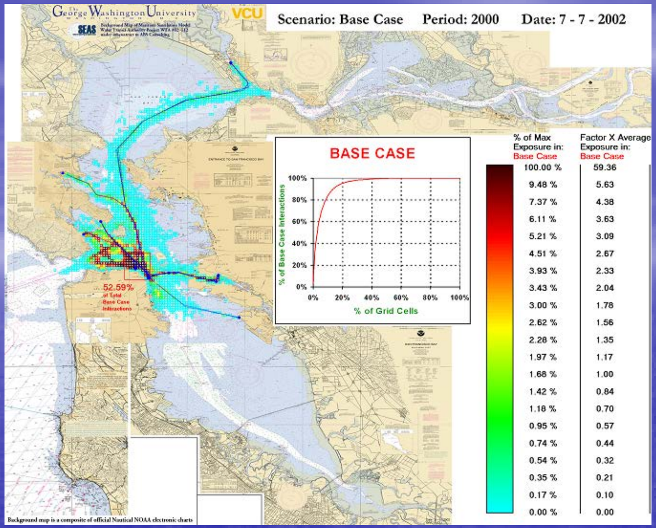
- Washington State Ferries Risk Assessment
  - Largest ferry system in the United States
  - Objective—Subchapter W determination, reduce risk alternatives to lifeboats
  - Simulation/expert judgment model improved based on NRC review of PWS study
  - Legislature approved funding of Safety Management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

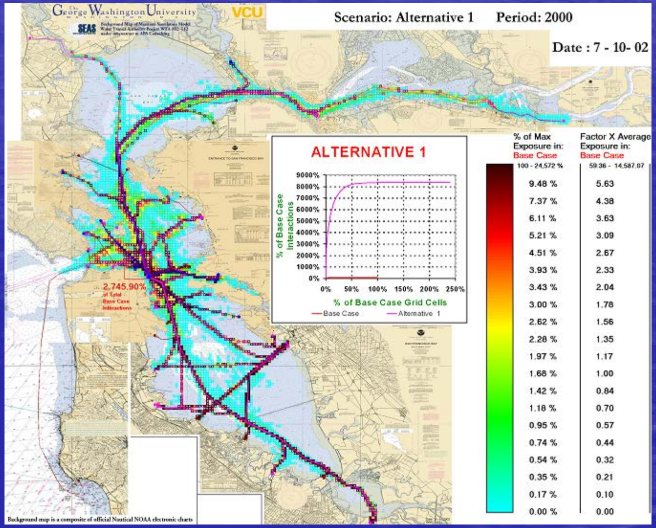


van Dorp, J. R., J. R. W. Merrick, J. Harrald, T. Mazzuchi, M. Grabowski. 2001. A Risk Management Procedure for the Washington State Ferries. *Risk Analysis* **21**(1) 127-142.

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

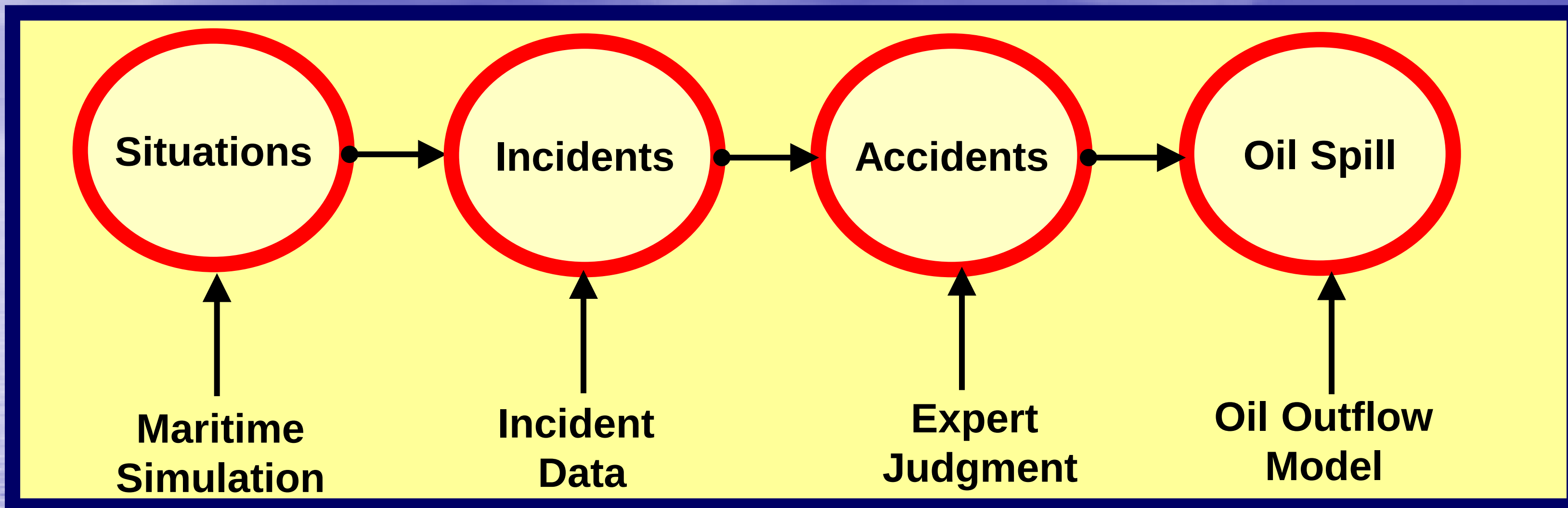




Merrick, J. R. W., J. R. van Dorp, J. P. Blackford, G. L. Shaw, J. Harrald, T.A. Mazzuchi. 2003. Traffic Density Analysis of Proposed Ferry Service Expansion in San Francisco Bay Using a Maritime Simulation Model. *Reliability Engineering and System Safety* **81**(2) 119-132.

CONTEXT OF VTRA STUDY

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



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

Scenario i

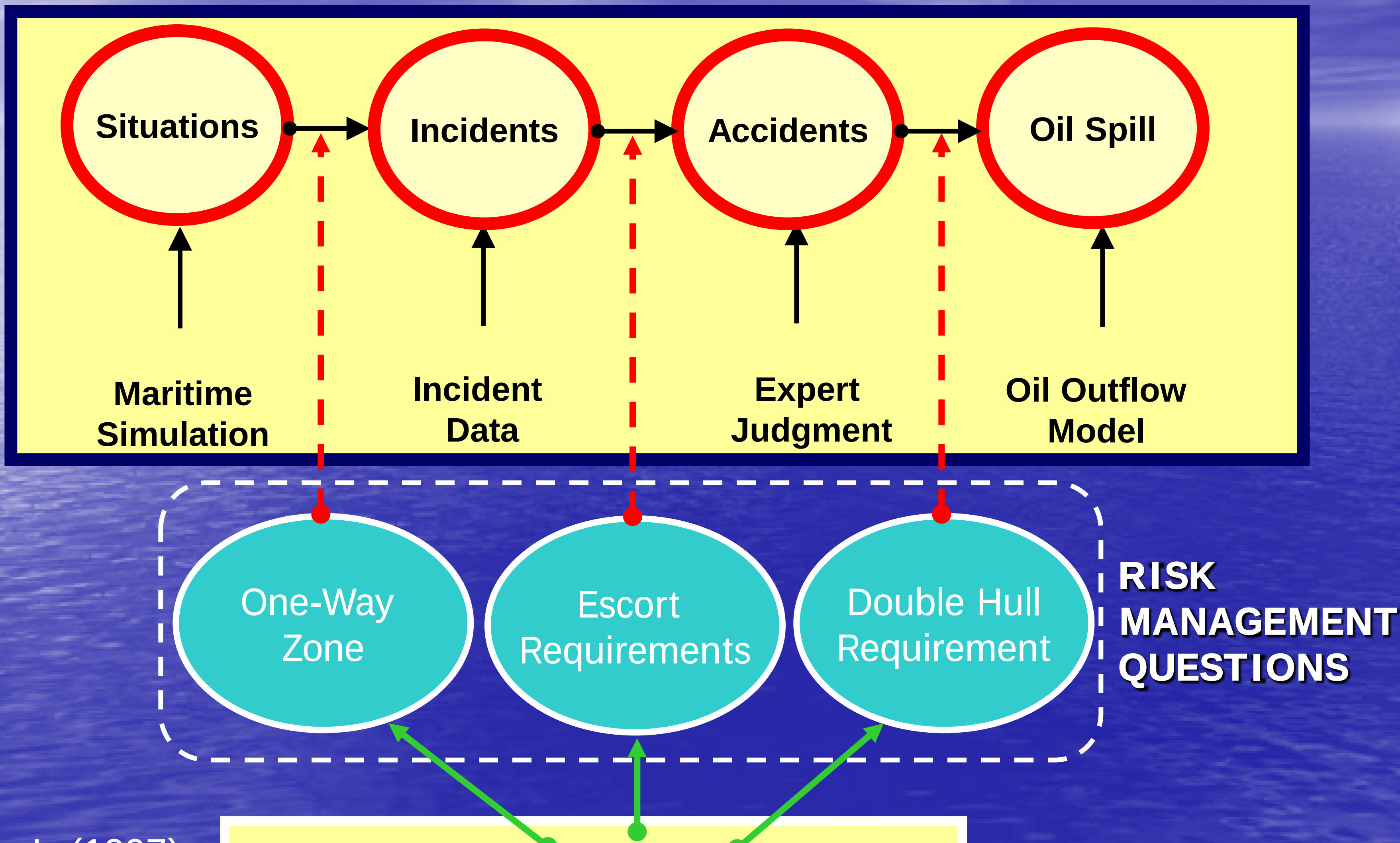
Likelihood i

Consequence i

Complete Set

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

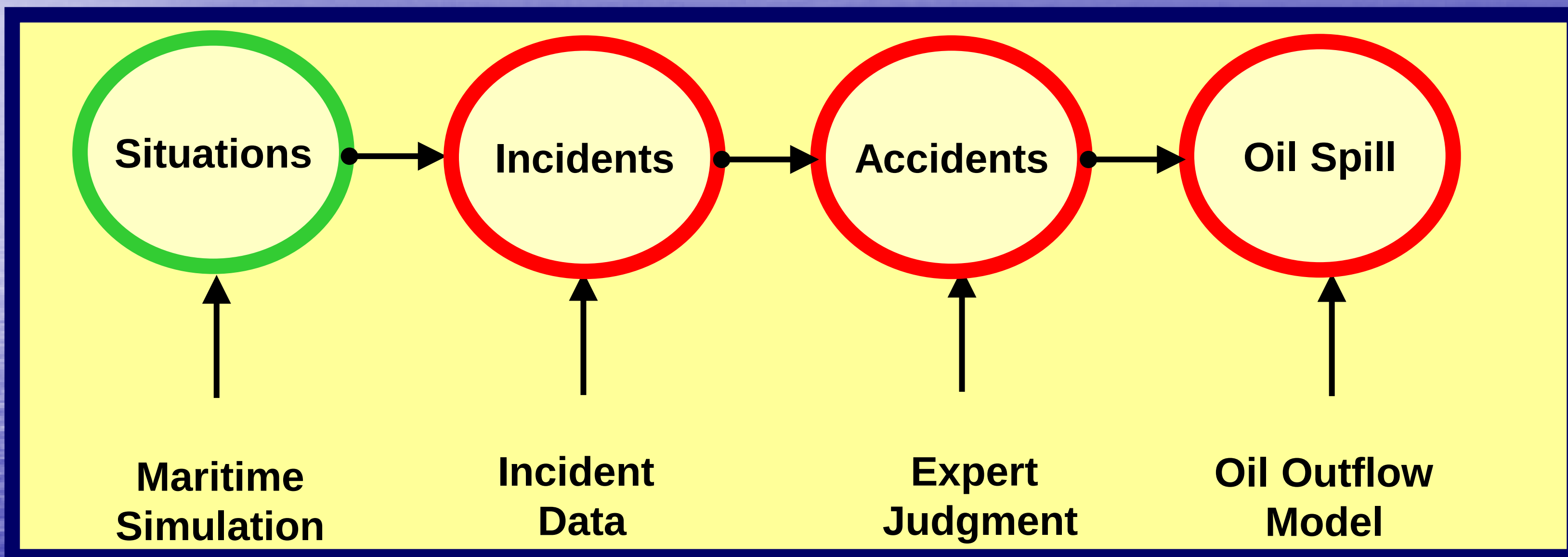
Risk Management of a Causal Chain



Kaplan's (1997) Risk Definition

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

Step 1: Generate Accident Scenarios

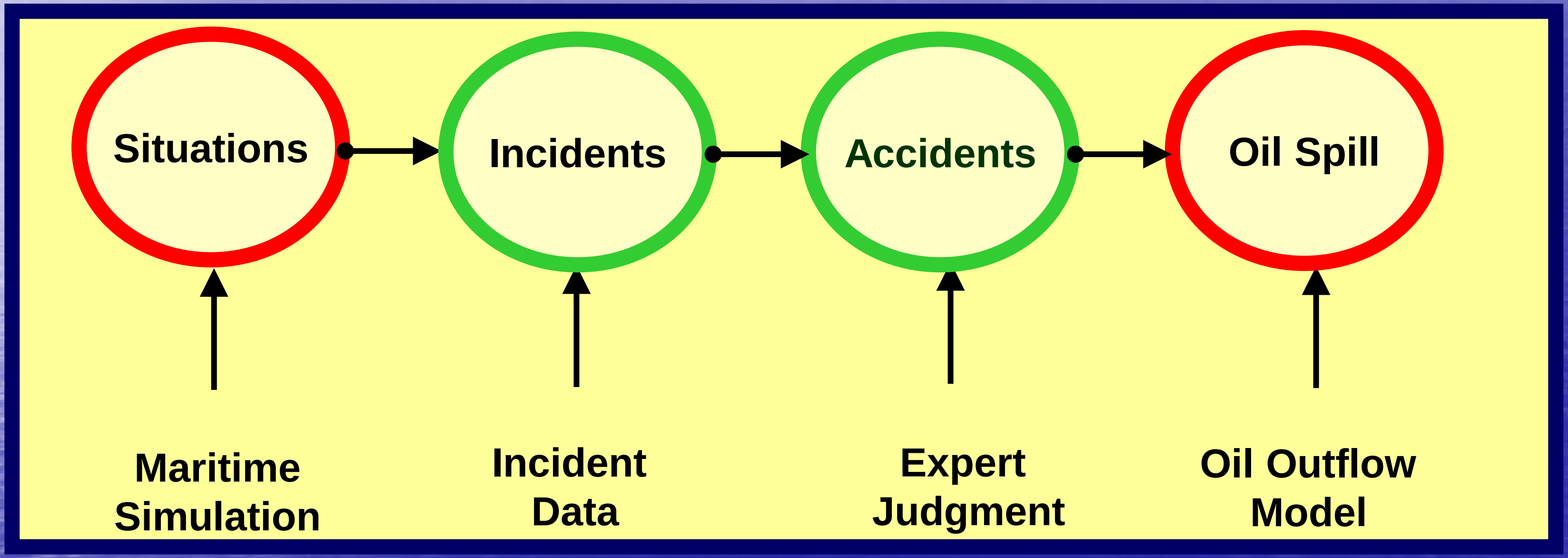


Joint work with:

VCU

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

Step 2: Evaluate Accident Likelihood per Accident Scenario



Joint work with:

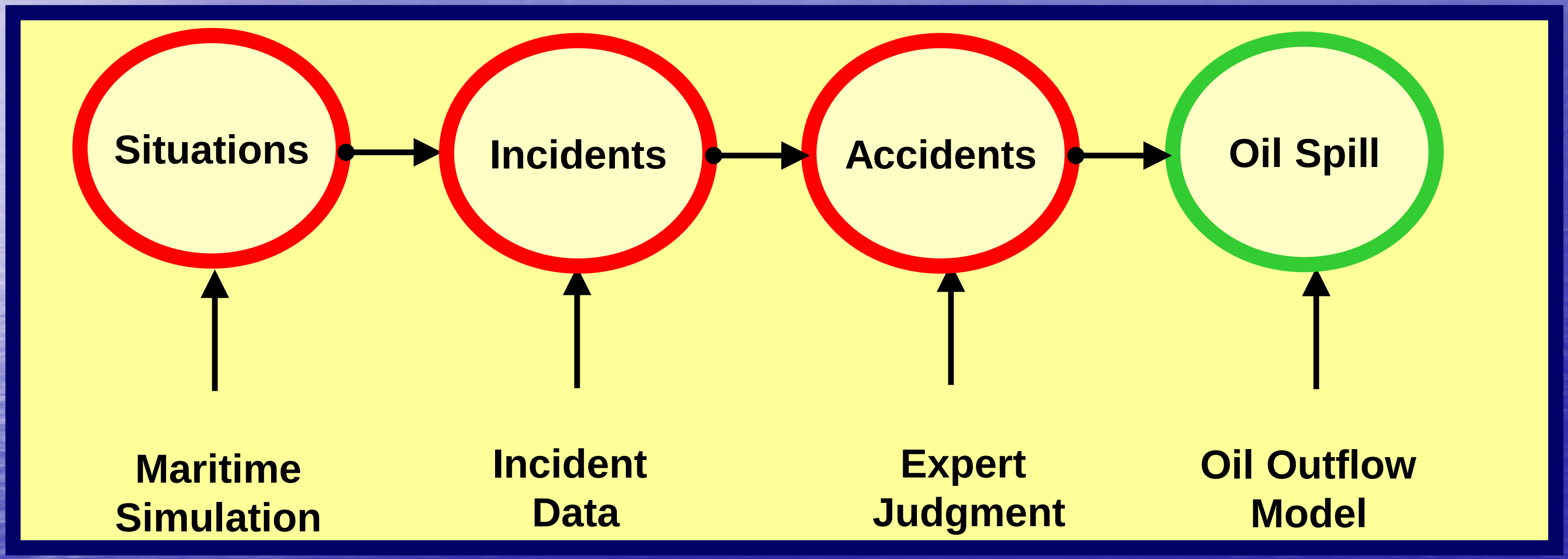
VCU Personnel:
Dr. Jason R. W. Merrick, and Team

VCU

RPI Personnel:
Dr. M. Grabowsku, and Team

Rensselaer

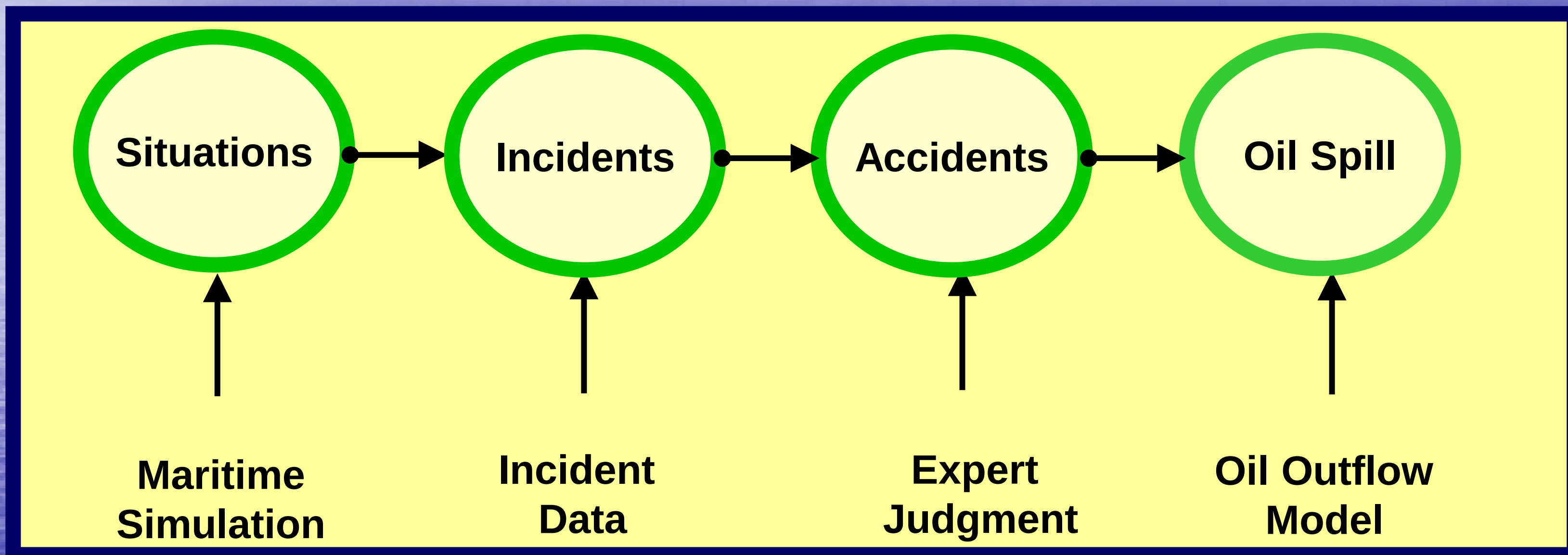
Step 3: Evaluate Consequence per Accident Scenario



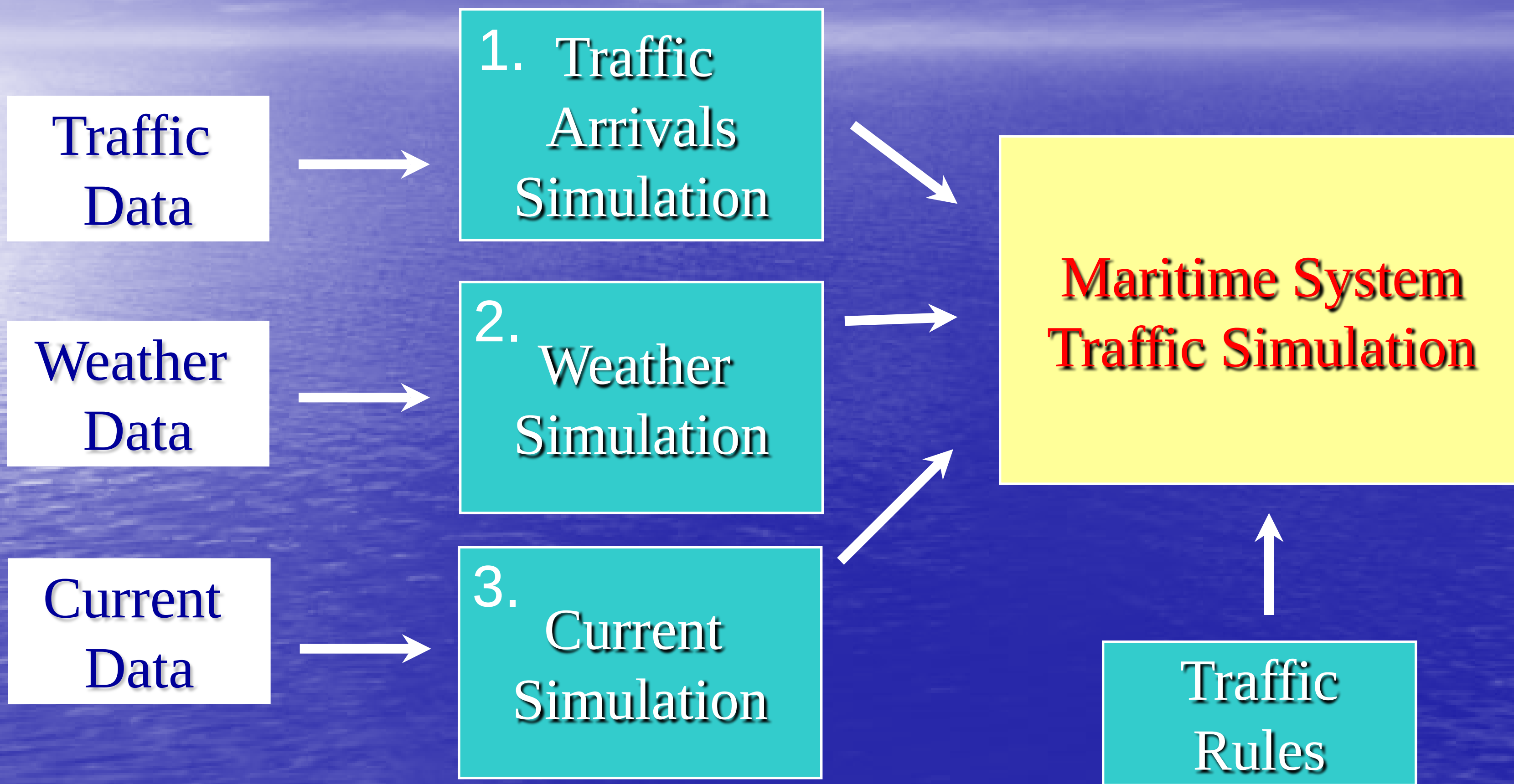
Joint work with:

TU Delft Personnel:
Giel van de Wiel

Step 4: Integrate Previous 3 Steps



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



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

Route Modeling:

Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

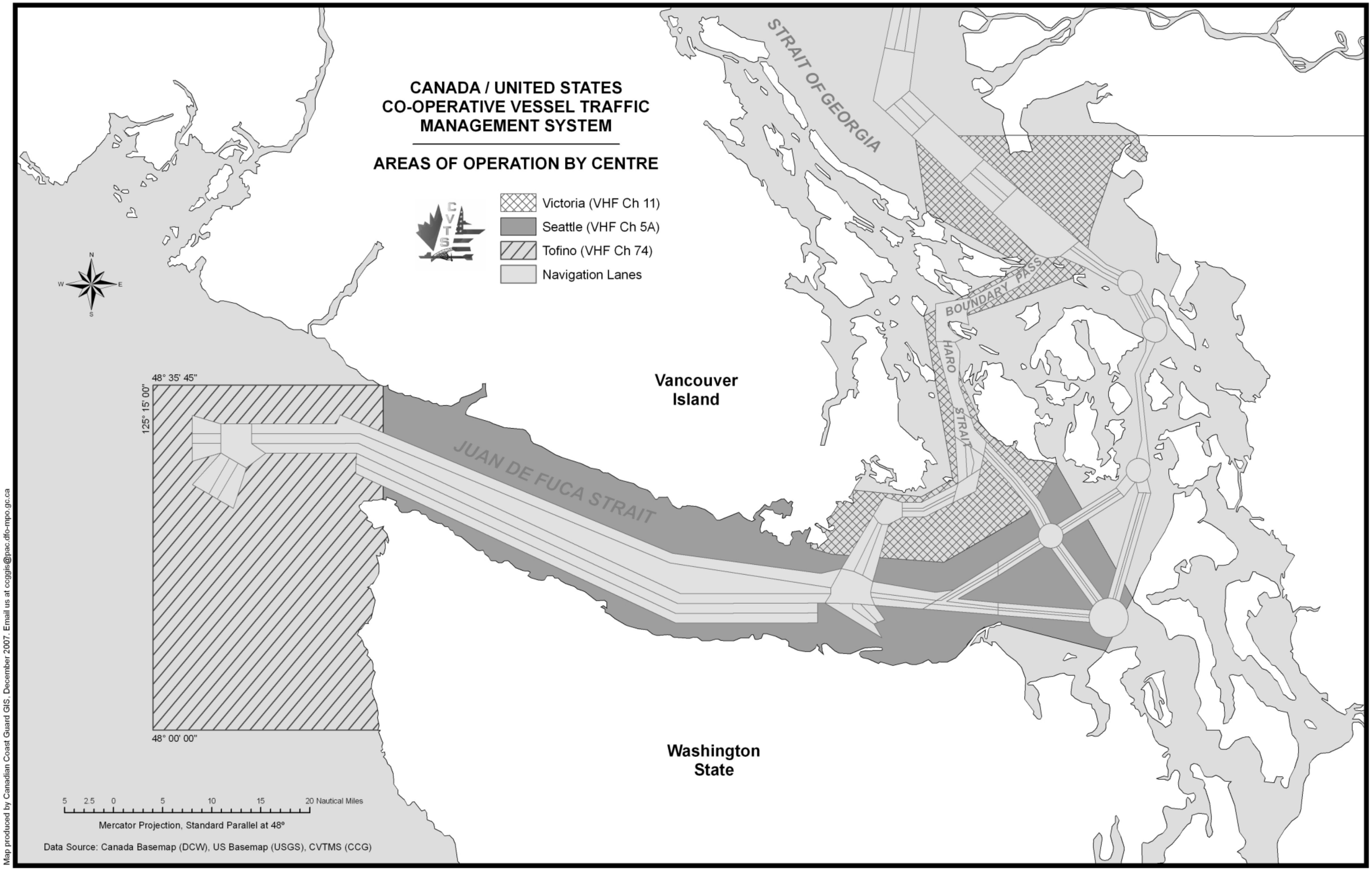
GWU Personnel:
Dr. Jack R. Harrald, Dr. J. Rene van Dorp, Dr. Greg Shaw,
Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
Dr. Martha Grabowski, Zhi Zhou

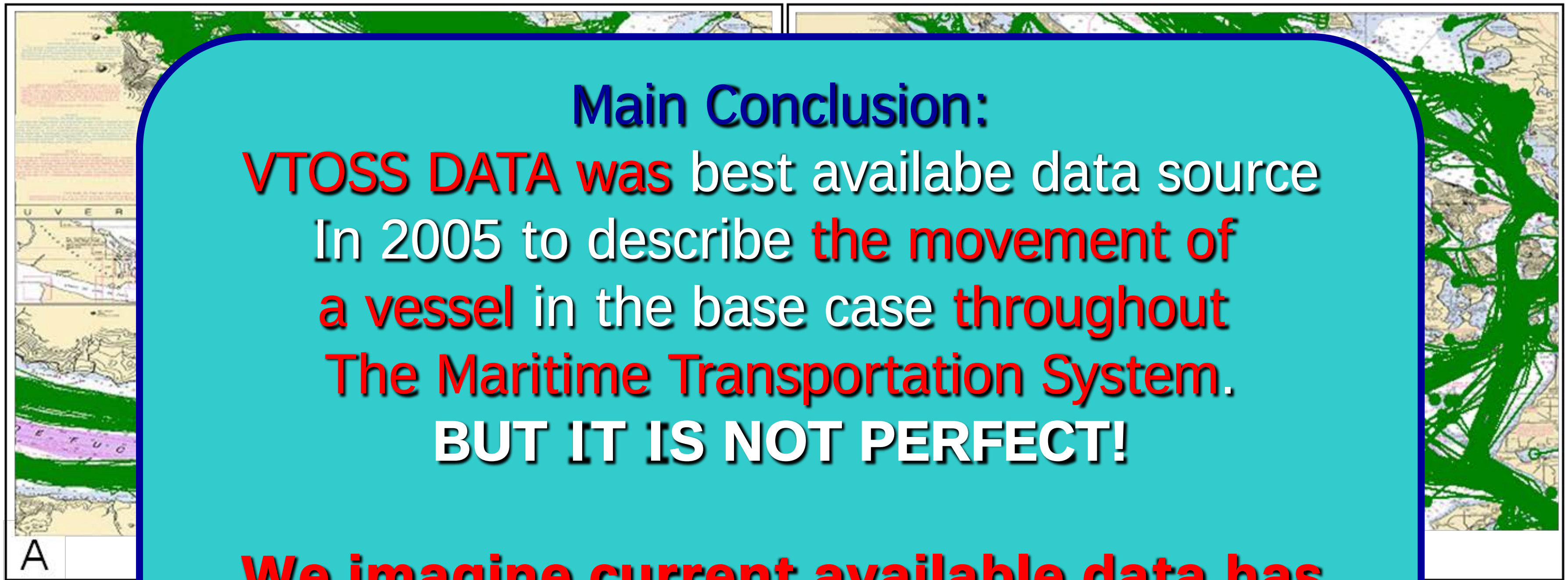
VCU Personnel:
Dr. Jason R. W. Merrick, Christina Werner

July 7, 2006

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 best availabe data source In 2005 to describe the movement of a vessel in the base case throughout The Maritime Transportation System.

BUT IT IS NOT PERFECT!

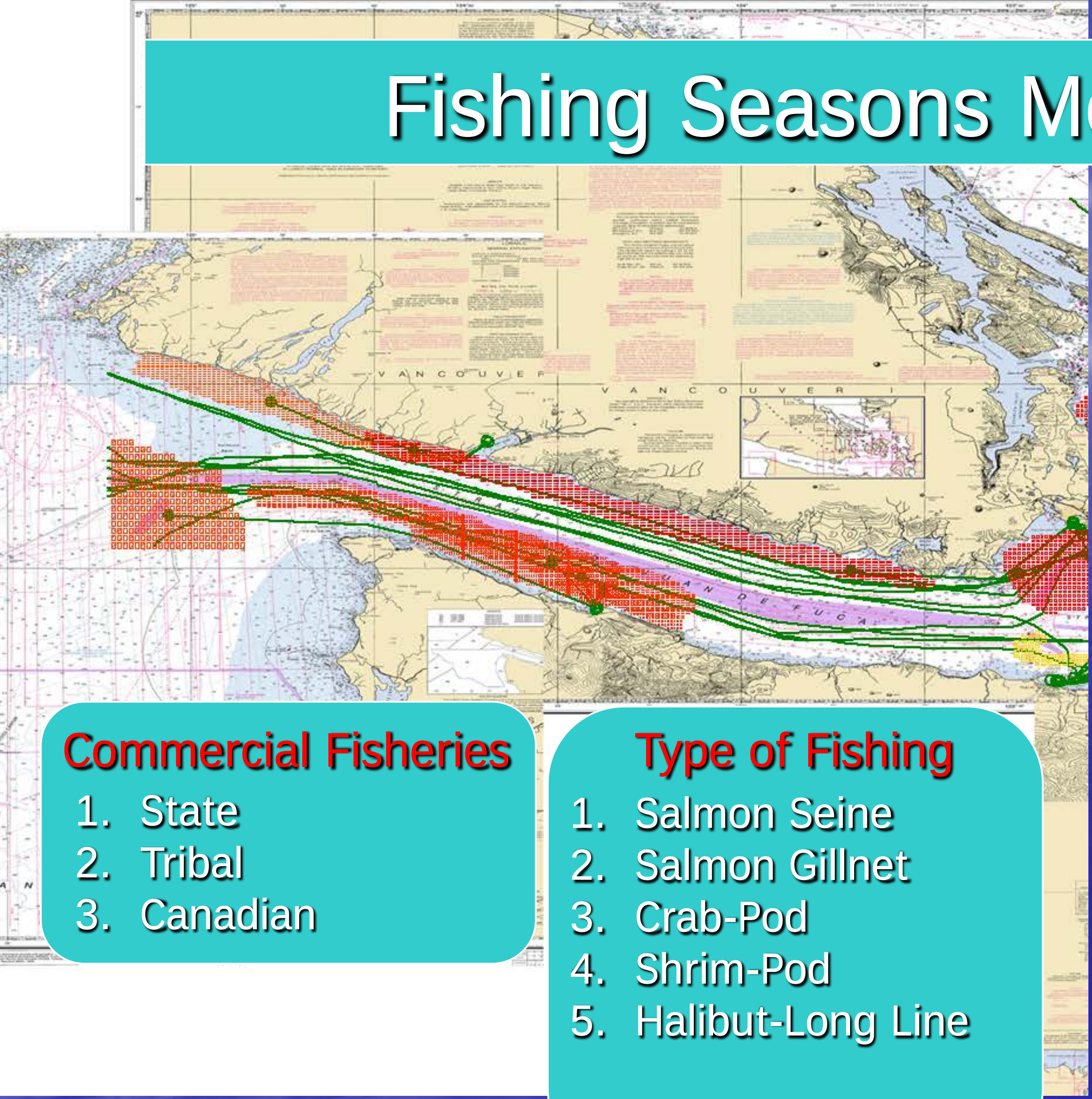
We imagine current available data has improved

Vessel Name												Beam	Draft
ITB BALTIMORE	CAL											32.23	12.8
ITB BALTIMORE	SEAT										.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 constructed traffic routes according to their arrivals in the VTOSS database

© GWU-RPI-VCU November 2011

Fishing Seasons Modeling



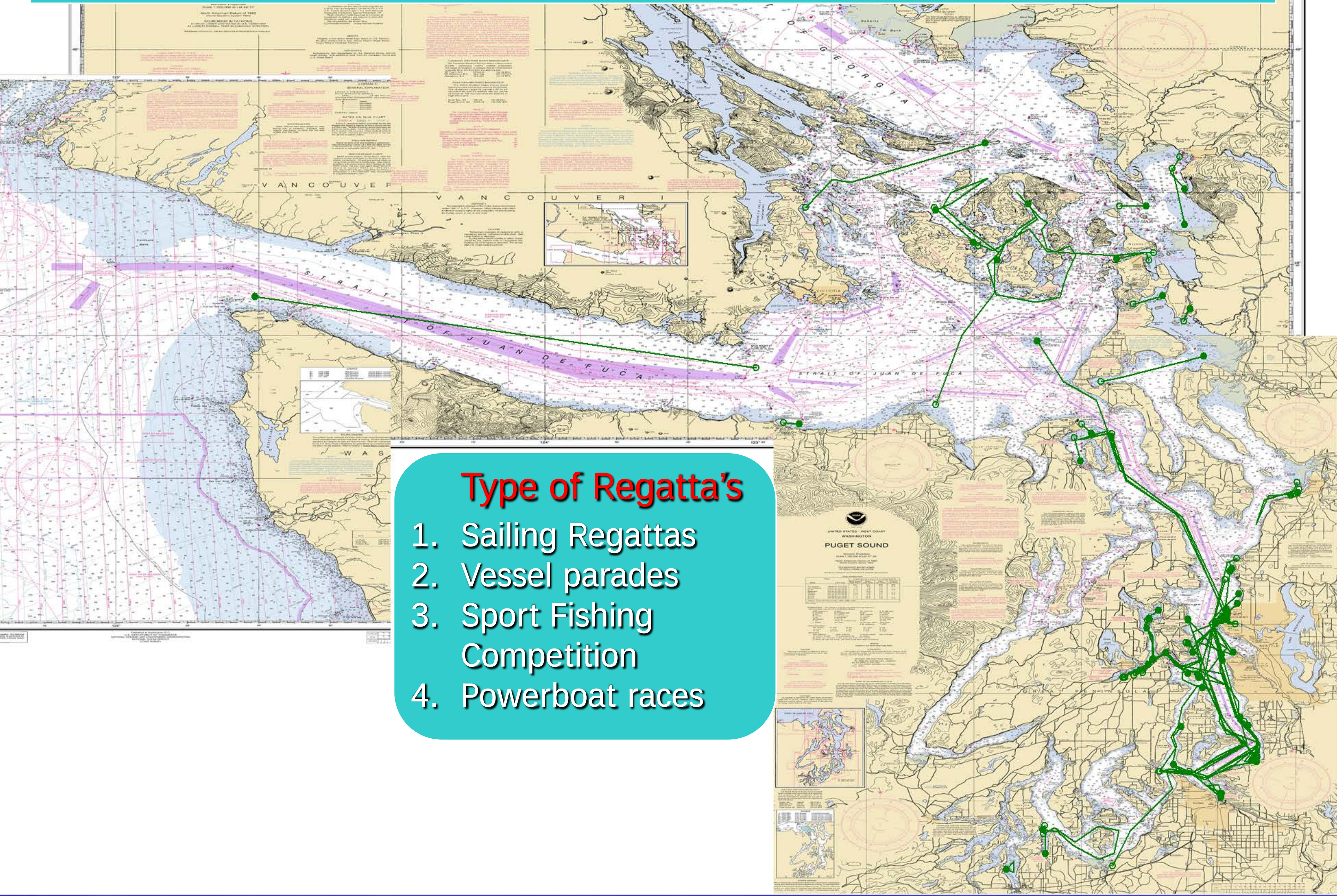
Commercial Fisheries

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.

Wind Model Presentation:
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GWU Personnel:
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Dr. Thomas A. Mazzuchi, Adil Caner Sener

RPI Personnel:
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VCU Personnel:
Dr. Jason R. W. Merrick, Kristina Werner

December 7, 2006

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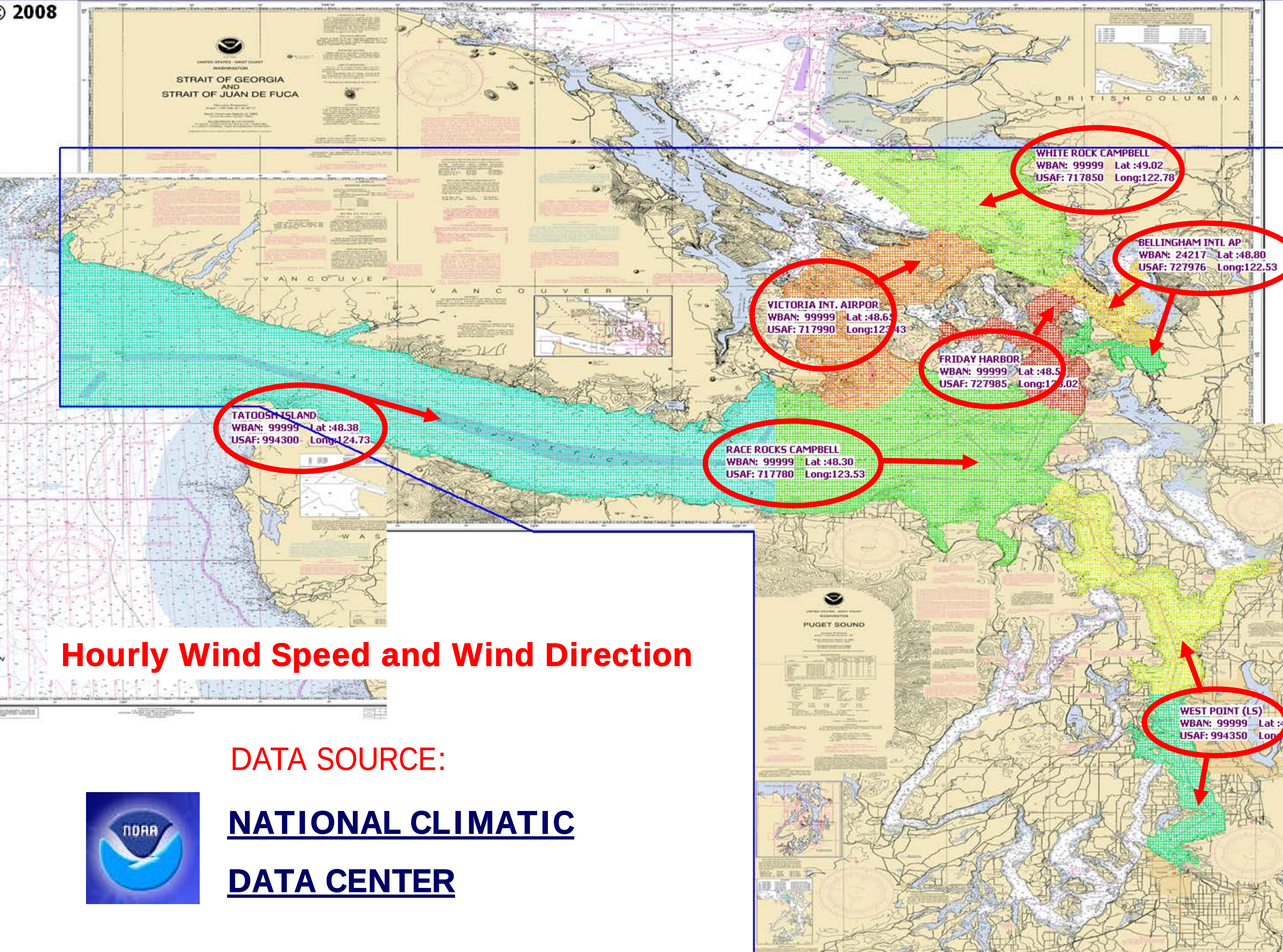
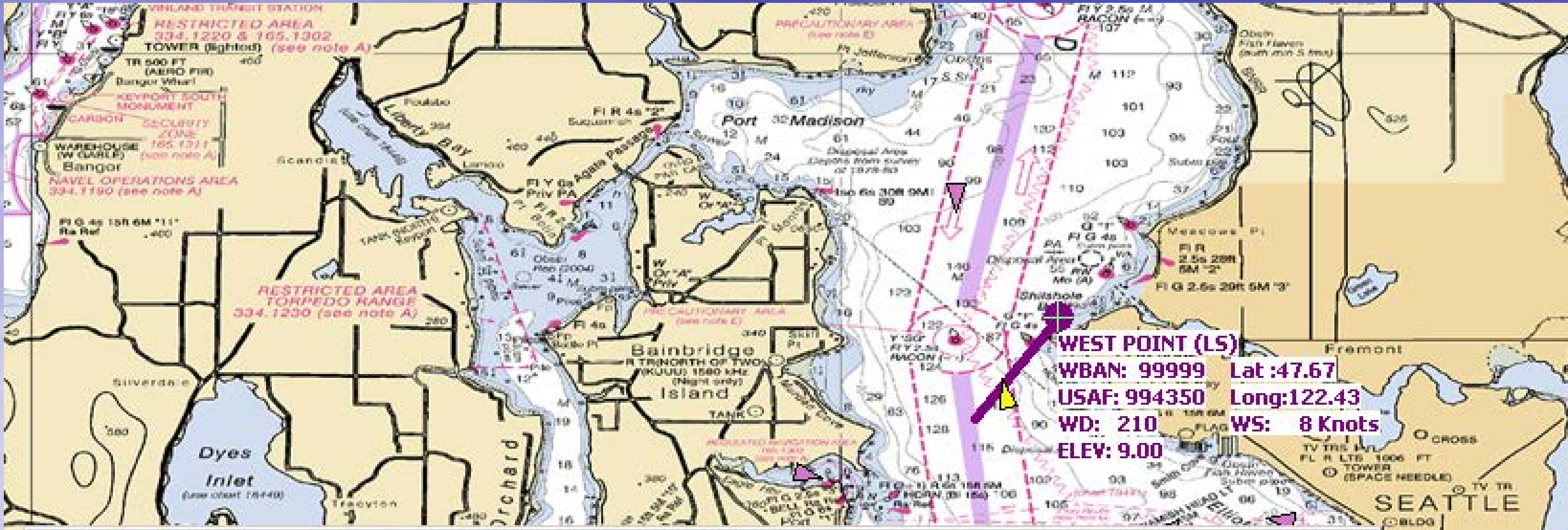


Hourly Wind Speed and Wind Direction

DATA SOURCE:

NATIONAL CLIMATIC DATA CENTER



Data base - Wind

YY	MM	DD	HH	BH WD	BH WS	FH WD	FH WS	RR WD	RR WS
2005	3	6	20	40	6	30	3	40	10
2005	3	6	21	10	6	30	5	60	12
2005	3	6	22	10	5	30	5	70	10
2005	3	6	23	50	7	90	3	70	8
2005	3	7	0	30	5	10	4	50	6
2005	3	7	1	30	5	10	0	60	8
2005	3	7	2	360	0	10	0	70	7
2005	3	7	3	360	0	360	3	70	8
2005	3	7	4	360	0	360	3	30	10
2005	3	7	5	360	0	360	4	30	7
2005	3	7	6	290	3	360	0	40	5
2005	3	7	7	290	0	360	0	250	1
2005	3	7	8	290	0	360	0	250	7
2005	3	7	9	280	3	360	0	250	7
2005	3	7	10	280	0	360	3	260	7
2005	3	7	11	280	0	360	0	270	8
2005	3	7	12	280	0	230	4	270	11

VISIBILITY Model Presentation:
Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

GWU Personnel:
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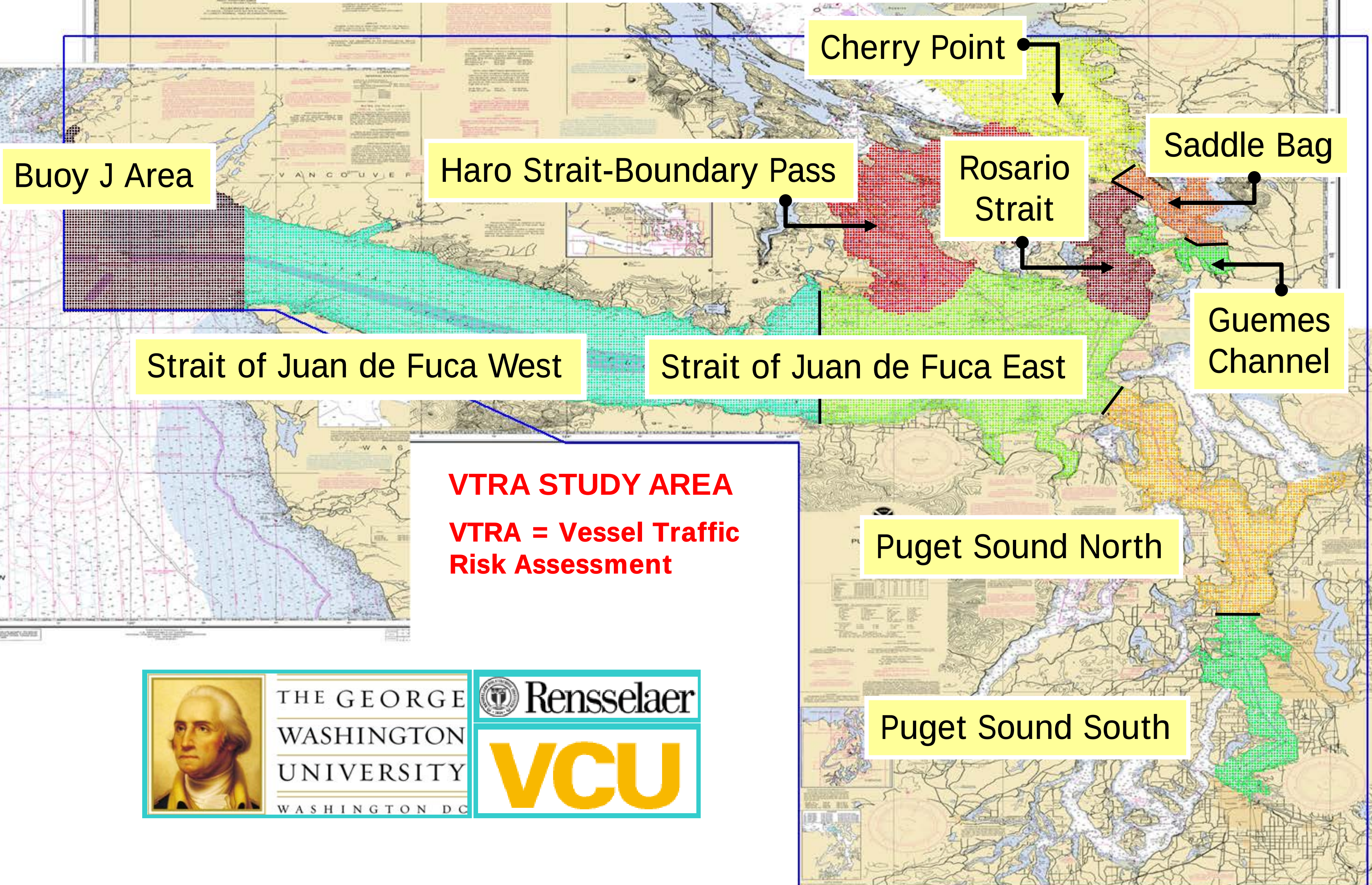
Definition of Visibility Locations



VTRA STUDY AREA

VTRA = Vessel Traffic Risk Assessment

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Sea Visibility Model

W = Water Surface Temperature (^oC)   D = Dew Point Temperature (^oC)

WS = Wind Speed

Sea Visibility = { Bad when (D - W) ≈ Δ and WS ≈ up to 3 Beaufort; Good Otherwise }

Good = More than 0.5 nautical mile

Bad = Less than 0.5 nautical mile

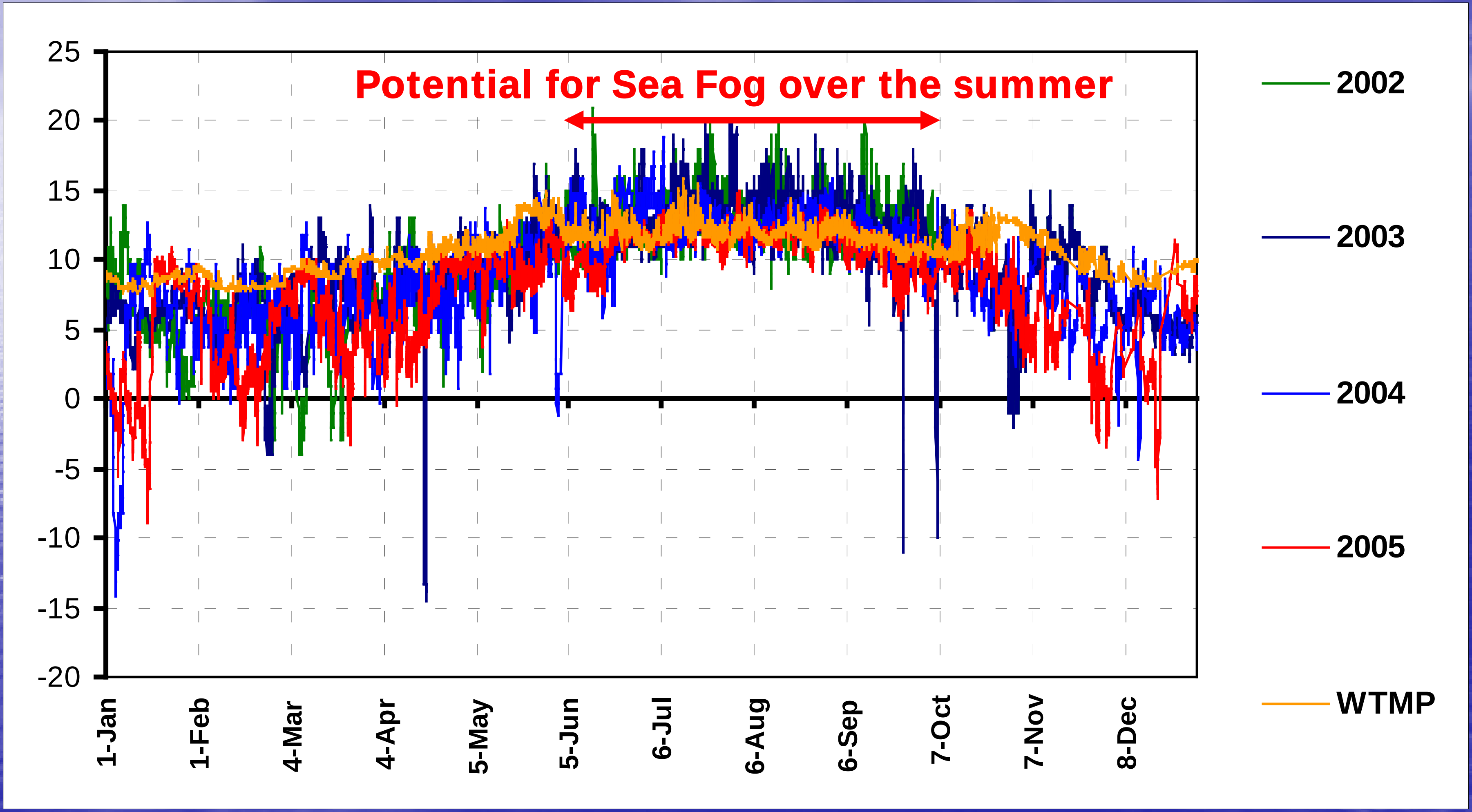
Δ between 0 and 2 Celsius (Patches of Fog)

Δ larger than 2 Celsius dense fog

Breeze up to 3 Beaufort ≈ 4-7 knots

Reference : Ray Sanderson, **Meteorology at Sea,** Stanford Maritime Limited, 1982

Time Series of WTMP and DEWPT For West Strait of Juan de Fuca



Current Model Presentation:

Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

GWU Personnel:
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December 7, 2006

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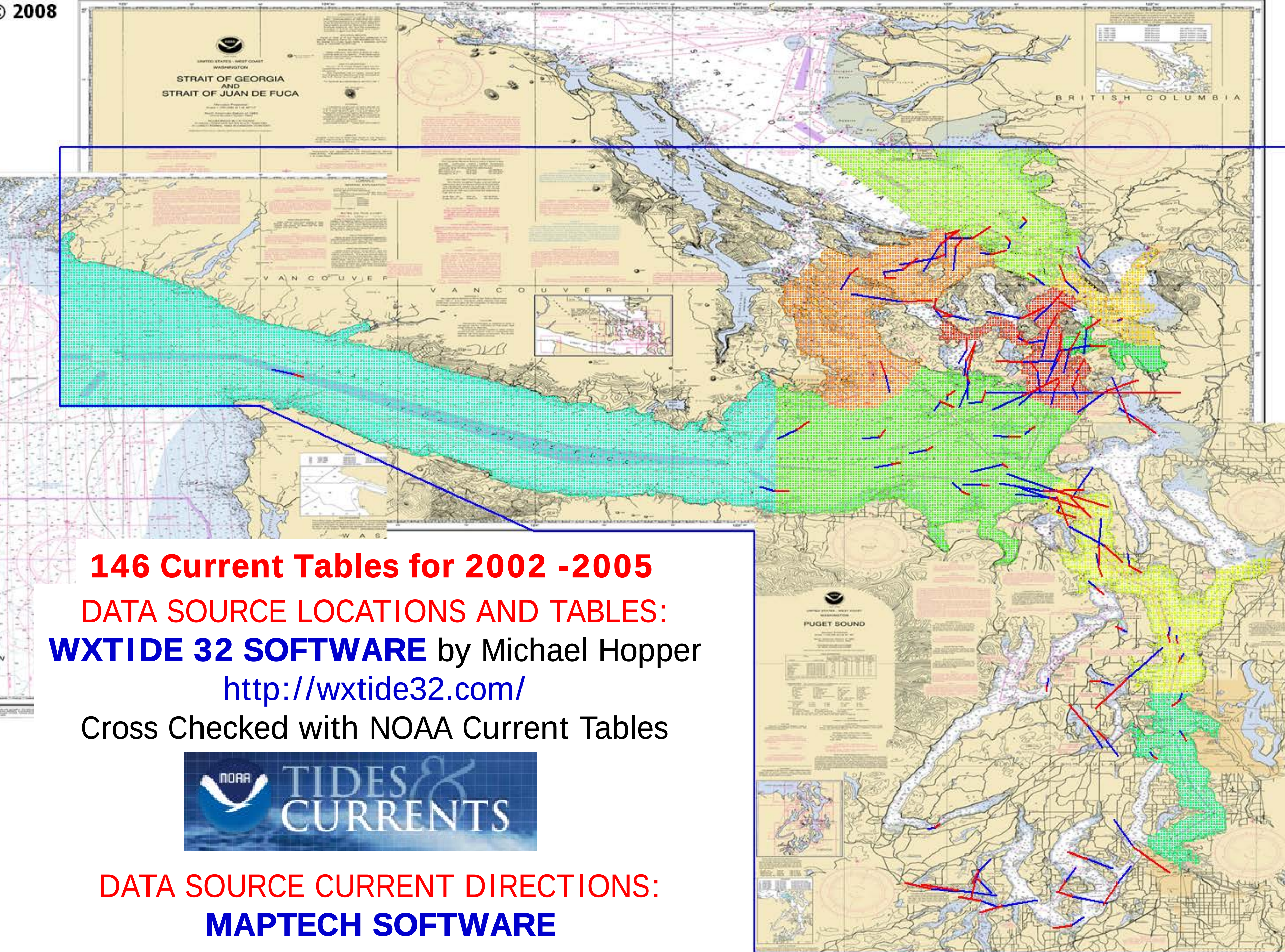

146 Current Tables for 2002 -2005

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

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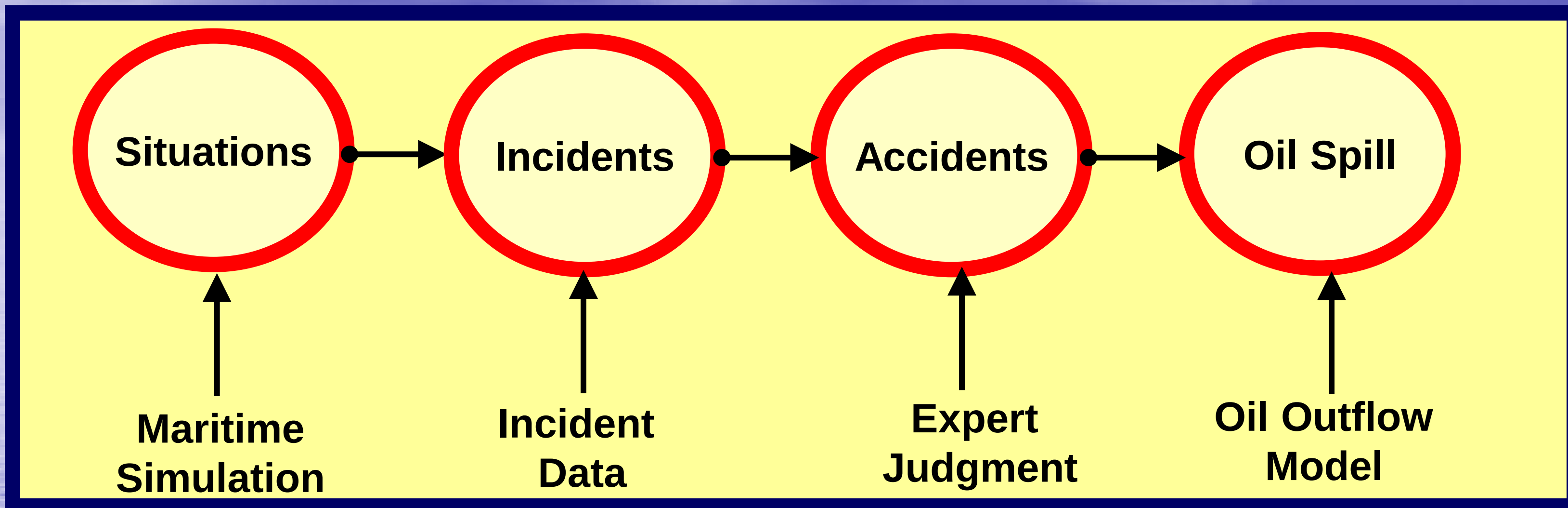


$$R = \{< s_i, l_i, x_i >\}_c$$

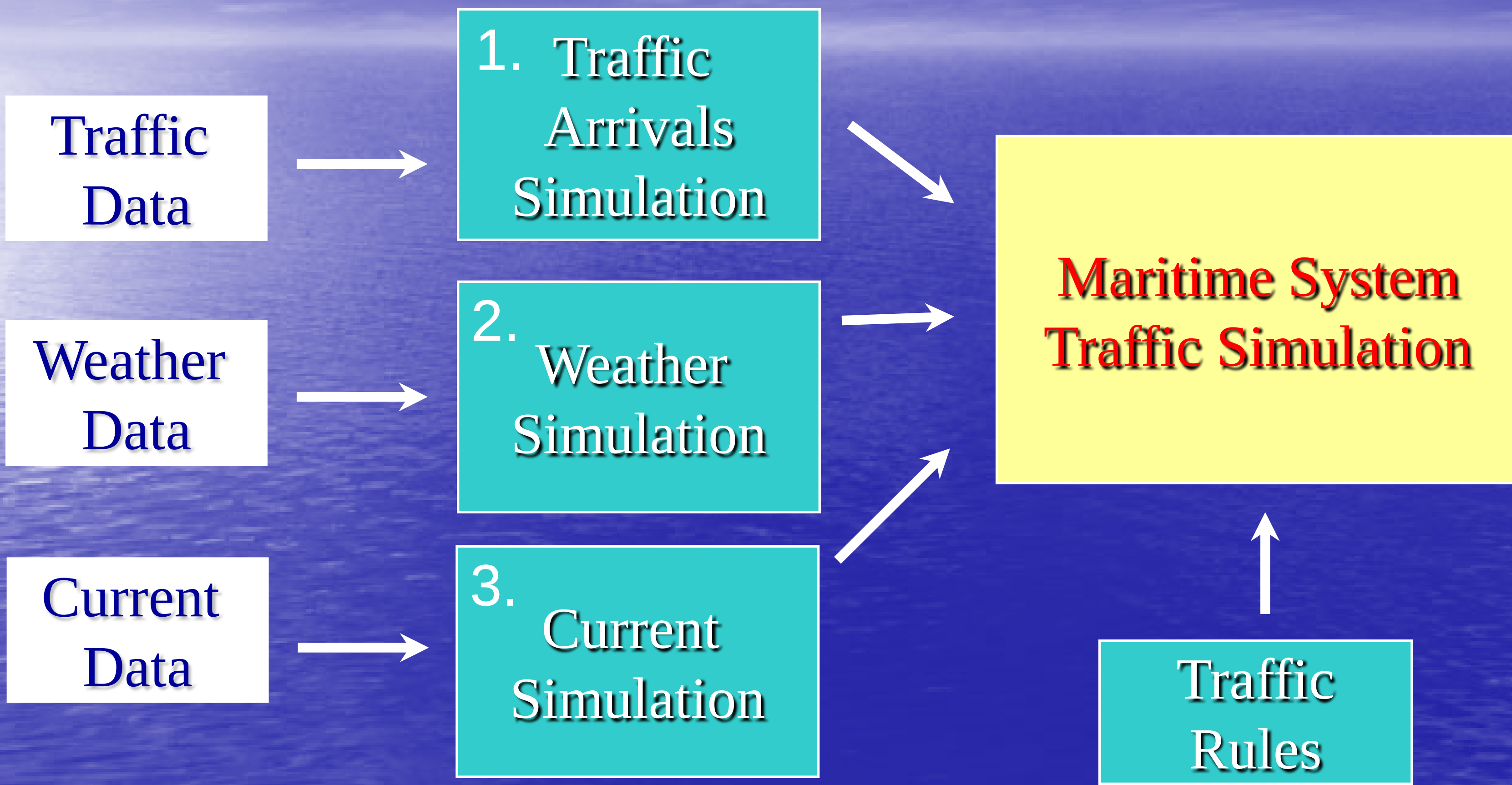
Scenario i
Likelihood i
Consequence i
Complete Set

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

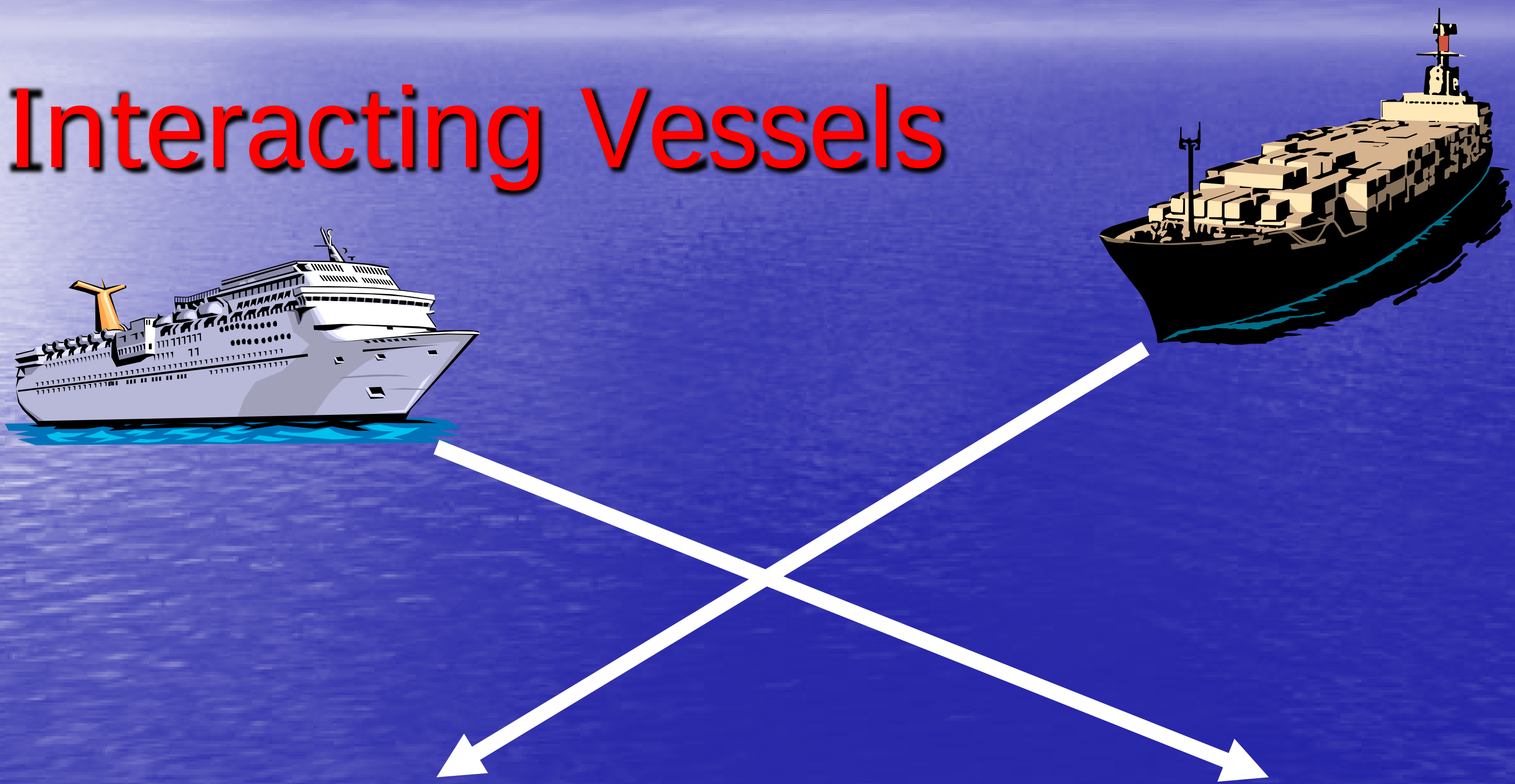
Using The Maritime System Simulation Model



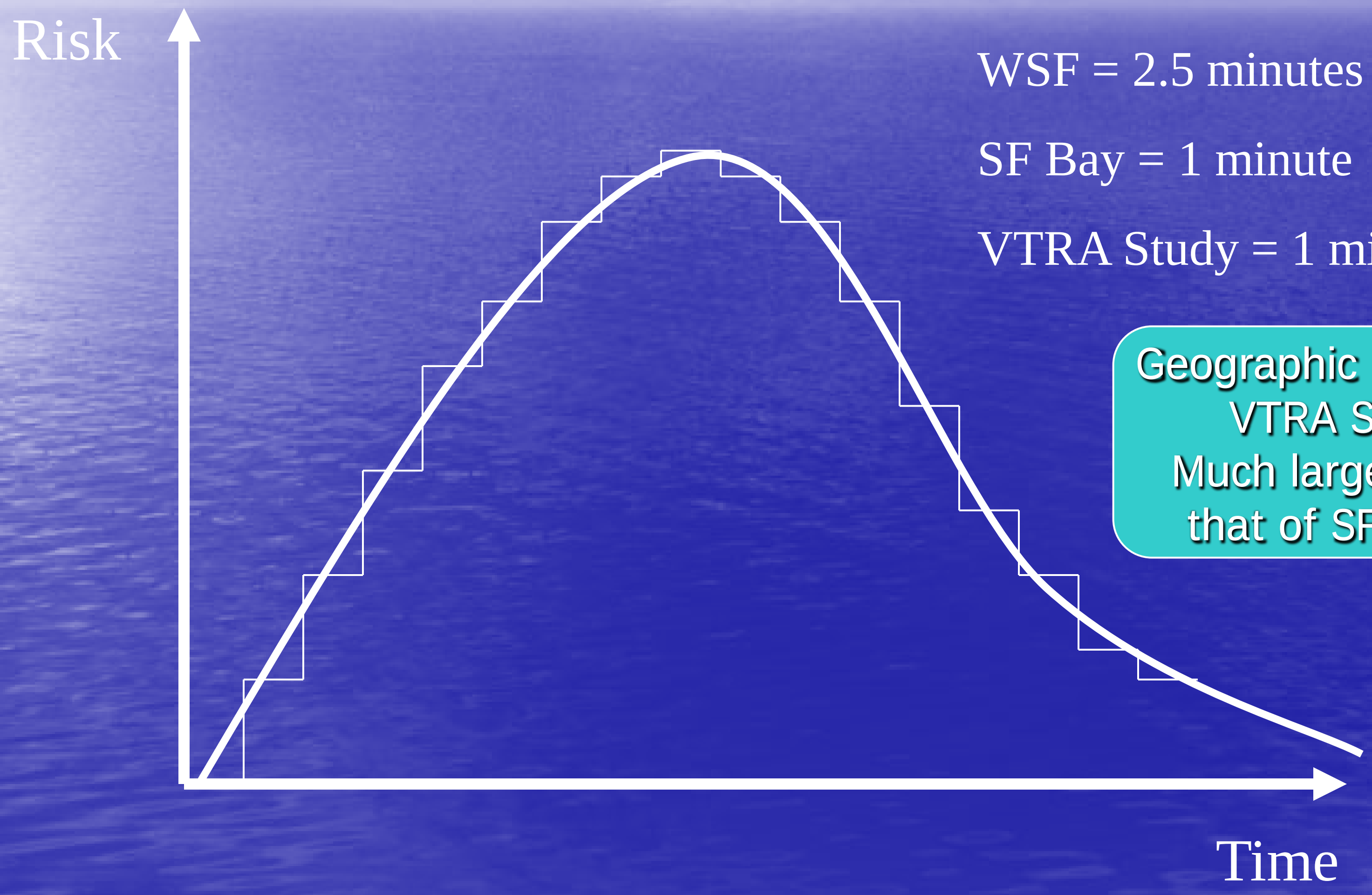
Required close cooperation with the USCG VTS and Puget Sound Harbor Safety Committee for data + validation

Count Accident Scenarios

Interacting Vessels



Risk During Interactions



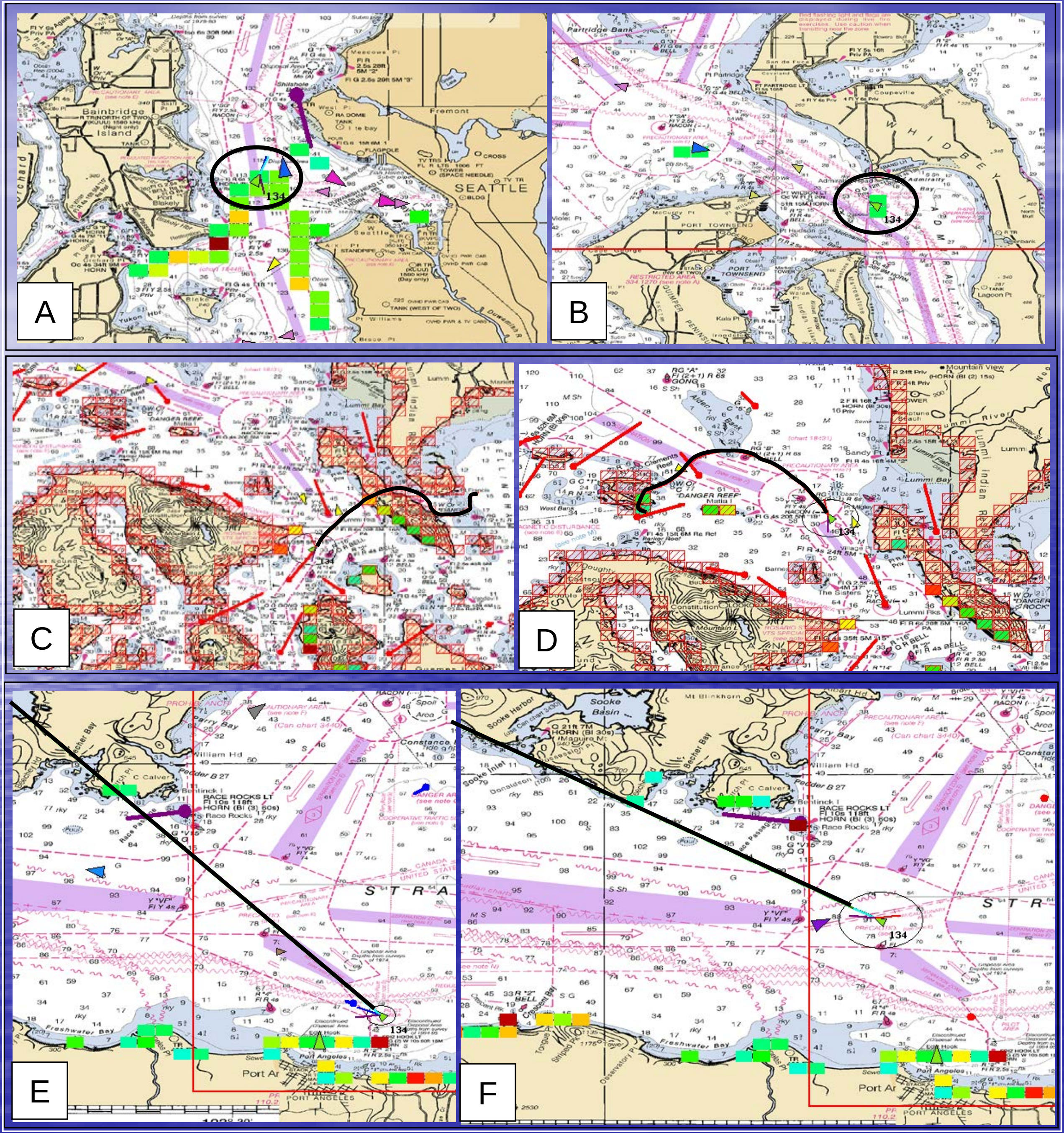
PWS = 5 minutes

WSF = 2.5 minutes

SF Bay = 1 minute

VTRA Study = 1 minute

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

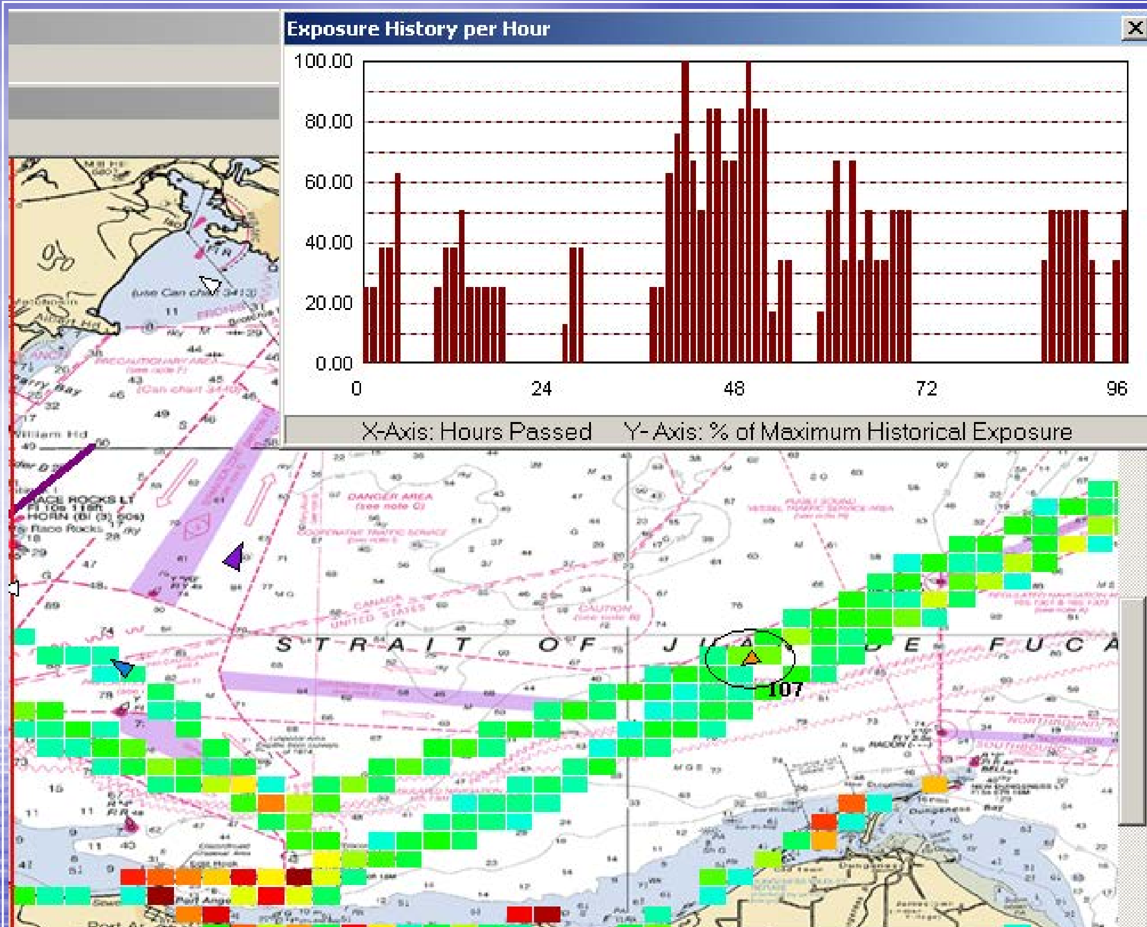


Generating Accident Scenarios:

Counting Collision Accident Scenario's

Counting Drift Grounding Accident Scenario's

Counting Powered Grounding Accident Scenario's



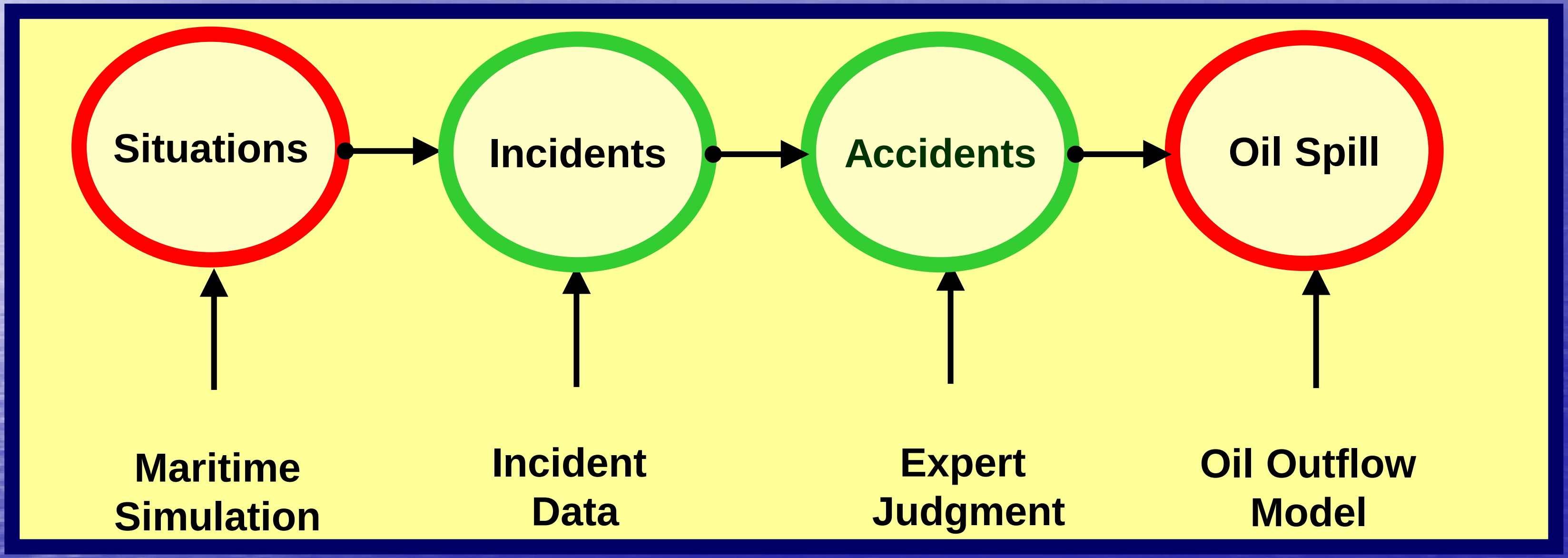
Data base - Vessel Interactions

Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	No of Occurrences
425120095	410901300	110222107	111122130	628013199	121094074	301132018	2
425121095	410901300	110222107	111122130	626009190	126094032	223021000	1
425121095	410901300	110222107	111122130	628013199	122094074	301132018	1
425121095	410901300	110222107	111122230	626009190	126094032	223021000	1
425121095	410901300	110222107	111122230	628013199	122094074	301132018	1
425126095	410901300	110222107	112122130	626009190	127094032	223022018	3
425127095	410901300	110222107	112122130	626009190	127094032	223022018	4
425128095	410901300	110222107	112122130	626009190	127094032	223022018	2
425174081	321004200	120262107	111112130	626009190	176082032	223032000	1

A

```
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;
```

Step 2: Evaluate Accident Likelihood per Accident Scenario



Joint work with:

VCU Personnel:
Dr. Jason R. W. Merrick, and Team

RPI Personnel:
Dr. M. Grabowsku, and Team

Gather Relevant Incident and Accident Data

- Accidents: Collisions, Powered Grounding, Drift Grounding and Allisions of Tank Ships and Tug\Tow Barges.
- Incidents: Vessel Propulsion Failure, Steering Failure, Navigational Aid Failure and Human Error.

This step involves pulling together data from multiple data sources ensuring no double counting and avoiding occurrence of missing data

Summary Incident Data

- Tankers calling at BP
  - 11 years of data
  - Propulsion failures: 31
  - Steering failures: 11
  - Nav. aid failures: 10
- ATBs and ITBs calling at BP
  - 7.5 years of data
  - Propulsion failures: 3
  - Steering failures: 2
  - Nav. aid failures: 2
- Human error incidents are rarely recorded
  - 4 accidents have occurred in data collection period
  - 3 of these were caused by human error and 1 by mechanical failure
  - Use 1 to 3 multiplier on mechanical failure rates

Joint work with:

Rensselaer

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

Summary Accident Data

- 11 years of data, 4 accidents
- 1 collision
  - The tanker Allegiance and its escort tug Sea King collided in Straits of Juan de Fuca east
- 1 grounding
  - ITB New York dragged anchor and grounded in 55 knots winds off March Point
- 2 allisions
  - Tanker Leyte Spirit allides with dock when trying to leave dock in high winds and seas
  - Tanker Overseas Arctic allides with piling bracket when docking at Tacoma

Joint work with:

Rensselaer

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

Calibration to Accident Data

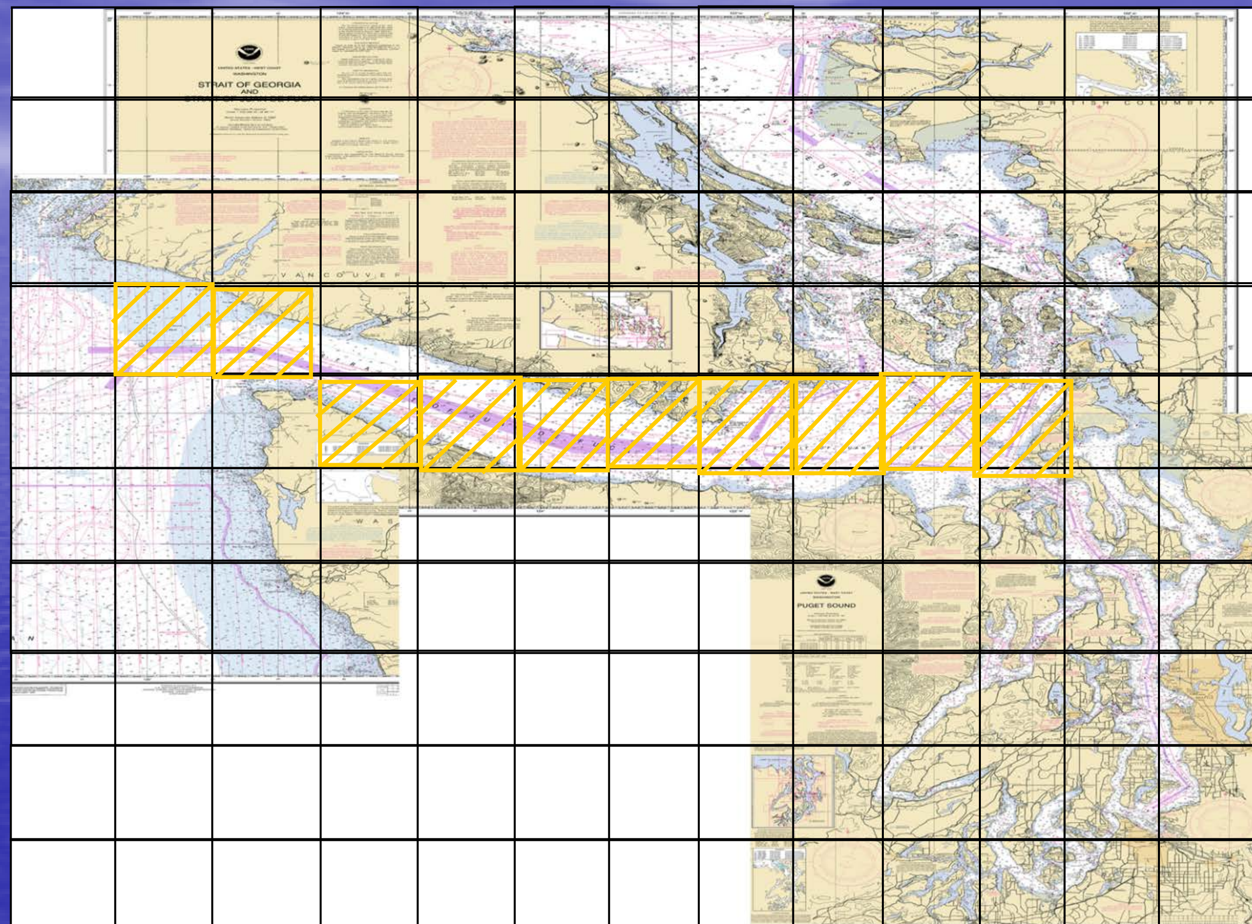
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

- Suppose all interactions are the same

$$\Pr(\text{Collision per Interaction}) = \frac{1}{130}$$



Calibration Step means that in Base Case Simulation the accident rate per year is the same as the historically observed accident Rate

Calibration to Accident Data

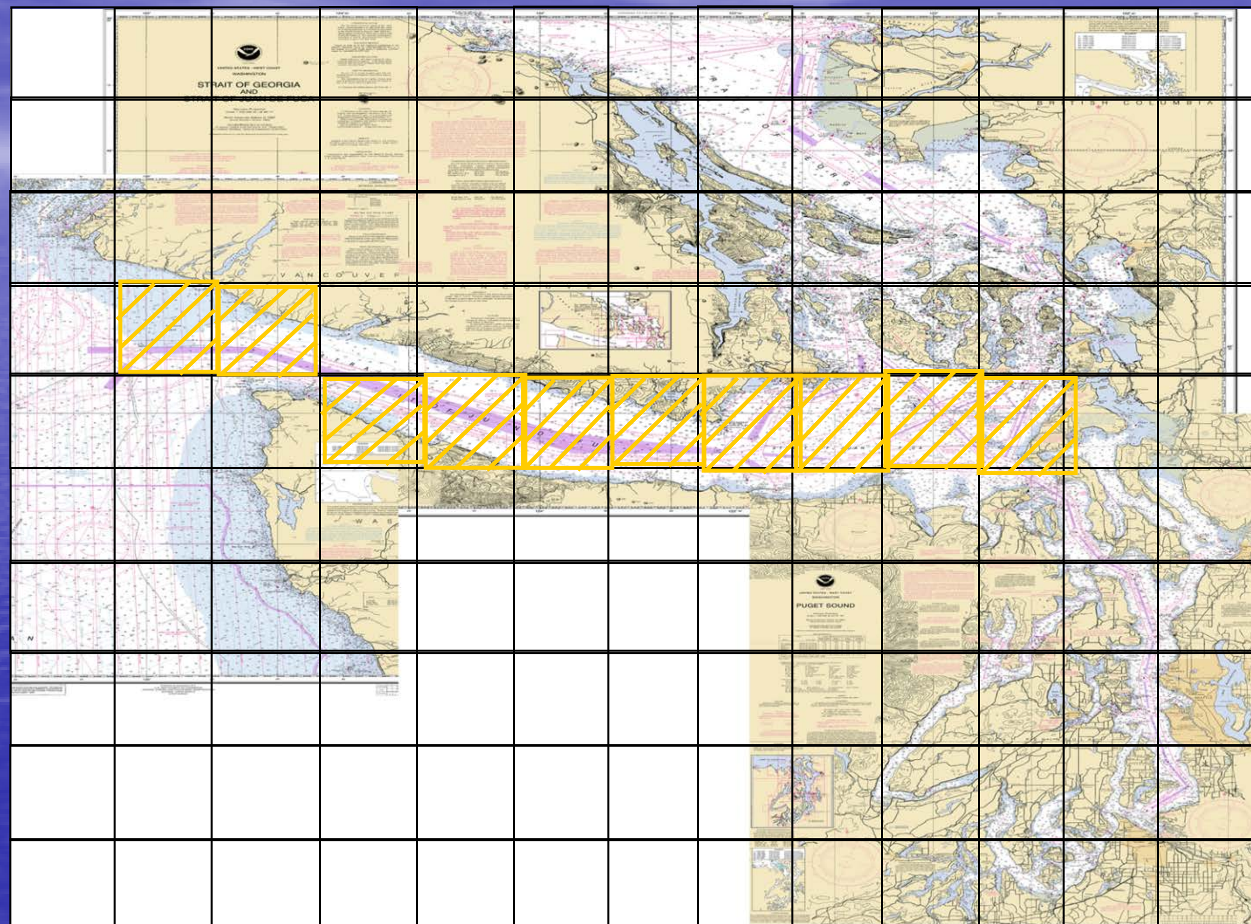
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

- Suppose all interactions are the same

$$\text{Pr(Collision per Interaction)} = \frac{1}{130}$$



DOES NOT MAKE SENSE BECAUSE LIKELIHOOD OF A COLLISION IS NOT THE SAME FOR EVERY INTERACTION

Calibration to Accident Data

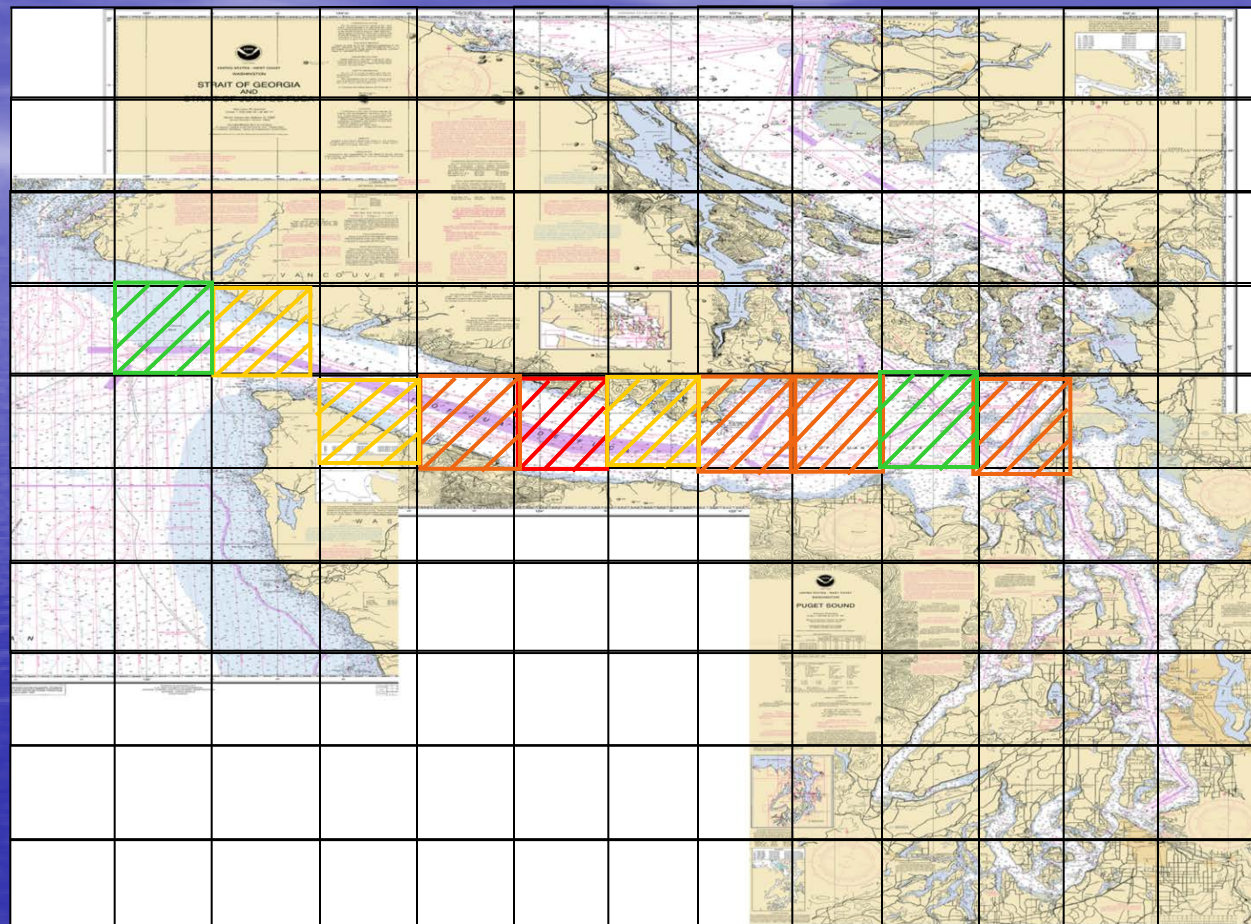
- Counting Grid: 130 Grid Cells

- Suppose we have a we a total of 130 Vessel Interactions evenly in 10 Grid Cells over the area.

- Suppose we have a we have a total of 1 Collision in our Data.

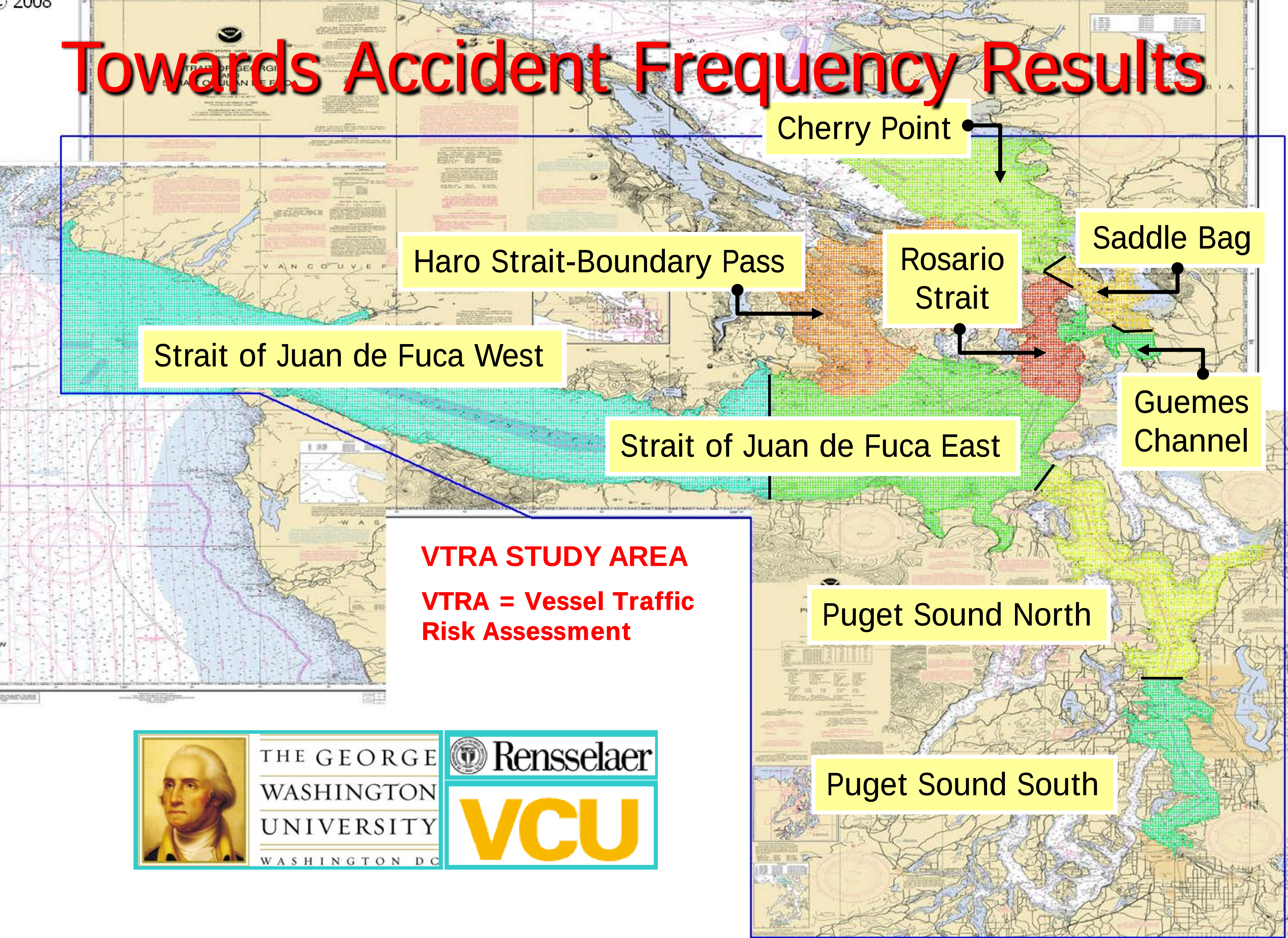
- Suppose all interactions are the same

$$\text{Pr(Collision per Interaction)} = \frac{1}{130}$$



CALLIBRATE SO OVERALL ACCIDENT RATE REMAINS THE SAME, BUT ACCOUNT FOR RELATIVE LIKELIHOOD OF ACCIDENTS IN DIFFERENT INTERACTIONS

Towards Accident Frequency Results



THE GEORGE WASHINGTON UNIVERSITY WASHINGTON DC

Rensselaer

VCU

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.

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.

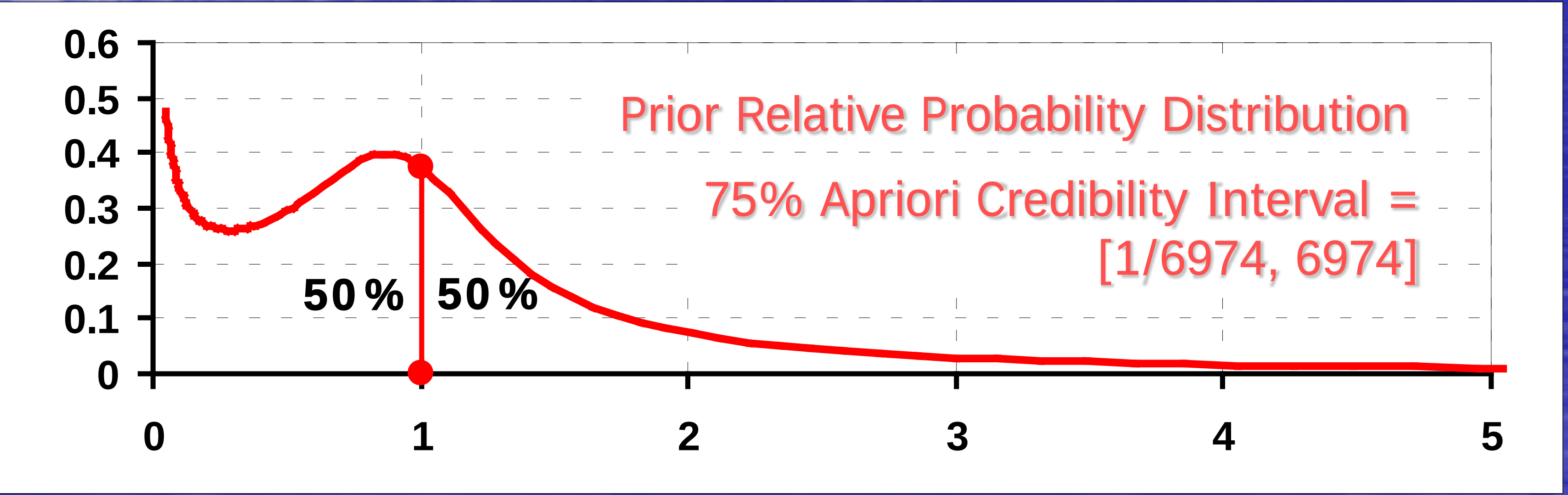
Summary of Expert Judgment Data Source

- 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.

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 eb-07
Brad 1st			6 7
Brad 2nd			7 7 7
Brad Tug			7 7 7
Tan Acc Give			7 7
Tan Acc Give Given Given Hu Given Near By Vessel Failure			7 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

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**



Q30

St

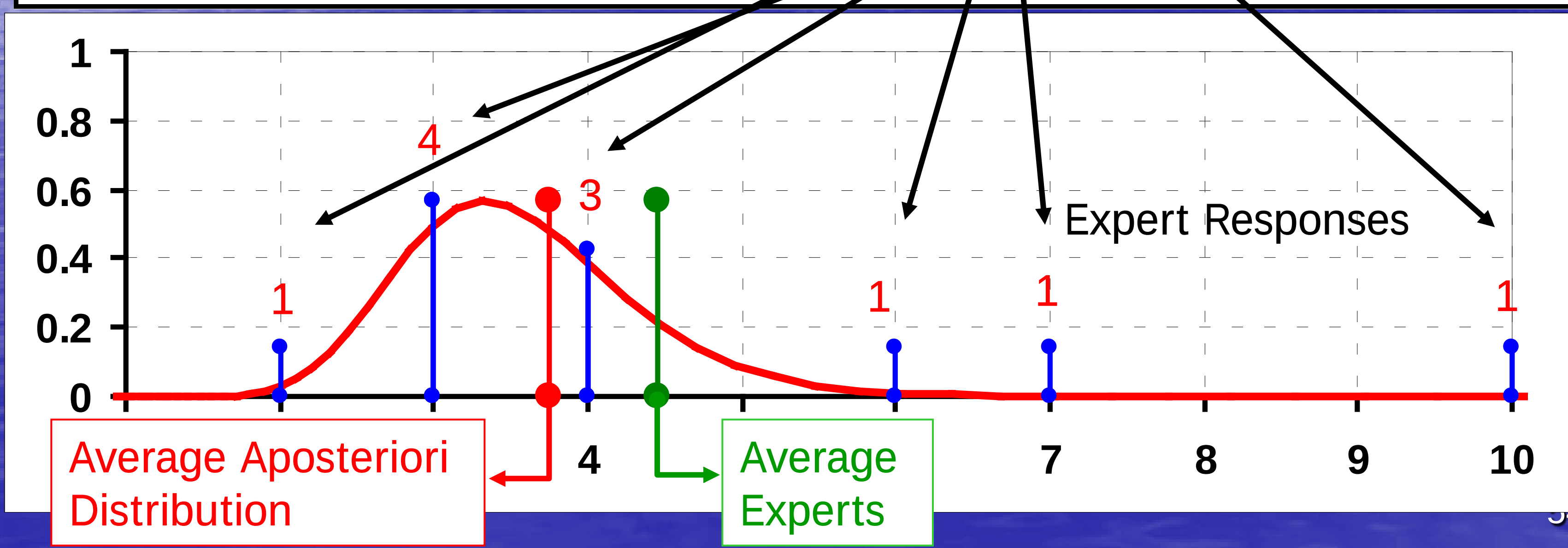
S

M

Along

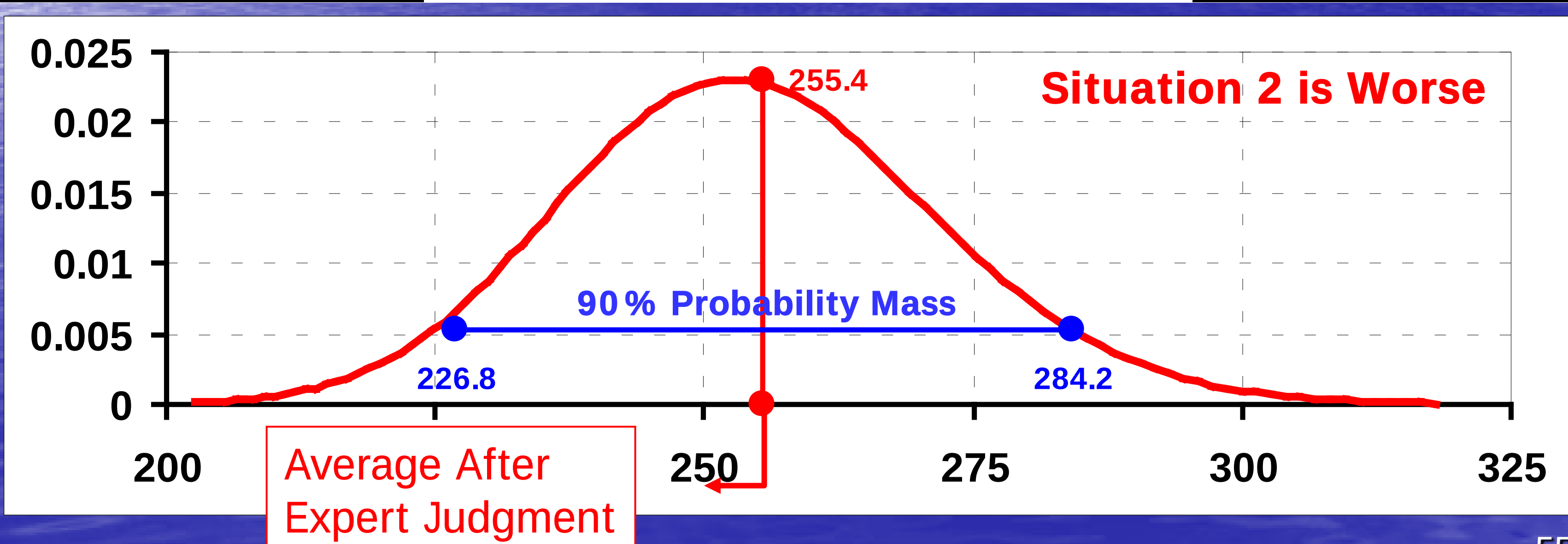
Average of **A posteriori distribution** is different than the **Average of the expert responses** since we combine in this average also the information of the expert responses to all the other 43 questions

Situation 1 is worse <==================X===================> **Situation 2 is worse**

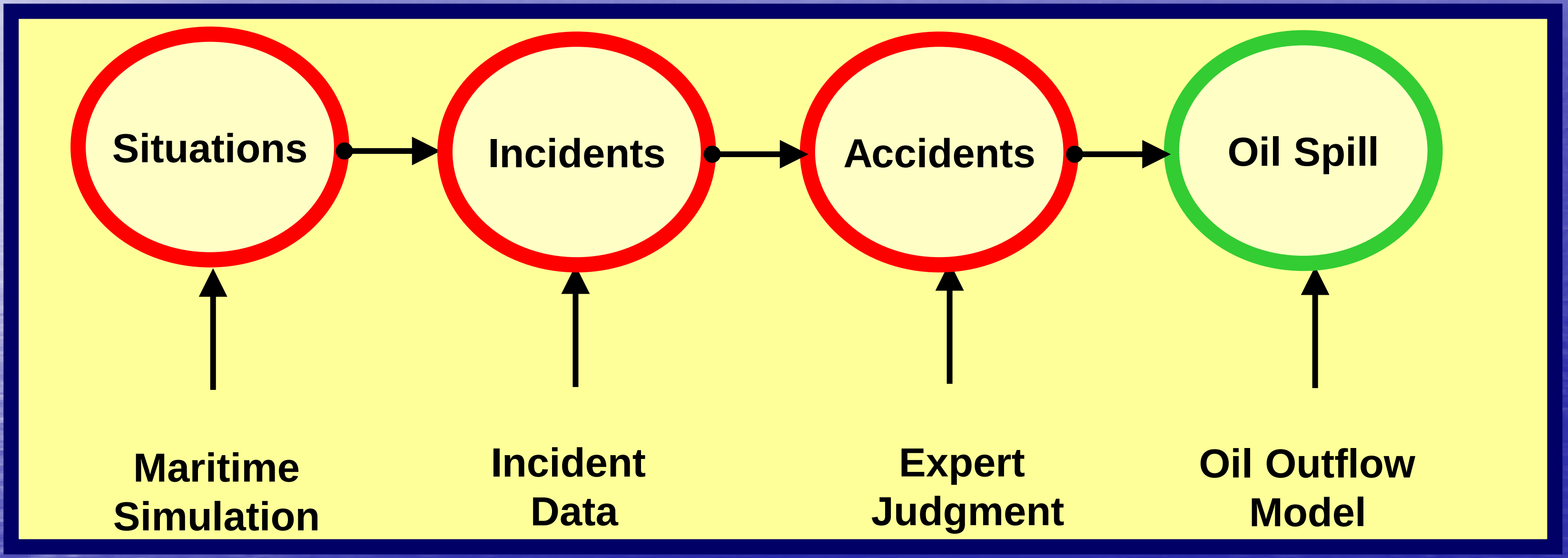


Situation 1	TANKER DESCRIPTION	Situation 2
Rosario Strait	**Location**	Guemes Channel
Inbound		-
Laden		
1 Escor		orts
One Tethe		ered
Shallow Draft Pa		
Crossing the		
Less than 1		
More than 0.5 mile Visibility	**Visibility**	-
Along Vessel	**Wind Direction**	-
Less than 10 knots	**Wind Speed**	-
Almost Slack	**Current**	-
Along Vessel - Same Direction	**Current Direction**	-

While Expert questions vary only
One attribute at a time we may
Now vary multiple attributes



Step 3: Evaluate Consequence per Accident Scenario



Joint work with:

TU Delft

Delft University of Technology

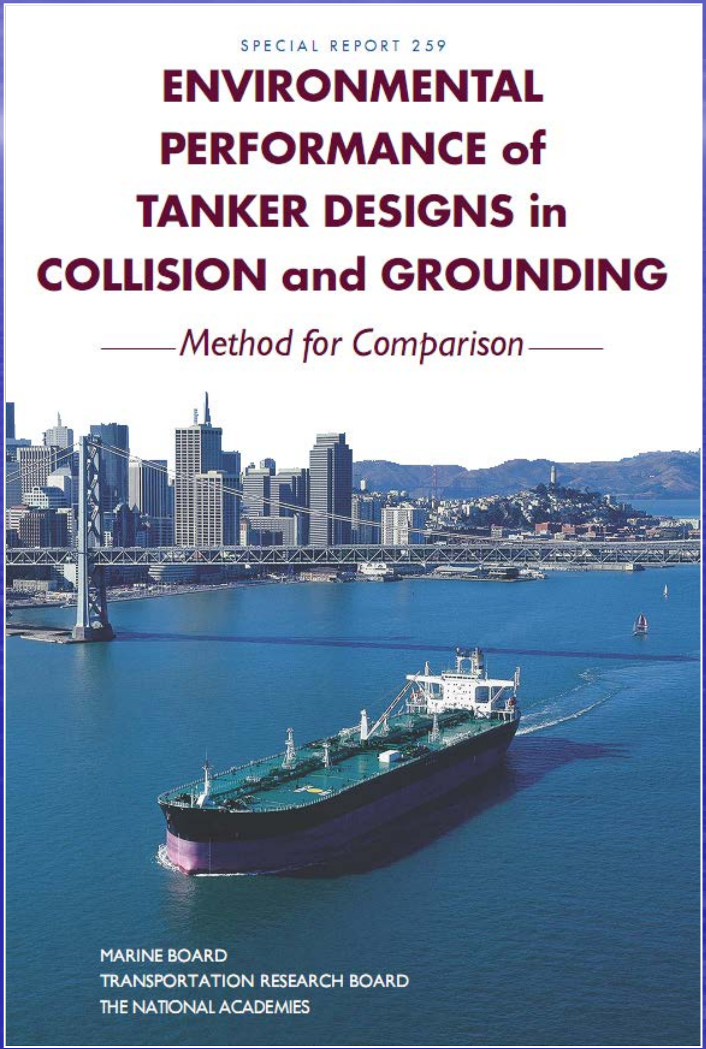
TU Delft Personnel:
Giel van de Wiel

NATIONAL RESEARCH COUNCIL SPECIAL REPORT 259

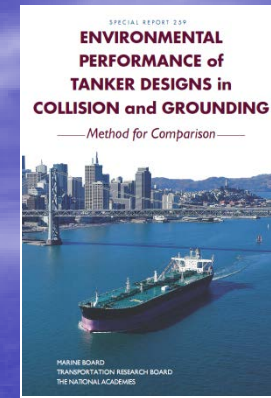
"Given the status of previous efforts to establish a methodology for comparing the environmental performance of alternative tanker designs, **the committee concluded that the development of a new approach was warranted**."

"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)."

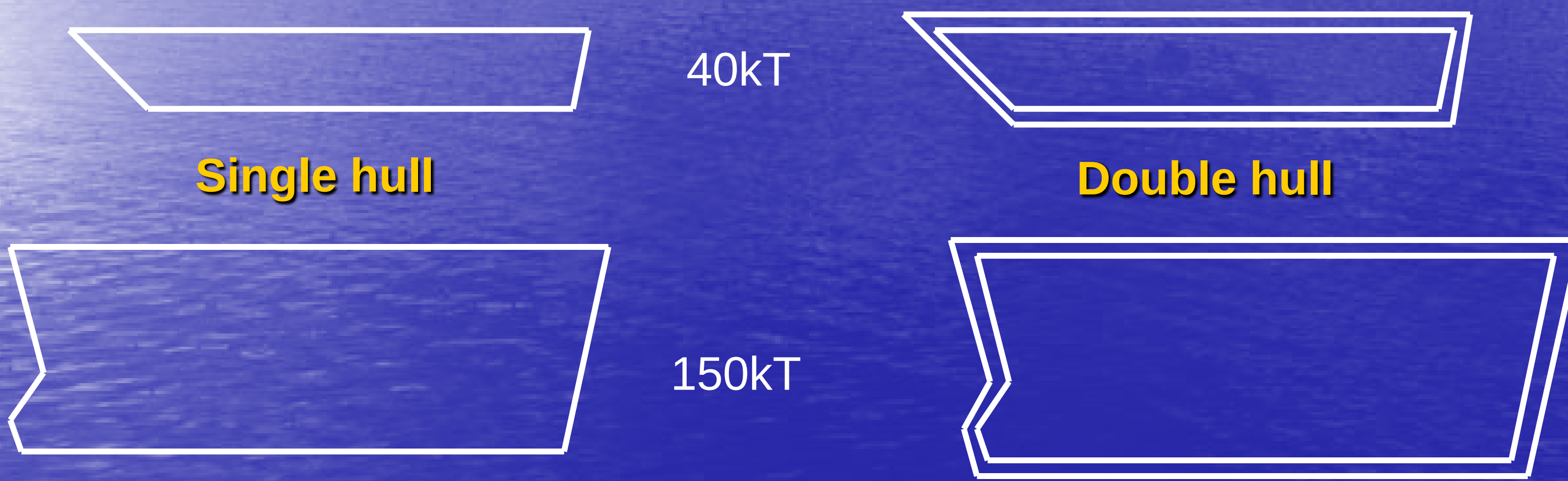
Quoted from: NRC Special Report 259



NATIONAL RESEACH COUNCIL SPECIAL REPORT 250



- **10,000 collision +**
- **10,000 grounding scenarios**
  - Applied to 4 tanker designs:



- **Use physical damage simulation software SIMCOL and DAMAGE to generate oil outflows (Computationally extensive)**

For our Oil Outflow model development computational efficiency is a requirement

A baseline system risk analysis using our maritime risk simulation generated:

157,670 collision and 1,236,603 grounding scenarios

Scope: collision and grounding scenarios

Answers 3 questions:

1. Given accident scenario what is the damage extent?
2. What is the probability of outflow given the damage extent?
3. Which compartments are affected, i.e. what is the total outflow volume?

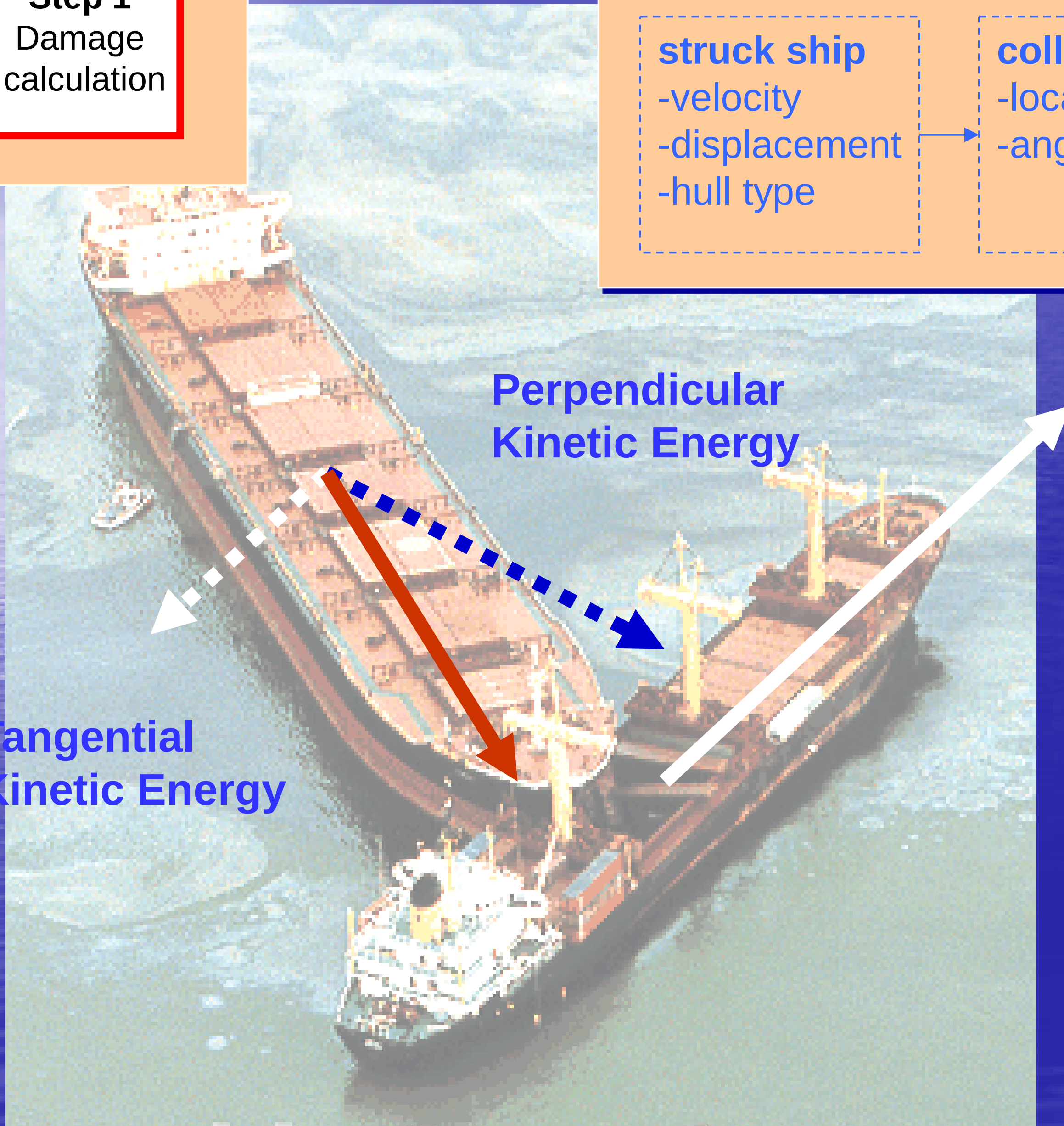
Step 1
Damage calculation

A SR 259 Collision Scenario

struck ship
- -velocity
- -displacement
- -hull type

collision
- -location
- -angle

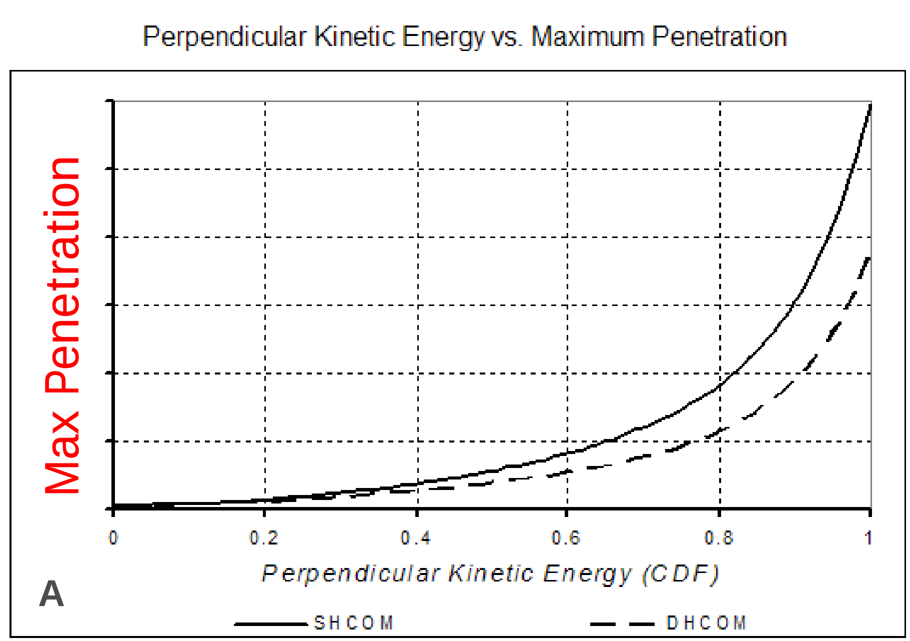
striking ship
- -velocity
- -displacement
- -bow angle

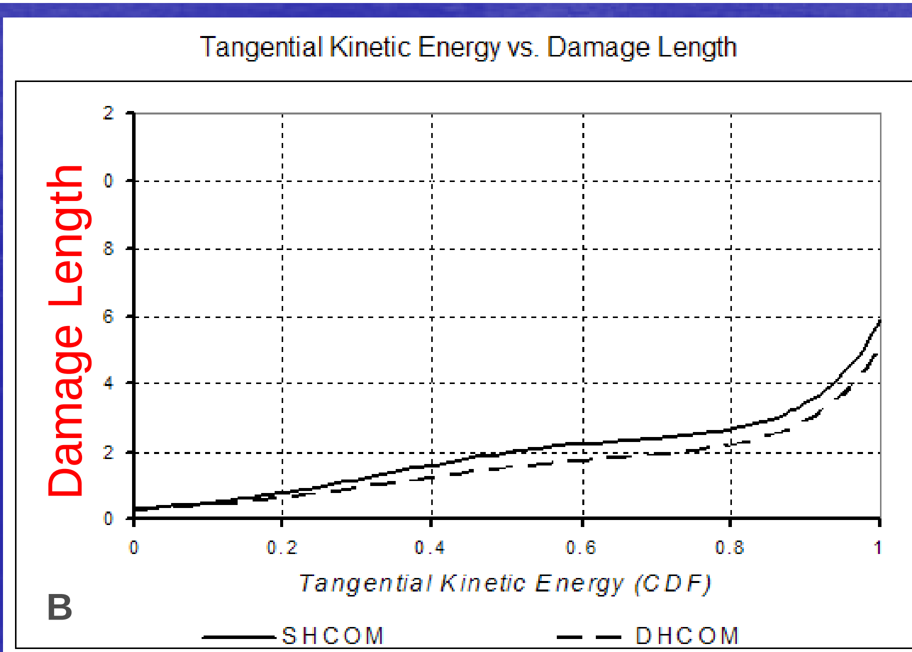


Step 1
Damage calculation

R^2 approx 70%

	SH40	SH150	SHCOM	DH40	DH150	DHCOM
number of data points	7467	7473	14940	7454	7466	14920
R^2-value	70.9%	68.1%	68.9%	71.5%	69.9%	70.6%
Mallows C_p-value	19.0	19.8	13.1	14.2	24.0	16.0
Coefficients						
β_0	-2.914	-2.661	-2.982	-2.931	-2.786	-2.632
$\beta_{1,1}$	3.078	-1.215	2.246	2.128	2.047	-0.117
$\beta_{2,1}$	5.550	5.303	5.231	6.180	4.692	4.670
$\beta_{3,1}$	0.031	-2.493	-3.369	0.708	-3.224	-1.973
$\beta_{4,1}$	0.546	1.613	1.188	0.655	1.429	1.155
$\beta_{5,1}$	-	-	0.223	-	-	0.052
$\beta_{1,2}$	-	10.181	0.687	0.598	-	5.792
$\beta_{2,2}$	-	-	-	-5.563	-	-
$\beta_{3,2}$	-	20.261	25.010	-	24.187	16.819
$\beta_{4,2}$	-	-0.931	-0.560	-	-0.784	-0.566
$\beta_{5,2}$	-	-	-	-	-	-
$\beta_{1,3}$	-	-8.145	-	-	-	-
$\beta_{2,3}$	-11.982	-6.405	-6.750	-	-5.410	-5.756
$\beta_{3,3}$	-	-68.750	-75.742	-13.309	-69.908	-53.668
$\beta_{4,3}$	-	-	-	-0.158	-	-
$\beta_{5,3}$	-	-	-	-	-	-
$\beta_{1,4}$	-2.924	-	-	-	-	-10.900
$\beta_{2,4}$	9.403	-	-	-	-	-
$\beta_{3,4}$	-	94.811	96.400	27.442	85.081	69.372
$\beta_{4,4}$	-	-	-	-	-	-
$\beta_{5,4}$	-	-	-	-	-	-
$\beta_{1,5}$	2.823	2.008	-	-	0.542	7.798
$\beta_{2,5}$	-	4.134	4.529	2.291	3.724	4.031
$\beta_{3,5}$	-0.480	-44.783	-43.224	-15.354	-36.872	-31.216
$\beta_{4,5}$	-	-	-	-	-	-
$\beta_{5,5}$	-	-	-	-	-	-

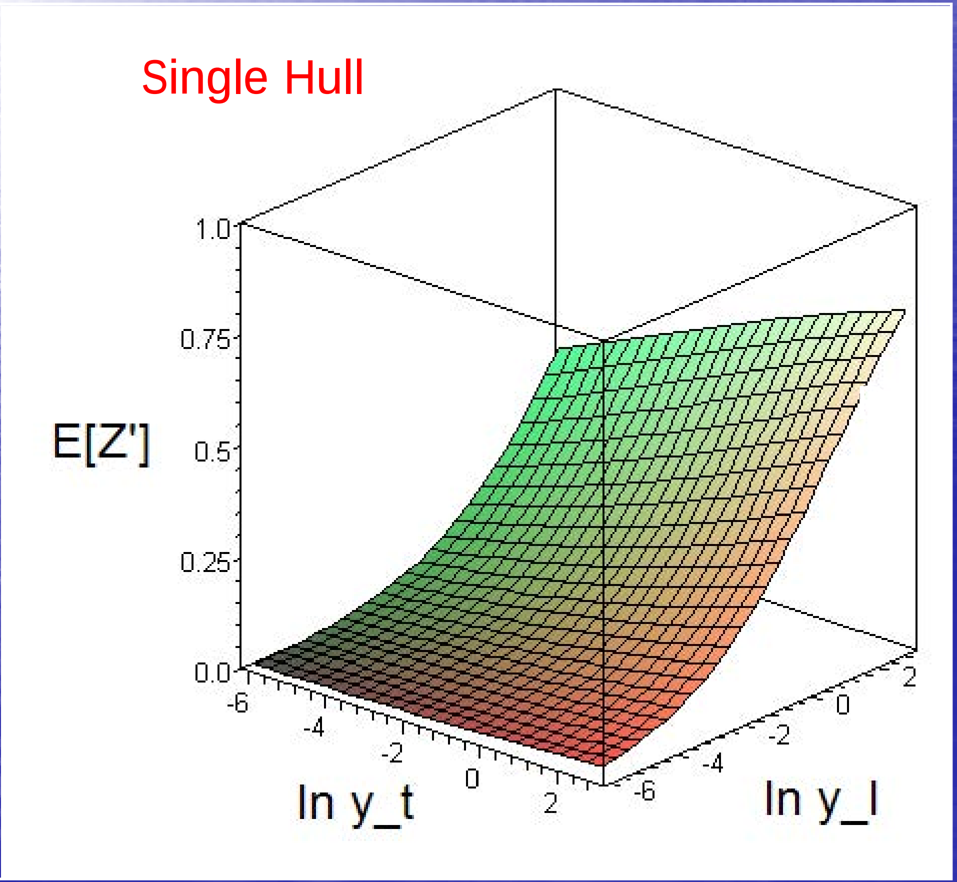


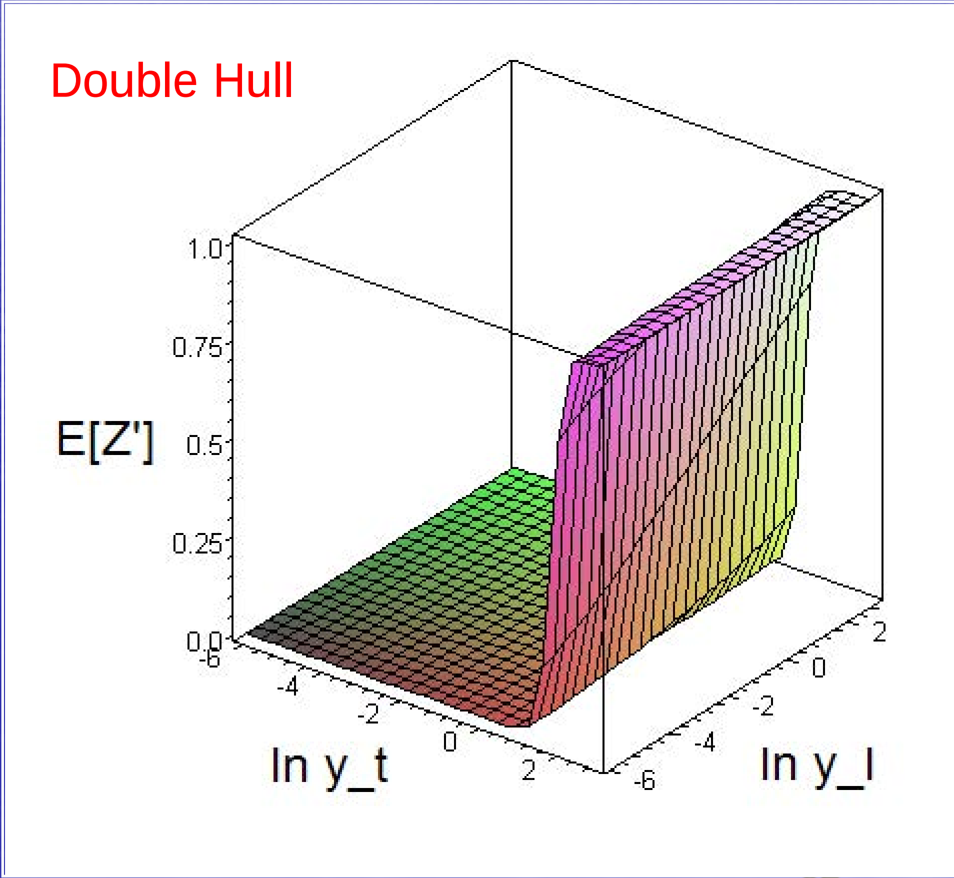


Step 2
Probability of rupture calculation

Gradual Function of both Longitudinal and Transversal Damage

Almost a Step Function in Transversal Damage only



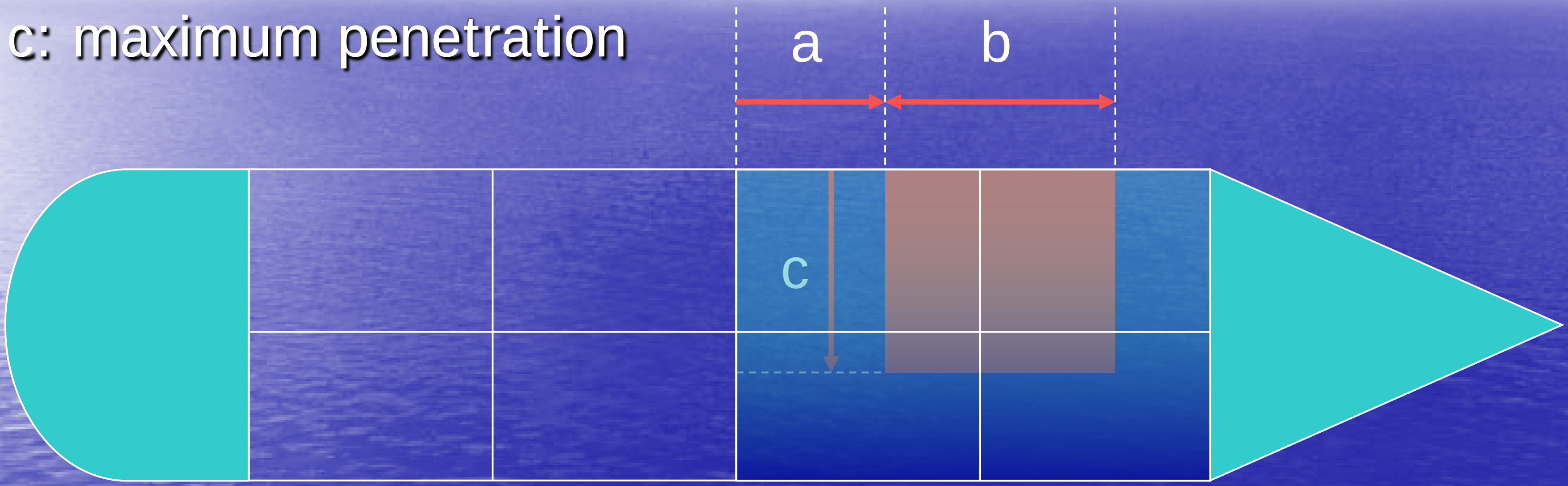


Outflow Volume (Collisions)

a: location from mid ship

b: damage length

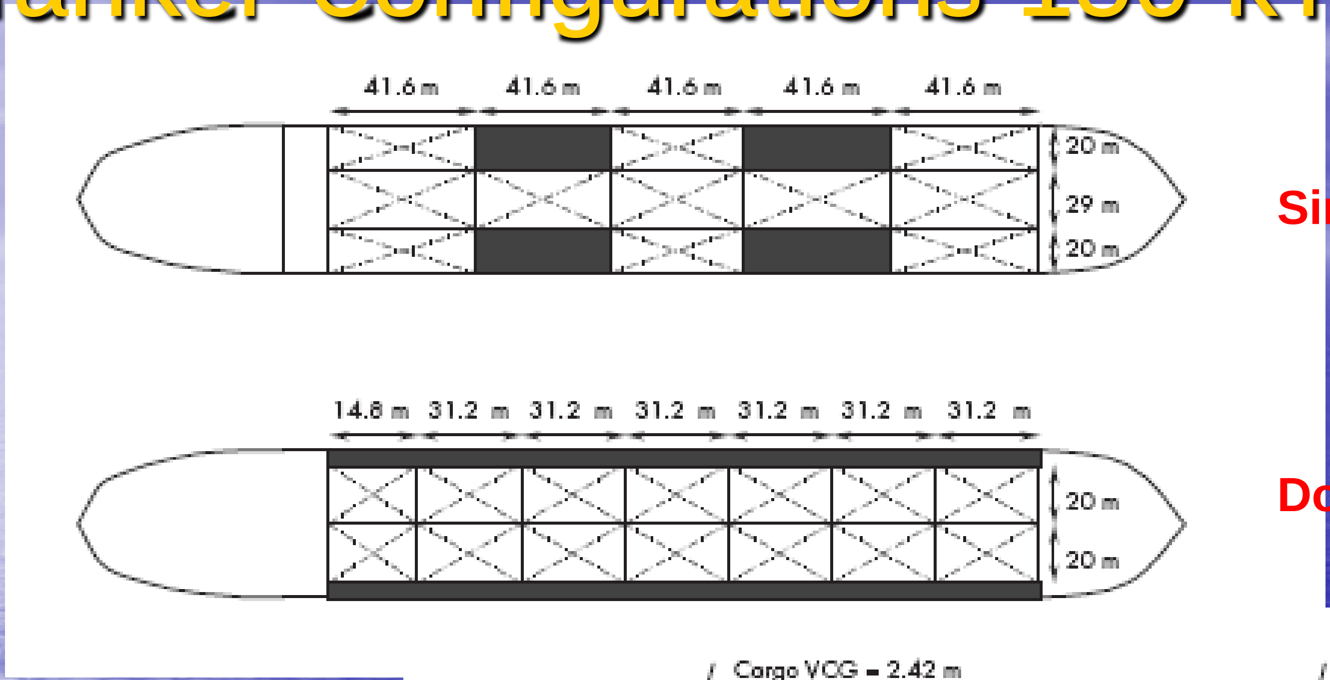
c: maximum penetration



Assumption 1: **worst case scenario:**
damage area is a square

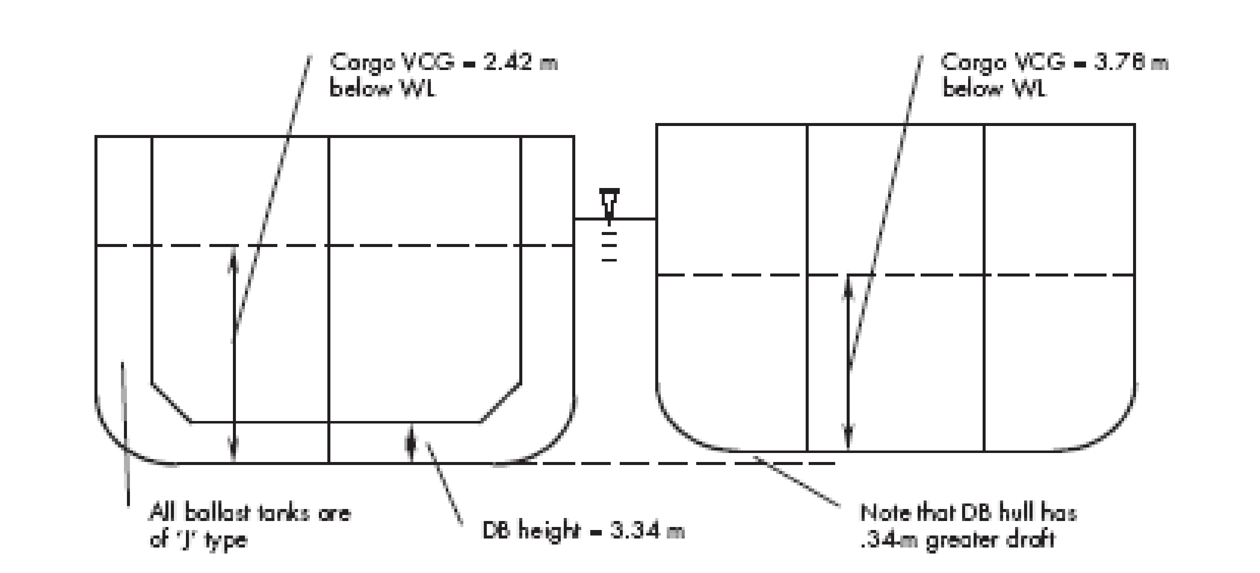
Assumption 2: **worst case assumption:**
all oil from a penetrated compartment is lost

Tanker Configurations 150 kT



Single Hull

Double Hull

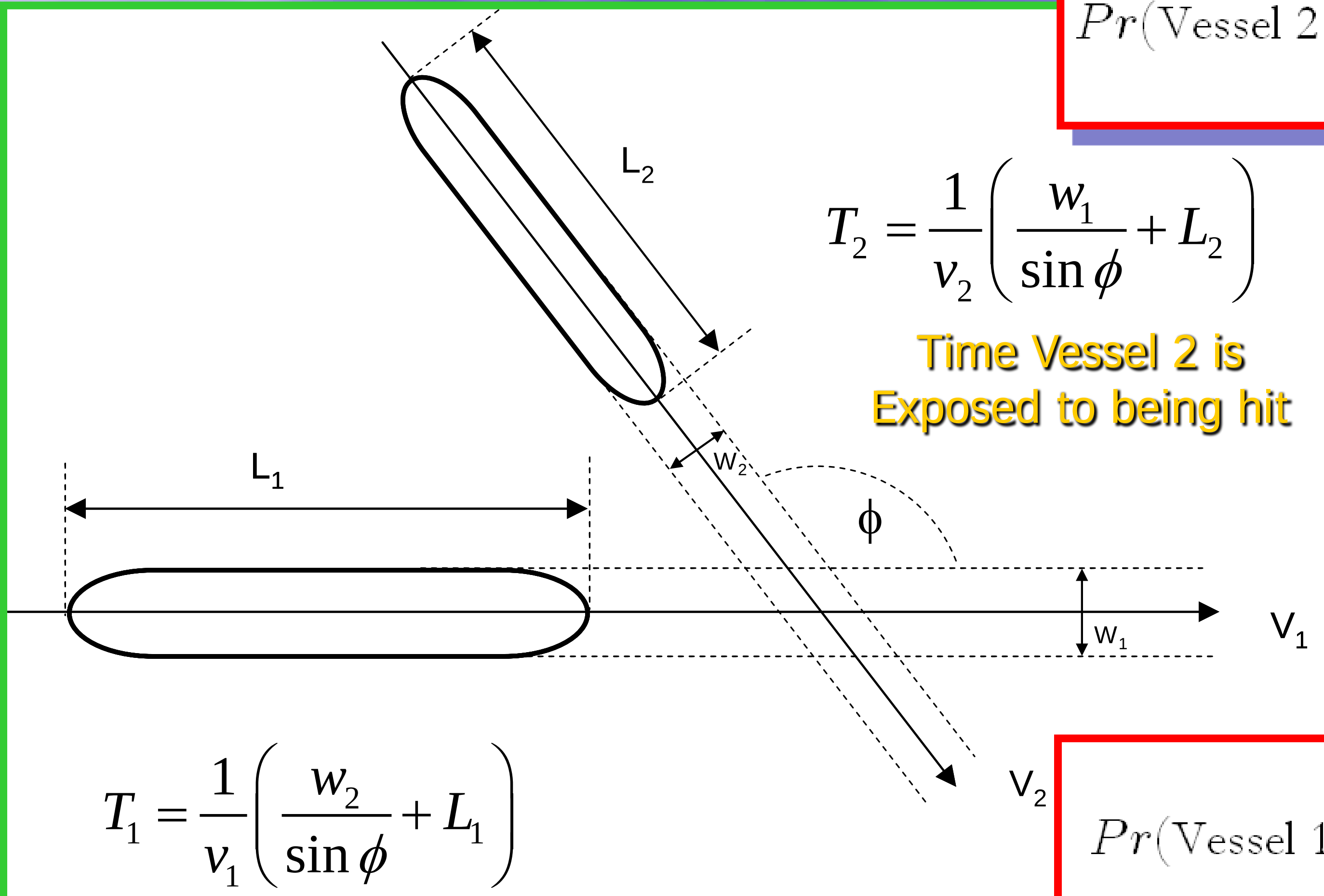


Taken From NRC 259 Report

Other Aspects of Oil Outflow model

Struck Probability Model

$$Pr(\text{Vessel 2 is struck}) = \frac{T_2}{T_1 + T_2}.$$



$$T_2 = \frac{1}{v_2}\left(\frac{w_1}{\sin\phi} + L_2\right)$$

Time Vessel 2 is Exposed to being hit

$$T_1 = \frac{1}{v_1}\left(\frac{w_2}{\sin\phi} + L_1\right)$$

Time Vessel 1 is Exposed to being hit

Vessel Size ↑
Struck Prob. ↑

Vessel Speed ↑
Struck Prob. ↓

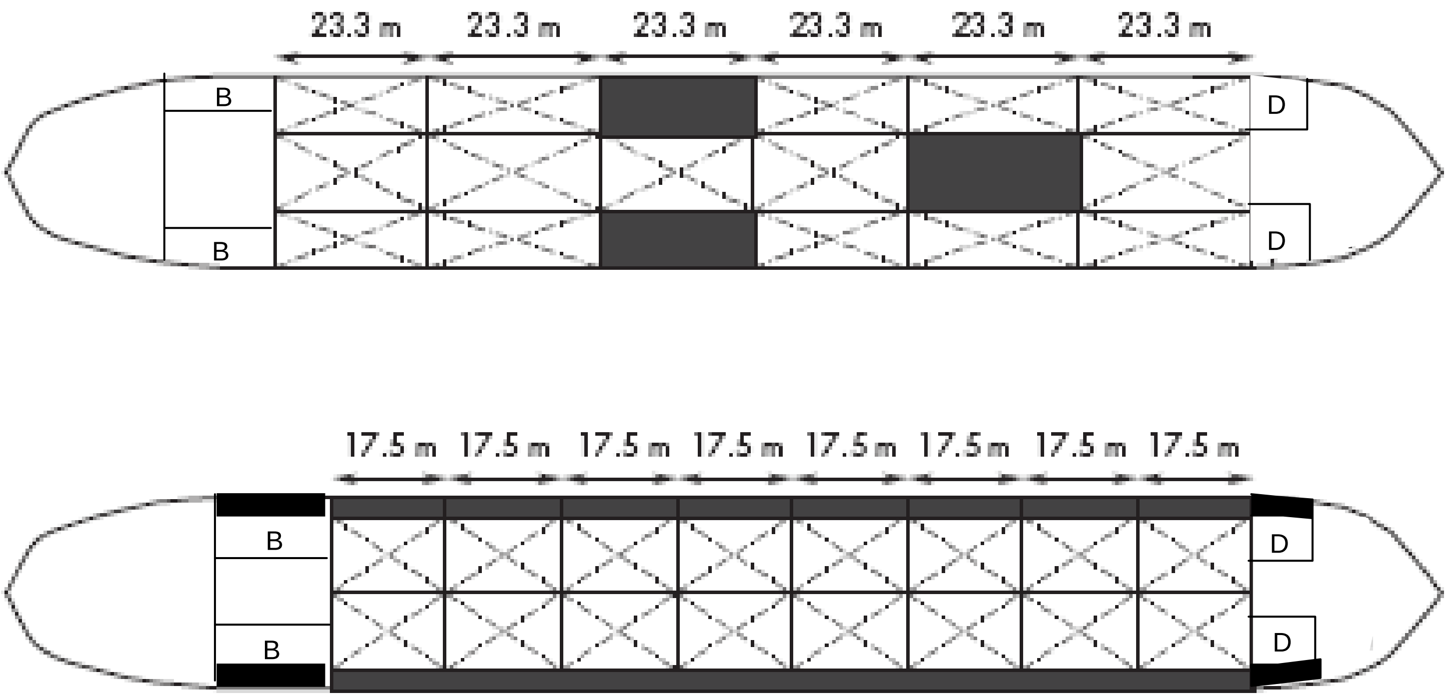
$$Pr(\text{Vessel 1 is struck}) = \frac{T_1}{T_1 + T_2}$$

Other Aspects of Oil Outflow model

Fuel Losses of Tankers and other Deep Draft Vessels

Worst Case assumptions for locations of Bunker Fuel and Diesel Fuel

Tanker Configurations 40 kT



Oil Outflow Categories

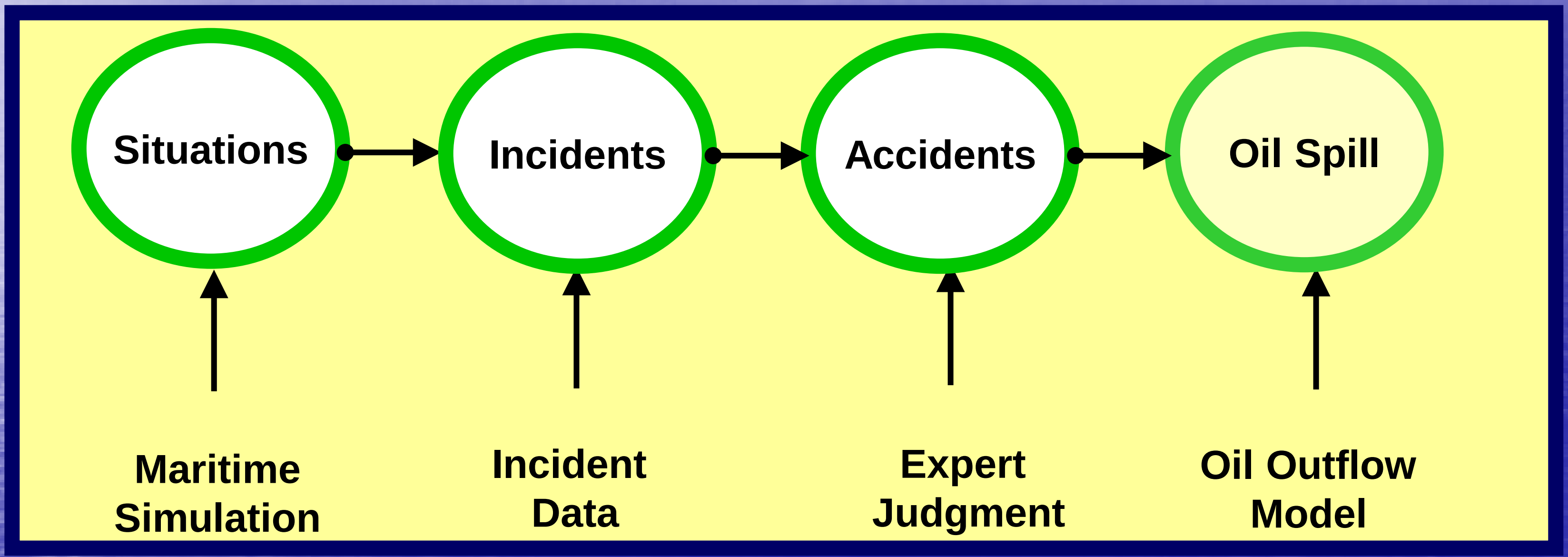
- **Vessel of Interest - Persistent Oil: VOI - PO**
  (Crude and Bunker Fuel) – Tanker, ATB, ITB

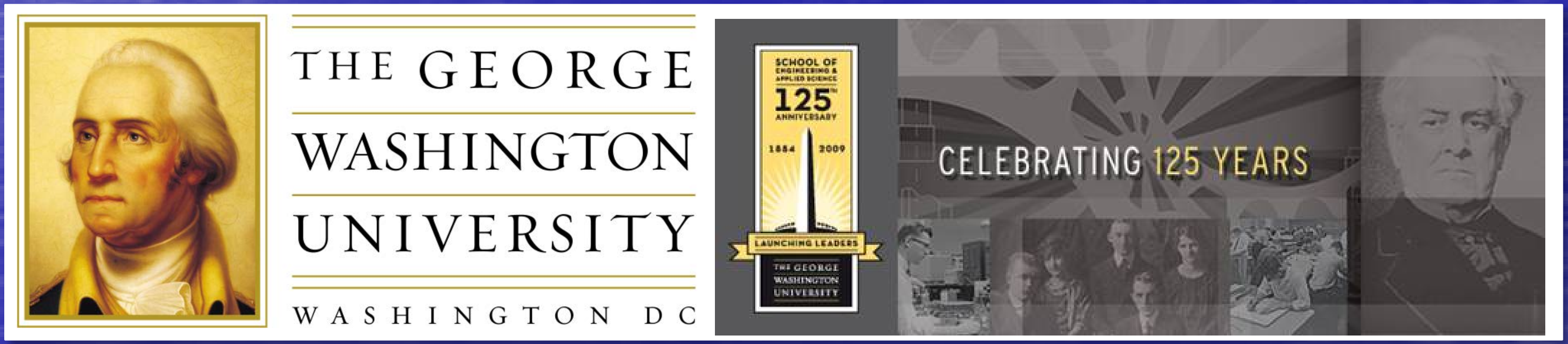
- **Vessel of Interest – Non Persistent Oil: VOI - NPO**
  (Product and Diesel Fuel) – Tanker, ATB, ITB

- **Interacting Vessel - Persistent Oil: IV - PO**
  (Crude and Bunker Fuel) – Colliding Vessels

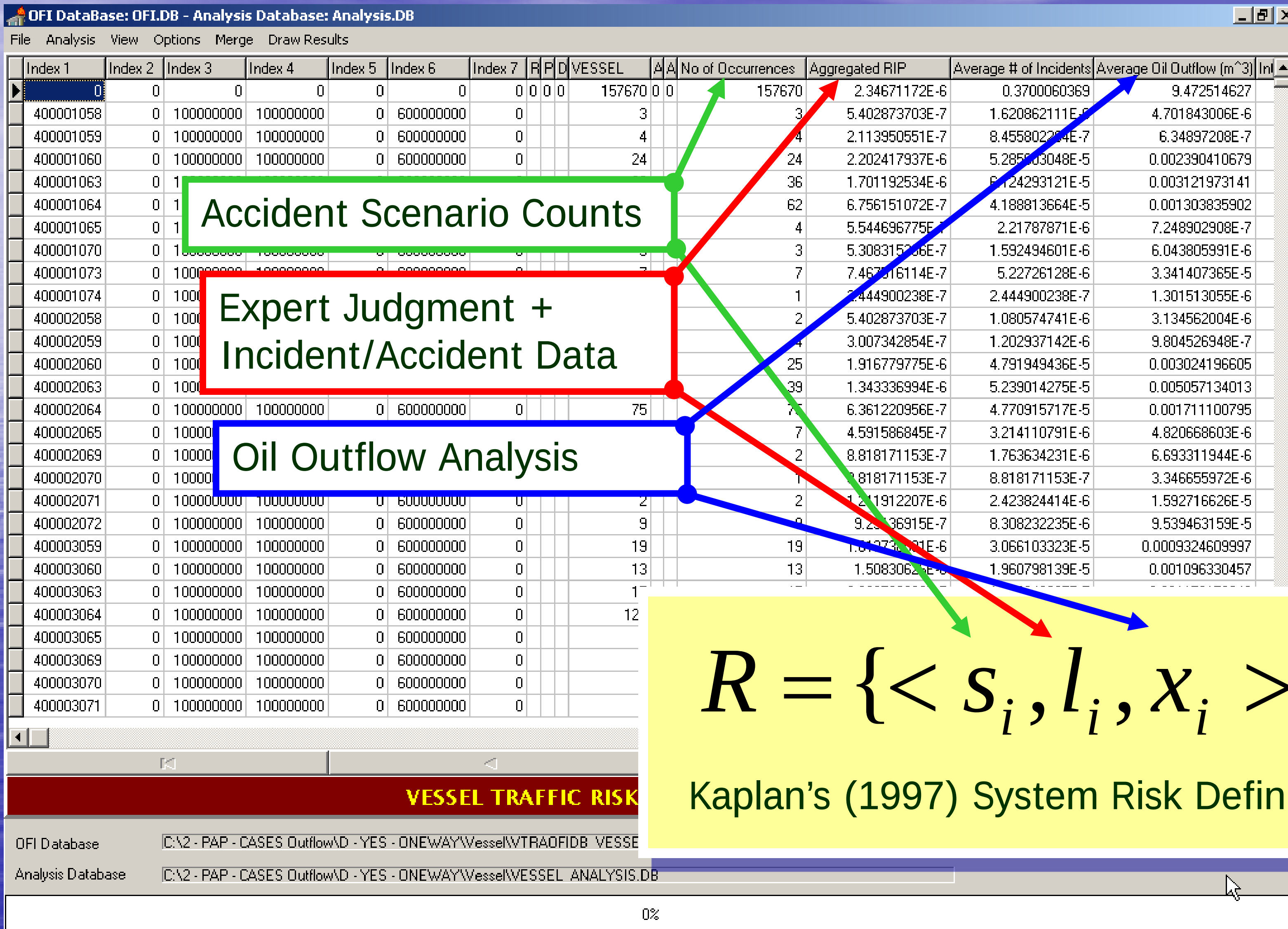
- **Interacting Vessel – Non Persistent Oil: IV - NPO**
  (Product and Diesel Fuel) – Colliding Vessels

Step 4: Integrate Previous 3 Steps





Develop Post-Processing Analysis Engine that integrates:



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

Kaplan's (1997) System Risk Definition

Description of Case Study

- The analysis results herein evaluate the effectiveness of the three risk intervention measures on the previous slide by considering four scenarios of an MTS simulation of the geographic area within the bleu border on the next slide.

- The vessels of interest (VOI's) are tankers, articulated tug barges and integrated tug barges serving six refineries within this geographic area. The approximate locations of these refineries are identified on the next slide. (One of them in the south operates only as a petroleum tank farm since 1998).

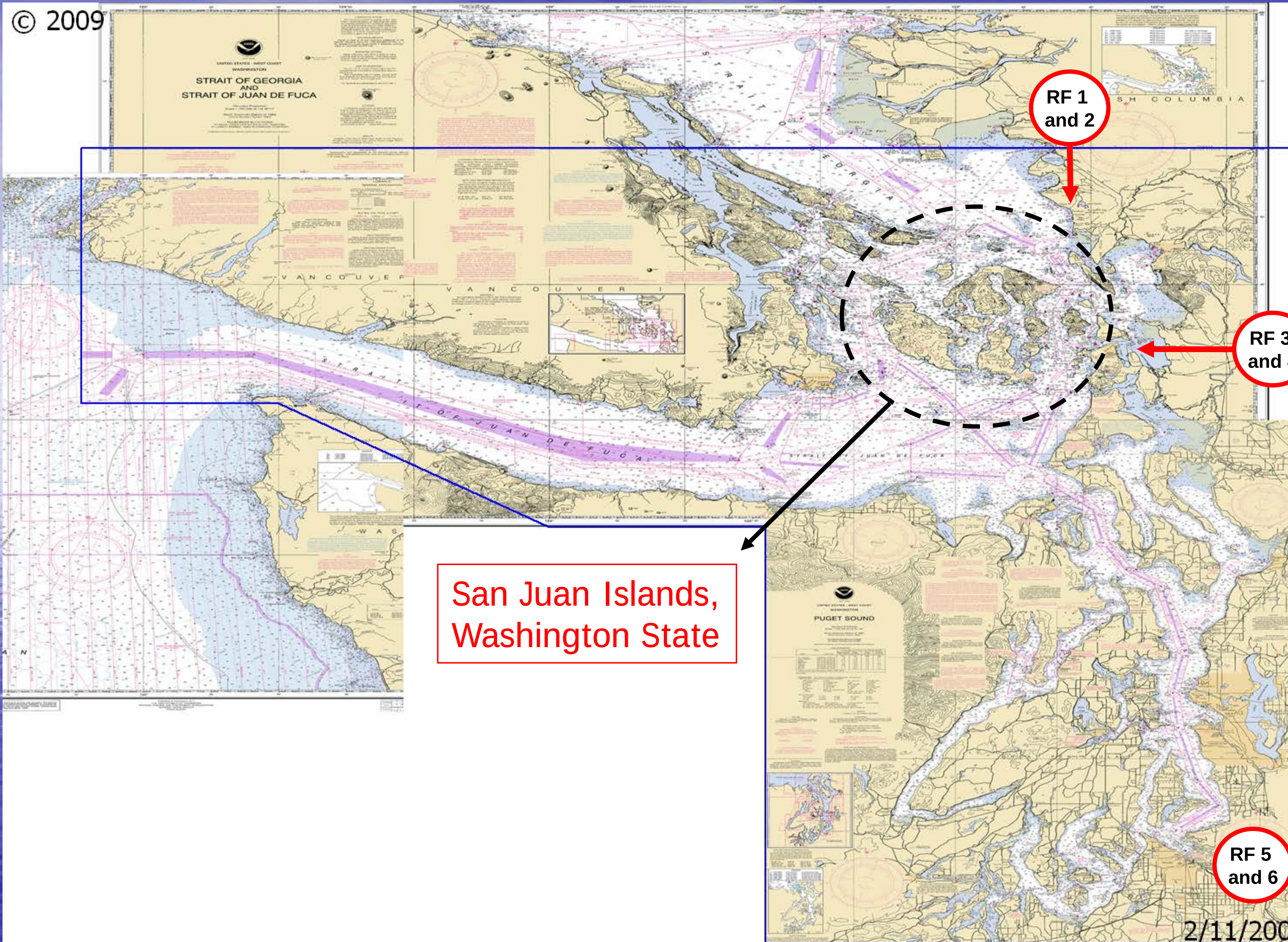
- The four scenarios in question are fictitious scenarios that look back in time, not into the future.

SCENARIO 1: Two-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

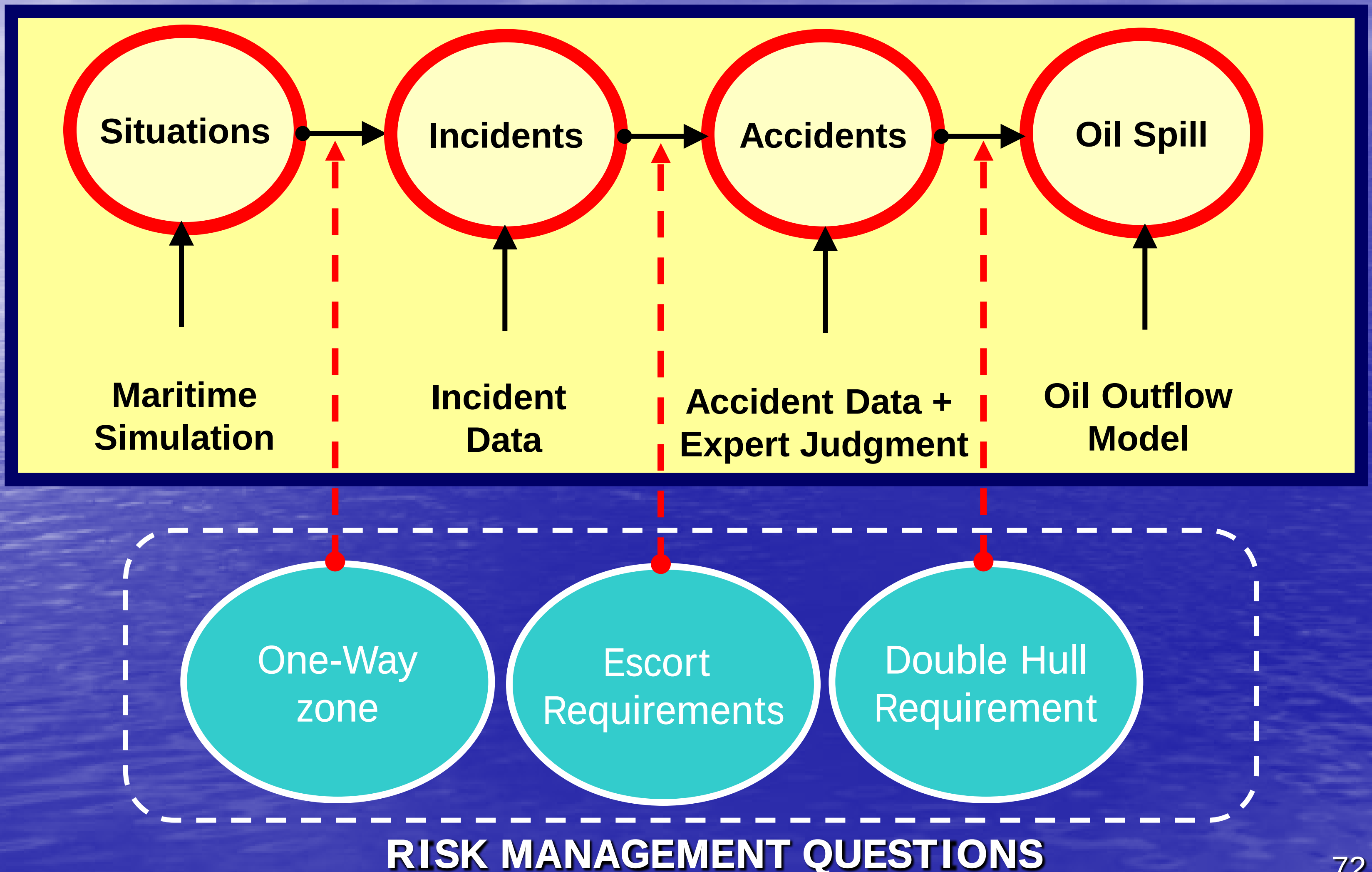
SCENARIO 2: One-way traffic in Rosario Strait, No Escorting and all VOI's have a single hull.

SCENARIO 3: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a single hull.

SCENARIO 4: One-way traffic in Rosario Strait, Escorting Scheme that mimics current regime in study area and all VOI's have a double hull.


© 2009
STRAIT OF GEORGIA
AND
STRAIT OF JUAN DE FUCA
PUGET SOUND
RF 1
and 2
RF 3
and 4
RF 5
and 6
San Juan Islands,
Washington State
2/11/200

Example Risk Management Effectiveness Analysis

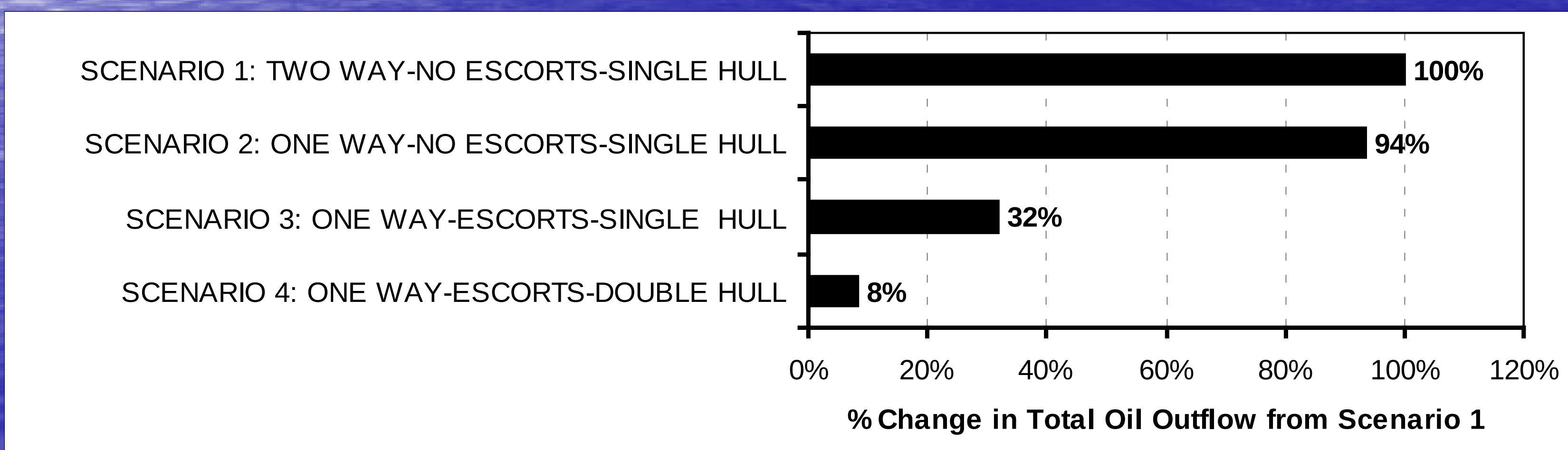


Average Annual Oil Outflow (m^3) by Scenario	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	4300.63
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	4027.72
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	1376.81
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	360.96

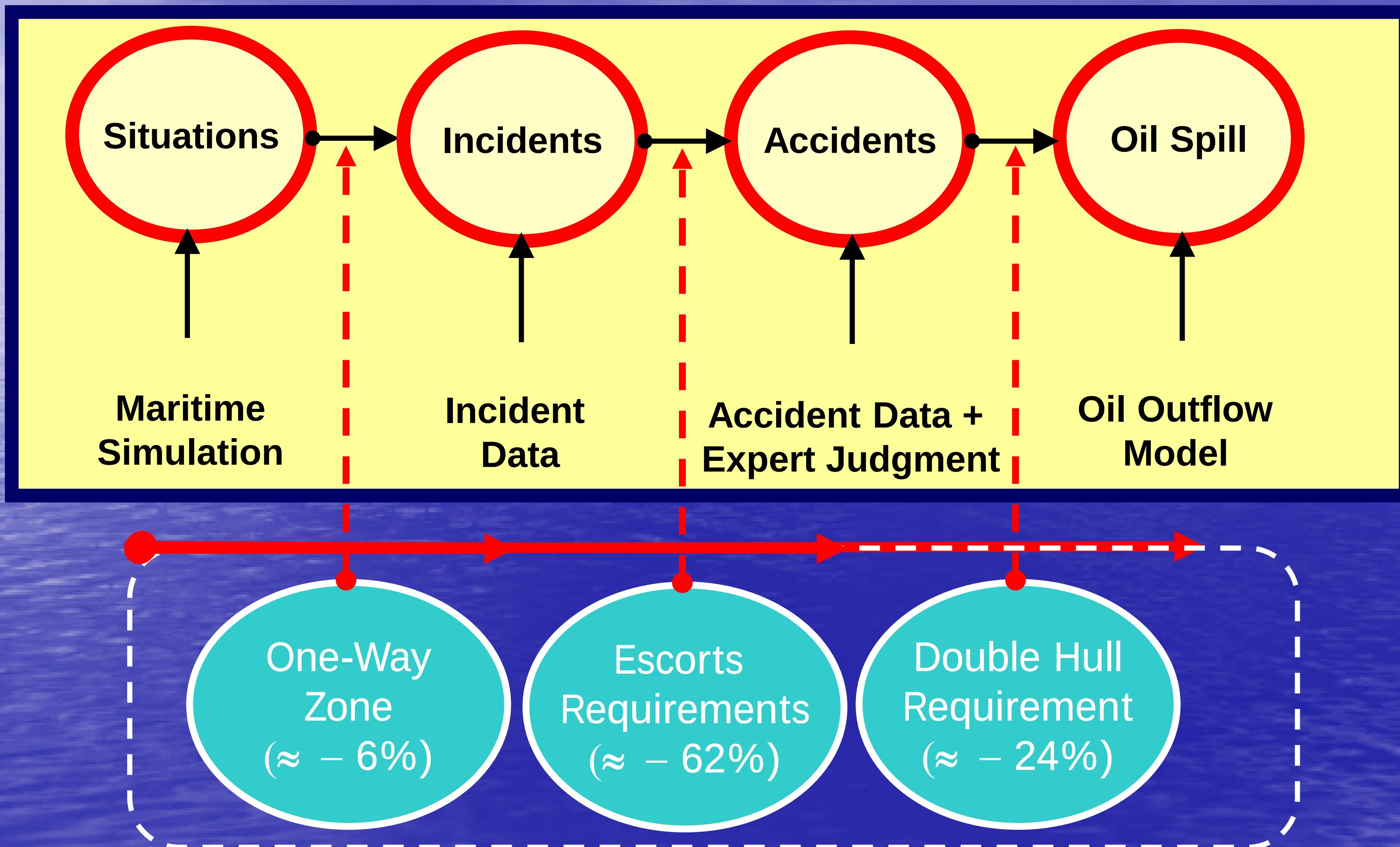
Percentage Change in Oil Outflow (m^3) from Scenario 1	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	100.0%
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	93.7%
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	32.0%
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	8.4%

≈ – 6%
≈ – 62%
≈ – 24%
≈ – 92%

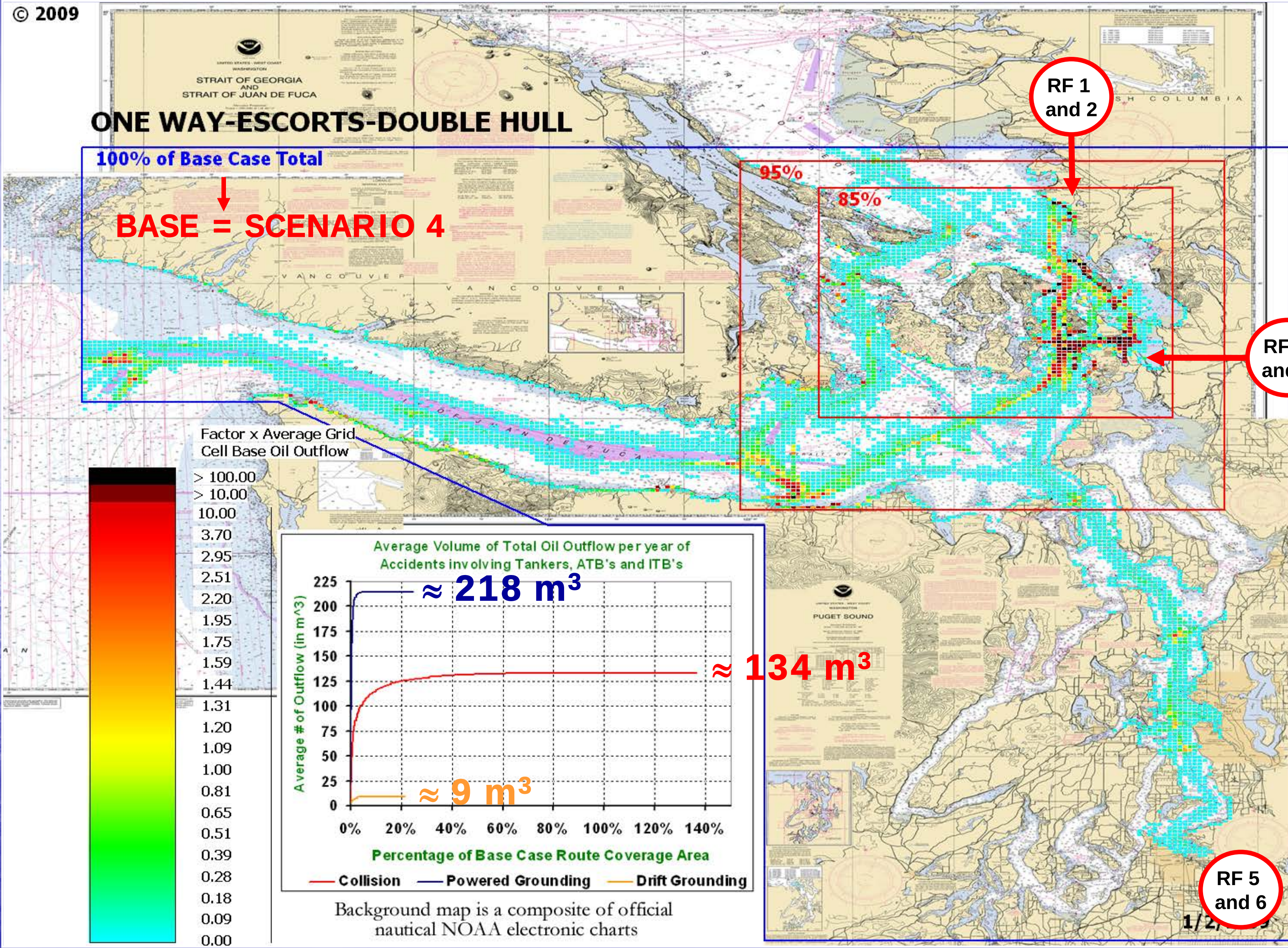
Percentage Change in Oil Outflow (m^3) from Scenario 4	Total Outflow
SCENARIO 1: TWO WAY-NO ESCORTS-SINGLE HULL	1191.4%
SCENARIO 2: ONE WAY-NO ESCORTS-SINGLE HULL	1115.8%
SCENARIO 3: ONE WAY-ESCORTS-SINGLE HULL	381.4%
SCENARIO 4: ONE WAY-ESCORTS-DOUBLE HULL	100.0%



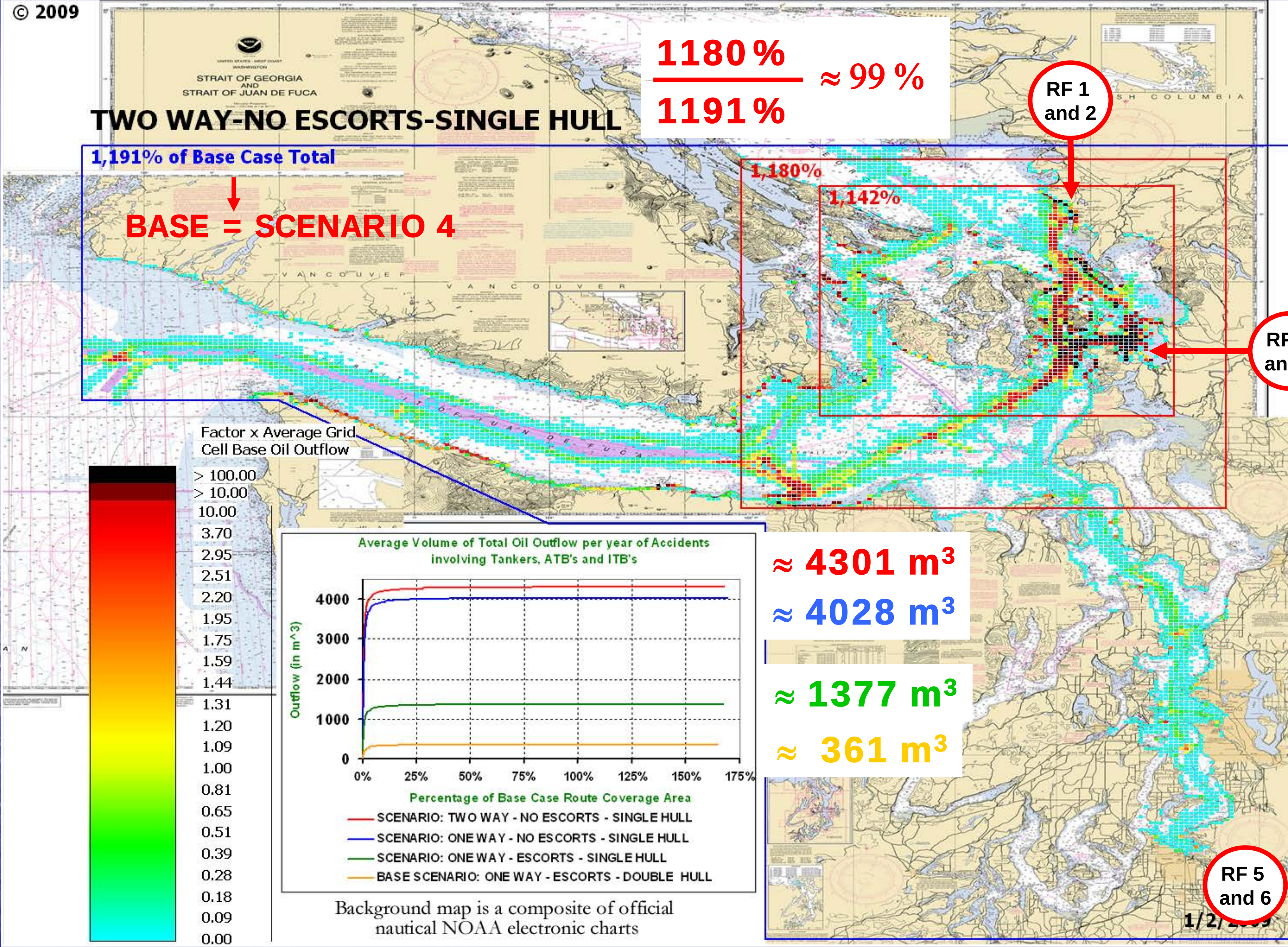
An Oil Spill is a series of cascading events referred to as a Causal Chain



OVERALL A ≈ 92% RISK REDUCTION FROM SCENARIO 1



OIL OUTFLOW GEOGRAPHIC PROFILE SCENARIO 4
ALL THREE RISK INTERVENTION IN PLACE



OIL OUTFLOW GEOGRAPHIC PROFILE SCENARIO 1
WITHOUT THREE RISK INTERVENTIONS IN PLACE

Observations

- In Scenario 1 (without the three risk interventions) 99% of average oil outflow resided in the larger red rectangle of the geographic profile.
- The three risk interventions remove about 92% of total average oil outflow from Scenario 1.
- Of the remaining 8% from Scenario 1 in Scenario 4, still 95% resides in larger red rectangle.
- Hence, the larger red rectangle in Scenario 4 seems to be the natural targeted area for further risk reduction after implementation of these three risk interventions.
- However, because two of the three risk interventions specifically target this area (one-way and escorting) and the third one (double-hull) also addresses this area (double-hull) it will be progressively more difficult to further reduce risk within that area.

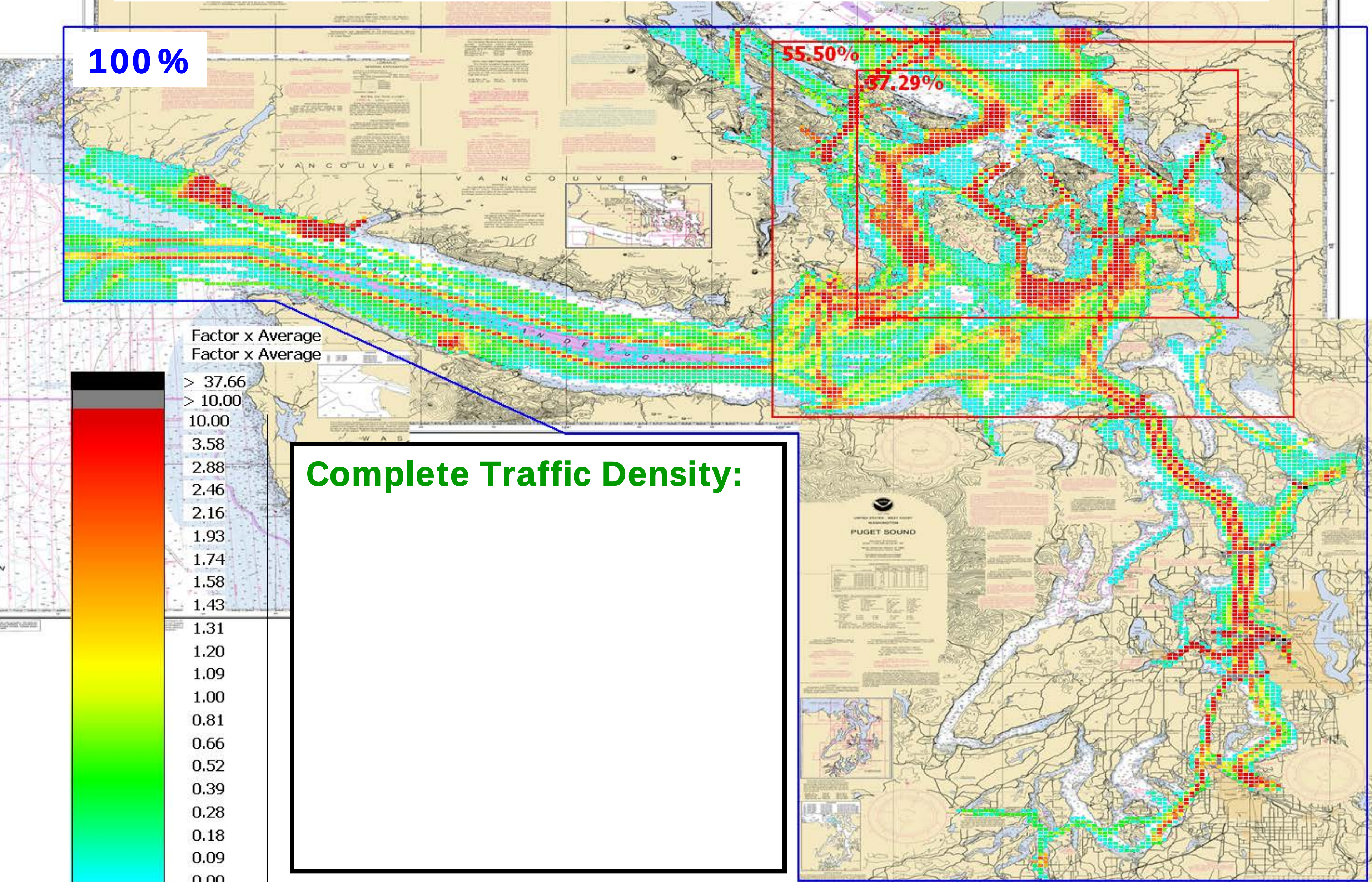
Special Thanks To:

- 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!!!!

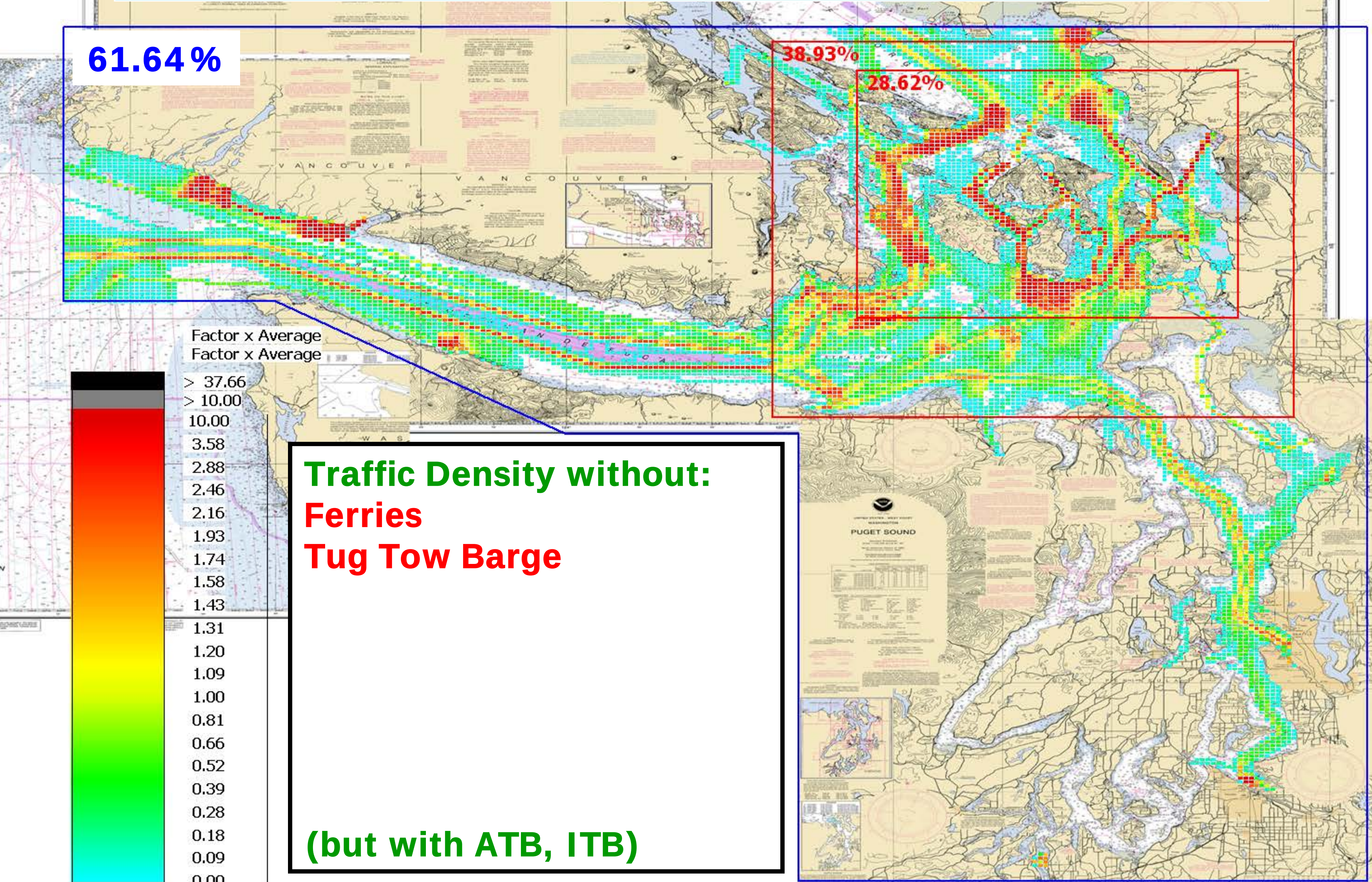
- Without their help, efficient and timely response to our repeated questions and data requests we would not have been able to further enhance and improve our MTS Risk Simulation Methodology.

A Complete Traffic Density Profile



Complete Traffic Density:

Compared to All Traffic



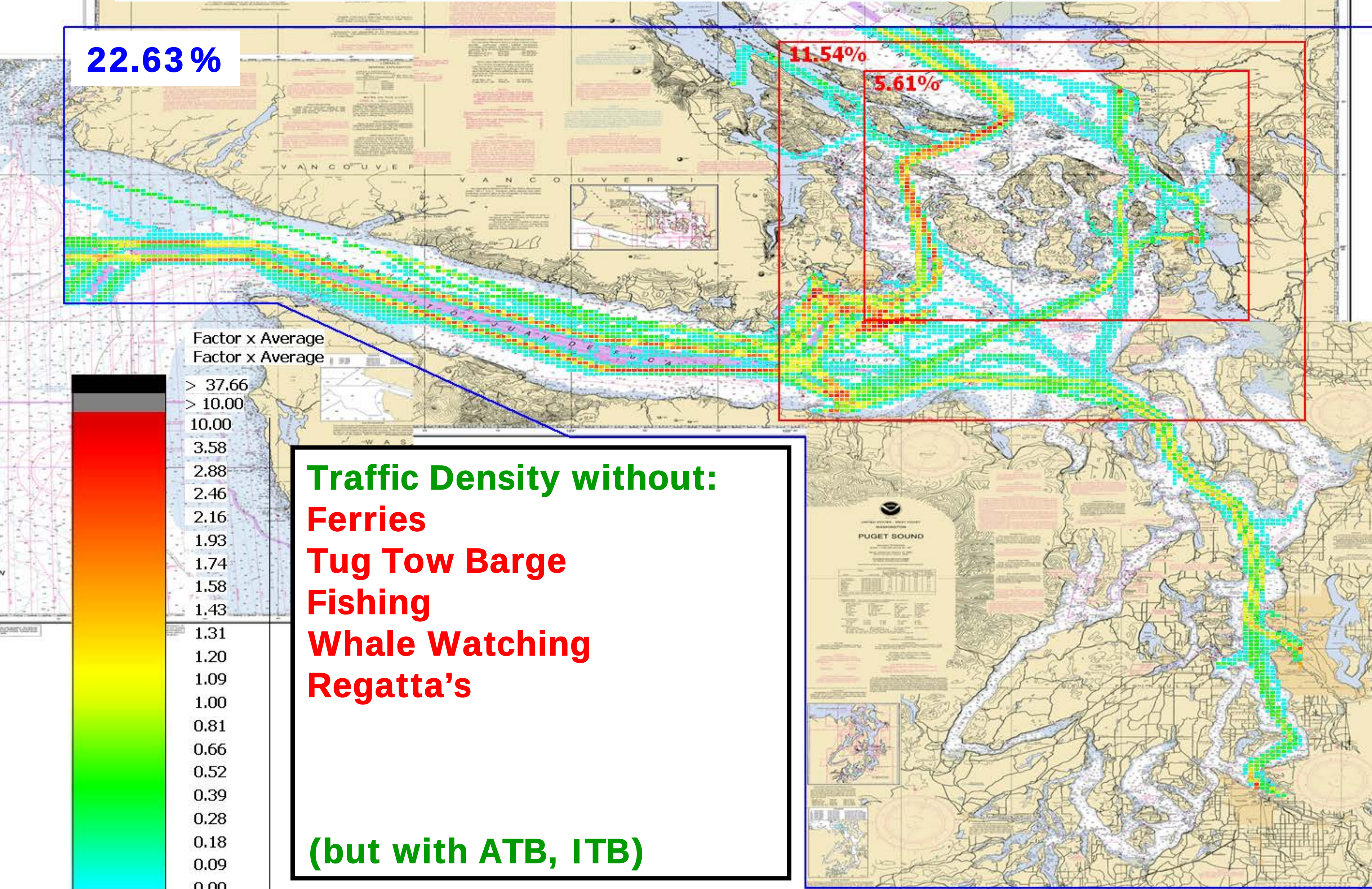
Traffic Density without:

Ferries

Tug Tow Barge

(but with ATB, ITB)

Compared to All Traffic

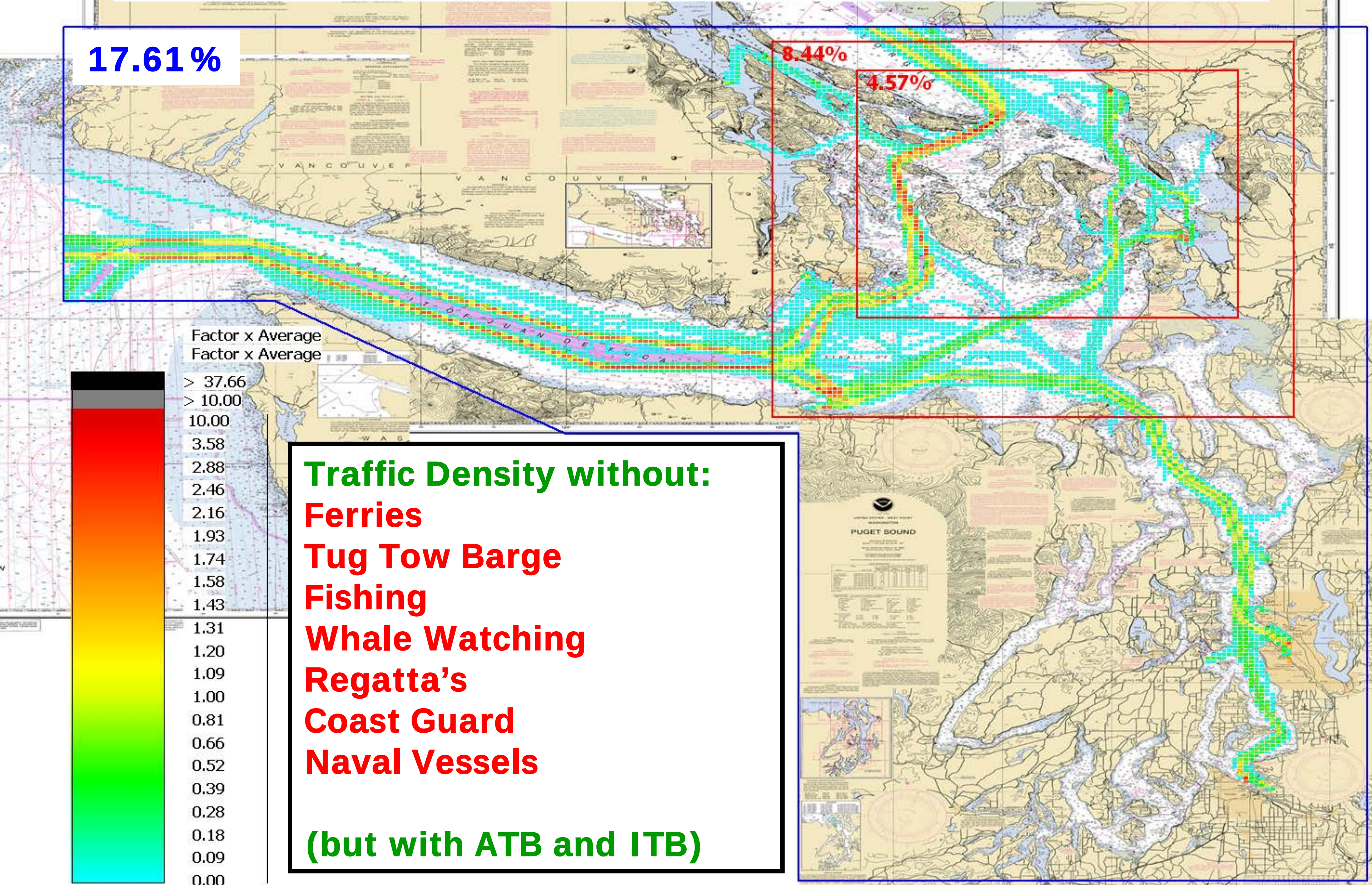


Traffic Density without:

Ferries
Tug Tow Barge
Fishing
Whale Watching
Regatta's

(but with ATB, ITB)

Compared to All Traffic



Traffic Density without:

Ferries

Tug Tow Barge

Fishing

Whale Watching

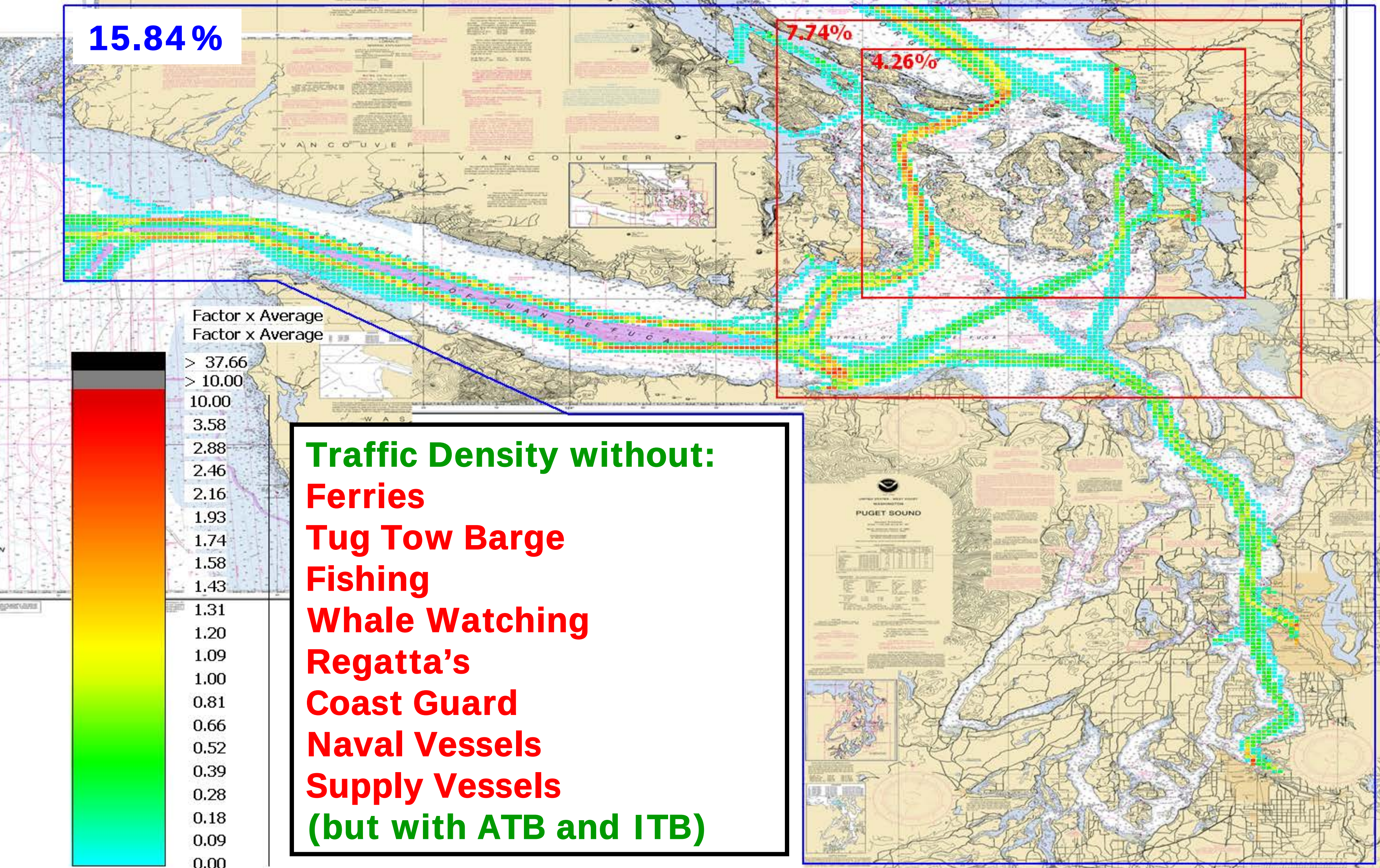
Regatta's

Coast Guard

Naval Vessels

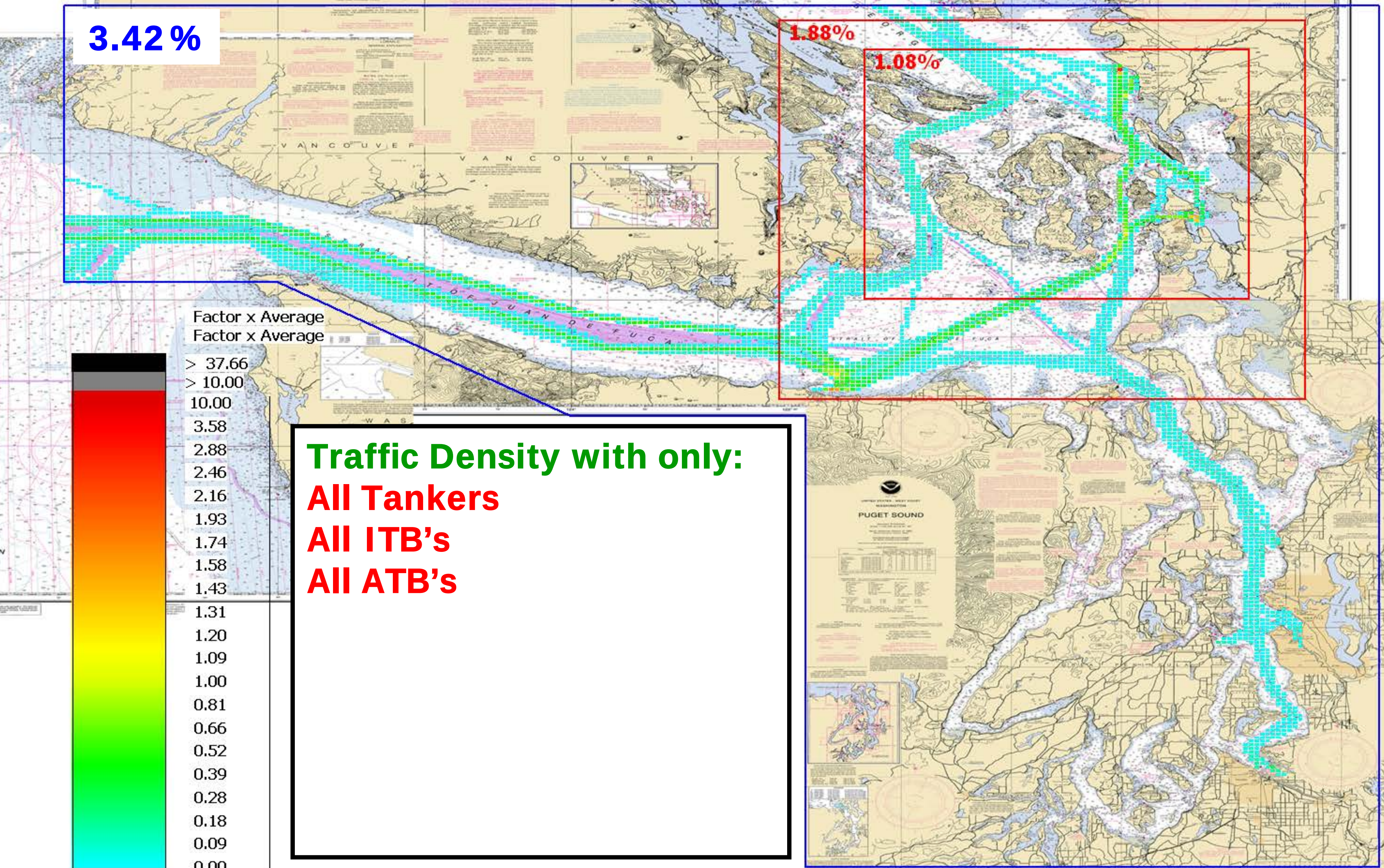
(but with ATB and ITB)

Compared to All Traffic



Traffic Density without:
Ferries
Tug Tow Barge
Fishing
Whale Watching
Regatta's
Coast Guard
Naval Vessels
Supply Vessels
(but with ATB and ITB)

Compared to All Traffic



Traffic Density with only:
All Tankers
All ITB's
All ATB's

QUESTIONS?