

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)

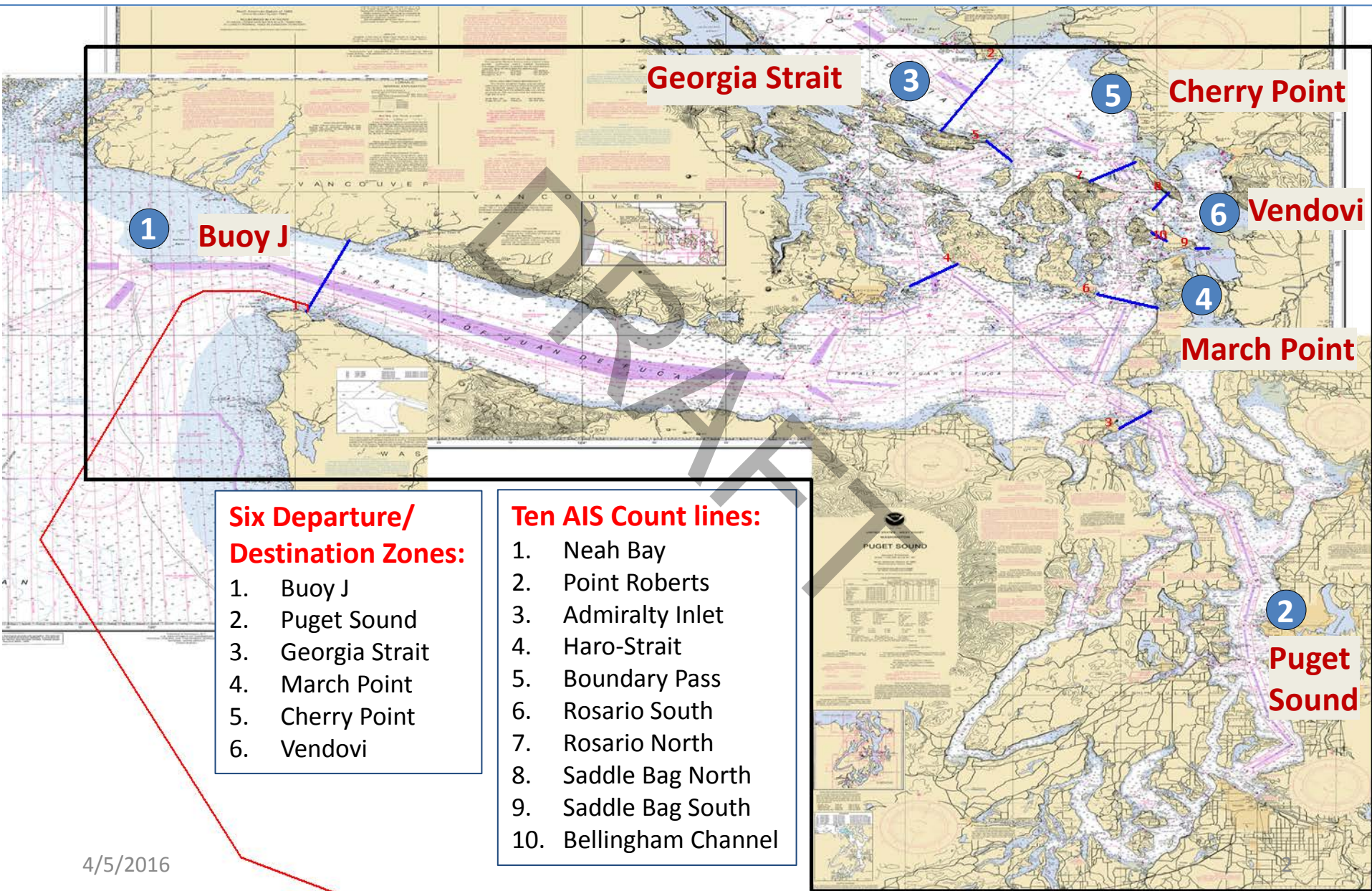
ATB TRAFFIC STREAM ANALYSIS USING AIS 2010 - 2015 CROSSING LINE COUNTS

Dr. J. Rene van Dorp and Dr. Jason R.W Merrick

April 2016



VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



Georgia Strait

3

Point Roberts Crossing Line

VTRA 2015 Waterway Schematic + AIS Crossing Lines

5

Cherry Point

6

Vendovi

Neah Bay Crossing Line

Haro Crossing Lines

Rosario Crossing Lines

Bellingham Channel Crossing Line

Saddle Bag Crossing Lines

4

March Point

Admiralty Inlet Crossing Line

1

Buoy J

AVERAGE VESSEL COUNT ERROR		
ATB	Cargo	Tanker
5	99	12

2

Puget Sound

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)

6 Departure Zones/Destination Zone

1: Buoy J Zone 3: Georgia Strait Zone 5: Cherry Point Zone
2: Puget Sound South Zone 4: March Point Zone 6: Vendovi Zone

Variable Definition:

$x_{ij} \equiv$ # of vessels traveling from Departure Zone i to Destination Zone j

$x_{ijH} \equiv$ # of vessels traveling from Dep. Zone i to Dest. Zone j **through Haro - Strait**

$x_{ijR} \equiv$ # of vessels traveling from Dep. Zone i to Dest. Zone j **through Rosario**

$x_{ijS} \equiv$ # of vessels traveling from Dep. Zone i to Dest. Zone j **through Saddle Bag**

$x_{ijB} \equiv$ # of vessels traveling from Dep. Zone i to Dest. Zone j **through Belling. Channel**

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



Buoy J Balance Equation:

$$x_{12} + x_{13} + x_{14} + x_{15R} + x_{15H} + x_{16B} + x_{16S} = x_{21} + x_{31} + x_{41} + x_{51R} + x_{51H} + x_{61B} + x_{61S}$$

Puget Sound Balance Equation:

$$x_{21} + x_{23H} + x_{23R} + x_{24} + x_{25} + x_{26B} + x_{26S} = x_{12} + x_{32H} + x_{32R} + x_{42} + x_{52} + x_{62B} + x_{62S}$$

Georgia Strait Balance Equation:

$$x_{31} + x_{32H} + x_{32R} + x_{34S} + x_{34R} + x_{35} + x_{36} = x_{13} + x_{23H} + x_{23R} + x_{43S} + x_{43R} + x_{53} + x_{63}$$

March Point Balance Equation:

$$x_{41} + x_{42} + x_{43S} + x_{43R} + x_{45S} + x_{45R} + x_{46S} + x_{46R} = x_{14} + x_{24} + x_{34S} + x_{34R} + x_{54S} + x_{54R} + x_{64S} + x_{64R}$$

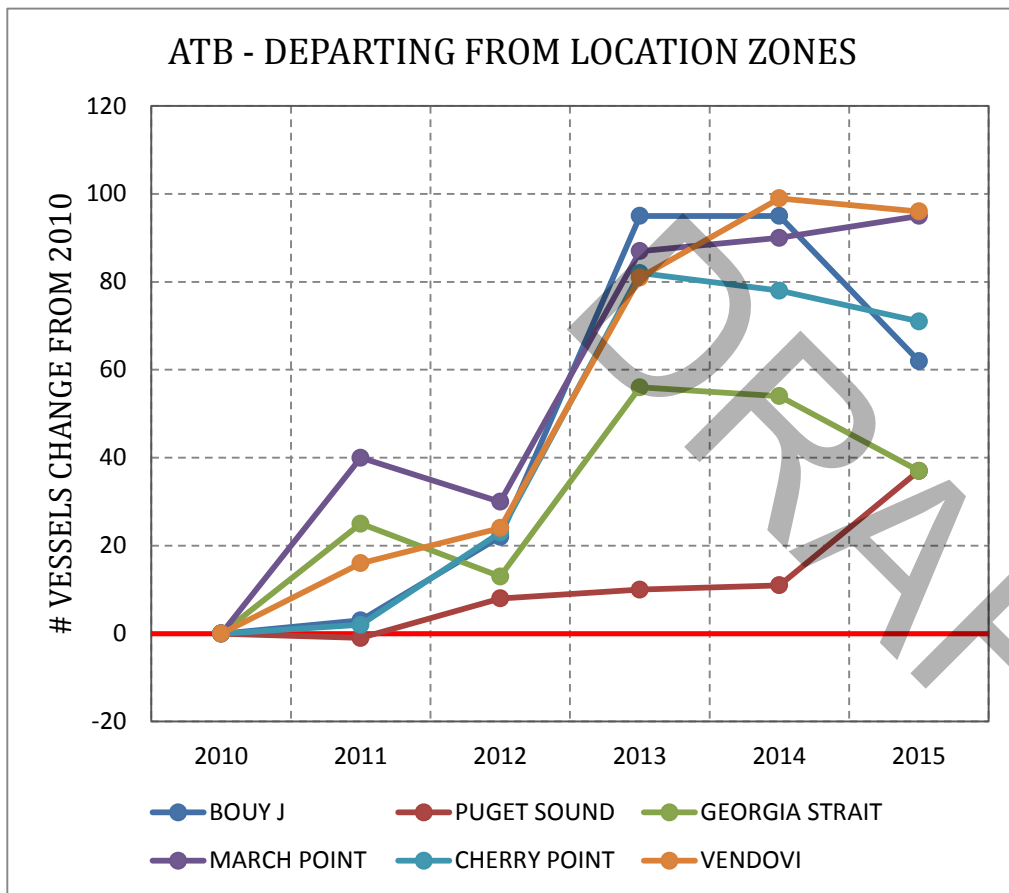
Cherry Point Balance Equation:

$$x_{51H} + x_{51R} + x_{52} + x_{53} + x_{54S} + x_{54R} + x_{56} = x_{15R} + x_{15H} + x_{25} + x_{35} + x_{45S} + x_{45R} + x_{65}$$

Vendovi Balance Equation:

$$x_{61B} + x_{61S} + x_{62B} + x_{62S} + x_{63} + x_{64S} + x_{64R} + x_{65} = x_{16B} + x_{16S} + x_{26B} + x_{26S} + x_{36} + x_{46S} + x_{46R} + x_{56}$$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



FROM	2010	2011	2012	2013	2014	2015
BOUY J	0	3	22	95	95	62
PUGET SOUND	0	-1	8	10	11	37
GEORGIA STRAIT	0	25	13	56	54	37
MARCH POINT	0	40	30	87	90	95
CHERRY POINT	0	2	23	82	78	71
VENDОВI	0	16	24	81	99	96

From Zone	Variable	2010	2011	2012	2013	2014	2015	Change Threshold
Buoy J	x12	0	-1	2	1	1	6	1
	x13	0	0	-3	-2	-2	-3	0
	x14	0	3	2	14	13	5	1
	x15r	0	-5	3	26	23	15	1
	x15h	0	0	4	3	5	1	0
	x16B	0	1	9	33	31	25	1
x16S	0	4	5	19	23	14	1	
Puget Sound	x21	0	-1	2	3	3	8	1
	x23h	0	0	0	0	1	3	0
	x23r	0	0	0	3	-1	-1	0
	x24	0	0	-2	-2	-1	7	1
	x25	0	0	5	6	4	8	1
	x26B	0	-1	3	6	5	12	1
x26S	0	2	1	-6	-2	2	0	
Georgia Strait	x31	0	1	-3	-3	-2	-2	0
	x32h	0	0	0	0	0	4	0
	x32r	0	0	1	6	0	-1	0
	x34S	0	15	7	21	23	21	1
	X34R	0	1	1	11	12	6	1
	x35	0	6	3	2	-3	-5	0
x36	0	2	5	18	23	16	1	
March Point	x41	0	1	3	20	13	7	1
	x42	0	0	2	0	0	6	1
	x43S	0	14	4	15	19	20	1
	x43R	0	1	4	16	13	8	1
	x45S	0	8	1	11	15	22	1
	x45R	0	0	6	16	13	11	1
x46S	0	13	3	-1	1	9	1	
x46R	0	2	6	9	16	12	1	
Cherry Point	x51h	0	0	5	5	10	0	0
	x51r	0	-4	5	33	31	20	1
	x52	0	0	5	10	9	10	1
	x53	0	7	4	5	2	0	0
	x54S	0	6	2	8	1	11	1
	x54R	0	0	7	19	23	21	1
x56	0	-6	-5	1	2	8	1	
Vendovi	x61B	0	2	2	11	14	9	1
	x61R	0	2	8	27	28	21	1
	x62B	0	-1	-1	-1	4	12	1
	x62R	0	1	0	-4	-3	2	0
	x63	0	2	4	18	19	11	1
	x64S	0	13	6	7	5	9	1
x64R	0	1	4	6	14	15	1	
x65	0	-5	2	16	19	18	1	

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VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



Buoy J Balance Equation:

$$x_{12} + x_{13} + x_{14} + x_{15R} + x_{15H} + x_{16B} + x_{16S} = x_{21} + x_{31} + x_{41} + x_{51R} + x_{51H} + x_{61B} + x_{61S}$$

Puget Sound Balance Equation:

$$x_{21} + x_{23H} + x_{23R} + x_{24} + x_{25} + x_{26B} + x_{26S} = x_{12} + x_{32H} + x_{32R} + x_{42} + x_{32H} + x_{52} + x_{62B} + x_{62S}$$

Georgia Strait Balance Equation:

$$x_{31} + x_{32H} + x_{32R} + x_{34S} + x_{34R} + x_{35} + x_{36} = x_{13} + x_{23H} + x_{23R} + x_{43S} + x_{43R} + x_{53} + x_{63}$$

March Point Balance Equation:

$$x_{41} + x_{42} + x_{43S} + x_{43R} + x_{45S} + x_{45R} + x_{46S} + x_{46R} = x_{14} + x_{24} + x_{34S} + x_{34R} + x_{54S} + x_{54R} + x_{64S} + x_{64R}$$

Cherry Point Balance Equation:

$$x_{51H} + x_{51R} + x_{52} + x_{53} + x_{54S} + x_{54R} + x_{56} = x_{15R} + x_{15H} + x_{25} + x_{35} + x_{45S} + x_{45R} + x_{65}$$

Vendovi Balance Equation:

$$x_{61B} + x_{61S} + x_{62B} + x_{62S} + x_{63} + x_{64S} + x_{64R} + x_{65} = x_{16B} + x_{16S} + x_{26B} + x_{26S} + x_{36} + x_{46S} + x_{46R} + x_{56}$$

Georgia Strait

3

Point Roberts Crossing Line

VTRA 2015 Waterway Schematic + AIS Crossing Lines

5 Cherry Point

Neah Bay Crossing Line

Haro Crossing Lines

Rosario Crossing Lines

Bellingham Channel Crossing Line

6 Vendovi

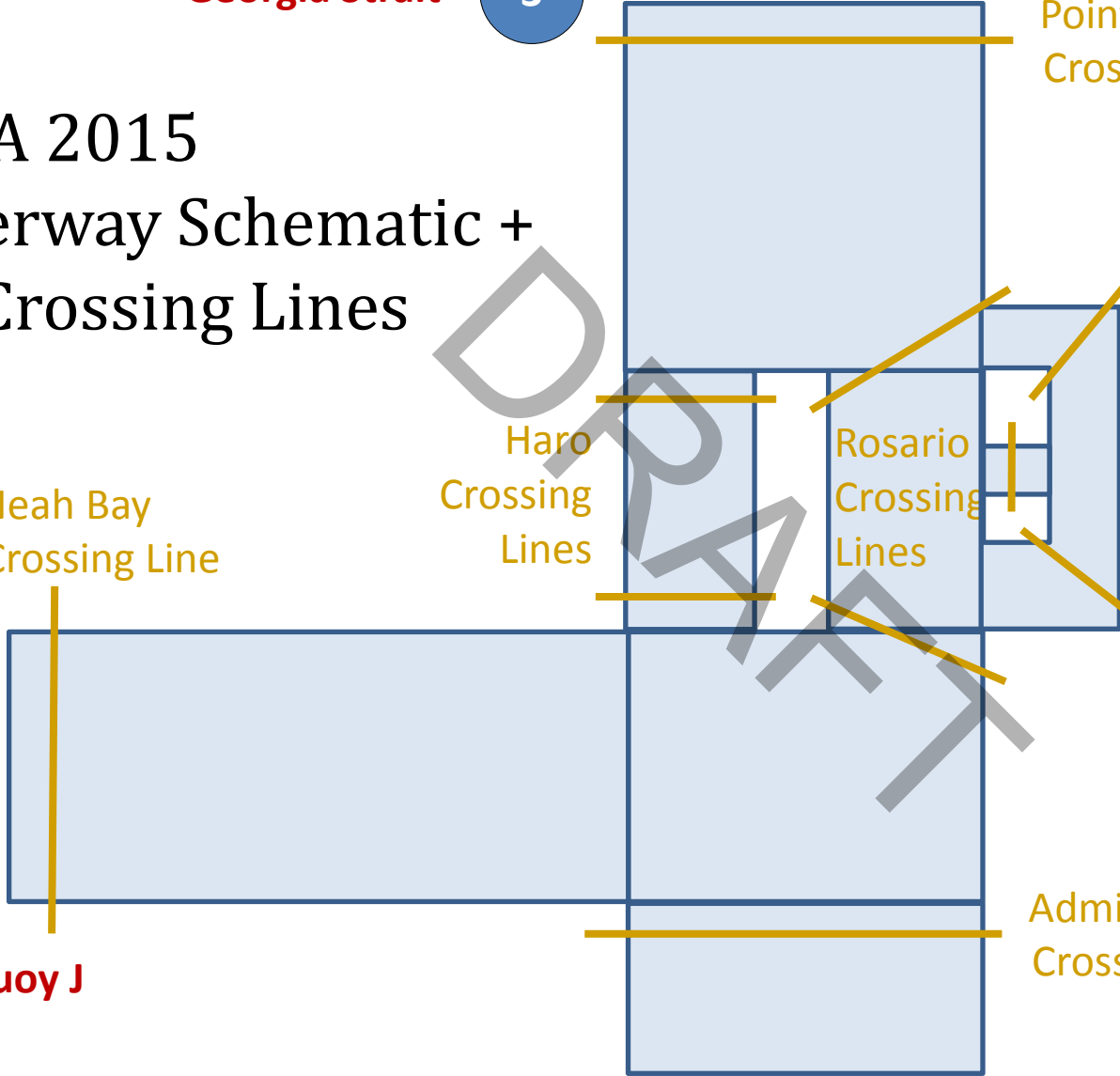
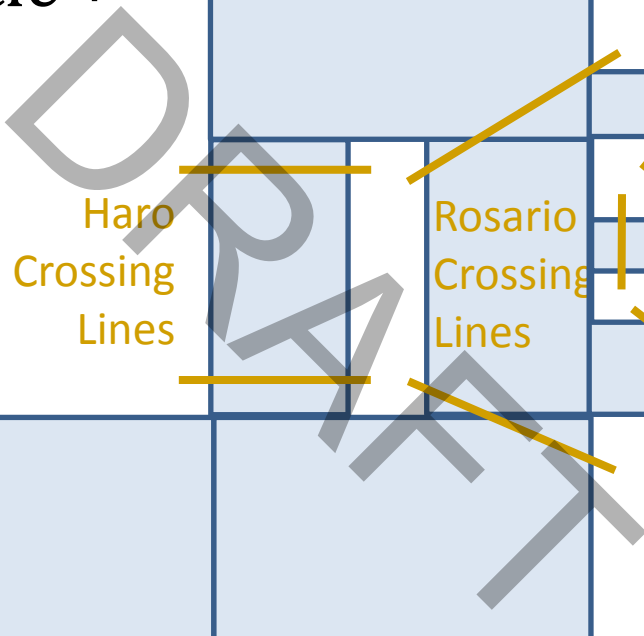
Saddle Bag Crossing Lines

4 March Point

Admiralty Inlet Crossing Line

1 Buoy J

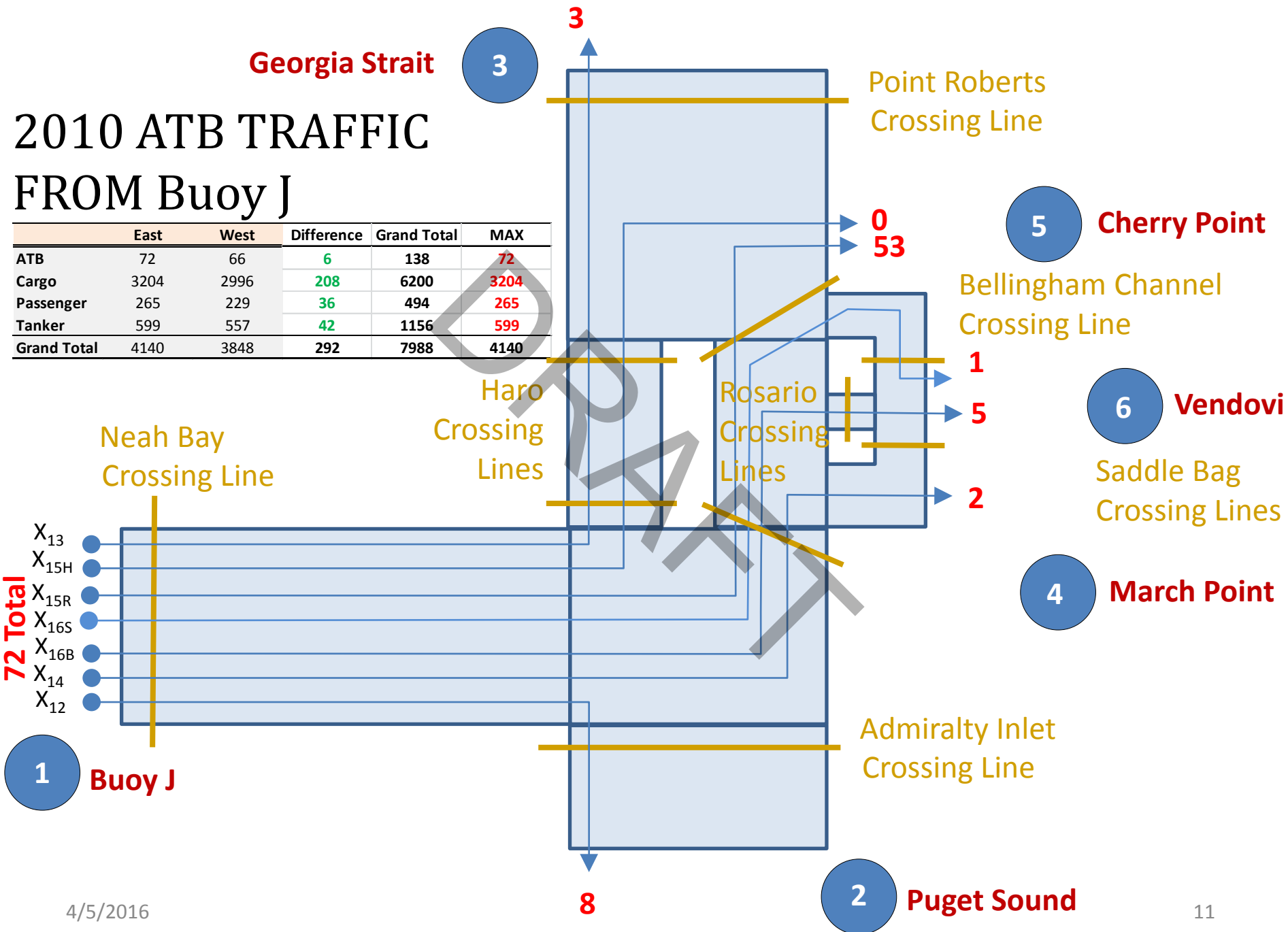
2 Puget Sound



Georgia Strait

2010 ATB TRAFFIC FROM Buoy J

	East	West	Difference	Grand Total	MAX
ATB	72	66	6	138	72
Cargo	3204	2996	208	6200	3204
Passenger	265	229	36	494	265
Tanker	599	557	42	1156	599
Grand Total	4140	3848	292	7988	4140



2010 TANKER TRAFFIC FROM Puget Sound

	North	South	Difference	Grand Total	MAX
ATB	23	20	3	43	23
Cargo	1696	1627	69	3323	1696
Passenger	852	849	3	1701	852
Tanker	75	73	2	148	75
Grand Total	2646	2569	77	5215	2646

Georgia Strait

3

0 3

Point Roberts Crossing Line

5

Cherry Point

Bellingham Channel Crossing Line

0

7

6

Vendovi

Saddle Bag Crossing Lines

6

2

4

March Point

Neah Bay Crossing Line

Haro Crossing Lines

Rosario Crossing Line

Admiralty Inlet Crossing Line

5

1

Buoy J

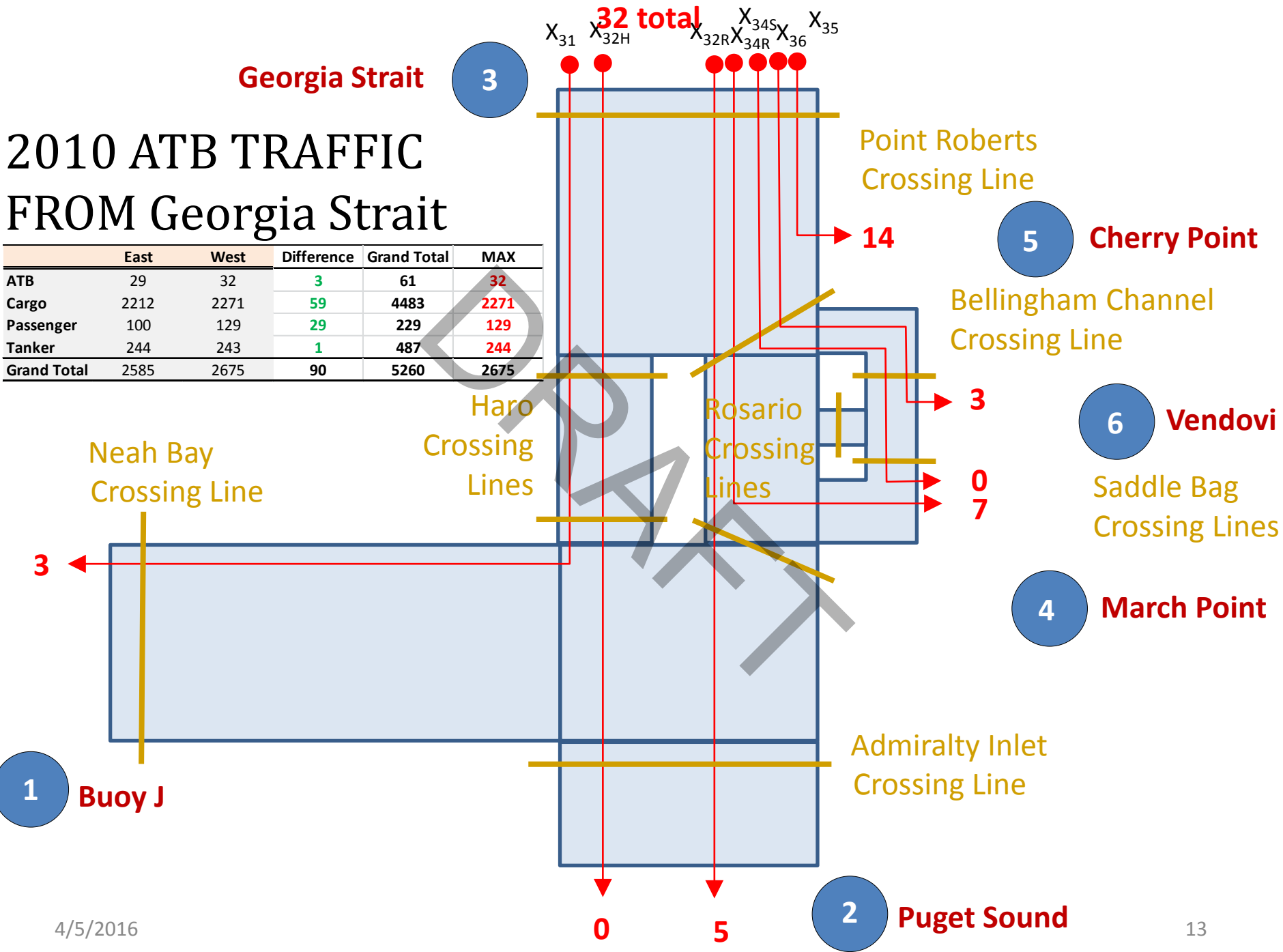
2

Puget Sound

X₂₁ X_{23H} X_{23R} X₂₅ X_{26B} X₂₄ X_{26S}
23 total

2010 ATB TRAFFIC FROM Georgia Strait

	East	West	Difference	Grand Total	MAX
ATB	29	32	3	61	32
Cargo	2212	2271	59	4483	2271
Passenger	100	129	29	229	129
Tanker	244	243	1	487	244
Grand Total	2585	2675	90	5260	2675



VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)

Other 2010 AIS Crossing Line Data

BOUNDARY PASS					
	North	South	Grand Total	Grand Total	Average
ATB	3	3	6	6	28
Cargo	2342	2145	4498	4487	1984
Passenger	99	76	205	175	491
Tanker	265	252	520	517	160
Grand Total	2709	2476	5229	5185	2661
HARO STRAIT					
	North	South	Grand Total	Grand Total	Average
ATB	3	3	6	6	30
Cargo	2180	2310	4522	4490	2128
Passenger	137	118	288	255	310
Tanker	246	271	517	517	202
Grand Total	2566	2702	5333	5268	2668
BELLINGHAM CHANNEL					
	North	South	Difference	Grand Total	Average
ATB	10	4	6	14	7
Cargo	22	48	26	70	35
Passenger	43	47	4	90	45
Tanker	23	3	20	26	13
Grand Total	98	102	4	200	100

ROSARIO SOUTH					
	North	South	Difference	Grand Total	Average
ATB	79	78	1	157	78.5
Cargo	66	71	5	137	68.5
Passenger	45	56	11	101	50.5
Tanker	311	320	9	631	315.5
Grand Total	501	525	24	1026	513
ROSARIO NORTH					
	North	South	Difference	Grand Total	Average
ATB	75	81	6	156	78
Cargo	53	57	4	110	55
Passenger	57	64	7	121	60.5
Tanker	252	270	18	522	261
Grand Total	437	472	35	909	454.5
SADDLEBAGS NORTH					
	North	South	Difference	Grand Total	Average
ATB	31	46	15	77	38.5
Cargo	20	4	16	24	12
Passenger	52	79	27	131	65.5
Tanker	90	61	29	151	75.5
Grand Total	193	190	3	383	191.5
SADDLEBAGS SOUTH					
	North	South	Difference	Grand Total	Average
ATB	38	36	2	74	37
Cargo	12	15	3	27	13.5
Passenger	1	3	2	4	2
Tanker	5	55	50	60	30
Grand Total	56	109	53	165	82.5

2010 ATB TRAFFIC FROM March Point

Georgia Strait

3

Point Roberts Crossing Line

1
9

5 Cherry Point

Bellingham Channel Crossing Line

0
2

6 Vendovi

Saddle Bag Crossing Lines

Rosario Crossing Lines

15
28

4 March Point

Neah Bay Crossing Line

1

X_{46S}
X_{45S}
X_{43S}
X_{46R}
X_{45R}
X_{43R}
X₄₂
X₄₁

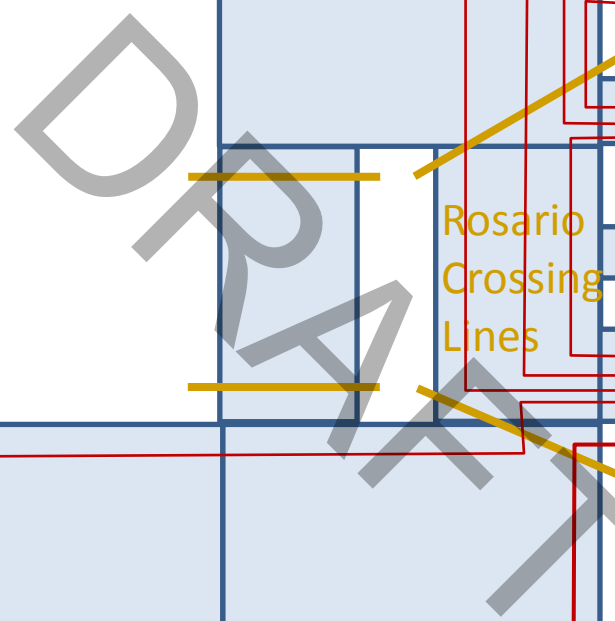
56 total

Admiralty Inlet Crossing Line

0

2 Puget Sound

1 Buoy J



2010 ATB TRAFFIC FROM Cherry Point

Georgia Strait

3

12

Point Roberts Crossing Line

- X₅₃
- X_{51H}
- X_{51R}
- X₅₂
- X_{54R}
- X_{54S}
- X₅₆

78 total

5

Cherry Point

Bellingham Channel Crossing Line

6

6

Vendovi

Saddle Bag Crossing Lines

4

March Point

Admiralty Inlet Crossing Line

2

Puget Sound

Neah Bay Crossing Line

0
60

1

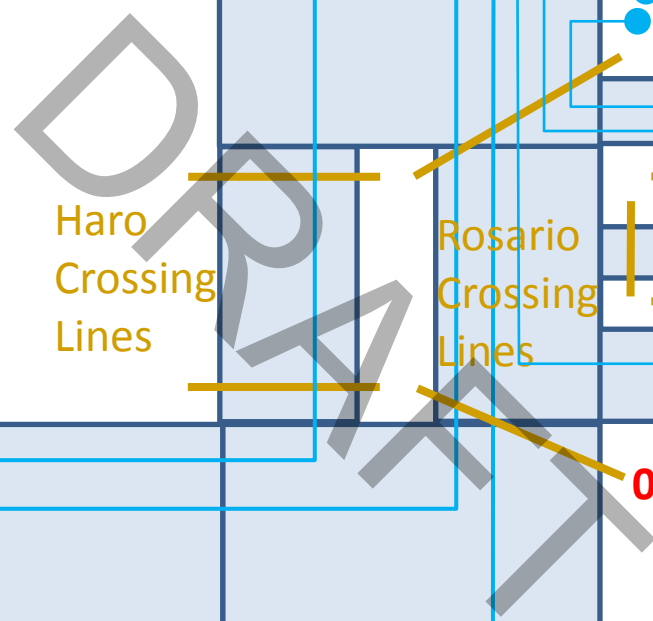
Buoy J

Haro Crossing Lines

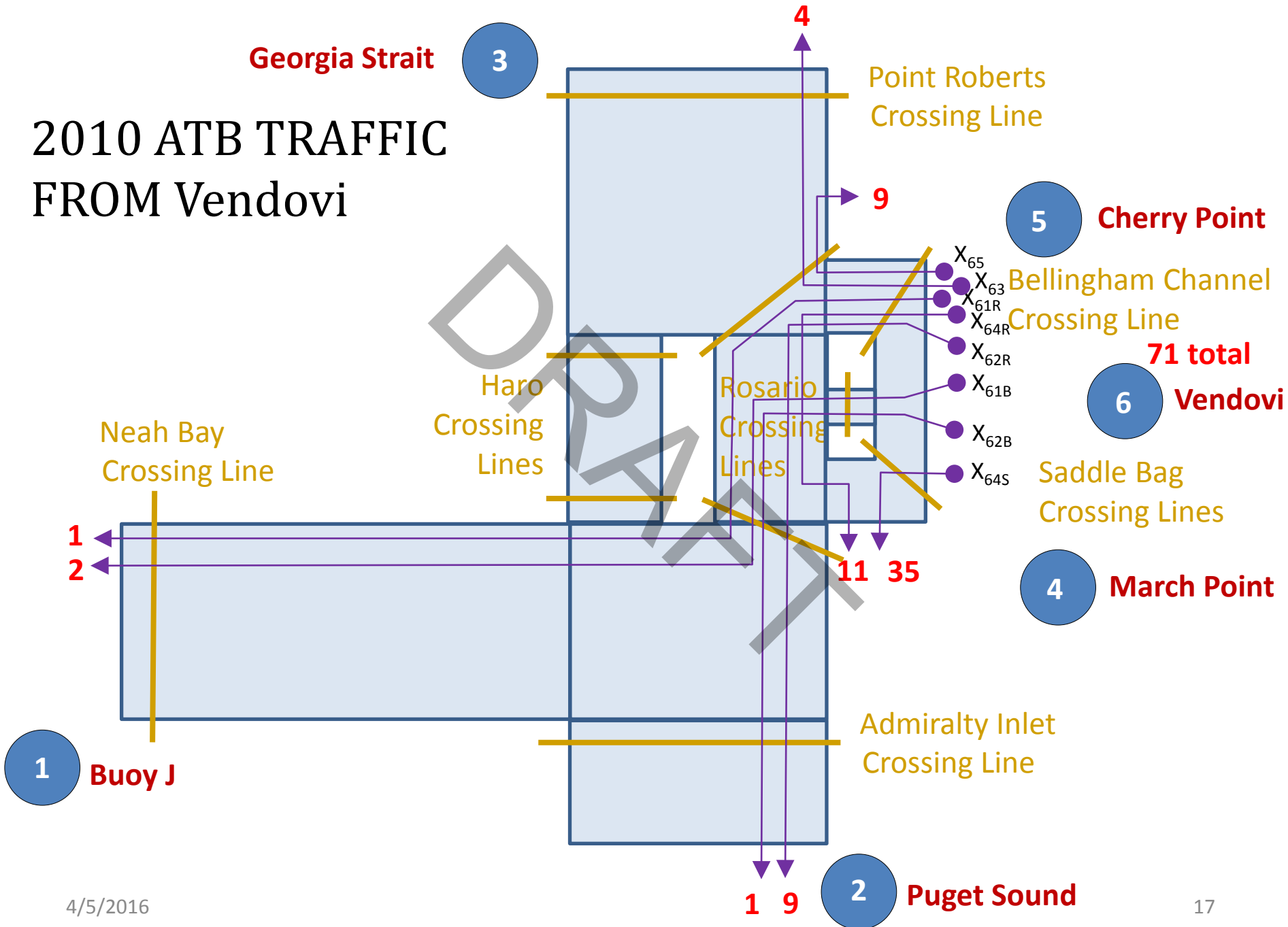
Rosario Crossing Lines

0 0

0



2010 ATB TRAFFIC FROM Vendovi



VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



Neah Bay Crossing Line Equations:

$$N - WB = x_{12} + x_{13} + x_{14} + x_{15R} + x_{15H} + x_{16B} + x_{16S}$$

$$N - EB = x_{21} + x_{31} + x_{41} + x_{51R} + x_{51H} + x_{61B} + x_{61S}$$

Admiralty Inlet Crossing Line Equations:

$$A - NB = x_{21} + x_{23H} + x_{23R} + x_{24} + x_{25} + x_{26B} + x_{26S}$$

$$A - SB = x_{12} + x_{32H} + x_{32R} + x_{42} + x_{52} + x_{62B} + x_{62S}$$

Point Roberts Crossing Line Equations:

$$P - NB = x_{31} + x_{32H} + x_{32R} + x_{34S} + x_{34R} + x_{35} + x_{36}$$

$$P - SB = x_{13} + x_{23H} + x_{23R} + x_{43S} + x_{43R} + x_{53} + x_{63}$$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)



Haro - Boundary Pass Crossing Line Equations:

$$H - NB = x_{13} + x_{15H} + x_{23H}$$

$$H - SB = x_{31} + x_{32H} + x_{51H}$$

$$B - NB = x_{13} + x_{15H} + x_{23H}$$

$$B - SB = x_{31} + x_{32H} + x_{51H}$$

Rosario Crossing Line Equations:

$$RS - NB = x_{14} + x_{15R} + x_{16B} + x_{16S} + x_{23R} + x_{24} + x_{25} + x_{26B} + x_{26S}$$

$$RS - SB = x_{32R} + x_{41} + x_{42} + x_{51R} + x_{52} + x_{61B} + x_{61S} + x_{62B} + x_{62S}$$

$$RN - NB = x_{15R} + x_{23R} + x_{25} + x_{43S} + x_{43R} + x_{45S} + x_{45R} + x_{63} + x_{65}$$

$$RN - SB = x_{32R} + x_{34S} + x_{34R} + x_{36} + x_{51R} + x_{52} + x_{54S} + x_{54R}$$

VESSEL TRAFFIC RISK ASSESSMENT (VTRA 2015)

Saddle Bag Crossing Line Equations:

$$SN - NB = x_{43S} + x_{45S} + x_{61S} + x_{62S} + x_{63} + x_{64R} + x_{65}$$

$$SN - SB = x_{16S} + x_{26S} + x_{34S} + x_{36} + x_{46R} + x_{54S} + x_{56}$$

$$SS - NB = x_{43S} + x_{45S} + x_{46S}$$

$$SS - SB = x_{34S} + x_{54S} + x_{64S}$$

Bellingham Channel Crossing Line Equations:

$$C - EB = x_{16B} + x_{26B}$$

$$C - WB = x_{61B} + x_{62B}$$