A Risk-based Methodology of Assessing the Adequacy of Charting Products in the Arctic Region:

Identifying the Survey Priorities of the Future

Presented to the NOAA Hydrographic Services Review Panel

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Adapted from Paper for US Hydro 2015, National Harbor MD By LCDR Michael O. Gonsalves, NOAA
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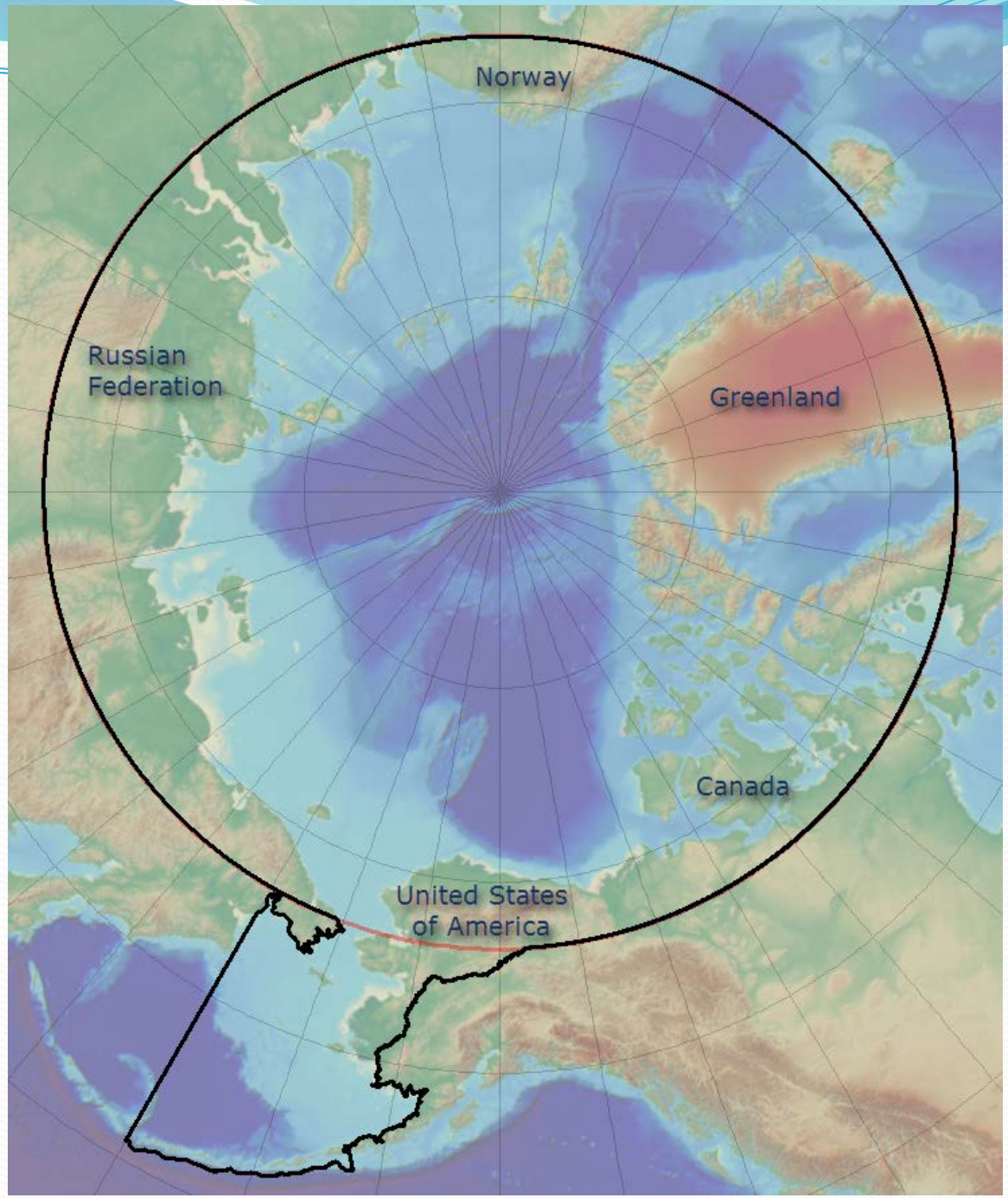
Background

- In 2014, the Arctic Regional Hydrographic Commission responded to a request by the Arctic Council's Protection of the Arctic Marine Environment (PAME) working group on the status of Arctic Charting.

Area of Study

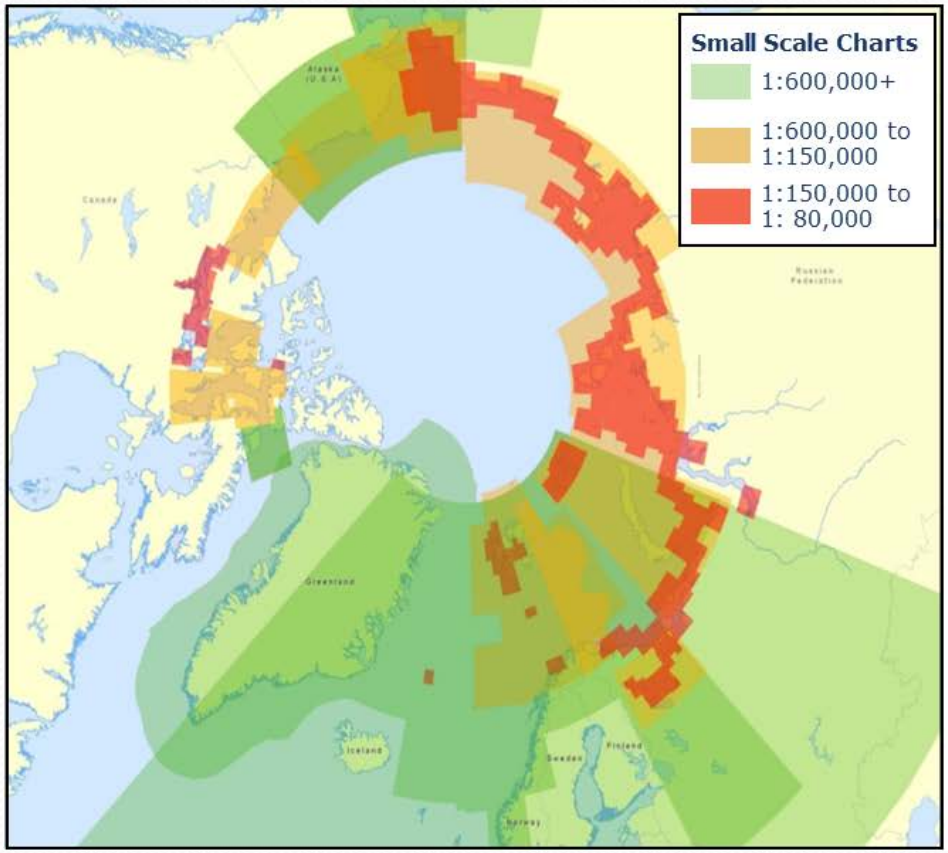


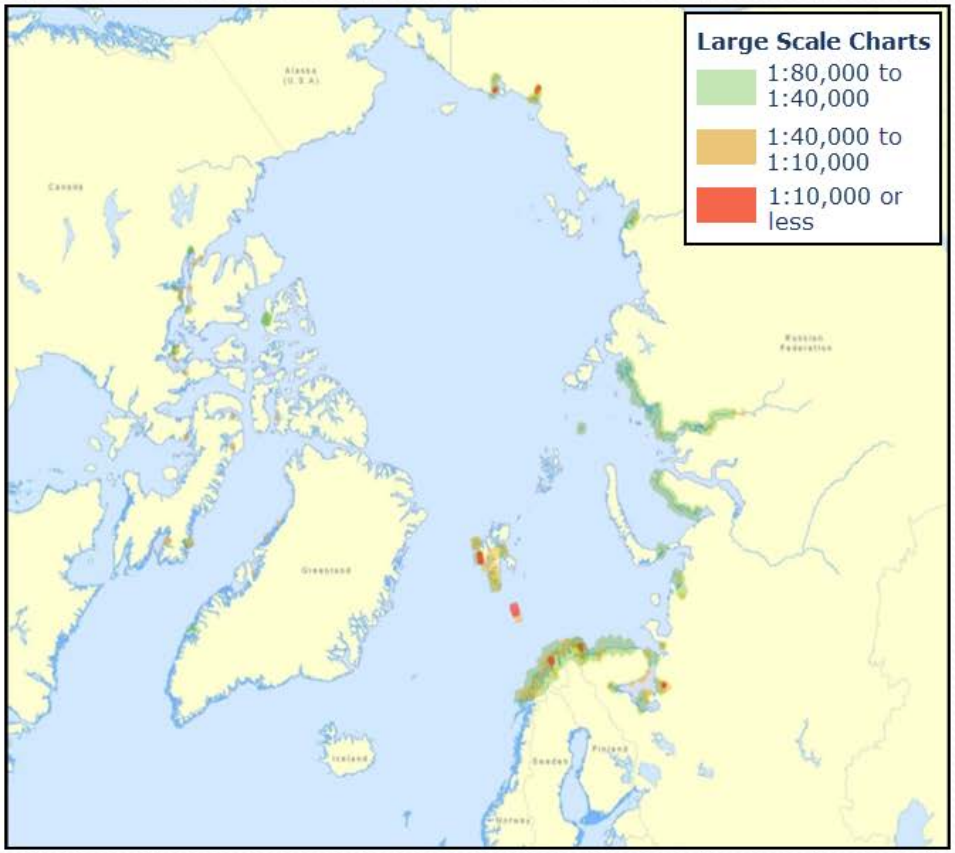
Acknowledgements:

- Canadian Hydrographic Service
- Norwegian Mapping Authority
- Danish Geodata Agency

Isn't the Arctic already charted?

- Chart coverage doesn't equal data quality…





ARHC's methodology to assess charting adequacy:

1. Assess confidence of the present hydrographic holdings (Age of data, Type of coverage, etc.).
2. Divide ocean into general depth bands (shallow, mid-depth, deep) factoring in seafloor complexity.

   Ex: across a broad flat shelf, 30m could be considered "deep"; whereas, in areas with the potential for sharp, sudden rises in the seafloor, 50m could be considered "shallow")
3. Intersect confidence (#1) with depth bands (#2) to develop potential areas of concern.

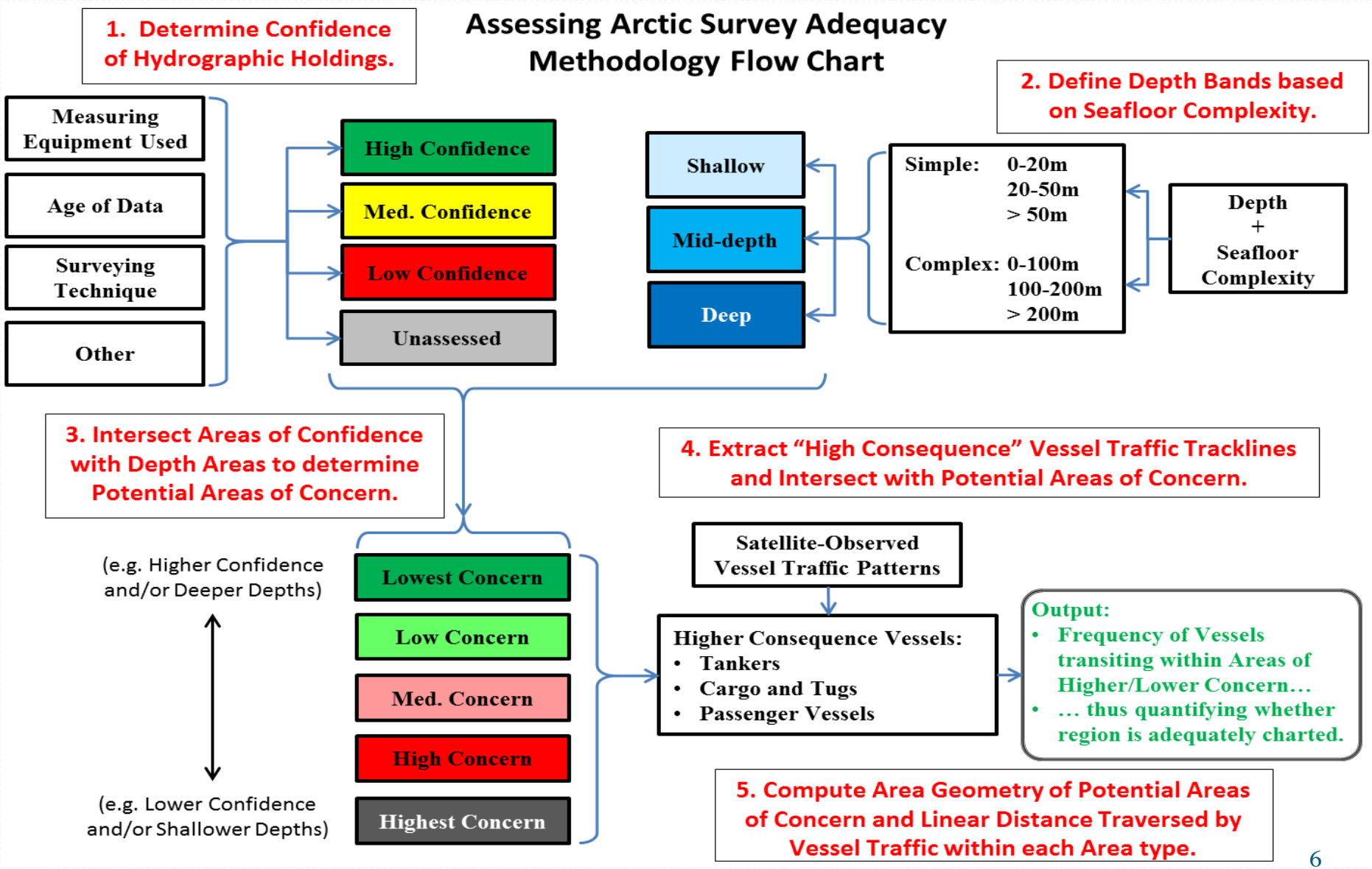
   Ex: Higher conf. hydro plus deeper depths = Lower concern

   Ex: Lower conf. hydro plus shallower depths = Higher concern
4. Assess historic traffic patterns as they relate to the areas of concern (#3).
5. Generate maps and statistics which can guide decision-making processes.

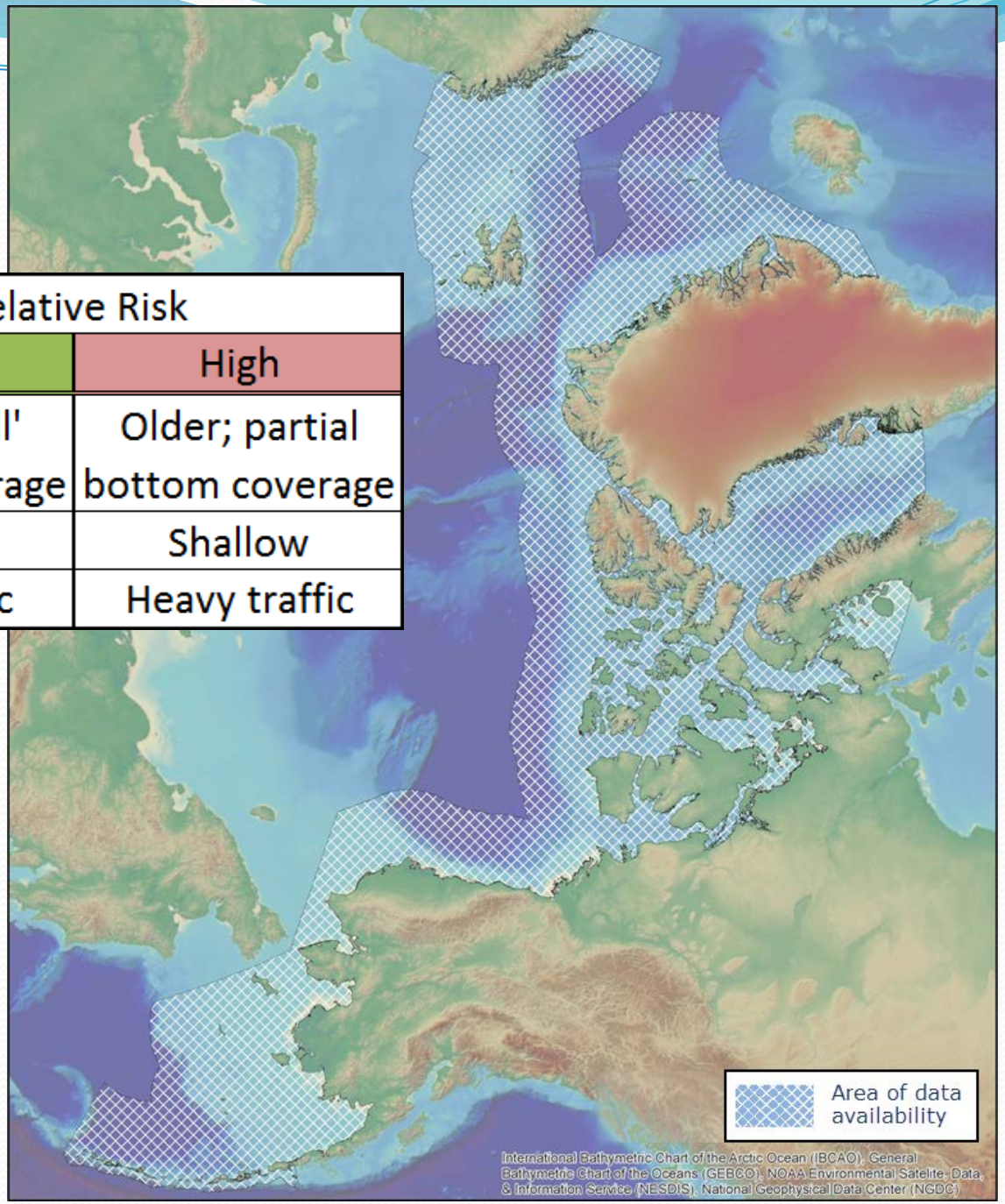
   Ex: Hydrographic organizations can determine survey priorities

   Ex: Coast Guards can determine where to stage equipment for or spill response events.

Methodology



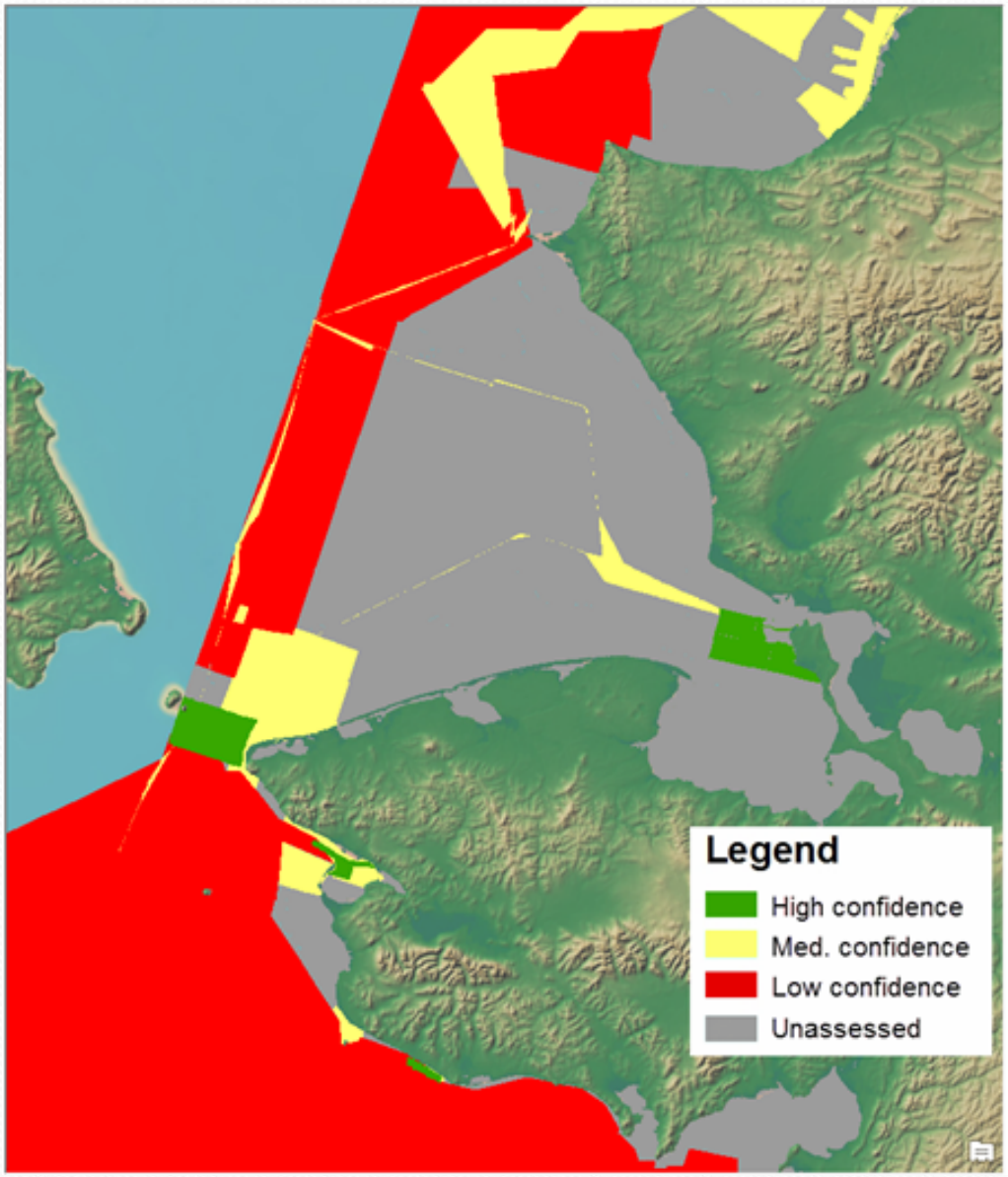
Data type:	Relative Risk	
	Low	High
Confidence of Hydrographic Data	Newer; 'full' bottom coverage	Older; partial bottom coverage
Water Depth	Deep	Shallow
Density of Traffic	Light traffic	Heavy traffic



Phase 1: Confidence of Hydrographic Data…

		Confidence Level			
Country	**Data Quality Metric**	**High**	**Medium**	**Low**	**Unassessed**
United States and Canada	CATZOC	**Category A**: Controlled, systematic survey with high position and depth accuracy. Data acquired using multibeam echosounder, channel, or mechanical sweep system.	**Category B**: Controlled, systematic survey achieving similar depth accuracy to Category A surveys, but with less position accuracy. Data acquired using modern survey echosounder.	**Category C**: Opportunistic survey achieving low depth and position accuracy. Equipment not specified.	Unassessed
Norway and Denmark	Equipment Type	Multibeam echosounder.	Singlebeam echosounder.	Pre-acoustic survey equipment or equipment not specified.	Unassessed

Step 1: Confidence of Hydrographic Data…

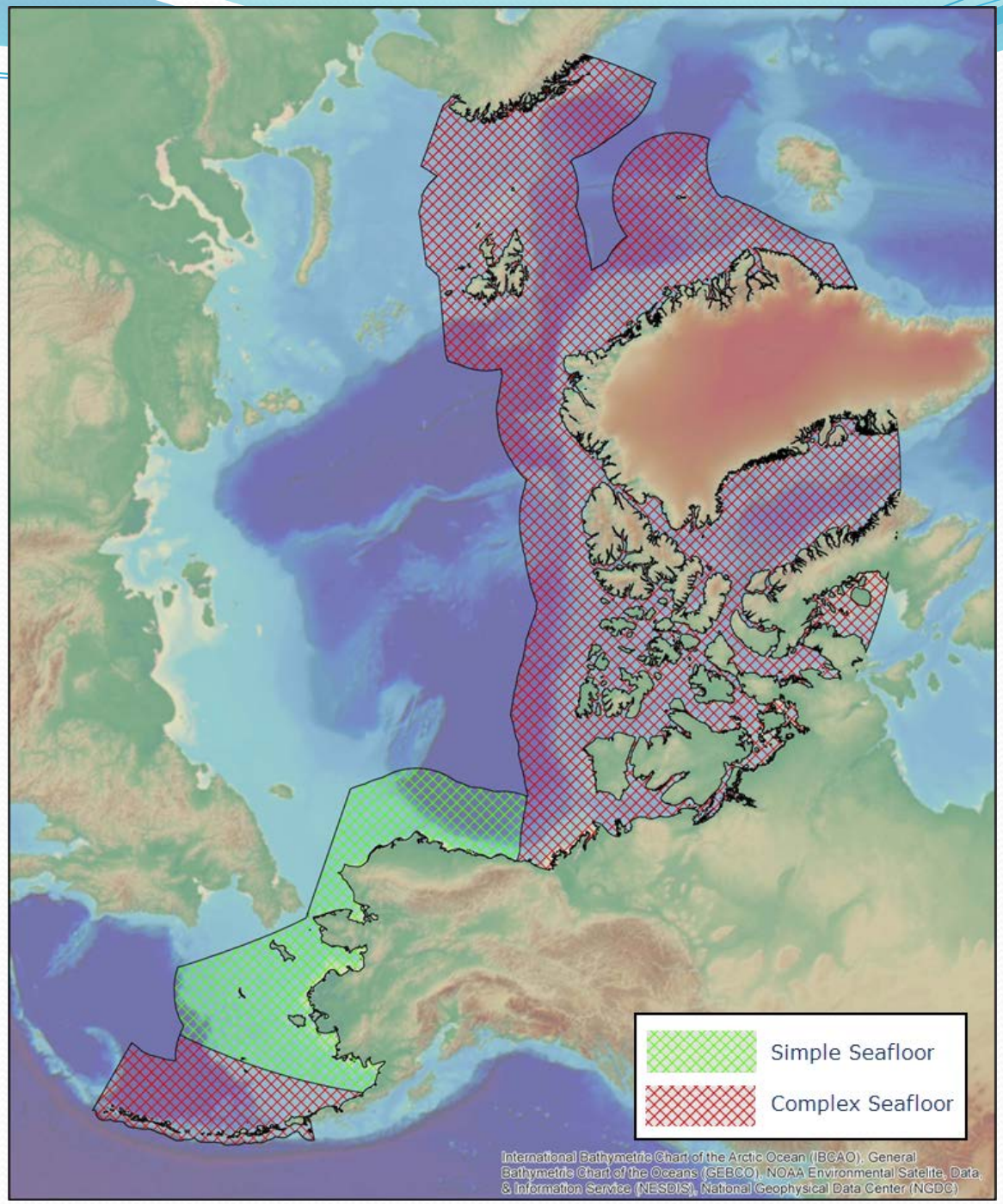


1. Determine Confidence of Hydrographic Holdings.

- Measuring Equipment Used
- Age of Data
- Surveying Technique
- Other

→ High Confidence
→ Med. Confidence
→ Low Confidence
→ Unassessed

Step 2: Depth and Seafloor Complexity…



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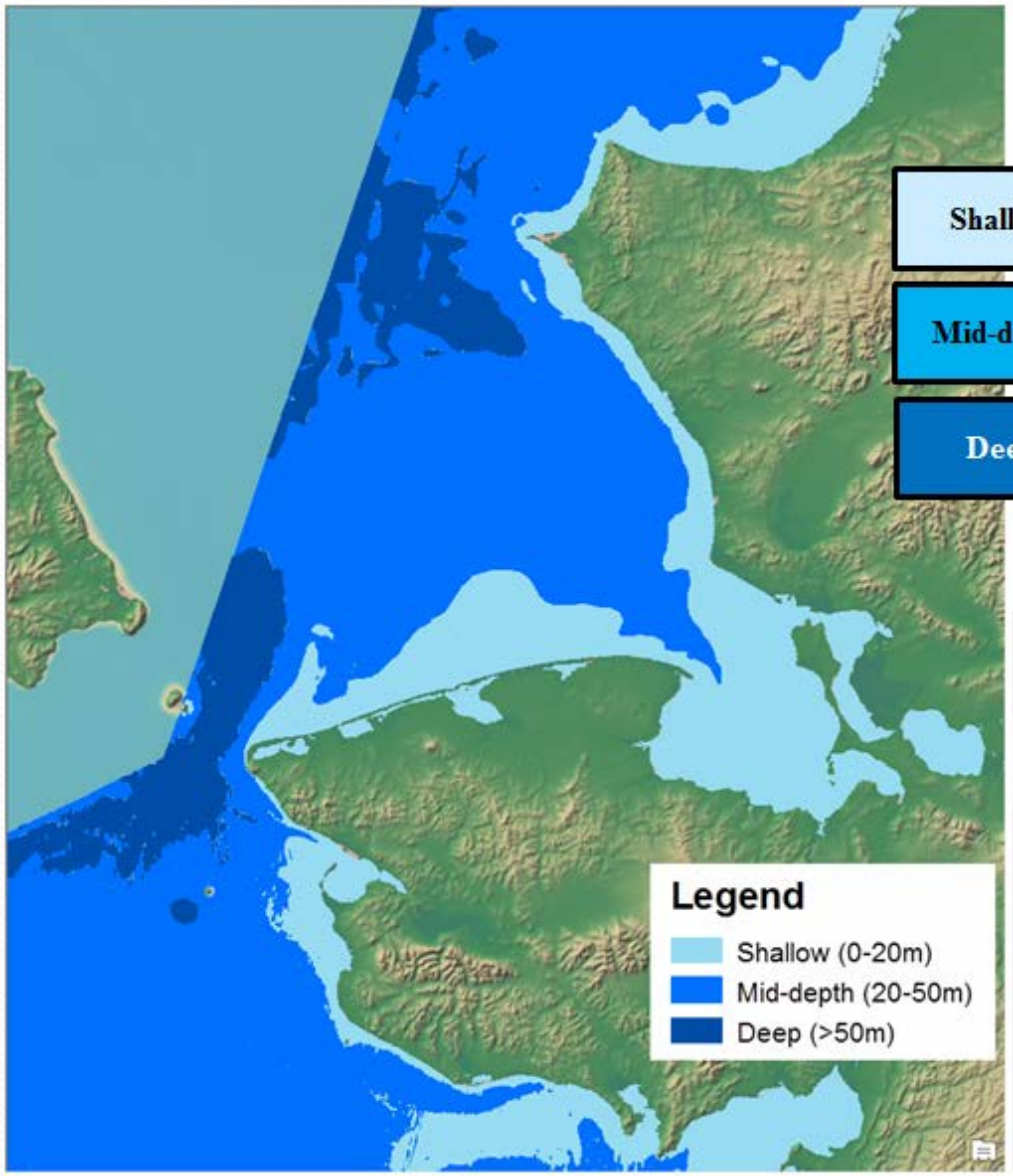


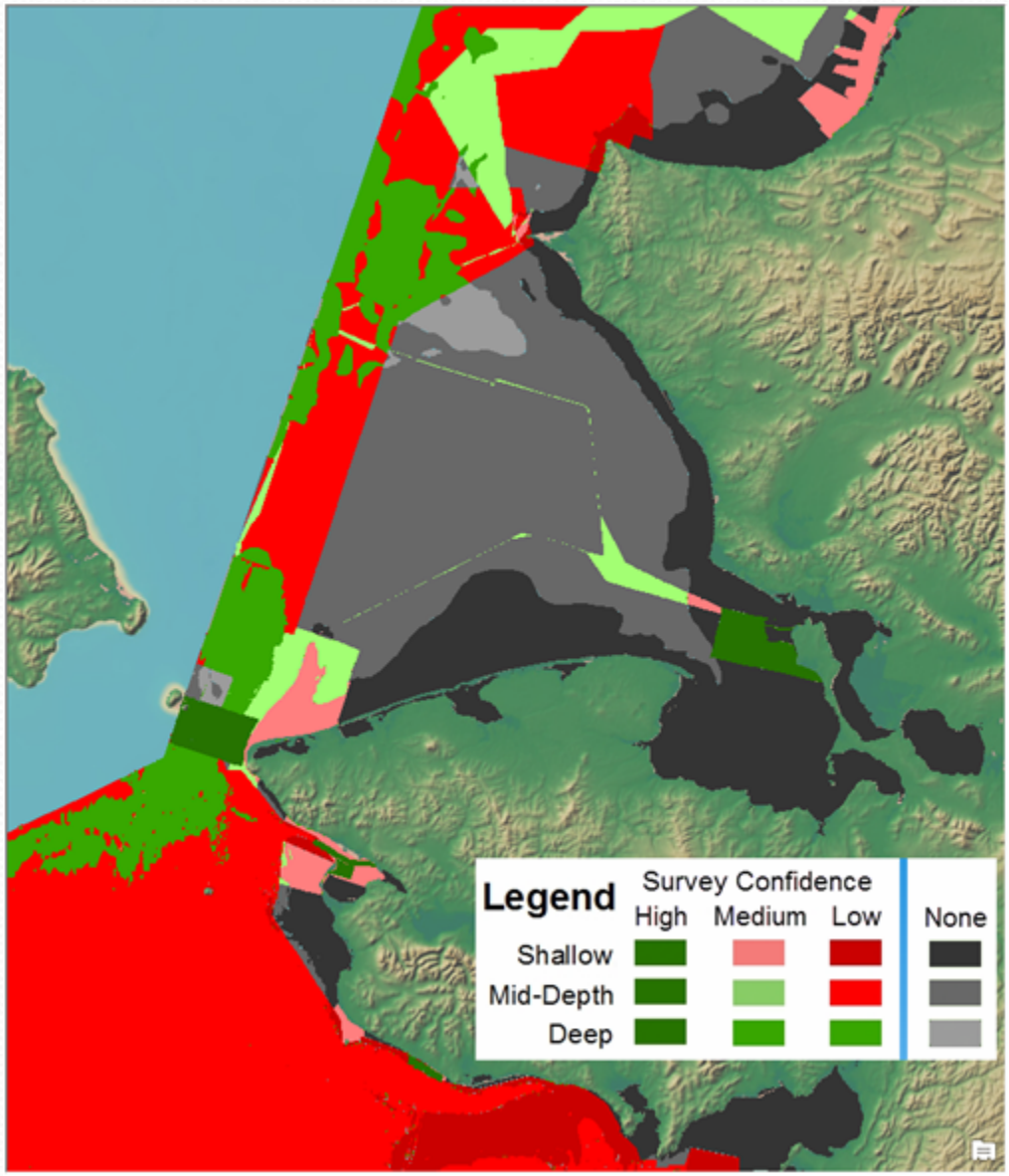
2. Define Depth Bands based on Seafloor Complexity.

- **Shallow**
- **Mid-depth**
- **Deep**

Simple:	**0-20m**	
	20-50m	
	> 50m	
Complex:	**0-100m**	
	100-200m	
	> 200m	

Depth + Seafloor Complexity

Step 3: Intersection of Confidence & Depth…



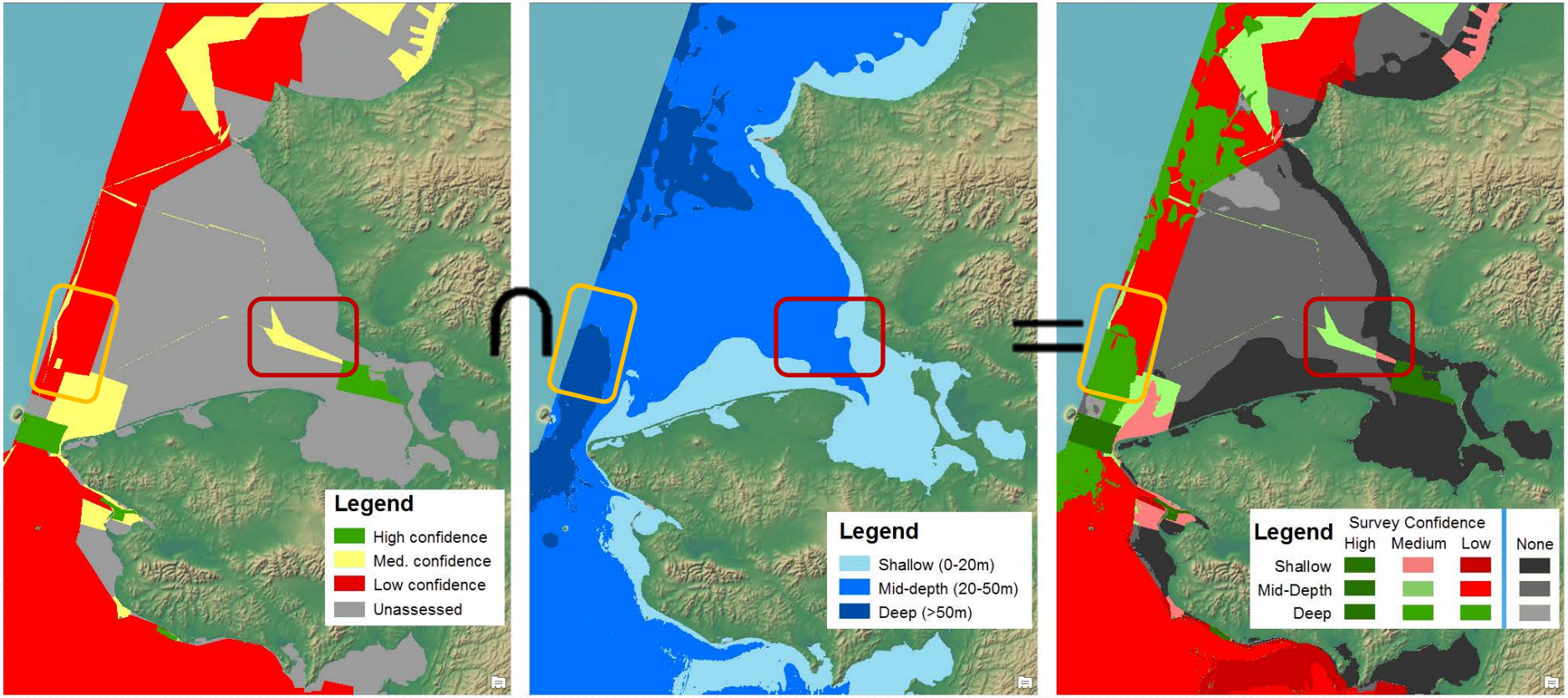
3. Intersect Areas of Confidence with Depth Areas to determine Potential Areas of Concern.

(e.g. Higher Confidence and/or Deeper Depths)

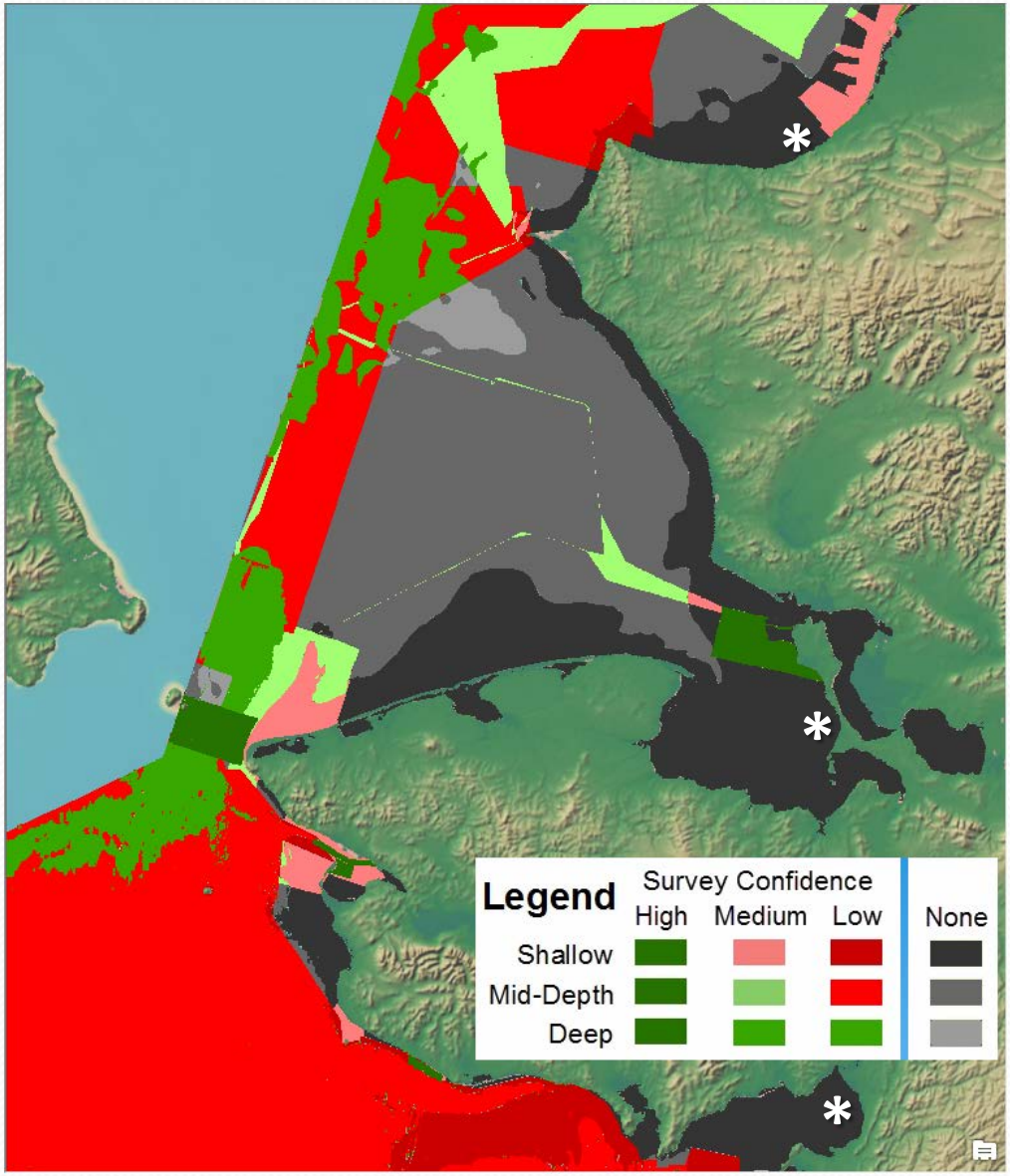
(e.g. Lower Confidence and/or Shallower Depths)

- Lowest Concern
- Low Concern
- Med. Concern
- High Concern
- Highest Concern

Step 3: Intersection of Confidence & Depth…

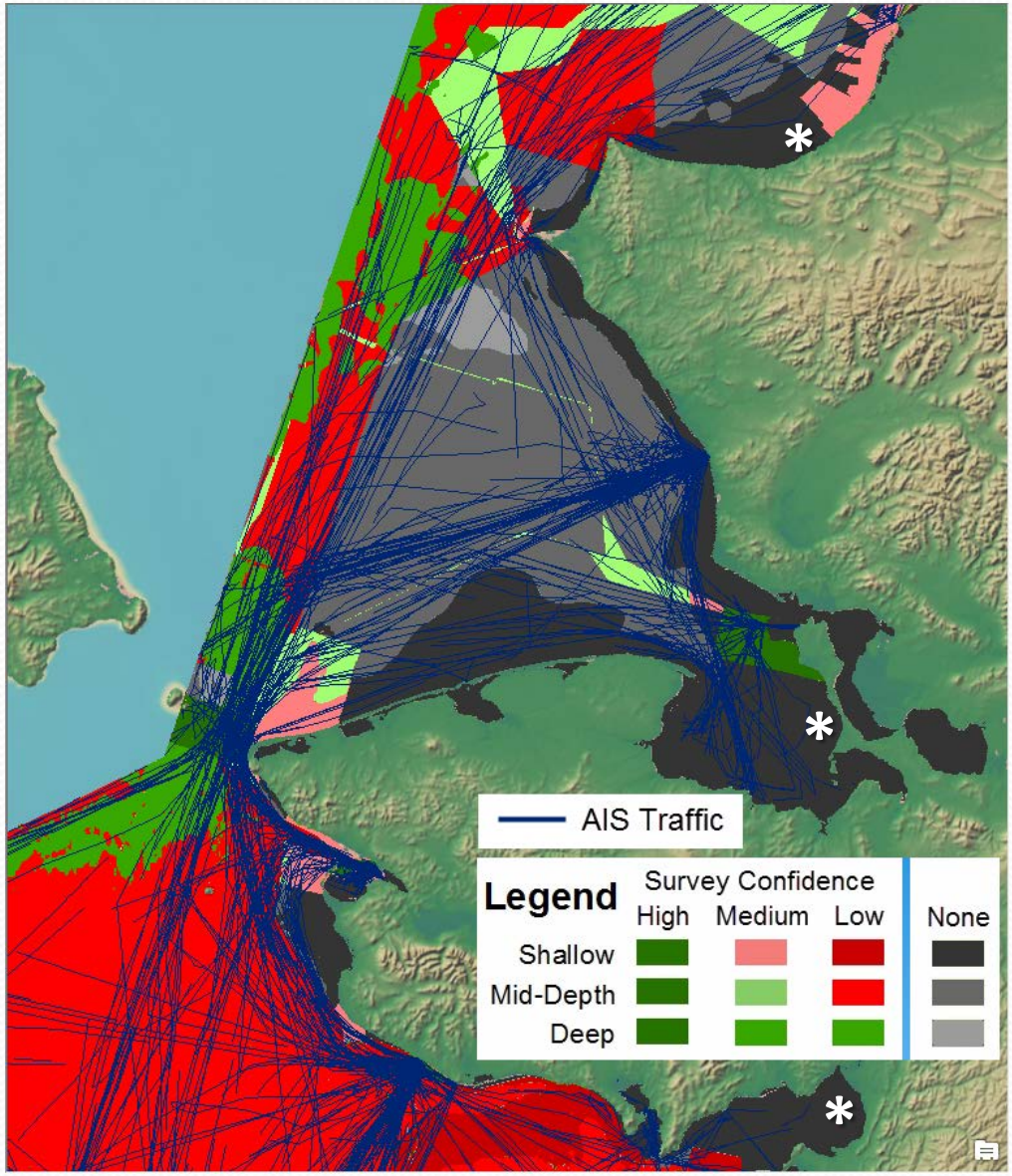


Step 3: Intersection of Confidence & Depth…



- Already, we have a reasonable hierarchy for a determination of survey priorities.
- One could reasonably argue that all three of the bays marked with the '*' are worthy of consideration for updated bathymetry.
- … still vast swaths of ocean; so, where are folks navigating?

Step 4: Incorporation of vessel traffic…



4. Extract "High Consequence" Vessel Traffic Tracklines and Intersect with Potential Areas of Concern.

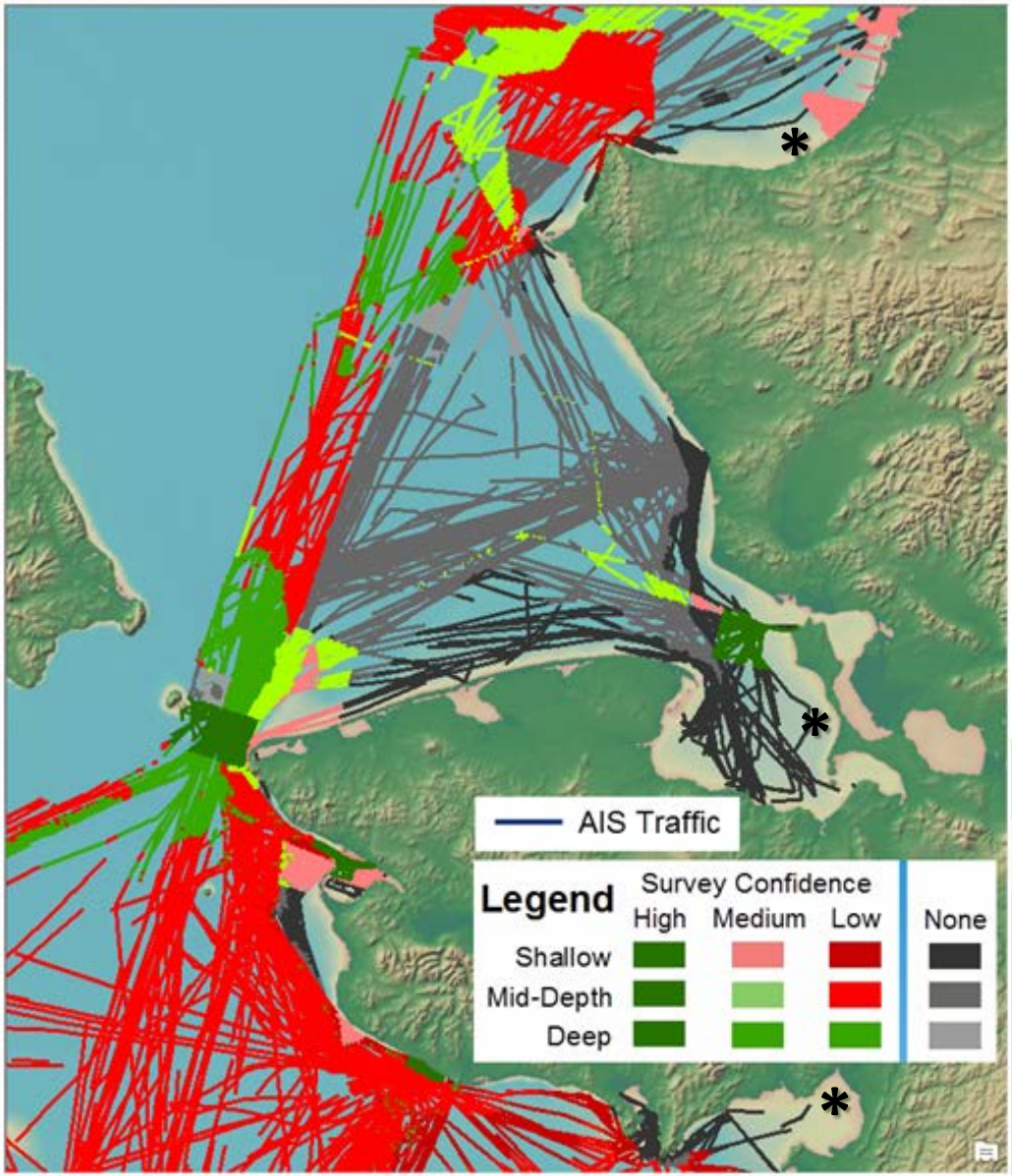
Satellite-Observed Vessel Traffic Patterns

↓

Higher Consequence Vessels:
- **Tankers**
- **Cargo and Tugs**
- **Passenger Vessels**

- Notice there are three shallow bays with an Unassessed confidence (marked with an *)…
- While all three were previously identified as potential areas of concern, only the center one experiences heavy traffic (thus, it could be increased in survey priority over the others).

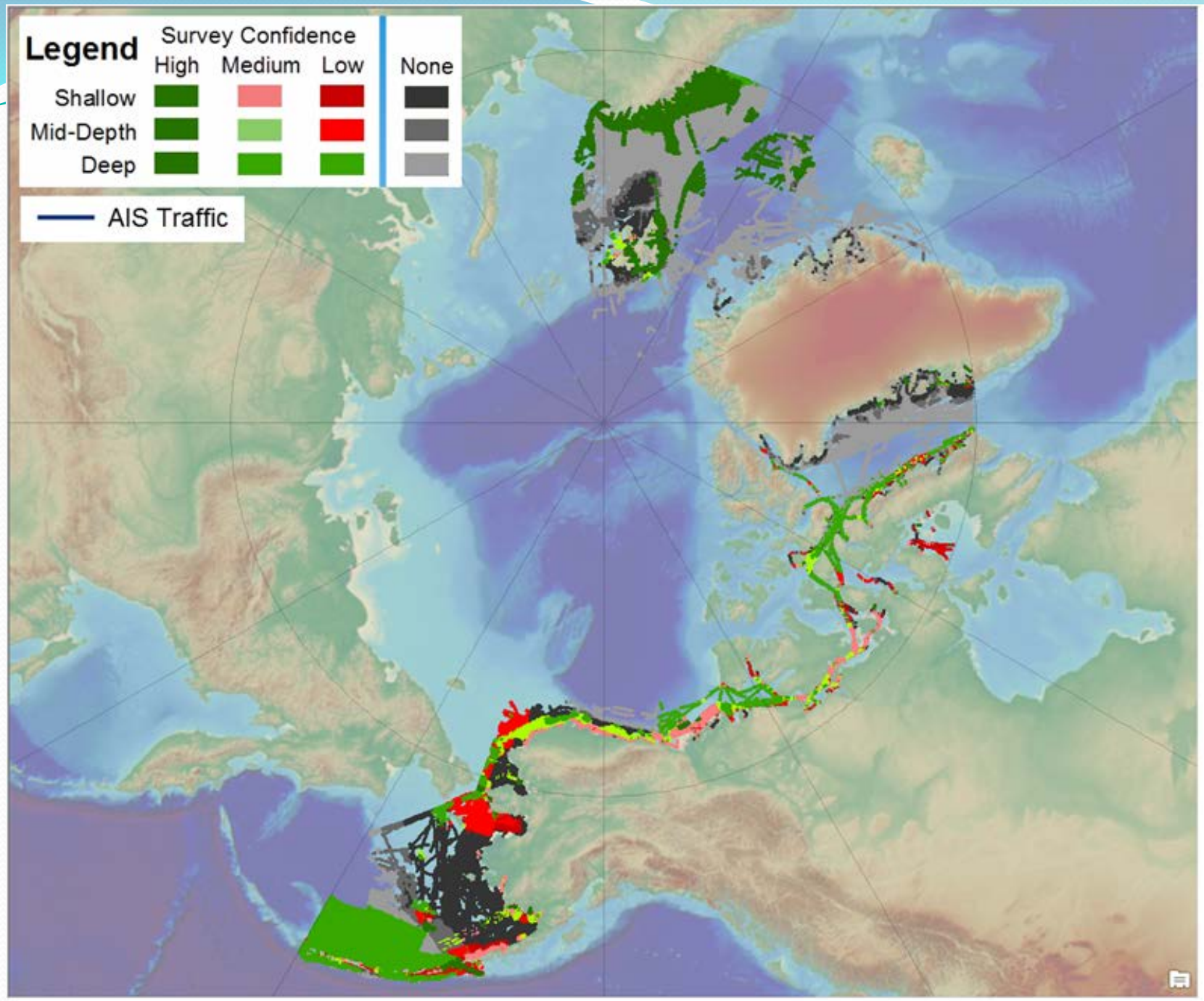
Step 5: Generate metrics…



5. Compute Area Geometry of Potential Areas of Concern and Linear Distance Traversed by Vessel Traffic within each Area type.

Higher Consequence Vessels:
- **Tankers**
- **Cargo and Tugs**
- **Passenger Vessels**

Output:
- **Frequency of Vessels transiting within Areas of Higher/Lower Concern…**
- **… thus quantifying whether region is adequately charted.**


Legend
Survey Confidence
High
Medium
Low
None
Shallow
Mid-Depth
Deep
AIS Traffic

Step 5: Arctic-wide metrics…

AREA

Combination of Canada, Denmark, Norwa… Confidence Level

Depth (m)	High sq. km	High %Total	Medium sq. km	Medium %Total
Shallow	51,151	0.7%	154,062	2.1%
Mid-Depth	53,158	0.7%	102,116	1.4%
Deep	301,997	4.2%	166,100	2.3%
Total	406,306	5.6%	422,278	5.8%

20%

Two factors at play:

- Hydrographic offices are surveying where vessels are going.
- Vessels are navigating where there is high confidence bathymetry.

TRAFFIC

Combination of Canada, Denmark, Norway and United States study areas

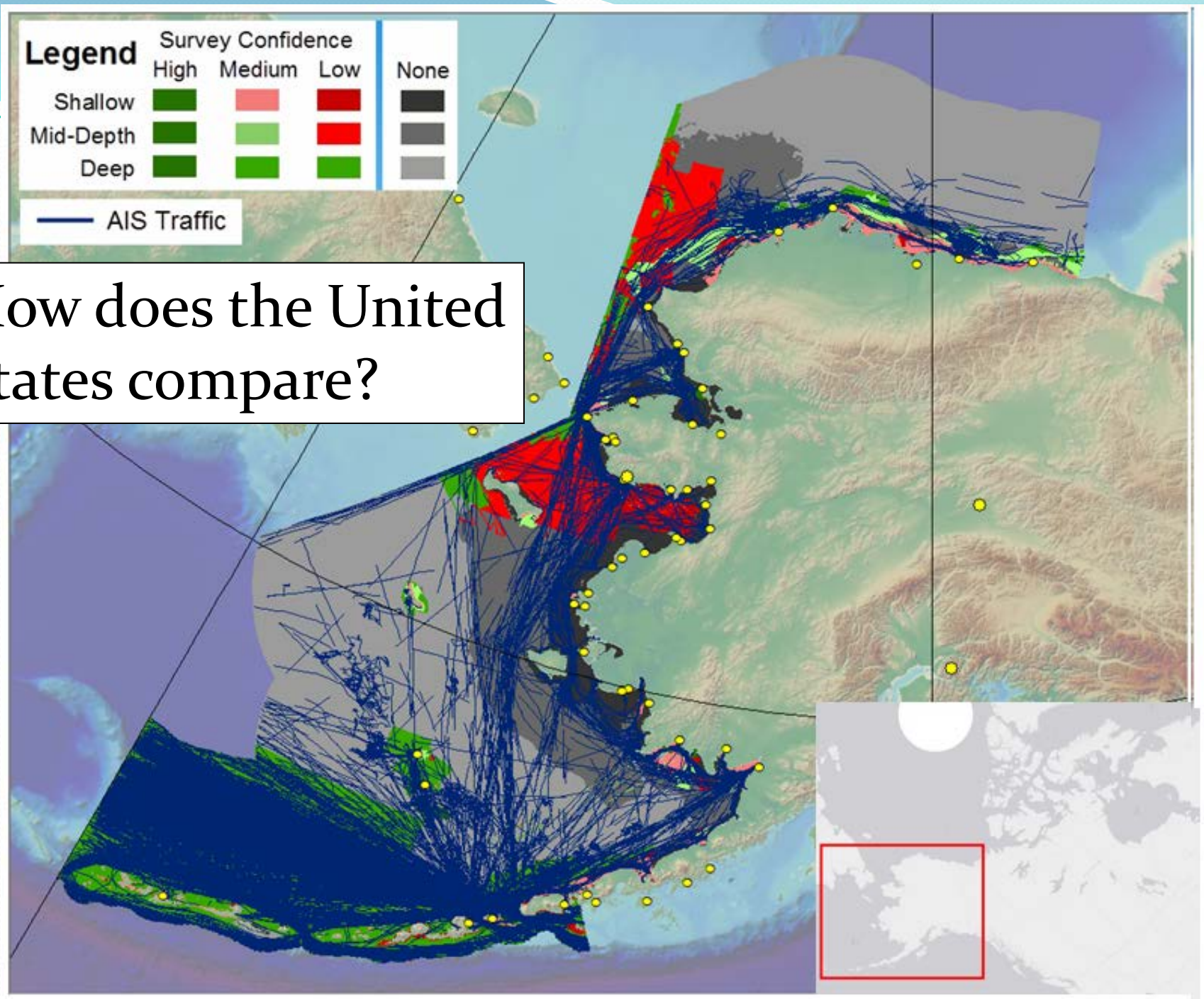
Confidence Level

Depth (m)	High LNM	High %Total	Medium LNM	Medium %Total	Low LNM	Low %Total	Unassessed LNM	Unassessed %Total
Shallow	477,412	9.1%	127,673	2.4%	17,800	0.3%	211,972	4.0%
Mid-Depth	576,983	11.0%	71,396	1.4%	69,372	1.3%	70,048	1.3%
Deep	1,419,646	27.0%	103,136	2.0%	1,399,784	26.6%	711,046	13.5%
Total	2,474,041	47.1%	302,205	5.7%	1,486,956	28.3%	993,066	18.9%

23%

77%

Total Linear Nautical Miles of Traffic (Combined): 5,256,268



How does the United States compare?

United States metrics…

AREA

Depth (m)	Confidence Level: High sq. km	High %Total	Medium sq. km	Medium %Total	Low sq. km	Low %Total	Unassessed sq. km	Unassessed %Total
Shallow	7,151	0.4%	46,340	2.4%	61,288	3.2%	101,443	5.3%
Mid-Depth	2,280	0.1%	48,647	2.6%	150,830	7.9%	252,610	13.2%
Deep	3,613	0.2%	26,111	1.4%	368,836	19.3%	838,347	44.0%
Total	13,044	0.7%	121,098	6.3%	580,954	30.5%	1,192,400	62.5%

76%

24%

TRAFFIC

Depth (m)	Confidence Level: High LNM	High %Total	Medium LNM	Medium %Total	Low LNM	Low %Total	Unassessed LNM	Unassessed %Total
Shallow	5,595	0.3%	31,657	1.4%	11,598	0.5%	160,641	7.3%
Mid-Depth	2,034	0.1%	40,244	1.8%	66,028	3.0%	24,854	1.1%
Deep	320,822	14.5%	21,633	1.0%	1,393,156	62.9%	137,675	6.2%
Total	328,451	14.8%	93,534	4.2%	1,470,782	66.4%	323,170	14.6%

20%

80%

United States

AREA		High	
		sq. km	%Total
Depth (m)	Shallow	7,151	0.4%
	Mid-Depth	2,280	0.1%
	Deep	3,613	0.2%
	Total	13,044	0.7%

TRAFFIC		High	
		LNM	%Total
Depth (m)	Shallow	5,595	0.3%
	Mid-Depth	2,034	0.1%
	Deep	320,822	14.5%
	Total	328,451	14.8%

'Whole' Arctic

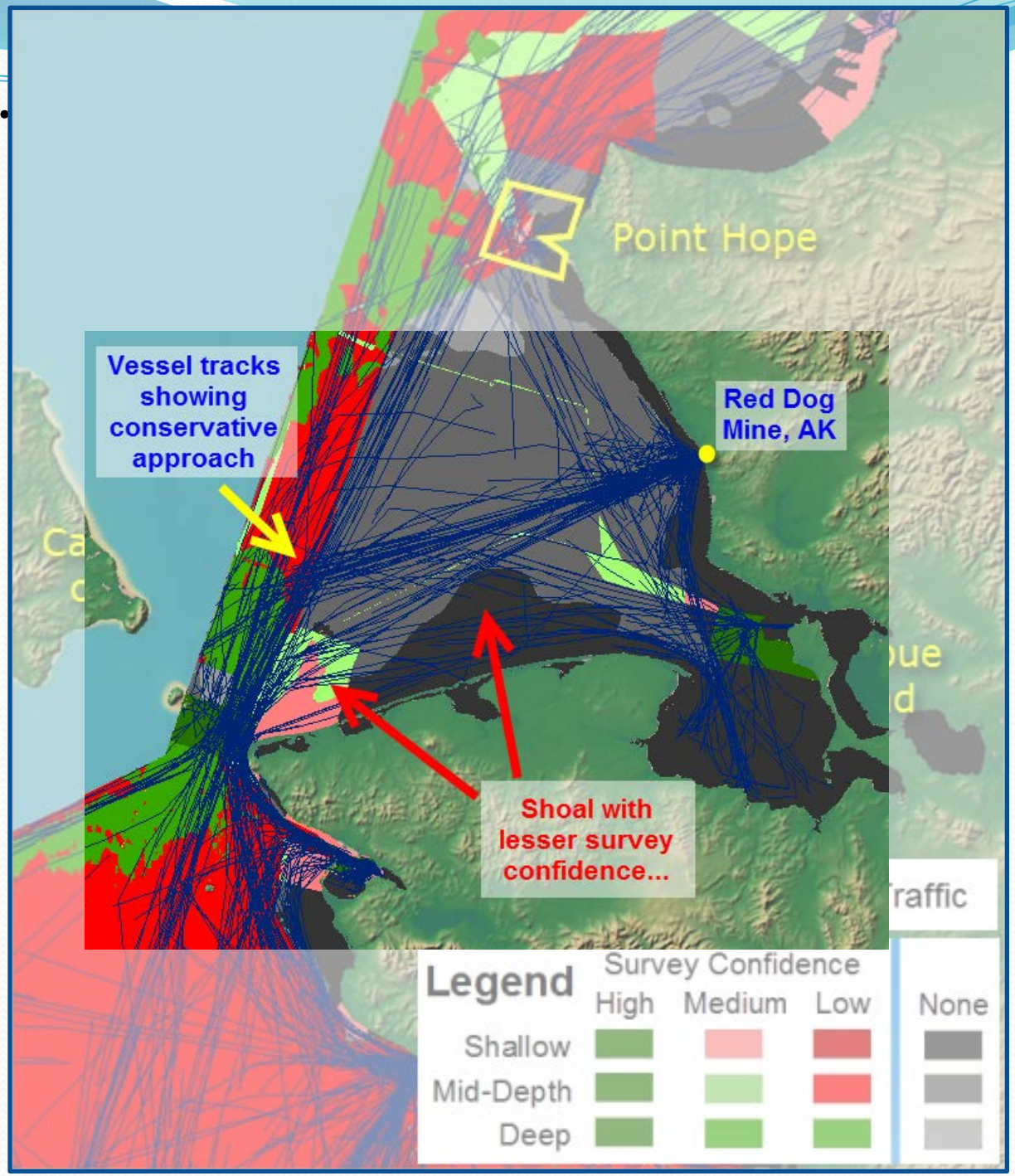
Two methods for improving the percentage of traffic within these areas of high confidence bathymetry:

- Targeted surveying in heavily transited areas of high concern.
- Development of offshore transit corridors.

- 'High Confidence' regions proxy for modern survey work…

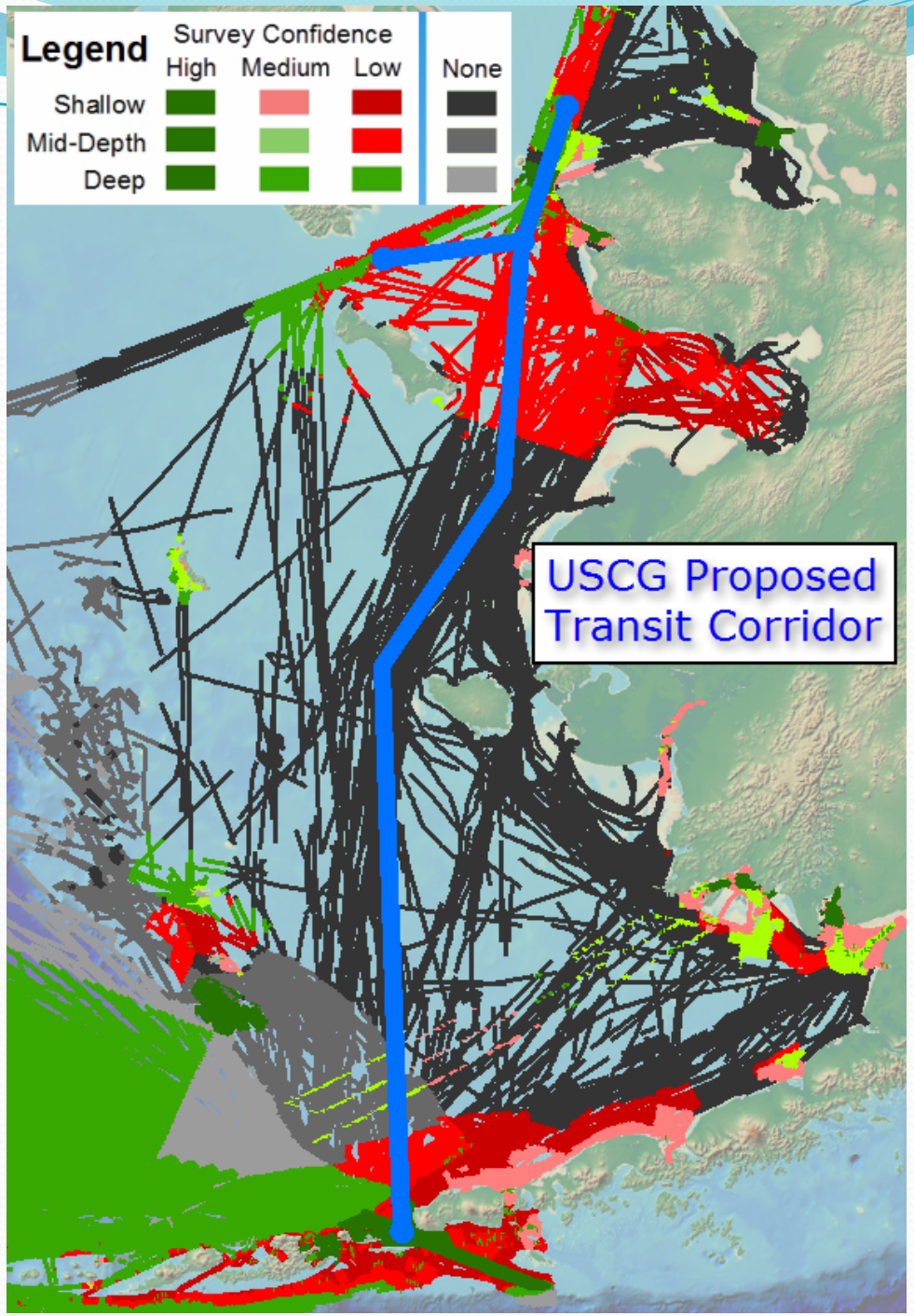
Targeted surveys…

- Port Clarence & Kotzebue Sound: relatively shallow, low confidence bathy in areas that are heavily transited.
- Point Hope & Cape Prince of Wales: mariners diverting preferred tracks due to low confidence bathymetry.

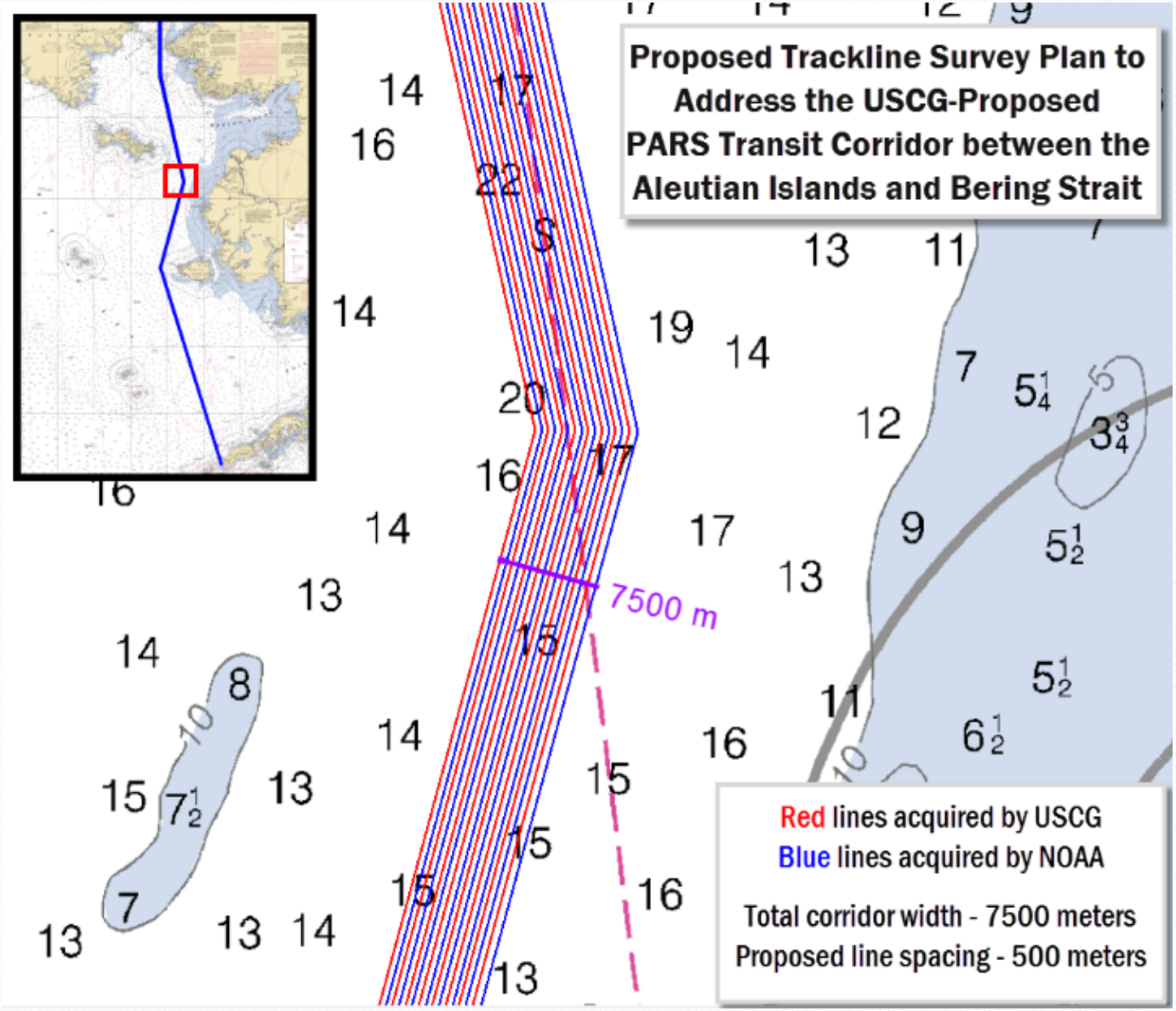


Transit Corridors…

- Partnering with the U.S. Coast Guard to develop an offshore transit corridor between Aleutians and Bering Strait.
- Increase high confidence bathymetry, encouraging mariners to alter transits into these corridors.



Transit Corridors…



Of course, some caution must be exhibited when drawing conclusions from AIS data…

- AIS data extracted between June 2012 – July 2013.
- When the supposition is “retreating sea ice will lead to increased marine traffic”, past navigation trends (while informative) are of limited value.

Speaking towards Arctic charting adequacy…

- On the one hand, only a small percentage of the Arctic (20%), can be characterized as being of lower concern…
- … however, a disproportionately large percentage of the vessel traffic (77%) occurs within this region.

Identifying survey priorities in the Arctic…

- This study suggests a targeted risk-based approach, elevating the priority of shallow regions, with low quality bathymetric data that are heavily transited.
- In addition, the U.S. will pursue the development of offshore survey corridors in broad regions of high concern.