Offshore Information for Area Contingency Planning

Offshore Worst Case Discharge Scenarios and Modeling

Arctic and Western Alaska ACP
Beaufort Sea

Technical Document #2
Appendix 2C

May 2023

Record of Changes

Change Number	Change Description	Section Number	Change Date	Name
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1 Introduction

In 2019, the Bureau of Safety and Environmental Enforcement (BSEE) sponsored a project in cooperation with the United States Coast Guard (USCG) to improve the content of the coastal zone area contingency plans (ACPs) with respect to the information necessary to effectively plan for and respond to large oil spills from offshore oil and gas facilities. This collaboration between BSEE, the Bureau of Ocean Energy Management (BOEM), USCG Sector Anchorage, Alaska Department of Environmental Conservation (ADEC), resource trustees, state agencies, oil spill removal organizations (OSROs), and the Arctic and Western Alaska Area Committee resulted in a series of technical documents that provide offshore information on:

- Oil and Gas Infrastructure (Arctic and Western Alaska Technical Document #1)
- Worst Case Discharge Scenarios (Arctic and Western Alaska Technical Document #2 and Appendices 2A-C)
- Response Concept of Operations (Arctic and Western Alaska Technical Document #3)
- Response Strategies and BMPs (Arctic and Western Alaska Technical Document #4)
- Sensitive Species Profiles (Arctic and Western Alaska Technical Document #5).

These documents were developed specifically for incorporation by reference into the coastal zone ACPs and are hosted on the BSEE Oil Spill Preparedness Division's (OSPD) website.

The WCD scenario information in Technical Document #2 is organized into three main components: Section 2 contains a description of key modeling concepts and reference scales that are useful for understanding the oil spill trajectory data and figures that have been developed for each of the WCD scenarios. Section 3 contains a series of tables that collate and summarize key information regarding all of the WCD scenarios that were developed for Alaska. Appendices 2A – 2C contain specific, more detailed WCD scenario modeling data and trajectory figures for each of the regions in the Arctic and Western Alaska ACP Planning Area. Appendix 2C contains the modeling information for the five offshore WCD Scenarios in the Beaufort Sea.

2 Meteorological and Oceanographic Conditions in Beaufort Sea

To understand the behavior of marine spills, it is necessary to analyze and evaluate the predominant environmental conditions in the area of interest. Winds and currents are the key forcing agents that control the transport and weathering of an oil spill. To reproduce the natural variability of the environment, the oil spill model requires wind and current datasets that vary both spatially and temporally. Optimally, the minimum window of time for stochastic simulations is 5 to 10 years; therefore, long-term records of wind and current data were obtained from the outputs of global numerical atmospheric and ocean circulation models for this modeling.

2.1 Wind Dataset – ECMWF

For the Beaufort Sea, wind data were obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis Product for an 8-year period (2008 to 2015), as described in Table 1. The ECMWF provides the ERA-Interim reanalysis product that includes wind hindcast data on a global scale. ERA-Interim covers the period of January 1st, 1979 to August 31st, 2019. Gridded data products include a large variety of three-hourly surface parameters, describing atmospheric as well as ocean-wave and land-surface conditions.

Table 1. Specifics of the wind dataset used for the modeling of the Beaufort Sea.

Name of Dataset	ERA-Interim
Coverage	140.3 °W – 134.3°E 59.3 °N – 84 °N
Owner/Provider	ECMWF
Horizontal Grid Size	0.75°x0.75°
Hindcast Period	2008 - 2015
Time Step	3 hourly

The wind conditions show great similarity across all the sites in the Beaufort Sea due to their proximity; therefore, only a single figure is presented here. near the Liberty spill site based on the ERA-Interim dataset. The annual ERA-Interim wind rose (Figure 1) near Liberty, within the Beaufort Sea shows the wind is predominately from the east-northeast, reaching up to 15 m/s on average. Wind speeds are presented in m/s, using meteorological convention (i.e., direction wind is coming from).

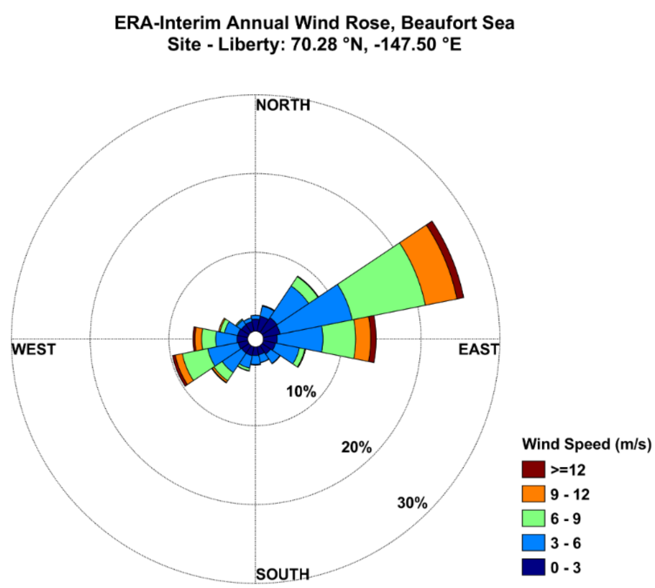

Figure 1. Annual ERA-Interim wind rose near Liberty within the Beaufort Sea. Wind speeds are in m/s, using meteorological convention (i.e., direction wind is coming from).

2.2 Global Current Dataset – TOPAZ4

Current data for the Beaufort Sea was obtained from the coupled ice-ocean model, TOPAZ4 (Towards an Operational Prediction system for the North Atlantic European coastal Zones) (Sakov *et al*., 2012). TOPAZ4 is a coupled ocean-sea ice data assimilation system for the North Atlantic and the Arctic, developed by the Nansen Environmental and Remote Sensing Center (NERSC) and publicly available through the Norwegian Meteorological Institute. Daily mean 3-dimensional current speed and direction were acquired for the time period May 1, 2008 – January 31, 2015 (Table 2).

Table 2. The specifics of the current datasets used for the modeling of the Beaufort Sea.

Name of Dataset	TOPAZ4
Coverage	131 °W – 136.2 °E 54.4 °N – 64.5 °N
Owner/Provider	E.U. Copernicus Marine Service Information
Bathymetry	GEBCO
Wind Forcing	ERA-Interim
Tides	-
Horizontal Grid Size	12.5 km
Hindcast Period	5/1/2008 – 11/2010 11/2011-1/31/2015
Output Frequency	Daily

The current conditions show great similarity for the Liberty, North Nikaitchuq Exploration, and Endicott Pipeline sites in the Beaufort Sea. However, the current condition near Northstar has a slightly differing direction. Therefore, this section will focus on the Liberty and Northstar sites. Figure 2 describes the variability of current speed and direction near the Liberty and Northstar potential spill sites based on the TOPAZ4 dataset. The annual TOPAZ4 rose near Northstar, within the Beaufort Sea shows the currents predominantly flow towards northwest, north-northwest, and southeast. Near Liberty, currents predominately flow towards the west-northwest and the east-southeast. Current speeds are displayed in cm/s, using oceanographic convention (i.e., direction current is going to).

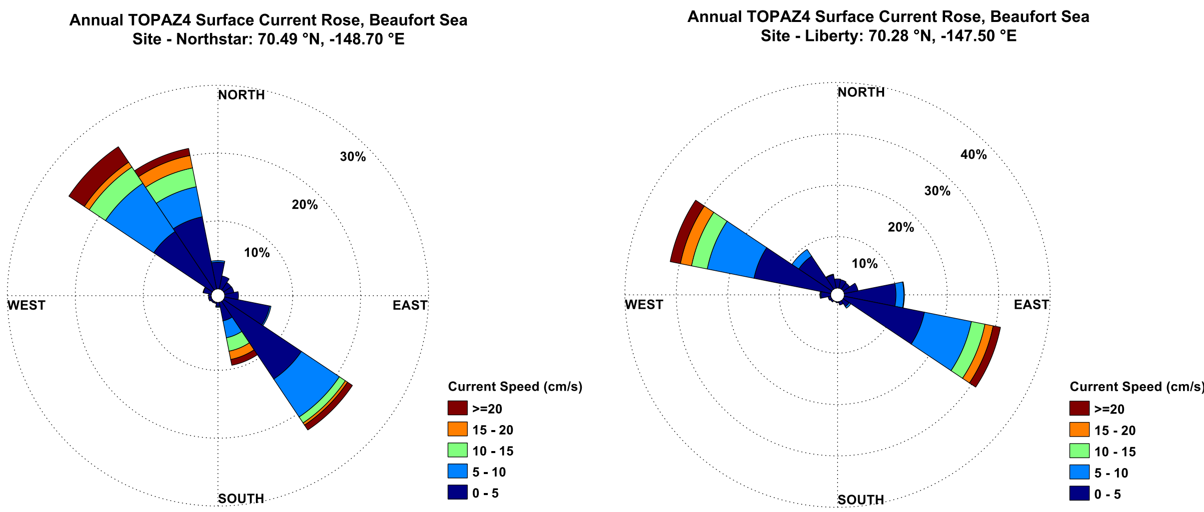

Figure 2. Annual TOPAZ4 rose near Northstar (left) and Liberty(right), within the Beaufort Sea. Current speeds in cm/s, using oceanographic convention (i.e., direction current is going to).

3 Nikaitchuq North Exploration – Open Water Surface Well Blowout

3.1 Scenario Description

The Nikaitchuq North Exploration – Open Water WCD Scenario is a surface well blowout with the following key parameters

Table 3. Scenario Key Parameters.

Discharge Depth (m)	Distance from Shore (NM)	Oil Type	Spill Type	Ice Coverage	Discharge Duration (days)	Discharge Flowrate (bbl/day)	Total Oil Discharged (bbl)
Surface	<1	Light Crude API = 38	Surface Well Blowout	Open Water	30	25,927	777,810

3.2 Potential Oil Contact with the Environment and Resources at Risk

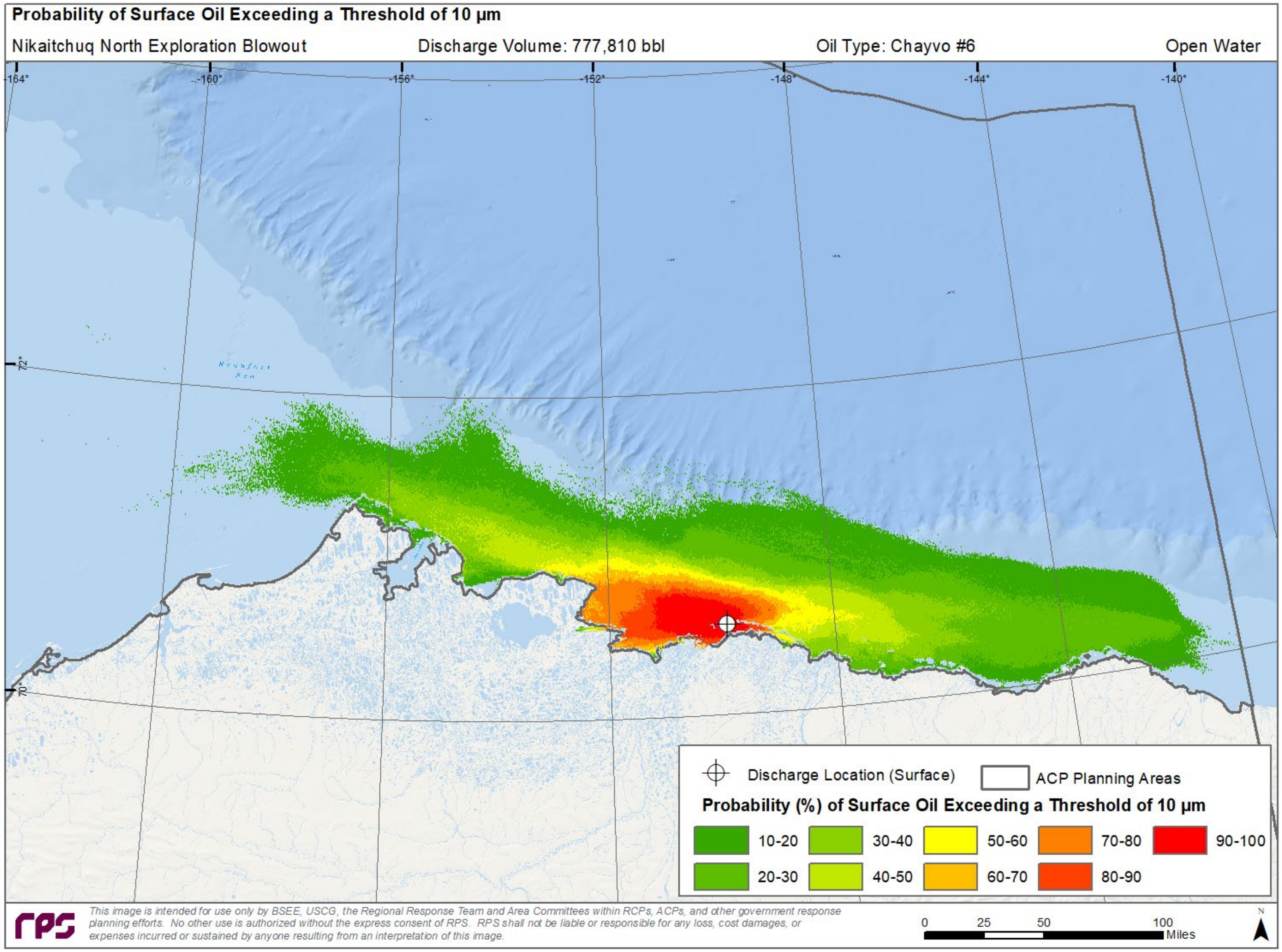

Figure 3. Probability Footprint for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

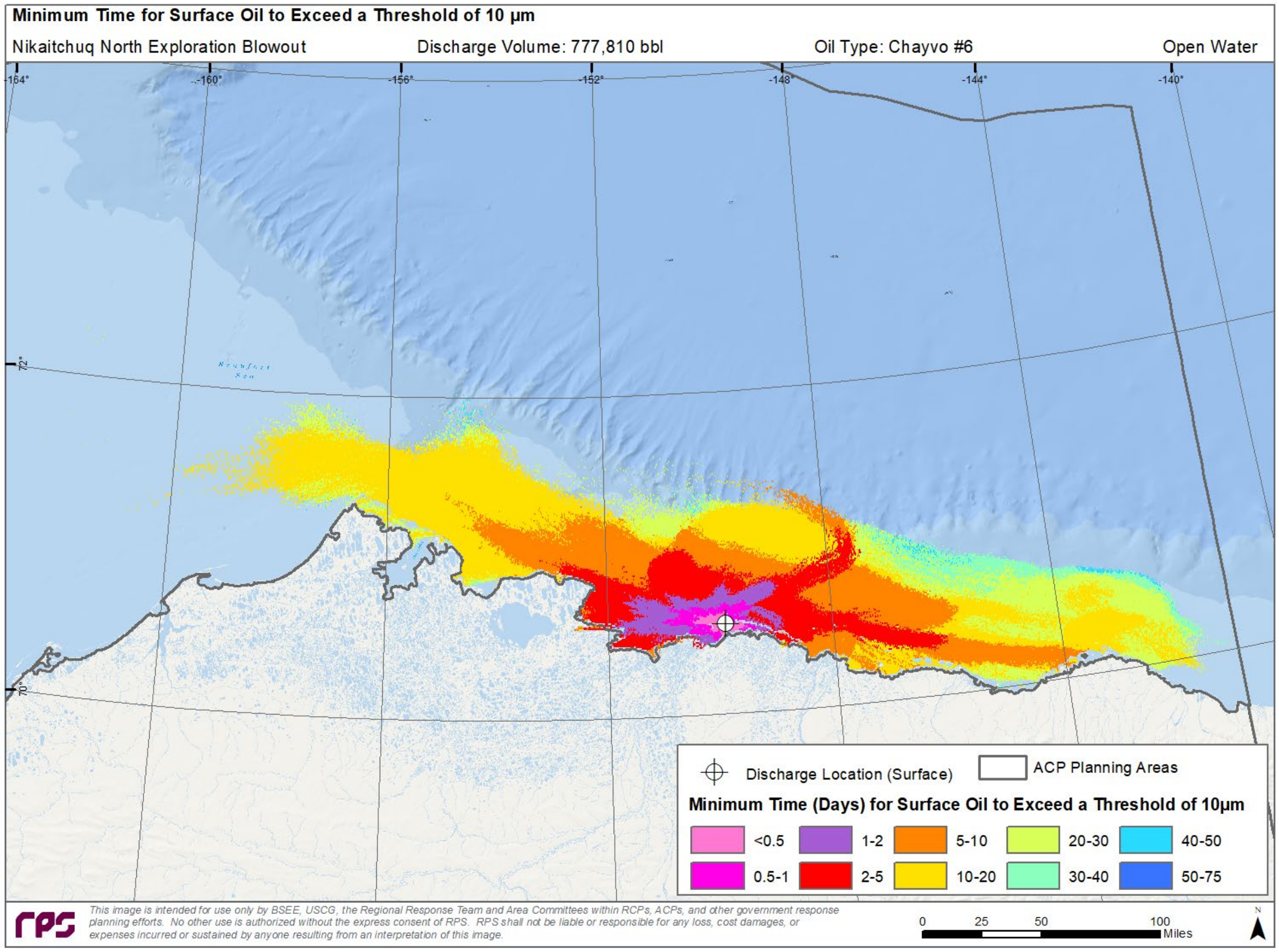

Figure 4. Minimum Time for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

Table 4. Oil Spill Stochastic Results – Predicted Shoreline Impacts.

Percentage of Simulations Reaching shore (%)	Percent volume of discharged oil reaching shore (%)		Time to Reach Shore (hours)	
	Maximum	Average	Minimum	Average
100	48	35	0.50	0.52

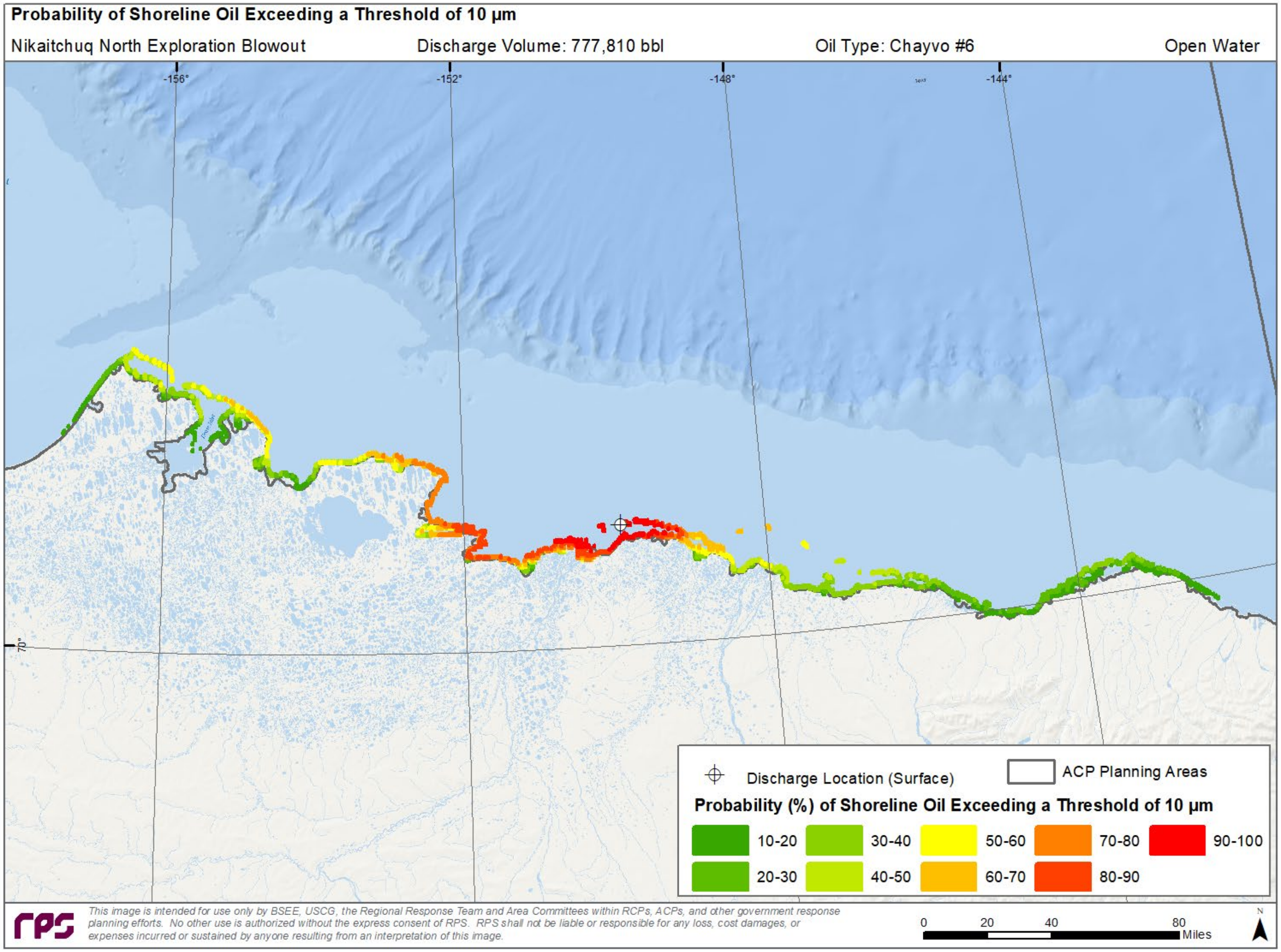

Figure 5. Probability Footprint for Oil on the Shoreline with Average Thickness greater than the Ecological Threshold of 10 µm. This thickness of oil may appear on the shore as dark stain or film. 10 µm is a conservative ecological screening threshold for potential sublethal effects on fauna and birds on the shoreline.

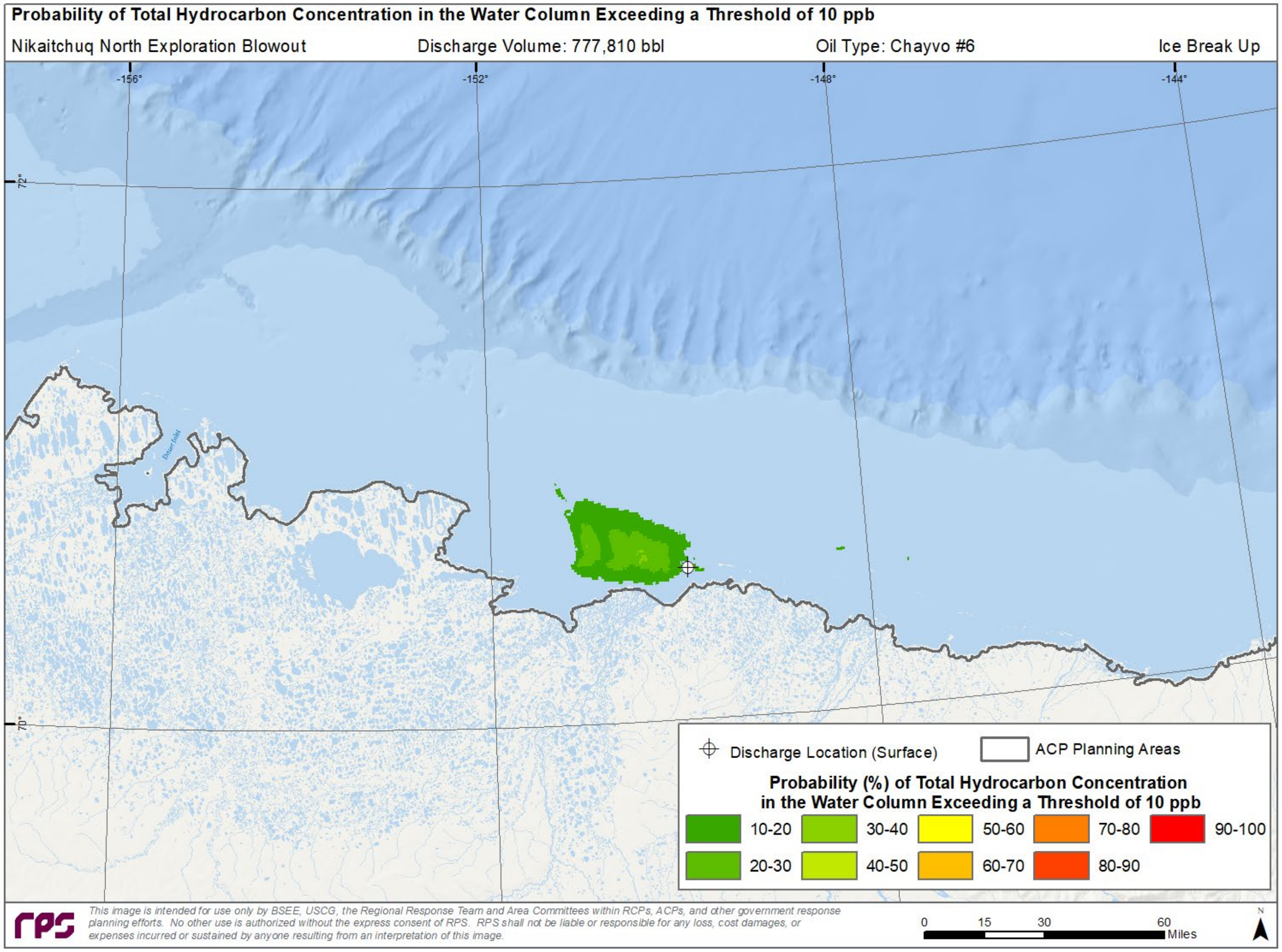

Figure 6. Probability Footprint for Total Hydrocarbon Concentration (THC) concentrations in the Water Column greater than the Ecological Threshold of 10 µg/L (~10 ppb). 10 ppb (µg/L) of whole oil (THC) corresponds to ~0.1 µg/L (~1 ppb) of dissolved Polycyclic Aromatic Hydrocarbons (PAHs) for fresh crude oils. This threshold can result in sublethal impacts to early life stages of fish and invertebrates in the upper ~20 meters of the water column if exposed to UV light.

The “worst case” deterministic simulation is a single oil trajectory run using the time period and ambient conditions that resulted in the greatest area of shoreline oiling. The simulation resulted in oiling in the following cumulative amounts:

- Swept Oiled Surface Area Exceeding 0.04 µm (Socioeconomic Impact) = 1,018,580 mi^2
- Swept Oiled Surface Area Exceeding 10 µm (Ecological Impact) = 1,013,572 mi^2
- Oiled Shoreline Exceeding 10 µm (Ecological Impact) = 826 mi
- Water Column Oil Exposure Exceeding 10 ppb Dissolved PAH (Ecological Impact) = 10,151 million m3
- Time to Shore = < 0.75 hrs

These impact values are calculated considering no response measures are taken to secure the source of the spill or to contain, remove, or disperse oil at the scene.

Table 5. Mass balance at the end of the worst case deterministic simulation (% of the total volume of oil discharged*).

Total Oil Discharged	Surface	Evaporated	Water Column	Sediment	Ashore	Degraded
777,810 bbl	5.4%	50.8%	0.9%	<0.1%	37.3%	5.5%

*Important to note these values are not indicative of the maximum amount of oil in each compartment, but instead show the final amount of oil in each compartment.

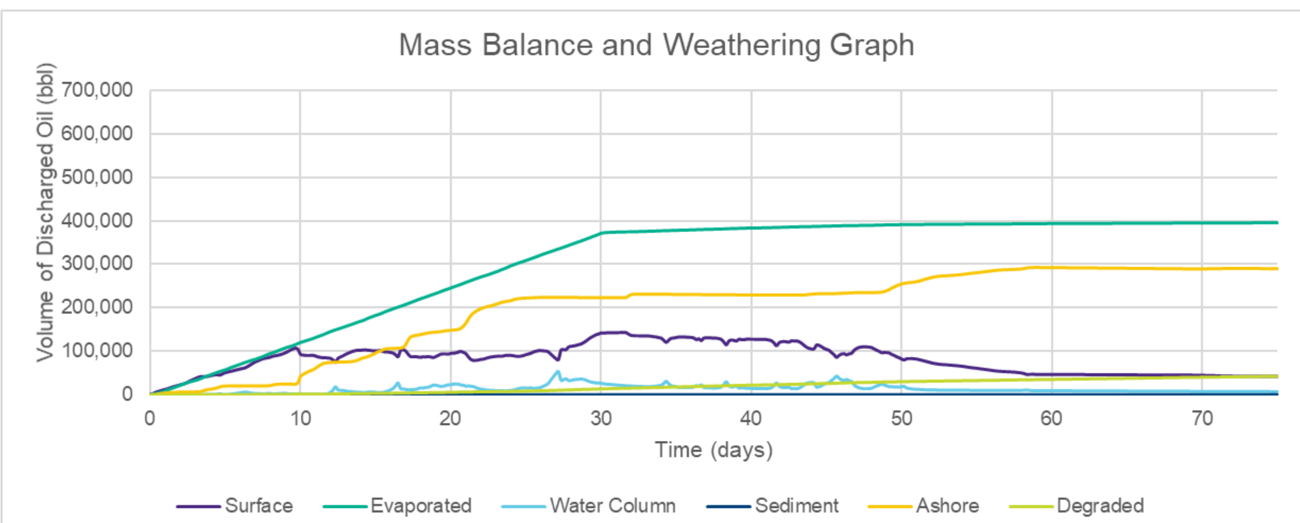

Figure 7. Mass Balance over Time for worst case deterministic simulation.

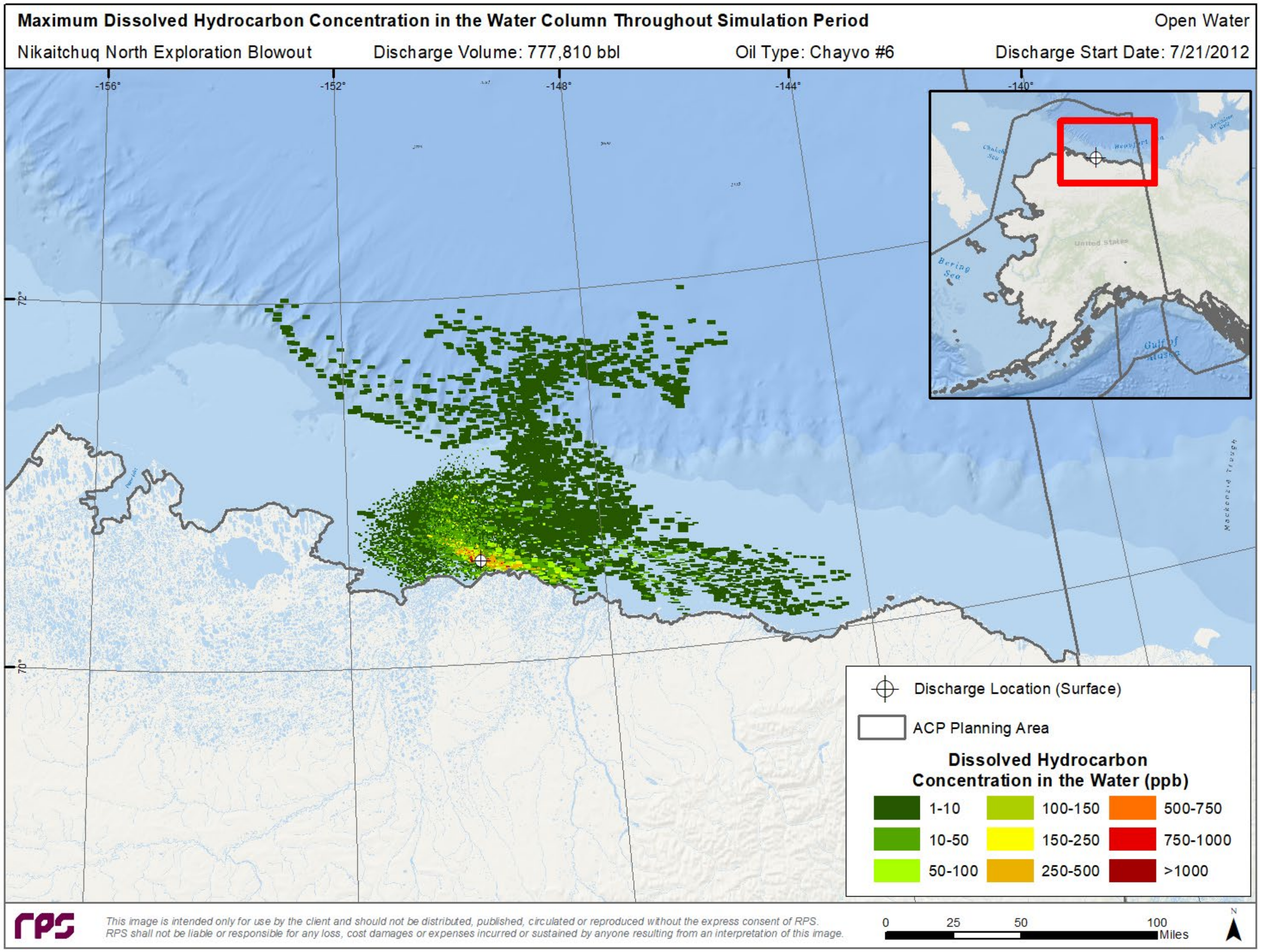

Figure 8. Cumulative Maximum Concentration of Dissolved Polycyclic Aromatic Hydrocarbons (PAH) within the water column at any time during the worst case deterministic simulation period. Dissolved PAH concentrations greater than ~10 µg/L (~10 ppb) could affect plankton in the upper ~20 m and impart sublethal to lethal effects on other water column biota (adult, juvenile fish, and invertebrates).

3.3 Response Planning Information

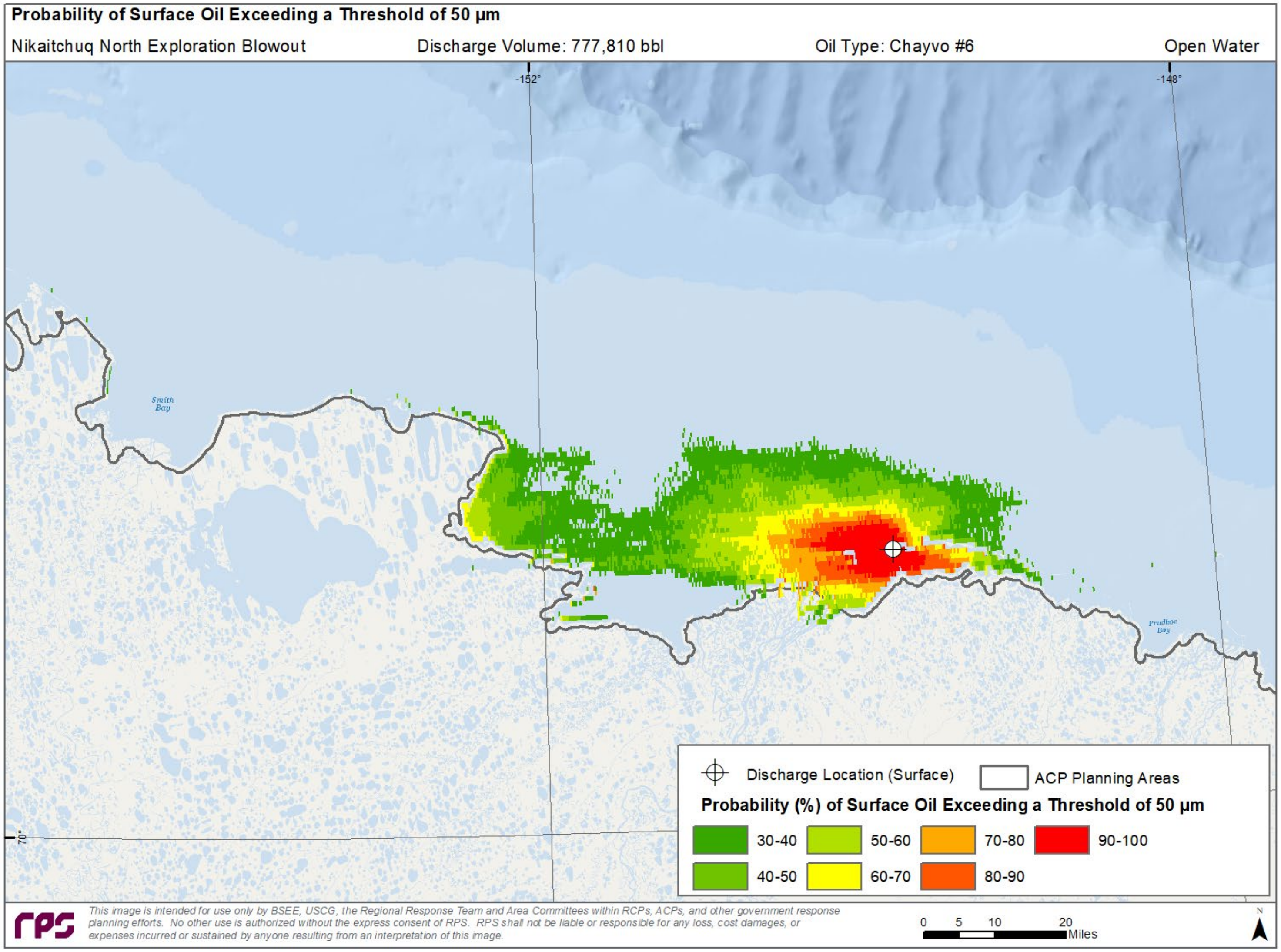

Figure 9. Probability Footprint for Surface Oil exposure greater than 50 µm. In this thickness range, oil will appear as a continuous to discontinuous patches of dark oil in quantities where high volume on-water mechanical recovery operations will be the most productive.

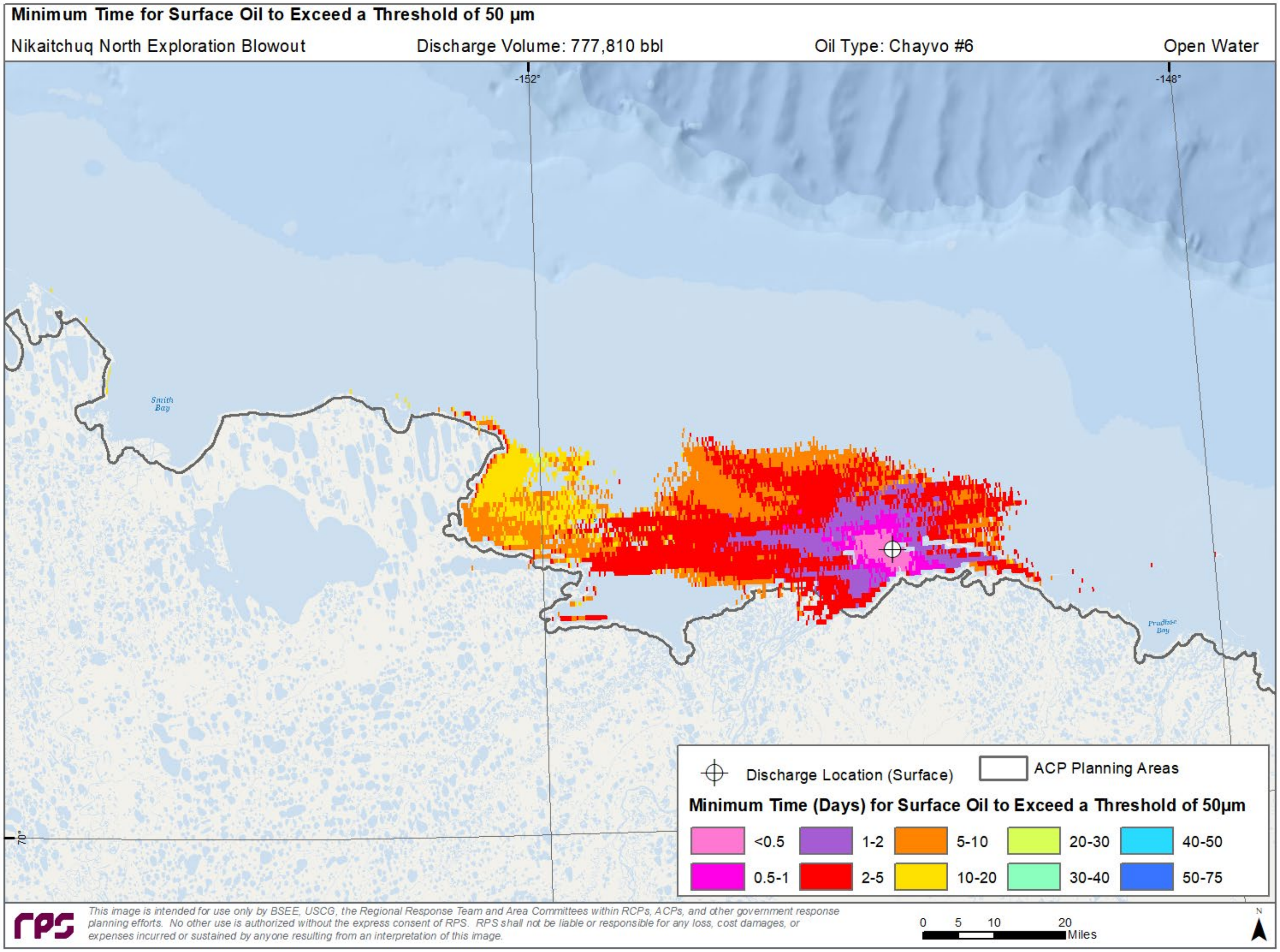

Figure 10. Minimum Travel Time for Surface Oil exposure greater than 50 µm.

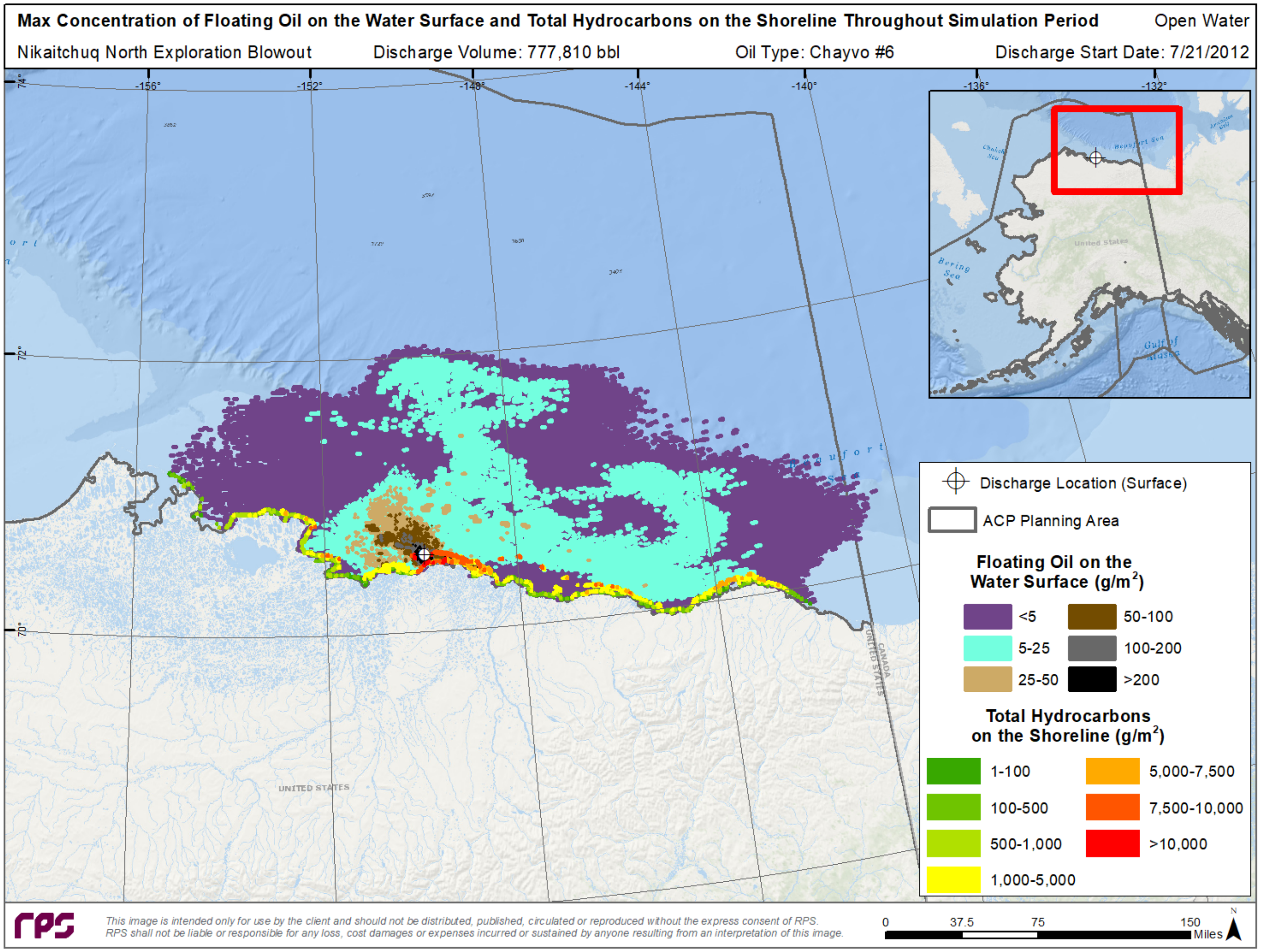

Figure 11. Cumulative Maximum Concentration of Floating Oil on the Water Surface and Total Hydrocarbons on the Shoreline at any time during the worst case deterministic simulation.

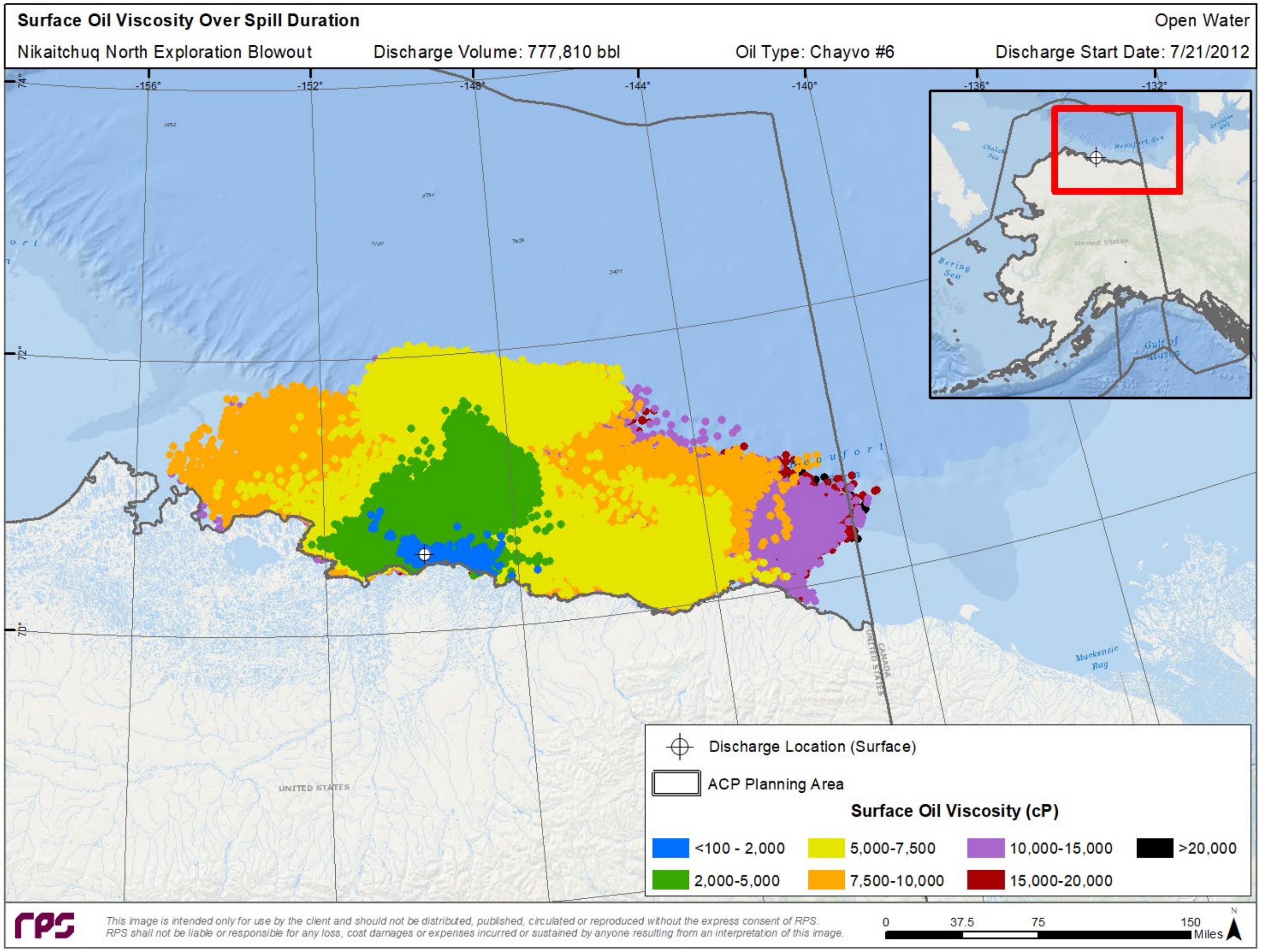

Figure 12. Cumulative footprint of exposure to surface floating oil greater than the minimum oil viscosity over a 75-day period for the worst case deterministic simulation. Viscosities greater than those mapped may be present at any location at any specific time in the simulation. This graphic provides a perspective of how oil viscosity may change as oil is transported away from the discharge site over time, and what areas may be amenable to dispersant operations where enough quantities of oil are present.

4 Nikaitchuq North Exploration – Ice Break Up Surface Well Blowout

4.1 Scenario Description

The Nikaitchuq North Exploration – Ice Break Up WCD Scenario is a surface well blowout with the following key parameters:

Table 6. Scenario Key Parameters.

Discharge Depth (m)	Distance from Shore (NM)	Oil Type	Spill Type	Ice Coverage	Discharge Duration (days)	Discharge Flowrate (bbl/day)	Total Oil Discharged (bbl)
Surface	<1	Light Crude API = 38	Surface Well Blowout	Ice Break Up	30	25,927	777,810

4.2 Potential Oil Contact with the Environment and Resources at Risk

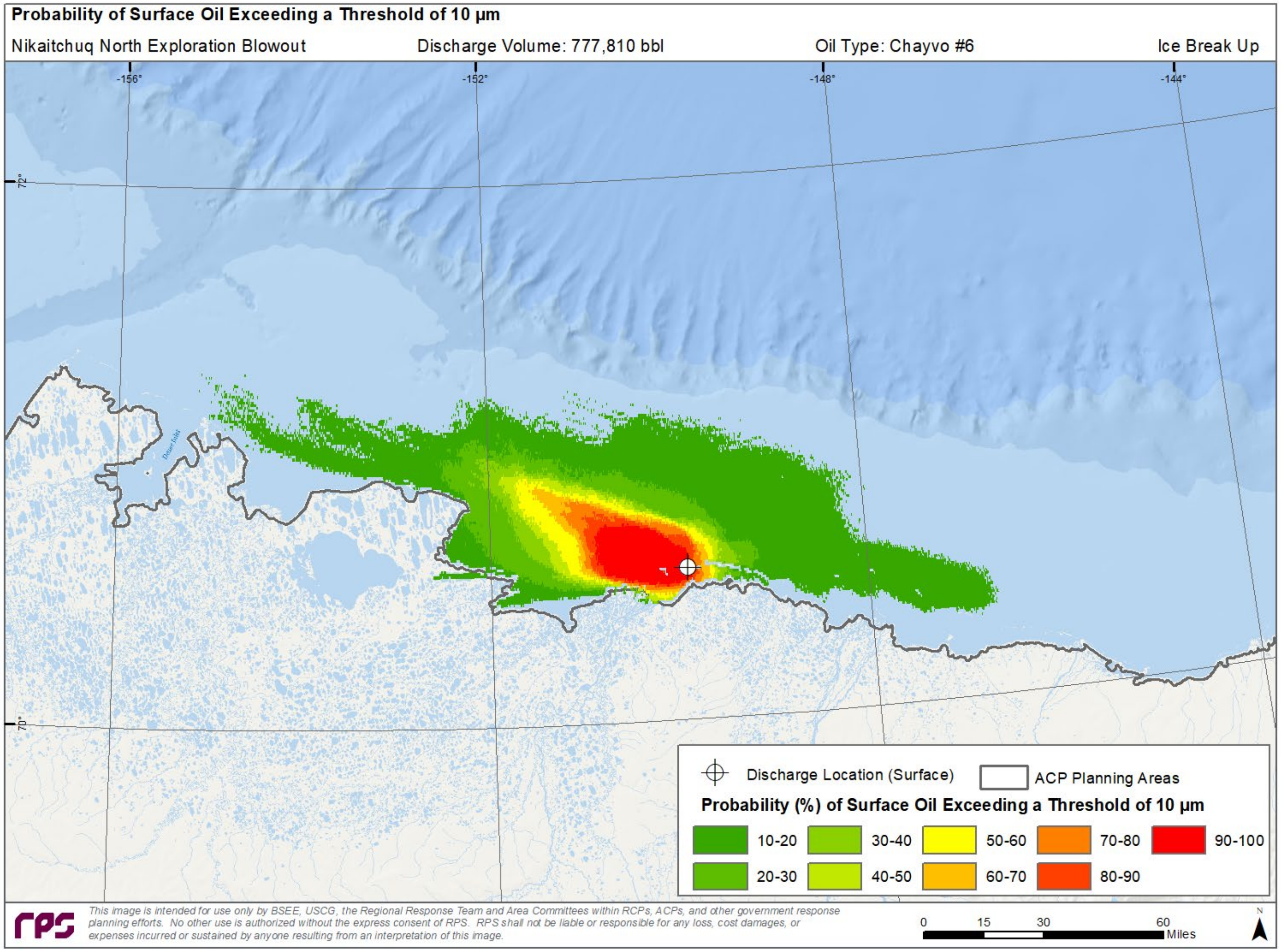

Figure 13. Probability Footprint for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

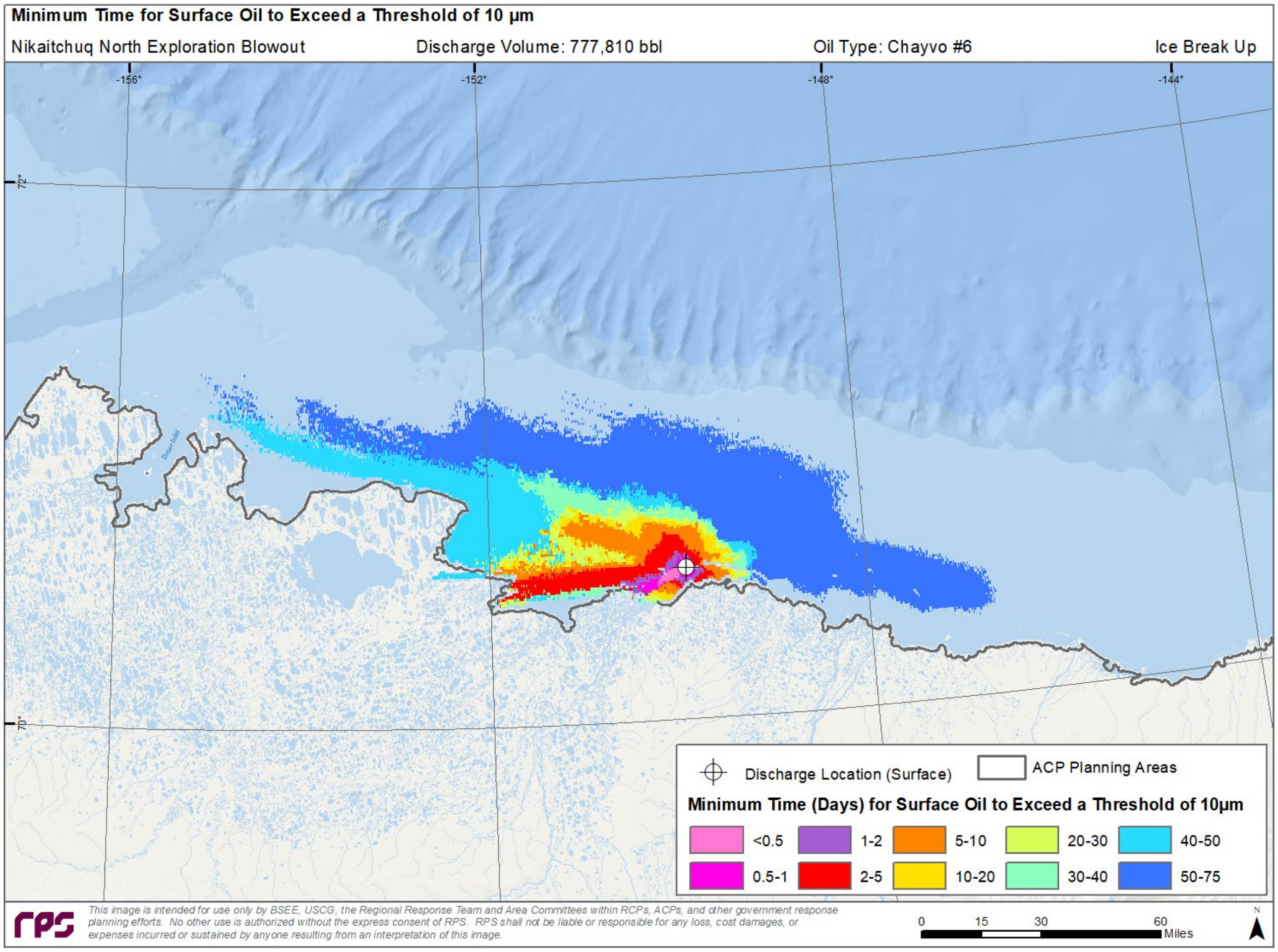

Figure 14. Minimum Travel Time for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

Table 7. Oil Spill Stochastic Results – Predicted Shoreline Impacts.

Percentage of Simulations Reaching shore (%)	Percent volume of discharged oil reaching shore (%)		Time to Reach Shore (hours)	
	Maximum	Average	Minimum	Average
100	41	10	0.50	0.52

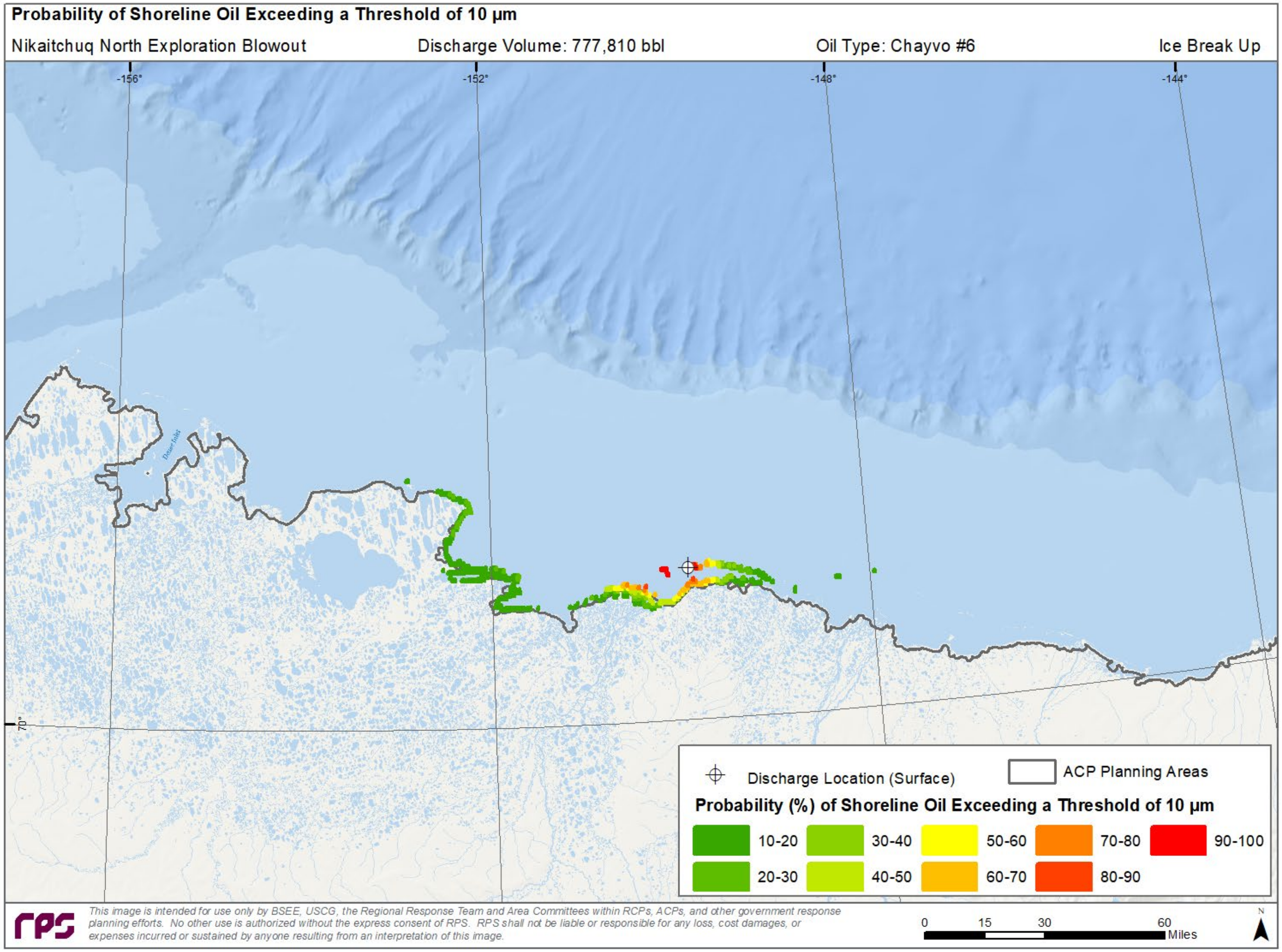

Figure 15. Probability Footprint for Oil on the Shoreline with Average Thickness greater than the Ecological Threshold of 10 µm. This thickness of oil may appear on the shore as dark stain or film. 10 µm is a conservative ecological screening threshold for potential sublethal effects on fauna and birds on the shoreline.

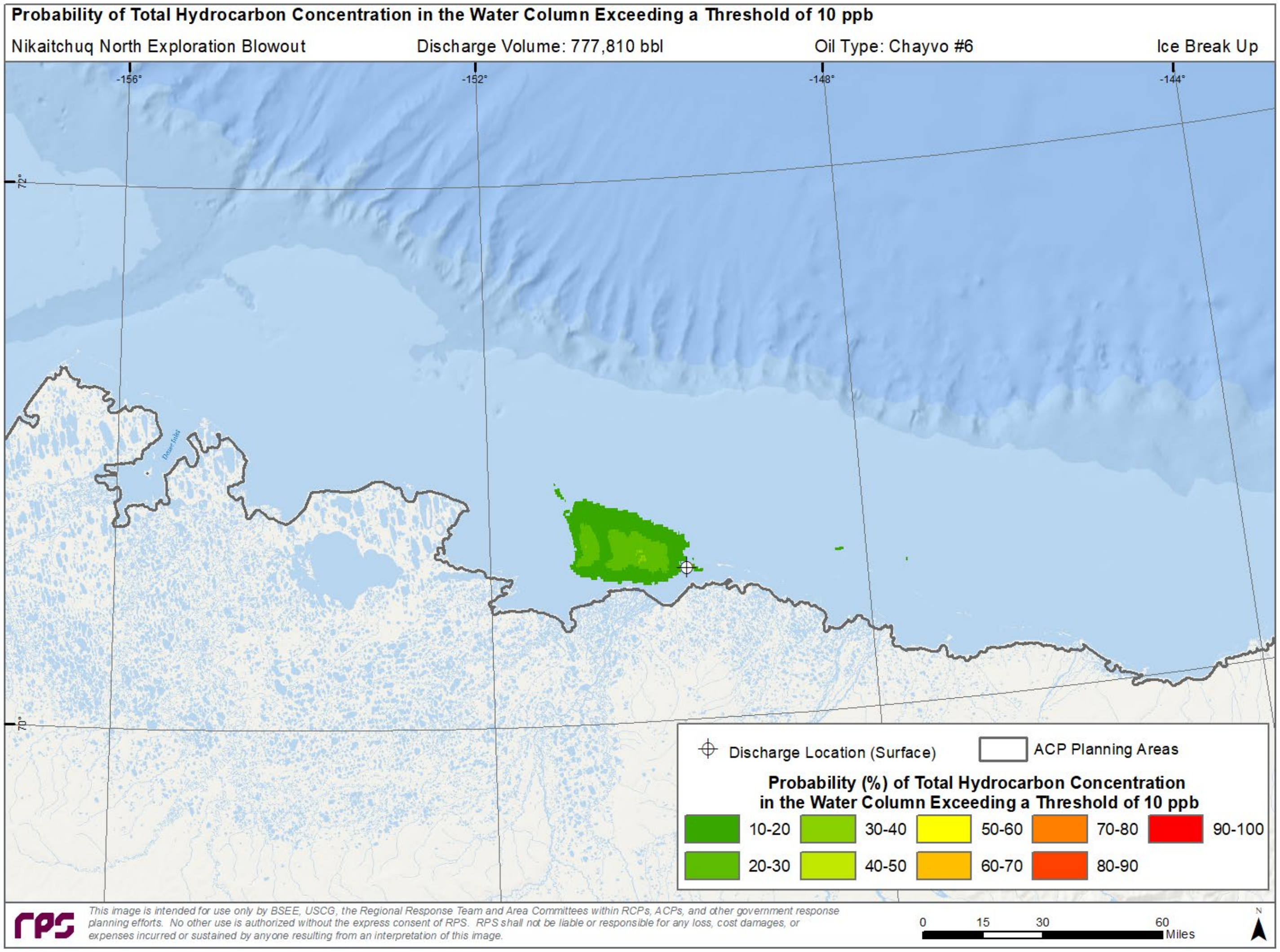

Figure 16. Probability Footprint for Total Hydrocarbon Concentration (THC) concentrations in the Water Column greater than the Ecological Threshold of 10 µg/L (~10 ppb). 10 ppb (µg/L) of whole oil (THC) corresponds to ~0.1 µg/L (~1 ppb) of dissolved Polycyclic Aromatic Hydrocarbons (PAHs) for fresh crude oils. This threshold can result in sublethal impacts to early life stages of fish and invertebrates in the upper ~20 meters of the water column if exposed to UV light.

The “worst case” deterministic simulation models is a single oil trajectory run using the time period and ambient conditions that resulted in the greatest area of shoreline oiling. The simulation resulted in oiling in the following cumulative amounts:

- Swept Oiled Surface Area Exceeding 0.04 µm (Socioeconomic Impact) = 1,101,137 mi^2
- Swept Oiled Surface Area Exceeding 10 µm (Ecological Impact) = 1,101,136 mi^2
- Oiled Shoreline Exceeding 10 µm (Ecological Impact) = 448 mi
- Water Column Oil Exposure Exceeding 10 ppb Dissolved PAH (Ecological Impact) = 909n m^3
- Time to Shore = <0.25 hrs

These impact values are calculated considering no response measures are taken to secure the source of the spill or to contain, remove, or disperse oil at the scene.

Table 8. Mass balance at the end of the worst case deterministic simulation (% of the total volume of oil discharged*).

Total Oil Discharged	Surface	Evaporated	Water Column	Sediment	Ashore	Degraded
777,810 bbl	23.2%	52.4%	0.4%	<0.1%	18.6%	5.3%

*Important to note these values are not indicative of the maximum amount of oil in each compartment, but instead show the final amount of oil in each compartment.

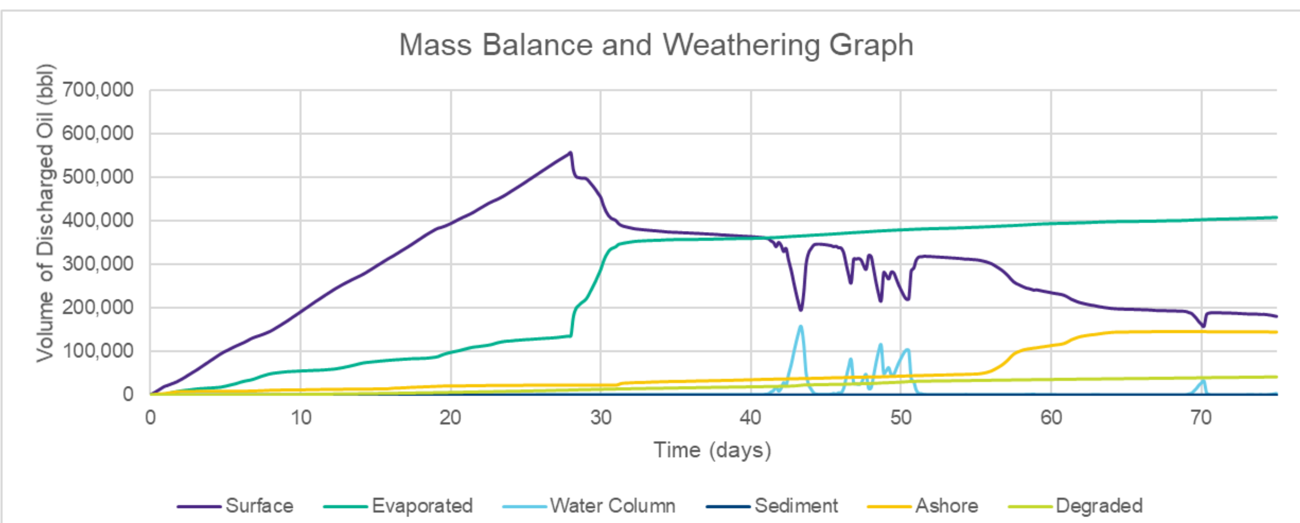

Figure 17. Mass Balance over Time for worst case deterministic simulation.

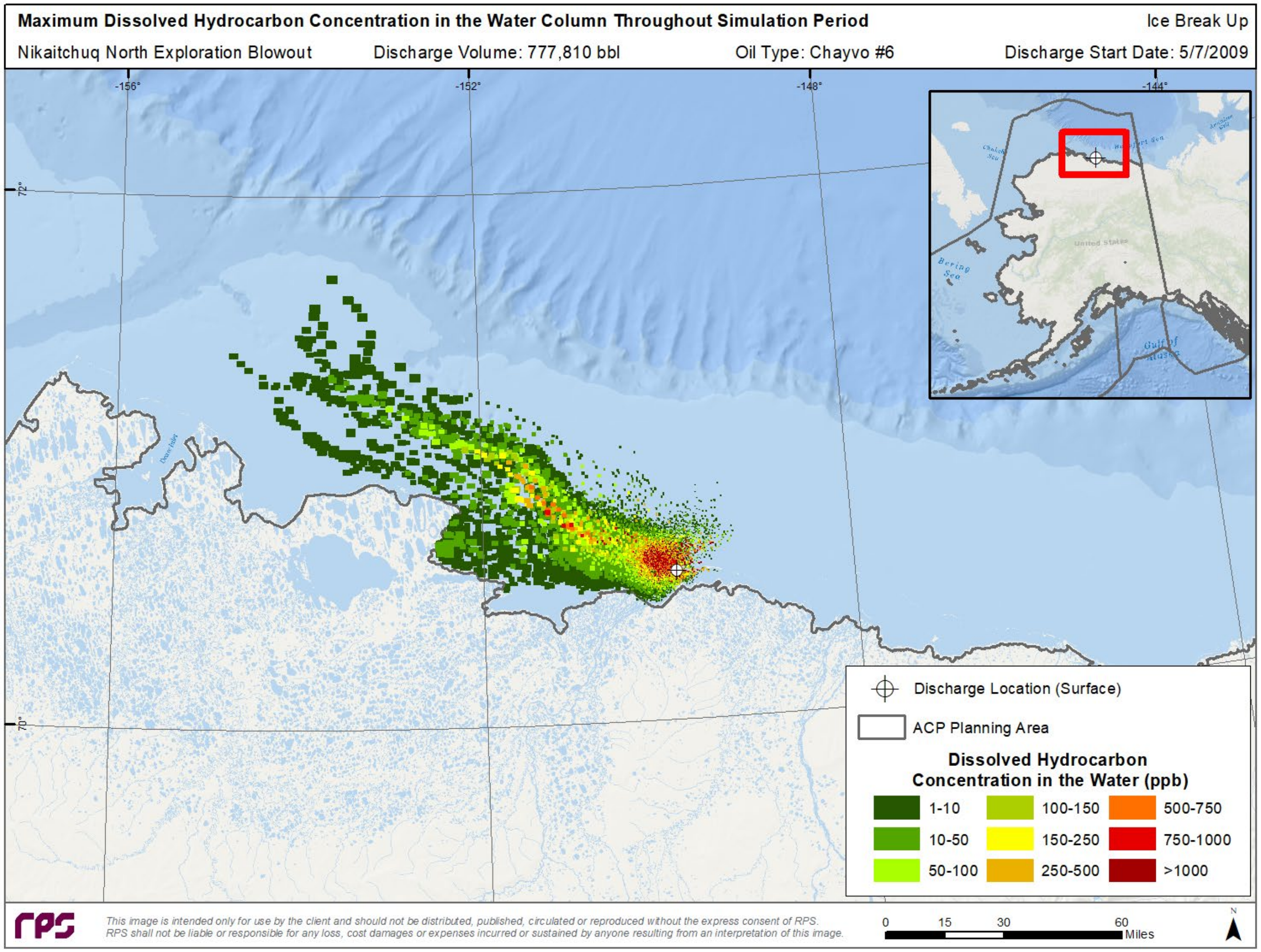

Figure 18. Cumulative Maximum Concentration of Dissolved Polycyclic Aromatic Hydrocarbons (PAH) within the water column at any time during the worst case deterministic simulation period. Dissolved PAH concentrations greater than ~10 µg/L (~10 ppb) could affect plankton in the upper ~20 m and impart sublethal to lethal effects on other water column biota (adult, juvenile fish, and invertebrates).

4.3 Response Planning Information

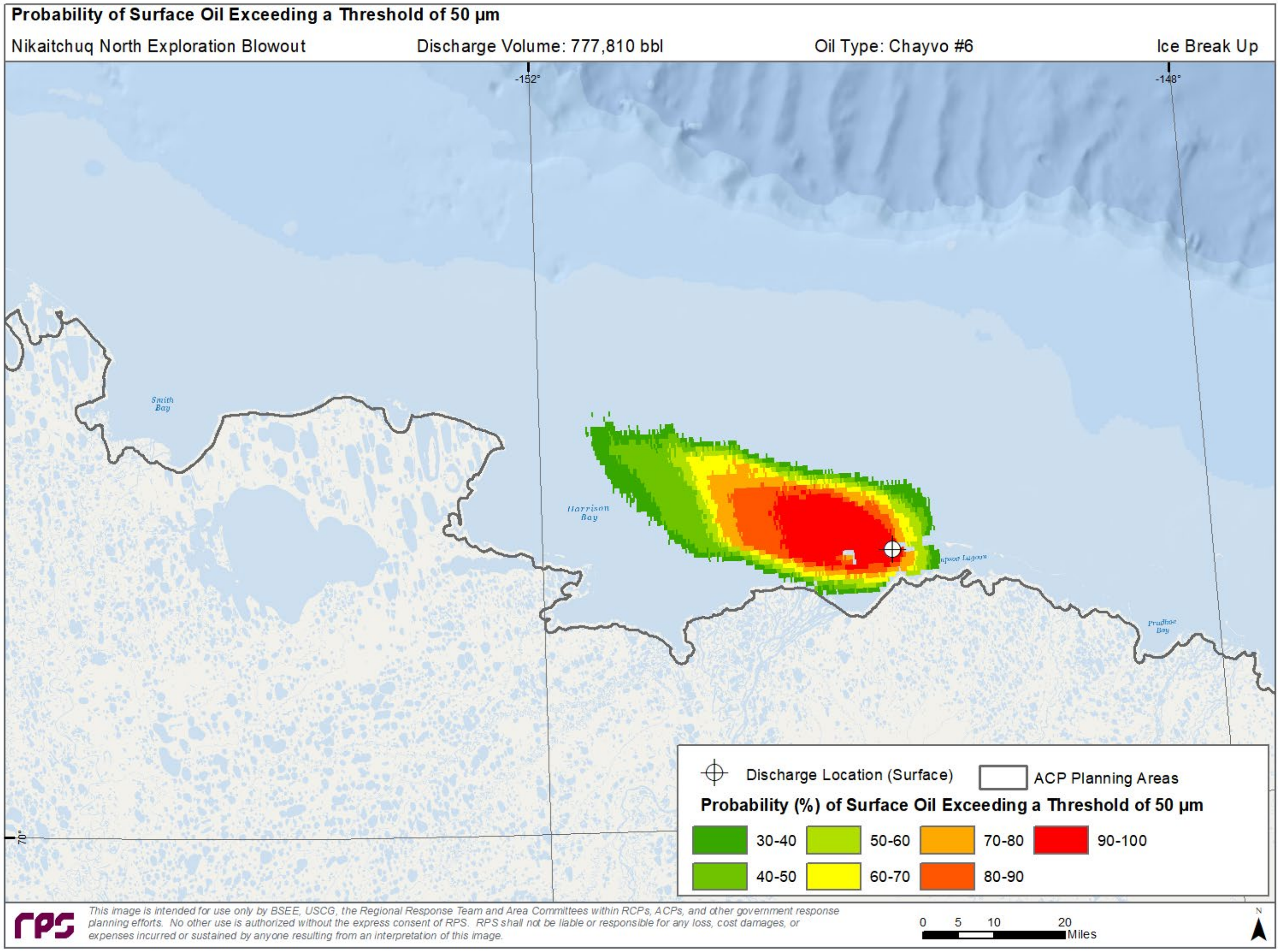

Figure 19. Probability Footprint for Surface Oil exposure greater than 50 µm. In this thickness range, oil will appear as a continuous to discontinuous patches of dark oil in quantities where high volume on-water mechanical recovery operations will be the most productive.

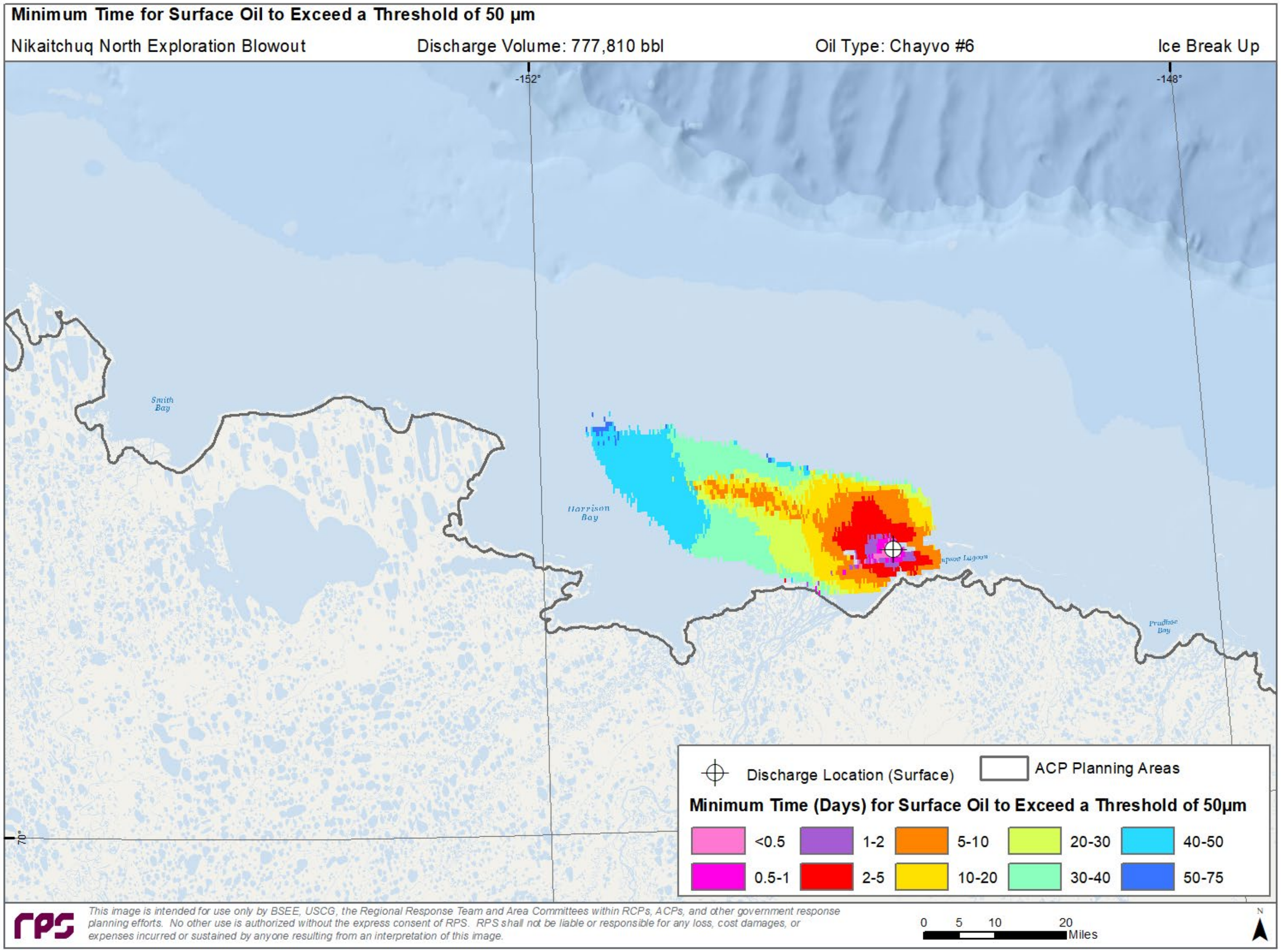

Figure 20. Minimum Travel Time for Surface Oil exposure greater than 50 µm.

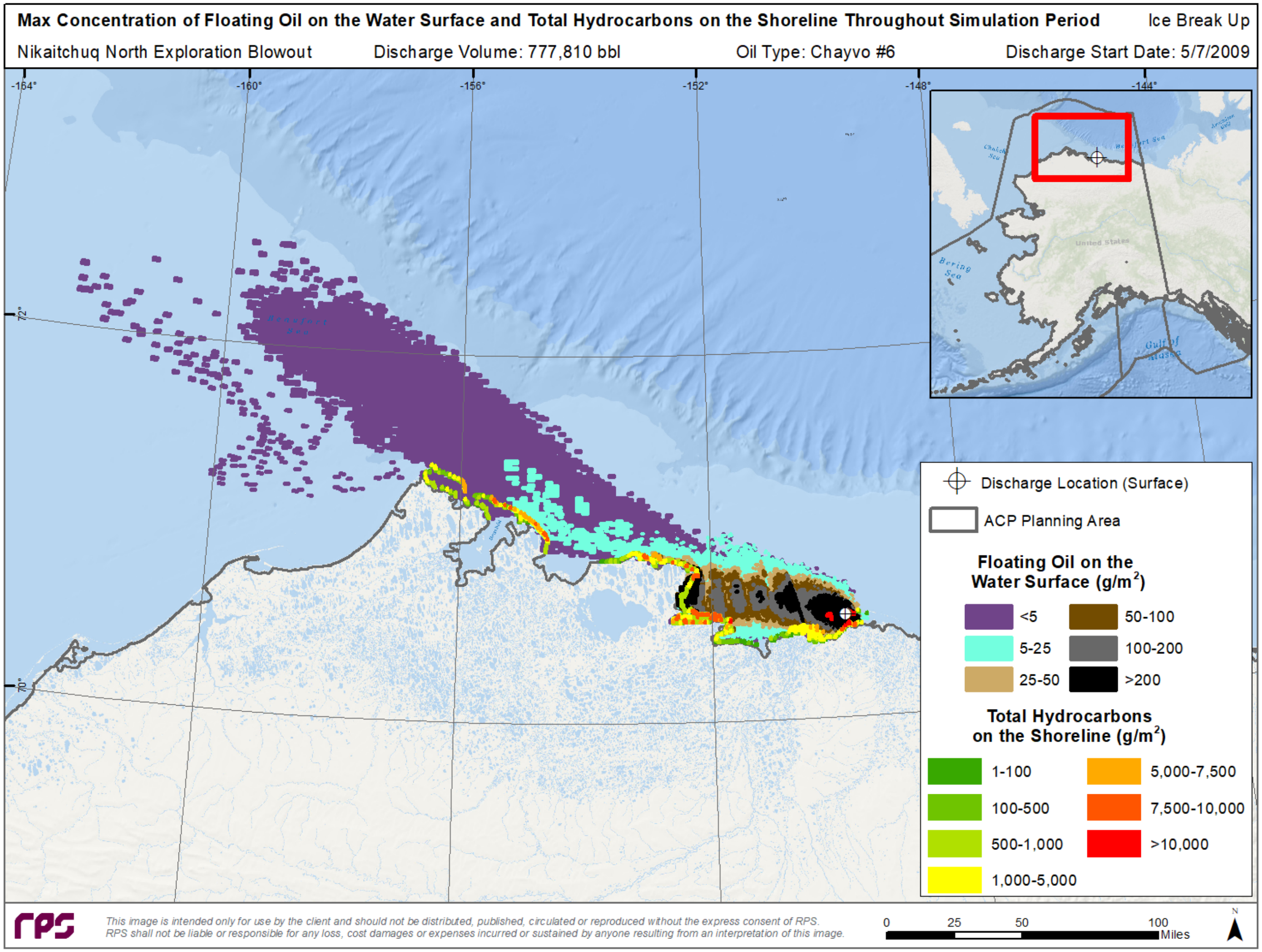

Figure 21. Cumulative Maximum Concentration of Floating Oil and Total Hydrocarbons on the Shoreline at any time during the worst case deterministic simulation.

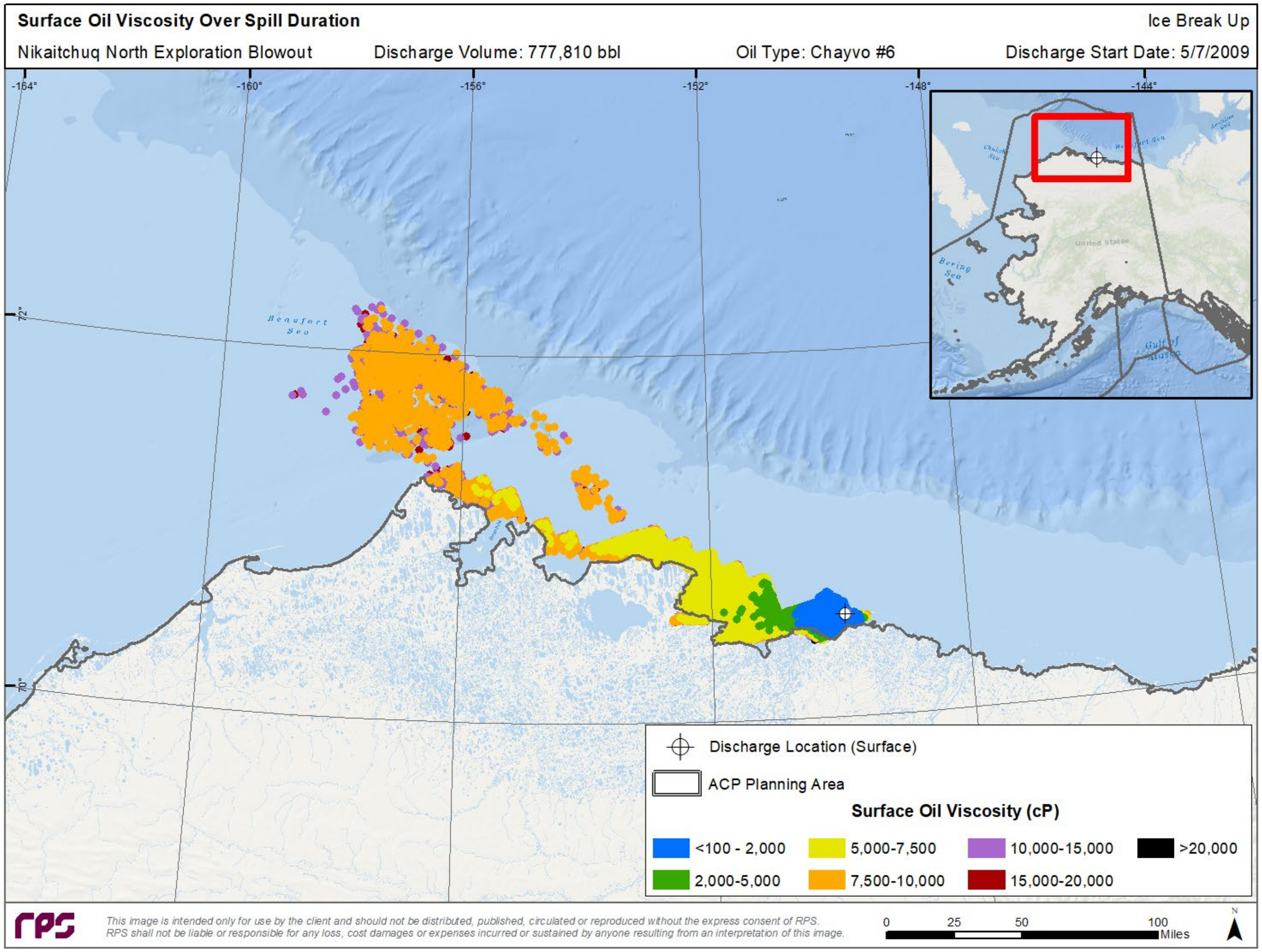

Figure 22. Cumulative footprint of exposure to surface floating oil greater than the minimum oil viscosity over a 75-day period for the worst case deterministic simulation. Viscosities greater than those mapped may be present at any location at any specific time in the simulation. This graphic provides a perspective of how oil viscosity may change as oil is transported away from the discharge site over time and what areas may be amenable to dispersant operations where enough quantities of oil are present.

5 Endicott Pipeline Discharge

5.1 Scenario Description

The Endicott Pipeline WCD Scenario is a pipeline discharge with the following key parameters:

Table 9. Scenario Key Parameters.

Discharge Depth (m)	Distance from Shore (NM)	Oil Type	Spill Type	Ice Coverage	Discharge Duration (days)	Discharge Flowrate (bbl/day)	Total Oil Discharged (bbl)
Surface	0.25	Heavy Crude API = 23.5	Pipeline Discharge	Open Water	1	4,885	4,885

5.2 Potential Oil Contact with the Environment and Resources at Risk

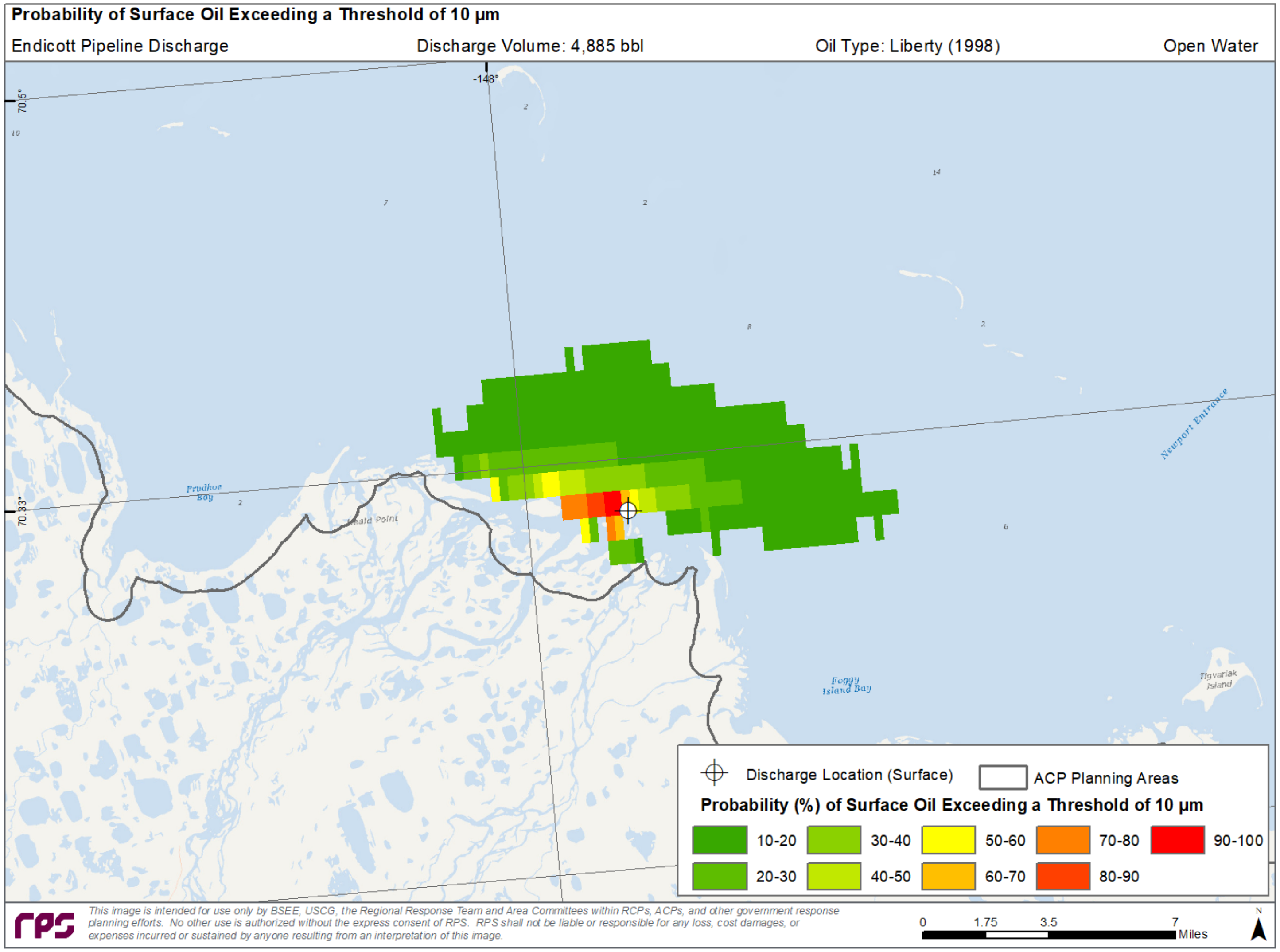

Figure 23. Probability Footprint for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

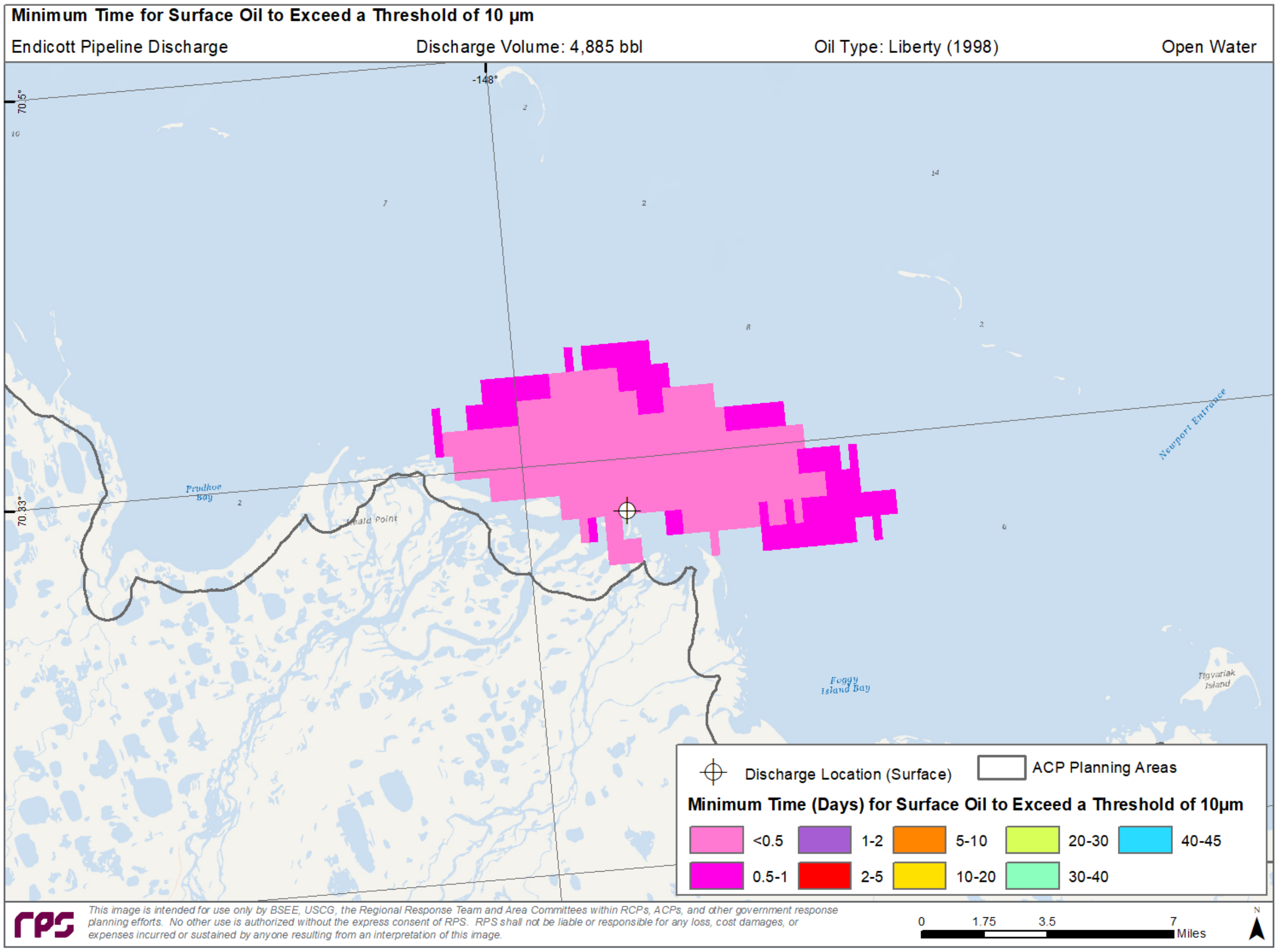

Figure 24. Minimum Travel Time for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

Table 10. Oil Spill Stochastic Results – Predicted Shoreline Impacts.

Percentage of Simulations Reaching shore (%)	**Percent volume of discharged oil reaching shore (%)**		**Time to Reach Shore (hours)**	
	Maximum	**Average**	**Minimum**	**Average**
100	98	91	1.0	1.2

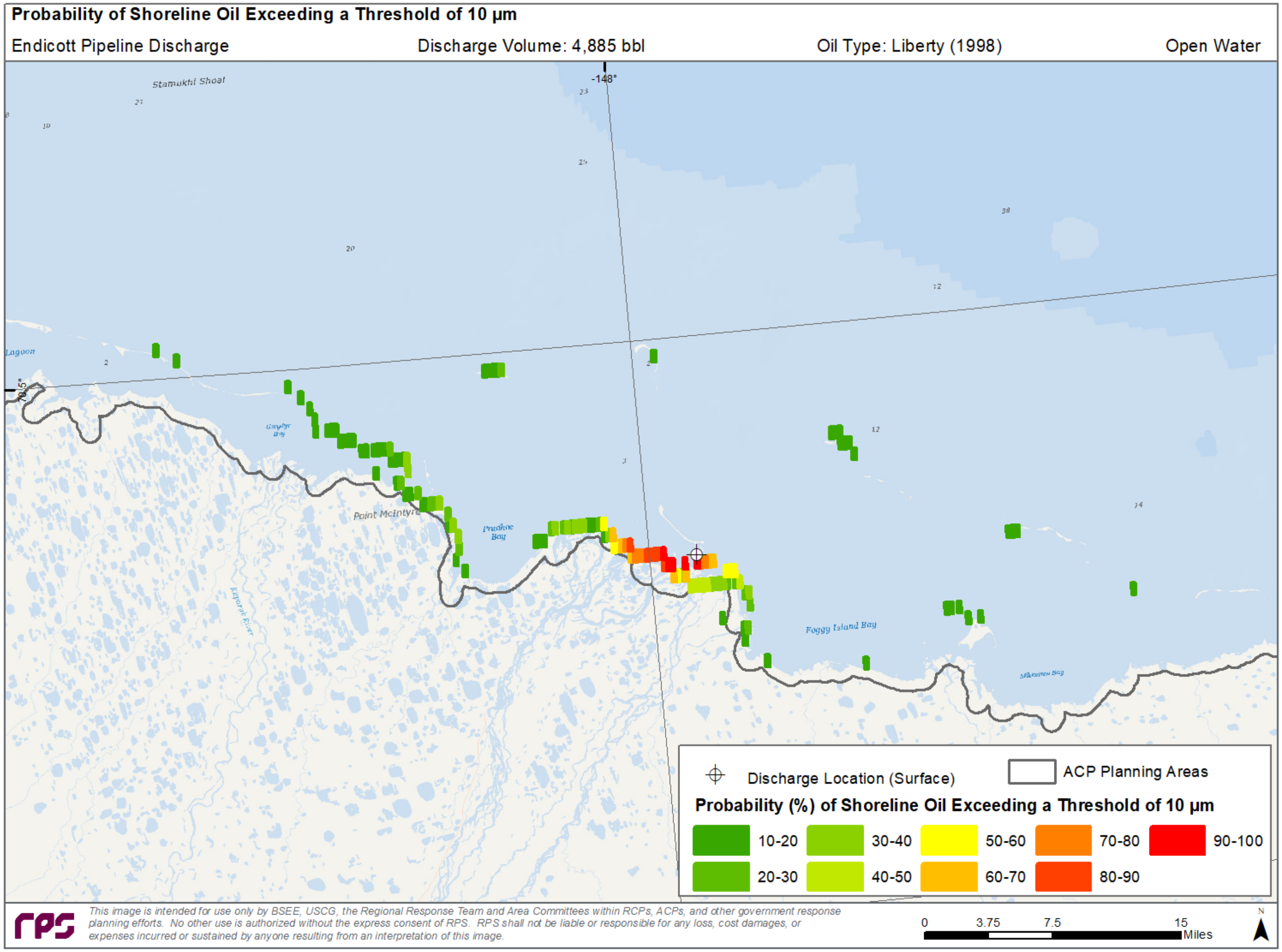

Figure 25. Probability Footprint for Oil on the Shoreline with Average Thickness greater than the Ecological Threshold of 10 µm. This thickness of oil may appear on the shore as dark stain or film. 10 µm is a conservative ecological screening threshold for potential sublethal effects on fauna and birds on the shoreline.

The “worst case” deterministic simulation models is a single oil trajectory run using the time period and ambient conditions that resulted in the greatest area of shoreline oiling. The simulation resulted in oiling in the following cumulative amounts:

- Swept Oiled Surface Area Exceeding 0.04 µm (Socioeconomic Impact) = 1,116 mi^2
- Swept Oiled Surface Area Exceeding 10 µm (Ecological Impact) = 1,116 mi^2
- Oiled Shoreline Exceeding 10 µm (Ecological Impact) = 77 mi
- Water Column Oil Exposure Exceeding 10 ppb Dissolved PAH (Ecological Impact) = 14 million m^3
- Time to Shore = <0.5 hrs

These impact values are calculated considering no response measures are taken to secure the source of the spill or to contain, remove, or disperse oil at the scene.

Table 11. Mass balance at the end of the worst case deterministic simulation (% of the total volume of oil discharged*).

Total Oil Discharged	Surface	Evaporated	Water Column	Sediment	Ashore	Degraded
4,885 bbl	<0.1%	7.6%	<0.1%	<0.1%	80.2%	12.2%

*Important to note these values are not indicative of the maximum amount of oil in each compartment, but instead show the final amount of oil in each compartment.

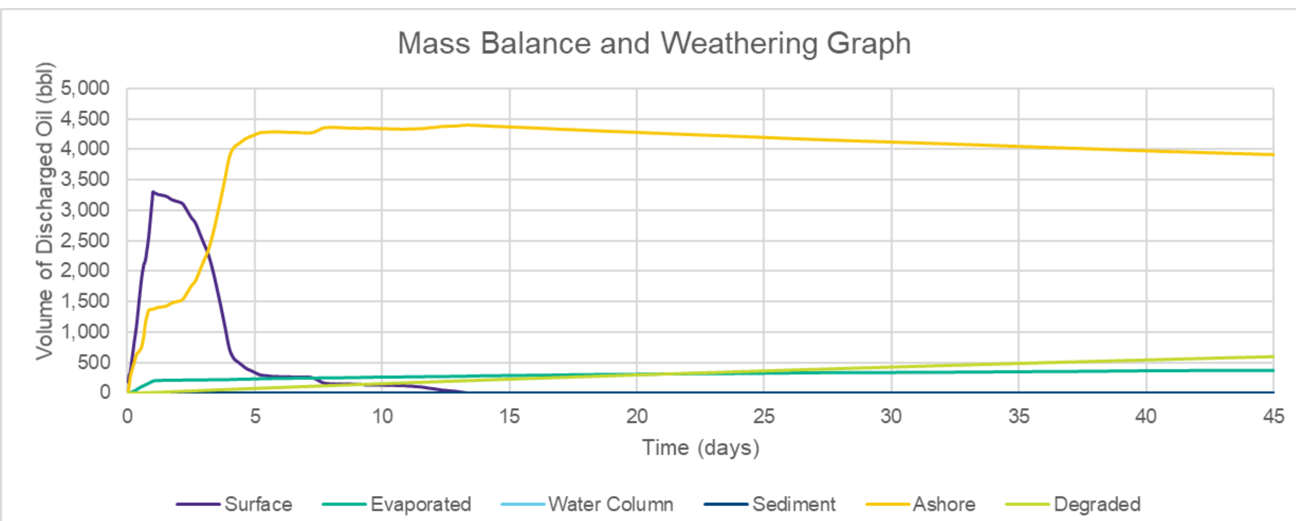

Figure 26. Mass Balance over Time for worst case deterministic simulation.

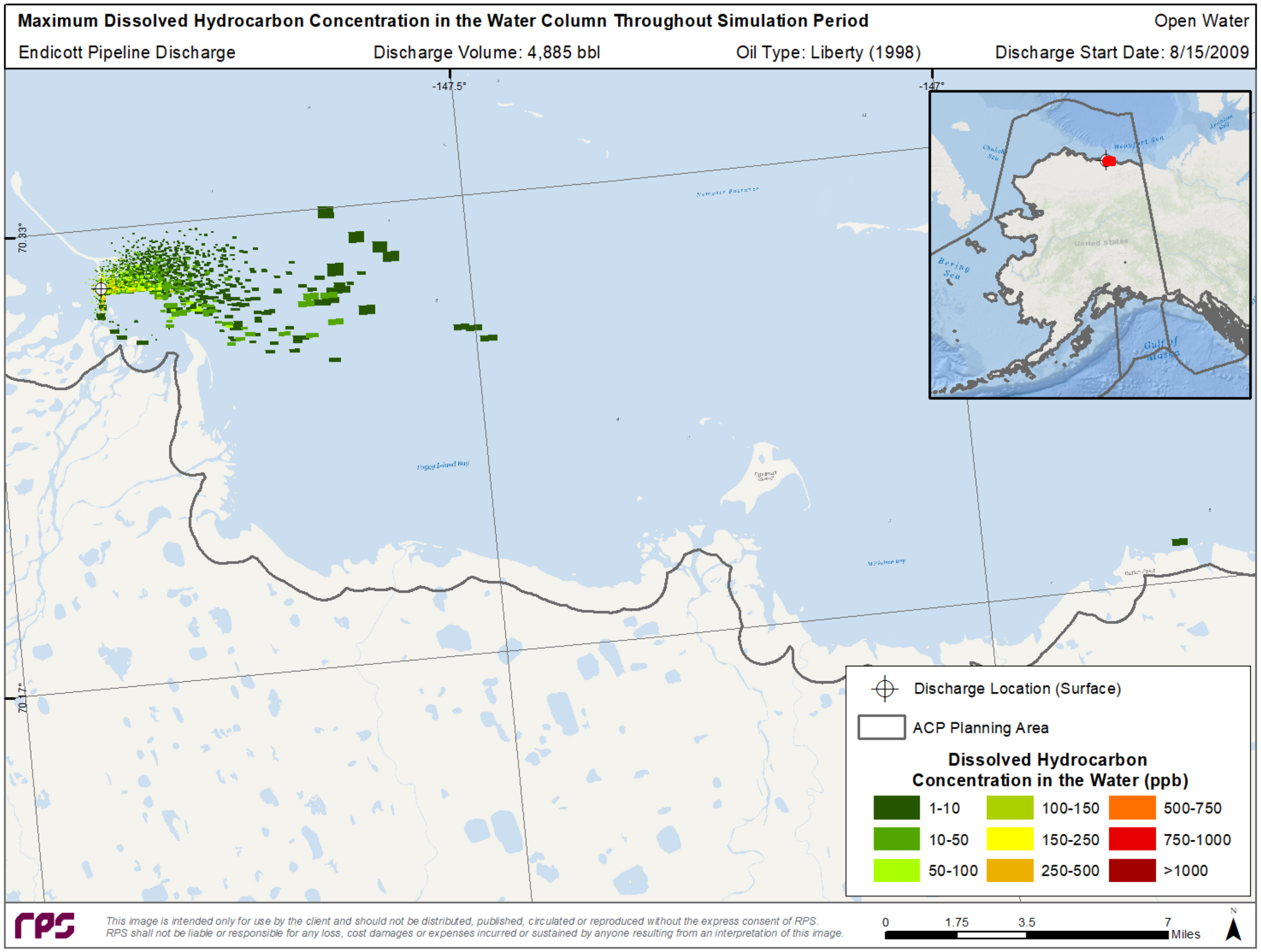

Figure 27. Cumulative Maximum Concentration of Dissolved Polycyclic Aromatic Hydrocarbons (PAH) within the water column at any time during the worst case deterministic simulation period. Dissolved PAH concentrations greater than ~10 µg/L (~10 ppb) could affect plankton in the upper ~20 m and impart sublethal to lethal effects on other water column biota (adult, juvenile fish, and invertebrates).

5.3 Response Planning Information

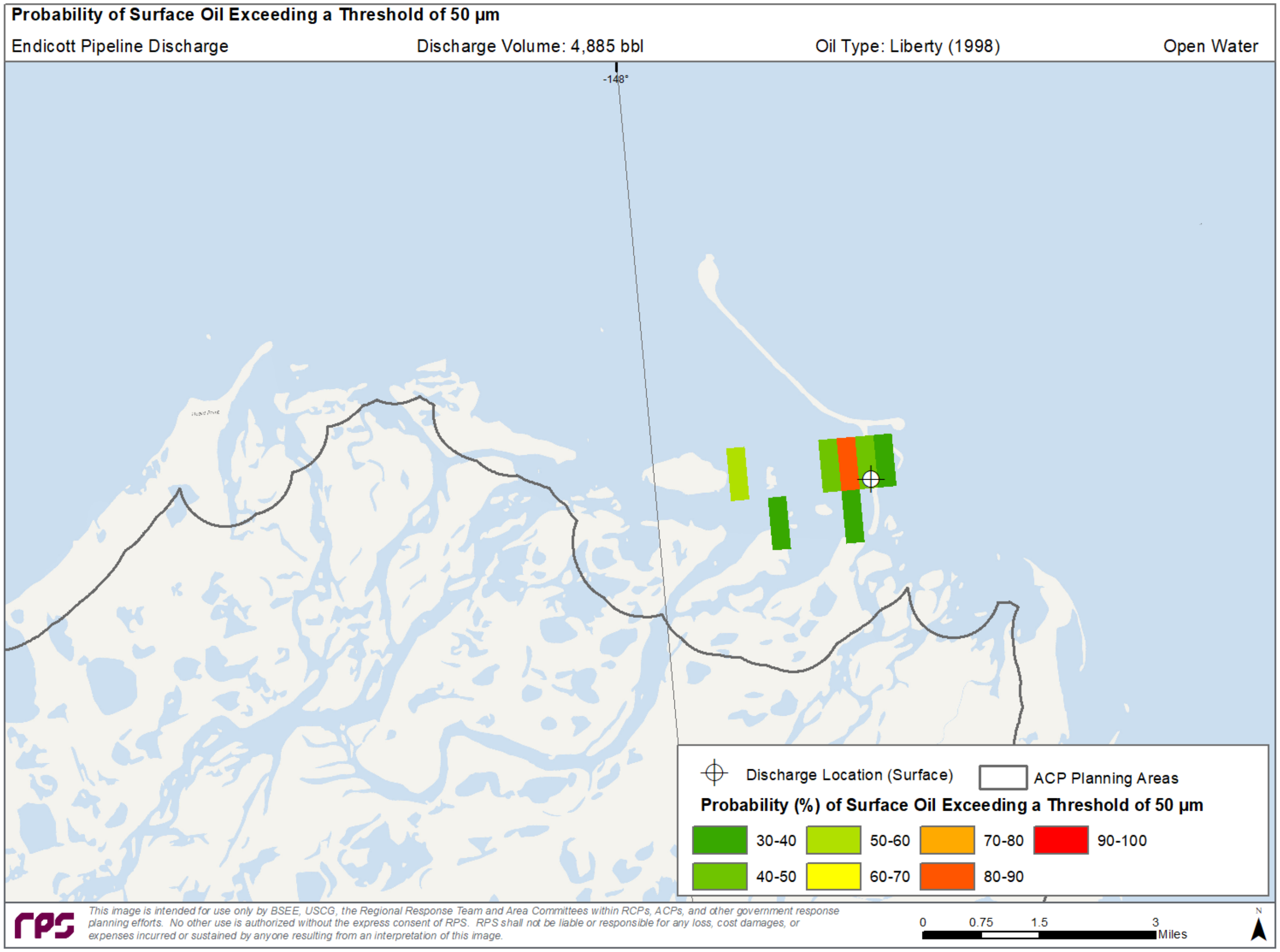

Figure 28. Probability Footprint for Surface Oil exposure greater than 50 µm. In this thickness range, oil will appear as a continuous to discontinuous patches of dark oil in quantities where high volume on-water mechanical recovery operations will be the most productive.

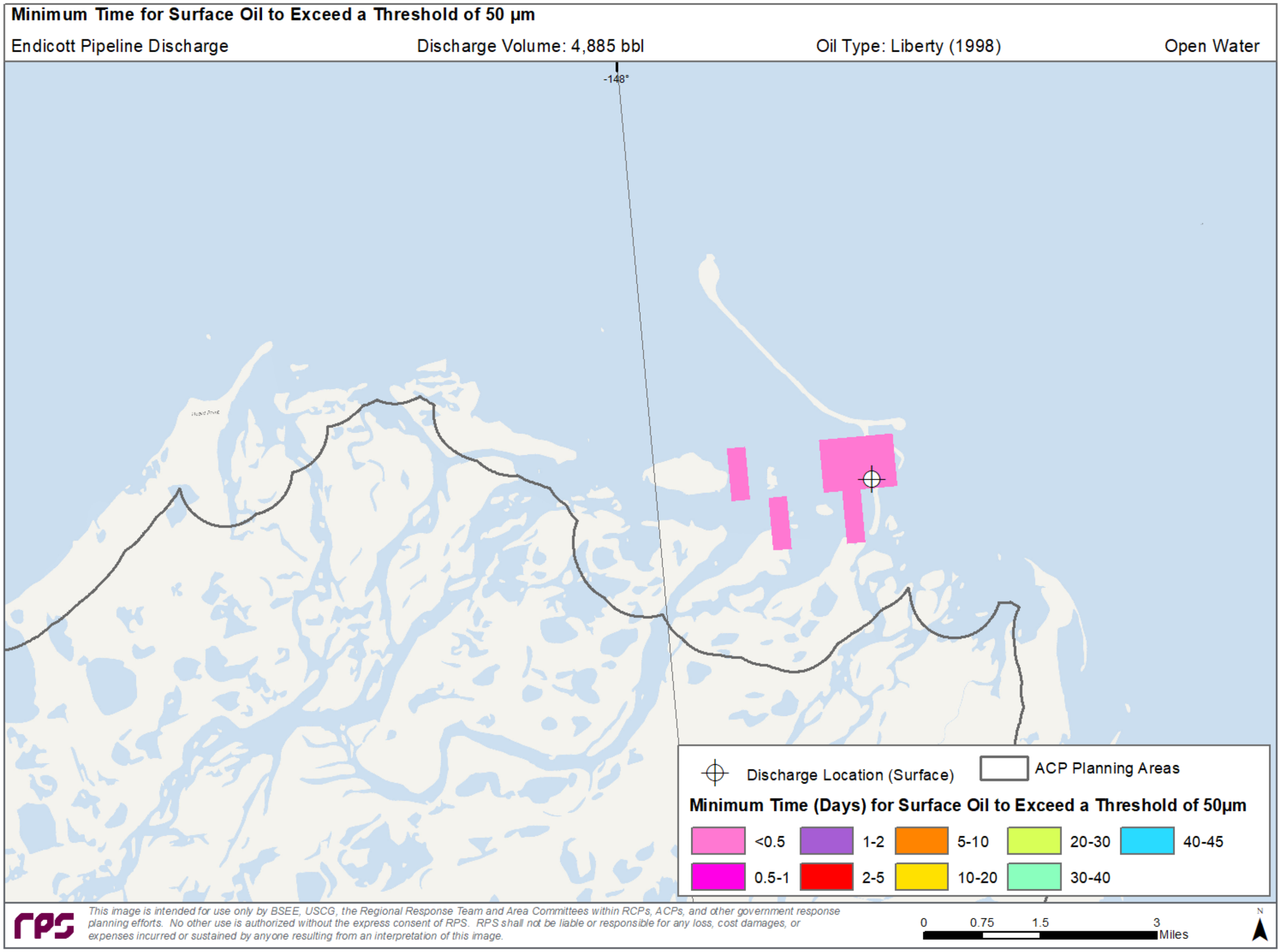

Figure 29. Minimum Travel Time for Surface Oil exposure greater than 50 µm.

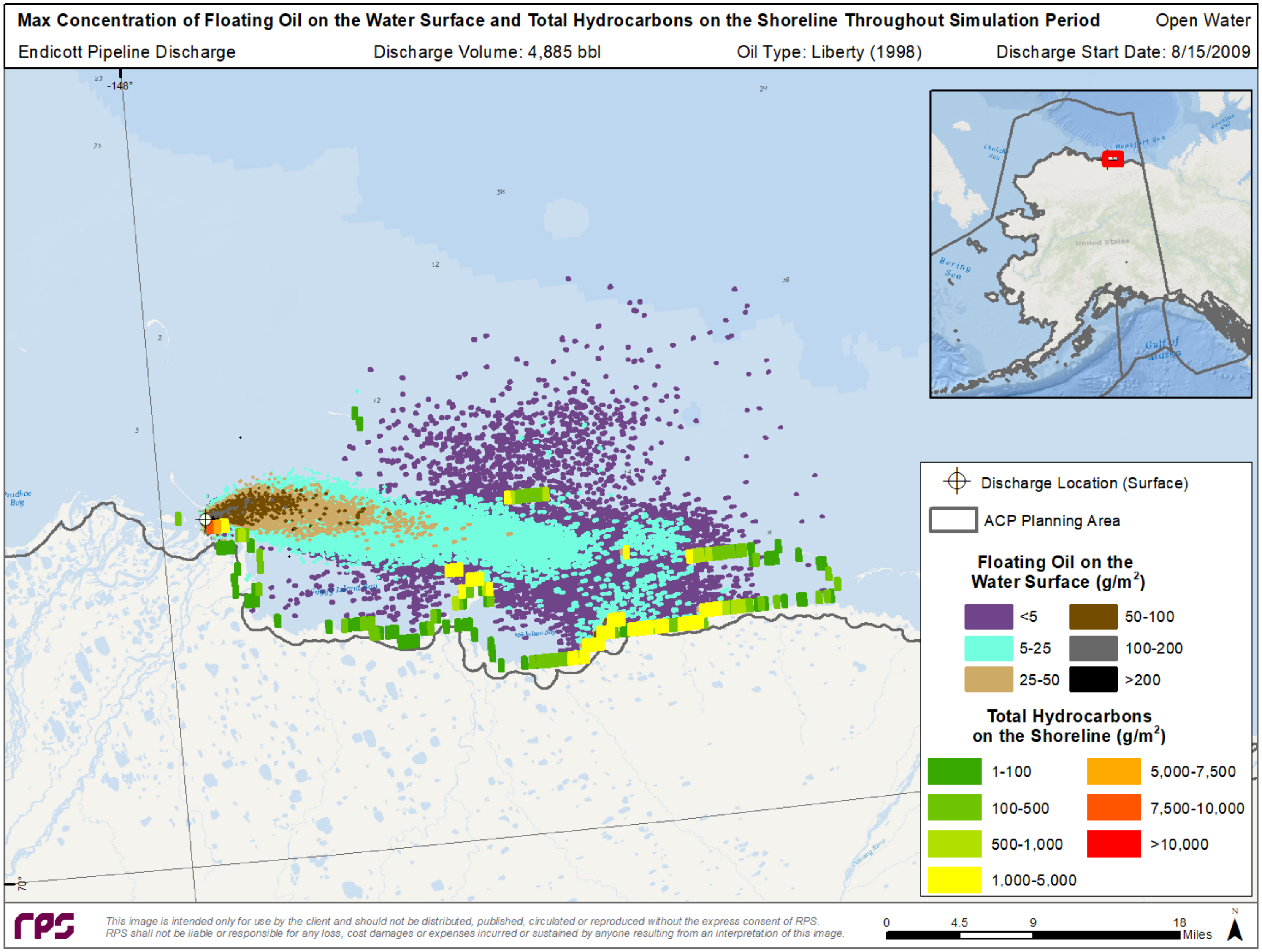

Figure 30. Cumulative Maximum Concentration of Floating Oil and Total Hydrocarbons on the Shoreline at any time during the worst case deterministic simulation.

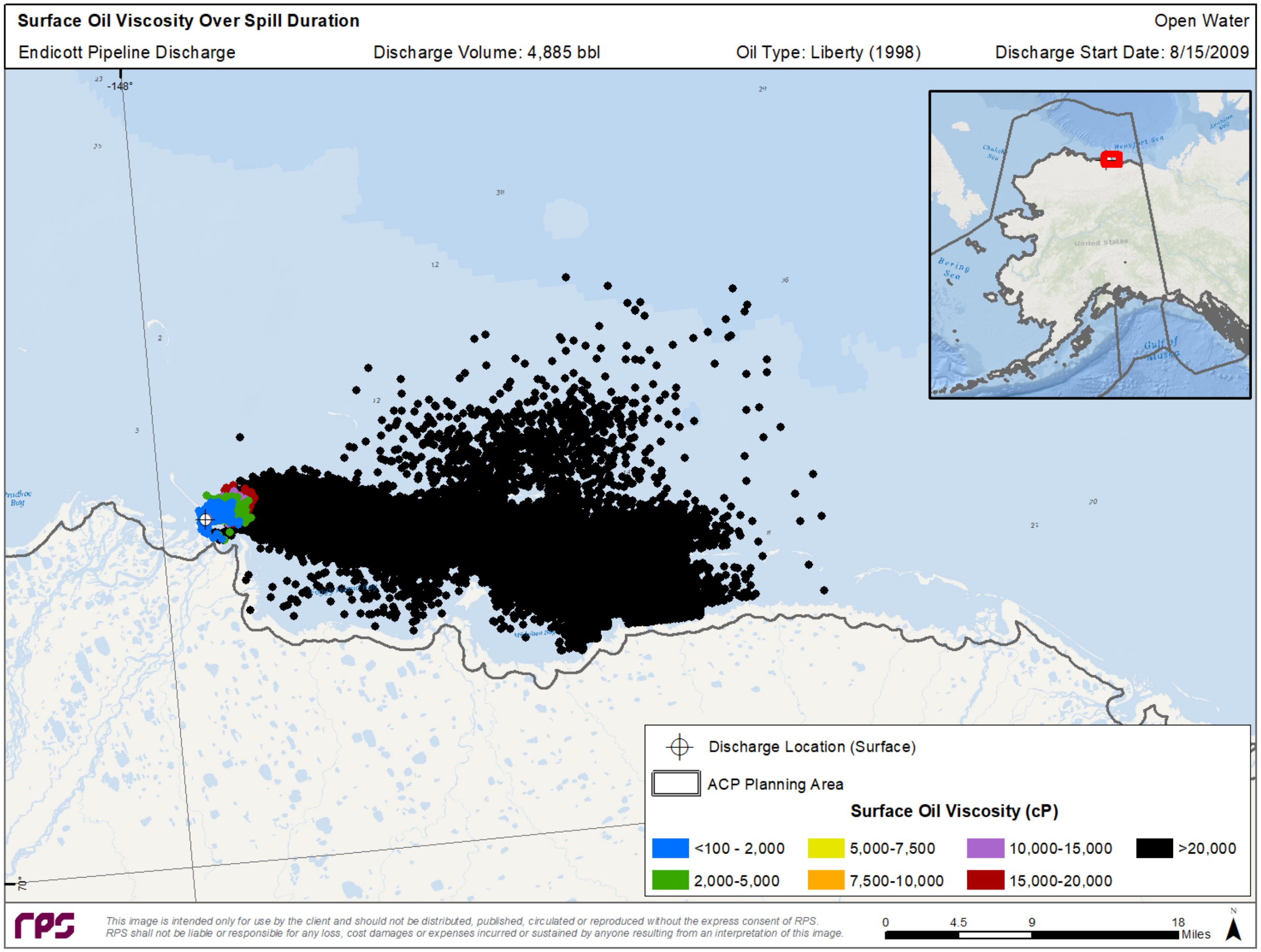

Figure 31. Cumulative footprint of exposure to surface floating oil greater than the minimum oil viscosity over a 45-day period for the worst case deterministic simulation. Viscosities greater than those mapped may be present at any location at any specific time in the simulation. This graphic provides a perspective of how oil viscosity may change as oil is transported away from the discharge site over time and what areas may be amenable to dispersant operations where enough quantities of oil are present.

6 Liberty A Development – Solid Ice – Surface Well Blowout

6.1 Scenario Description

The Liberty A Development – Solid Ice WCD Scenario is a surface well blowout with the following key parameters:

Table 12. Scenario Key Parameters.

Discharge Depth (m)	Distance from Shore (NM)	Oil Type	Spill Type	Ice Coverage	Discharge Duration (days)	Discharge Flowrate (bbl/day)	Total Oil Discharged (bbl)
Surface	4.5	Heavy Crude API = 27	Surface Well Blowout	Solid Ice	30	91,000	2,730,000

6.2 Methodology

The methodology used in the Liberty A Development scenario is unique due to the oil discharge on solid ice and is based on a model by Belore, et al. (1998). This model estimates the distance and width of surface oil deposition by percent of total oil spilled. To use this methodology, the gas flow rate (mmscf/day) must be determined based on the oil flow rate and gas-to-oil ratio (GOR). Then, based on that value, points representing distance vs. percent of oil fallout can be located on a graph such as the one below (Figure 33).

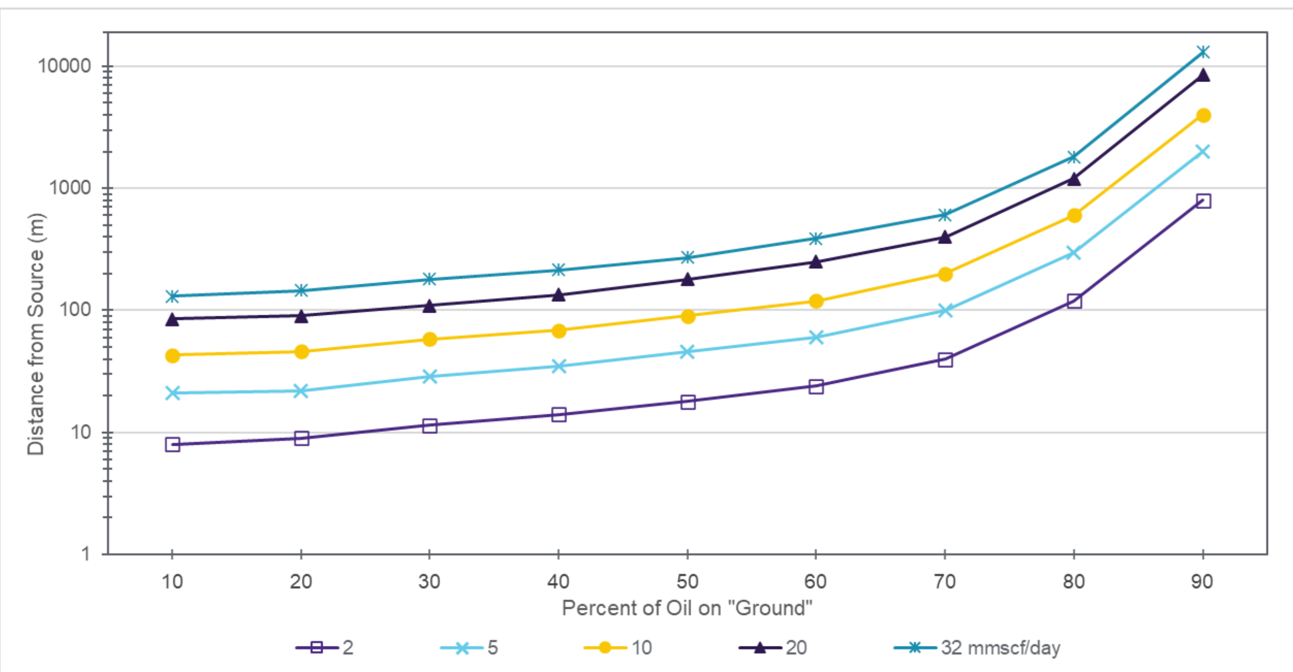

Figure 32. Percent of Oil Fallout vs. Distance from Source (assuming a 6.3 inch ID pipe) (Belore et al., 1998).

The width of the plume at the distance from source point for each percentage of the oil's fallout (assuming constant wind direction) can then be identified from a similar graph.

According to Belore et al. (1998), wind speed did not impact the results using this model because of the counteracting effects of higher wind velocity increasing rise height as well as downwind transport. Higher rise height retained the oil closer to the source, but the wind transport balanced that effect.

6.3 Application

Determining the Gas Flow Rate

Belore et al. (1998) presents model results quantifying the oil distance and width vs. percent oil fallout for two pipe diameter cases, 4-inch and 6.3-inch. Based on Belore et al. (1998), the gas exit velocity impacts the height of the jet rise of the release and significantly impacts the distance of oil fallout travel.

For the Liberty A Development scenario modeled in this study, the gas flow rate based on the oil flow rate and GOR is approximately 79.4 mmscf/day. Applying this value to the 6.3-inch pipe scenario presented in Belore et al. (1998) would result in a much greater gas exit velocity than would actually be present for a 79.5 mmscf/day gas flow rate in an 8.5-inch pipe. The model-indicated high exit velocity also may not be possible, based on sonic flow limitations. Thus, instead of extrapolating the model, an equivalent gas flow rate was calculated as the gas flow rate with the same velocity in a 6.3-inch pipe, as a 79.5 mmscf/day gas flow rate would have in an 8.5-inch pipe. This value was approximately 43.6 mmscf/day.

Determining the Oil Fallout Percent vs. Distance from Source Relationship.

The adjusted gas flow rate volume of 43.6 mmscf/day is higher than the highest value presented in the graphs in Belore et al. (1998). In order to extrapolate these values, the figure images for oil distance and width for the 6.3-inch pipe case were copied, rectified, and applied as background to Microsoft Excel charts. The chart axes were matched to the ones in the paper, and data was created to match the points in the chart until they aligned visually. Those values were then reorganized into a series showing distance vs. gas flow rate for each fallout oil percent (e.g., 10%, 20%, 30 %). Linear best fit relationships were then created (all had r-squared values greater than 0.99). Those equations were then used to determine the distance width of oil at each percent value for a flow rate of 43.6 mmscf/day.

6.4 Results

The distance and width of fallout oil is shown below (Table 13). This table can be read as follows: 50% of the total oil volume released is predicted to fall on the ice surface within 372 m of the release point, and the plume (assuming a constant wind direction) is 75 m wide at this point.

Table 13. Percent Oil Fallout in Distance from the spill site.

	Percent Oil Fallout								
	10	20	30	40	50	60	70	80	90
Distance from source (m)	178	197	244	293	372	535	839	2,483	17,911
Width (m)	38	41	49	57	75	97	157	415	2,453

These distances were used to create triangular polygons representing the area over with each percent of total oil would be deposited. For these polygons, the spill site for the WCD scenario was used, and the Alaska Albers projected coordinate system was assumed. An example wind direction was selected based on the predominant wind direction during the season of interest (September through February) for a demonstration map (Figure 34). To facilitate the SIMAP simulation with varying wind directions over the spill duration (30 days), eight sets of polygons were created with each representing deposition locations for cardinal or intercardinal wind direction (e.g. west, northeast, south).

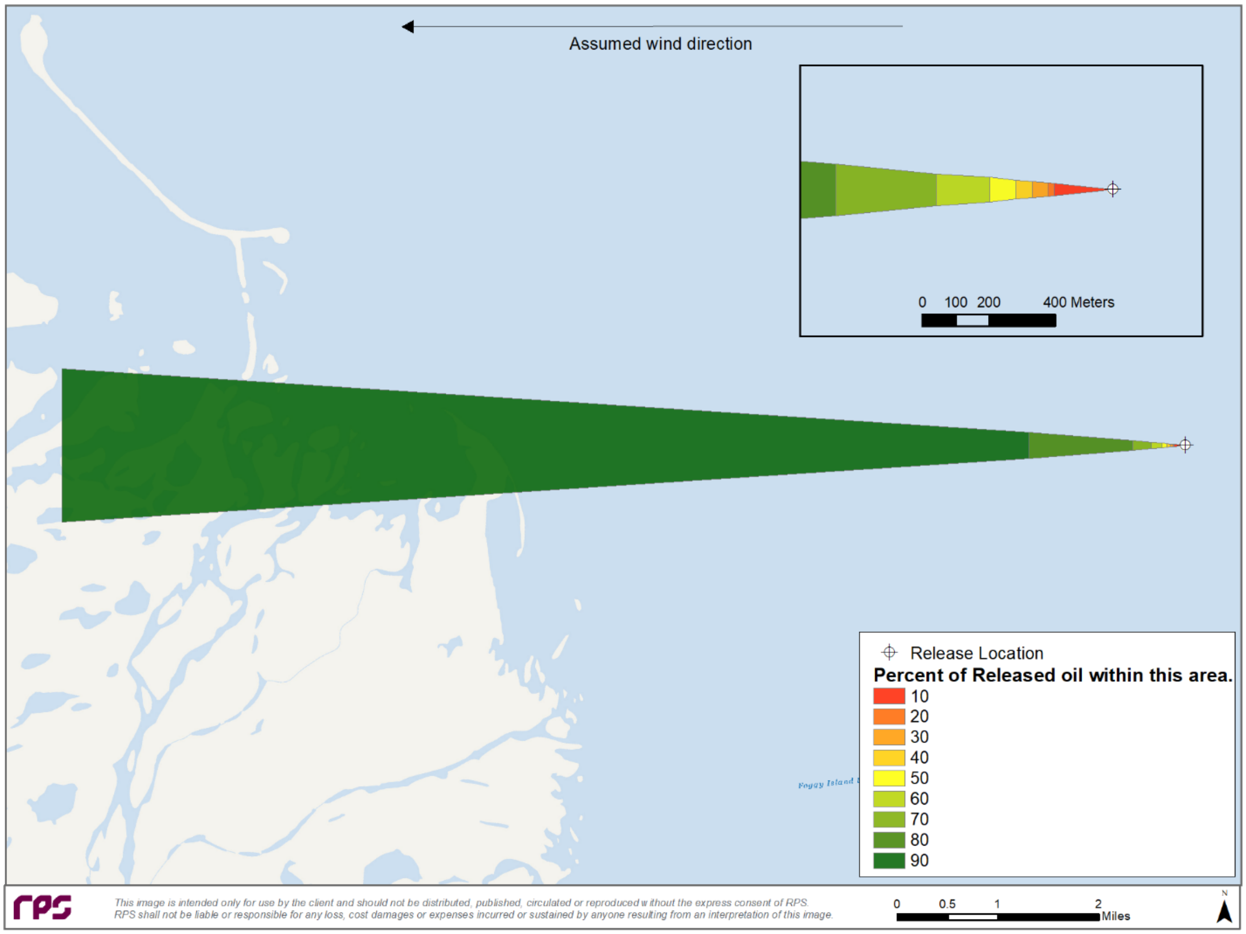

Figure 33. Polygon areas representing the location of the oil deposition.

6.5 Weathering of Oil on the Ice

The oil deposition information was used to initialize SIMAP. To apply this information for the SIMAP simulation, wind direction data was obtained for the 30-day discharge period. A sample time period from January 1 to January 30, 2008 was selected as a representative 30-day period of winter time conditions. The oil was assumed to be deposited on top of the ice after rising into the air and falling in a direction based on the changing wind direction over time. At each 15-minute time-step, the wind direction was categorized into one of the eight direction bins described above. From the representative wind direction polygon, 20 points were selected as the deposition locations for that time step. The model would then move to the next time step and select a wind direction bin and a new set of 20 points. Thus, over the 30-day spill duration, oil would deposit in directions in accordance with the wind directions over time.

SIMAP was used to predict the oil weathering over the 75-day simulation period. As the oil spread over the ice surface and remained there, it was predicted to evaporate over time and degrade. A summary of the oil mass balance information at the end of the 75-day simulation is presented in Table 14, while the mass balance information over time is presented in Figure 35.

Figure 36 shows the cumulative maximum concentration of oil on top of ice through the simulation period. These results assume 100% ice cover, no oil transport (i.e., on land fast ice), and no oil penetration into the ice/snow. Penetration into ice/snow and subsequent snow coverage would reduce the rates of evaporation and degradation.

Table 14. Mass balance at the end of the SIMAP simulation (% of the total volume of oil discharged*).

Total Oil Discharged	Surface	Evaporated	Water Column	Sediment	Ashore	Degraded
2,730,000 bbl	67.7	14.3	0.0	0.0	0.0	18.0

*Important to note these values are not indicative of the maximum amount of oil in each compartment, but instead show the final amount of oil in each compartment.

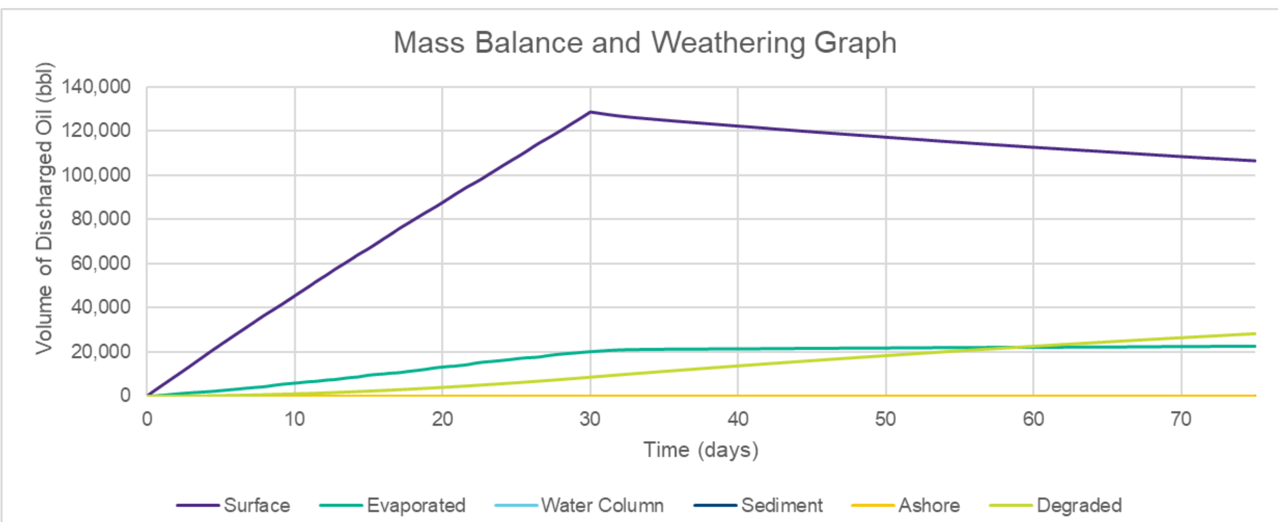

Figure 34. Mass Balance over time for the SIMAP simulation.

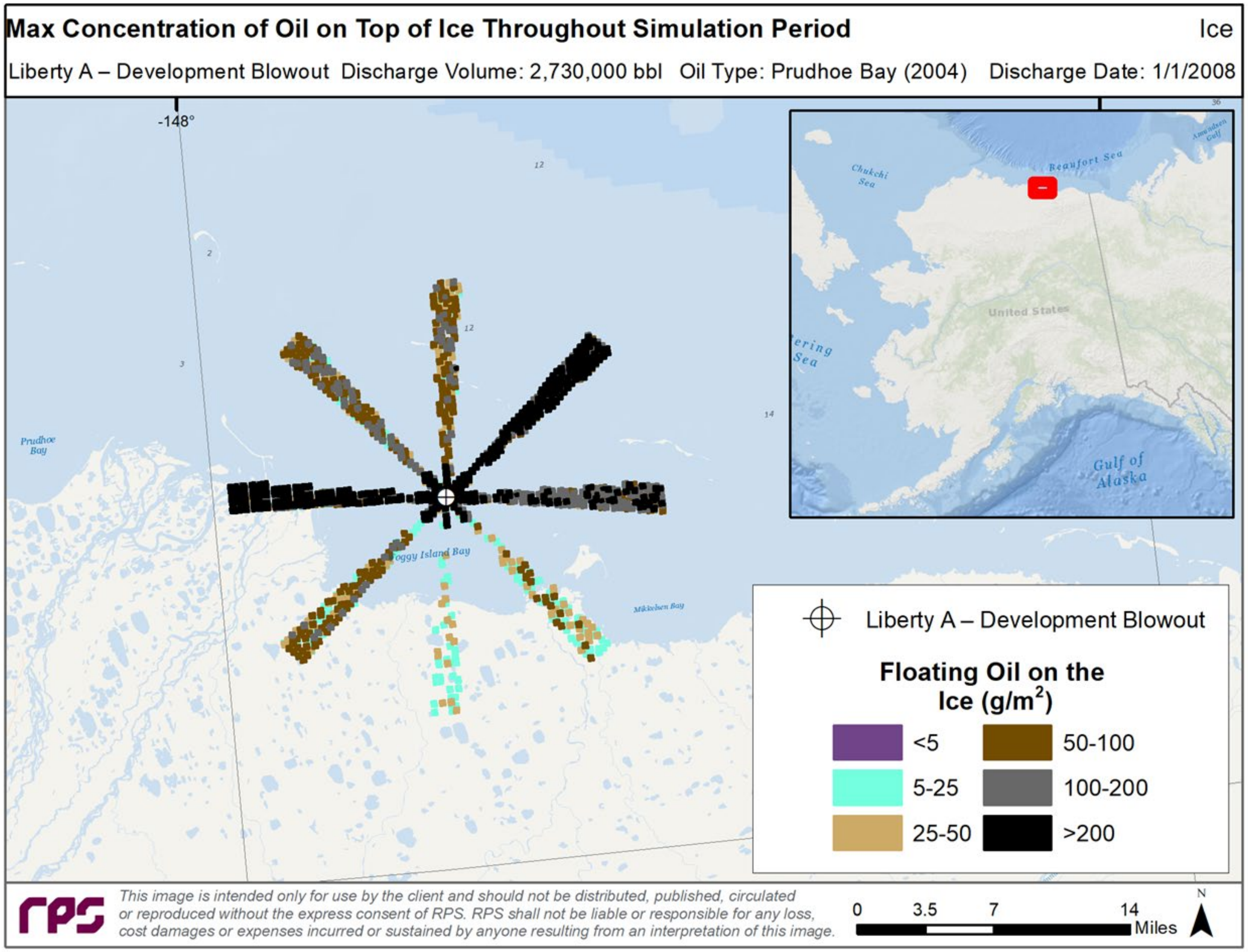

Figure 35. Cumulative maximum concentration of oil on ice at any time during the SIMAP simulation.

7 Liberty B Production – Open Water – Surface Well Blowout

7.1 Scenario Description

The Liberty B Production – Open Water WCD Scenario is a surface well blowout with the following key parameters:

Table 15. Scenario Key Parameters.

Discharge Depth (m)	Distance from Shore (NM)	Oil Type	Spill Type	Ice Coverage	Discharge Duration (days)	Discharge Flowrate (bbl/day)	Total Oil Discharged (bbl)
Surface	4.5	Heavy Crude API = 27	Surface Well Blowout	Open Water	30	91,000	2,730,000

7.2 Potential Oil Contact with the Environment and Resources at Risk

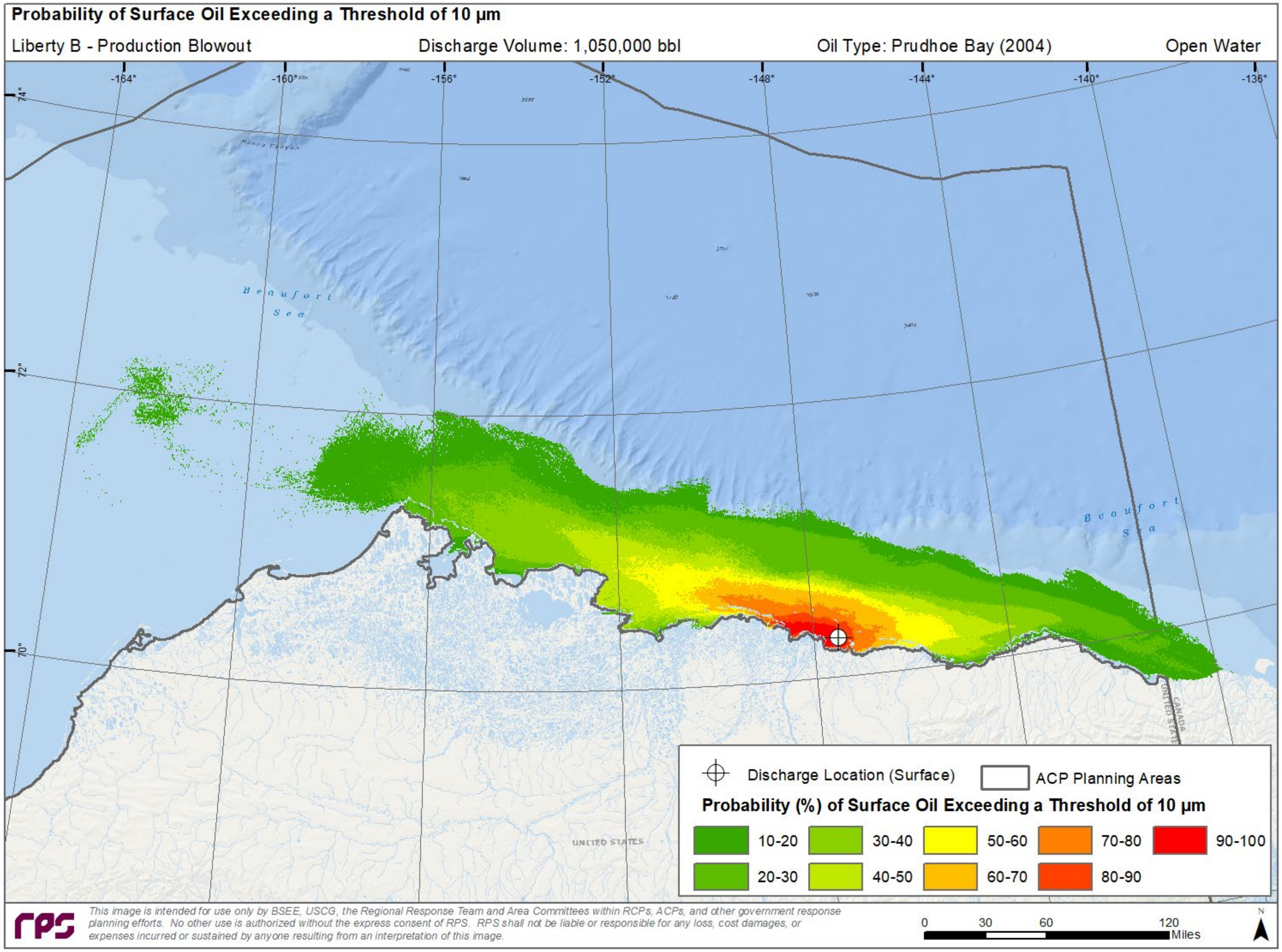

Figure 36. Probability Footprint for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

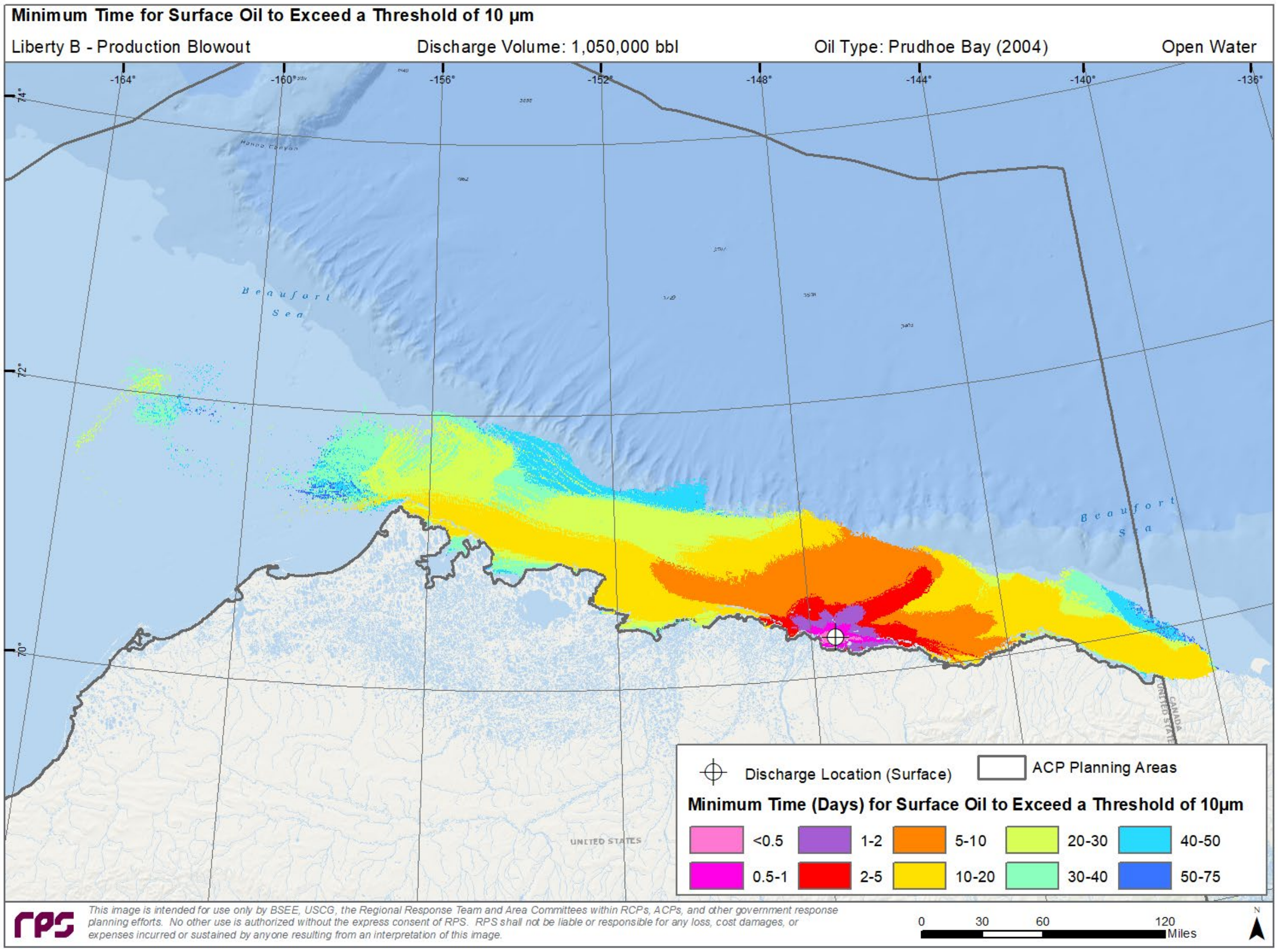

Figure 37. Minimum Travel Time for Oil on the Water Surface with Average Thickness greater than the Ecological Threshold of 10 µm.

Table 16. Oil Spill Stochastic Results – Predicted Shoreline Impacts.

Percentage of Simulations Reaching shore (%)	Percent volume of discharged oil reaching shore (%)		Time to Reach Shore (hours)	
	Maximum	Average	Minimum	Average
100	43	26	6.0	51.8

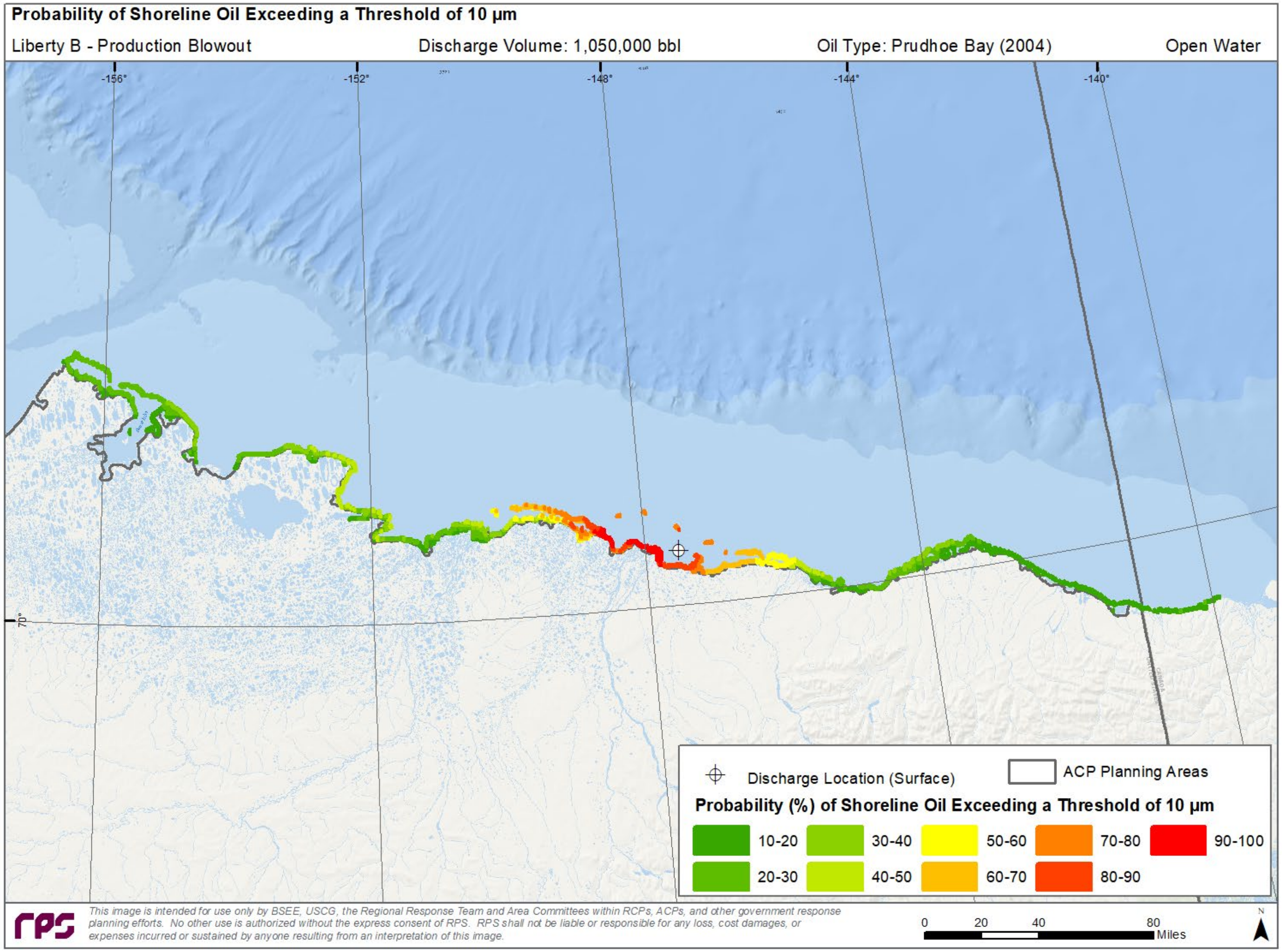

Figure 38. Probability Footprint for Oil on the Shoreline with Average Thickness greater than the Ecological Threshold of 10 µm. This thickness of oil may appear on the shore as dark stain or film. 10 µm is a conservative ecological screening threshold for potential sublethal effects on fauna and birds on the shoreline.

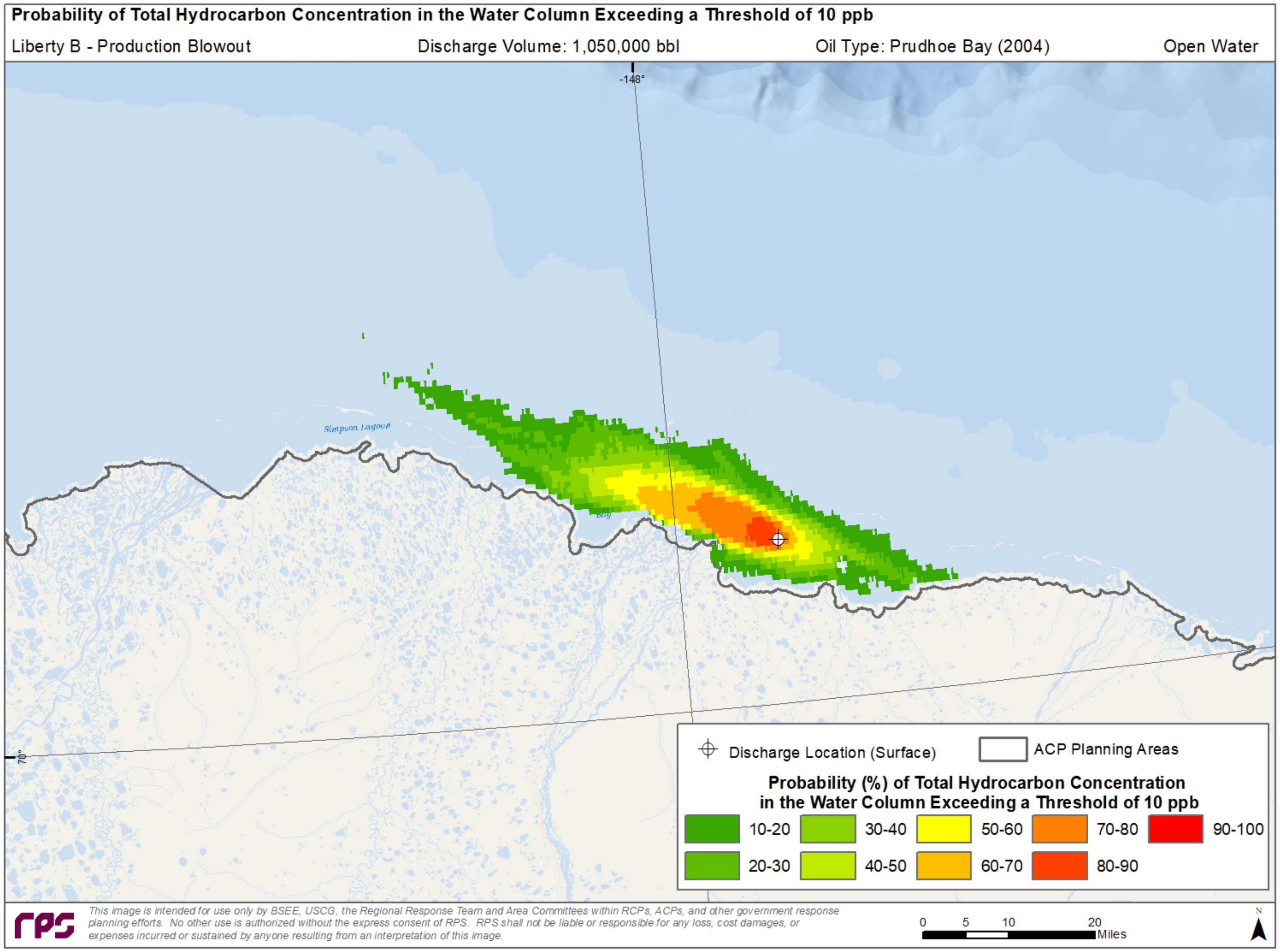

Figure 39. Probability Footprint for Total Hydrocarbon Concentration (THC) concentrations in the Water Column greater than the Ecological Threshold of 10 µg/L (~10 ppb). 10 ppb (µg/L) of whole oil (THC) corresponds to ~0.1 µg/L (~1 ppb) of dissolved Polycyclic Aromatic Hydrocarbons (PAHs) for fresh crude oils. This threshold can result in sublethal impacts to early life stages of fish and invertebrates in the upper ~20 meters of the water column if exposed to UV light.

The “worst case” deterministic simulation models is a single oil trajectory run using the time period and ambient conditions that resulted in the greatest area of shoreline oiling. The simulation resulted in oiling in the following cumulative amounts:

- Swept Oiled Surface Area Exceeding 0.04 µm (Socioeconomic Impact) = 321,418 mi^2
- Swept Oiled Surface Area Exceeding 10 µm (Ecological Impact) = 322,326 mi^2
- Oiled Shoreline Exceeding 10 µm (Ecological Impact) = 817 mi
- Water Column Oil Exposure Exceeding 10 ppb Dissolved PAH (Ecological Impact) = 4,447 million m^3
- Time to Shore = 18.5 hrs

These impact values are calculated considering no response measures are taken to secure the source of the spill or to contain, remove, or disperse oil at the scene.

Table 17. Mass balance at the end of the worst case deterministic simulation (% of the total volume of oil discharged*).

Total Oil Discharged	Surface	Evaporated	Water Column	Sediment	Ashore	Degraded
1,050,000 bbl	30.6%	19.6%	<0.1%	<0.1%	33.7%	16.2%

*Important to note these values are not indicative of the maximum amount of oil in each compartment, but instead show the final amount of oil in each compartment.

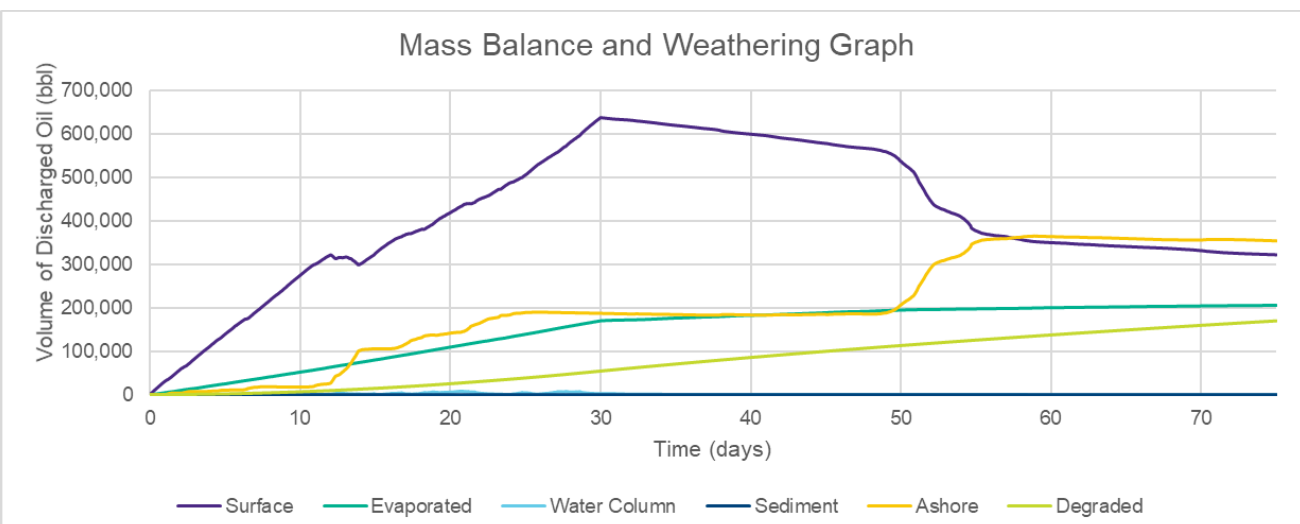

Figure 40. Mass Balance over Time for worst case deterministic simulation.

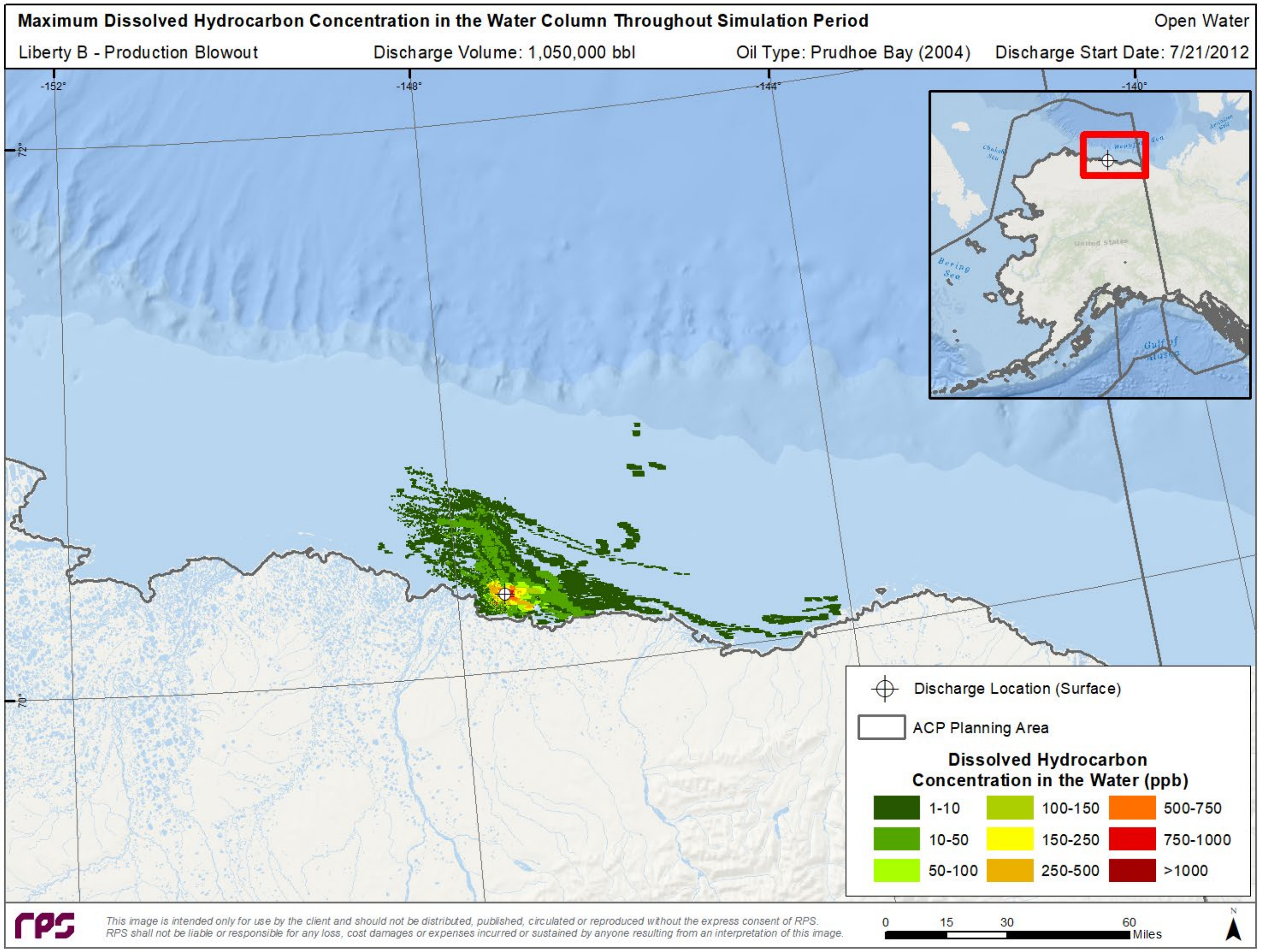

Figure 41. Cumulative Maximum Concentration of Dissolved Polycyclic Aromatic Hydrocarbons (PAH) within the water column at any time during the worst case deterministic simulation period. Dissolved PAH concentrations greater than ~10 µg/L (~10 ppb) could affect plankton in the upper ~20 m and impart sublethal to lethal effects on other water column biota (adult, juvenile fish, and invertebrates).

7.3 Response Planning Information

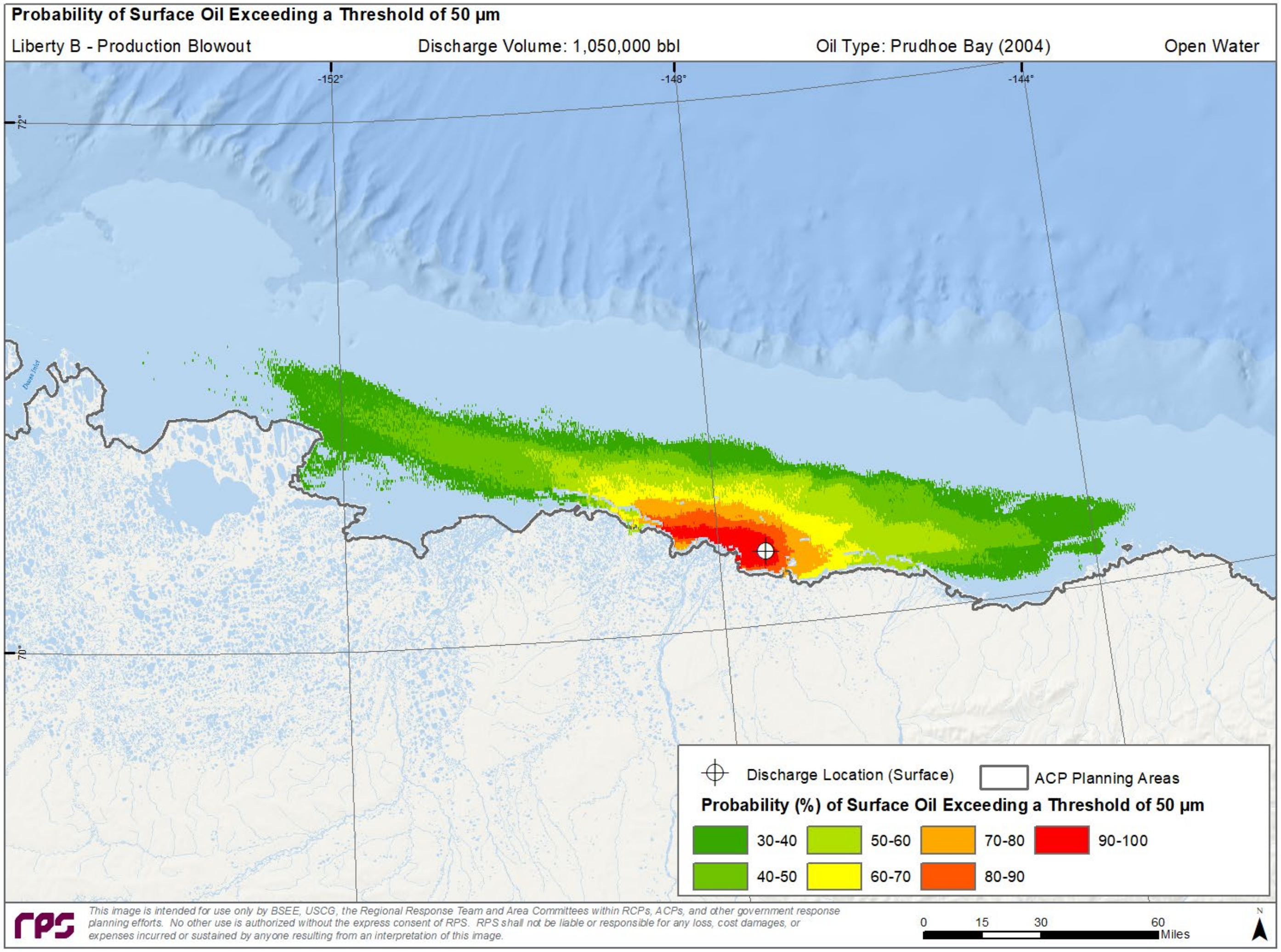

Figure 42. Probability Footprint for Surface Oil exposure greater than 50 µm. In this thickness range, oil will appear as a continuous to discontinuous patches of dark oil in quantities where high volume on-water mechanical recovery operations will be the most productive.

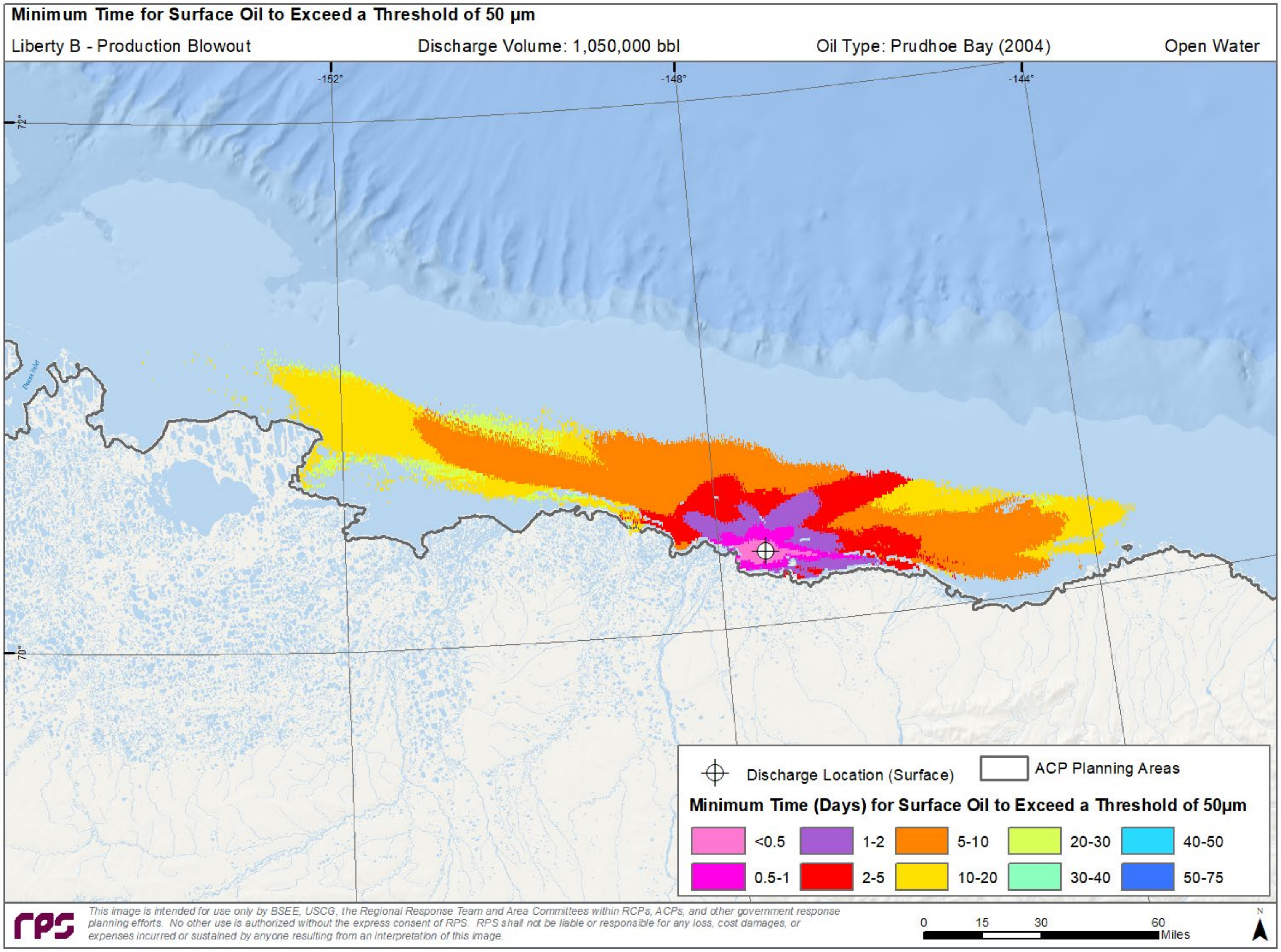

Figure 43. Minimum Travel Time for Surface Oil exposure greater than 50 µm.

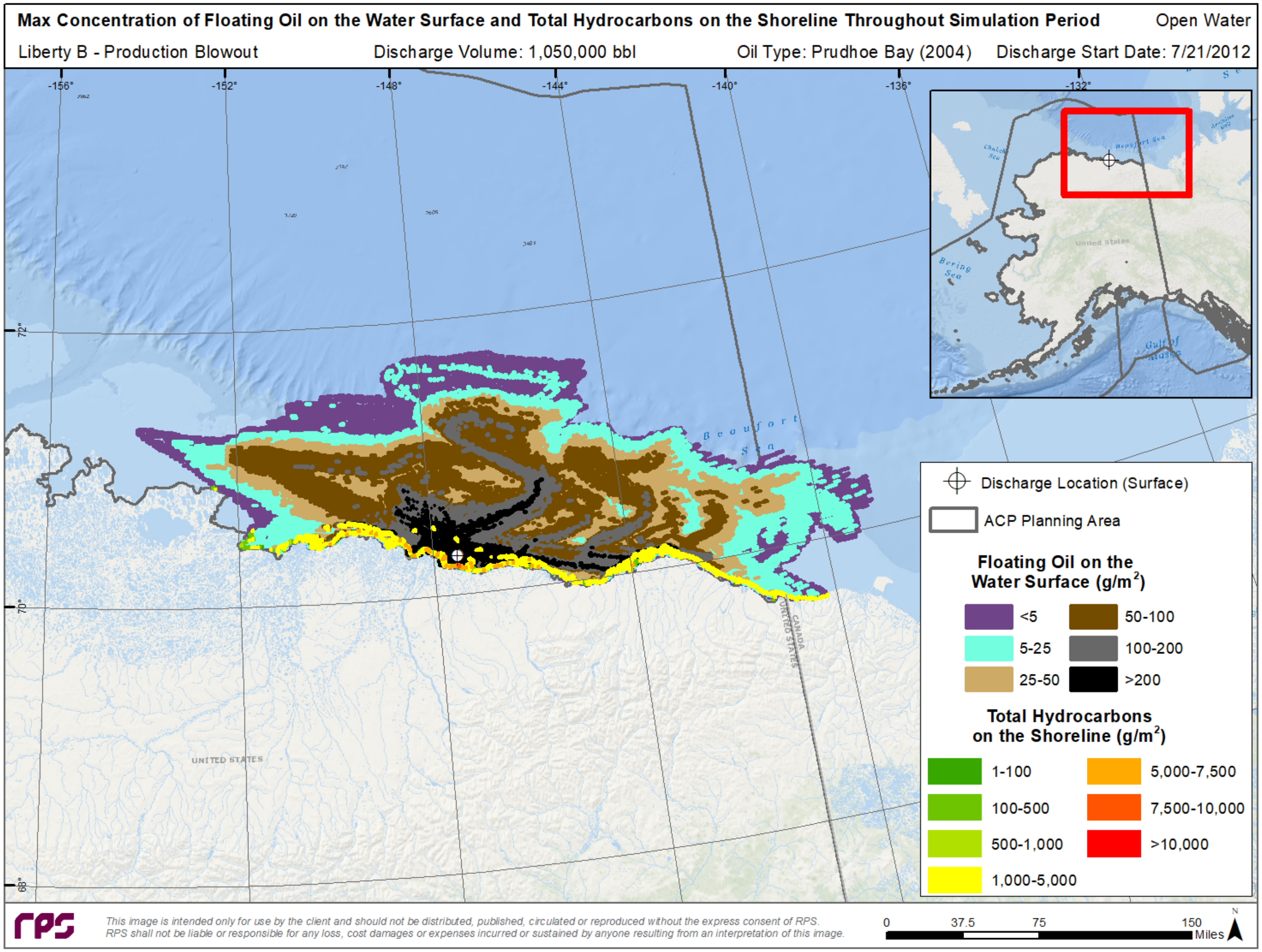

Figure 44. Cumulative Maximum Concentration of Floating Oil and Total Hydrocarbons on the Shoreline at any time during the worst case deterministic simulation.

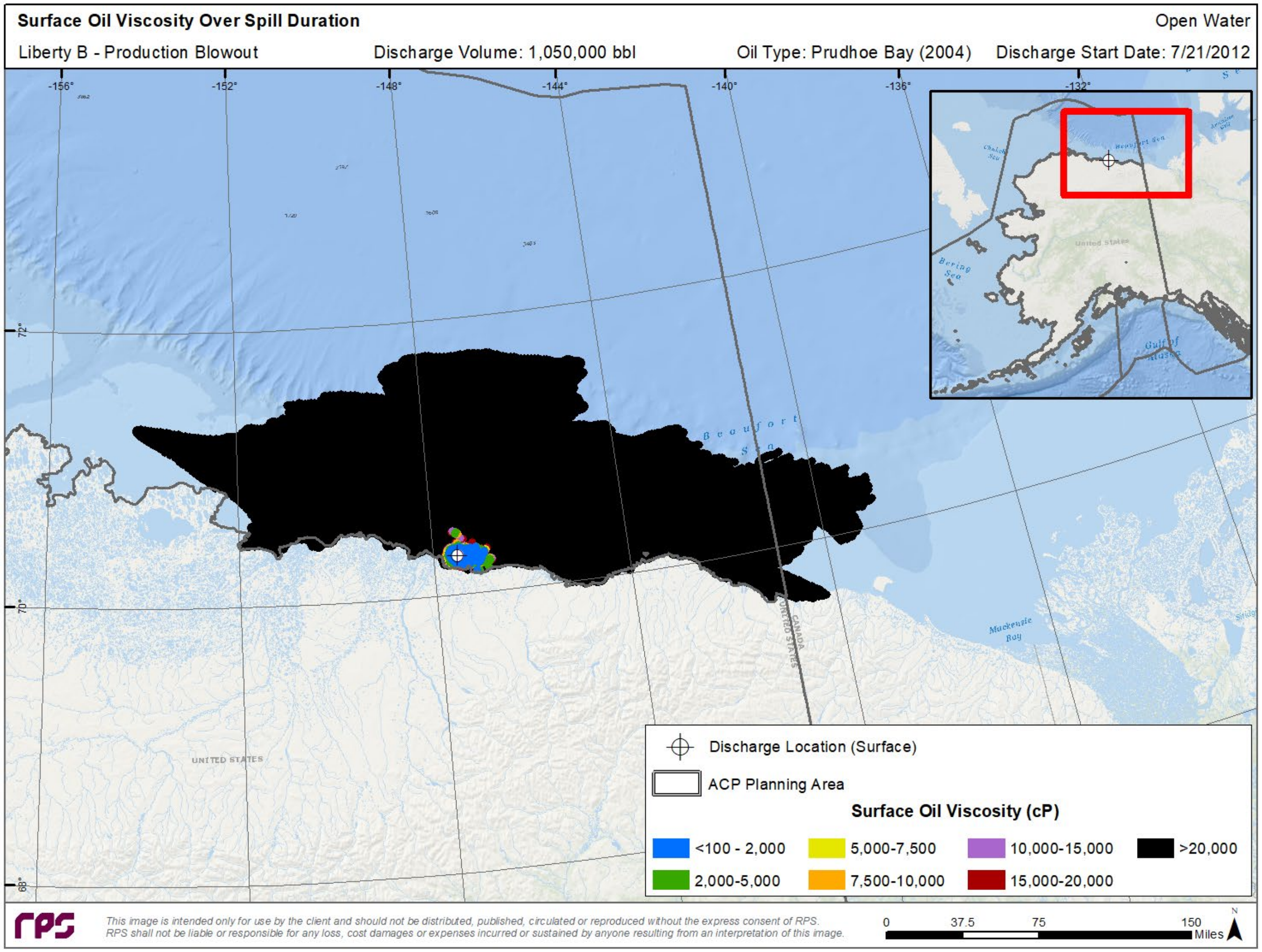

Figure 45. Cumulative footprint of exposure to surface floating oil greater than the minimum oil viscosity over a 75-day period for the worst case deterministic simulation. Viscosities greater than those mapped may be present at any location at any specific time in the simulation. This graphic provides a perspective of how oil viscosity may change as oil is transported away from the discharge site over time and what areas may be amenable to dispersant operations where enough quantities of oil are present.

8 References

Belore, R. C., J. McHale, and R. Chapple, 1998. Oil Deposition Modeling for Surface oil Well Blowouts. In: Proceedings of the AMOP Technical Seminar on Environmental Contamination and Response, Environmental Protection Service, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 432-436.