Aleutian Islands Risk Assessment

Impact of Environmental Conditions on Vessel Incident Response in the ALEUTIAN ISLANDS

Report to the Aleutian Islands Risk Assessment Advisory Panel & Management Team

A Response Gap Analysis

January 30, 2014

Prepared by: Nuka Research & Planning Group, LLC.

nuka
RESEARCH & PLANNING GROUP, LLC.
P.O. Box 175
Seldovia, Alaska 99663
tel 907.234.7821
fax 240.394.4855
contact@nukaresearch.com

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EXECUTIVE SUMMARY

Nuka Research and Planning Group, LLC implemented a response gap analysis for the Aleutian Islands region. The purpose of the analysis is to inform the development of a recommended optimal response system as part of the Aleutian Islands Risk Assessment (AIRA). The National Fish and Wildlife Foundation (NFWF), the U.S. Coast Guard (USCG), and the Alaska Department of Environmental Conservation (ADEC) initiated the Aleutian Islands Risk Assessment in 2009.

Environmental limits are established for a set of response operations: emergency towing, salvage (lightering), mechanical recovery (open-water and nearshore), dispersant application (from aircraft and vessels), and aerial surveillance. Limits are based on published literature, standards, and incident reports and reviewed by the Analysis Team for the AIRA.

The environmental limits are then compared to historic environmental data from National Data Buoy Center buoys in the Southeast Bering Sea, Southwest Bering Sea, North Pacific, and Northeast Pacific and airports at Cold Bay, Dutch Harbor, and Adak. The nearshore mechanical recovery analysis used marine forecasts in place of buoy data.

A Response Gap Index (RGI) is generated for each location. The RGI estimates the amount of time a particular type of operation would *not* be possible based on this methodology. This is presented for each location and in two different operating seasons (summer and winter) for comparison. The table below shows the RGI combined across locations for each type of operation and the amount of time that a response *would* be expected to be possible when averaged across the entire year.

RESPONSE TACTIC	Response Not Possible	Response May be Possible
Emergency Towing	2%	98%
Helicopter Lightering	20%	80%
Open-water Mechanical Recovery	72%	28%
Nearshore Mechanical Recovery -- Unalaska Bay *(Daytime only)*	52%	48%
Aerial Application of Dispersants	72%	28%
Vessel Application of Dispersants	64%	36%
Air Observations -- Fixed Wing *(Daytime only)*	18%	82%

In addition, the percentage of time when commercial flights into Dutch Harbor and Adak is presented as an indication of the viability of air logistics to support a response in the region. Commercial jet arrivals are cancelled or diverted 26% of the time to Dutch Harbor and 8% of the time to Adak. Scheduled turboprop flights are cancelled or diverted 13% of the time to Dutch Harbor.

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Table of Contents

Impact of Environmental Conditions on Vessel Incident Response in the ALEUTIAN ISLANDS: *A Response Gap Analysis*

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1. INTRODUCTION AND PURPOSE OF THE REPORT

The Advisory Panel and Management Team of the Aleutian Islands Risk Assessment seek recommendations for enhanced salvage and oil spill response services in the region. These operations also necessitate basic logistical support and aerial surveillance. In recommending such services, the project's Analysis Team considered the way that environmental conditions such as wind, waves, temperature, and fog or clouds could impact the ability to deploy such services in a timely manner.

The Analysis Team implemented a response gap analysis to better understand the potential impact of environmental factors on rescue or response operations. This approach builds on previous analyses focused specifically on spill response and expands these to include emergency towing, aerial observation, logistics (in terms of air support), and marine salvage (focused on lightering).

1.1 Overview of AIRA

The National Fish and Wildlife Foundation (NFWF), the U.S. Coast Guard (USCG), and the Alaska Department of Environmental Conservation (ADEC) initiated the Aleutian Islands Risk Assessment to assess the risks and potential mitigation measures associated with maritime transportation in the Bering Sea and the Aleutian Archipelago, as defined by the project study area (see Figure 2.1). At the conclusion of Phase A, an Advisory Panel recommended that emergency towing, salvage, and spill response services should generally be enhanced in the Aleutian Islands.

Nuka Research and Planning Group, LLC (Nuka Research) has prepared this study for the Aleutian Islands Risk Assessment Advisory Panel and Management Team with support from Pearson Consulting, LLC, The Glosten Associates, Moran Environmental Recovery, and Moran Towing, on contract to NFWF.

1.2 Organization of this Report

This report describes the general approach and concept of the response gap methodology in Section 2. Sections 3 – 7 presents the limits and response gap results emergency towing, salvage (focusing on lightering), mechanical oil recovery operations (both open-water and nearshore environments), dispersant application (from vessels and aircraft), and aerial surveillance. Section 8 uses a modified approach is used to indicate how often aircraft may be unable to deliver personnel, supplies, and equipment to major airports in the area. Finally, Section 9 provides a brief summary discussion.

2. OVERVIEW OF THE RESPONSE GAP APPROACH & CONCEPT

The analytical approach applied here originated in a 2007 response gap analysis for oil spill response for Prince William Sound (Nuka Research, 2006; Nuka Research, 2007; Nuka Research, 2008).[1] Subsequently, SL Ross applied a similar approach to the Canadian Beaufort Sea (2011), the Living Oceans Society conducted a partial analysis (focusing on wave height only) for the area near Dixon Entrance in British Columbia, and Nuka Research (2012) conducted a more comprehensive RGA of the Dixon Entrance area. This study draws on previously established understanding of which environmental factors impact response, and builds on to the approach by proposing and analyzing an RGA using limits for salvage operations and air logistics in addition to spill response.

2.1 Approach

The results of the response gap analysis for each of type of operations are based on the following general steps:

1. Compile historic environmental data for relevant environmental conditions. For this study, four buoy and three airport stations were chosen. (See Figure 2.1.)
2. Establish operational limits for a set of environmental factors based on published literature and best professional judgment. Environmental conditions are considered to be green (no impact on operations), yellow (expected to impact the operations or their effectiveness), or red (precludes deployment or response ineffective).
3. Compare the operational limits to the historic data in a hindcast to determine the percentage to time of time any operational limit is exceeded.
4. Estimate the Response Gap Index (RGI). The RGI is an estimate of how often a response would be precluded by environmental conditions based on the environmental dataset. For instance, an RGI of 25% indicates that, due to environmental conditions, a response would be impossible or ineffective 25% of the time.

There are some variations on this general approach found in the subsequent sections. First, the response gap analysis for mechanical recovery in the nearshore environment uses environmental data based on marine forecasts, since the buoys used for sea state data (see Section 2.2) represent open-water conditions. Additionally, the air logistics response gap does not seek to identify specific limits for safe air travel, but instead uses records of cancelled or diverted commercial flight operations. Any variations on the general approach are explained in subsequent sections.

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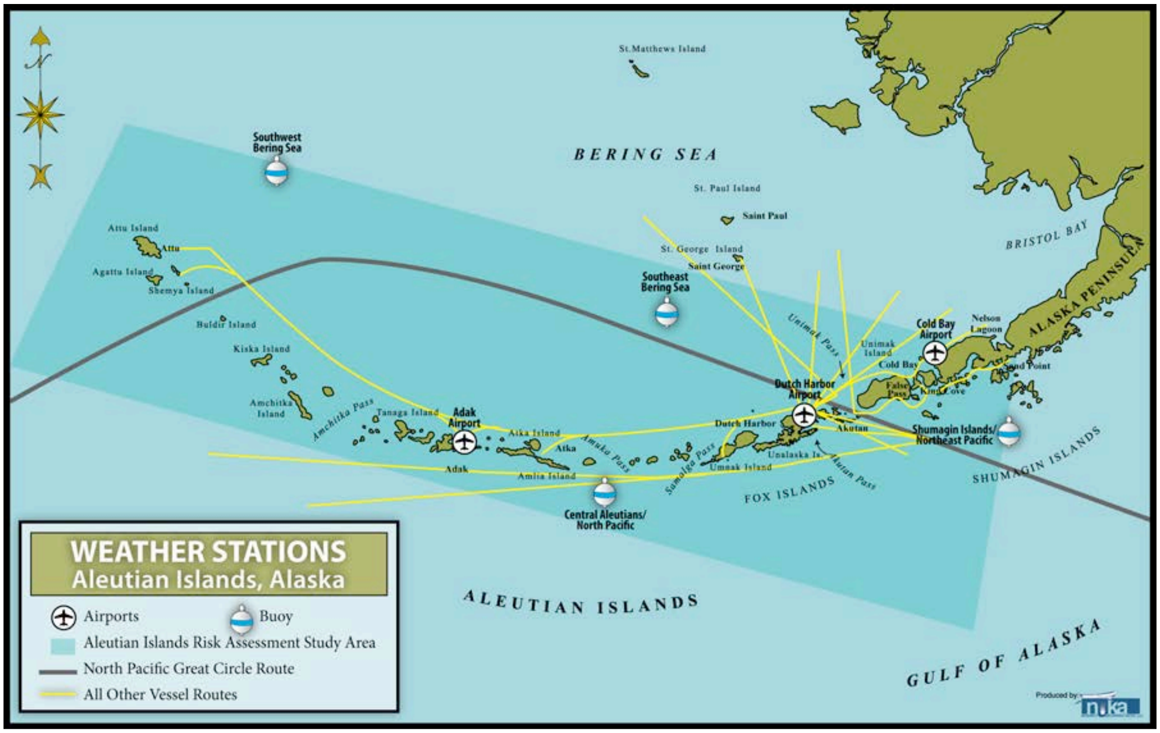
[1] The methodology used for Nuka Research's Prince William Sound analyses for both mechanical response (2007) and non-mechanical response (2008) was initially proposed for review in 2006 (Nuka Research, 2006).

2.2 Environmental Factors and Datasets Used

Nuka Research compiled, prepared, and summarized environmental data from seven National Oceanographic and Atmospheric Administration (NOAA) weather stations located near typical vessel routes through the Aleutian Islands and adjacent areas of the Bering Sea and North Pacific. As shown in Figure 2.1, these weather stations are all within the AIRA study area, and include three shore stations (Adak, Dutch Harbor/Unalaska, and Cold Bay airports) and four buoys (Southwest Bering Sea, Southeast Bering Sea, Central Aleutians/North Pacific, and Northeast Pacific/Shumagin Islands).



WEATHER STATIONS

Station	Data Source	Identifier / Location	Record Begins	Record Ends
Southwest Bering Sea	NDBC	Buoy #46070	September 2006	August 2012
Central Aleutians/ North Pacific	NDBC	Buoy #46072	July 2002	August 2012
Southeast Bering Sea	NDBC	Buoy #46073	May 2005	April 2011
Northeast Pacific/ Shumagin Island	NDBC	Buoy #46075	May 2004	August 2012
Cold Bay Airport	NCDC	Cold Bay, AK	January 2005	September 2012
Dutch Harbor/ Unalaska Airport	NCDC	Unalaska, AK	February 2005	August 2012
Adak Airport	NCDC	Adak, AK	January 2005	September 2012

Figure 2.1 Weather stations used for environmental data characterization (vessel traffic routes taken from DNV and ERM, 2010)

The National Climatic Data Center (NCDC) manages the data collected at the shore stations, while the National Data Buoy Center (NDBC) manages the buoys and associated data. The data was collected for a range of years, beginning in 2002 and ending in 2012. The data summary, completeness of the data, and other considerations related to the datasets are discussed in a separate document, "Characterizing Environmental Conditions in the Aleutian Islands" (Nuka Research, 2013).

Data on the following parameters were collected: wind speed and gusts; temperature; significant wave height (buoys only); dominant wave period (buoys only); and visibility (airports only). Wave steepness was calculated based on significant wave height and dominant wave period. Table 2.1 describes the data collected for each parameter.[2] In the case of temperature, wind speed, and wave height, the data was then converted, as noted in the table.

Table 2.1 Description of parameters used

PARAMETER	**DESCRIPTION: BUOYS** *Southwest Bering Sea, Central Aleutians/North Pacific, Southeast Bering Sea, Northeast Pacific/Shumagin Islands*	**DESCRIPTION: SHORE STATIONS** *Cold Bay Airport, Dutch Harbor Airport, Adak Airport*
WIND		
Wind direction	Average wind direction (degrees) measured over an 8-minute period.	Average wind direction (tens of degrees) measured over a 2-minute period.
Wind speed	Average wind speed (m/s) measured over an 8-minute period. (Converted to knots.)	Average wind speed (m/s) measured over a 2-minute period. (Converted to knots.)
Gusts	Peak 5-second wind speed (m/s) over an 8-minute period. (Converted to knots.)	N/A
SEA STATE[3]		
Significant Wave Height	Average of the tallest one-third of all waves (m) during a 20-minute period. (Converted to feet.)	N/A
Dominant Wave Period	Wave period with the maximum energy, i.e., the most pronounced wave period.	N/A
Wave Steepness	Calculated from dominant wave period and significant wave height. Wave Steepness = WHT / (g * DWP^2) where: • WHT = Wave Height • g = acceleration from gravity	N/A

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[2] Summary statistics for all parameters are presented in "Characterizing Environmental Conditions in the Aleutian Islands" (Nuka Research, 2013).

[3] Section 5.3 describes the variation on this approach used for the nearshore sea state data. Marine forecasts were used for this piece of the analysis because there are no weather buoys in the nearshore area.

PARAMETER	DESCRIPTION: BUOYS *Southwest Bering Sea, Central Aleutians/North Pacific, Southeast Bering Sea, Northeast Pacific/Shumagin Islands*	DESCRIPTION: SHORE STATIONS *Cold Bay Airport, Dutch Harbor Airport, Adak Airport*
	(32.174 ft/s^2) • DWP = dominant wave period	
VISIBILITY		
Horizontal Visibility	N/A	Measured in statute miles (SM).
Ceiling	N/A	Measured in feet above ground level (AGL).
Daylight	Daylight is calculated for all stations based on station coordinates.	
TEMPERATURE		
Air Temperature	Temperature measured (Cº) at time of recording. (Converted to Fº.)	Temperature measured (Cº) at time of recording. (Converted to Fº.)

Nuka Research compiled the available data for the parameters listed in Table 2.1, removed duplicate records, and culled the dataset for anomalous records. The latter were identified with the input of a meteorologist (Gramman, 2012) and focused on records representing extremes that did not align with the location and/or season.

2.3 Impact of Environmental Factors on Operations

The environmental factors of wind, sea state, visibility, and temperature all impact operations.

2.3.1 Environmental Factors Incorporated in this Analysis

Wind

While wind is a primary driver of sea state, wind alone can also affect operations. These impacts may be different depending on whether winds are sustained or gusting. Wind shear, which represents how gusty the wind is, is used as a separate factor for the analysis of air operations (both for observation and dispersant application).

Sea State

Sea state refers to wave height, wave period (frequency), and wave steepness. When wave height is small, wave period has little effect on response operations. As wave height increases, waves of a short period have greater effect on response operations than waves of a longer period. Short, choppy waves have a more significant effect than long, ocean swells.

Temperature

High and low temperature extremes can adversely affect oil spill response operations, but in the Aleutian Islands low temperatures are more likely to impair operations. Temperature data is limited to airport surface readings. Winds aloft in the winter, however, may bring colder temperatures than the airport thermometer readings, especially the south and southwest winds in the Bering Sea, which arrive over sea ice and/or across mainland Alaska. Aircraft may therefore be exposed to colder temperatures than vessels (and colder than the temperatures used in this study).

Visibility

Factors that may hamper visibility include darkness, fog, snow, heavy precipitation, or low clouds.

Visibility is measured at the airport stations, but there are recognized differences applicable throughout this analysis in terms of both the cloud ceiling and surface visibility (which may be hampered by sea fog, fog, or precipitation) between the onshore and marine environments. In particular, sea fog is known to occur in the study area, especially in summer. Anecdotally, the incidence is reported as higher offshore than at shore stations. (Fett et al., 1993)

Offshore fog could have a significant impact on the ability to conduct the operations considered in this study, but there are no known quantitative records of its occurrence.

Visibility data in nautical miles is taken from the closest airport station. This was the best available data: while visibility recorded at airports may not represent the exact conditions at the buoy location, it does provide for the inclusion of the prevailing pattern of clouds or fog observed in the general operating area, which would otherwise be omitted entirely from the study.

Table 2.2 summarizes these impacts as they pertain to the response operations considered in this study.

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Table 2.2 Potential impacts of environmental factors on operations. *Aerial surveillance and air logistics are combined here because both are based on the ability to safely operate fixed- or rotary-wing aircraft in the area. They are considered separately in the response gap analyses because the extent of the impact of different conditions varies between them due to assumptions about the different aircraft used and the heightened importance of visibility for aerial observation purposes.*

	Wind	Sea State	Temperature	Visibility
Towing	• Vessels unable to keep on station	• Crew unable to work on deck • Vessels unable to keep on station or operate safely	• Crew unable to work on deck (ice or hypothermia)	• Unable to safely approach vessel in distress
Lightering with a (heavy lift helicopter)	• Unable to use airports safely • Unable to conduct helicopter sling operations safely	• Crew unable to work on deck • Deck heaving precludes safe helicopter and sling operations	• Crew unable to work on deck (ice or hypothermia) • Ground crew operations inhibited or prevented	• Unable to operate aircraft safely • Unable to co-ordinate visually between aircraft and surface/vessel crews
Mechanical recovery	• Vessels unable to keep on station • Crew unable to work on deck • Equipment and workboat deployment and retrieval impeded • Boom failure	• Boom failure • Vessels unable to keep on station or operate safely • Skimmer failure • Crew unable to work on deck or deploy/retrieve equipment • Inability to track and oil	• Crew unable to work on deck (ice or hypothermia) • Mechanical equipment failure due to icing • Vessel instability due to icing	• Unable to monitor oil • Vessels unable to keep on station
Dispersants (aerial application)	• Prevent dispersant from reaching target or from reaching the water's surface in sufficient concentrations	• If waves are too small, there is insufficient mixing energy • If waves are too large, marginal benefit of dispersants is negated	Mechanical failure of equipment/spray nozzle due to icing	• Unable to monitor oil • Unable to operate aircraft safely

	Wind	Sea State	Temperature	Visibility
Dispersants (vessel application)	• Prevent dispersant from reaching target or from reaching the water's surface in sufficient concentrations	• If waves are too small, there is insufficient mixing energy • If waves are too large, marginal benefit of dispersants is negated	• Crew unable to work on deck (ice or hypothermia) • Mechanical failure of equipment/spray nozzle due to icing • Vessel instability due to icing	• Unable to monitor oil • Vessels unable to keep on station
Logistics and aerial surveillance	Unable to use airports safely	Not applicable to aircraft operation.	Ground crew operations inhibited or prevented	• Unable to operate aircraft or use airports safely (variable) • Inability to track and encounter oil (aerial observation)

2.3.2 Environmental factors not incorporated in this analysis

Currents and ice may also impact marine operations, but are not considered in this study both due to a lack of data and because they are not expected to have a significant impact in this region.

Currents

Currents can significantly impact oil spill response operations. In rivers, passes, or narrow embayments, the entire response system is captured in the current and there is little or no relative movement between the various components of the response system, preserving the systems' ability to operate. However, currents can cause problems in areas where eddies or tidal rips occur, disrupting the relative positions of system components, or when the current sets the response system into shoal waters. Tidal rips in particular can cause otherwise gentle swells to become breaking waves; these sites are sometimes also associated with shallow passes.

Currents can impede or prevent response operations in the following ways:

- Boom failure,
- Oil becoming submerged and thus not available to recovery, and
- Vessels unable to keep on station.

Currents were not considered for the purposes of this study because only ocean currents are likely to be encountered by the systems considered, and there are no methods to measure local currents such as tidal rips.

Ice

Ice can impede or prevent response operations in the following ways:

- Failure of skimming systems,
- Vessels unable to keep on station,
- Boom failure, and
- Inability to track and encounter oil.

Sea ice is not a hindrance to shipping along the major east-west routes in the study area,[4] though it does affect shipping throughout Bristol Bay and along Alaska's west coast. Neither the buoy stations nor the onshore airport stations record the presence of ice, and is not included in the response limits used in this analysis.

2.4 Estimating the Response Gap

For each of the environmental factors considered (see Table 2.1, above), Nuka Research established limits at which operations are not impaired (green), possibly

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[4] Personal communication from Capt. David Arzt, Alaska Marine Pilots and AIRA Risk Assessment Advisory Panel member. January 29, 2013.

impaired (yellow), and not possible/effective (red). These limits were then applied to historic data (or historic marine forecasts, for the nearshore environment) to estimate the amount of time that response is not impaired, possible but impaired, or not possible/effective.

A response gap index (RGI) was created to reflect the interactions among environmental factors (Table 2.3). Even if no single environmental factor is ruled "red" (response not possible or not effective), the challenge of dealing with "yellow" (response possibly prevented) conditions for two or more factors at the same time can be expected to make effective response impossible and results in a "red" outcome for that time period.

Table 2.3 Applying the Response Gap Index

If…	Then the RGI is…
…*any* environmental factor is ruled RED	Red (response not possible/effective)
…*all* environmental factors are ruled GREEN	Green (response not impaired)
…*only one* environmental factor is YELLOW and the rest are GREEN	Green (response not impaired)
…*two or more* factors are ruled YELLOW	Red (response not possible/effective)

Data for each location were analyzed for wind, sea state (wave height and steepness), temperature, and visibility. For each operating area, the response gap was calculated for each environmental factor separately, then combined in the RGI.

It is often possible to determine, from an incomplete set of readings, whether the condition was red or not, since any two "yellows" or one "red" in the remaining readings are sufficient to set the index to red. However, it is very difficult to establish an incomplete reading as green, since in most cases, even a single unmeasured parameter could drive the index to red (if it was extreme). As such, incomplete readings are likely biased towards a red index. In keeping with our conservative approach overall, we calculate the response gap index based only on periods where data for all environmental factors were available.

2.5 Assumptions

The response gap analysis relies on several important assumptions:

Availability of Equipment for On-scene Deployment

The response gap analysis assumes that the equipment and personnel are available and ready to respond. This requires advanced planning and commitment of resources as well as having qualified personnel in the right place at the right time. It also requires that environmental conditions are conducive to safely moving personnel and resources to the locations demanded by the response operation; this is partially addressed by the air logistics response gap analysis.

Interactions Among Environmental Factors

Interactions among environmental factors have a significant impact on operating limits. For example, low temperatures and strong winds cause freezing spray that may impede or prevent response operations much sooner than either temperature or wind alone. Likewise, waves of a certain height are much more limiting in the presence of a strong wind or in times of low visibility. These interactions are accounted for by using the RGI described above to combine observed weather conditions and determine whether response was possible for each observational period. (Nuka Research, 2007)

Response Capacity Degradation due to Environmental Factors

The degradation of response does not occur at a single point, nor is it necessarily linear in nature. For instance, response efficiency does not go from 100% to 0% as wind increases one knot from a "yellow" value to a "red" value. Likewise, a wind of 10 knots does not indicate that the response efficiency is exactly half that at 20 knots. The degradation curve is probably different for each environmental factor, and is additionally contingent on the particular equipment models, vessels, and crew abilities. This further complicated the task of setting discrete operational limits. We accounted for capability degradation in a simplified way by establishing the three tiered, color-coded categories of limitations for each environmental factor. (Nuka Research, 2007)

2.6 Considerations and Limitations of the Approach

The response gap analysis is inherently limited in the following ways.

Weather Data is Recorded at a Single Location

The observations used in this study reflect actual conditions at the location of the data buoys and airports (or forecasted conditions for the nearshore analysis). It is assumed that the recorded conditions are reflective of conditions in nearby waters, but conditions can and do vary from the buoy locations and localized effects may make a specific location quite different than the weather station data recorded.

Historical Weather Data May Not be a Reliable Predictor of Future Conditions

Nuka Research makes no attempt to forecast changes in the environmental parameters used in this report, though differences in future conditions as compared to the historical data presented here can be expected to occur due to global climate change.

Better Quantification of Response Limits would Improve Results

The response system limits used in this analysis are based largely on published information and best professional judgment. Full-scale trials could be conducted to better establish response limitations quantitatively. Despite the large number of drills, exercises, and actual responses that have been conducted in the past 20 years, little quantitative data on effectiveness has been collected during these events.

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3. PREVENTING A RELEASE: EMERGENCY TOWING

3.1 Overview and Assumptions for Emergency Towing

3.1.1 Overview of Operations

When a vessel suffers a loss of steering or propulsion, the first response attempt will most likely be to take it under tow and bring it to a safe harbor. These vessels may be dedicated rescue tugs, or may be any towing-capable vessel that is in the area and able to arrive on scene quickly. In order to make a save, the towing vessel must have the necessary equipment on board to establish and maintain a tow, and have sufficient power and other design features to control and then maneuver the vessel.

This response gap analysis focuses on the impact of environmental conditions on the ability to establish the towing connection. As with the other response operations considered, it assumes that the necessary equipment and vessels are both present on-scene and comprised of the adequate technology in terms of crew training, the vessel capability, and towing gear.

3.1.2 Operating Limits

The ability to maneuver a towing vessel close to a ship and successfully deploy a towline is affected by several factors: high sea state and winds can make it unsafe for the tug to maneuver too close to the distressed vessel. Visibility less than 0.1 nm can also make it difficult or impossible to attach a towline in high seas conditions; however, it is rare that very strong winds and high seas are paired with low visibility. Available visibility data does not provide allow for distinctions in the relevant range. For this reason, horizontal visibility limits are not included in the analysis, but their potential impact is acknowledged.

The limits below are based on reports from rescue towing operations in the Aleutian Islands region[5] and consultation with the analyst who conducted the tow vessel capability analysis for other subtasks in the AIRA.[6] The most relevant case is the *Selendang Ayu*. The National Transportation Safety Board report on the *Selendang Ayu* response indicates that the tug *Sydney Foss* made up a tow with the disabled freighter in winds estimated at 45-55 knots and sea states of 20-25 feet after sunset. Ultimately the tug and tow gear did not save the freighter, but they proved that a tow can be established in extreme conditions. After the *Sydney Foss* tow line broke, the USCG Cutter *Alex Haley* attempted but was unable to establish a tow in wind estimated at 65 knots and a sea state of at least 35 feet.

Table 3.1 presents the limits used for emergency towing. These limits focus on the

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[5] Documentation reviewed: National Transportation and Safety Board report from the *M/V Selendang Ayu* accident (NTSB, 2006), ADEC situation reports from the *M/V Golden Seas* incident (2010), and the Incident Data Log for the Kulluk incident in 2012 (USCG, 2012).

[6] Personal communication with Garth Wilcox, PE, The Glosten Associates (December 2, 2013).

ability of the vessel to achieve a tow, and do not consider whether the vessel could arrive on scene in time to do so or the ability to maintain the tow.

Table 3.1 Emergency towing rescue limits

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
W (Wind in knots)	**W** < 45	45 ≤ **W** ≤ 60	**W** > 60
H (Wave height in ft)	**H** < 20	20 ≤ **H** ≤ 30	**W** > 30
Daylight/Darkness	**Daylight**	**Darkness**	not used

3.2 Response Gap for Emergency Towing

This section presents the results of the analysis for emergency towing.

3.2.1 Response Gap Index

This section presents the RGI – which considers the effect of *combining* individual factors – for individual locations and for all locations combined. Overall, assuming that the necessary vessels and equipment were on-scene and the crew appropriately trained, it would be extremely rare – just 1-3% of the time at different locations – that weather conditions would outright preclude attempts to establish an emergency tow. This is true year-round, which contrasts to other response operations where winter conditions would very often preclude deployment. Table 3.2 presents the RGI.

Table 3.2 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round, summer, and winter)[7] for EMERGENCY TOWING

STATION	**RGI Red Year-Round**	**RGI Red Spring/Summer (Apr – Sep)**	**RGI Red Fall/Winter (Oct – Mar)**
SW Bering Sea + Adak	2%	<1%	4%
SE Bering Sea + Dutch Harbor	1%	<1%	2%
North Pacific / Central Aleutians + Adak	3%	<1%	4%
NE Pacific / Shumagin Islands + Cold Bay	2%	<1%	3%
All Stations, Combined	**2%**	**<1%**	**4%**

Figure 3.1 shows the RGI on a yearly cycle. Areas of dark green are those for which all factors were green; areas of light green had one condition yellow and the others green. There were very few times when conditions were red, and these were all cases where just one factor was red or yellow.

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[7] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

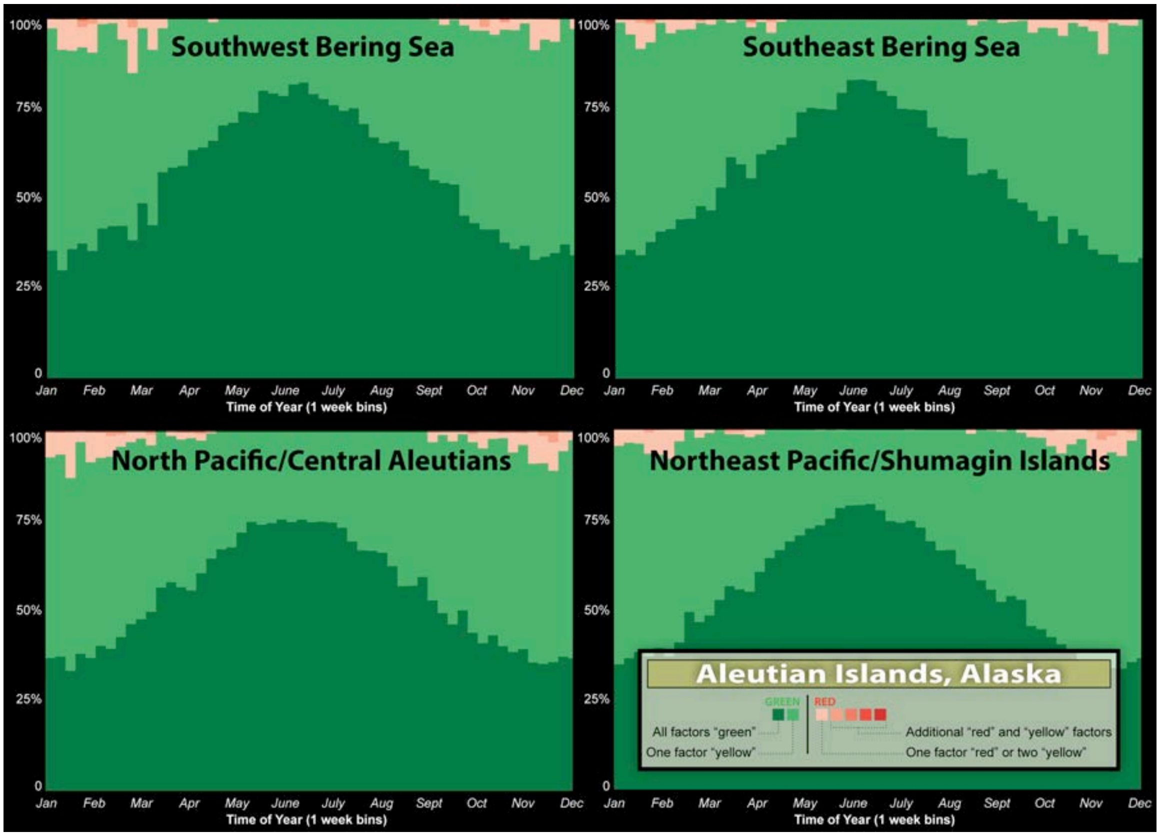

Figure 3.1 Response gap index at each buoy station throughout the year for EMERGENCY TOWING

3.2.2 Individual Factors

Table 3.3 shows the percentage of time when each environmental factor is considered green, yellow, and red, both combined across locations and at each location. Wind is never red, and waves are only rarely so. Red results in the RGI, therefore, are primarily based on the few times during the night that sea state conditions are yellow.

Table 3.3 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for EMERGENCY TOWING

All Locations – Combined			
Environmental Factor	**GREEN**	**YELLOW**	**RED**
Wind	100%	<1%	0%
Sea State	97%	3%	<1%
Daylight	58%	42%	0%
Southwest Bering Sea + Adak			
Wind	100%	<1%	0%
Sea State	96%	3%	<1%
Daylight	58%	42%	0%
Southeast Bering Sea + Dutch Harbor			
Wind	100%	<1%	0%
Sea State	97%	2%	<1%
Daylight	58%	42%	0%
North Pacific/Central Aleutians			
Wind	100%	<1%	0%
Sea State	95%	4%	<1%
Daylight	57%	43%	0%
Northeast Pacific/Shumagin Islands			
Wind	100%	<1%	0%
Sea State	97%	3%	<1%
Daylight	58%	42%	

4. PREVENTING A RELEASE: LIGHTERING (SALVAGE)

Salvage operations refer to a wide range of activities. For the purpose of this study, we have chosen to focus on the lightering of oil from a stricken vessel as one of the critical salvage activities that may be needed for pollution prevention, particularly from grounded vessels.

4.1 Overview of Salvage Operations

Heavy-lift helicopter lightering was successfully used to remove fuel from the *Selendang Ayu*. This method was selected over ship-to-ship lightering because of safety and performance advantages in the area's adverse weather and heavy seas.[8] It is also the focus of this response gap analysis, which considers the impact of winds and other factors on the ability to implement such operations.

Lightering by helicopter lift has the disadvantage of being costly and slow. It proved the only viable lightering technique for the *Selendang Ayu*, but it would be marginally effective where the lightering time-window is brief, or where the volume of oil that needs to be moved is very large.

Lightering can also be conducted by transferring oil from the stricken vessel to another vessel; this is considered to be more likely subject to limitations caused by heavy sea states, which prevail in the operating area, and so only a general discussion is provided.

4.1.1 Description of heavy lift helicopter lightering

Helicopters may carry external cargo in tanks suspended beneath the airframe. The load is attached to a belly hook, which the helicopter must have previously installed. A swivel is placed between the hook and the cargo, to allow it rotate during flight, preventing twisting or windup of the suspended load. If at any time the helicopter becomes endangered, the pilot may release the load.

The cargo-carrying tank and swivel may be attached directly to the belly, may be separated from the belly hook by a short line, or may be suspended on a "longline" – typically 50 feet or 100 feet in length, but longer in extreme cases. For most salvage operations using helicopter external cargo, short lines are a preferred option. Longline operations have unique utility in the right situations, but require special pilot training.

External cargo, or "sling", operations have the advantage of letting a helicopter move odd-sized or bulky cargo, and rapidly ferry large volumes of cargo without landing for internal loading. This not only increases cycle time, but also enables the

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[8] M/V Selendang Ayu: Choice of Salvor. Memorandum. January 5, 2005. Retrieved from: http://dec.alaska.gov/spar/perp/response/sum_fy05/041207201/041207201_doc_salvagememo.pdf

helicopter to lift cargo from ground on which it cannot land. With the addition of a longline and skilled pilot, they enable extraction of cargo from locations too enclosed for safe entry. (Based on NIAC, 2009)

4.2 Operating Limits

Helicopter operations are limited by a variety of factors, such as pilot ability and experience with a particular operation, wind shear/ turbulence, density altitude, individual helicopter capability, and payload. Ultimately, operations are conducted at pilot's discretion. However, general environmental and operational limits can be developed.

While operational limits have not been previously defined for helicopter lift operations to lighter oil from marine vessels, widely accepted limits have been established for wildfire suppression operations, including sling operations, where cargo is moved externally in cargo nets suspended below the helicopter. Wildfire helicopter operations are also frequently conducted at very low altitudes, and the full performance capabilities of the aircraft are called upon. For this study, Nuka Research uses the operational limits in the Interagency Helicopter Operations Guide[9] (IHOG) as a guideline for what is expected to be possible, reasonable, and within pilot comfort for marine salvage operations (NIAC, 2009).

Helicopters are divided into three general weight/payload capacity categories: Type 1 (Light), Type 2 (Medium), and Type 3 (Heavy). For purposes of cargo lightering and other salvage-related heavy lift operations, Type 1 (Heavy) helicopters are the suitable group. The S-64 Skycrane and Boeing CH-47 Chinook were used as an example aircraft in this analysis, because of their capabilities and general availability throughout the Pacific Northwest. (The Chinook was used for lightering operations during the *M/V Selendang Ayu* response.) The IHOG limitations for safe operation of the example helicopter were used for both sustained winds and gust spread (wind shear).

Temperature limits are based on the safety limits for ground crews operating in exposed environment of vessel decks. To conduct sling operations, ground crews must prepare and attach the cargo units to helicopter's lead (choker) line. There is also some concern with aircraft icing, since external cargo operations in cold conditions with expose the helicopter to freezing spray. The hazards of cold temperatures are largely universal for aircraft and ground crew, regardless of vessel size.

Sea state is not used as a limit. Since the primary impact of sea state on helicopter external cargo operations is to create heaving on the vessel deck, the impact of sea state will vary with vessel size. The size and stability of vessels in distress may vary considerably.

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[9] The IHOG is widely accepted, being used for wildfire operations by 7 agencies, including USDA Forest Service (USFS), Bureau of Land Management (BLM), Bureau of Indian Affairs, Fish and Wildlife Service (FWS), and National Park Service (NPS), and other participating federal and state agencies. The USFS, BLM, and NPS use the IHOG for all agency helicopter operations, regardless of mission. See: http://www.nwcg.gov/pms/pubs/pms510/00_pms510.pdf

Helicopters operate best under daylight and civil twilight conditions. Although it is nominally possible to conduct sling operations at night, this is usually considered a last resort. We apply a yellow condition to night-time, reflecting its marginal viability, and the fact that – regardless of pilot willingness to work in darkness - complicating factors are likely to prohibit operations.

IHOG interprets VFR conditions as those with ½ mile horizontal visibility, while current FAA code designates VFR as horizontal visibility greater than one mile, with the exception that: "a helicopter may be operated clear of clouds if operated at a speed that allows the pilot adequate opportunity to see any air traffic or obstruction in time to avoid a collision," (14 CFR 191). We used this set of constraints to apply a red limit to conditions with ½ mile visibility (or worse), and designate green conditions beyond one mile of visibility.

Sea state has a complex effect on lightering by helicopter. The direction, height, and steepness of the waves are likely to influence the stability of the vessel from which oil is being removed, which will, in turn, determine whether crew are able to safely and effectively maneuver the equipment on deck. This analysis does not consider these factors, however, as they are so dependent on the size and positioning of the hypothetical ship, and possibly also the tidal cycle, that limits could not be established.

Table 4.1 summarizes the limits used in this analysis.

Table 4.1 Limits for LIGHTERING using helicopter sling operation (based on IHOG, FAA Visual Flight Rules,[10] and expert review)

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
W (Wind in knots)	**W** < 30	30 ≤ **W** < 40	**W** ≥ 40
S (Shear: gusts minus wind in knots)	**S** < 10	10 ≤ **S** < 15	**S** ≥ 15
T (Temperature ºF) **W** (Wind in knots)	**T** ≥ 26, or otherwise not included in yellow or red conditions	16 < **T** < 26 and **W** ≥ 12	**T** ≤ 16 and **W** ≥ 5
V (Visibility in nautical miles)	**V** > 1	1 ≥ **V** > 0.5	**V** ≤ 0.5
C (Ceiling in feet)	**C** > 1200	1200 ≥ **C** > 500	**C** ≤ 500
Daylight/Darkness	**Daylight**	**Darkness**	not used

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[10] 14 CFR Part 91, General Operating and Flight Rules (FAA Regulations)

4.3 Response Gap

This section presents the results of the analysis for lightering oil from a stricken vessel using a helicopter sling lift operation.

4.3.1 RGI for Helicopter Sling Operations (Lightering)

Medium and heavy helicopter sling operations are normally viable. On average, conditions are red only 20% of the time across the different locations. When the RGI is green, which is most of the time, conditions are marginal slightly less than half the time, usually due to darkness. The overall pattern is one of green conditions interrupted only occasionally by severe weather (primarily in winter) and low visibility.

Because helicopters can conduct these operations in lower visibility conditions than needed for the aerial application of dispersants, the RGI is significantly lower even though both operations rely on aircraft.

Table 4.2 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round)[11] for LIGHTERING using helicopter sling operation

STATION	**RGI Red** Year-Round	**RGI Red** Spring/Summer (Apr – Sep)	**RGI Red** Fall/Winter (Oct – Mar)
SW Bering Sea + Adak	18%	19%	17%
SE Bering Sea + Dutch Harbor	17%	11%	22%
North Pacific / Central Aleutians + Adak	17%	19%	15%
NE Pacific / Shumagin Islands + Cold Bay	27%	27%	27%
All Stations, Combined	**20%**	**19%**	**20%**

Figure 4.1 shows the strong seasonal pattern of good vs. marginal conditions (dark green vs. light green) in the RGI for helicopter sling operations. However, in contrast to other tactics, which are heavily influenced by sea state, the overall seasonal RGI variation is relatively flat.

The extent of marginal (light green) conditions suggests that additional factors such as sea state, wave direction, and tide (if incorporated for their effect on ships being lightered) may tip many observational periods from a marginal green to a red condition. Summer response gaps appear to result from visibility factors (visibility, ceiling).

Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

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[11] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

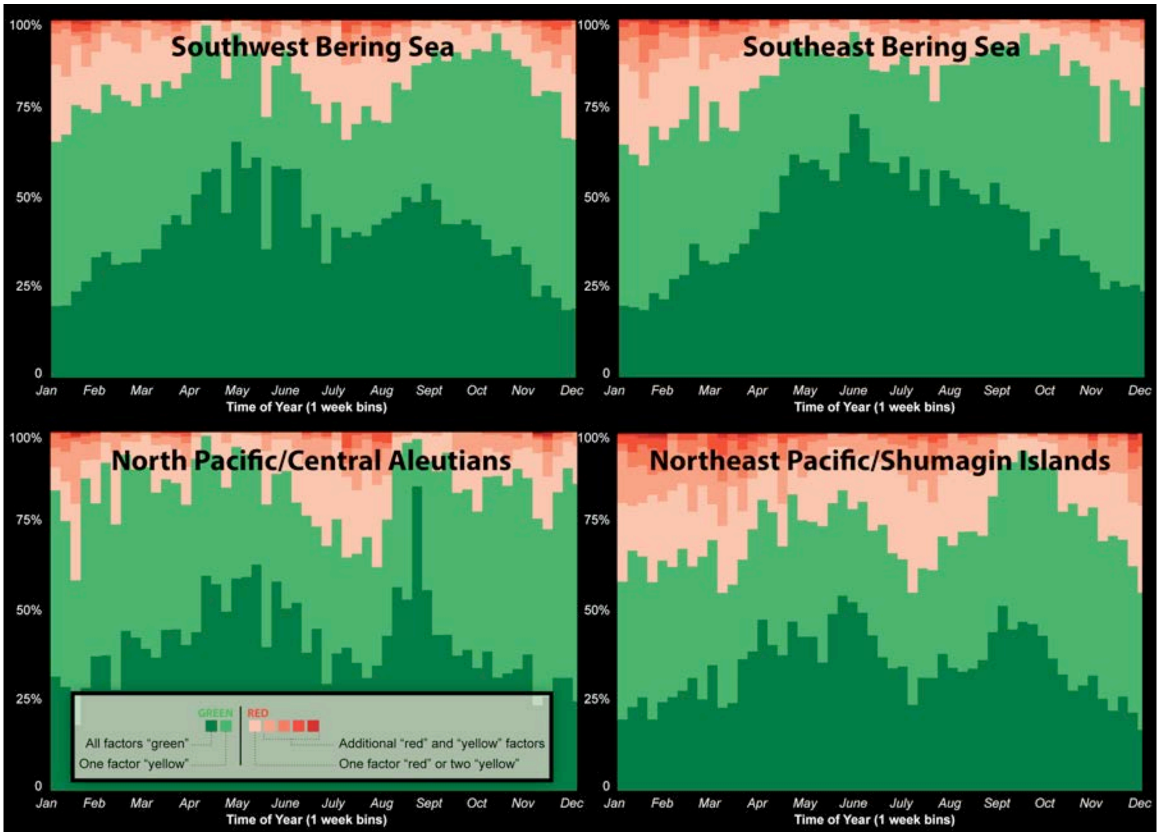

Figure 4.1 Distribution of RGI at each buoy station for LIGHTERING using helicopter sling operation

4.3.2 Impact of Individual Factors

Table 4.3 summarizes the likely impact of individual factors on this response operation. The cloud ceiling limit is the most likely to preclude operations on its own (from 4% to 9% of the time across locations), but this is much less significant than the influence of sea state on the spill response operations in Section 5. Visibility, on the other hand, seldom creates a red condition, but is marginal (yellow) 42% to 49% of the time. Much of this is attributable to darkness.

Table 4.3 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for LIGHTERING using helicopter sling operation

All Locations – Combined			
Environmental Factor	**GREEN**	**YELLOW**	**RED**
Wind	95%	5%	< 1%
Shear	99%	1%	< 1%
Sea State	96%	3%	1%
Air Temperature	54%	45%	1%
Visibility & Daylight	76%	15%	9%
Ceiling	95%	5%	< 1%
Southwest Bering Sea + Adak			
Wind	96%	4%	None
Shear	100%	None	None
Sea State	98%	1%	< 1%
Air Temperature	54%	45%	1%
Visibility & Daylight	75%	17%	8%
Ceiling	96%	4%	None
Southeast Bering Sea + Dutch Harbor			
Wind	91%	8%	1%
Shear	100%	None	None
Sea State	97%	3%	None
Air Temperature	57%	43%	0%
Visibility & Daylight	84%	11%	5%
Ceiling	91%	8%	1%
North Pacific/Central Aleutians			
Wind	96%	4%	None
Shear	99%	1%	None
Sea State	99%	1%	None
Air Temperature	50%	49%	1%
Visibility & Daylight	75%	17%	8%
Ceiling	96%	4%	None
Northeast Pacific/Shumagin Islands			
Wind	96%	4%	None
Shear	99%	1%	None
Sea State	91%	6%	3%
Air Temperature	56%	42%	2%
Visibility & Daylight	71%	17%	13%
Ceiling	96%	4%	None

4.4 Ship-to-ship Lightering

In addition to removing oil from a vessel via airlift, it can also be lightered to another vessel. In the case of a spill from a large tanker or similar vessel, helicopter lightering may be practically impossible due to the sheer volume of oil carried. In this case, the vessel must be towed to protected waters for ship-to-ship lightering, and emergency towing (not ship-to-ship lightering under the given conditions) becomes the most immediately crucial operation.

Review of *M/V Selendang Ayu* experience, existing guidelines[12] on ship-to-ship lightering and the geography and environmental conditions of the Aleutians strongly indicates that ship-to-ship is not the preferred lightering method for the area. Sea state limits, in particular, make it much less feasible than helicopter lightering, due to the hazards of mooring vessels alongside one another. Nuka Research conducted a simple analysis of the frequency with which wave height alone would preclude ship-to-ship lightering based on buoy data collected for this analysis.

Based on input from the Analysis Team and published guidelines (see above), we used a wave height of > 6 and < 8 feet for a “yellow” condition and ≤ 8 feet for a “red” condition. The results are summarized in Table 4.4, below, which shows when average recorded wave height for each location, for each month, would be red, yellow, or green using the limits mentioned above. The aggregate picture is that, in offshore locations, sea state alone renders ship-to-ship lightering unsafe during average conditions for roughly half the year. A multi-factor response gap analysis would be expected to yield much higher RGI by incorporating more factors.

Table 4.4 Summary of average wave height (feet) for each location, across months from 2007-2012. *Shaded colors refer to and whether conditions were green (wave height ≤ 6 ft.), yellow (> 6 and ≤ 8 ft.), or red (wave height > 8 ft.).*

	Southwest Bering Sea	Central Aleutians/ North Pacific	Southeast Bering Sea	Northeast Pacific/ Shumagin Islands
January	12	13	10	11
February	12	13	10	12
March	10	11	9	10
April	9	11	9	10
May	6	7	5	7
June	5	6	4	6
July	4	6	4	5
August	5	6	5	6
September	8	9	8	8
October	10	10	10	10
November	11	12	10	11
December	12	13	10	12

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[12] Merchant Shipping Notice 1829 (M) suggests environmental limits for ship-to-ship transfer at the end: Beaufort Force 6, Swells > 2 m, winds > 27 knots. Coast Guard 33 CFR Part 156 [CGD 93–081] RIN 2115–AE90 Designation of Lightering Zones, Section 156.320 Minimum Operating Conditions suggests a prohibition of mooring for ship-to-ship lightering at winds >= 30 knots and seas >= 10 feet in the same direction, and that winds and seas in opposite directions may make mooring unsafe at only a few knots of wind.

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5. SPILL RESPONSE: MECHANICAL RECOVERY

This section describes the response gap analyses for both offshore and nearshore mechanical response operations. The offshore analysis uses wind and sea state data from the buoys; because there are no buoys in the nearshore areas, marine weather forecasts have been used for sea state. Operations may vary in the nearshore and open water environments, in terms of the type of vessels and equipment used, but the basic mechanics of the approach remain the same.

5.1 Overview and Assumptions for Open-water Mechanical Recovery

5.1.1 Overview of Operations

Mechanical response operations focus on physically containing the slick by collecting it with boom and recovering it while still on the surface of the water. In order to function effectively, mechanical response requires conditions that allow for the safe operation of vessels and their crew, including the ability to deploy boom and keep in the appropriate position (either moving or stationary) and operate on-water skimming equipment. Typical open-water mechanical recovery tactics and equipment are described in the Spill Tactics for Alaska Responders (STAR) Tactics Manual (ADEC, 2006) and CISPRI Technical Manual (CISPRI, 2013).

5.1.2 Operating Limits

Nuka Research has identified limits based on the assumption that the equipment will represent standard available technology and be comparable to the offshore oil spill response equipment maintained by major U.S. oil spill response organizations. With this basic assumption, the limits can be applied to the historical environmental data to calculate a response gap that is applicable to a range of potential response configurations: if the weather conditions preclude the effective deployment of one skimmer, for example, those same conditions would preclude the effective deployment of an entire force of skimmers.

Table 5.1 shows the limits used for each environmental factor. The limits were chosen based on review of ASTM International's Standard Practice for Classifying Water Bodies for Spill Control Systems, F 625 (ASTM, 2000), U.S. Coast Guard Classification of Oil Spill Removal Organizations (USCG, 2013), the Prince William Sound Tanker Oil Discharge Prevention and Contingency Plan (RPG 2012), CISPRI Technical Manual (CISPRI, 2013), and the best professional judgment of Nuka Research in consultation with the AIRA Analysis Team.

Table 5.1 Open-water mechanical recovery limits

ENVIRONMENTAL FACTOR	**GREEN** **Response:** *Not Impaired*	**YELLOW** **Response:** *Impaired*	**RED** **Response:** *Not Possible/Effective*
$\mathbf{W}$ (Wind in knots)	$\mathbf{W} < 21$	$21 \leq \mathbf{W} < 30$	$\mathbf{W} \geq 30$
$\mathbf{H}$ (Wave height in feet) $\mathbf{S}$ (Wave steepness)	$\mathbf{H} \leq 3$	$3 < \mathbf{H} < 6$ when $\mathbf{S} \geq 0.0025$ or $4 < \mathbf{H} < 8$ when $\mathbf{S} < 0.0025$	$\mathbf{H} \geq 8$ or $\mathbf{H} \geq 6$ when $\mathbf{S} \geq 0.0025$
$\mathbf{T}$ (Temperature °F) $\mathbf{W}$ (Wind in knots)	$\mathbf{T} \geq 26$, or otherwise not included in yellow or red conditions	$16 < \mathbf{T} < 26$ and $\mathbf{W} \geq 12$	$\mathbf{T} \leq 16$ and $\mathbf{W} \geq 5$
$\mathbf{V}$ (Visibility in nautical miles) **Daylight/Darkness**	$\mathbf{V} \geq 0.5$ **Daylight**	$0.5 > \mathbf{V} \geq 0.125$ in **Daylight** or $\mathbf{V} \geq 0.5$ in **Darkness**	$\mathbf{V} < 0.125$ in **Daylight** or $\mathbf{V} < 0.5$ in **Darkness**

5.2 Response Gap for Open-water Mechanical Recovery

This section presents the results of the analysis for open-water mechanical recovery.

5.2.1 Response Gap Index

This section presents the RGI – which considers the effect of *combining* individual factors – for individual locations and for all locations combined. Thus, in addition to estimating that a response may be precluded based on one factor being red, the RGI considers any time period when two or more factors are yellow to be red as well. Table 5.2 shows the RGI for each location in summer and winter as well as overall for the year.

Overall, the RGI for open-water mechanical recovery in the Aleutian Islands is an estimated 72%, or almost three-quarters of the time. Not surprisingly, this increases to 90% of the time in the winter (when the same conditions that would challenge a spill response may also challenge a vessel rescue or salvage operation to prevent a spill in the first place). On the other hand, with an RGI of 47% for the summer months, an open-water mechanical recovery operation may be able to be mounted more than half the time.

Looking across the different stations, the Northeast Pacific/Shumagin Islands location has the largest response gap of the four buoys at 78% year round, while the Southeast Bering Sea has the smallest at 66%. The best possible chance of mounting a response based on historical conditions would be in the summer months at the Southeast Bering Sea/Dutch Harbor location, where the RGI is at its lowest for open-water mechanical recovery, at 39%.

Table 5.2 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round, summer, and winter)[13] for OPEN-WATER MECHANICAL RECOVERY

STATION	**RGI Red** Year-Round	**RGI Red** Spring/Summer (Apr – Sep)	**RGI Red** Fall/Winter (Oct – Mar)
SW Bering Sea + Adak	71%	43%	90%
SE Bering Sea + Dutch Harbor	66%	39%	86%
North Pacific / Central Aleutians + Adak	78%	50%	93%
NE Pacific / Shumagin Islands + Cold Bay	74%	55%	90%
All Stations, Combined	**72%**	**47%**	**90%**

Figure 5.1 shows the annual variability in the RGI at different locations. All locations show significant seasonal variability, with a greater likelihood of an effective response in the summer months.

Wide regions of light green and light red show the extent of marginal conditions. The extent of "light green" areas (marginally good) versus relatively few "dark green" (very good conditions) suggests that recovery equipment would be operating near the margin most of the time, and compounding factors such as crew inexperience, fatigue, equipment that is not suited to the type of oil spilled, or lower quality equipment could render a response ineffective even under these marginally "green" conditions.

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[13] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

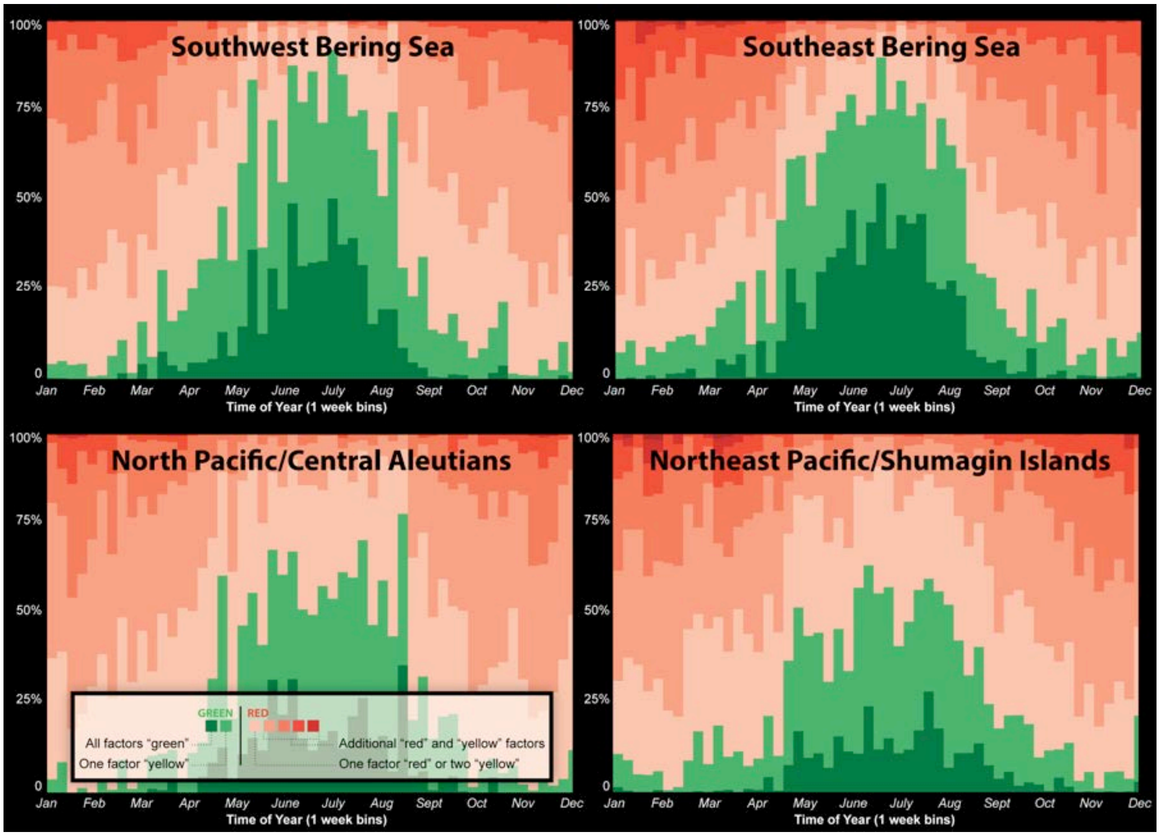

Figure 5.1 Response gap index at each buoy station throughout the year for OPEN-WATER MECHANICAL SPILL RESPONSE[14]

The response gap estimates for the buoys describe an extreme environment in which response would likely be precluded from 66-78% of the time. During the majority of complete records for times that fall under "green" in the RGI, at least one environmental factor is still "yellow." Even when conditions permit recovery operations, they are often marginal. Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

5.2.2 Individual Factors

Table 5.3 shows the percentage of time when each environmental factor is considered green, yellow, and red, both combined across locations and at each location. In this table, individual factors are considered "green" much of the time, with figures over 50% for all factors except for sea state. Except for sea state, it is unlikely that operations would be precluded by a single factor. However, sea state alone could prevent operations 60% of the time on average across all areas, and up to 67% at the North Pacific/Central Aleutians location.

Visibility is also relatively likely to impair a response, if not entirely preclude it, largely due to darkness.

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[14] Only complete data sets are shown: even where one or more data points may have been "red," results are not shown unless *all* data points were available for that time period.

Table 5.3 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for OPEN-WATER MECHANICAL RECOVERY

All Locations – Combined			
Environmental Factor	**GREEN**	**YELLOW**	**RED**
Wind	75%	20%	5%
Sea State	13%	27%	60%
Air Temperature	97%	3%	< 1%
Visibility & Daylight	57%	42%	1%
Southwest Bering Sea + Adak			
Wind	79%	18%	4%
Sea State	15%	27%	59%
Air Temperature	96%	3%	1%
Visibility & Daylight	57%	42%	1%
Southeast Bering Sea + Dutch Harbor			
Wind	68%	23%	8%
Sea State	19%	27%	55%
Air Temperature	95%	4%	1%
Visibility & Daylight	58%	42%	< 1%
North Pacific/Central Aleutians			
Wind	76%	20%	4%
Sea State	7%	25%	67%
Air Temperature	100%	< 1%	None
Visibility & Daylight	57%	43%	1%
Northeast Pacific/Shumagin Islands			
Wind	75%	21%	4%
Sea State	11%	29%	61%
Air Temperature	97%	3%	< 1%
Visibility & Daylight	56%	43%	1%

5.3 Overview and Assumptions for Nearshore Mechanical Recovery

Mechanical recovery in nearshore areas can be a critical part of sensitive area protection during a spill response.

While we used buoy records for our hindcast of sea states in the open water environment, there are no similar buoys in the nearshore areas of the Aleutian Islands. Instead, for this subsection of the analysis, we created our hindcast of sea state data based on National Weather Service wave forecasts for Unalaska Bay to provide one indication of what nearshore conditions may look like in the region.

Operating in local bays and lees created by protective shorelines, nearshore recovery occurs within local microclimates. The rugged topography, geographic extent, and exposure of the Aleutians make this all the more significant. Forecasting response gaps for nearshore recovery is equally local and reliant on accurate local data sets – most critically, local winds and sea state.

5.3.1 Overview of Operations

Nearshore mechanical recovery is similar to open-water recovery, but with smaller vessels and lighter equipment in order to operate in shallower and more protected waters as compared to open-water operations. Skimmers, boom, and other equipment are more lightly built, both for ease-of-handling and to fit with strategy of attacking spills with a large force of light, mobile strike teams capable of operating in shallow water. While the differences in vessels and equipment facilitate mobility and enable operations in shallow waters or confined areas, the effectiveness of nearshore response operations is heavily influenced by sea state. (CISPRI, 2013; ADEC, 2006; ASTM, 2000; RPG, 2012) Because of the safety consideration of operating in a confined sea space and shallow water, nearshore mechanical recovery is not attempted in darkness.

The complex mosaic of open and protected embayments in the shorelines of the Aleutian Islands means that conditions in many locations can be expected to vary widely over time, depending the prevailing weather and direction of swell. Thus, nearshore recovery may be feasible in some areas at the same time that it – or open-water recovery – is impossible in others. Deeply nested bays may have mild wave conditions and exposure, such as protected portions of Captain's Bay, Unalaska (P.N.D. Engineers, 2010), while more open bays can receive may swell heavy enough to seriously hamper shipping operations (Fett *et al.*, 1993).

5.3.2 Approach Used

While the airport data on winds, visibility, and temperature could be applied, there are no continuous sea state records for the nearshore areas. Nuka Research tested various methods of applying a response gap analysis to existing environmental datasets, and determined the best approach was the extract forecast wave heights from National Weather Service (NWS) Bulletins[15] for the same overall time period as used with the buoy data. A custom-built computer program was used to extract forecasted daily wave heights.

The dataset used for this nearshore recovery analysis combines weather readings at the semi-protected Unalaska Airport, with NWS wave forecasts for Unalaska Bay, which is partly open to the Bering Sea. (Even within Unalaska Bay and Dutch Harbor's associated bays, local conditions can be expected to vary widely.)

The use of NWS wave forecasts has the following implications for the response gap: (1) the use of marine forecasts is inherently less reliable than using records of actual environmental conditions because it depends on the ability of the forecasters to predict conditions; (2) this approach uses daily forecasts (taken at noon each day), as opposed to the hourly data taken from the offshore buoys; (3) waves are only forecasted in integers, which provides a coarser dataset and likely means that waves that may be expected to be 2.5 feet, for example, are likely described as "3 foot waves"; and (4) predictions also may be expressed as ranges, for example, "up to 3 foot waves" when the actual conditions turn out to be less than 3 foot waves. Overall, the use of this dataset is expected to portray more extreme conditions (i.e., higher

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[15] Bulletins are published by the NWS Forecast Office at: http://pafc.arh.noaa.gov/marfcst.php?fcst=FZAK51PAFC. Data were downloaded from the National Climactic Data Center's HDSS Access System at: http://has.ncdc.noaa.gov/pls/plhas/HAS.FileAppSelect?datasetname=9957ANX

sea states) than actually existed. Thus resulting in a higher estimate of the time period when no response is possible.

5.3.3 Operating Limits

In general, nearshore operations have less tolerance of high winds and sea states than open-water operations (ADEC, 2006; CISPRI, 2012; RPG, 2012). Nearshore vessels can potentially operate in some degree of reduced visibility, especially if the operators have local knowledge, but the dangers of collision and grounding are also significant in reduced visibility, since oil recovery activities require deviating from typical travel patterns.

Table 5.4 Limits used for nearshore mechanical spill response

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
W (Wind in knots)	$\mathbf{W} < 15$	$15 \leq \mathbf{W} < 25$	$\mathbf{W} \geq 25$
H (Wave height in feet)	$\mathbf{H} = 1$ or 2	$H = 3$	$\mathbf{H} > 3$
T (Temperature ^{o}F) **W** (Wind in knots)	$\mathbf{T} \geq 26$, or otherwise not included in yellow or red conditions	$16 < \mathbf{T} < 26$ and $\mathbf{W} \geq 12$	$\mathbf{T} \leq 16$ and $\mathbf{W} \geq 5$
V (Visibility in nautical miles) **Daylight/Darkness**	$\mathbf{V} \geq 0.5$ **Daylight**	$0.5 > \mathbf{V} \geq 0.125$ in **Daylight** or $\mathbf{V} \geq 0.5$ in **Darkness**	$\mathbf{V} < 0.125$ in **Daylight** or $\mathbf{V} < 0.5$ in **Darkness**

5.4 Response Gap for Nearshore Recovery

This section presents the results of the analysis for nearshore mechanical recovery.

5.4.1 Overall RGI

The overall Response Gap Indices of 60% (during all hours) or 52% (during daylight hours) indicates that a nearshore response is unlikely to be implemented half the time, only considering daylight hours. Sea state is the key limiter on operations: it almost exclusively accounted for the times when one factor alone was enough to make the RGI red.

The sea-state forecast was applied to one hour *per day* (at the time corresponding to forecast conditions) throughout the dataset, meaning the number of data points used to formulate the RGI is smaller than for the other operations. Using this smaller dataset reduced sample size, but the sample size still exceeds 1,000 individual response gap calculations.

Table 5.5 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round, summer, and winter)[16] for NEARSHORE MECHANICAL RECOVERY

LOCATION	**RGI Red** Year-Round	**RGI Red** Spring/Summer (Apr – Sep)	**RGI Red** Fall/Winter (Oct – Mar)
Unalaska Bay (all hours)	60%	43%	73%
Unalaska Bay (daylight only)	52%	34%	66%

Figure 5.2 shows how the RGI changes throughout the calendar year. The large areas of light red and light green indicate the extent to which the forecasted nearshore conditions in Unalaska Bay are marginal. Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

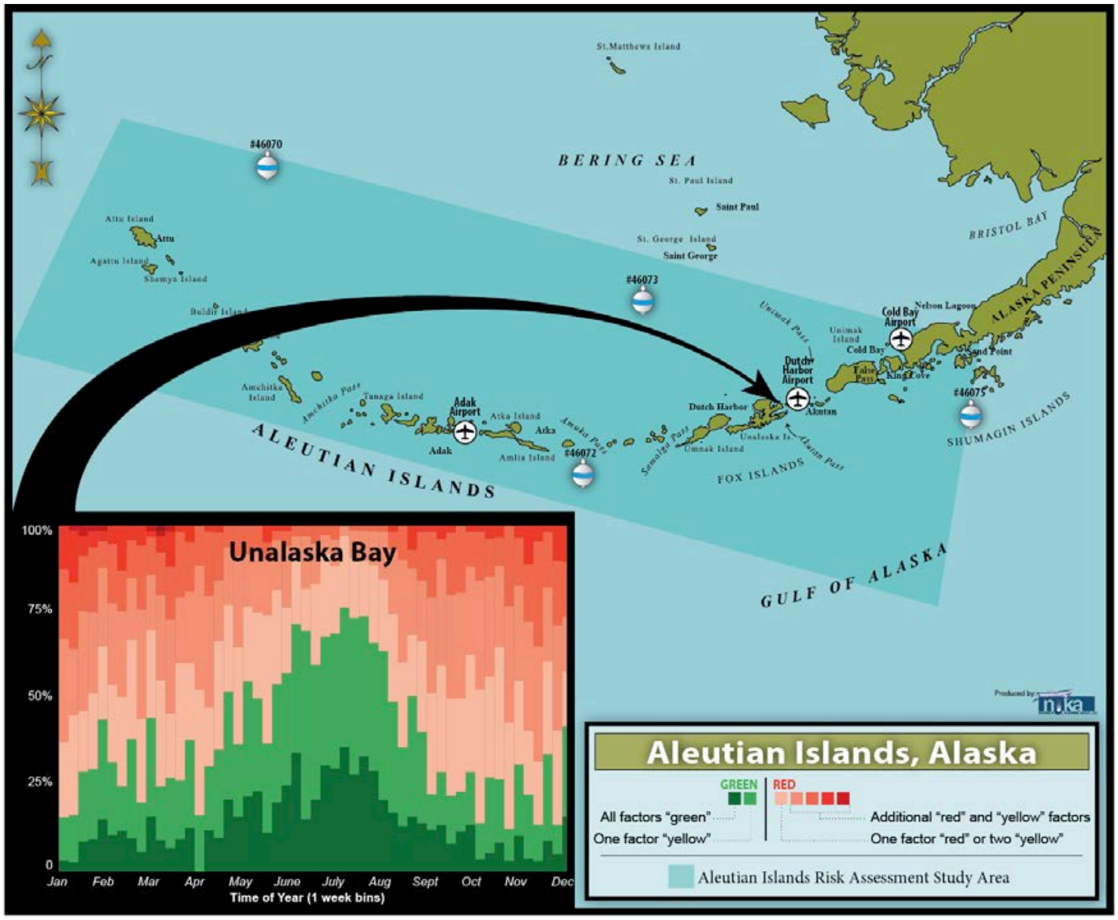

Figure 5.2 Response gap index at Unalaska Bay throughout the year for NEARSHORE MECHANICAL SPILL RECOVERY

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[16] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding. Time periods were chosen to reflect the general climatic seasons of the area.

5.4. Individual Factors

Table 5.6 shows the percentage of time when each environmental factor is considered green, yellow, and red, both combined across locations and at each location. Similar to open-water mechanical recovery (Table 5.2), sea state is the only factor that is likely to preclude a response on its own, which it is estimated to do 49% of the time. Both sea state and wind, however, are commonly marginal, or yellow. Table 5.6 shows visibility as being extremely unlikely to impact a response; this is largely because the nearshore analysis eliminated nighttime operations because they were considered to be unsafe during darkness due to the need for boats to maneuver in confined areas and shallow waters in order to conduct nearshore recovery activities. (For open-water recovery, night was considered to have a marginal impact).

Table 5.6 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for NEARSHORE MECHANICAL RECOVERY

Nearshore Oil Recovery in Unalaska Bay			
Env'l Factor	**Green**	**Yellow**	**Red**
Wind	80%	17%	3%
Waves*	30%	21%	49%
Air Temperature	97%	2%	1%
Visibility	58%	42%	< 1%

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6. SPILL RESPONSE: DISPERSANT APPLICATION

Non-mechanical spill response uses chemical or thermal processes instead of containing and recovering the oil. This typically includes the application of chemical dispersants or the in-situ burning of slicks on the surface of the water. For this analysis, we focus on dispersants applied from vessels and aircraft as the most likely of the current non-mechanical response technologies to be applied in the Aleutian Islands area. In-situ burning was not included because it would require both containment (subject to the same limitations as mechanical recovery) as well as ignition and sustained burning, which are compromised by wind, waves, cold temperatures, and low visibility (RPG, 2012).

6.1 Overview and Assumptions

Dispersants are chemicals that speed up the natural dispersion process of an oil slick. They can be applied to the slick from vessels and/or aircraft. Effective dispersant application requires that the appropriate product be applied during the window of opportunity when the slick is accessible on the water's surface.

Dispersants require a certain amount of mixing energy in order to be effective. Whereas calm waters are the most conducive to mechanical containment and recovery, it is possible for the water to be too calm for dispersants to work as intended. On the other hand, when waves reach a certain point the added benefit of adding the dispersants is negligible since the waves will naturally disperse the oil. The operating limits used for aerial dispersants reflect this by including both maximum *and* minimum wave heights. It is assumed that when dispersants are applied by vessels, the vessel propellers can provide the needed mixing energy (ADEC, 2006; Alyeska, 2013; SINTEF, 2009).

6.2 Operating Limits for Aerial Dispersants

The response limits in Table 6.1 were developed based on a previous non-mechanical response gap analysis for Prince William Sound (Nuka Research, 2008) and more recent operational reports from the Deepwater Horizon spill response in the Gulf of Mexico (National Commission, 2011).

Visibility is particularly critical to aerial operations: aircraft must be able to safely operate using Visual Flight Rules (VFR) and must also be able to see the oil and verify that the dispersant reaches the oil as intended. Horizontal and vertical visibility are important. Nighttime operations are considered to be "red."

Based on experience reported from the Deepwater Horizon spill response, a minimum horizontal visibility of 4 nm was established. This experience also recommended a minimum of a 1500-foot ceiling; based on the low aerial congestion expected in the Aleutian Islands region, and allowing for the fact that Alaskan pilots are generally experienced with low ceiling conditions, we applied an additional "yellow" zone down to 800 feet (National Commission, 2011).

While spraying from the air enables greater surface coverage, the prevailing winds may be strong and turbulent enough to carry the dispersant chemicals away from the targeted area or make them too diffused by the time they reach it.

Table 6.1 shows the limits used for each environmental factor.

Table 6.1 Limits for AERIAL DISPERSANT APPLICATION

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
W (Wind in knots)	$W < 22$	$22 \leq W < 27$	$W \geq 27$
H (Wave height in feet)	$2 \leq H < 9$	$1 \leq H < 2$	$H < 1$ or $H \geq 9$
T (Temperature ºF)	$T > -40$	not used	$T \leq -40$
V (Visibility in nautical miles)	$V > 4$	not used	$V \leq 4$
C (Ceiling in feet)	$C > 1500$	$1500 \geq C > 800$	$C \leq 800$
Daylight/Darkness	**Daylight**	not used	**Darkness**

6.3 Response Gap for Aerial Dispersants

This section presents the results of the analysis for the aerial application of dispersants.

6.3.1 Response Gap Index for Aerial Dispersants

This section presents the RGI – which considers the effect of *combining* individual factors – for individual locations and for all locations combined. Overall, the RGI for aerial dispersant application is an estimated 72%, again almost three-quarters of the time (this is the same as the combined, average RGI for open-water mechanical recovery). This includes a range from an RGI of just 47% in the Southeast Bering Sea during the summer to North Pacific/Central Aleutians 89% at that same location in the winter. Table 6.3 summarizes the overall percentage of time when it could be determined based on available data that a response would likely be not possible or effective based on historical conditions (i.e., "red" using the RGI approach).

Table 6.2 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round)[17] for AERIAL DISPERSANT APPLICATION

STATION	RGI Red Year-Round	RGI Red Spring/Summer (Apr – Sep)	RGI Red Fall/Winter (Oct – Mar)
SW Bering Sea + Adak	72%	55%	85%
SE Bering Sea + Dutch Harbor	65%	47%	80%
North Pacific / Central Aleutians + Adak	76%	54%	89%
NE Pacific / Shumagin Islands + Cold Bay	75%	63%	86%
All Stations, Combined	**72%**	**55%**	**85%**

Figure 6.1 shows the annual variability in the RGI. All locations show significant seasonal variability with no consistent pattern of effective dispersant by season. During winter, all four locations exceed aerial dispersant limits during the majority of daylight hours due to periods of heavy seas. There are times when response is precluded by low visibility due to fog and low cloud ceilings during the summer, even though there is more daylight and the sea state is not so high that dispersants would be only marginally effective, if at all. The summertime response gaps are therefore truly based on an inability to deploy the tactic, not the fact that high sea states make the application of dispersants unwarranted.

Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

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[17] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

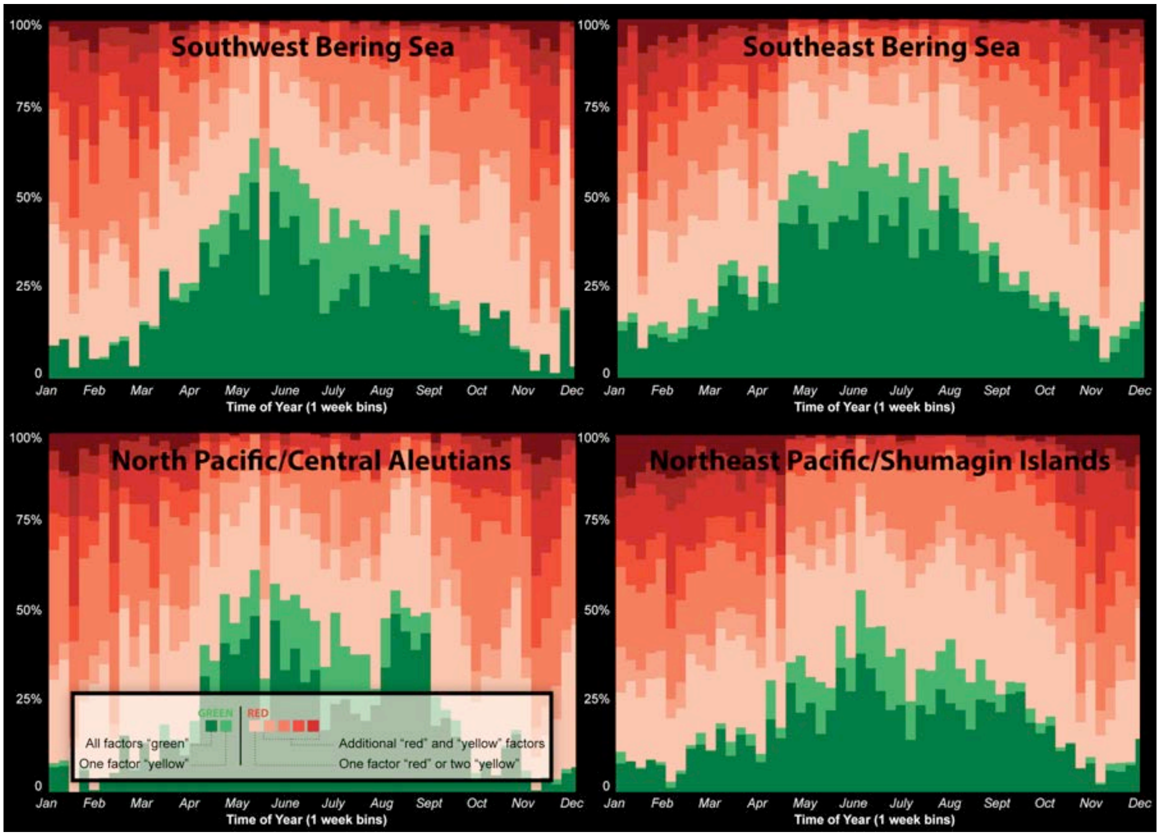

Figure 6.1 Response gap index at each location throughout the year for AERIAL DISPERSANT APPLICATIONS

6.3.2 Impact of Individual Factors on Aerial Dispersants

Table 6.3 shows the percentage of time that each factor is found to be green, yellow, or red, at each location. Sea state alone can create red conditions across the buoy stations 33% to 48% of the time, almost entirely due to heavy seas.[18] Yet many of these times may be due to sea state being high enough that the addition of dispersants would have a negligible effect due to the natural mixing energy of the waves. Therefore, many of these red conditions correspond to times when no spill response would be effective, and natural dispersion is enhanced. Wind, visibility/darkness, and the cloud ceiling all have a comparable ability to prevent operations by themselves, though these red conditions may also overlap.

Finally, this analysis uses only sustained (8-minute average) wind speeds near the ocean surface. If gustiness is taken into account, turbulent air may expand the response gaps caused by wind by promoting air mixing and – in extreme cases – making low-level flight unsafe. To some extent, these conditions are expected to be concentrated in bad weather, when sea state gaps are likely to already exist.

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[18] The sea state was rated red because the sea state was too *low* only 4 times out of approximately 57,000 readings. All of the other times that sea state rendered a red reading were due to wave heights greater than or equal to 9 feet.

Table 6.3 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for AERIAL DISPERSANT APPLICATION

All Locations – Combined			
Environmental Factor	**GREEN**	**YELLOW**	**RED**
Wind	78%	12%	10%
Sea State	59%	1%	40%
Air Temperature	100%	None	None
Visibility & Daylight	49%	35%	16%
Ceiling	68%	17%	15%
Southwest Bering Sea + Adak			
Wind	82%	11%	7%
Sea State	61%	1%	39%
Air Temperature	100%	None	None
Visibility & Daylight	45%	34%	21%
Ceiling	67%	18%	15%
Southeast Bering Sea + Dutch Harbor			
Wind	72%	14%	14%
Sea State	64%	3%	33%
Air Temperature	100%	None	None
Visibility & Daylight	51%	37%	12%
Ceiling	76%	15%	9%
North Pacific/Central Aleutians			
Wind	80%	12%	8%
Sea State	52%	< 1%	48%
Air Temperature	100%	None	None
Visibility & Daylight	48%	36%	16%
Ceiling	67%	18%	15%
Northeast Pacific/Shumagin Islands			
Wind	78%	12%	10%
Sea State	60%	< 1%	40%
Air Temperature	100%	None	None
Visibility & Daylight	48%	35%	17%
Ceiling	63%	16%	21%

6.4 Operating Limits for Dispersants Applied from Vessel Platform

Many of the potential effects of different environmental factors are the same for dispersants applied from vessels or aircraft: high winds will make it harder to accurately target the slick and will spread the dispersant over a wider area, thereby reducing the treatment rate. Cold temperatures present risks to crew safety or equipment, operators must be able to find the oil, and if the waves are larger than 9 feet, dispersant have negligible effects anyway.

Because vessels operate closer to the slick, some of the limits are different, as shown in Table 6.4. This is particularly relevant to the effects of wind, which are expected to be somewhat less from the surface-level vessel application than an aerial application.[19]

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[19] Due to lack of surface friction, wind speed increases with vertical distance from the ground. We could not reliably quantify the effect over a rough and varying sea surface, but qualitatively note it.

The most significant differences in the operating limits for vessel and aerial dispersant application relate to sea state and daylight/darkness. Unlike for aerial dispersant applications, there is no lower limit for sea state: since vessels themselves can be used to churn the water, dispersant applications can be effective even in calm seas. Also, dispersants can be sprayed from vessels at night, under otherwise ideal conditions, though not successfully sprayed from an aircraft in the dark.

Table 6.4 Limits for VESSEL DISPERSANT APPLICATION (Nuka Research, 2007; except as noted)

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
W (Wind in knots)	**W** < 18	18 ≤ **W** < 26	**W** ≥ 26
H (Wave height in feet) **S** (Wave steepness)	**H** ≤ 3	4 < **H** < 8 when **S** ≥ 0.0025 or 5 < **H** < 9 when **S** < 0.0025	**H** ≥ 9 or **H** ≥ 8 when **S** ≥ 0.0025
T (Temperature ºF) **W** (Wind in knots)	**T** ≥ 26, or otherwise not included in yellow or red conditions	16 < **T** < 26 and **W** ≥ 12	**T** ≤ 16 and **W** ≥ 5
V (Visibility in nautical miles)	**V** > 1	1 ≤ **V** < 0.125	**V** ≤ 0.125
Daylight/Darkness	**Daylight**	**Darkness**	n/a

6.5 Response Gap for Dispersants Applied from Vessel Platform

This section presents the results of the analysis for dispersants applied from a vessel.

6.5.1 Response Gap Index

This section presents the RGI – which considers the effect of *combining* individual factors – for individual locations and for all locations combined. With a combined average RGI of 64%, the application of dispersants from vessels could be expected to be able to be deployed more frequently than mechanical recovery (where the combined average RGI was 72% for open-water recovery, which used the same data). The lowest (31%) RGI is found in the Southwest Bering Sea, while the highest RGI (87%) is found in the North Pacific/Central Aleutians, for winter and summer, respectively.

Table 6.5 presents the RGI numerically, while Figure 6.2 presents the annual RGI cycle showing the nuance of times when the RGI is caused by either one or multiple factors being red. Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

Table 6.5 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round)[20] for VESSEL DISPERSANT APPLICATIONS

STATION	RGI Red Year-Round	RGI Red Spring/Summer (Apr – Sep)	RGI Red Fall/Winter (Oct – Mar)
SW Bering Sea + Adak	62%	31%	83%
SE Bering Sea + Dutch Harbor	60%	35%	80%
North Pacific/Central Aleutians + Adak	69%	36%	87%
NE Pacific/Shumagin Islands + Cold Bay	65%	41%	84%
All Stations, Combined	**64%**	**36%**	**84%**

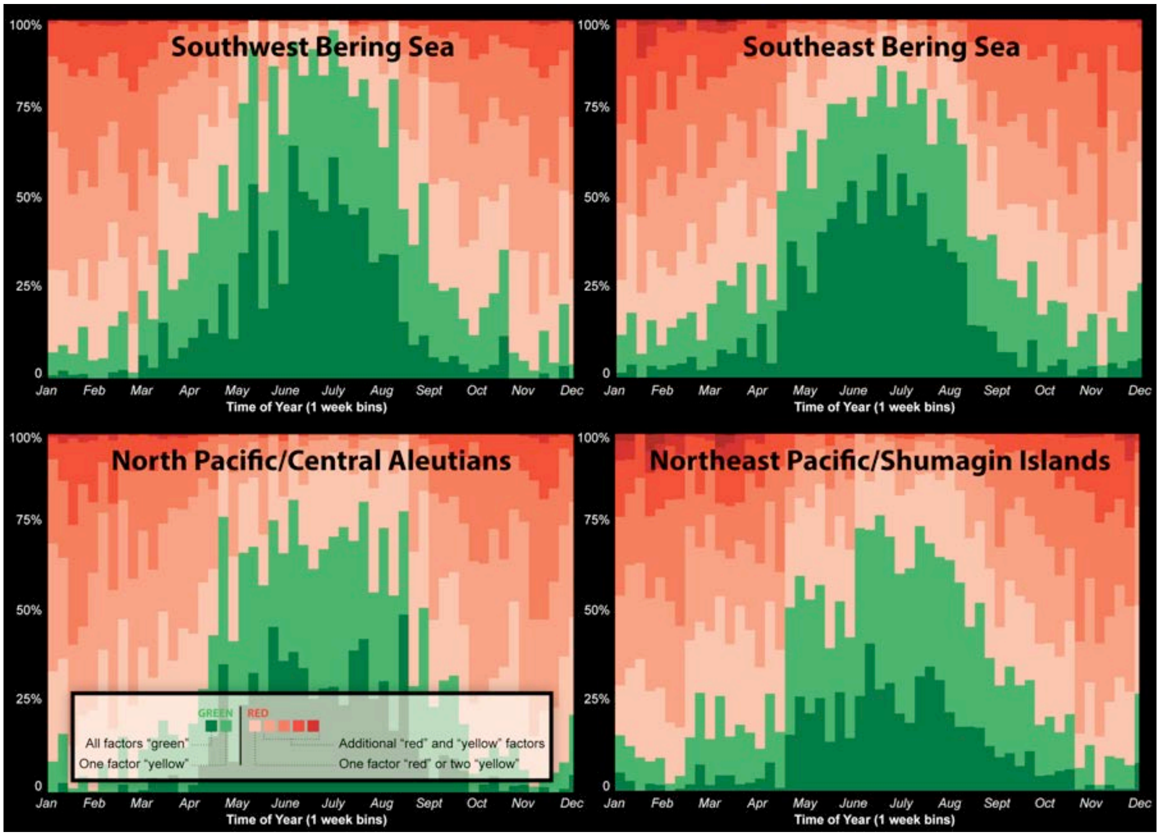

Figure 6.2 Response gap index at each location throughout the year for VESSEL DISPERSANT APPLICATIONS

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[20] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

6.5.2 Impact of Individual Factors on the Application of Dispersants from a Vessel

Table 6.6 shows the percentage of time when each environmental factor is considered green, yellow, and red, both combined across locations and at each location.

Sea state is once again the environmental factor that is the most likely to be red by itself across all geographical areas. Because darkness is considered yellow, instead of red, for the application of dispersants from vessels, cloud ceiling is not a factor and horizontal visibility has much less impact than for the application of dispersants from aircraft.

Table 6.6 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for the APPLICATION OF DISPERSANTS FROM A VESSEL

All Locations – Combined			
Environmental Factor	**GREEN**	**YELLOW**	**RED**
Wind	62%	28%	10%
Sea State	25%	29%	46%
Air Temperature	96%	3%	1%
Visibility & Daylight	53%	46%	1%
Southwest Bering Sea + Adak			
Wind	67%	26%	7%
Sea State	29%	27%	44%
Air Temperature	99%	1%	None
Visibility & Daylight	54%	45%	1%
Southeast Bering Sea + Dutch Harbor			
Wind	55%	31%	14%
Sea State	32%	29%	39%
Air Temperature	96%	4%	None
Visibility & Daylight	56%	44%	< 1%
North Pacific/Central Aleutians			
Wind	63%	29%	8%
Sea State	17%	30%	53%
Air Temperature	99%	1%	None
Visibility & Daylight	48%	51%	1%
Northeast Pacific/Shumagin Islands			
Wind	62%	29%	9%
Sea State	22%	32%	46%
Air Temperature	91%	5%	4%
Visibility & Daylight	52%	45%	3%

7. AERIAL SUPPORT FUNCTIONS: AERIAL SURVEILLANCE

Aerial observation and tracking of an oil spill is crucial to the effective deployment of response tactics, such as mechanical recovery and the application of dispersants. Aerial observation can also be used to assess a vessel's situation and inform planning for salvage operations. In addition to the environmental conditions considered here, it is limited by a set of environmental and operational limits, such as visibility over the spill, wind conditions at the airport, fuel availability, and pilot hours.

The response gap analysis for aerial surveillance is based on airport records for Adak, Dutch Harbor, and Cold Bay airports, identifying the approximate frequency that aircraft can operate from these airports for the purpose of aerial observation.

7.1 Overview and Assumptions for Aerial Surveillance

7.1.1 Overview of Operations

Air observation overlaps with light air logistics. Small aircraft suitable for air observation, such a twin-engine turboprops and Type 1 and 2 helicopters, are also suitable for light logistics, like ferrying small cargos and personnel into remote airstrips, or slinging cargo loads of less than a few tons, depending on the situation and aircraft.

7.1.2 Operating Limits

Two aircraft were used for this analysis as representative of the type that would be used for aerial observation: a Twin Otter small airplane and Bell 212 medium helicopter. The limits in Table 7.1 are based on parameters for the safe operation of these aircraft. (The limits for helicopters are different than for fixed-wing aircraft because helicopters can operate in higher crosswinds.)

To track and observe oil using current standard technology, aircraft must be able to take off and land safely and to observe the oil from the operating altitude over the water. As noted, conditions at the airport and at the spill location are not always the same; however, for this analysis, airport visibility is used as a proxy for visibility at the spill site, since there are no consistent historical records of visibility over the water.

Both gusts and absolute wind speed are used for absolute wind limits. A strong gust can move or even flip an aircraft at critical times, regardless of the continuous wind speed – for instance, when an airplane or helicopter is just lifting off. Wind shear – the difference between gusts and continuous wind speeds – represents the turbulence of wind conditions.[21,22] Aircraft are also limited by crosswind ratings,

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[21] Although unstable air conditions can occasionally lead to strong gusts even in relatively calm conditions, strong gusts are usually associated with strong, continuous wind conditions.

[22] Weather conditions which lead to airport shut-downs cannot be completely extracted the from the available data sets. Airport data does not always include crucial local effects. For example,

which establish the maximum crosswind an aircraft can safely tolerate in takeoff and landing.

This analysis assumes all observation aircraft are heated and can operate in cold conditions.

Table 7.1 Limits used for aerial observation (based on FAA Visual Flight Rules,[23] representative aircraft and expert input)

ENVIRONMENTAL FACTOR	**GREEN Response:** *Not Impaired*	**YELLOW Response:** *Impaired*	**RED Response:** *Not Possible/Effective*
Fixed Wing **W** (Wind in knots)	$\mathbf{W} < 30$	$30 \leq \mathbf{W} < 40$	$\mathbf{W} \geq 40$
Helicopter **W** (Wind in knots)	$\mathbf{W} < 40$	$40 \leq \mathbf{W} < 50$	$\mathbf{W} \geq 50$
S (Shear: gusts minus wind in knots)	$\mathbf{S} < 10$	$10 \leq \mathbf{S} < 15$	$\mathbf{S} \geq 15$
T (Temperature ºF)	$\mathbf{T} > -40$	not used	$\mathbf{T} \leq -40$
V (Visibility in nautical miles)	$\mathbf{V} > 3$	$3 \geq \mathbf{V} > 0.5$	$\mathbf{V} \leq 0.5$
C (Ceiling in feet)	$\mathbf{C} > 1200$	$1200 \geq \mathbf{C} > 500$	$\mathbf{C} \leq 500$
Daylight/Darkness	**Daylight**	not used	**Darkness**

7.2 Response Gap

This section presents the results of the analysis for aerial observation using both fixed- and rotary-wing aircraft. Of course, aircraft will need to have suitable conditions throughout their flight plan in order to implement surveillance activities.

7.2.1 RGI for Aerial Observation

This section presents the RGI – which considers the effect of *combining* individual factors – for individual locations and for all locations combined. Overall, the RGI for helicopters and fixed-wing aircraft are similar, at an average RGI of 52% for helicopters and 53% for fixed-wing aircraft. There is also very little variation across the three airport locations (even though they are more than 600 miles apart) and seasons. See Tables 7.2 and 7.3. By contrast, if only daylight hours are considered, the RGI for fixed-wing aircraft drops to 18%.

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at Dutch Harbor airport, winds crossing high terrain alongside the runway can create a "lee side eddy" – a horizontal, rolling eddy over the runway, making takeoff and landing unsafe. Another key hazard, especially at both Dutch Harbor and Adak, is moderate to extreme bird concentrations (AirNav.com). Whether aviation is safe is affected by complicating elements like individual aircraft limits and loading, pad location, and pilot judgment. Therefore, this analysis indicates only the minimum times when small aircraft aviation will be shut down.

[23] 14 CFR Part 91, General Operating and Flight Rules (FAA Regulations)

Table 7.2 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round, summer, and winter)[24] for AERIAL OBERVATION USING HELICOPTERS

STATION	RGI Red Year-Round	RGI Red Spring/Summer (Apr – Sep)	RGI Red Fall/Winter (Oct – Mar)
Adak	52%	44%	59%
Dutch Harbor	49%	36%	60%
Cold Bay	53%	43%	62%
All Stations, Combined	**52%**	**41%**	**60%**

Table 7.3 Summary of percent of time when RGI is RED – response may not be possible - at each location and all locations combined (year-round, summer, and winter)[25] for AERIAL OBERVATION USING FIXED WING AIRCRAFT

STATION	RGI Red Year-Round	RGI Red Spring/Summer (Apr – Sep)	RGI Red Fall/Winter (Oct – Mar)
Adak	54%	45%	61%
Dutch Harbor	50%	36%	61%
Cold Bay	55%	44%	63%
All Stations, Combined	**53%**	**42%**	**62%**

Figure 7.1 shows the annual variability in the RGI at different locations for fixed-wing aircraft (the results for helicopters were almost identical). Most of the red periods result from nighttime conditions. The extent of marginal red (light red) conditions suggests that nighttime observation equipment, if effective for tracking and observing spills, could substantially increase the effectiveness of aerial observation.

Appendix A shows the RGI at each location throughout the year in a calendar format, including periods for which there are data gaps.

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[24] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

[25] Year-round conditions are not the exact average of summer and winter conditions, due to the different day-lengths, the 5- and 7-month periods used, and rounding.

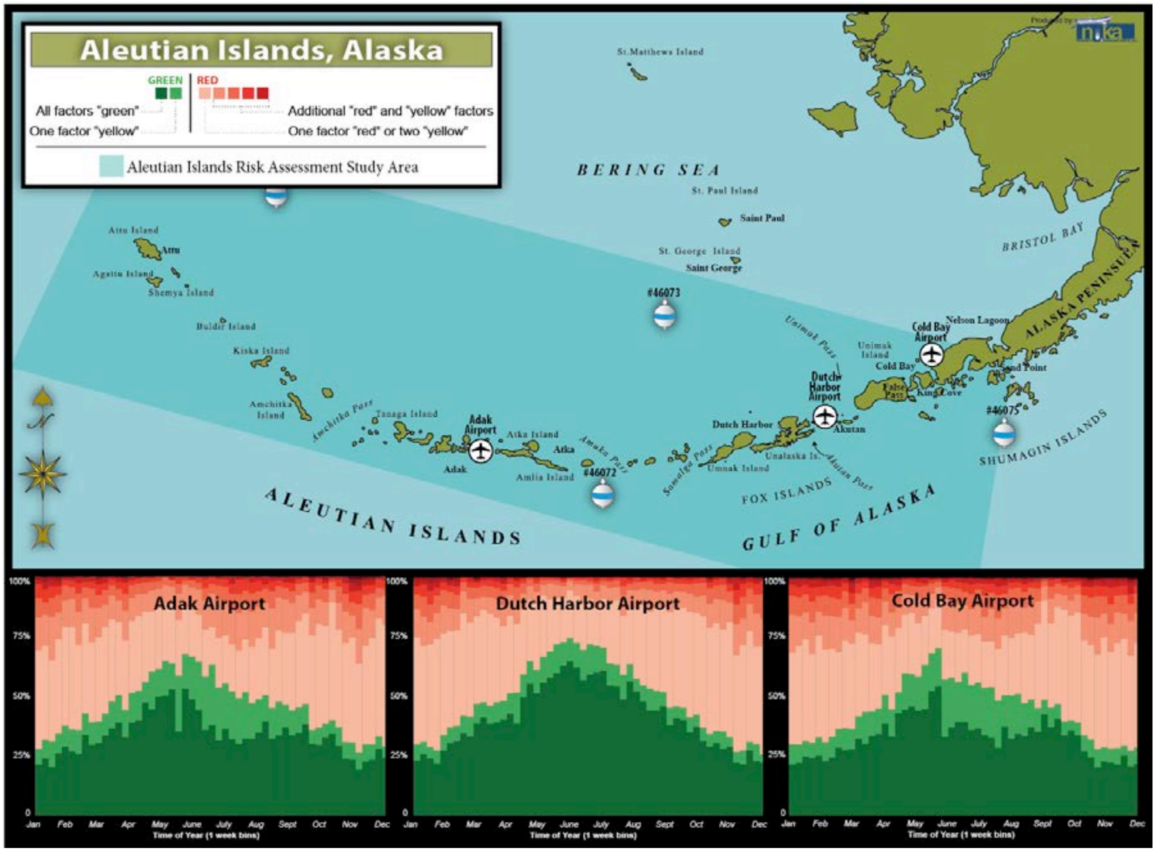

Figure 7.1 Response gap index at each buoy station throughout the year for AERIAL OBSERVATION USING FIXED WING AIRCRAFT

7.2.2 Impact of Individual Factors on Aerial Observation

Table 7.4 shows the percentage of time when each environmental factor is considered green, yellow, and red, both combined across locations and at each location. At all three airport locations, darkness – which has the same affect on both helicopters and fixed-wing aircraft - is most likely to be the predominant limiting factor.

Table 7.4 Percentage of green (not impaired), yellow (impaired), and red (not possible or effective) readings at all stations combined, and at individual stations for AERIAL OBSERVATION USING HELICOPTERS AND FIXED WING AIRCRAFT

Air Observation: All Locations – Combined						
Env'l Factor	**Green**		**Yellow**		Red	
	Airplane	Helicopter	Airplane	Helicopter	Airplane	Helicopter
Windspeed	89%	98%	8%	2%	3%	>1%
Wind Shear	73%		18%		9%	
Air Temperature	100%		None		None	
Visibility	86%		12%		2%	
Daylight / Darkness	57%		Not used		43%	
Ceiling	79%		13%		8%	
Adak						
	Helicopter	Airplane	Helicopter	Helicopter	Airplane	Helicopter
Windspeed	97%	7%	2%	97%	7%	<1%
Wind Shear	77%		16%		7%	
Air Temperature	100%		None		None	
Visibility	83%		16%		1%	
Daylight / Darkness	57%		Not used		43%	
Ceiling	Green		Yellow		Red	
Dutch Harbor						
	Helicopter	Airplane	Helicopter	Helicopter	Airplane	Helicopter
Windspeed	98%	6%	2%	98%	6%	2%
Wind Shear	70%		19%		11%	
Air Temperature	100%		None		None	
Visibility	90%		9%		1%	
Daylight / Darkness	57%		Not used		43%	
Ceiling	86%		9%		4%	
Cold Bay						
	Airplane	Helicopter	Airplane	Helicopter	Airplane	Helicopter
Windspeed	87%	97%	10%	3%	3%	< 1%
Wind Shear	71%		19%		10%	
Air Temperature	100%		None		None	
Visibility	85%		13%		3%	
Daylight / Darkness	58%		Not used		42%	
Ceiling	74%		15%		11%	

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8. AERIAL SUPPORT FUNCTIONS: AIR LOGISTICS

Logistics in the Aleutian Islands rely on air and sea transportation. For the purposes of oil spills and salvage, the important resources for an early-stage response will necessarily already be in or near the archipelago, or flown in by air. By sea, Dutch Harbor is roughly 600 statute miles from Kodiak and 850 from Anchorage. Seattle and Vancouver are more than 1800 miles away.

Weather conditions affect air logistics, for the obvious reason that they can be prohibitive to aviation. In the Aleutian area, these conditions can include fog/low cloud ceiling, driving snow, runway snow or icing, and high winds and turbulence. Extreme low temperatures are not a major concern, despite the high latitude, due to the moderating marine influence.

Other factors will also affect the success of air logistics operations, including airport facilities, airport congestion, runway condition and length, fuel supplies, and having sufficient numbers of trained personnel in the right place when needed. These factors fall outside the scope of this response gap study.

8.1 Approach to Understanding Gaps in Air Logistics

Because aircraft consistently operate in the region – unlike spill response or salvage operations which are deployed only for emergencies or occasional exercises – we can consider the “response gap” for air logistics in terms of the frequency of commercial flight cancellations into key airports in the region. Even though we do not know the reason for the cancellation (for example, whether it was due to low visibility or high winds, or factors beyond those in the environmental dataset, such as runway icing or mechanical problems), the Federal Aviation Administration (FAA) data already incorporates all relevant environmental factors by recording whether a flight into an Aleutian Islands region airport was cancelled or diverted, i.e., equated a “red” condition using the RGI approach.

Because flights may be cancelled due to conditions anywhere along their route, the cancellation of a flight from Anchorage to Dutch Harbor, for example, does not necessarily indicate that conditions were unsuitable for flying within the Aleutian Islands region itself. For this reason, we use flight cancellations at Aleutian region airports to indicate a gap in the ability to deliver personnel, equipment, and supplies from Anchorage or other locations out of the region; these cancellations do not indicate whether aircraft could be used locally for surveillance or dispersant applications.

8.2 Overview of Operations and Potential Limits

8.2.1 Overview of Operations

Aircraft used will vary depending on cargo and airfield parameters. Small numbers of key personnel may be deployed by small prop planes, enabling the use of very short and unimproved, or even improvised, runways. Medium-weight equipment and larger groups may be moved by midweight transport aircraft, such as the C-130, which is able to use most significant airports in the islands, including Dutch Harbor. Finally, some equipment, like heavy helicopters, can only be moved in heavy transport aircraft. These aircraft will likely fly into Cold Bay or Adak.

In the case of a very large incident, large numbers of personnel and amounts of equipment may be flown on chartered jets from out-of-state. Depending on incident-needs and on-the-ground logistics, these jets will probably use Adak, Cold Bay, or Anchorage. From these locations, personnel and material could be redeployed using lighter aircraft.

8.3 Recorded Flight Cancellations

The Federal Aviation Administration (FAA) records the incidence of on-time, delayed, diverted, and cancelled flights for major airports and certain air carriers. Unalaska (Dutch Harbor) and Adak Island are included in the public database, with Alaska Airlines information. Cold Bay is not.

Overall, while weather conditions may challenge the delivery of equipment and personnel for a response, this can be expected to happen no more than a quarter of the time for commercial flights, and may be less often for cargo deliveries. While flying into or around the region may be prevented for days at a time, overall, it appears reasonable to plan on some amount of cascading of resources from outside the region.

8.3.1 Dutch Harbor Flights Cancelled or Diverted

Alaska Airlines flies both jets and, more recently, turboprop aircraft (contracted through PenAir) into Dutch Harbor. Overall, the turboprop flights into Dutch Harbor were cancelled or diverted less frequently than jets. As noted in Table 8.1, below, the flight cancellation and diversion data for the two types of aircraft span different sets of years.

During an 8-month period from 2003-2004,[26] 26% of the 461 jet flights were cancelled or diverted at Dutch Harbor. This sample did not include February-May, a period which includes some of Dutch Harbor's lowest visibility and highest wind speeds in the area (Nuka Research, 2013).

Over 32 months, 7,175 turboprop flights were scheduled to service Dutch Harbor, or an average of more than 7 flights per day. These aircraft have a higher success rate, with an annual 3-year average of only 13% of scheduled flights failing to land. However, seasonality is a crucial factor: during January of 2011 and 2012, almost one-third (28%) of PenAir Saab 340 flights coming to Dutch Harbor were cancelled or diverted. During January 2004, 31% of Alaska Airlines 737 flights failed to arrive in Dutch Harbor. January is consistently the month in which turboprop flights are most likely to be cancelled or diverted based on 2010 – 2012 data. However, arrival rates vary considerably for a given month across years, suggesting that weather conditions can vary considerably. For instance, May turboprop arrivals from 2010-

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[26] Longer records were not available through the FAA, and were not successfully secured from Alaska Airlines.

2012 vary from 96% success rate to only a 76% success rate. Of the 8-month record for jet landings in Dutch Harbor, the worst month was October, in which 42% of flights were cancelled or diverted.

Table 8.1 Percentage of scheduled flights that were cancelled or diverted coming to Dutch Harbor (Boeing 737 and Saab 340). *The years noted refer to the years for which data was available for that calendar month.*

JET Alaska Airlines Boeing 737 (461 total scheduled flights)		**TURBOPROP PenAir Saab 340 (7,175 total scheduled flights)**	
Month	**% Cancelled or diverted**	**Month**	**% Cancelled or diverted**
January (2004)	31%	January (2011-2012)	28%
February	No data	February (2011-2012)	15%
March	No data	March (2011-2012)	12%
April	No data	April (2011-2012)	15%
May	No data	May (2011-2012)	11%
June (2003)	14%	June (2010-2012)	9%
July (2003)	29%	July (2010-2012)	10%
August (2003)	16%	August (2010-2012)	11%
September (2003)	32%	September (2010-2012)	6%
October (2003)	42%	October (2010-2012)	9%
November (2003)	14%	November (2010-2012)	15%
December (2003)	34%	December (2010-2012)	18%
Combined average	**26%**	**Combined average**	**13%**

8.3.2 Adak Flights Cancelled or Diverted

Only 8% of flights to Adak were diverted or cancelled, year round, though it also had less traffic overall: 1,042 flights came in over 10 years, in comparison to Dutch Harbor's 461 jet flights over eight months. In relative traffic volume for the sample periods, Adak saw only 15% of the Alaska Airlines jet traffic of Dutch Harbor. Table 8.2 summarizes this information.

Table 8.2 Percentage of scheduled flights that were cancelled or diverted coming to Adak (Boeing 737). *Percentages are based on data from 2003-2013.*

JET Alaska Airlines Boeing 737 (1,042 total scheduled flights)	
Month	**% Cancelled or diverted**
January	17%
February	6%
March	11%
April	1%
May	3%
June	1%
July	8%
August	11%
September	5%
October	8%
November	5%
December	14%
Combined average	**8%**

9. DISCUSSION

Everyone knows the weather is bad in the Aleutians. The fact that six lives were lost when the rescue helicopter was struck by a wave while they were being lifted from the *M/V Selendang Ayu* means nobody can ever think it will be an easy place to conduct marine rescue, repairs, or recovery of lost oil or other cargo or fuel. This report seeks to put some quantitative analysis to that general knowledge and provide information for the recommendation of an optimal system that is practical and realistic given the environmental conditions. Safety is always the highest priority in any response and to the maximum extent possible we have tried to include safety as a factor in response limitations.

Table 9.1 summarizes the RGI for each tactic (averaged across all applicable locations), including both the percentage of time that the RGI is red and the corresponding amount of time when a response may be possible.

Table 9.1 Combined, average RGI for each tactic and percentage of time response may be possible

RESPONSE TACTIC	RGI Red Year-Round (Response Impossible)	Response May be Possible
Emergency Towing	2%	98%
Helicopter Lightering	20%	80%
Open-water Mechanical Recovery	72%	28%
Nearshore Mechanical Recovery -- Unalaska Bay (Daytime only)	52%	48%
Aerial Application of Dispersants	72%	28%
Vessel Application of Dispersants	64%	36%
Air Observations -- Fixed Wing (Daytime only)	18%	82%

9.1 Overall Observations

Overall, darkness and sea state appear to have the greatest effect on the ability to deploy the response operations considered here.

While this analysis conveys overall that response in the Aleutian Islands region is likely to be precluded or significantly compromised by environmental conditions, the good news is that the pollution prevention activities of emergency towing and lightering via helicopter are the most likely activities to be able to be implemented. The RGI for these operations is much lower than for spill response activities, though mounting such operations requires that the necessary tow vessels, aircraft, and equipment be available (including adequate storage).

The RGI for aerial observation is also lower than for the response tactics. This at least means that in the event of an incident or accident, responders will be fairly likely to be able to get the information they need in order to plan for response activities when they can ensue, or understand and anticipate the spill trajectory and therefore the resources that may be affected.

The average RGI are fairly similar for spill response operations, which can be expected to be very challenging if they can be implemented at all. All three open-water tactics have large seasonal variations in feasibility, with RGIs rising to 84% to 90% in the winter, meaning that any of these response operations would be, at best, possible less than 20% of the time. Of these, the application of vessel dispersants has the lowest RGI to a small degree.

For nearshore mechanical recovery, we believe that the fact that we had to use marine forecasts to represent sea state makes this number conservative when compared to other RGI. At least some of the Aleutian Islands have embayments that offer protection from the sea and these locations always have sensitive habitat and are used as a refuge for many sensitive species. Experience during the *Selengdang Ayu* response proved that nearshore response, shoreline protection, and shoreline cleanup tactics could be successfully implemented, even through the winter months.

9.2 Operating in Darkness

As noted, darkness has a crucial impact on open-water response. This analysis assumes that many of the operations considered here could be implemented in darkness (open-water mechanical recovery, vessel application of dispersants, and helicopter lightering), but that operating at night will be more challenging than operating in daylight, and thus susceptible to being precluded by marginal (yellow) conditions in other categories.

Nighttime operations require specific equipment, training, and exercises in order to be conducted successfully and safely. Without these, nighttime operations would be precluded. Table 9.2 shows the RGI for different operations if nighttime is omitted entirely as an option (for example, if a response system was not adequately equipped and experienced). The RGI are *lower* because they refer only to the expected RGI during *daylight* hours.

Table 9.2 RGI for all time periods and RGI with night excluded from the analysis

Location	RGI for All Time Periods			RGI with Night Excluded as an Option for All		
	Overall	Summer	Winter	Overall	Summer	Winter
Emergency Towing						
North Pacific	3%	<1%	4%	<1%	<1%	1%
Northeast Pacific	2%	<1%	3%	<1%	0%	<1%
Southeast Bering Sea	1%	<1%	2%	<1%	0%	<1%
Southwest Bering Sea	2%	<1%	4%	<1%	0%	1%
Average	2%	<1%	4%	<1%	<1%	<1%
Helicopter Lightering						
North Pacific	17%	19%	15%	9%	11%	8%
Northeast Pacific	27%	27%	27%	18%	18%	18%
Southeast Bering Sea	17%	11%	22%	9%	6%	11%
Southwest Bering Sea	18%	19%	17%	9%	11%	8%
Average	20%	19%	20%	11%	11%	11%
Open-water Mechanical Recovery						
North Pacific	78%	50%	93%	64%	35%	86%
Northeast Pacific	74%	55%	90%	60%	42%	81%
Southeast Bering Sea	66%	39%	86%	50%	29%	76%
Southwest Bering Sea	71%	43%	90%	54%	30%	79%
Combined Average	72%	47%	90%	57%	34%	81%
Nearshore Mechanical Recovery						
Unalaska Bay	60%	43%	73%	52%	34%	66%
Aerial Application of Dispersants						
North Pacific	76%	54%	89%	57%	34%	76%
Northeast Pacific	75%	63%	86%	58%	47%	71%
Southeast Bering Sea	65%	47%	80%	40%	25%	58%
Southwest Bering Sea	72%	55%	85%	50%	36%	67%
Average	72%	55%	85%	51%	36%	68%
Vessel Application of Dispersants						
North Pacific	69%	36%	87%	54%	24%	78%
Northeast Pacific	65%	41%	84%	50%	30%	74%
Southeast Bering Sea	60%	35%	80%	46%	26%	69%
Southwest Bering Sea	62%	31%	83%	44%	20%	69%
Average	64%	36%	84%	49%	25%	72%
Air Observations (Fixed Wing)						
Adak Airport	54%	45%	61%	19%	19%	19%
Cold Bay Airport	55%	44%	63%	22%	22%	22%
Dutch Harbor Airport	50%	36%	61%	13%	10%	17%
Average	53%	42%	62%	18%	17%	19%

9.3 Prevalence of "Marginal" Red/Green Conditions

Even though the RGI is presented as a single percentage of time when a response could be expected to be prevented by conditions, we also see that in many cases that are coded as "red" or "green" are only marginally so. Many times when a response could be considered possible (or "green") are accompanied by a yellow condition for the same time period (shown by light green on the figures in each section). Responders familiar with typical Aleutian Islands conditions are likely to be the best suited to operating in these marginally green conditions, if they have the necessary equipment and training. On the other hand, the marginally red conditions indicate that improvements in the ability to deal with just one environmental factor – such as operating more effectively in darkness, for example – could improve the RGI by shifting those observational periods from red to green.

9.4 Considering the RGI Over Time

This study does not consider whether there is enough time with conditions conducive to a response to be able to deploy the tactics: each hourly period is evaluated without consideration of the hour before or after. For example, this means if is a three-hour window of green conditions in the middle of a stormy day, the RGI for that day would be considered 12%. In reality, it is unlikely that a response force would be mobilized and deployed during that window (though this time could be used for aerial observation, depending on the proximity of the spill site to an airport). Prudence and the priority of responder safety will dictate when a window of opportunity can actually result in a period of response activity. In this way, the RGI may actually *over*estimate the percentage of time that a response is actually possible. This may be especially true for an area like the in the Aleutians, where responders may have to travel great distances without the benefit of safe harbors in which to wait out periods of poor conditions.

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Appendix A

The figures in Appendix A show periods when conditions are known for sure to be green (requiring that there is data for all conditions, and that they are all green) or known for sure to be red (because one or more factors for which data is available were red). It does not include observational periods that could not be definitively determined to be red or green due to gaps in information about some or all of the environmental factors. The pale blue and yellow shading shows the daylight/darkness as it changes throughout the year.

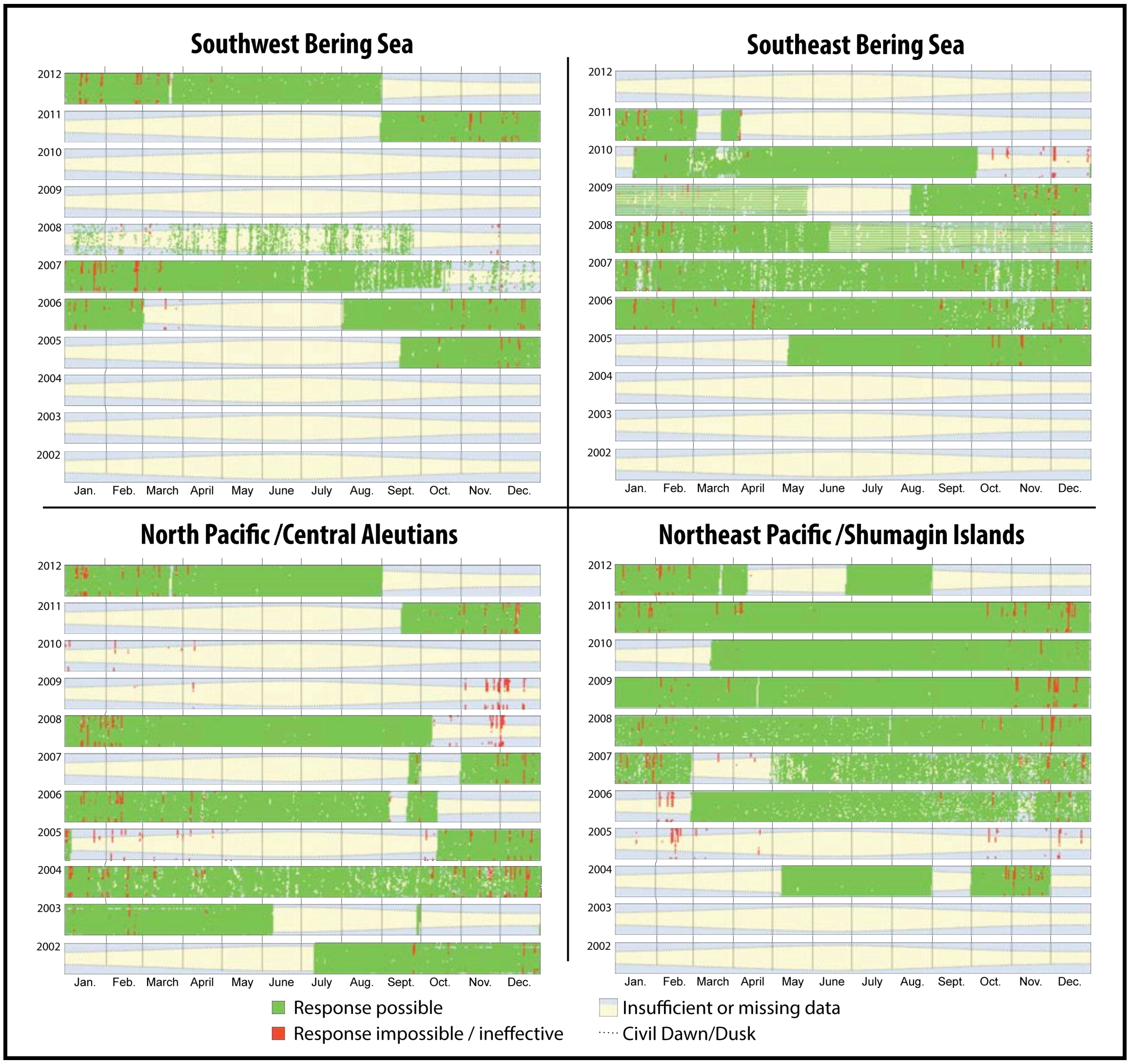

Figure A-1 Distribution of RGI at each buoy station for EMERGENCY TOWING

Figure A-2 Distribution of RGI at each buoy station for LIGHTERING WITH HELICOPTER SLING

Figure A-3 Distribution of RGI at each buoy station for OPEN-WATER MECHANICAL RECOVERY

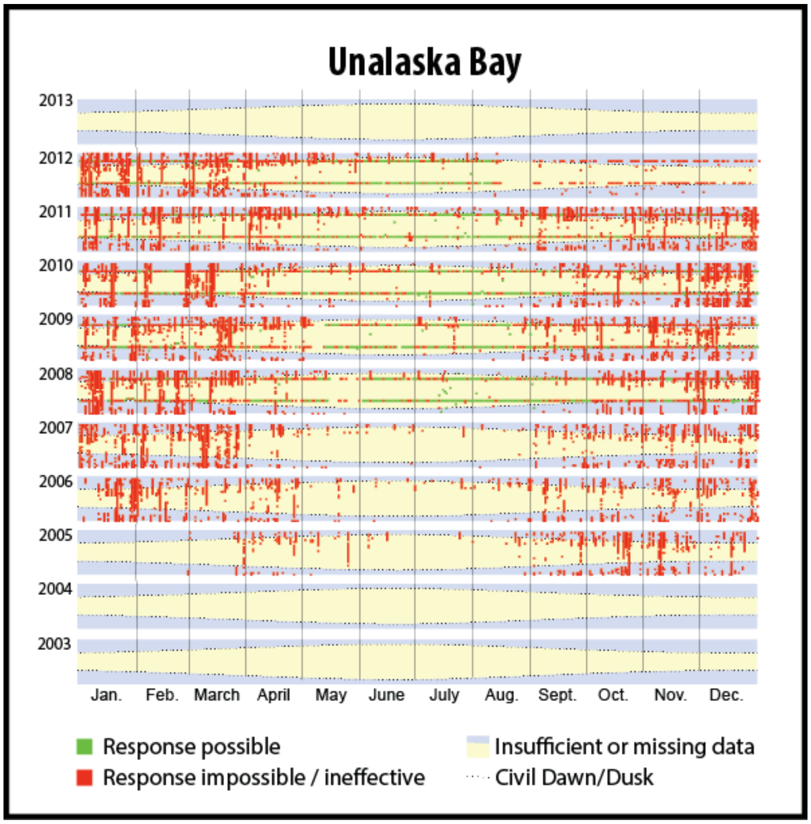

Figure A-4 Distribution of RGI at Unalaska Bay for NEARSHORE MECHANICAL RECOVERY

Figure A-5 Distribution of RGI at each buoy station for AERIAL DISPERSANT APPLICATIONS

Figure A-6 Distribution of RGI at each buoy station for DISPERSANT APPLICATION FROM VESSEL

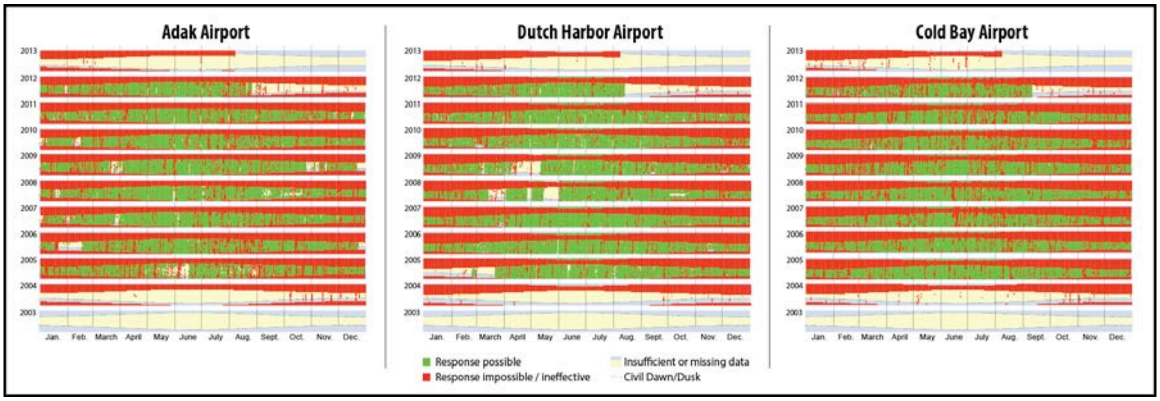

Figure A-7 Distribution of RGI at each buoy station for AERIAL OBSERVATION USING FIXED WING AIRCRAFT