OCEAN RENEWABLE POWER COMPANY

U.S. DEPARTMENT OF ENERGY

ACOUSTIC MONITORING OF BELUGA WHALE INTERACTIONS WITH COOK INLET TIDAL ENERGY PROJECT

DE-EE0002657

FINAL TECHNICAL REPORT

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Project Title:	**Acoustic Monitoring of Beluga Whale Interactions with the Cook Inlet Tidal Energy Project**
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EXECUTIVE SUMMARY

Cook Inlet, Alaska is home to some of the greatest tidal energy resources in the U.S., as well as an endangered population of beluga whales (*Delphinapterus leucas*). Successfully permitting and operating a tidal power project in Cook Inlet requires a biological assessment of the potential and realized effects of the physical presence and sound footprint of tidal turbines on the distribution, relative abundance, and behavior of Cook Inlet beluga whales. ORPC Alaska, working with the Project Team—LGL Alaska Research Associates, University of Alaska Anchorage, TerraSond, and Greeneridge Science—undertook the following U.S. Department of Energy (DOE) study to characterize beluga whales in Cook Inlet – Acoustic Monitoring of Beluga Whale Interactions with the Cook Inlet Tidal Energy Project (Project).

ORPC Alaska, LLC, is a wholly-owned subsidiary of Ocean Renewable Power Company, LLC, (collectively, ORPC). ORPC is a global leader in the development of hydrokinetic power systems and eco-conscious projects that harness the power of ocean and river currents to create clean, predictable renewable energy. ORPC is developing a tidal energy demonstration project in Cook Inlet at East Foreland where ORPC has a Federal Energy Regulatory Commission (FERC) preliminary permit (P-13821).

The Project collected baseline data to characterize pre-deployment patterns of marine mammal distribution, relative abundance, and behavior in ORPC's proposed deployment area at East Foreland. ORPC also completed work near Fire Island where ORPC held a FERC preliminary permit (P-12679) until March 6, 2013. Passive hydroacoustic devices (previously utilized with bowhead whales in the Beaufort Sea) were adapted for study of beluga whales to determine the relative abundance of beluga whale vocalizations within the proposed deployment areas. Hydroacoustic data collected during the Project were used to characterize the ambient acoustic environment of the project site pre-deployment to inform the FERC pilot project process. The Project compared results obtained from this method to results obtained from other passive hydrophone technologies and to visual observation techniques performed simultaneously. This Final Report makes recommendations on the best practice for future data collection, for ORPC's work in Cook Inlet specifically, and for tidal power projects in general.

This Project developed a marine mammal study design and compared technologies for hydroacoustic and visual data collection with potential for broad application to future tidal and hydrokinetic projects in other geographic areas. The data collected for this Project will support

the environmental assessment of future Cook Inlet tidal energy projects, including ORPC's East Foreland Tidal Energy Project and any tidal energy developments at Fire Island. The Project's rigorous assessment of technology and methodologies will be invaluable to the hydrokinetic industry for developing projects in an environmentally sound and sustainable way for areas with high marine mammal activity or endangered populations. By combining several different sampling methods this Project will also contribute to the future preparation of a comprehensive biological assessment of ORPC's projects in Cook Inlet.

COMPARISON OF ACTUAL ACCOMPLISHMENTS WITH GOALS AND OBJECTIVES

Objectives:

1. *Develop and implement the technology to acoustically detect beluga whales by recording their vocalizations and echolocations.*

   The first objective involved the comparison of the 2009 visual observations and 2009 Team Cook Inlet Beluga Acoustics (Team CIBA) acoustic data collected from two Passive Acoustic Monitoring (PAM) devices: the Ecological Acoustic Recorders (EAR) and C-Pod (Task 1.1). It also utilized information from a Team CIBA study to design, build, calibrate and test two other PAM devices for Cook Inlet deployments: Directional Autonomous Seafloor Acoustic Recorders (DASARs) and an Acousonde (Task 1.2).

   <u>Accomplishments</u>
   The comparison of visual and acoustic data was completed, allowing an assessment of efficacy of visual observations to hydroacoustic detections by EAR and C-Pod devices.

   Greeneridge Sciences designed a custom DASAR, named the Cook Inlet DASAR. Four DASARs were built; but after a short test deployment in 2010 that included an Acousonde acoustic recorder, it was decided that the Acousonde would not be included in future deployments as battery and memory storage could not supply long-term data collection. Two DASARS were deployed at Fire Island for the overwinter time period from 2010-2011.

2. *Use paired acoustic and visual monitoring to study the baseline (pre-deployment) distribution, relative abundance, and behavior of beluga whales in the proposed tidal turbine deployment areas, near Fire Island and East Foreland, Cook Inlet, Alaska. Correlate visual and acoustic detections of whales.*

   Visual observation work at Fire Island was completed by November 2011 and totaled 122 days of visual observations between June 2009 – November 2009 and May 2010 – November 2010 (Task 2). LGL summarized the baseline distribution of beluga whales observed near the project site at Fire Island in reports (Attachment A and B).

   Visual observations continued at East Foreland in September and October 2012 and May 2013, but efforts were limited to vessel-based marine mammal observers (MMOs) monitoring PAM deployment and retrieval operations. Because of logistical challenges of shore-based observations at East Foreland and limited budget available to support these efforts through the end of the project performance period, no long-term visual monitoring were conducted at this location. During deployment and retrieval operations at East Foreland, an MMO observed several seals on each expedition but no belugas at the Project site. During a mooring inspection on April 26, 2013, ORPC personnel incidentally observed a beluga approximately one mile south of the Project site. This observation was shared with National Marine Fisheries Service (NMFS) for their Opportunistic Sightings Database.

Hydroacoustic data were collected at Fire Island utilizing EARs and C-Pods as part of the Team CIBA project as well as from two DASARs deployed with this Project. Visual observations overlapped with EAR deployment for 89 days, C-Pod deployment for 55 days and DASAR deployment for 9 days. The DASARs, EAR and C-Pod were co-deployed for 163 days. At East Foreland DASARs were the only devices deployed with no meaningful overlap with either visual observations or other PAM devices. 123 days of hydroacoustic data were recorded at East Foreland.

<u>Accomplishments</u>
Visual observations were successfully implemented at Fire Island and performed for 122 days. LGL completed annual final reports on the results of this data collection (Attachment A and B); these reports were shared with NMFS and are available publically at http://alaskafisheries.noaa.gov/protectedresources/whales/beluga.htm. The visual observation and hydroacoustic data collected at Fire Island were compared to each other, as well as to hydroacoustic data from PAM devices and from each PAM device to the other PAM devices. Hydroacoustic data were collected at East Foreland and successfully detected belugas there (Attachment C: Report on beluga detections at the East Foreland Project site).

3. *Determine the baseline acoustic environment of the study areas pre-deployment.*

The data from short duration and overwinter PAM deployments at Fire Island and East Foreland were analyzed to assess the ambient acoustic environment. A unique feature of the DASARs was the utilization of three hydrophones within each DASAR allowing removal of "pseudo-noise" contamination, potentially enabling more accurate measurements of ambient sound than recording devices equipped with only a single hydrophone (Attachments C and D).

<u>Accomplishment</u>
Ambient sound was characterized at East Foreland and Fire Island, with and without pseudo-noise removed, to compare the efficacy of this method and enhance the rigor of ambient sound data collected with a stationary hydrophone system.

4. *Provide recommendations on best practice for collecting data on beluga marine mammal occurrence in Cook Inlet for future data collection and project monitoring efforts.*

Through this Project, ORPC gained experience working at two distinct sites utilizing two entirely different modalities (visual and hydroacoustic data collection) and several different PAM technologies (EAR, C-Pod and DASAR). This experience allowed ORPC to compare and contrast different data collection techniques, technologies, and data analysis methods.

Accomplishment
Comparison of data collected concurrently between visual and hydroacoustic data (EAR and C-Pod) highlighted that each technique was effective in detecting belugas at different times and at different ranges from the project site, showing the relevance of each technique. Analysis of data from the different hydrophone types showed a striking difference between the detections from a device that targets echolocations (C-Pod) from devices that target the frequency of social vocalizations (EAR and DASAR) and showed that collecting data on these two different hydroacoustic signals from beluga whales added value to understanding belugas' use of a given habitat. Comparison of devices targeting social vocalizations showed a tendency for continuous recording over a limited frequency range (DASAR) to be more effective in detecting belugas than a duty-cycled device with a wider frequency range (EAR). Ambient sound characterization was successfully performed utilizing a stationary PAM device - the DASAR - and included filtering some pseudo-noise out of the data to provide a more robust representation of actual ambient sound conditions.

SUMMARY OF PROJECT ACTIVITIES

Original Hypotheses
The Project proposed adapting the use of passive hydroacoustic devices and visual observations to determine both relative abundance and location of beluga whale vocalizations at proposed deployment areas of tidal energy devices and comparing the efficacy of each method for rigorous data collection to allow comparison of beluga use of an area before and after the deployment of tidal energy devices.

Approaches Used
Several data collection approaches were used including visual observations as well as hydroacoustic measurements utilizing three different types of PAM devices: EARs, C-Pods, and DASARs.

Visual observations
Visual observations were the most established and utilized method for collecting data on beluga occurrence in Cook Inlet when this Project began. Typically, visual observations were made from relatively long detection ranges and from a good vantage point. By using this approach, data collected for this Project could be compared with data collected at other project sites. There were, however, several disadvantages of visual observations: (1) observations were limited to daylight hours, (2) there were seasonal limitations due to inclement weather in fall, winter and

spring, (3) ice floes impeded effective visual observations, and (4) there were limits in duration of effective continual observations due to observer fatigue.

Visual observations of the presence, abundance, and surface-behavior of beluga whales and other marine mammals were conducted by trained observers stationed on a tower atop a cliff 64.5 m (212 ft) above the Mean Low Water line overlooking the proposed Deployment Area. Observers surveyed for belugas from land (at the observation site), as well as from the air during flights to and from Fire Island. Observations were also conducted from a research vessel used to transport observers to and from Fire Island on a few occasions and from the deployment and retrieval vessel used for PAM device operations at Fire Island and East Foreland.

Land-based observers used hand-held binoculars, spotting scope, a survey grade theodolite, and the naked eye to search for belugas in the proposed Deployment Area and surrounding areas as far as the Susitna River and Point MacKenzie. Beluga locations were recorded in two ways: (1) by using a 500 m x 500 m (1,640 ft x 1,640 ft) grid-cell map of the field of view and, (2) using a theodolite and software combination. See Figure 1 for the field of view of visual observers at the Fire Island observation site.

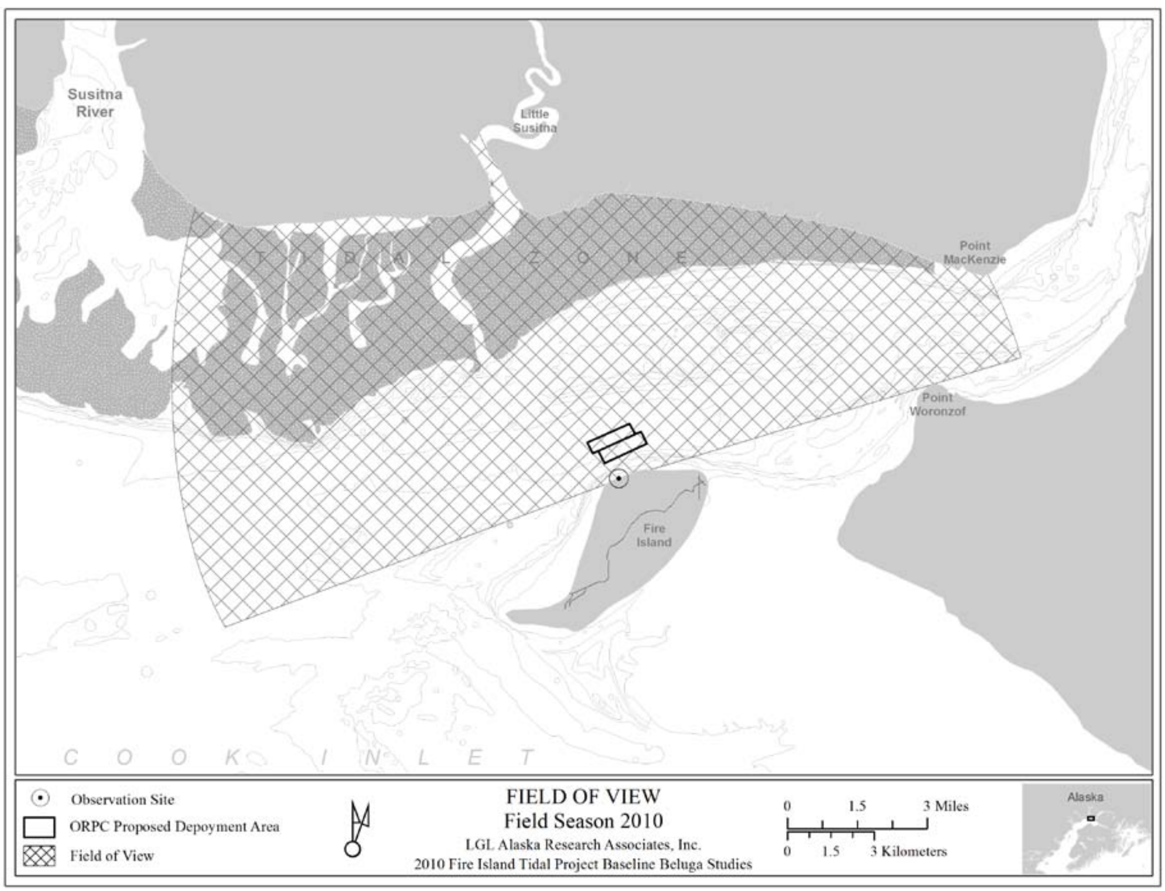


Figure 1. The maximum field of view as seen from the observation tower and measured with the theodolite. The Deployment Area may be subject to change upon further development of the Project.

For this Project visual observations were performed for a total of 122 days at Fire Island. This included concurrent observations with 89 days of EAR deployment, 55 days of C-Pod deployment and 9 days of DASAR deployment. Because the overlap with DASAR data collection was not significant, the focus of comparison with PAM data collection was on the concurrent observations with EAR and C-Pod deployments. Overall visual observations detected beluga whales on 48 of the 122 days or 39% of the time. During the times of concurrent deployment, visual observations proved effective detecting whales on 33 days when they were not acoustically detected by the EAR and 13 days they were not detected by the C-Pod. By comparison there were 4 days when the C-Pod detected whales that were not visually observed and 4 days in which the EAR detected whales that were not visually observed, while there were 11 days of concurrent detections between visual observations and PAM detections. The larger amount of visual observations as compared to PAM detections may largely be due to the greater range of detection, up to 7 km, as compared to an assumed (but not measured) range of approximately 1.5-3 km for the EAR and 1 km for the C-Pod. However, there were 7 occasions when visual observations were made within 4 km of the PAM devices that were not acoustically detected; two of which were a single beluga whale less than 1 km away from the PAM devices. It is possible that this indicated a lack of frequent vocalizations for solitary beluga whales or small groups.

Visual observations were demonstrated to be an effective means to augment hydroacoustic data as they clearly enhanced the understanding of beluga use of an area, particularly by extending the observation field to a larger area but also by detecting whales that may not be engaged in vocalizing. Data on whales over a wide spatial range from the Project could help estimate at what range behavioral responses (if any) to a project might be noticed.

<u>Hydroacoustic data collection</u>

Three different PAM technologies were utilized at Fire Island and one at East Foreland.

Two DASARs manufactured by Greeneridge Sciences, one Ecological Acoustic Recorder (EAR) from Oceanwide Science Institute, and one C-Pod manufactured by Chelonia Ltd. were deployed at Fire Island (Figure 2), whereas two DASARs were utilized at East Foreland. Each of these devices has specific capabilities and limitations based on the nature of the deployment configurations required for long-term autonomous deployment in Cook Inlet. Table 1 outlines the specifications of each device as they were configured for deployment in Cook Inlet. Of key importance in distinguishing the capabilities of each device was the frequency range over which they each sample sound. The DASAR had the lowest frequency range sampling from 100 – 2250 Hz, which only covers the lower portion of the beluga whale vocalization spectrum. However, due to the lower sample rate, it is able to record continuously during long-term deployment. The EAR samples sound from 1000 - 12,000 Hz, covering nearly the entire range of beluga vocalizations. But due to the higher sample rate, it must be duty-cycled to only record 10% of the time to conserve limited hard drive and battery storage during long-term deployments. The C-Pod sampled the highest frequency range of the devices from 20,000 – 160,000 Hz and covered the range of echolocation clicks used by beluga whales. While the C-Pod is able to monitor continuously over this range during long-term deployments, it is designed to process the sound data onboard and only logs detections rather than recording the acoustic signals themselves, thus allowing it to conserve hard drive space over long term deployments. This analysis compared the efficacy of these different PAM devices as they were configured for long-term deployment in Cook Inlet and for efficacy in detecting beluga whale vocalizations at potential tidal energy sites in Cook Inlet.

Figure 2. Cook Inlet DASAR and mooring frame, left. Ready for deployment onboard vessel, right.

Table 1. *Fire Island data collection and analysis*

Device	**Sampling**	**Range of Sound**	**Mode**	**Target**
DASAR 101 and 103	Continuous	100 - 2,250 Hz	Recording	Beluga vocalizations; ambient sound levels
EAR	Duty cycled to record 10% of the time, 30 seconds every 5 minutes.	1,000 and 12,000 Hz	Recording	Beluga vocalizations
C-Pod	Continuous	Up to 160,000 Hz	Detection logging	Beluga echolocations

For purposes of comparison the Fire Island deployment was the main focus, as co-deployment of the devices allowed comparison of their efficacy in detecting beluga whales. Between November 13, 2010 and April 24, 2011 two DASARs were deployed north of Fire Island in northern Cook Inlet, Alaska, near ORPC's proposed deployment area for a tidal energy project. Deployment required a Land Use Permit from the Alaska Department of Natural Resources (LAS 27690). The DASARs (SN 101 and 103) continually sampled for sounds over the 163 days of deployment to collect data on beluga vocalizations near the project area and ambient sound levels in Cook Inlet. At the same time a mooring containing an EAR (vocalizations) and C-Pod (echolocations) were operating in the same vicinity with the C-Pod. The EAR was configured for duty-cycling recording 10% of the time, 30 seconds every 5 minutes. The C-Pod continuously sampled for echolocations and data logged detections after on-board processing, but did not store sound files. These PAM devices were all located within 700 m of one another, with DASAR SN103 and the EAR/C-Pod mooring within 300 m of one another (Figure 3). The data were processed from DASAR SN103, the EAR and C-Pod for the 163-day period of co-deployment in order to compare the efficacy of each device for detecting belugas in the project area and to gather baseline information on frequency and seasonality of beluga occurrence at the project site.

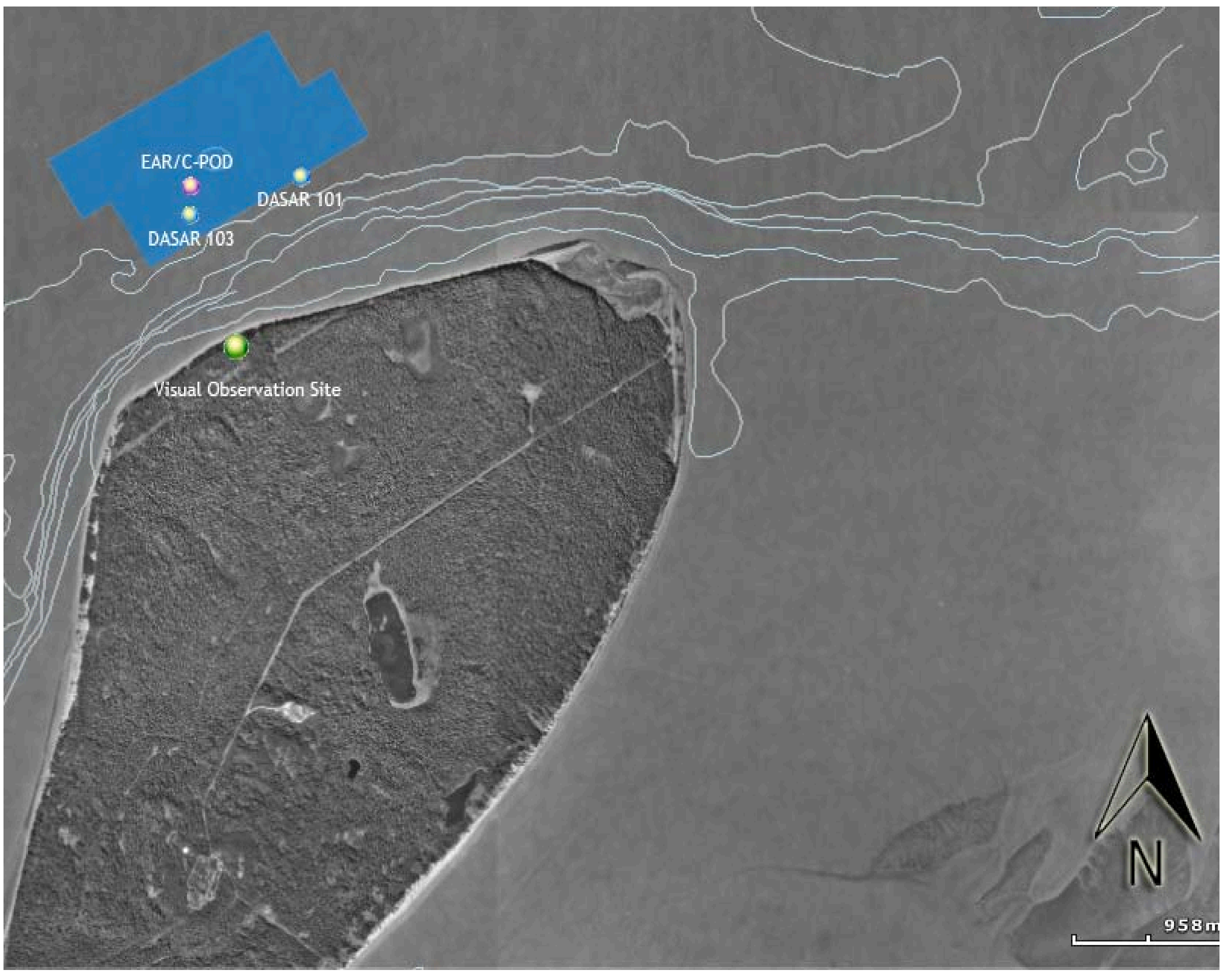


Figure 3. Relative location of the EAR/C-Pod and DASAR moorings, as well as the visual observation tower.

Belugas were detected hydroacoustically in all months near the Fire Island Project site. The EAR detected beluga vocalizations in November, March and April, while the DASAR and the C-Pod detected vocalizations and echolocations, respectively, in all months of deployment. Figure 4 displays the total days per month containing detections of beluga whale vocalizations or echolocations per month for each device. Figure 5 shows the total number of detections per month, while the total duration of detections per month is displayed in Figure 6. It should be noted that the classification of detections and detection time was based on how the data from the EAR were analyzed and presented to ORPC. The EAR data analysis classified detection as a single continuous detection if a subsequent beluga call was heard within one hour of the previous beluga call. If more than one hour elapsed it was classified as a new detection, to which the same rule applied: if yet another call was heard within one hour it was classified as continuous. The duration of the detection also had to be classified; thus two beluga calls less than 60 minutes apart constituted a continuous detection. The data from the other devices were normalized to this classification in order to allow comparison, although the data from the C-Pod and DASAR allowed for more finer-scale analysis.

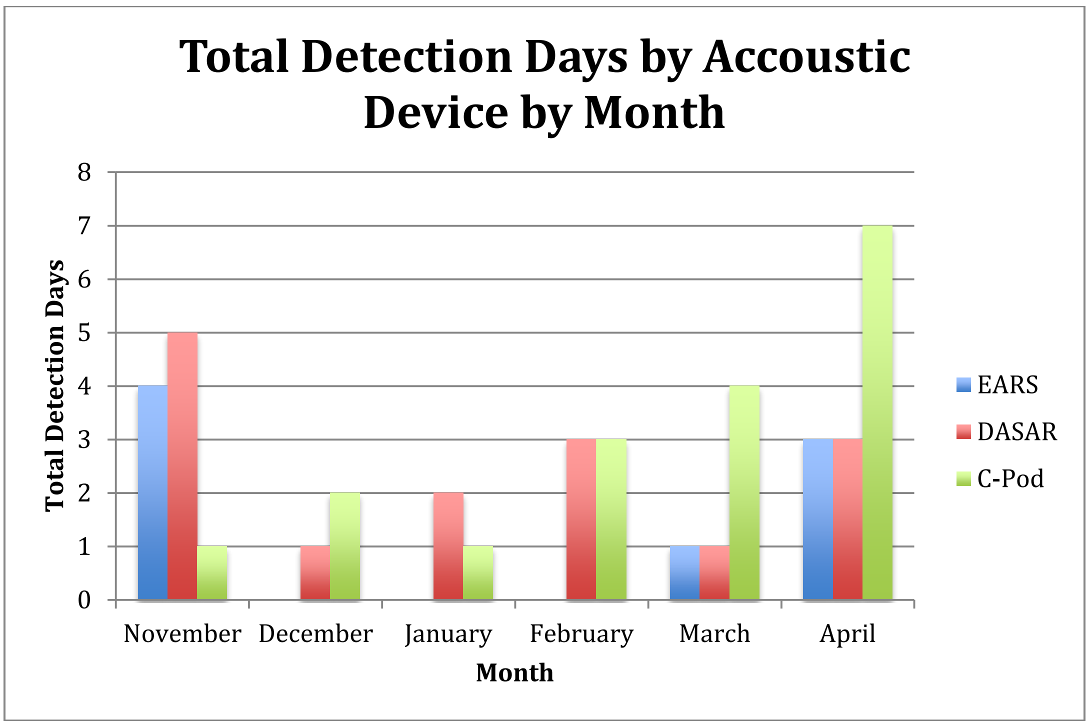


Figure 4. The number of days with detections by month for each PAM device recording at Fire Island between November 13, 2010 and April 24 2011.

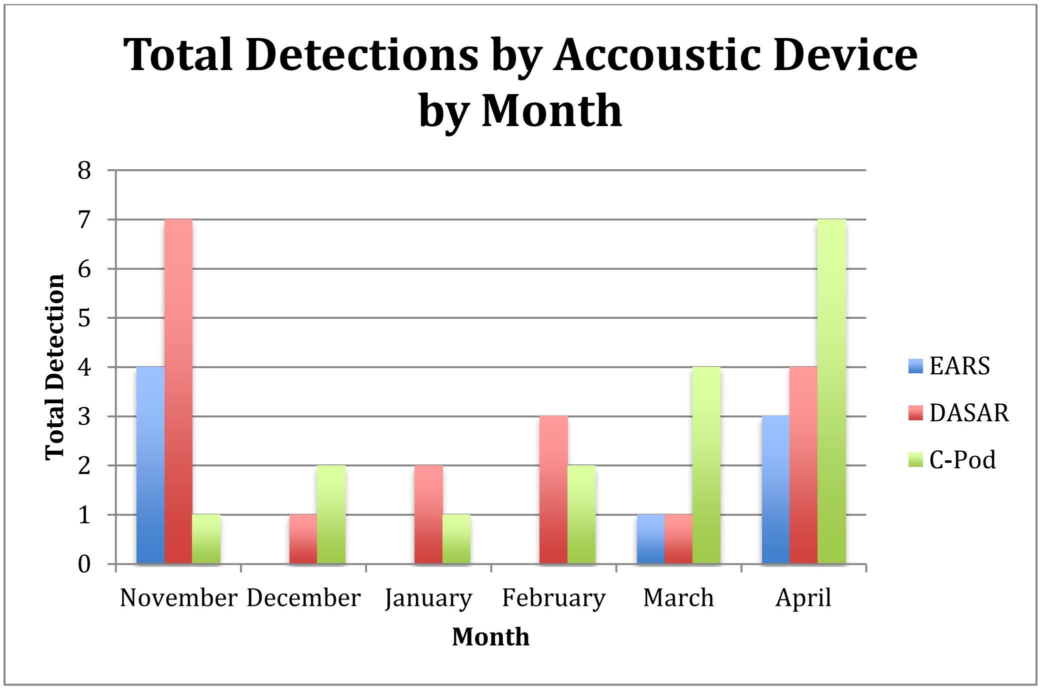


Figure 5. Total number of detections per month by device for each PAM device recording at Fire Island between November 13, 2010 and April 24 2011. A single detection was defined as one beluga detection with no further detections within one hour. If another detection was encountered within one hour, it was included as the same detection until at least one hour elapsed with no detection.

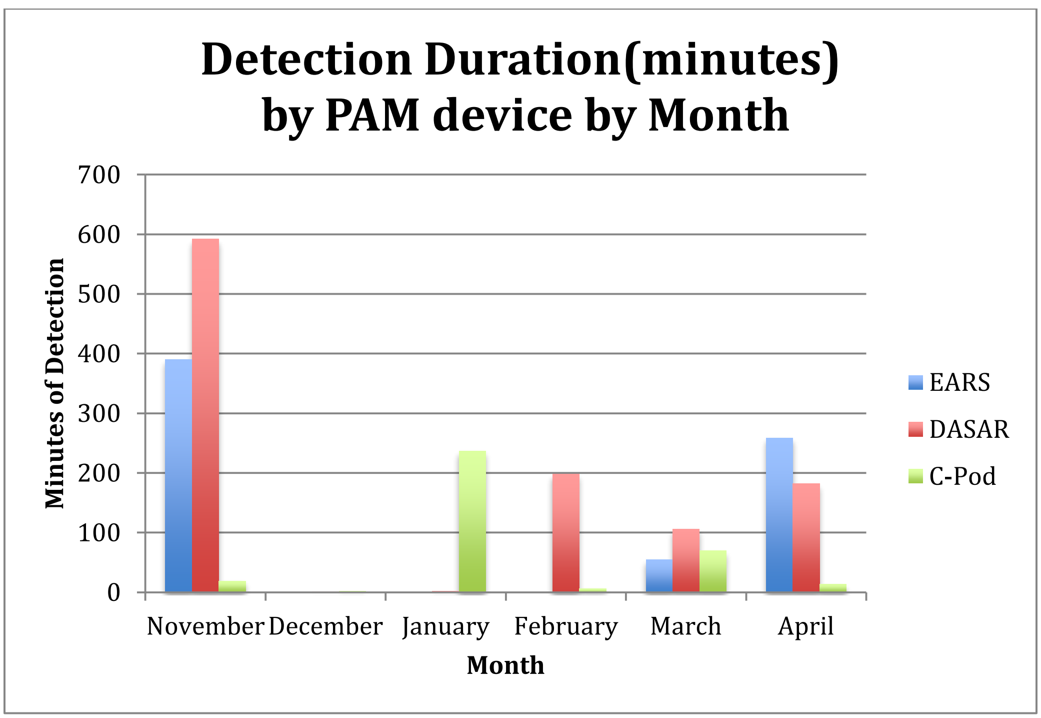


Figure 6. Total detection time by device for each PAM device recording at Fire Island between November 13, 2010 and April 24 2011. Detection time was classified similar to the total number of detections where subsequent detections within one hour of one another were classified as continuous detections. * Note: It is difficult to see due to scale, but DASAR had 1 minute of detections in December and 2 minutes in January, C-Pod had 2 minutes of detections in December and 6 minutes in March.

The C-Pod detected belugas on 17 (10.5%) of 163 days of co-deployment with the DASAR (Table 2). The DASAR had positive beluga detections on 15 (9%) of the days, and the EAR made detections on 8 (5%) of the days. There was one day the EAR detected a beluga, and the DASAR did not. However, the DASAR made detections on 8 days when the EAR did not. The C-Pod had lower levels of correspondence with the other two devices than they had with each other, detecting beluga whales on only 4 days concurrently with the EAR and 3 with the DASAR (Table 2). This may be because the C-Pod sampled for echolocation sounds while the EAR and DASAR sampled for vocalization sounds.

Table 2. *Number of days with concurrent detection by each PAM device at the Fire Island site*

Same Day Device Detection (11/13/2010 - 4/24/2011)			
	EARS	**C-Pod**	**DASAR**
EARS	8 days	4 days	7 days
C-Pod		17 days	3 days
DASAR			15 days

<u>Concurrent detections</u>
On limited occasions there were true concurrent detections by the different devices. The EAR and DASAR, for example, detected belugas concurrently four times. However, due to the fact that EAR data as delivered to ORPC was only presented on an hourly basis, rather than indicating exact times of beluga call detections, it is impossible to tell if there were detections at the exact same moment, indicative of the same call being recorded by both devices. The DASAR and C-Pod detected belugas simultaneously on two occasions – November 28, 2011 from 8:44 - 9:03 and March 26, 2011 from 22:09 - 22:10. On no occasions during the 163 day deployment period did the EAR and C-Pod detect belugas simultaneously.

East Foreland data collection and analysis

A single DASAR was deployed for a one-month test deployment at East Foreland on September 26, 2012, and successfully recovered on October 21, 2012. Following the recovery on October 21, 2012, two DASARs were deployed the same day for the overwinter time period. Due to challenging environmental conditions at the site, only one DASAR was recovered in June 2013.

The recovered DASAR showed significant damage, and had stopped recording acoustic data on January 27, 2013. Between both deployments, a total of 123 days of data were successfully collected and analyzed for beluga detections.

Figures 7, 8, and 9 show the analysis of beluga vocalizations recorded near the East Foreland site. Successful data collection included 5 days in September, all of October, November, and December, and the first 27 days of January. While this limited data set does not provide a complete picture of beluga use of the area, detections in November, December, and January confirmed beluga presence at those times. Long detection durations in December may be indicative of more intensive use of the area during that month. As no data existed on beluga use of this area in the overwinter time period, this data was invaluable in confirming the presence of beluga whales near the Project site during mid-winter months.

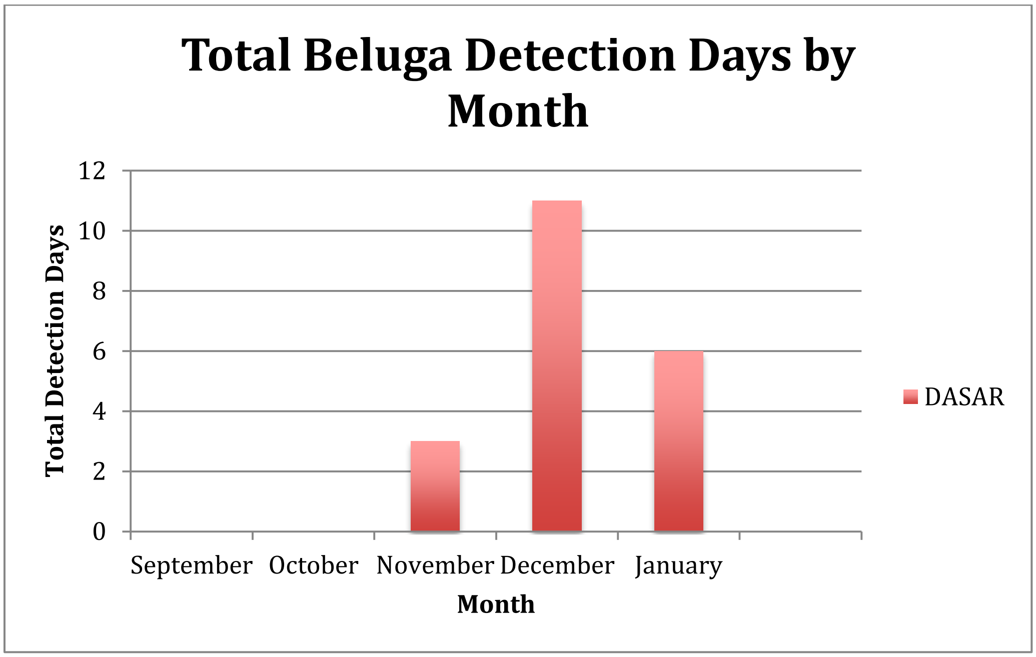


Figure 7. The number of days with detections by DASAR at East Foreland from Sept 21 2012-January 27 2013. Note - September only included 5 days of monitoring and January included 27 days of monitoring,

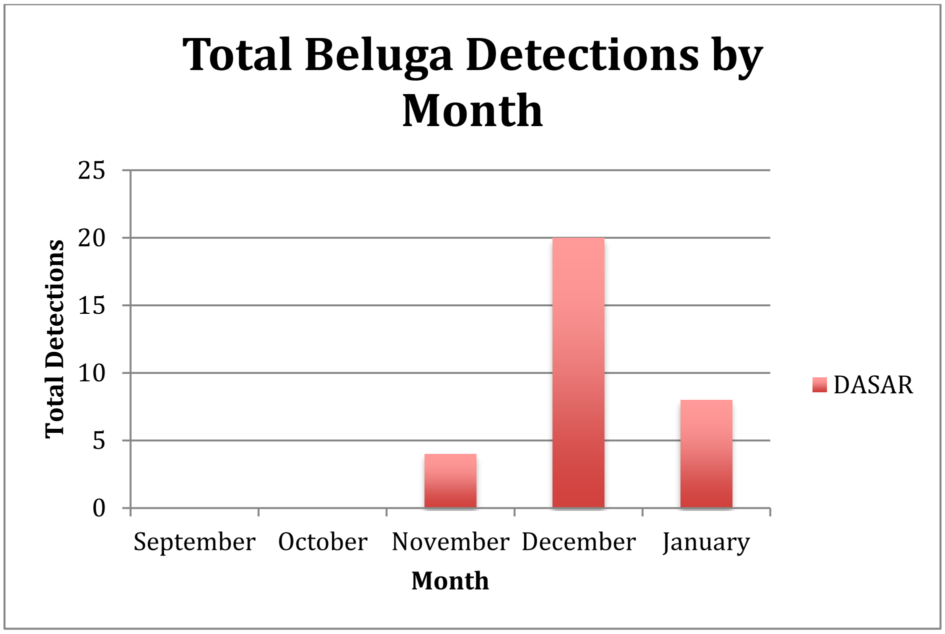


Figure 8. Total number of detections per month by DASAR deployment at East Foreland from Sept 21 2012-January 27 2013. A single detection was defined as a beluga detection with no further detections within one hour. If another detection was encountered within one hour it was included as the same detection until at least one hour elapsed with no detection. Note: September only included 5 days of monitoring and January included 27 days of monitoring.

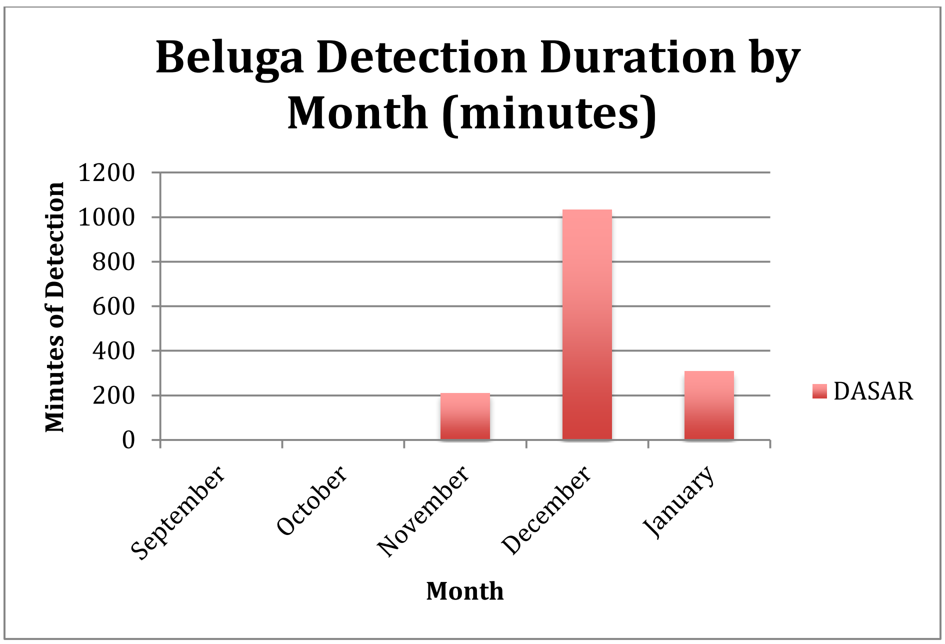


Figure 9. Total detection time by DASAR deployment at East Foreland from Sept 21 2012-January 27 2013. Detection time was classified similar to the total number of detections where subsequent detections within one hour of one another were classified as continuous detections. Note: September only included 5 days of monitoring and January included 27 days of monitoring.

Ambient Sound data collection and analysis

Characterizing the ambient acoustic environment of a potential tidal energy site, both before and after project deployment, is an important component of successful permitting of a tidal energy project. Conducting this characterization is challenging because the natural acoustic environment of high-energy tidal sites can at times exceed harassment thresholds for marine mammals established by NMFS as 120 dB @ 1 μPa for continuous noise, complicating the ability to measure and understand if a tidal energy device itself is contributing to this harassment level of sound. Furthermore, anthropogenic underwater noise can further exacerbate this problem and make it difficult to differentiate noise produced from a tidal energy device from an already noisy ambient environment. For instance, at the East Foreland site during a one-month test deployment, vessels were detected in the recordings on every day but one day, and airguns used for seismic exploration were detected on four days, approximately 3% of the time. The problem is further complicated by the logistical difficulties of accurately measuring sound in areas of strong tidal currents due to self-noise (e.g., cable strum or resonance of device cavities) or pseudo noise (e.g., noise generated by turbulent water flowing by the hydrophone). Several methods have been investigated to mitigate this latter noise contamination effect. One method utilized by ORPC in Maine involved using a Drifting Noise Measurement System (DNMS) that allowed the hydrophone to float by the site with the tidal currents, eliminating current-induced noises. The method investigated here involved utilizing the inherent design advantage of the DASARs for Cook Inlet to mitigate noise contamination.

In the Cook Inlet DASARS, the acoustically-transparent ABS plastic shroud provided physical protection against debris and reduced flow noise at the hydrophone heads. In addition, multiple hydrophones within the DASAR enabled further reduction in pseudo-noise contamination in post-processing by exploiting the spectral coherence between two hydrophones to identify pseudo-noise contamination (Deane 2000)[i] and then applying a correction to sound pressure spectral density levels using the coherence estimate (Buck and Greene 1980).[ii] These methods allowed a more rigorous assessment of ambient acoustic levels from a stationary device while providing long-term data collection of ambient sound levels.

For analysis purposes, the acoustic data set was “sampled” at the first 60 s of every 128 MB file, or about once an hour. The sampled data was then analyzed using spectral estimation, and then pseudo noise was removed utilizing the aforementioned spectral coherence method. After analyzing the data from Fire Island and East Foreland utilizing this method, there was an average decrease in ambient sound levels of 3.3–3.9 dB at Fire Island and 2.3 dB at East Foreland compared to the same sound levels before the pseudo noise was diminished utilizing spectral coherence methods.

Figure 10 shows the percentile sound spectral density without pseudo noise removed from overwinter data collected at East Foreland, and Figure 11 shows the same data with pseudo noise removed utilizing this method. In both spectrograms, peak sound levels around 260 Hz and 620 Hz were likely induced by resonance associated with the cavity of the DASAR itself, a sound contamination that could not be removed by the spectral coherence method since the sound was correlated on all hydrophones. Figure 12 and Figure 13 show the same data analyzed in one-third octave band levels again with and without pseudo-sound removed, respectively. It is clear, particularly around the 50% percentile (i.e., 50% of the time), that this method noticeably reduced reported ambient sound levels. Utilizing this technique to remove some of the pseudo-sound contamination not only provided a more rigorous assessment of ambient sound levels, but also enhanced the possibility of detecting low signal-to-noise level marine mammal calls within the frequency of interest for marine mammal detection. For a more detailed description of the analysis of ambient sound levels at Fire Island and East Foreland, see Attachments C and D.

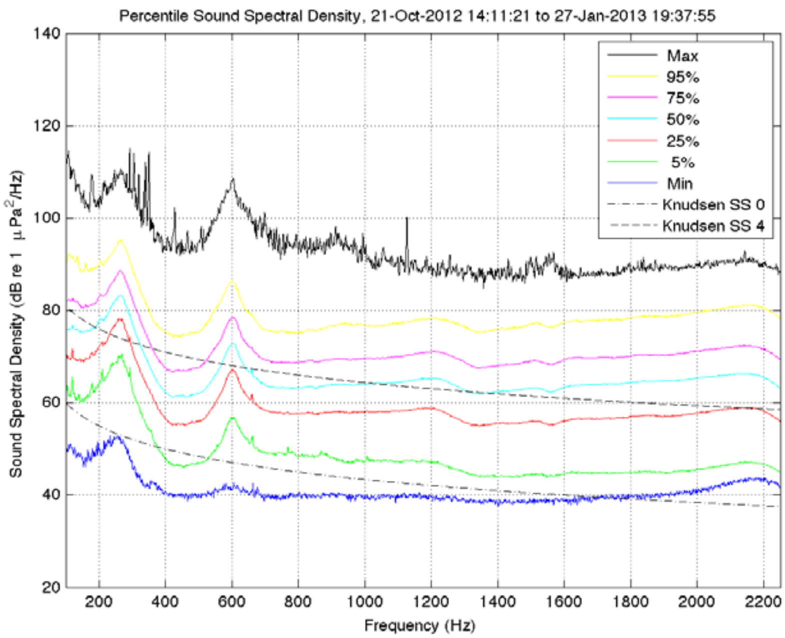


Figure 10. Percentile sound pressure spectral density levels measured by DASAR SN101 over the overwinter deployment period October 21, 2012 – January 27, 2013 at the East Foreland site.

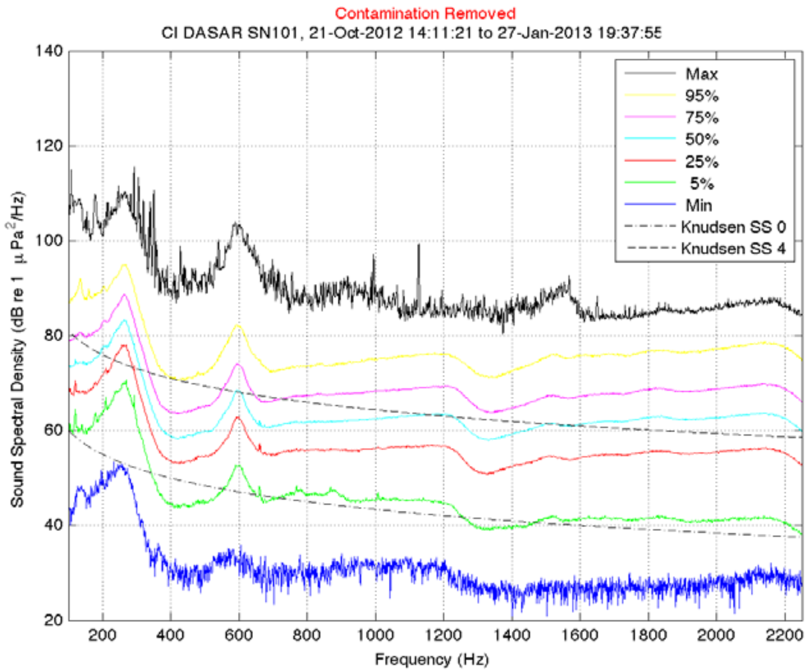


Figure 11. Percentile sound pressure spectral density levels measured by DASAR SN101 over the overwinter deployment period October 21, 2012 – January 27, 2013 at the East Foreland site with pseudo-sound noise contamination removed.

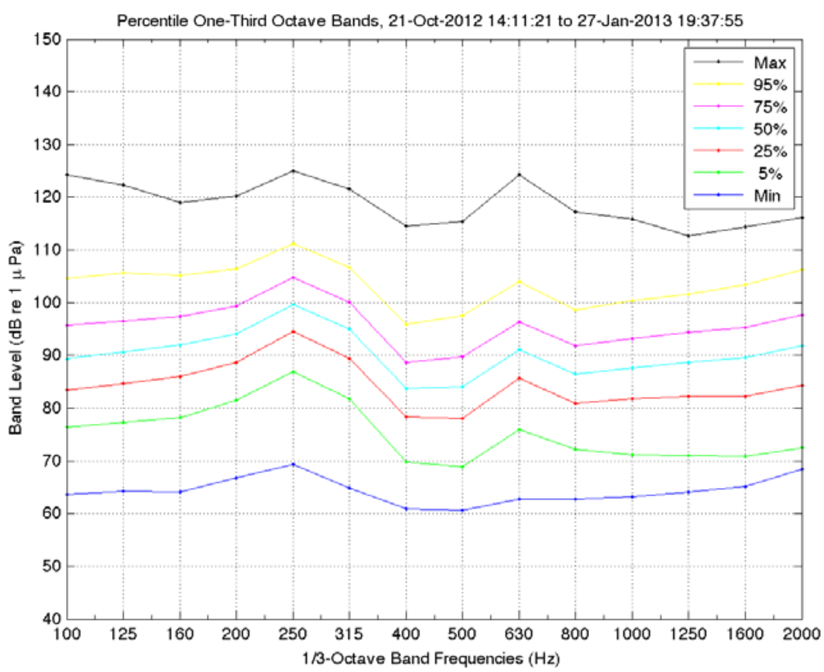


Figure 12. Percentile one-third octave band levels measured by DASAR SN101 over the overwinter deployment period October 21, 2012 – January 27, 2013 at East Foreland.

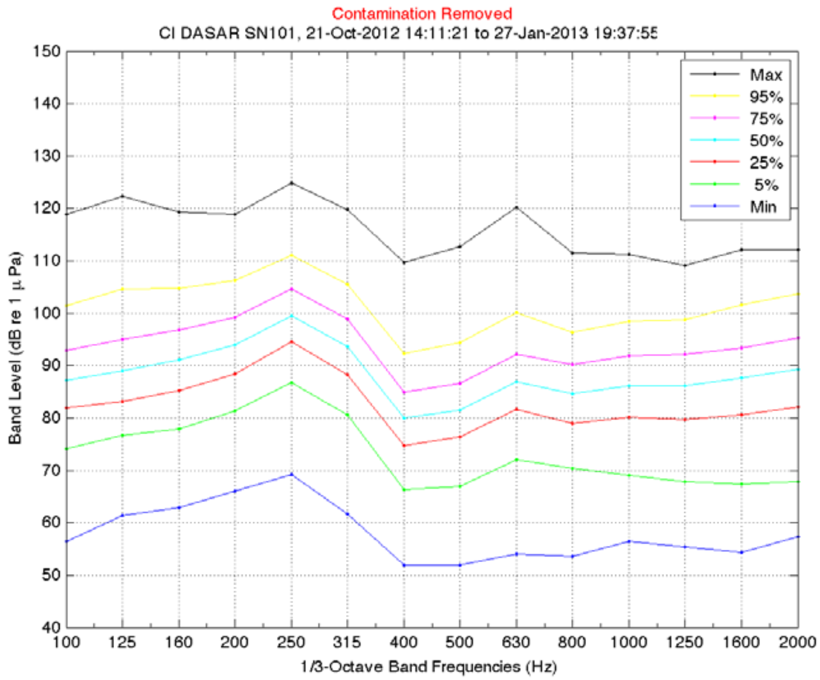


Figure 13. Percentile one-third octave band levels measured by DASAR SN101 over the overwinter deployment period, with pseudo-sound noise contamination removed October 21, 2012 – January 27, 2013 at the East Foreland site.

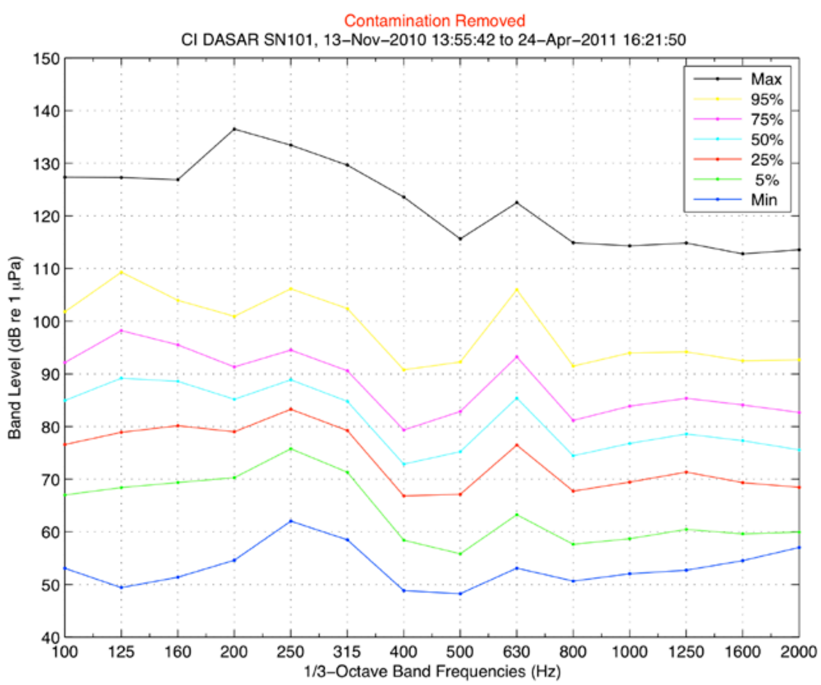


Figure 14. Percentile one-third octave band levels measured by DASAR SN101 over the overwinter deployment period, with pseudo-sound noise contamination removed November 13, 2010 – April 24, 2011 at the Fire Island site.

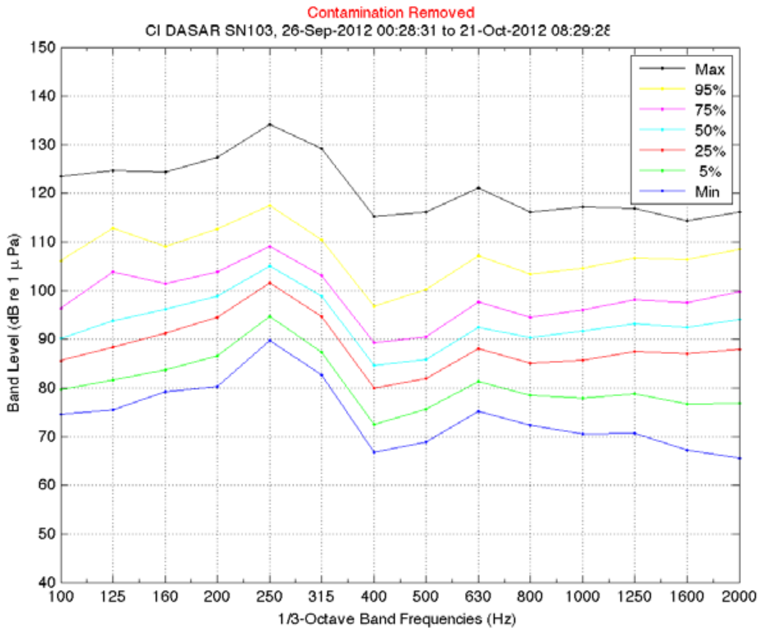


Figure 15. Percentile one-third octave band levels measured by DASAR SN103 at the East Foreland site from September 26, 2012 – October 21, 2012 with pseudo-sound noise contamination removed.

The relatively long data sets from each over winter deployment allow some measure of confidence that ambient sound levels were well characterized for ice-free and winter ice conditions. Short-term deployments in the fall at each site also provided further information at times when anthropogenic sounds were more prevalent.

Comparison of the longer term overwinter data from East Foreland to Fire Island (Figure 13 and Figure 14) showed that maximum sound levels were higher at Fire Island, while average sound levels were 10 dB to 20 dB higher at East Foreland than at Fire Island.

Maximum (100%) sound levels hovered around the 120 dB threshold at the East Foreland site for frequencies between 100 Hz and 300 Hz, with a 120 dB peak occurring near 630 Hz (likely due to the aforementioned DASAR cavity resonance), while median (50%) levels varied between 80 dB and 100 dB over the 100–2000 Hz frequency range that was measured. At Fire Island, maximum (100%) sound levels exceeded the 120 dB threshold between 100 and 450 Hz with a peak at 630 Hz and the maximum peak over 130 dB, while median levels (50%) ranged between 75 and 90 dB over the entire 100–2000 Hz frequency range that was measured. This data suggests that either extreme tidally-induced sounds or anthropogenic sounds skewed maximum sound levels at Fire Island, while the stronger current velocities at East Foreland led to higher overall ambient sound levels. Interestingly, at East Foreland, the shorter term data set collected between September 26, 2012 and October 21, 2012 also showed higher maximum sound levels (100%) and slightly higher average (50%) sound levels than the long-term data set at the East Foreland site. Again, this could be due to several factors, including anthropogenic sounds (such as increased human activity around East Foreland during the ice-free season compared to months with heavy ice) or possibly differences in the acoustic environment where the short-term deployment was located versus the long-term deployment that was 1 km further north. Unfortunately, an analysis of the maximum received sound levels and their specific sources was not possible under the scope and budget of this project, but it is likely that the peak levels experienced at both sites were comprised of natural tidally-induced noise and anthropogenic sounds. Figure 15 shows the correlation between the peak received sound levels recorded by DASAR SN101 deployed at Fire Island between December 5, 2010 and December 7, 2010 compared to predicted tidal flows at that time. The strong correlation between sound levels and tidal flows was evident here. Similarly, Figure 16 showed a relationship between predicted tidal heights and received sound level of DASAR SN 103 deployed at East Foreland between September 26, 2012 and October 21, 2012. Peaks in this data can be seen increasing to above the 120 dB level at times of peak tidal exchange within the deployment month. As illustrated in Figure 17, some anthropogenic sources at East Foreland were also identified that contributed to maximum sound levels; in this case, vessel noise and airgun seismic surveys, although an in-depth analysis of peak received levels from these sources and how they ultimately impacted overall ambient sound levels were not completed under this Project.

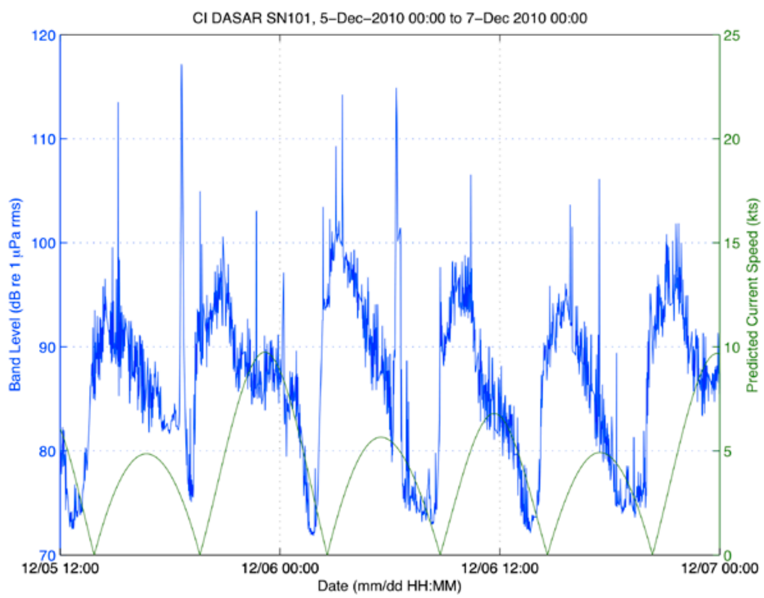


Figure 15. Band level (blue) and tidal current (green) as a function of time for DASAR SN101 deployed at Fire Island for the two-day period of December 5–7, 2010.

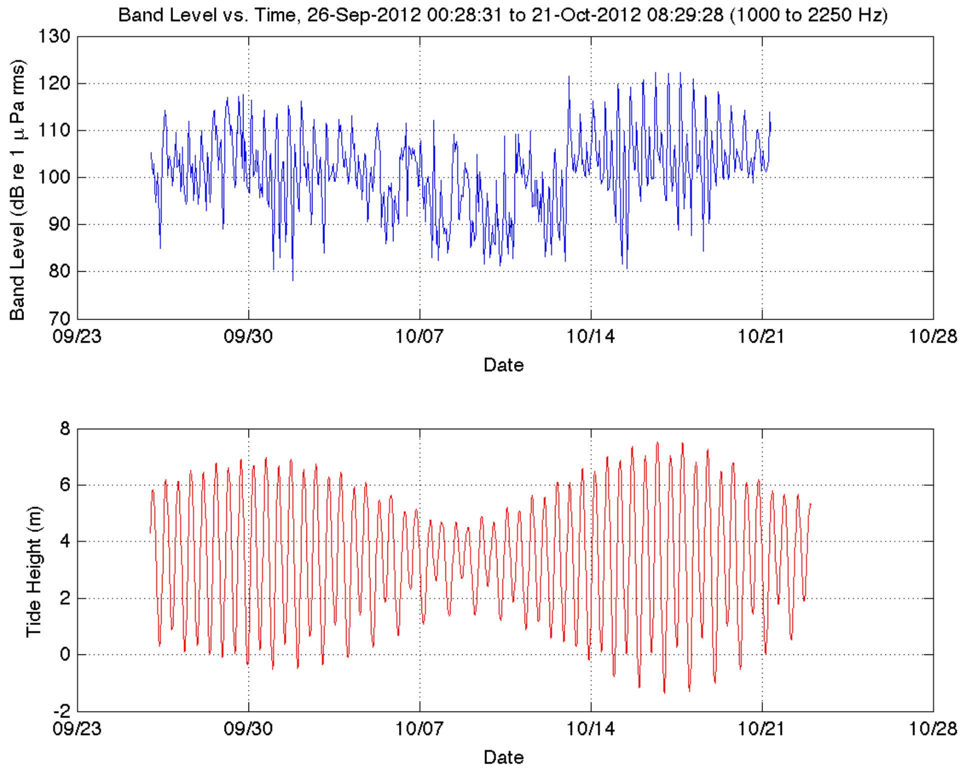
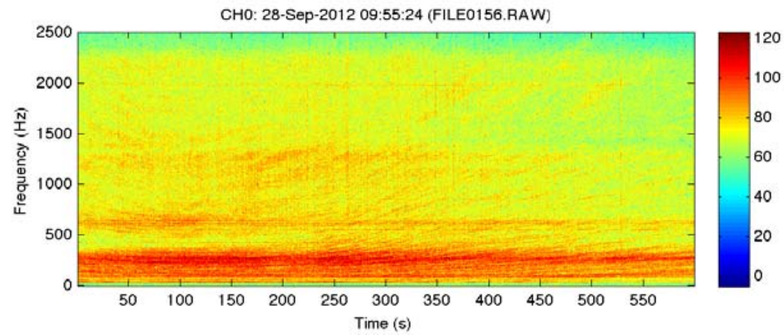
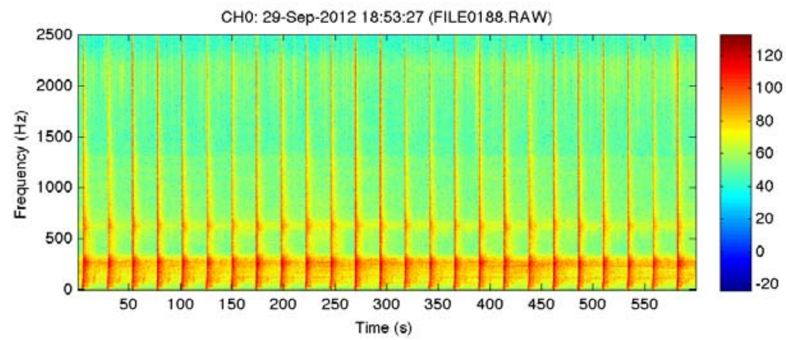


Figure 16. Band level for DASAR SN103 deployed at East Foreland between September 26, 2012 and October 21, 2012 (blue, upper plot) and tidal height (red, lower plot) as a function of time across the one-month test deployment period.



(a) Vessel noise



(b) Impulsive noise (airguns)

Figure 17. Anthropogenic sound sources at East Foreland recorded by DASAR SN103 in September 2012

Problems Encountered

ORPC overcame and adapted to several unforeseen challenges to achieve success in completing the Project objectives:

- Logistical challenge of performing visual observations at remote locations
- Challenges with reliable long-term deployment and successful retrieval of PAM devices
- Analysis of large amounts of data
- Difficulties in successfully using a new design of DASAR to localize beluga calls

Visual observation logistics

Difficulties in performing visual observations at Fire Island included getting observers out to the remote site and positioning them at a vantage point with an adequate field of view. To accomplish this ORPC and LGL organized a charter flight service to fly observers to and from Fire Island on a daily basis and established an overnight camp in case weather or daylight conditions made flying back on the same day imprudent. This arrangement included a mile long walk to the observation site each day and proved effective for the duration of the Project allowing 122 days of successful visual observations to be performed. To allow observations to be effective and not inhibited by vegetation or landscape interference, a site was chosen atop a bluff overlooking the Project site, and a tower was erected to elevate the observers to sufficient height. This provided observers with an ample field of view to observe the project site (see Figure 1 and Attachments A and B for a detail of the field of view). Construction and placement of a tower required a Land Access Permit from the U.S. Coast Guard (License HSCG-Z71117-09-RP-054L).

PAM device deployment and retrieval at sites with strong tidal currents

Deployment and retrieval of scientific equipment moored in Cook Inlet has long been a challenge. The request from NMFS that data be collected throughout the year establishing presence or absence of beluga whales within the Project areas required that PAM devices be in place and recording throughout the winter. Due to heavy ice floe activity in Cook Inlet during winter months from November to April that precluded small vessel operations for recovery or deployment of PAM devices, the PAM device deployments had to last up to 6 months, further complicating this challenge.

Based on experience from deployments of other scientific equipment and acoustic recorders in Cook Inlet and the deployment and retrieval of DASARs in the Beaufort Sea, the Project team chose to use redundant recovery methods for the DASARs deployed at Fire Island that included an acoustically-releasable pop-up buoy as well as a ground line attached to an auxiliary anchor that could be grappled in the case that the pop-up buoy retrieval failed. This approach proved prudent as the pop-up buoy mechanism on both DASARs failed when excessive abrasion of the chains that attached the pop-up buoys to the DASAR moorings caused the chains to part and the buoys to be lost during the course of the overwinter deployment. Fortunately, grappling for the ground lines proved successful, though challenging and time-consuming. Both DASARs were eventually recovered by this method although the ground lines sustained significant damage during the duration of the deployment due to abrasion with the seafloor. Grappling may not have been a viable recovery mechanism at a more energetic site or over a longer deployment.

Based on experience with the deployment of other scientific equipment at the site, ORPC knew that the site was highly energetic with a challenging bottom that included numerous boulders that would make the pop-up buoys and ground lines likely ineffective for overwinter deployments. The Project team redesigned the recovery system to utilize an abrasion resistant steel cable tethered to a permanent anchor at the MLLW line to allow the line to avoid abrasion and interactions with winter ice as much as possible and to be recoverable from shore at extreme low tides. However, over the course of the winter, the steel cable attached to each DASAR parted, and the recovery crew resorted to grappling for these cables off shore. One DASAR was successfully recovered by this method though it had sustained significant damage over the course of the deployment and had ceased functioning on January 27, 2014, i.e., 99 days into the deployment (Figure 18). The other DASAR was not recovered.

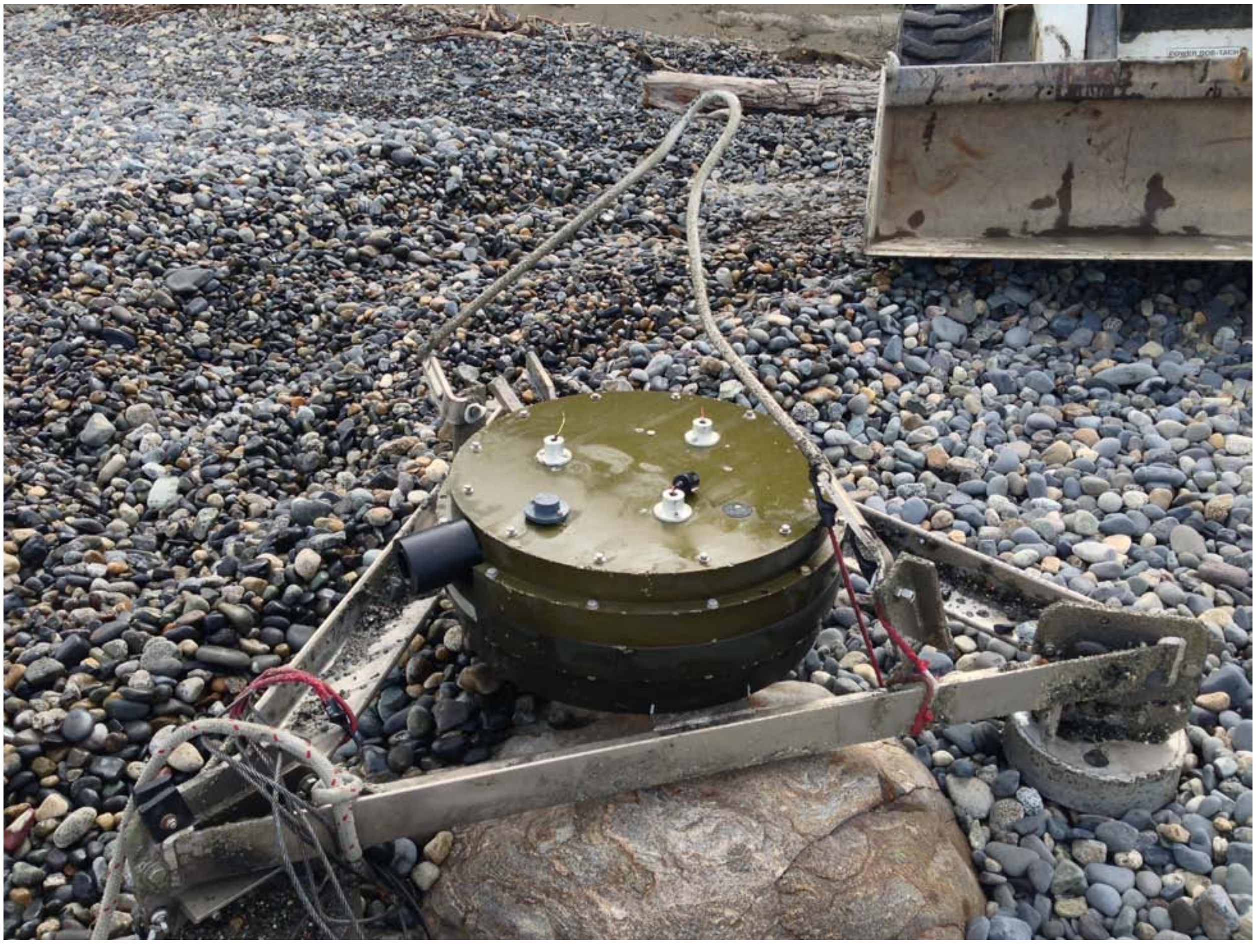


Figure 18. DASAR SN 101 after recovery on June 24, 2013, eight months after deployment at East Foreland showing damages including lost ABS cover, missing two of three hydrophones and bent mooring frame.

Based on these experiences, ORPC will consider alternative and redundant systems in highly energetic and challenging sites such as the East Foreland:

- Alternative and redundant pop-up buoy systems
- Buoys tethered to become accessible only at the lowest tides (a technique used with relative success by local commercial fishermen)
- Housing recording systems within the buoyant sections of pop-up buoys or utilizing acoustic release mechanisms in conjunction with positively-buoyant recorders, either equipped with tracking devices should they release prematurely (Figure 19)

Figure 19. EAR and C-Pod in prototype mooring used by Team CIBA in Cook Inlet with PAM devices housed in buoyant portion of pop-up buoy system.

Data analysis

The continual recording of the DASAR devices generated huge amounts of data that made manual analysis unfeasible. To address this, Greeneridge Sciences applied a whistle detector algorithm developed previously for delphinid vocalizations which allowed automated detection of beluga vocalizations. The algorithm was designed for cetaceans with distinctly different call characteristics and was not optimized for belugas. Thus, despite adjusting the algorithm's input parameters to try to represent beluga vocalizations, the automated detector produced an inordinately large percentage of false detections. Consequently, significant time was required to manually review all of the detections to discern actual beluga whale vocalizations from other sounds.

After filtering the results of the automated detector, the initial report on beluga detections from Fire Island later proved to be highly inaccurate, as 44% of the reported detections (by detection duration) and 70% of the reported detections (by number of detection events) were later identified as sounds generated from ice movement, not beluga vocalizations. The results presented in this final report have been verified by acousticians familiar with ice noise to ensure that all beluga detections were classified correctly. (See Attachment E for a revised report from the Fire Island data set after reanalysis of the data.) These results significantly affected the earlier interpretation of the data, which informed subsequent data collection, and highlights the importance of effective and robust data analysis.

Ability to localize vocalizations
The original scope of this Project included utilizing two or more DASARs to localize individual beluga vocalizations that were simultaneously detected by two or more DASARs. This would provide a more rigorous data set on whether belugas were present or absent and whether they were calling from within the Project area. To accomplish this, each DASAR would provide not only a recording of received sounds but also a bearing indicating the direction from which the call originated. By triangulating the bearings from two or more DASARs to a given beluga call, a location of the call could then be estimated. Previous versions of the DASAR utilized in the Beaufort Sea have proven this capability by localizing Bowhead whale calls. However, those DASARS rely upon an accelerometer-based sensor that measures particle velocity rather than acoustic pressure in order to estimate direction to a received sound. Due to the high current velocities in Cook Inlet, it was determined that such a sensor would likely be ineffective since particle velocity sensors are highly sensitive to pressure fluctuations likely to be induced by current flow, in which very small sensor movements overwhelm the signal of interest. Instead, Greeneridge attempted a somewhat novel approach utilizing three hydrophones within each DASAR configured in a short baseline triangular configuration with approximately 1 ft between each hydrophone. The intent was to utilize the short baseline array configuration within each DASAR to discern the difference in phase of the received sound at each hydrophone, allowing the bearing of the received sound to be identified through post-processing of the data. Significant time was spent developing an algorithm based upon this method, but ultimately a successful algorithm proved elusive and further attempts to localize sounds in this manner were abandoned in order to focus project resources where they were most effective.

<u>Departure from Planned Methodology</u>
There were several departures from the planned methodology that the Project team worked through.

The first departure was the relocation of ORPC's pilot project in Cook Inlet from Fire Island to East Foreland in the middle of this Project’s performance period. There were a number of factors that influenced this decision: (1) the stronger tidal energy resource, (2) closer access to grid connection and marine infrastructure at the East Foreland, and (3) NMFS’s opinion that the habitat at East Foreland was less utilized by the beluga whale population than that at Fire Island, and was thus a preferable initial pilot project site. Data were therefore collected at both locations and provided a comparison of both the ambient acoustic environment and beluga use of each area. In addition, work at each location provided experience deploying and retrieving hydrophones in different marine environments. Unfortunately, a full year of hydro acoustic data was not collected at either site.

The original proposal included utilizing the directional capability of the DASARs to localize beluga vocalizations. As explained above, the algorithm to do so was not successfully implemented, so localization of the calls did not prove possible during this Project. Discussions with federal agencies made it clear, however, that the presence/absence data collected would meet permitting requirements in lieu of successful localization data for beluga whale vocalizations within the Project area.

The original proposal also included performing data collection before and after installation of a tidal energy device. As a tidal turbine was not installed in Cook Inlet within the performance period of this project, data collection after installation of a tidal energy device was not possible. Comparison of before and after data and assessment of the potential effect of tidal energy device installation and operation on beluga use of the area was thus not possible.

The original proposal did not include development and implementation of pseudo-noise removal from the ambient sound measurements. The addition of this analysis to the data collected at each site was incorporated to increase the rigor of the ambient sound measurements and added an unforeseen and valuable aspect to the Project.

<u>Recommendations on the best practice for future data collection</u>
Visual observations were utilized in this Project as the most tried and true method for data collection on beluga presence in the Cook Inlet area. These methods again proved effective in collecting data during ice-free months and daylight hours. When possible logistically and cost effectively, visual observations added value to marine mammal data collection efforts, and provided information on marine mammal presence, behavior, group size, and relative age-class (i.e., presence of calves) that is largely indeterminable by passive acoustic devices. The data collected in conjunction with PAM monitoring during this Project highlighted the fact that visual observations played a role in detecting marine mammals that were sometimes missed by hydroacoustic devices and expanded the understanding of marine mammal use of an area during times that visual observations were possible. However, it was also clear the visual observations alone cannot be relied upon in a locations where seasonal restrictions did not allow year-round monitoring of a project area.

For this reason, PAM devices also have a significant role to play in understanding year-round use of an area by marine mammals. For this Project, the three PAM devices investigated for data collection showed differing results in detecting beluga whales. Ultimately, however, the DASAR and C-Pod were effective in detecting beluga whales in all months of deployment while the EAR only detected whales during three of the six months of concurrent deployment with the C-Pod and DASAR. It appears that the EAR alone was not an adequate data collection device in this application as it painted a somewhat incorrect picture by implying that belugas were not present in the Fire Island Project area mid-winter. However, in all Cook Inlet deployments the EAR has been co-deployed with a C-Pod and, in this case, the results that beluga whales were present in all months of deployment would have been similar to those derived from the DASAR. Ultimately, it is apparent that coupling PAM devices that allow detection of both social vocalizations (EAR and DASAR) and echolocations (C-Pod) provided the most rigorous approach to ensuring that accurate presence and absence data is collected. In the case of this Project, it also appeared that the lower frequency range, but continuous recording of the DASAR was a more effective approach to detecting social vocalizations than the larger frequency range using 10% duty-cycling of the EAR alone. It should be noted that the comparison between PAM devices in this Project was limited to a single deployment at one site targeting a specific marine mammal species, it may not be the case that the DASAR outperforms the EAR in detecting vocalizations in other conditions. All of the devices tested proved effective in deployment, retrieval, and reliable operation over long-term deployment at Fire Island.

Overall design and implementation of reliable deployment and retrieval systems proved to be a challenge for this Project and the associated Team CIBA project. Long-term deployments at Fire Island proved effective for all of the PAM devices deployed there, though retrievals were somewhat problematic and introduced risk in securing invaluable overwinter data. At the East Foreland site, by comparison, overwinter deployments were only 50% successful with one of two DASARs being lost. Furthermore, the recovered DASAR sustained damage during its overwinter deployment that shortened the data collection window and may require a follow on deployment in a future field season in order to complete year round data collection efforts. This could be a significant setback to a project, causing a delay of a year or more if a year of continuous data was required for successful project permitting. More work is thus necessary in order to enhance the reliability of deployment and retrieval systems for PAM devices deployed in high energy environments for long-term monitoring in order to better ensure that the valuable data is recovered at the end of the deployment period.

Long-term ambient sound data collection and analysis was successfully completed as part of this project for both the Fire Island and East Foreland sites. The methodology used involved spectral coherence analysis to remove some pseudo-noise from the data and allow a more rigorous approach to ambient sound characterization. While this method appeared effective, it was not completely effective in reducing self-noise such as “drum head” resonance associated with the DASAR housing itself. Another proven approach to collecting ambient sound measurements at tidal sites involved the use of drifting hydrophones such as the DNMS used by ORPC at the Cobscook Bay Tidal Energy Project. This system collected very rigorous data on ambient sound as both self- and pseudo-noise were nearly eliminated by the device floating with the tidal currents. However, this method can only capture short snapshots of ambient sound and would require many repeated deployments to effectively characterize ambient sound levels at different tidal stages for a given site. By coupling the two methods together and comparing their measurements, it would be possible to verify the accuracy of the stationary noise measurement system with the DNMS, and thereby allow the long-term data set to be calibrated and ensure the long-term ambient sound analysis was accurate.

PRODUCTS

Posters

Land-based beluga observations from Northwest Fire Island, Upper Cook Inlet, Alaska, June-November 2009. McGuire, T., Bourdon, M., Kirchner, R., McCann, & M., Worthington, M. Alaska Marine Science Symposium. (2010).

Land-based beluga observations from Northwest Fire Island, Upper Cook Inlet, Alaska, June-November 2009, and May-November 2010. Bourdon, M., McGuire, T., Kirchner, R., Hesselbach, C., Johnson, R., & Worthington, M. Alaska Marine Science Symposium. (2011).

Presentations

McCann, M., ORPC Tidal Energy Projects. Marine Mammals and Renewable Energy Projects Seminar. 18 Biennial Conference, Society of Marine Mammalogy, Quebec City, Canada, October 11, 2009.

McGuire, T. Cook Inlet beluga whale studies: visual and passive acoustic studies of beluga whales around Cook Inlet Tidal Project. Marine Mammals and Renewable Energy Projects Seminar. 18 Biennial Conference, Society of Marine Mammalogy, Quebec City, Canada, October 11, 2009.

Data

All ORPC-AK Cook Inlet Beluga Whale reports are available publically at: http://alaskafisheries.noaa.gov/protectedresources/whales/beluga.htm

COMPUTER MODELING

Not applicable to this project

[i] Deane, G.B. 2000. Long time-base observations of surf noise. **J. Acoust. Soc. Am.** 107(2): 758–770.

[ii] Buck, B.M. and C.R. Greene. 1980. A two-hydrophone method of eliminating the effects of nonacoustic noise interference in measurements of infrasonic ambient noise levels. **J. Acoust. Soc. Am.** 68(5):1306–1308.

Pre-Deployment Visual Monitoring for Beluga Whales in and near the Cook Inlet Tidal Energy Project Proposed Deployment Area, June-November 2009.

Final Report

Prepared by:

Alaska Research Associates, Inc.

1101 E. 76th Ave., Suite B
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Prepared for:

ORPC Alaska
911 W. 8th Ave., Suite 205
Anchorage, AK 99501

January 2010

Suggested citation for final report:

McGuire, T. L., and M. L. Bourdon. 2009. Pre-Deployment Visual Monitoring for Beluga Whales in and near the Cook Inlet Tidal Energy Project Proposed Deployment Area, June-November 2009. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, for Ocean Renewable Power Company, Anchorage, AK. 36 p. + Appendices.

EXECUTIVE SUMMARY

Introduction

Cook Inlet is home to some of the greatest tidal energy potential in the United States. It is also home to an endangered population of beluga whales (*Delphinapterus leucas*). Successful permitting and operation of an ORPC tidal power project near Fire Island in Upper Cook Inlet will require assessment of the potential and realized effects of the sound footprint and physical presence of tidal turbines on the distribution, relative abundance, and behavior of Cook Inlet beluga whales. This is a report of a study by LGL Alaska Research Associates, Inc., sponsored by ORPC to visually monitor beluga whale presence, relative abundance, and behavior off of the north side of Fire Island, Upper Cook Inlet, Alaska in 2009.

The study plan to survey for beluga whales in and near the proposed Deployment Area was developed by ORPC and reviewed by regulatory and resource agencies as part of the FERC pre-consultation process. A copy of the approved study plan is included in Appendix A.

The study had two primary objectives:

1. Estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the Proposed Deployment Area during ice-free months of 2009.
2. Provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project.

ORPC is collaborating with the Alaska Department of Fish and Game (ADF&G) to share data from visual and passive acoustic detections of beluga whales in and around the proposed Deployment Area near Fire Island, June through November 2009. Results of this collaboration will be presented in a separate report.

Methods

An observations site was selected on Fire Island that gave the maximum vantage of the proposed Deployment Area. After required authorizations were secured and the potential observation site was identified, NMFS personnel visited the site prior to the commencement of 2009 field operations and confirmed the viability of the site for making visual observations (with the caveat that vegetation obstructing the field of view be cleared from the site, which it subsequently was). Observations began on June 17, 2009 and continued until November 11, 2009. Observers were at the observation site three to five days a week for a total of 20-24 hrs/wk. Observations were only conducted during daylight hours. All tidal stages were sampled.

Visual observations of the presence, abundance, and surface-behavior of beluga whales and other marine mammals were conducted by trained observers stationed on a cliff 64.5 m (212 ft) above the mean low water line overlooking the proposed Deployment Area. Observers surveyed for belugas from land (at the observation site) and air (during flights to and from Fire Island).

Observers used hand-held binoculars, spotting scope, a survey grade theodolite, and the naked eye to search for belugas in the proposed Deployment Area and surrounding areas as far as the Susitna River and Point MacKenzie. Beluga locations were recorded in two ways: 1) by using a 500 m x 500 m (1,640 ft x 1,640 ft) grid-cell map of the field of view and, 2) using a theodolite and software combination.

Aerial observers used the unaided eye, clinometer, global positioning system (GPS) unit, and a grid-cell map to locate and record beluga whales during crew-transport flights between Anchorage and Fire Island. Incidental beluga sightings were obtained by observers surveying from the beach while walking to the observation site, and from interviews with pilots. During twice-daily crew-transport flights, observers asked the pilots when and where they saw belugas during their other flights and how many belugas they saw. During visual observations for belugas, observers also searched for and recorded other marine mammals in the proposed Deployment Area and field of view. Observers measured and recorded hourly environmental conditions, as well as the presence of vessels in the field of view and the presence of birds on the water in or near the proposed Deployment Area. Data recorded using Pythagoras™ (a marine mammal tracking program) were imported in a Geographic Information System (GIS). The locations of all belugas were mapped relative to the proposed Deployment Area and the observation site.

Results

Visual observations were conducted for a total of 73 days (479.5 hours) between June 17 and November 11, 2009. Belugas were seen on 31 of the 73 observation days. Belugas were seen most often and in the greatest numbers in August, and were never seen in October. Belugas were never seen in the proposed Deployment Area, but instead were seen in and around the mouth of the Little Susitna River. Belugas were seen only once during crew-transport flights. The sighting occurred on August 25, when a group of 15-20 belugas was seen in the channel between Fire Island and Point Woronzof. Spernak Air pilots reported seeing beluga whales in the mouths of the Beluga, Ivan, Susitna, and Little Susitna rivers, as well as at the mouth of Ship Creek and at the mouth of the Chuit River, but not in or near the proposed Deployment Area or around Fire Island.

Harbor seals were seen on four of the 73 observation days, and were only seen in June and September. Harbor seals were not seen in the proposed Deployment Area. Apart from harbor seals (and beluga whales), no other marine mammals were seen.

Discussion

This study was, to our knowledge, the first dedicated survey for beluga whales from Fire Island, Alaska. The primary objective of the study was to estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the ORPC proposed Deployment

Area during ice-free months of 2009. Belugas were not seen in or near the proposed Deployment Area during the five-month observation period (mid-June through mid-November).

The absence of beluga whales in the proposed Deployment Area during this study was not surprising given that other studies have consistently demonstrated patterns of belugas congregating elsewhere in the rivers and bays of Upper Cook Inlet during the summer and fall.

The second objective of this study was to provide information to ORPC, NMFS, and FERC on beluga whale sightings and location**s** relative to the Cook Inlet Tidal Energy Project. This objective has been met with monthly progress reports from LGL to ORPC, which ORPC in turn distributes to NMFS and FERC. Copies of these reports are publically available at http://www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm#orpc. This final report is a summary of the six monthly reports.

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ACKNOWLEDGMENTS

The people and institutions listed below are sincerely thanked for their support.

Fieldwork in 2009 was done by: Robert Kirchner, Marc Bourdon, Megan Blees, Reid Johnson, Katie Christie, Bob Rodrigues, Chris Kaplan, Tamara McGuire, and Amy Baker. Data entry and data analysis were done by Robert Kirchner, Marc Bourdon, Tamara McGuire, Katie Christie, and Megan Blees. Marc Bourdon prepared the maps and Vicki Priebe and Megan Blees formatted the report. Joel Ortega-Ortiz, Glenn Gailey, and Suzanne Yin are thanked for their help with Pythagoras. We appreciate the support provided by Monty Worthington (ORPC AK), Mary T. McCann (HDR|DTA), Mike Spernak and his team at Spernak Air, Steve Braund and his crew, and Steve Gilbert and the Fire Island Wind Project team. Michael Link (LGL) is acknowledged for his backing of LGL's venture into the field of tidal power.

NMFS
Mandy Migura, Kate Savage, Susan Walker

Permit
Cook Inlet Region Inc. (CIRI); the local Native Corporation who owns the majority of Fire Island lands, granted a permit to allow for access to the island.

United States Coast Guard (USCG) License HSCG-Z71117-09-RP-054L was executed on June 8, 2009 to allow observers to utilize the observation site at the NW corner of the island, and amended in July to allow for the construction of an observation tower.

Reviewer
Bob Rodrigues, LGL Alaska Research Associates, Inc.

INTRODUCTION

ORPC Alaska, LLC (ORPC), a subsidiary of Ocean Renewable Power Company, LLC, is an Alaska-based, tidal energy technology and project development company. Ocean Renewable Power Company has developed proprietary OCGen^{TM}, TidGen^{TM,} and RivGen^{TM} technology that will convert the energy in ocean, tidal, and river currents into emission-free electricity. ORPC was granted a Preliminary Permit (P-12679) by the Federal Energy Regulatory Commission (FERC) for its project site in Upper Cook Inlet, and has recently submitted a draft application for a FERC Pilot Project License for its Cook Inlet Tidal Energy Project, which would allow OPRC to install a 5MW pilot project, in a phased approach beginning with an initial 1MW installation in 2011. This pilot project license would have a duration of up to eight years. Pilot projects are small, short-term, removable projects that must be carefully monitored to ensure that there are no unacceptable adverse environmental effects. The projects are designed to be easily and quickly shut down and/or removed if such effects are encountered that cannot be mitigated. This pilot project will provide data necessary for a potential commercial scale expansion both in terms of technological viability and environmental sustainability of the project.

While Cook Inlet is home to some of the greatest tidal energy potential in the United States, it is also home to an endangered population of beluga whales (*Delphinapterus leucas*). Successful permitting and operation of a tidal power project in Cook Inlet will require a rigorous biological assessment of the potential and realized effects of the sound footprint and physical presence of tidal turbines on the distribution, relative abundance, and behavior of Cook Inlet beluga whales. A study plan to survey for beluga whales in and near the proposed Deployment Area was developed by ORPC and reviewed by regulatory and resource agencies as part of the FERC pre-consultation process. A copy of the approved study plan is included in Appendix A.

Beluga whales use sound for communication, navigation, predator/prey interactions, and hazard avoidance. Underwater sound associated with installation and operation of equipment during Pilot Project operations may temporarily alter beluga whale behavior and presence in the proposed Deployment Area. In addition, the physical presence and operation of the turbine in the proposed Deployment Area has the potential to affect the distribution, relative abundance, and/or behavior of beluga whales. Information is needed to evaluate the current use of the proposed Deployment Area by belugas and to assess potential risks to belugas during deployment and operation of tidal energy modules.

Understanding and quantifying potential effects of ORPC's Cook Inlet Tidal Energy Project on beluga whales is critical to the success of the project. The Cook Inlet beluga whale Distinct Population Segment (DPS) was listed in October 2008 as endangered by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). It is also designated as depleted under the Marine Mammal Protection Act (MMPA). Critical habitat was proposed by NMFS in December 2009, with Upper Cook Inlet, including the ORPC proposed Deployment Area, proposed as Critical Habitat Type 1 (high value/high sensitivity) for beluga whales (NMFS 2009a). FERC cannot issue a hydropower license to ORPC without a Biological Opinion from NMFS indicating that the project will not jeopardize the Cook Inlet beluga population.

Numerous visual surveys of beluga whales have been undertaken in the upper parts of Cook Inlet in conjunction with environmental studies for the Port of Anchorage, Knik Arm Bridge, and Seward Highway Projects (Funk et al. 2005, Prevel-Ramos et al. 2006, Markowitz and McGuire 2007). However, limited information is available for the ORPC module proposed Deployment Area near Fire Island (Figure 1).

This report of a study by LGL Alaska Research Associates, Inc. (LGL) was sponsored by ORPC to visually monitor beluga whale presence, relative abundance, and behavior off the north side of Fire Island, Upper Cook Inlet, Alaska in 2009. Information presented in this report provides data that will be used to characterize pre-deployment patterns of beluga whale presence, distribution, relative abundance, and surface behavior in and near the Cook Inlet Tidal Energy Project proposed Deployment Area. Continued studies in future years have been proposed and would consist of monitoring during and after deployment of the generating equipment to determine beluga whale interaction with the OCGen™ Module and the proposed Deployment Area. Results from the pre- and post- deployment years will be compared to determine if underwater noise and/or physical presence of the module is associated with changes in beluga distribution, relative abundance, and behavior (i.e., behavior visible at the surface).

The study had two primary objectives:

1. Estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the proposed Deployment Area during ice-free months of 2009.
2. Provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project.

ORPC is collaborating with the Alaska Department of Fish and Game (ADF&G) to share data from visual and passive acoustic detections of beluga whales in and around the proposed Deployment Area near Fire Island, June through November 2009. Passive acoustic sampling is paired with visual sampling to compare the two methods of observation and to complement the data sets of each method. Through correlation of these data sets we will gain an understanding of how the two methods overlap in their verification of beluga presence and of their limitations in reference to each other. Pairing visual and acoustic observations will increase our abilities to detect belugas in the Deployment Area. ADF&G uses an acoustic mooring package consisting of two types of acoustic recorders, one (the Ecological Acoustic Recorder or EAR) to record low-frequency sounds and one (the C-Pod to record high-frequency sounds). ADF&G will analyze the recorded data from the EAR/C-Pod array deployed in 2009. LGL will analyze the visual observation data from 2009. LGL and ADF&G will collaborate to correlate visual and acoustic data. Results of this collaboration will be presented in a separate report.

METHODS

Site Selection and Observation Schedule

A permit from Cook Inlet Region, Inc. (CIRI; the majority land owner on Fire Island) was secured on May 13, 2009 to allow a reconnaissance visit to the island on May 14, 2009. Concurrently, ORPC pursued a license from the United States Coast Guard (USCG) to use the Race Point Lighthouse Reservation lands, which provided a vantage of the proposed deployment site, for the observation site for investigation of beluga whale use of the area. USCG License HSCG-Z71117-09-RP-054L was executed on June 8, 2009 to allow observers to use the location for the observations until November 13, 2009. An observations site was selected near Race Point that was accessible from pre-existing trails on the island, and gave the maximum vantage of the proposed Deployment Area (Figure 1).

After required authorizations were secured and the potential observation site was identified, ORPC invited NMFS personnel to visit the site prior to the commencement of 2009 field operations. On June 15, 2009 Tamara McGuire and Chris Kaplan of LGL accompanied Kate Savage of NMFS to the observation site (Mandy Migura of NMFS was invited but was unable to attend). During the visit, Kate Savage confirmed the viability of the site for making visual observations (although with the caveat that vegetation obstructing the field of view be cleared from the site, which it subsequently was). Beluga field observations began on June 17, 2009. The study plan (Appendix A) states that beluga observations would begin in May 2009, but this timeline was incompatible with the timing of obtaining the permits needed to access and conduct observations from Fire Island. Observations will be conducted in May 2010 instead of May 2009. Observations were scheduled to continue through November 13, 2009. Due to poor weather conditions which precluded observers from accessing the island, the final field observations for 2009 were on November 11.

Observations were generally made four days a week during five-hour shifts (20 hrs/wk total) from June 17, 2009 to August 2, 2009, three days a week for eight-hour shifts (24 hrs/wk total) from August 3, 2009 to October 14, 2009, and three to five days per week with varying shift lengths dependent on weather and daylight availability from October 19, 2009 through November 11, 2009 (24 hrs/wk). Observations were only conducted during daylight hours during which all tidal stages were sampled over the field season.

The observation team chartered daily round trip aircraft service between Fire Island and Merrill Field in Anchorage, AK. The crew hiked approximately 3 km (2 mi) through marsh, beach, meadow and woods to reach the observation site. Over the course of the season, the crew maintained two small cabins near the northeast corner of Fire Island as safety shelters. The crew had to remain on the island overnight eight times throughout the season due to poor weather conditions or observation obligations. Observers traveled and worked in pairs due to safety concerns related to the remoteness of the observation site.

Visual Observations

Visual observations of the presence, abundance, and surface-behavior of beluga whales and other marine mammals were conducted by trained observers stationed at the observation site, a bluff ~64.5 m (212 ft) above the mean low water line overlooking the proposed Deployment Area. The distance between the observation site and the center of the proposed Deployment Area was 1.4 km (0.87 mi; Figure 1). Visual observers were necessary due to the turbid water of Cook Inlet which made underwater observations (from still cameras, video cameras, or divers) unfeasible.

In July, ORPC received a supplemental USCG license to allow an elevated platform to be constructed on an existing foundation at the site that would improve the vantage of visual observations, a modification that NMFS personnel agreed would be useful. The construction of an observation tower began in July and was completed in early August. Observations were conducted from the tower beginning August 4. The observation tower provided observers with safety from bears and moose, shelter from winds and rain, and a higher vantage that reduced the need to continually prune vegetation in order to keep it from obstructing the view of the proposed Deployment Area. The tower was 4.5 m (14.8 ft) high which, combined with the bluff height, resulted in an observer height 69.8 m (229 ft) above mean low water, and an increased field of view of the project area (Figure 2).

Beluga Sightings

Observers surveyed for belugas from land (at the observation site) and air (during flights to and from the island). Observers also obtained incidental beluga sighting information from crew-transport plane pilots. Nine observers were on the observation team; all were experienced field biologists and those observers new to the project were always paired with more-experienced team members.

Land-based Observations

Observers used hand-held binoculars (7 x 50, with built-in reticles and compass), a tripod-mounted spotting scope (20 x 60), a survey grade theodolite (Sokkia DT-5), and the unaided eye to search for belugas in the proposed Deployment Area and surrounding areas from the Susitna River to Point MacKenzie (Figure 1). When a beluga whale was sighted, observers recorded the time, location, group size, whale color (i.e., white, gray, or calf, defined as <2/3 adult size, usually dark gray and swimming alongside a larger beluga), direction of travel, (i.e., N, S, E, W) and behavior. Focal group behavioral information (Mann 2000) was collected including behavioral state (traveling, milling, diving, resting, and feeding) and inter-individual distance/group spread. Predominant and secondary surface-behaviors were recorded for each group sighted. A beluga had to be seen by one or both observers in order for it to be recorded as a confirmed sighting; surface disturbances (i.e., splashes or "footprints") or sounds were recorded as possible sightings.

Locations were recorded in two ways: 1) using a 500 m x 500 m (1,640 ft x 1,640 ft) grid-cell map of the field of view and, 2) using a theodolite and software combination. LGL has developed and employed a grid system to record the locations and movements of Cook Inlet beluga whales in Upper Cook Inlet, including Knik Arm (Funk et al. 2005), the Port of Anchorage (Markowitz and McGuire 2007) and along Turnagain Arm (Markowitz et al. 2007). This system has proven effective for documenting whale group location and movements on a coarse scale (500 m x 500 m or 1 km x 1 km grids [1,640 ft x 1,640 ft or 0.62 mi x 0.62 mi]). In applying this technique, trained observers used a combination of compass bearings taken from binoculars and landmarks to place whale groups at any given time in a grid cell.

Use of a surveyor's theodolite to monitor the location and movement patterns of whales and dolphins is a well-established technique (reviewed by Samuels and Tyack 2000), and LGL has found it to be particularly effective for monitoring beluga whales' distances from, and responses to, human activities in Cook Inlet (Prevel-Ramos et al. 2006, Markowitz and McGuire 2007). During theodolite tracking sessions, data were entered directly into a laptop computer in a Microsoft® Access database. Using this technique, computer calculations made with Pythagoras™ (Gailey and Ortega-Ortiz 2000) whale-survey software provided accurate, real-time estimates of the distance of whales from the proposed Deployment Area. To ascertain the accuracy of the theodolite, GPS tracks from a small boat were compared to the fixes taken of the same boat with the theodolite. A GIS analyst later compared the boat's GPS track line to the track line created by the theodolite and Pythagoras™ software. In cases when the theodolite was not working (e.g., dead batteries, high winds) the grid cell map was used as a backup to determine whale locations. The theodolite was the preferred means of spatial designation and the grid system was always maintained as a back up.

Aerial-surveys

Aerial observers used the unaided eye, clinometer (measures angle), global positioning system (GPS) receiver, and a grid-cell map to locate and record beluga whales during crew-transport flights between Anchorage and Fire Island in a Cessna 207 and a Cessna 107. Flights were usually at an altitude of 150-300 m (492-984 ft) at approximately 160 km/hr (99 mi/hr). Both observers scanned for belugas. When whales were detected, observers recorded the angle, altitude, GPS location, time and the number of belugas. Observers also recorded the belugas' estimated location on a grid cell map and later refined that location using the data recorded during the sighting. The flight path of the plane was recorded using the track function on the GPS receiver.

Incidental Observations

Incidental beluga sightings were obtained by observers surveying from the beach while walking to the observation site, and from interviews with pilots. During twice-daily crew-transport flights, observers asked the pilots when and where they saw belugas during their other flights and how many belugas they saw.

Other Marine Mammal Sightings

During visual observations for belugas, observers also searched for and recorded other marine mammals in the proposed Deployment Area and field of view. If a marine mammal was seen, observers recorded the time, location, group size, behavior, and travel pattern of the mammal. The theodolite and grid cell map were used to record the marine mammal's location. Marine mammal sightings were later mapped in the same manner as beluga sightings.

Environmental Conditions

Observers measured and recorded environmental data including air temperature, wind speed and direction, cloud cover, Beaufort Sea state, visibility (i.e., ability to see far shore), angle of glare, and presence of whitecaps. Temperature and wind speed were measured with an anemometer/thermometer. Environmental conditions were recorded on the hour, or when any significant changes occurred.

Vessel Sightings

During observations for belugas, observers also recorded the presence of vessels in the field of view. If a vessel was seen, observers recorded the time, location, type, and name of the vessel. The theodolite was used to map and track vessels.

Bird Sightings

Observers noted the presence of birds on the water in or near the proposed Deployment Area. Species and number were recorded when possible. Observers also kept a log of birds flying around the observation site. Bird sightings were not mapped.

Analysis

Data recorded using Pythagoras™ were imported in a Geographic Information System (GIS) using ESRI's ArcGIS 9.3. The locations of all belugas were mapped relative to the proposed Deployment Area and the observation site. When the theodolite data were not available, data derived from the grid cell maps were used. Data derived both from the theodolite and the grid cells were recorded in point format. However, the use of points produced a static representation of a dynamic animal, so the beluga locations for each day were grouped into areas and mapped in relation to the proposed Deployment Area and observation station. These maps were then compiled into monthly maps of beluga locations to give a broader view beluga distribution. Daily beluga sighting maps are found in Appendix B.

RESULTS

Visual Observations

Land-Based Observation Effort and Beluga Sightings

Visual observations were conducted on a total of 73 days (479.5 hours) from June 17 through November 11, 2009 (Table 1). Belugas were seen on 31 of the 73 observation days (Table 1). Belugas were seen most often and in the greatest numbers in August, and were never seen in October (Table 1; Figure 3). The closest distance between the observation site and belugas was 2.7 km (1.7 mi), although the mean distance was 5.1 km (3.2 mi). Belugas were never seen in the proposed Deployment Area (Table 1), but instead were seen in and around the mouth of the Little Susitna River and toward the Susitna River (Figures 4-10; Appendix B, C, and D). Beluga densities for all months of observation combined were greatest at the outflow of the Little Susitna River (Figure 11).

Methods of Determining Sighting Location

Two different methods (grid-cell maps and theodolite) were used to determine the location of marine mammal sightings. Little discrepancy in beluga locations was apparent for the two methods, although it appeared that mapped locations of belugas tracked with the theodolite were at a somewhat greater distance from the observation site than those locations mapped based on estimated location/distance with grid cell (i.e., observers tended to visually underestimate distance slightly; Figures 12-14). Track lines created by the GPS onboard a small boat positioned the boat in the same location as did theodolite tracking of the same boat from the observation station (Figure 15).

Aerial-surveys

Belugas were seen only once during crew-transport flights. The sighting occurred on August 25 when a group of 15-20 belugas was seen in the channel between Fire Island and Point Woronzof (Figure 16). Flight paths of all crew-transport flights are presented in Figure 17.

Incidental Observations

During the reconnaissance visit to the island on May 14, 2009, marine mammals were seen by Chris Kaplan (LGL), Monty Worthington (ORPC), and Tamara McGuire (LGL). A beluga mother/calf pair was seen diving and traveling along a line of current in the vicinity of the proposed Deployment Area and remained in the area for over an hour, although their exact location could not be determined because the observers did not have a theodolite or grid cell map. The calf did not appear to be a newborn, but rather a calf from 2008 or 2007. The calf was dark gray, relatively large, did not have fetal folds, and did not display the uncoordinated swimming/surfacing behavior typical of newborns (McGuire et al. 2009). In addition to the mother/calf pair, one beluga (or possibly two) was seen diving along the west side of the island; this beluga appeared to be white, although color and number of animals were difficult to confirm due to strong glare. On this same day, observers also noted a lone harbor seal (*Phoca vitulina*) in the vicinity of the proposed Deployment Area.

Spernak Air pilots reported seeing beluga whales in the mouths of the Beluga, Ivan, Susitna, and Little Susitna rivers, as well as at the mouth of Ship Creek and at the mouth of the Chuit River over the course of the field season (Figure 18). The largest groups were seen in July and August at the mouths of the Susitna and Little Susitna rivers. Due to frequent pilot activity over the Inlet, they were often able to relate how long a group of belugas were at a given location (Table 2). Pilots did not report seeing beluga whales in or near the proposed Deployment Area or around Fire Island.

Belugas were not seen from the beach by observation crews during their twice-daily walks between the runway and the observation site, June through November. On September 8, observers at the observation station noted a possible beluga near the base of the observation station cliff. This sighting could not be confirmed as a beluga sighting because the body of the animal was never seen. The surface disturbance and associated exhalation sound indicated that a beluga may have surfaced at this location, although it is possible that this sighting could have been confused with a harbor seal observed in the same vicinity during the same time period.

Other Marine Mammal Sightings

Harbor seals were seen on four of the 73 observation days (Table 3), and were only seen in June and September. Harbor seals were not seen in the proposed Deployment Area (Figure 19). Apart from harbor seals (and beluga whales), no other marine mammals were recorded.

Environmental Conditions

Sighting conditions were rated as good on 25 days, fair on 39 days, and poor on nine days. Poor sighting conditions in June were due to smoke and haze from forest fires, and poor sighting conditions in October were due to rain and fog. Observers were able to see to the far shore (the mouth of the Little Susitna River) on 72.5 of the 73 observation days. Mean wind speed was 6.1 km/hr (3.8 mi/hr), and wind speed ranged from 0-44 km/hr (0-27 mi/hr). Mean Beaufort sea state was 1.6. Mean air temperature was 12.2 ^{o}C (54 ^{o}F), and ranged from -8 to 36 ^{o}C (18 to 97 ^{o}F). Rain was noted on 18 days, fog on five days, and snow on one day (Table 4).

Vessel Sightings

Skiffs were the most commonly seen vessels and were seen on 23 of the 73 observation days. Vessels with set-nets were seen on three days, all in July (Table 5).

Bird Sightings

Gulls were the most commonly seen birds on the water in or near the proposed Deployment Area. More gulls were seen in September than in any other month. Black scoters (*Melanitta nigra*), surf scoters (*Melanitta perspicillata*), and unidentified birds were also seen in or near the proposed Deployment Area (Table 6). Scoters were only seen in the month of July.

DISCUSSION

This study was, to our knowledge, the first dedicated survey for beluga whales from north Fire Island, Alaska. The primary objective of the study was to estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the ORPC proposed Deployment Area during ice-free months of 2009. Belugas were not seen in or near the proposed Deployment Area during the five-month observation period (mid-June through mid-November).

The absence of beluga whales in the proposed Deployment Area during this study was not surprising given that other studies have consistently reported patterns of beluga whale presence in the rivers and bays of Upper Cook Inlet during the summer and fall. These studies have included aerial and boat-based surveys of Upper Cook Inlet, tagging studies, and land-based observations in Knik Arm, Turnagain Arm, and near the Chuit River (Rugh et al. 2000, 2005, 2006, 2007; Funk et al. 2005; Hobbs et al. 2005; Goetz et al. 2007; Markowitz and McGuire 2007; Markowitz et al. 2007; Nemeth et al. 2007; McGuire et al. 2008, 2009; Shelden et al. 2008a,b,c, 2009a,b). The north side of Fire Island has neither rivers nor bays, nor does it contain "estuarine areas, or shallow areas adjacent to medium and high low accumulation streams" (Goetz et al. 2007), which are considered preferred habitat features for Cook Inlet belugas as defined by NMFS (NMFS 2009a). Belugas are known to prey on a variety of fish and invertebrates, and salmon (*Onchorhynchus* spp) and eulachon (*Thaleichthys pacificus*) have been found to be important prey species (Fried et al. 1979, Hazard 1988, Huntington 2000, Moore et al. 2000). There are no documented salmon or eulachon[1] runs on Fire Island. They are however, known to spawn in the Susitna River and other rivers in Upper Cook Inlet in May and July (Calkins 1989).

The tracks of 15 belugas instrumented with satellite tags 1999-2003 showed belugas were sometimes in the vicinity of Fire Island, although movement patterns suggest they passed the island while transiting between other areas (Hobbs et al. 2005). Belugas were tracked near Fire Island in all seasons. Belugas were not observed using waters in or near the proposed Deployment Area to transit between areas of known occurrences (e.g., the mouth of the Susitna River and Knik Arm) during the current study.

Our observations of beluga whale presence in and near the Little Susitna River throughout the summer and fall with a peak in August are consistent with patterns detected from aerial surveys by NMFS (1993-2009; Rugh et al. 2000, 2005, 2006; Shelden et al. 2008a,b,c, 2009a,b). Observers during aerial surveys flown by NMFS June 2-9, 2009 reported groups of belugas in Chickaloon Bay and the Susitna Delta (defined as the near shore area between the Beluga and Little Susitna rivers; Shelden et al. 2009a). Observers during NMFS surveys flown August 11-13, 2009 reported groups of belugas near the Ivan, Susitna, and Little Susitna Rivers, as well as in Knik Arm (Shelden et al. 2009b). In previous years, aerial surveys (conducted annually in June, and sometimes in May, July, and August) have detected belugas off of the Susitna Delta in the summer, but not around Fire Island (Rugh et al. 2000), the only exception being two belugas reported northeast of Fire Island on June 14, 2007 (Rugh et al. 2007).

Beluga whales were reported in the Susitna Delta in May, June, July, and August, but not in September or October during boat-based surveys in May through October 2006 (Nemeth et al. 2007). Belugas were not seen as the vessel transited near Fire Island during any of these months.

[1] During the site visit to the Fire Island in May, observers noted many dead (spawned) eulachon on the beach on the north side of Fire Island; it was assumed these dead eulachon were carried downstream in the Susitna or Little Susitna rivers by the current and washed up on Fire Island by the tide.

The absence of beluga sightings from the Fire Island observation station in October was notable, particularly because belugas were again seen in November at the mouth of the Little Susitna River. NMFS does not conduct aerial surveys for belugas in October, and aerial-survey data for this time period are not available for comparison. Two boat-based photo-identification surveys were conducted by LGL in October 2009. Beluga whales were observed in the mouth of the Little Susitna River during a survey on October 1. No whales were encountered along the Susitna Delta (including the mouth of the Little Susitna River) on the October 6 photo-identification survey, although belugas were seen in Knik and Turnagain arms (LGL, unpublished data) on this and subsequent days in October. Spernak Air pilots reported seeing whales at the mouth of the Little Susitna River on six days in October 2009. On three of the six days, observers were not at Fire Island. On two days in October, pilots saw belugas up the Little Susitna River around the first bend, where belugas would not have been visible to observers on Fire Island. Not enough detail was provided about the other sighting made by pilots to be able to determine if the belugas were up the river or if the sighting was made at a time when observers were at the observation stations.

The second objective of this study was to provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project. This objective has been met with monthly progress reports from LGL to ORPC, which ORPC in turn distributed to NMFS and FERC. Copies of these reports are publicly available at http://www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm#orpc. This report is a summary of the six monthly reports.

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Shelden, K.E.W., K.T. Goetz, C. Sims and B.A. Mahoney. 2008c. Aerial surveys of belugas in Cook Inlet, Alaska, September and October 2008. National Marine Fisheries Service, NMML Unpublished Field Report, 8 p.

Table 1. Monthly observation effort and beluga sightings from the Fire Island Alaska observation site in 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

Month	# Days of Observation	# Hours of Observation	# Days Belugas Sighted	Percent Observation Days Belugas Sighted	# Beluga Groups Sighted	# Beluga Sightings	# Beluga Sightings/ Hour	Belugas in Deployment Area?	Closest Distance between Observation Station & Belugas (km)
June	9	41.9	5	55.6	5	14	0.3	No	2.7
July	16	81.2	4	25.0	4	78	1.0	No	3.7
August	14	112.0	14	100.0	16	497	4.4	No	4.5
September	14	111.3	5	35.7	6	128	1.2	No	7.1
October	13	96.5	0	0.0	0	0	0.0	No	NA
November	7	36.6	3	42.9	4	40	1.1	No	7.3
2009 Total	**73**	**479.5**	**31**	**42.5**	**35**	**757**	**1.6**	**No**	**2.7**

Table 2. Reports of incidental sightings from Spernark Air pilots, as reported to LGL observers.

Month	Date	Location	Number of Whales	Comments
July	2009JUL23	Susitna River	100	
August	2009AUG04	Little Susitna River	70	
August	2009AUG05	Little Susitna River	100	
August	2009AUG10	Little Susitna River	70	
August	2009AUG12	Little Susitna River	55	There all day
August	2009AUG17	Little Susitna River	100	Feeding
August	2009AUG18	Little Susitna River	21	
August	2009AUG19	Ship Creek	NA	No count
August	2009AUG25	Beluga River	8	Traveling
August	2009AUG25	Little Susitna River	22	Traveling
September	2009SEP12	Beluga River	30	
September	2009SEP16	Ivan River	20	
September	2009SEP16	Susitna River	10	
September	2009SEP19	Susitna River	22	
September	2009SEP23	Beluga River	43	
September	2009SEP24	Little Susitna River	20	There all week
September	2009SEP25	Little Susitna River	20	There all week
September	2009SEP29	Susitna River	20	
September	2009SEP30	Little Susitna River	54	
September	2009SEP30	Susitna River	NA	No count
October	2009OCT06	Little Susitna River	NA	No count
October	2009OCT08	Beluga River	30	
October	2009OCT09	Beluga River	30	
October	2009OCT10	Beluga River	30	
October	2009OCT11	Little Susitna River	30	
October	2009OCT17	Susitna River	11	
October	2009OCT18	Little Susitna River	NA	No count
October	2009OCT21	Little Susitna River	NA	No count
October	2009OCT24	Little Susitna River	15	Around first bend
October	2009OCT26	Chuitna River	4	
October	2009OCT26	Little Susitna River	10	Around first bend
October	2009OCT27	Susitna River	3	
October	2009OCT27	Susitna River	4	
November	2009NOV03	Susitna River	5	Traveling
November	2009NOV07	Little Susitna River	15	
November	2009NOV11	Little Susitna River	20	

Table 3. Harbor seal sightings from the Fire Island Alaska observation site in 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

Month	# Days of Observation	# Hours of Observation	# Days Harbor Seals Sighted	# Harbor Seal Sightings	In Deployment Area?
June	9	41.9	1	1	No
July	16	81.2	0	0	No
August	14	112.0	0	0	No
September	14	111.3	3	4	No
October	13	96.5	0	0	No
November	7	36.6	0	0	No
2009 Total	**73**	**479.5**	**4**	**5**	**No**

Table 4. Monthly environmental conditions from the Fire Island Alaska observation site in 2009.

Month	# Days of Observation	# Days Conditions Good	# Days Conditions Fair	# Days Conditions Poor	# Days Able to See Far Shore	Mean Wind Speed (km/hr)	Range of Wind Speed (km/hr)	Mean Beufort Sea State	Mean Air Temp (°C)	Range of Air Temp (°C)	# Days with Rain	# Days with Fog	# Days with Snow
June	9	5	2	2	9.0	2.0	0 − 16	1.4	17.6	10 − 29	2	0	0
July	16	6	9	1	16.0	1.5	0 − 10	1.4	21.7	14 − 36	5	0	0
August	14	2	11	1	13.5	1.5	0 − 13	1.9	19.5	8 − 36	4	1	0
September	14	6	7	1	14.0	9.1	0 − 24	1.7	10.8	2 − 19	4	0	0
October	13	2	7	4	13.0	11.4	0 − 44	1.8	5.7	-1 − 15	3	3	0
November	7	4	3	0	7.0	11.3	0 − 30	1.5	-2.1	-8 − 3	0	1	1
2009 Total	**73**	**25**	**39**	**9**	**72.5**	**6.1**	**0 − 44**	**1.6**	**12.2**	**-8 − 36**	**18**	**5**	**1**

Table 5. Monthly sightings of vessels seen from the Fire Island Alaska observation site in 2009. Vessel sightings are expressed in number of days each vessel type was seen per month.

Month	# Days of Observation	Motorized Barge	Dive Vessel	ORPC Survey Vessel	Skiff	Fishing Boat	Tanker	Tug/ Tug & Barge	Container Ship	Set-Net Vessel	Crane Dredge	Coast Guard Vessel	LGL Zodiac	Other Vessel
June	9	0	0	7	4	2	0	2	0	0	0	0	0	0
July	16	0	0	2	10	0	0	3	0	3	1	1	3	3
August	14	0	0	8	6	4	1	2	1	0	0	1	3	4
September	14	2	4	1	3	0	1	8	0	0	0	0	0	0
October	13	1	0	0	0	0	0	2	6	0	0	0	1	0
November	7	0	0	0	0	0	0	1	1	0	0	1	0	0
2009 Total	**73**	**3**	**4**	**18**	**23**	**6**	**2**	**18**	**8**	**3**	**1**	**3**	**7**	**7**

Table 6. Monthly sightings of birds seen from the Fire Island Alaska observation site in 2009. Bird sightings are reported for birds seen on the water in or near the proposed Deployment Area.

Month	# Days of Observation	# Gulls	# Black Scoters	# Surf Scoters	# Unidentified Birds
June*	9	x	x	x	x
July	16	7	3	2	0
August	14	7	0	0	6
September	14	25	0	0	0
October	13	0	0	0	0
November	7	2	0	0	0
2009 Total	**73**	**41**	**3**	**2**	**6**

* Information not collected in June

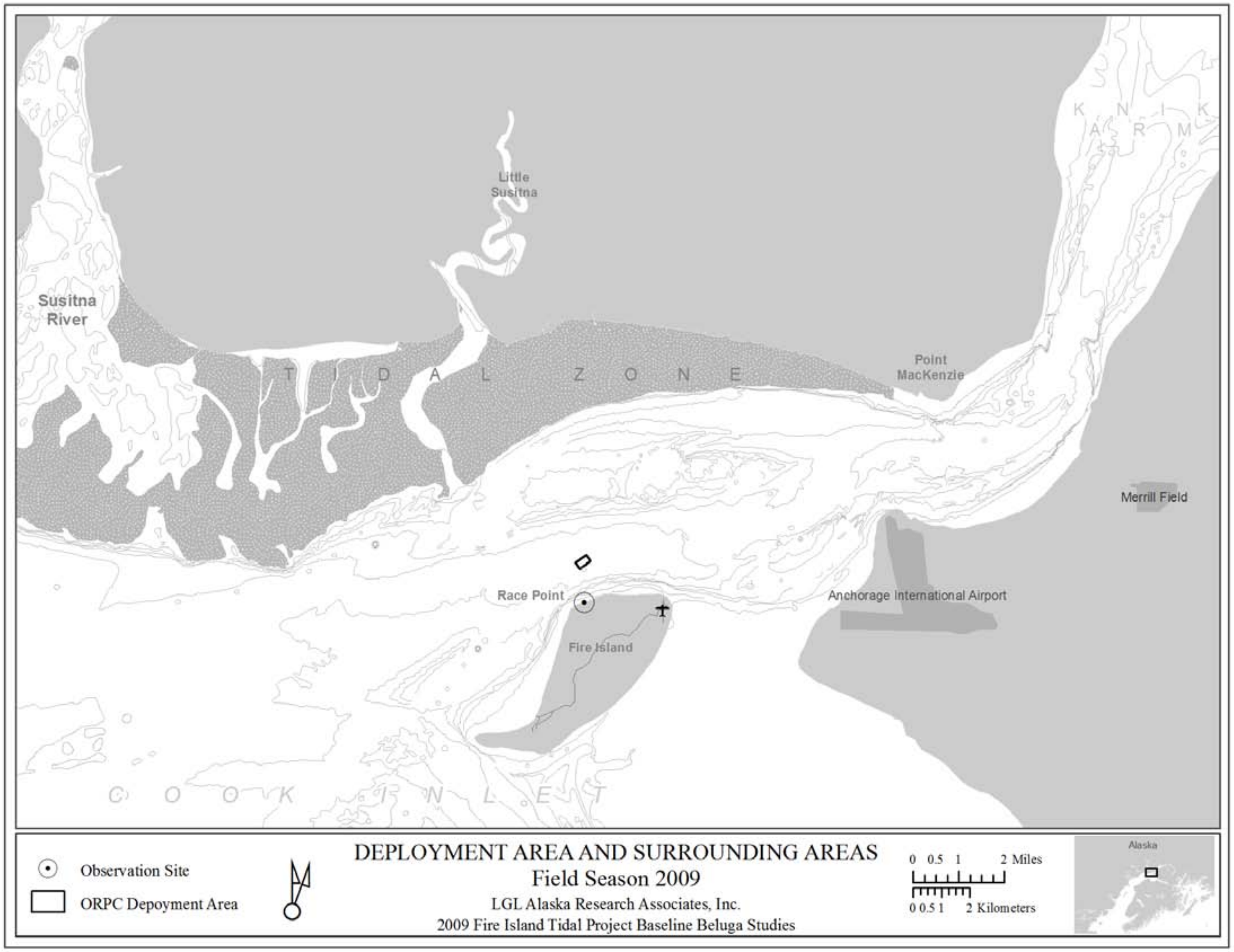

Figure 1. A map of Upper Cook Inlet showing the ORPC proposed Deployment Area, the Fire Island observation site, and major features presented in the text. Prominent areas visible from the observation site include the Susitna River to the West, the Little Susitna River to the north, and Point MacKenzie to the east.

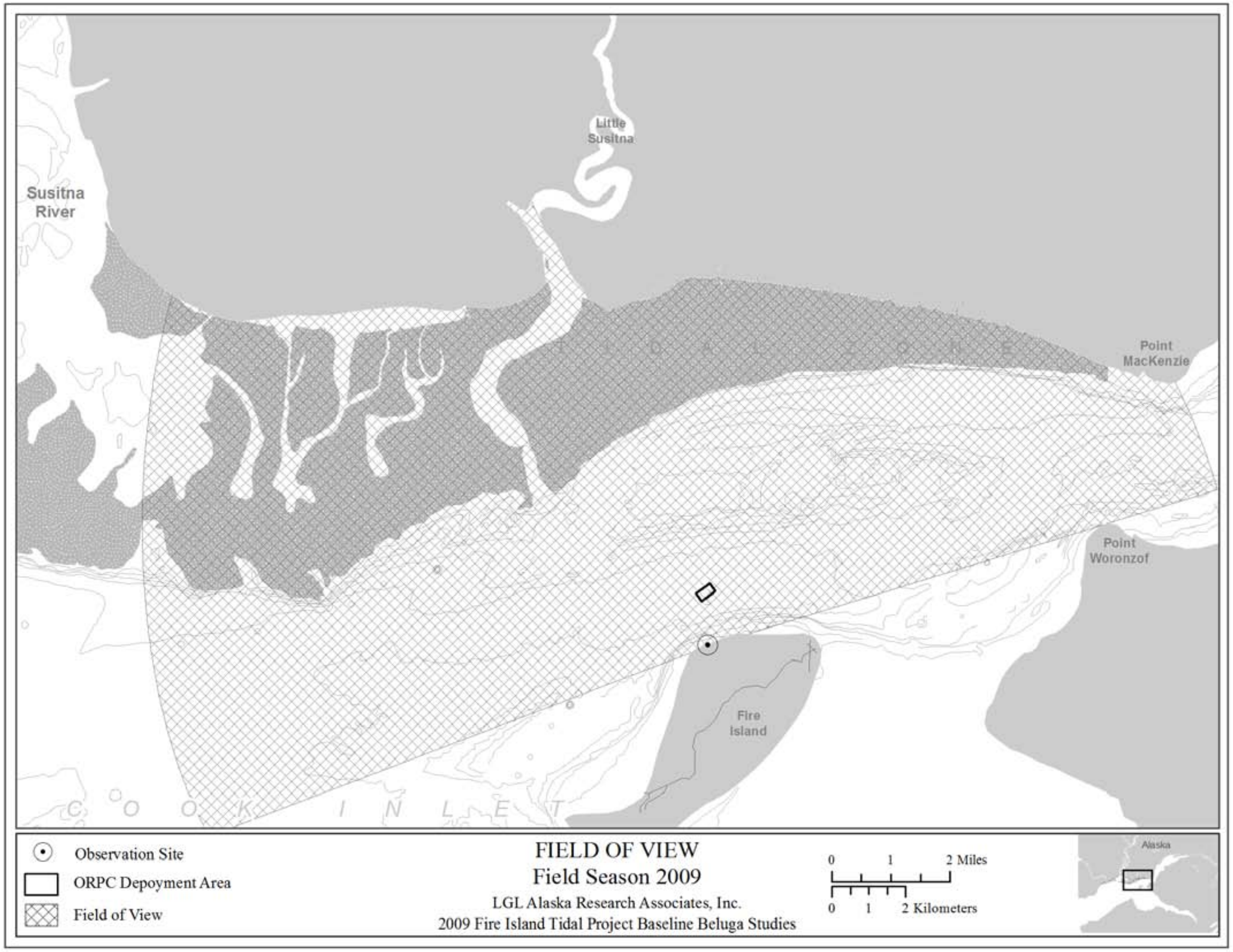

Figure 2. The maximum field of view as seen from the observation site tower and measured with the theodolite. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

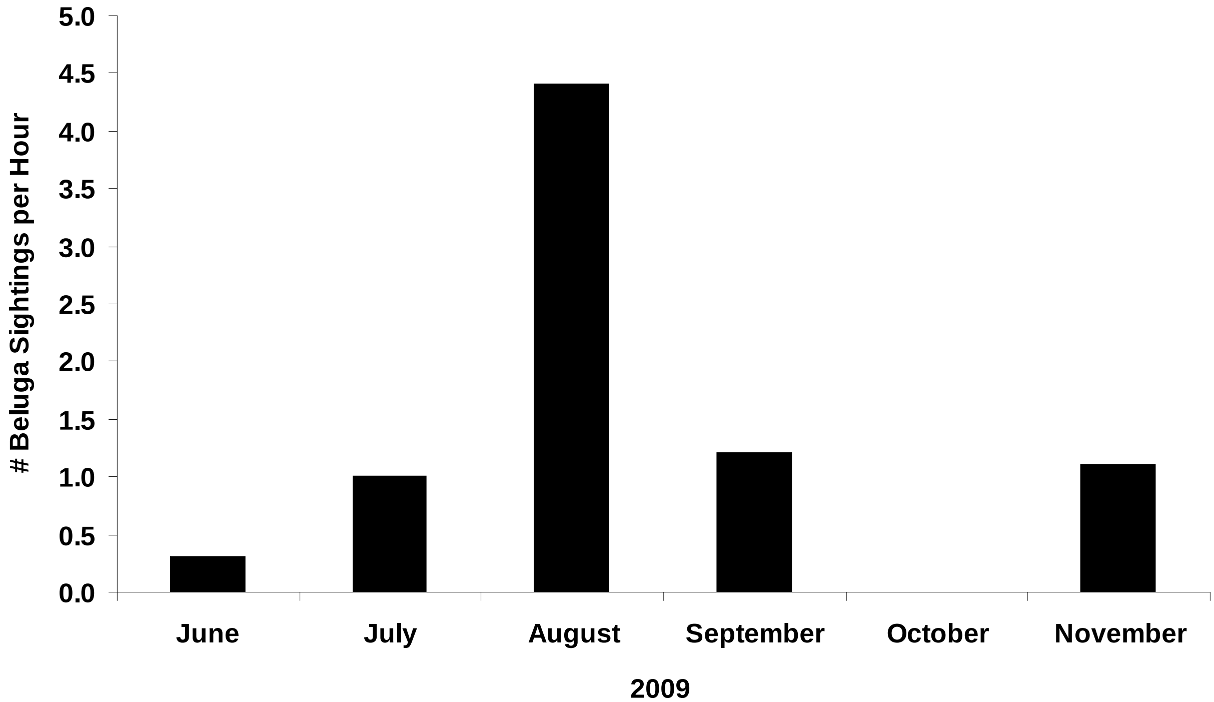

Figure 3. Number of belugas sighted per hour from the Fire Island observation site in 2009.

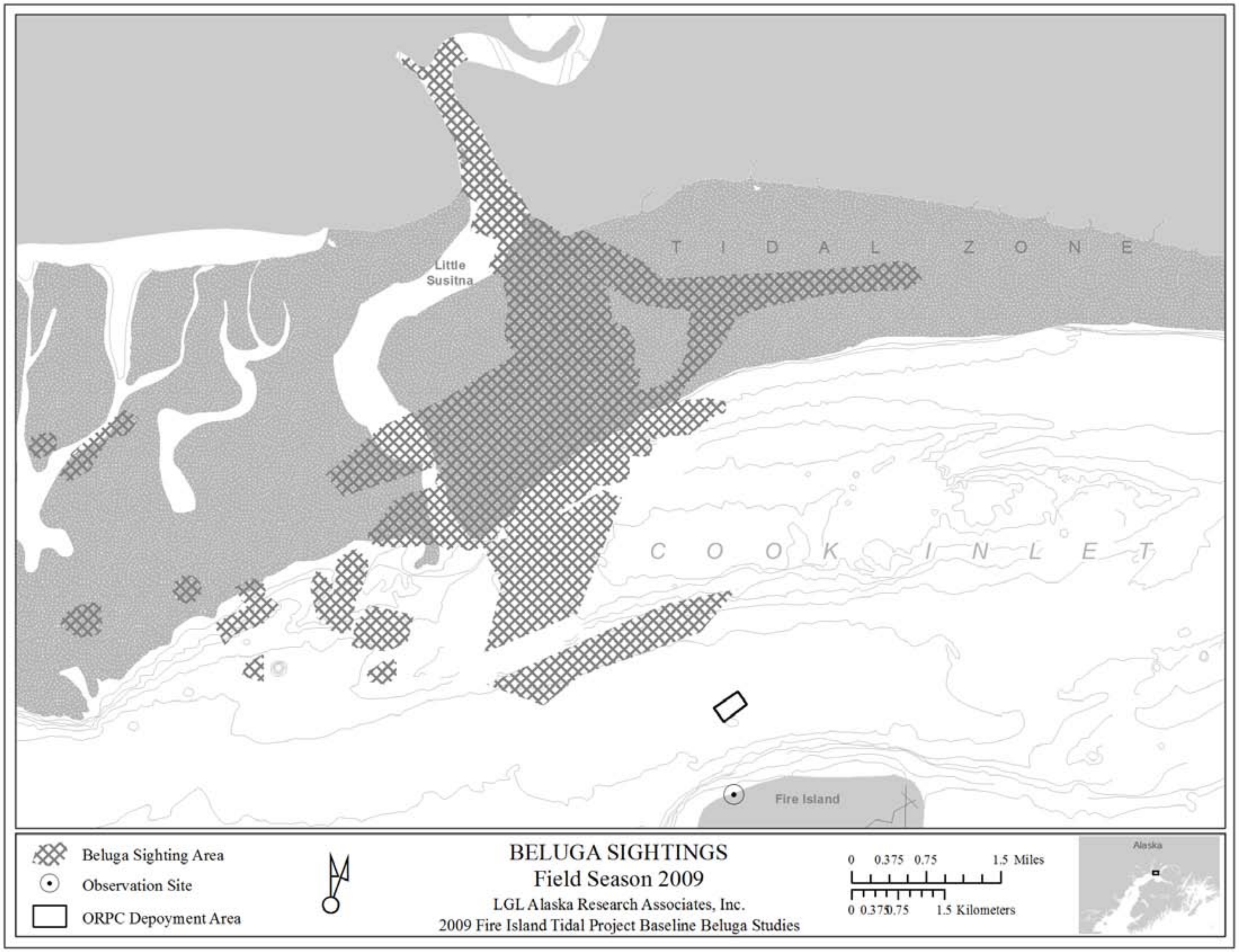

Figure 4. Locations of all beluga sightings between June 17 and November 11, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

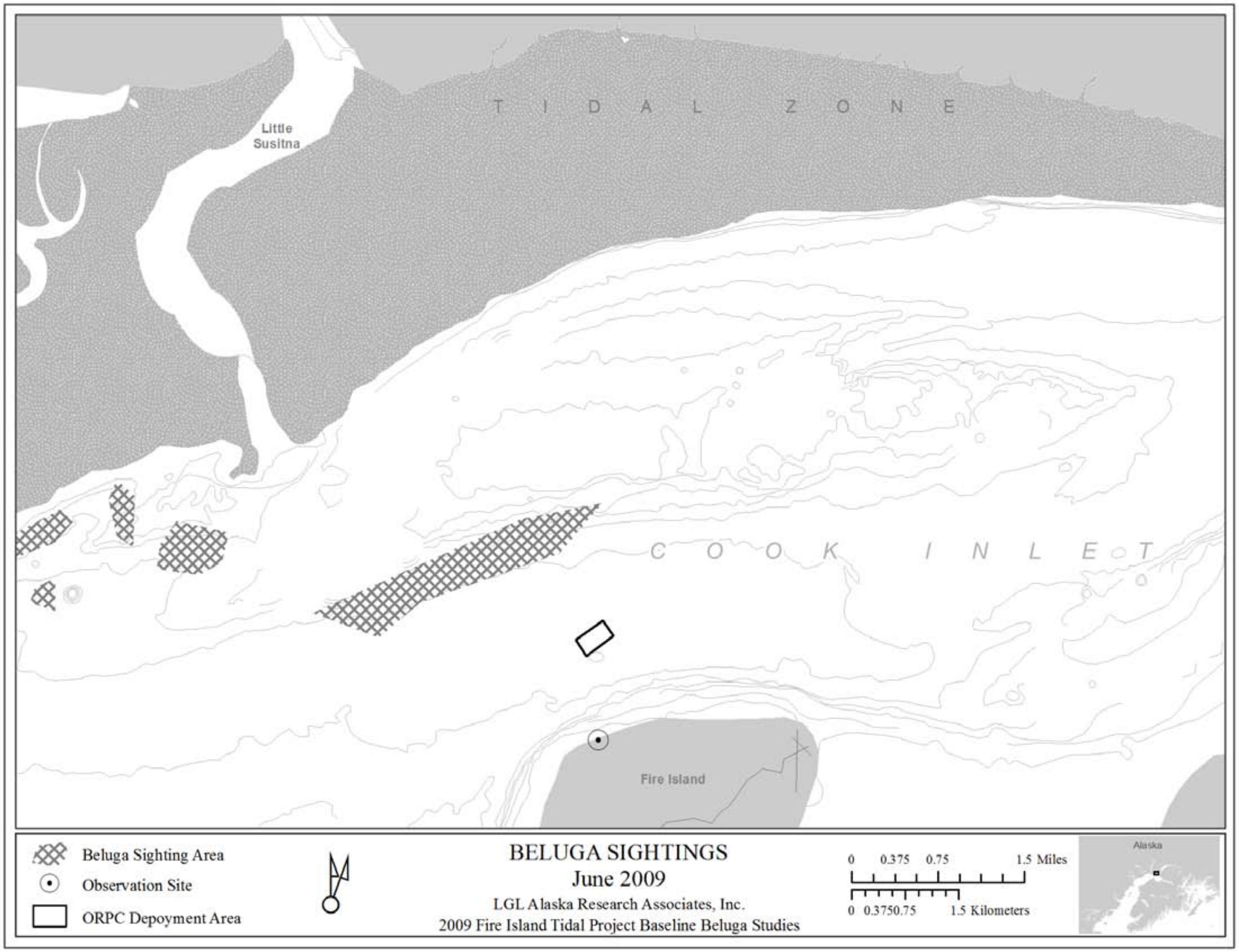

Figure 5. Locations of all beluga sightings in June 2009. Observations began on June 17. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

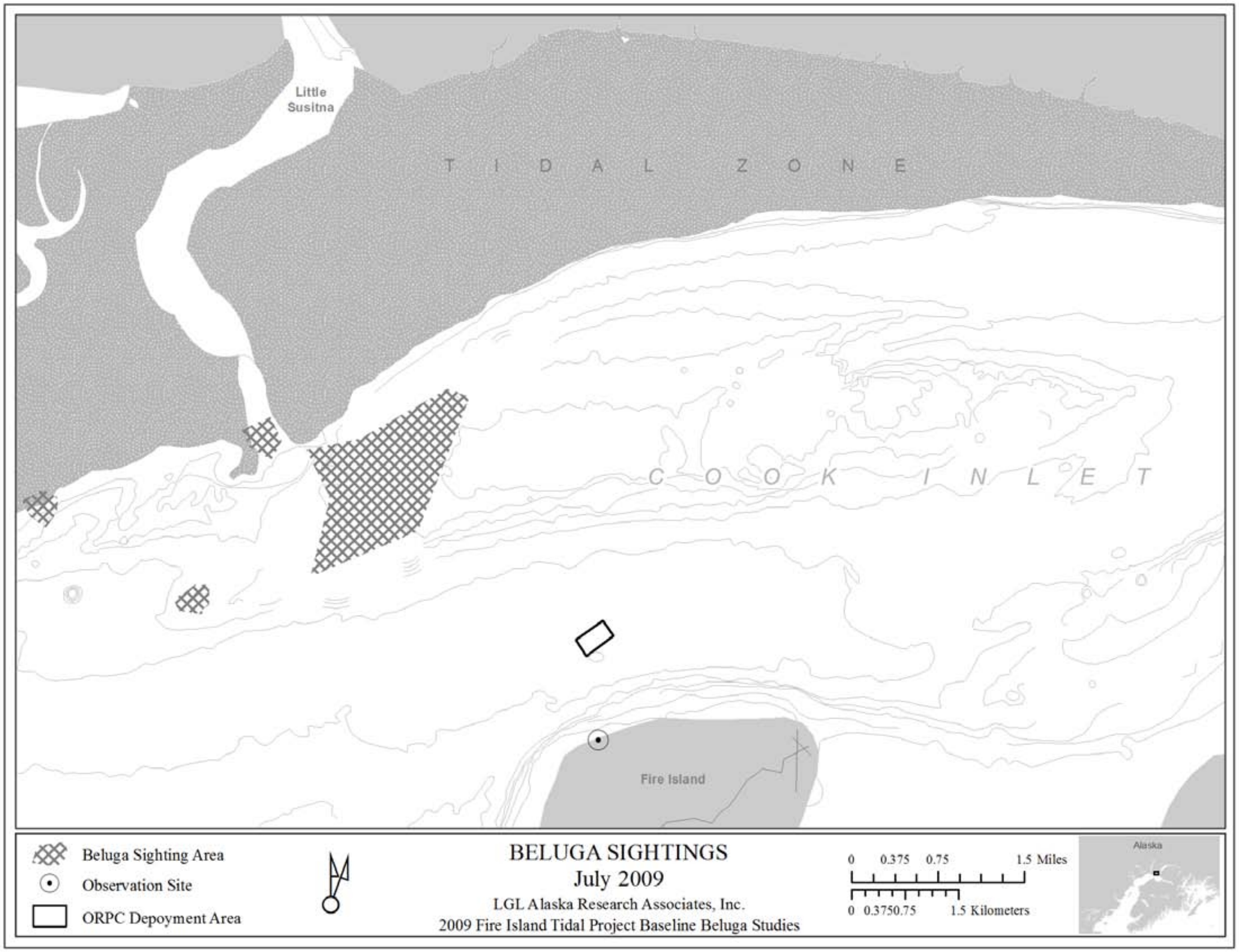

Figure 6. Locations of all beluga sightings in July 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

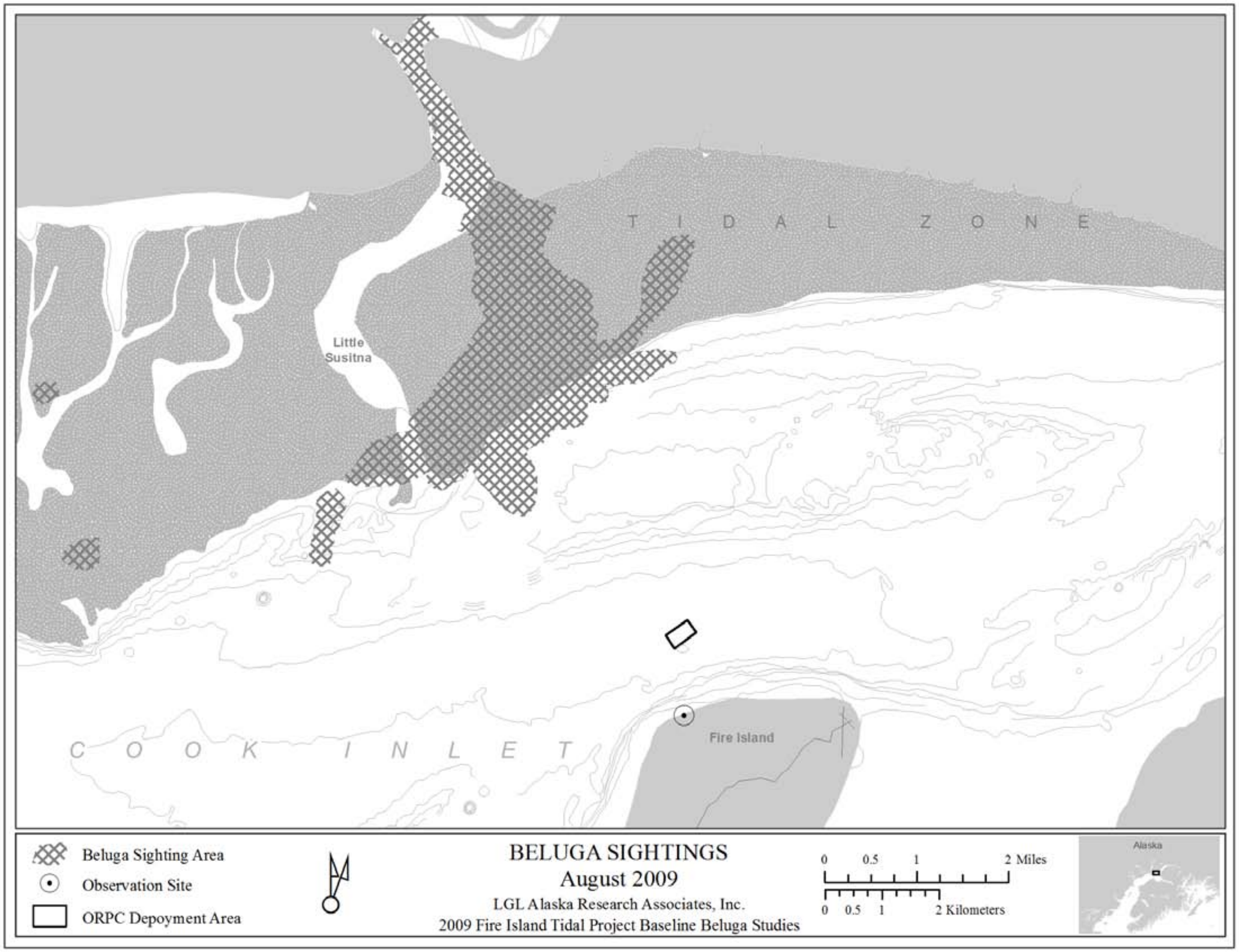

Figure 7. Locations of all beluga sightings in August 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

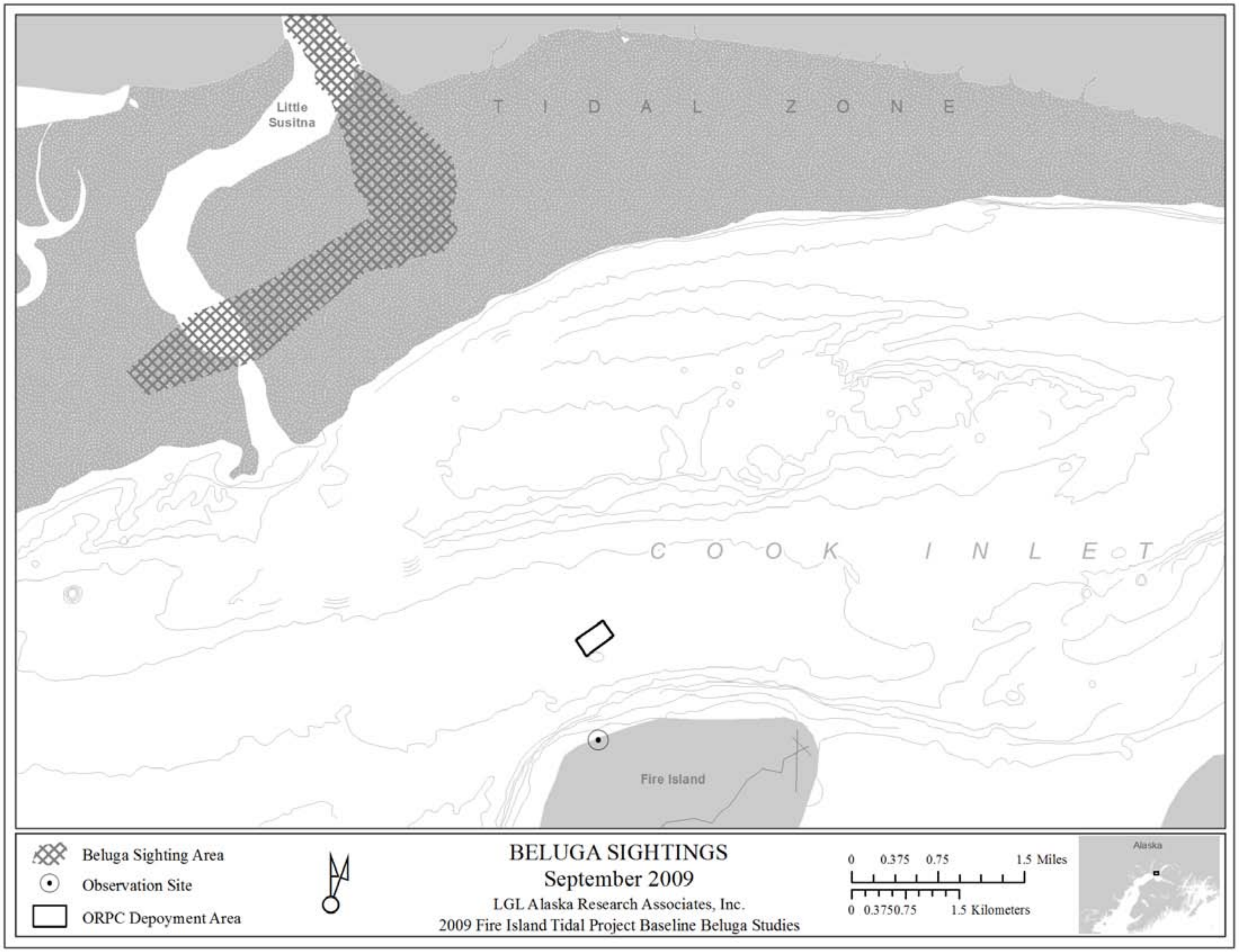

Figure 8. Locations of all beluga sightings in September 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

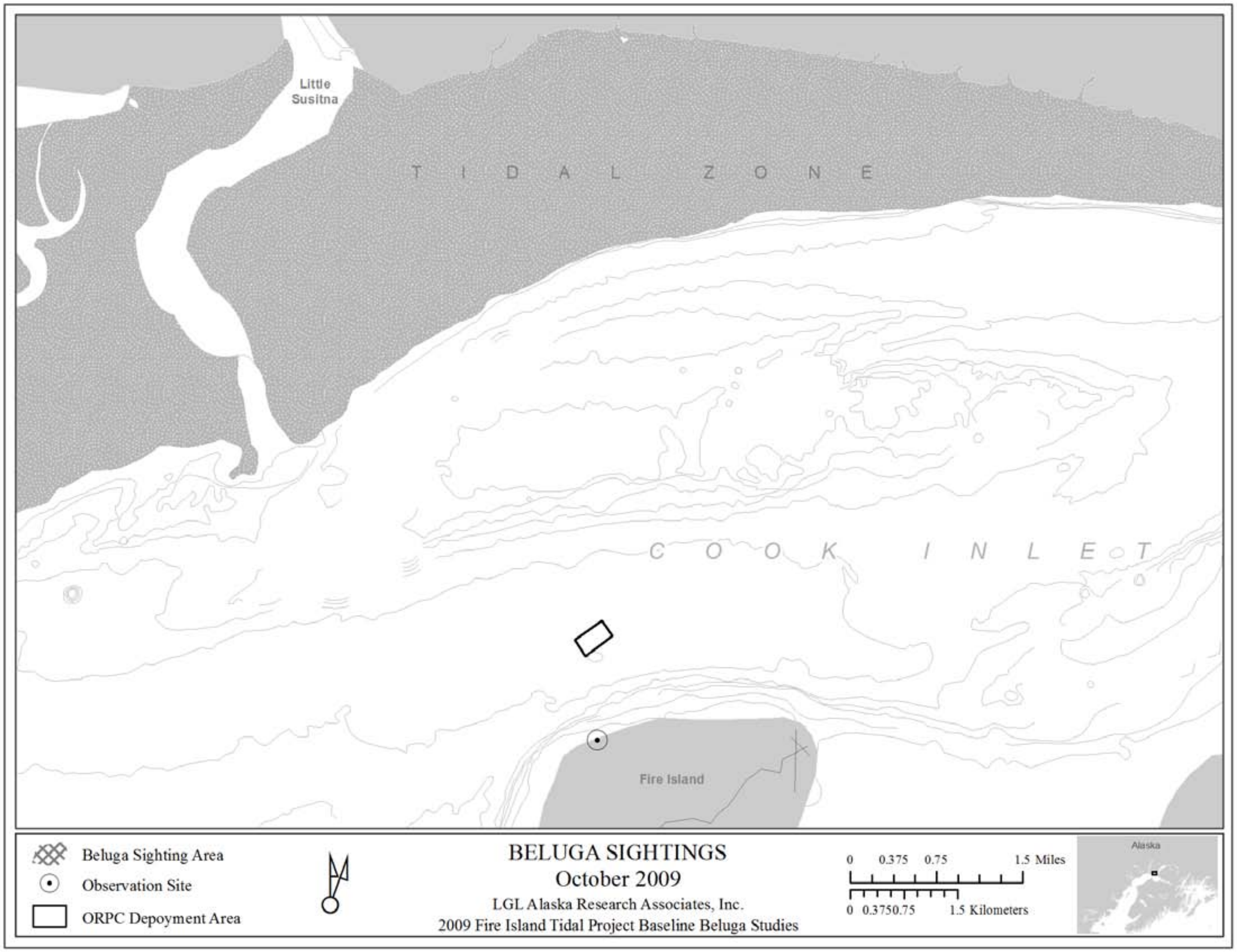

Figure 9. Locations of all beluga sightings in October 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

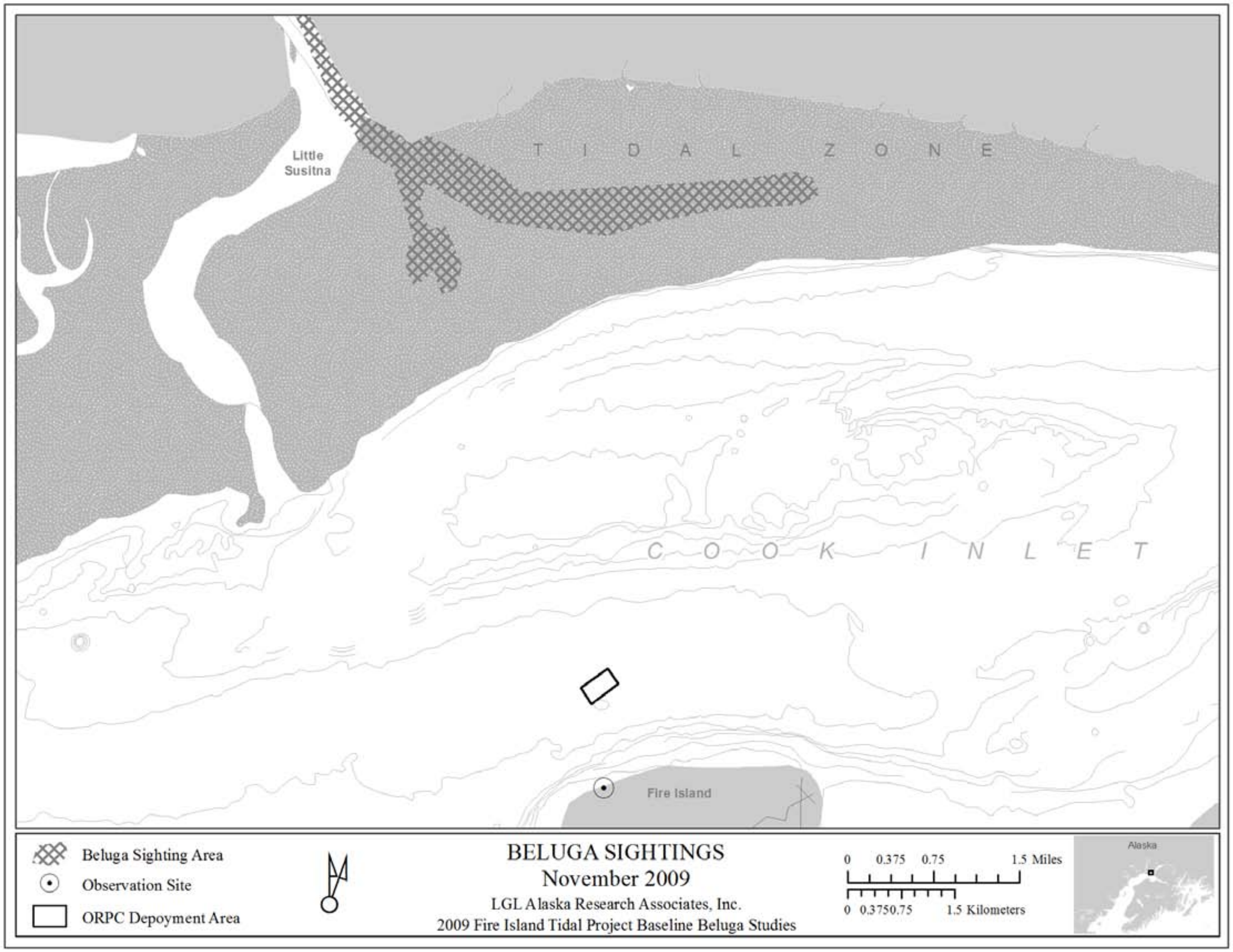

Figure 10. Locations of all beluga sightings in November 2009. Observations concluded November 11, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

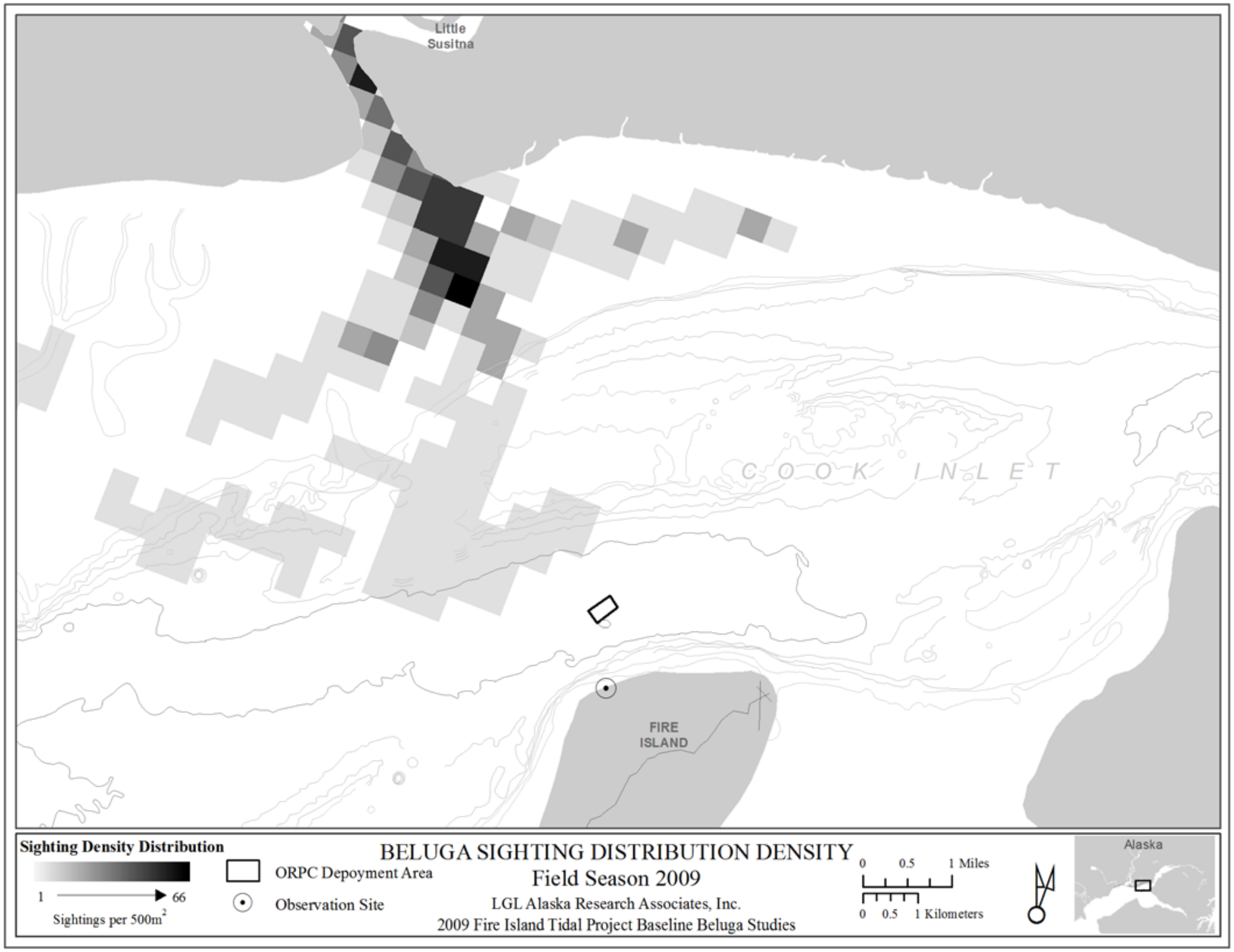

Figure 11. Density of beluga sightings between June 17 and November 11, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

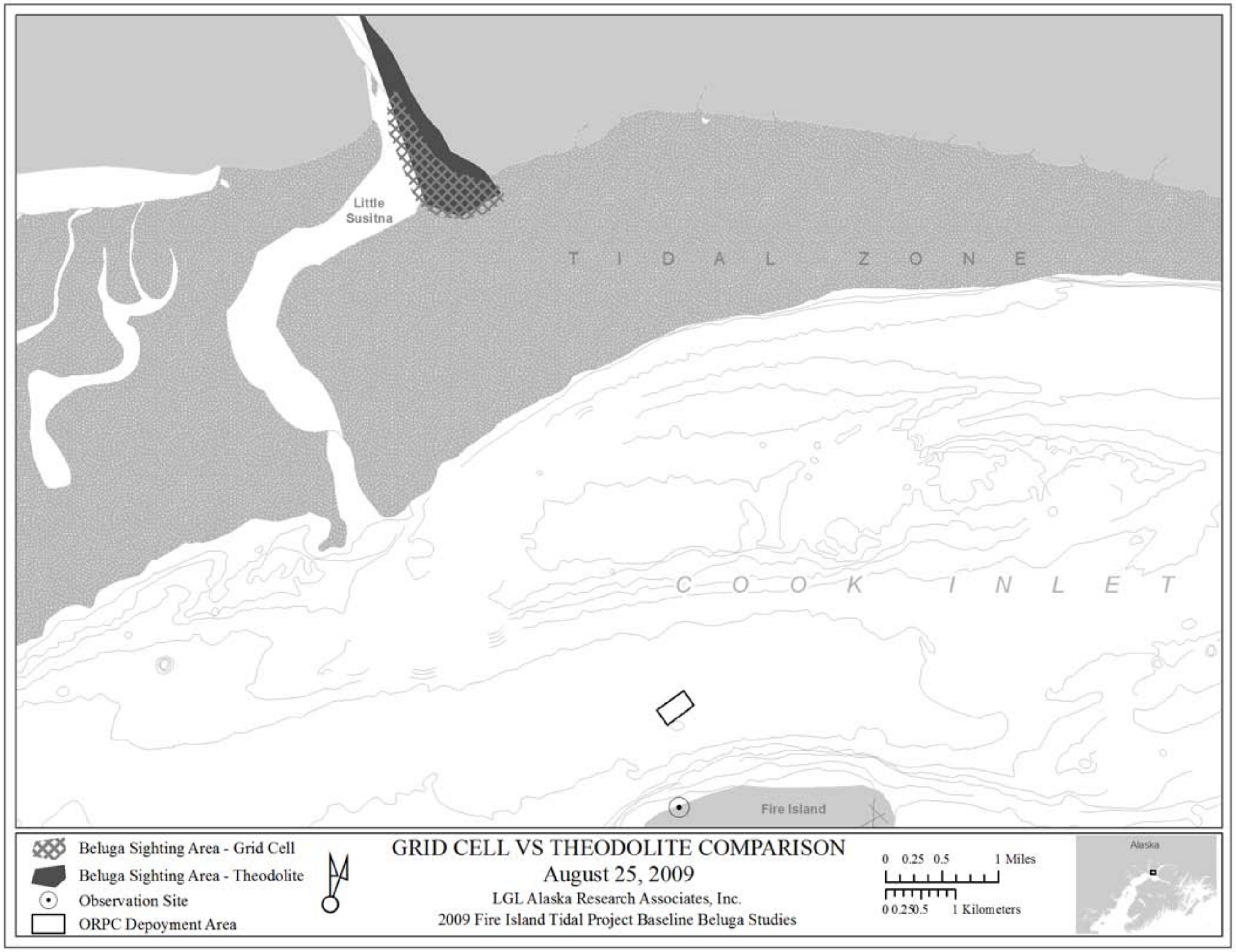

Figure 12. Comparison of methods used to obtain locations of beluga sightings on August 25, 2009. Observers used both grid-cell maps and the theodolite to determine the location of the same beluga sightings. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

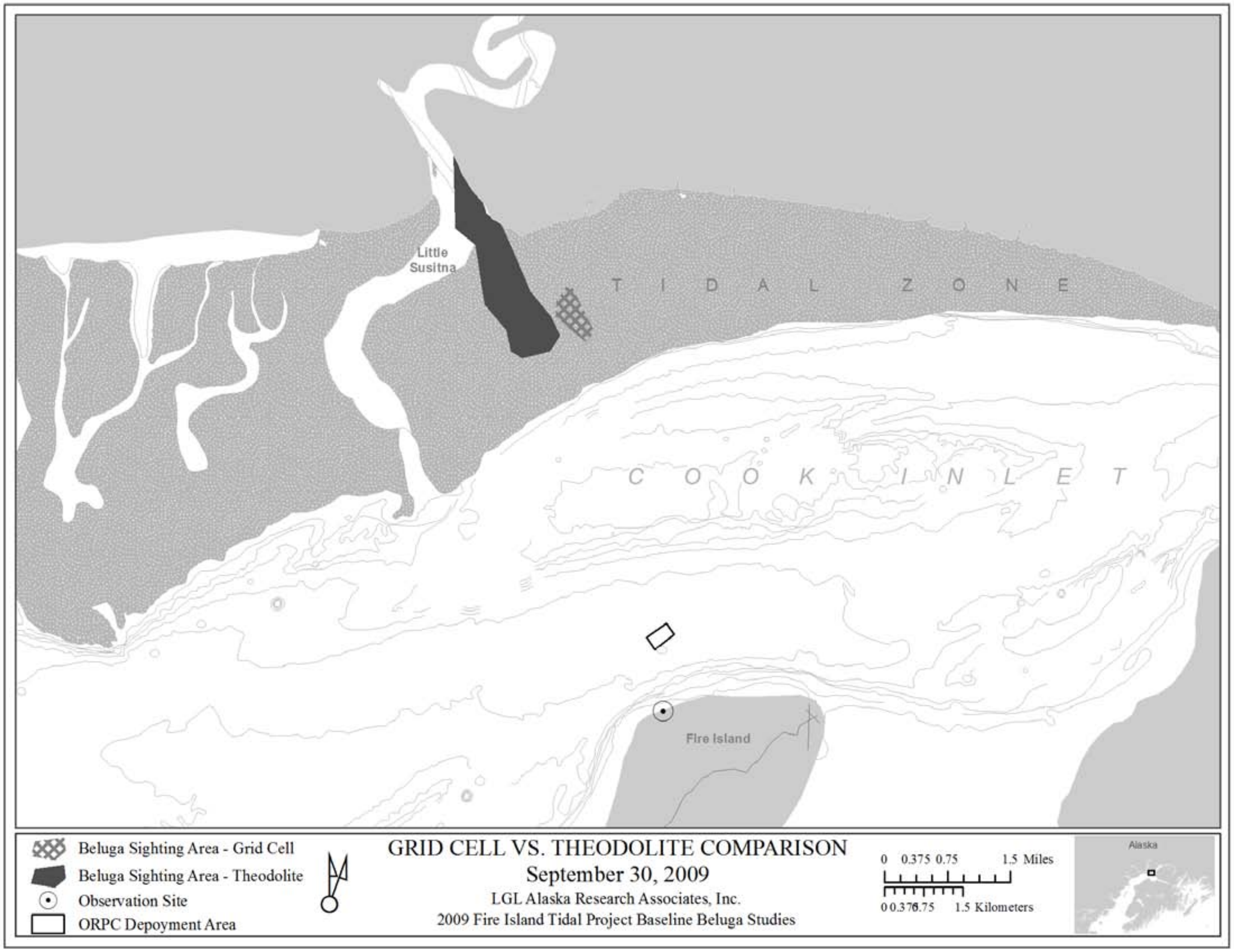

Figure 13. Comparison of methods used to obtain locations of beluga sightings on September 30, 2009. Observers used both grid-cell maps and the theodolite to determine the location of the same beluga sightings. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

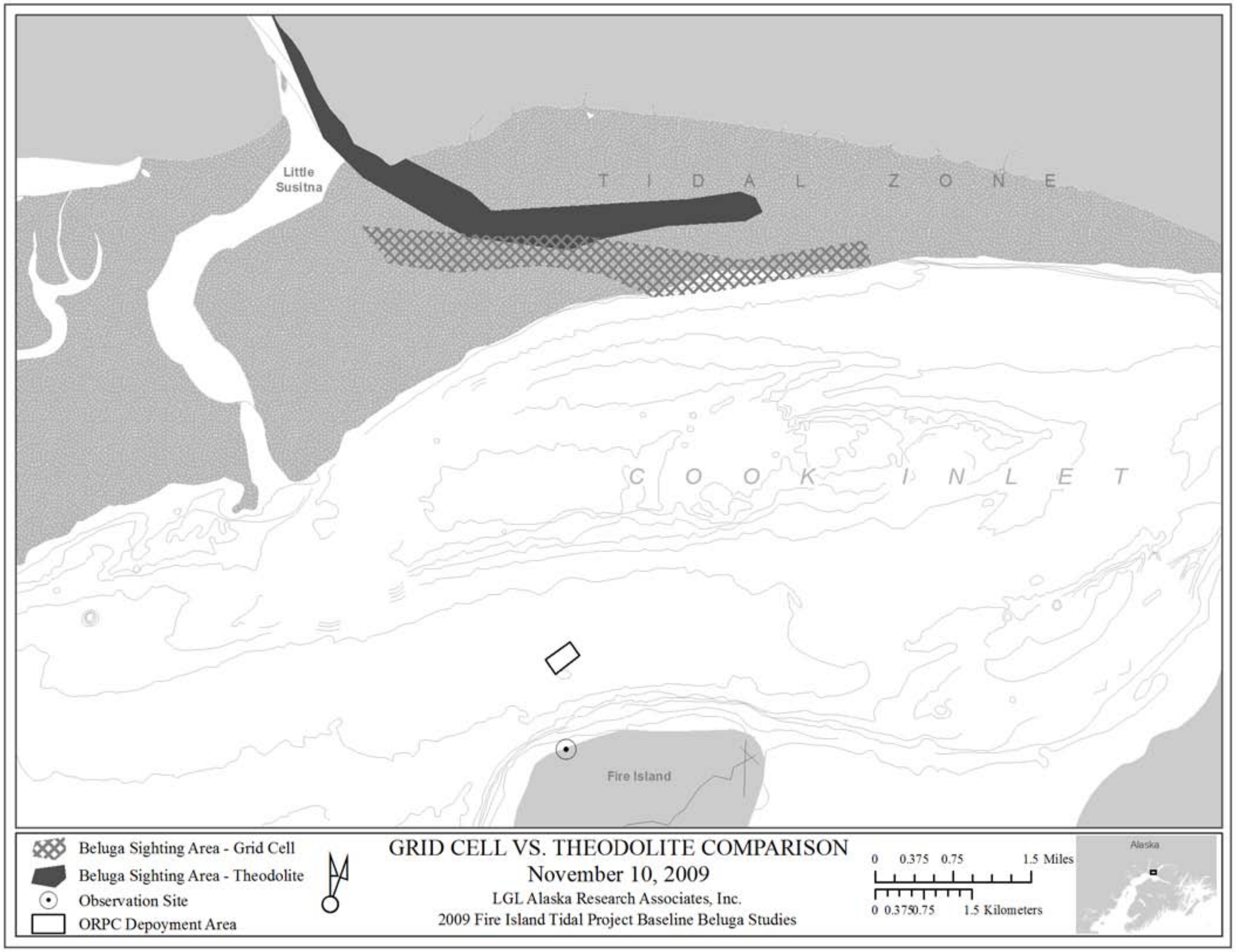

Figure 14. Comparison of methods used to obtain locations of beluga sightings on November 10, 2009. Observers used both grid-cell maps and the theodolite to determine the location of the same beluga sightings. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

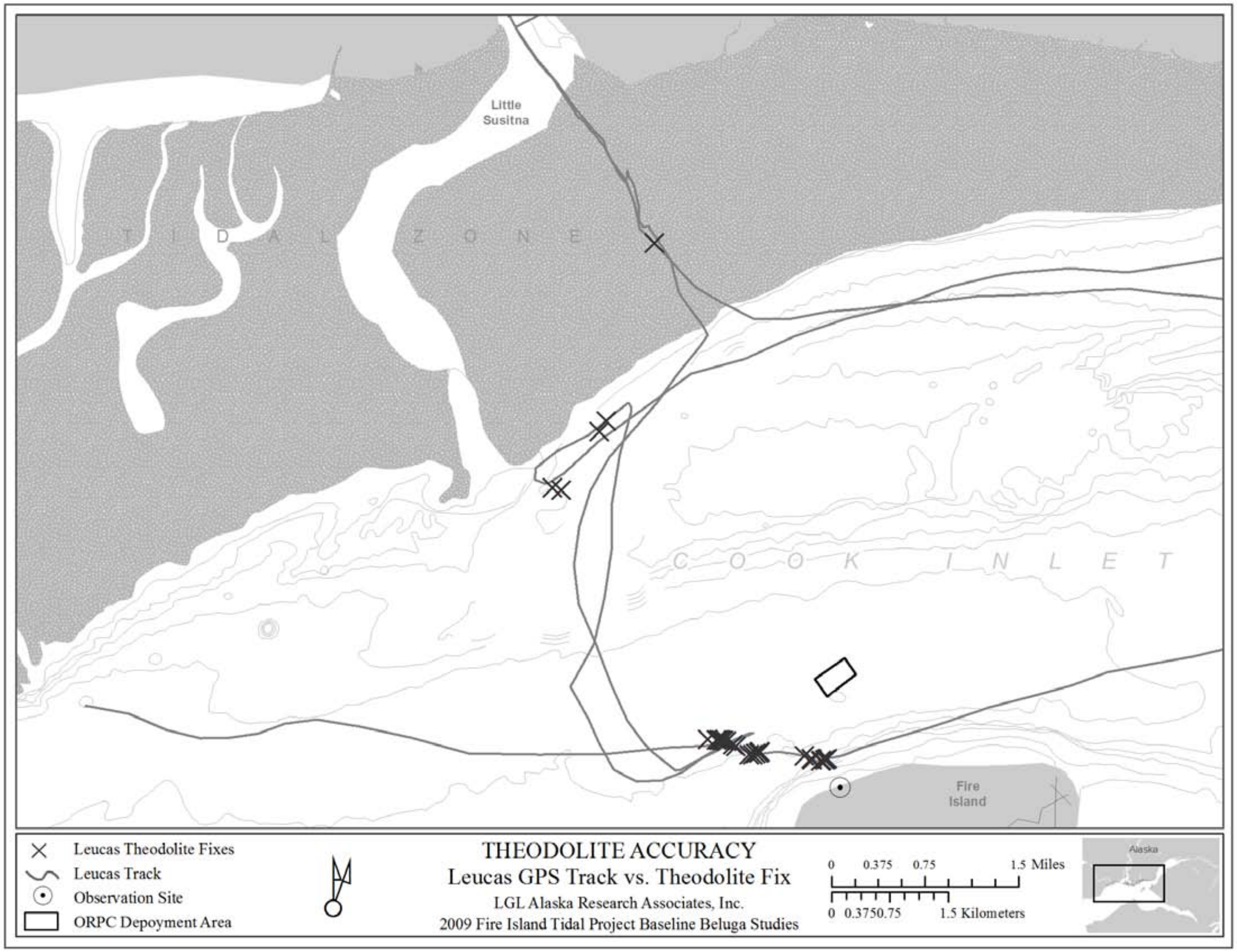

Figure 15. Comparison of GPS tracks of a small boat (the Leucas) and simultaneous theodolite position fixes of the same boat taken from the observation site. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

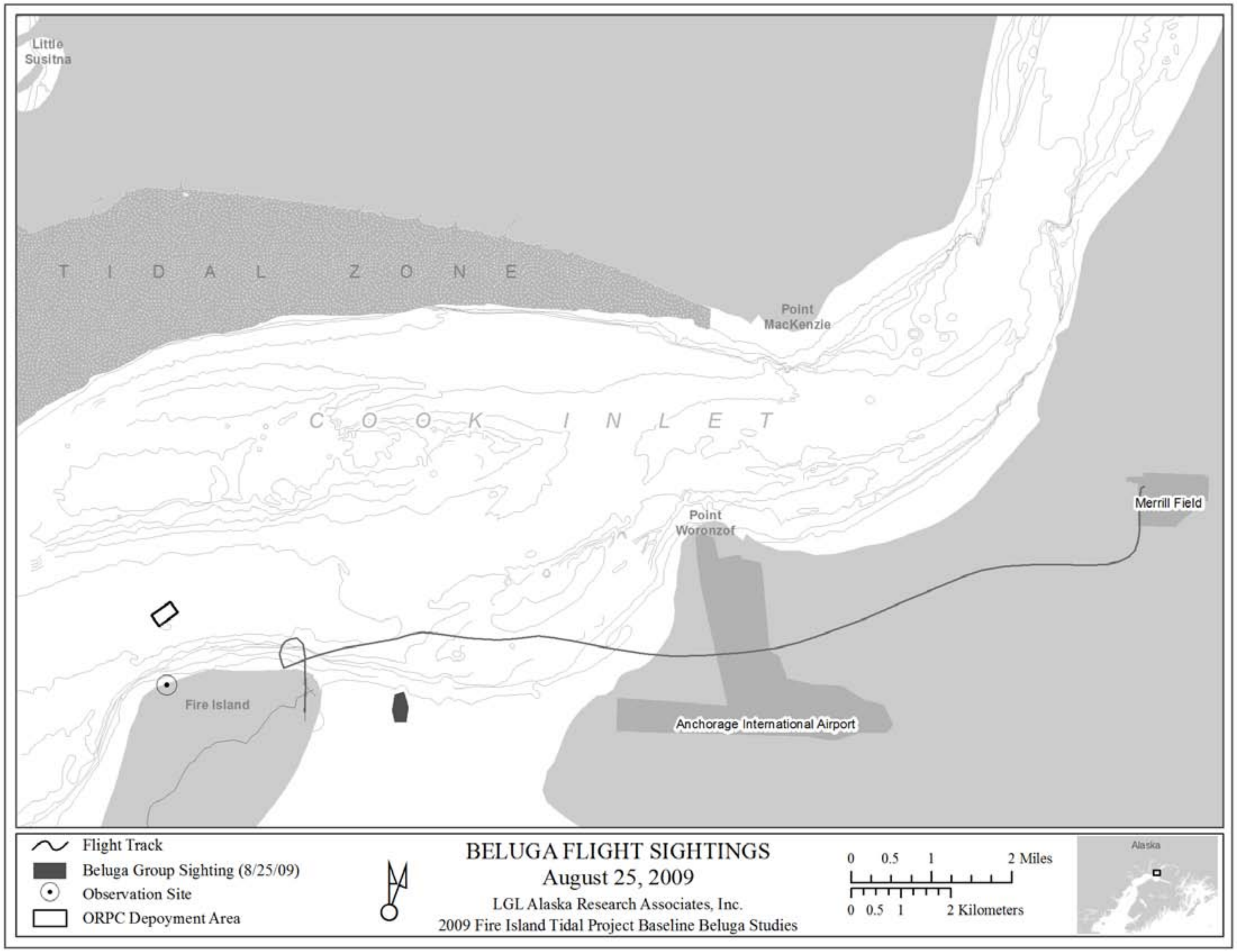

Figure 16. Location of 15-20 belugas sighted during a crew-transport flight on August 25, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

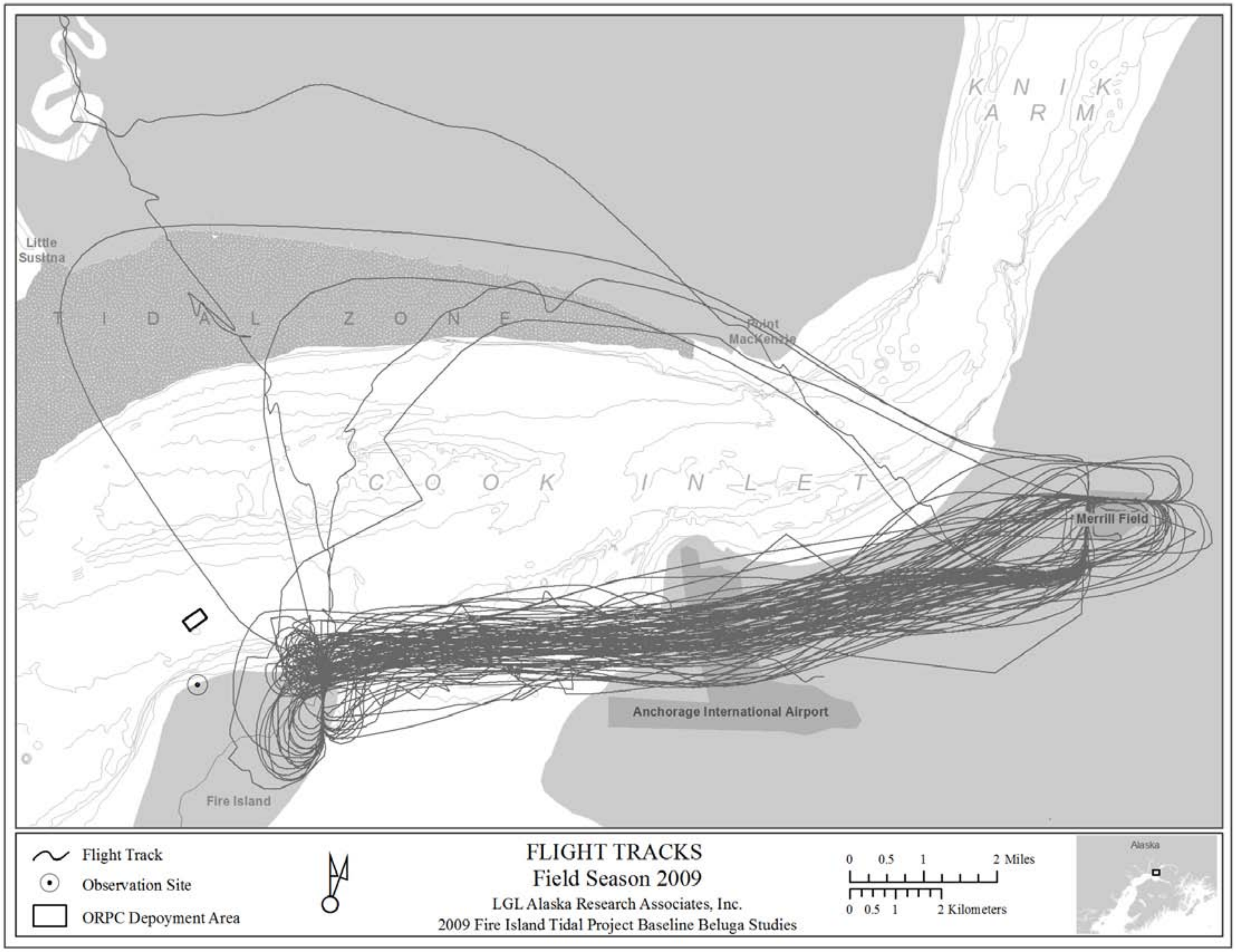

Figure 17. Tracks of crew-transport flights from June 17, 2009 to November 13, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

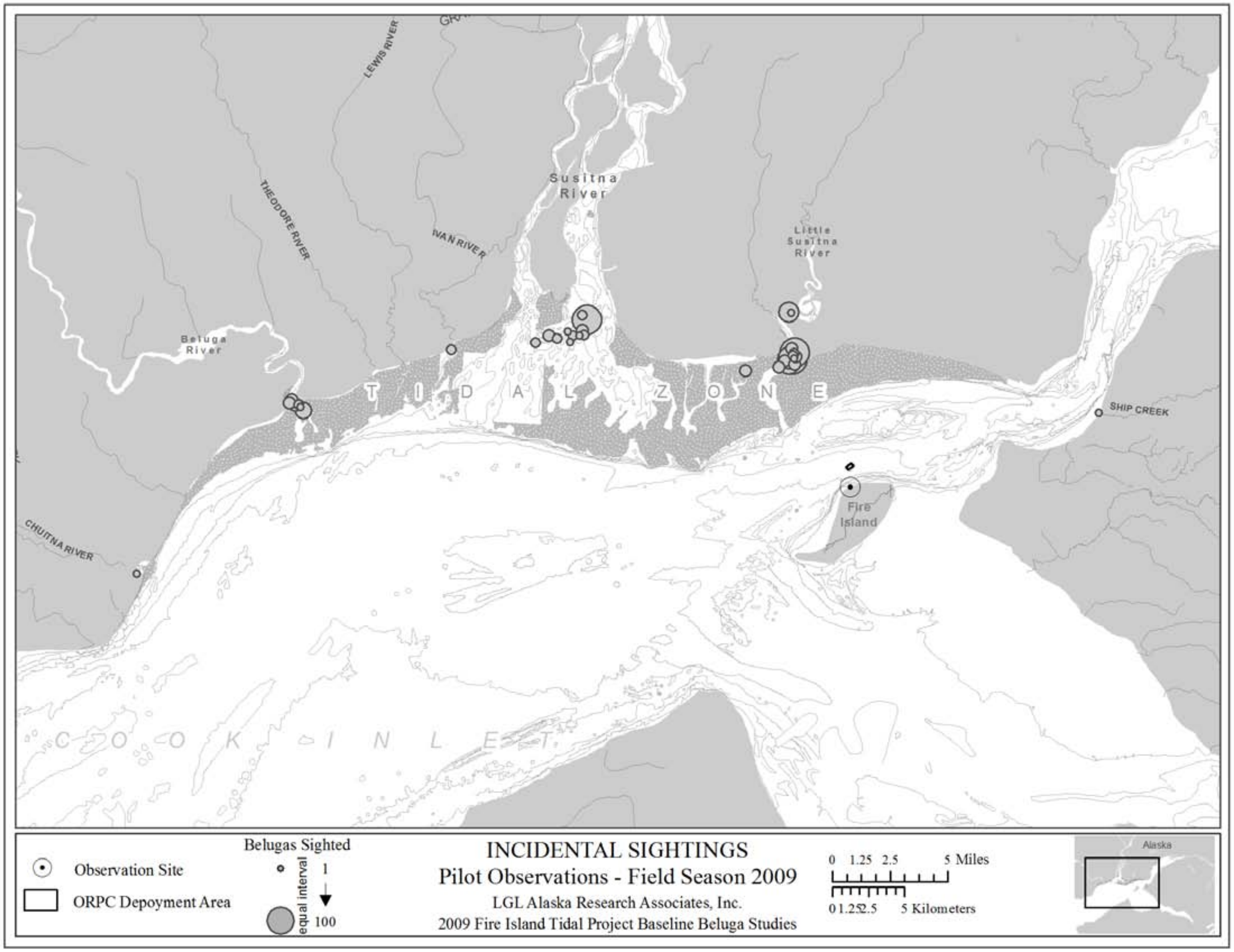

Figure 18. Location and estimated group sizes of belugas observed by Spernak air pilots on flights other than crew transport to Fire Island, July through November, 2009 (pilots did not report seeing belugas in June). The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

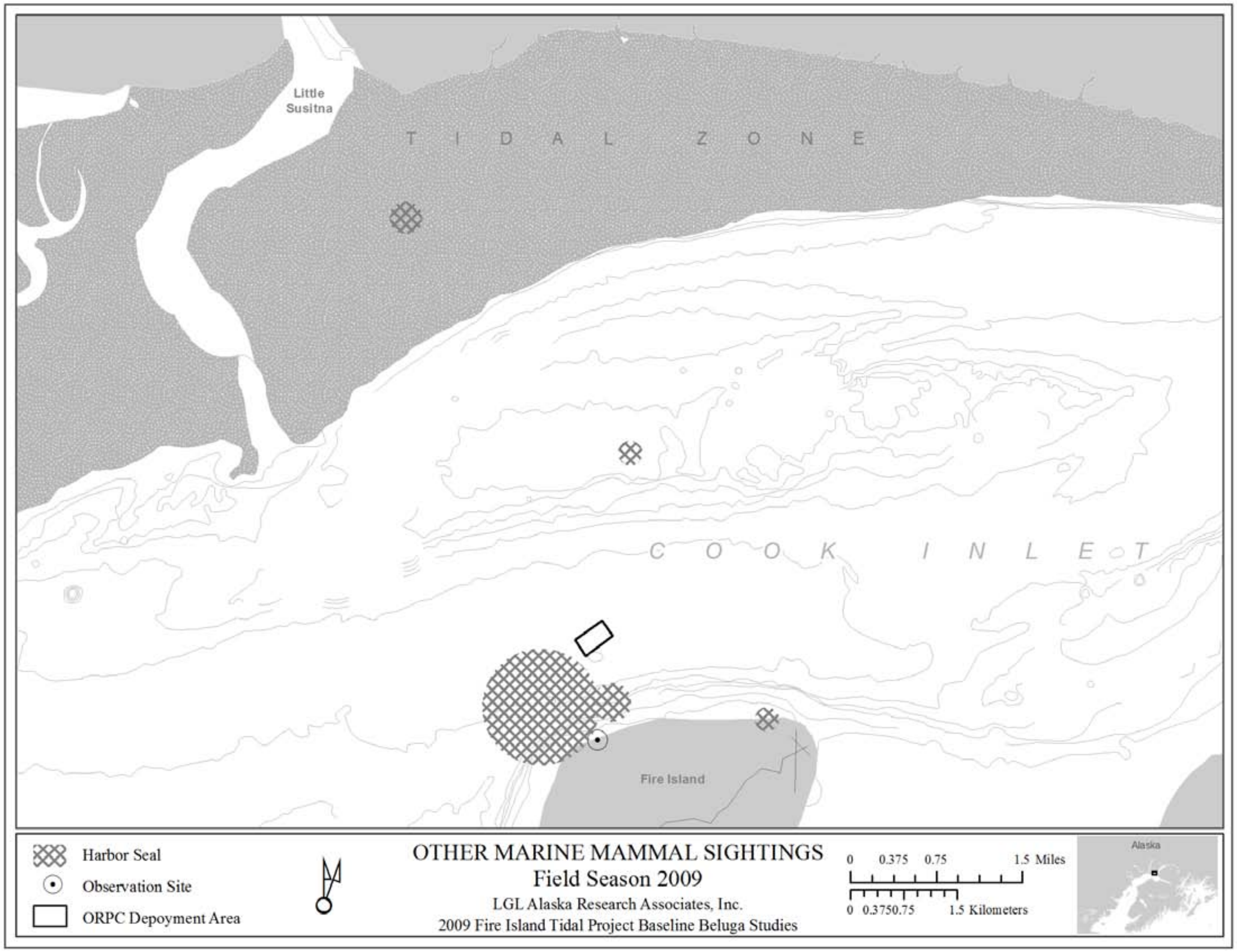

Figure 19. Locations of harbor seals sighted from June 17, 2009 to November 11, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

APPENDIX A

ORPC ALASKA PRE-DEPLOYMENT BELUGA WHALE OBSERVATIONS STUDY PLAN – 3/23/09

1.0 DESCRIPTION OF ISSUE

ORPC Alaska, LLC (hereinafter, ORPC), a subsidiary of Ocean Renewable Power Co., is applying to the Federal Energy Regulatory Commission (FERC) for a pilot license for the Cook Inlet Tidal Energy Pilot Project, FERC Project No. 12679 (hereinafter, Pilot Project or Project). The Project will evaluate the potential for a new source of clean, renewable energy generation using tidal energy resources in Upper Cook Inlet (UCI). The purpose of the Pilot Project is to collect the engineering and environmental effects information to support the project description and environmental analysis of a larger commercial project. ORPC has developed a proprietary modular ocean current generation device, the OCGen™ Module (module). The core component of the OCGen™ technology is ORPC's proprietary turbine-generator unit (TGU), which utilizes advanced design cross-flow turbines to drive a permanent magnet generator located between the turbines and mounted on the same shaft. Multiple TGUs are combined to form one module. Each module proposed for deployment in Cook Inlet will be comprised of 4 TGUs.

The Project will consist of a phased deployment and operation of 5 modules over an expected 8 year license term. Each module has an estimated peak capacity of 1 megawatt (MW) in a 6 knot current. For the site-specific conditions in UCI, a single module will consist of two half-modules, each with 2 TGUs. The overall dimension of each half-module is approximately 91 feet (ft) (28 meter [m]) in length by 28 ft (8.5 m) high and 14 ft (4.2 m) wide. The modules will be placed approximately 42 ft (12.8 m) below the surface at Mean Lower Low Water (MLLW). ORPC plans to deploy the modules in a phased approach. During the first phase, 1 module will be deployed during May/July of 2011, pending all regulatory approvals. During the second phase, ORPC anticipates installing an additional four modules in July/August, 2012, within the designated Pilot Project Deployment Area (Deployment Area) (Figure A1).

Information on beluga whale presence, habitat use and behavior in the proposed project area is critical for evaluating potential project effects and for meeting regulatory requirements under the ESA, the Marine Mammal Protection Act (MMPA), and under FERC regulations for hydropower licensing. There have been numerous surveys of beluga whales in the upper parts of Cook Inlet as part of the environmental studies conducted for the Port of Anchorage, Knik Arm Bridge, and Seward Highway Projects (Markowitz and McGuire 2007, Ramos et al. 2006, Funk et al. 2005). However, there is limited information for the Deployment Area near Fire Island.

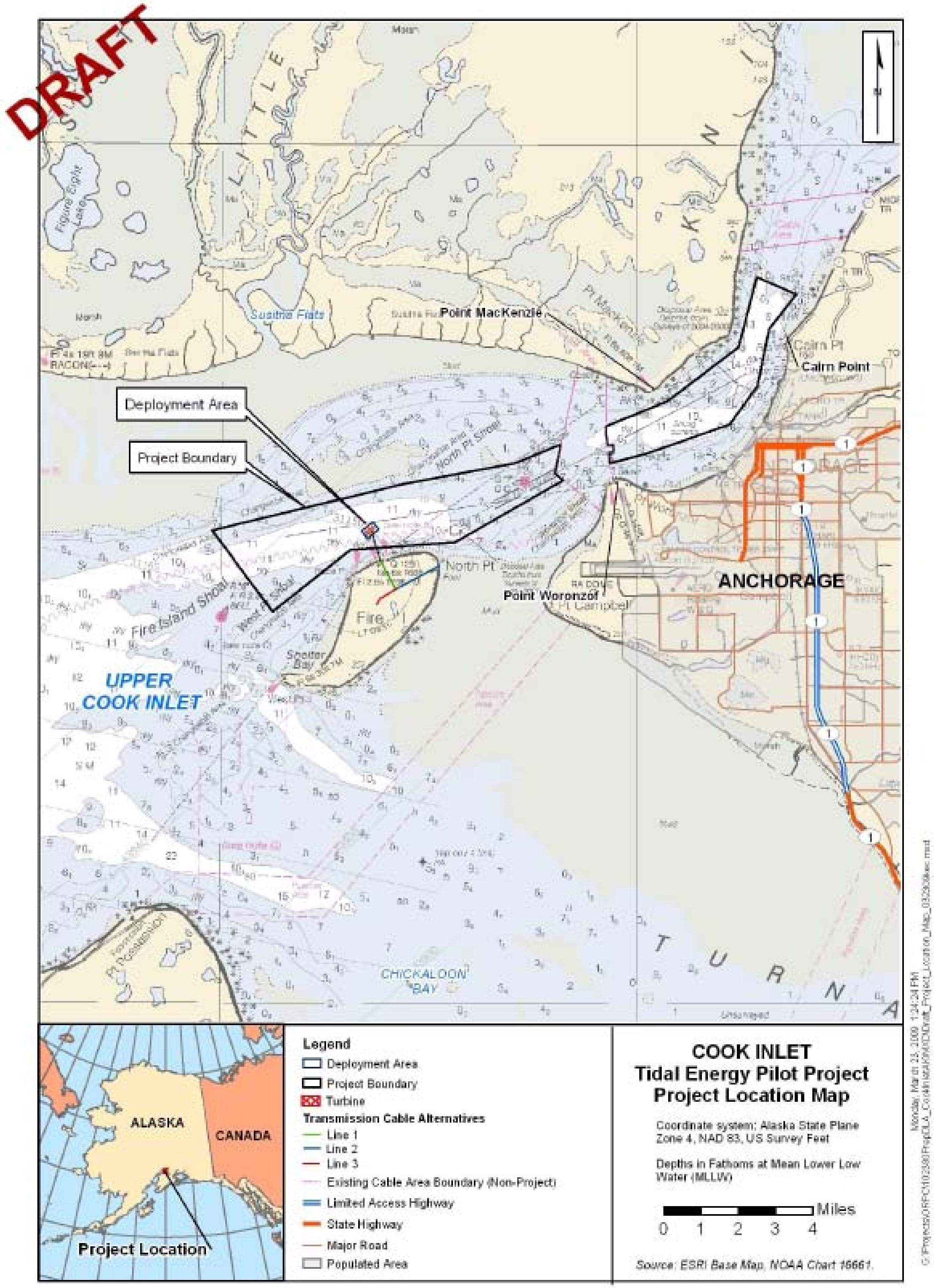

Figure A1. Project Location Map.

2.0 RELEVANT EXISTING INFORMATION

The Cook Inlet beluga whale (*Delphinapterus leucas*) Distinct Population Segment (DPS) has recently been listed as endangered by National Oceanic and Atmospheric Administration (NOAA) under the Endangered Species Act (ESA). Surveys on beluga whales in Cook Inlet documented a decline in abundance of nearly 50 percent between 1994 and 1998, from an estimate of 653 whales to 347 whales (National Marine Fisheries Service [NMFS] 2008). This decline was mostly attributed to the subsistence harvest (through 1998); however, even with the restrictions on this harvest, the population has continued to decline by 1.45 percent per year from 1998 to 2008. Annual surveys have continued since 1994, and indicate this population is not recovering (NMFS 2008).

Critical habitat has not been designated but NOAA Fisheries has designated Knik Arm as a Type 1 habitat of high value/high sensitivity for beluga whales (NMFS 2008). These areas are full of shallow tidal flats, river mouths, or estuarine areas, and are important for foraging and calving habitats. Use of this habitat varies during the year with the potential of belugas occurring within the vicinity of the Deployment Area in most months. Depending on the season, belugas can occur in both offshore and coastal waters. During the spring and summer, Cook Inlet belugas are generally concentrated near the warm, shallow waters of river mouths where prey availability is high due to seasonal fish runs. Most of the calving in Cook Inlet occurs from mid-May to mid-July in the vicinity of these warm-water river mouths (Nemeth et al. 2007). In general, belugas are more dispersed throughout the Upper and Middle Inlet during winter months rather than concentrated at river mouths. The Little Susitna River mouth and Susitna Flats, documented beluga use areas, are approximately four miles and further from the deployment area.

Beluga whales using Knik Arm and UCI are exposed to variable conditions due to the large tidal fluctuations that occur in the arm and in UCI in general. Funk et al. (2005), conducted shore-based observations of beluga whales in Knik Arm to characterize whale movement patterns and to determine important habitat locations in relation to tidal patterns. The study found that changes in water depth associated with the tidal cycle greatly influenced the habitat available, the patterns of whale movement, and the habitat used by belugas in Knik Arm (Funk et al. 2005). As the tide flooded, beluga whales typically moved into the upper reaches of Knik Arm. Whales moved south towards the Sixmile Creek/Eagle Bay area and out of the upper reaches of Knik Arm as the ebb tide began. Movements of beluga whales in Knik Arm with tides are highly predictable. Riding the tides is likely to be energetically efficient, and may decrease the chances of stranding. Prior to this there had been no published reports describing these movements or clear correlations between tidal changes and beluga distributions and habitat use in Cook Inlet (Moore et al. 2000). The influence of tides on the movement of beluga whales that reside in or use coastal estuaries in Russian waters was summarized by Kleinenberg et al. (1964). Inshore migrations by belugas occurred primarily during flood tides in areas with marked tidal fluctuations. Beluga whales were reported to migrate along the shore during high spring tides with movements into rivers driven by prey availability (Kleinenberg et al. 1964 as cited in Funk et al. 2005).

Beluga whales have been observed to feed most efficiently in summer months, possibly building up energy reserves for the winter. Belugas are reported by Native hunters to have only 2-3 inches (in) (5-7.5 centimeter [cm]) of blubber in April and May but up to 12 in (30.5 cm) in the fall (Huntington 2000). Beluga whales feed throughout the water column and on the sea floor although they appear to focus their foraging efforts at streams and rivers where fish are highly concentrated. In general, belugas usually dive for about 3-15 minutes while hunting for food. Other beluga populations inhabiting shallow coastal areas are known to make shallow dives while foraging for food (Martin et al. 2000). They can travel for about 1.5 miles during a dive and commonly dive to a depth of 66 feet (20 m) to hunt. They can dive to greater depths ranging 1,000 to 2,000 feet (305 to 610 m) at times, however greater dive depths are associated with populations that inhabit deep water and not those in relatively shallow coastal habitat (Martin et al. 2000). In the winter, Cook Inlet belugas concentrating in deeper waters in the mid Inlet (further south of the deployment area) make deep feeding dives (NMFS 2008).

3.0 NEED FOR ADDITIONAL INFORMATION

Information on the numbers, behavior, and habitat use of belugas has been collected for recent projects in UCI, north of Fire Island. A limited amount of information is available for the western reach of the proposed project area, the Deployment Area off of Fire Island. Agency staff has indicated that Cook Inlet beluga whales are known to use the habitat in the proposed Project Area (Figure A1) on a regular basis, and the vicinity of Cairn Point is an important migratory route for whales as they move into and out of Knik Arm. More localized information is needed in order to evaluate existing use of the proposed Deployment Area by belugas and assess potential risks to whales during deployment of tidal energy modules.

4.0 PRE-DEPLOYMENT STUDY PLAN

4.1 Study Plan Goals and Objectives

The primary objective of the proposed study is to assess the distribution and movement of beluga whales in the Deployment Area off the north side of Fire Island.

4.2 Study Area

The proposed study area for beluga observations is the area to the north of Fire Island, with focus on the Deployment Area (Figure A2).

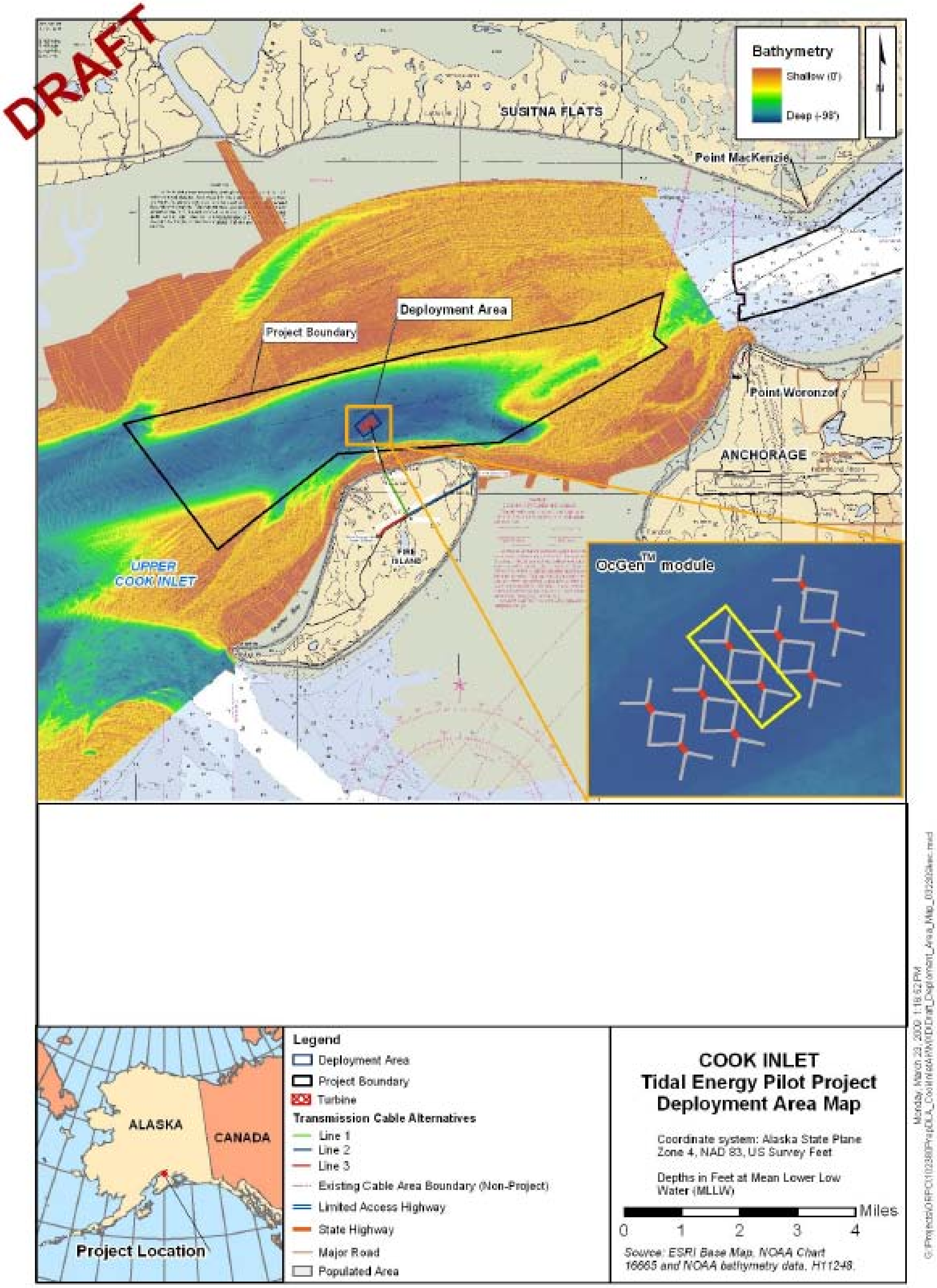

Figure A2. Deployment Area Map.

4.3 Methods

The proposed baseline monitoring study is adapted from similar shore-based visual observation studies as referenced above. The pre-deployment monitoring will take place over the course of the 2009 field season (May-November) and is expected to begin mid-late May. Given the large observation area and safety concerns on the remoteness of the area, two observers will be stationed on Fire Island.

Data collected at the monitoring stations will include: start and end time, environmental conditions (including Beaufort sea state), and beluga whale sighting information, including whale location, direction of travel, speed, group number, number and age class of whales if possible, and additional behavioral observations. Incidental observations of other marine mammals in the project area will be noted. Monitoring session frequency will coincide with habitat use patterns and will typically range from 2 to 6 days/week throughout the season (average of 4 days/week from May through November). The observer will conduct visual monitoring sessions utilizing binoculars, spotting scope, theodolite with laptop computer, and digital camera with zoom lens. Daily observations will average 6 hours with adjustments for seasonal occurrence and abundance. Photo documentation of beluga whale and other marine mammal sightings will be taken to confirm sightings. The precise location of the observation site and details of the study methodology will be refined in consultation with appropriate regulatory and resource agencies prior to initiating the survey.

4.4 Data Analysis and Reporting

Results of the beluga observations will be summarized in a draft report in December 2009. The results of the beluga observations will be incorporated into the final license application to be filed March 2010. Map figures will be created to document observation locations and photo-documentation of sightings will be provided in an appendix.

Further, the results will provide guidance to ORPC in evaluating the need for additional sites or an increased effort in development of a post-deployment beluga monitoring plan.

4.5 Schedule

The pre-deployment baseline beluga observations are expected to start mid to late May and continue through the ice-free season, possibly November, 2009. The precise location of observation sites and details of the study methodology will be refined in consultation with appropriate regulatory and resource agencies prior to initiating the survey. Results of the beluga observations will be summarized in a draft report in December 2009.

5.0 References

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APPENDIX B

MAPS OF DAILY BELUGA WHALE SIGHTINGS

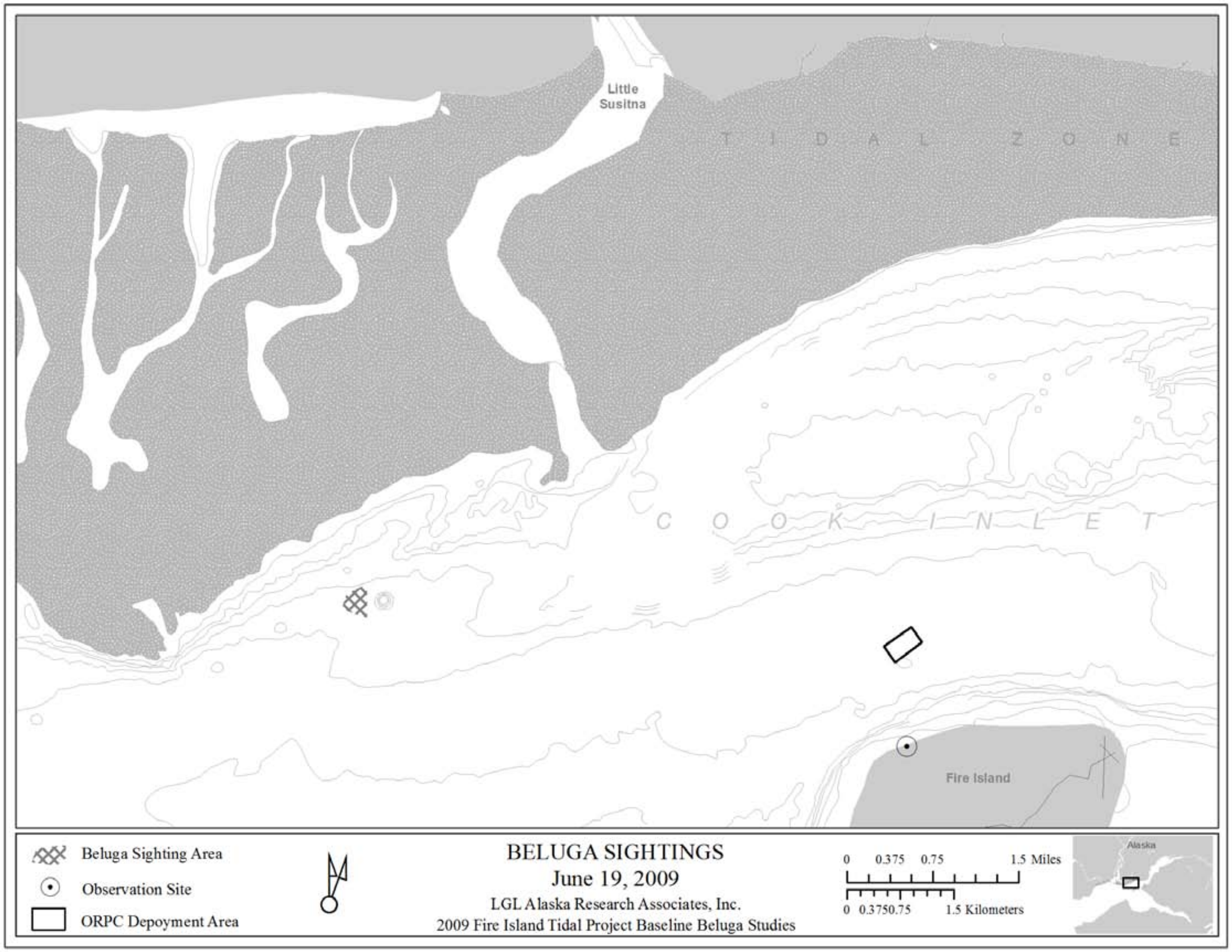

Figure B1. Locations of beluga whales sighted on June 19, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

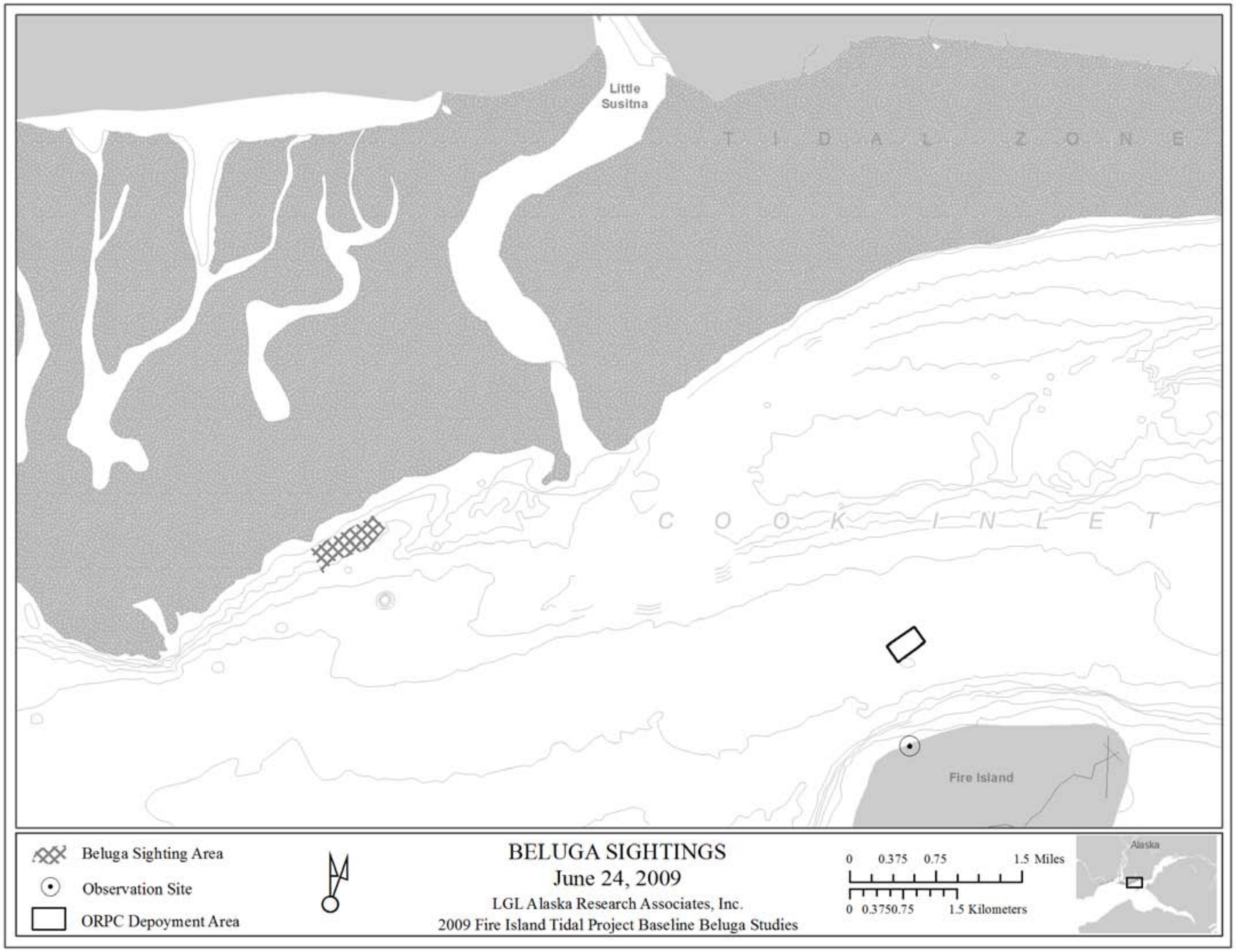

Figure B2. Locations of beluga whales sighted on June 24, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

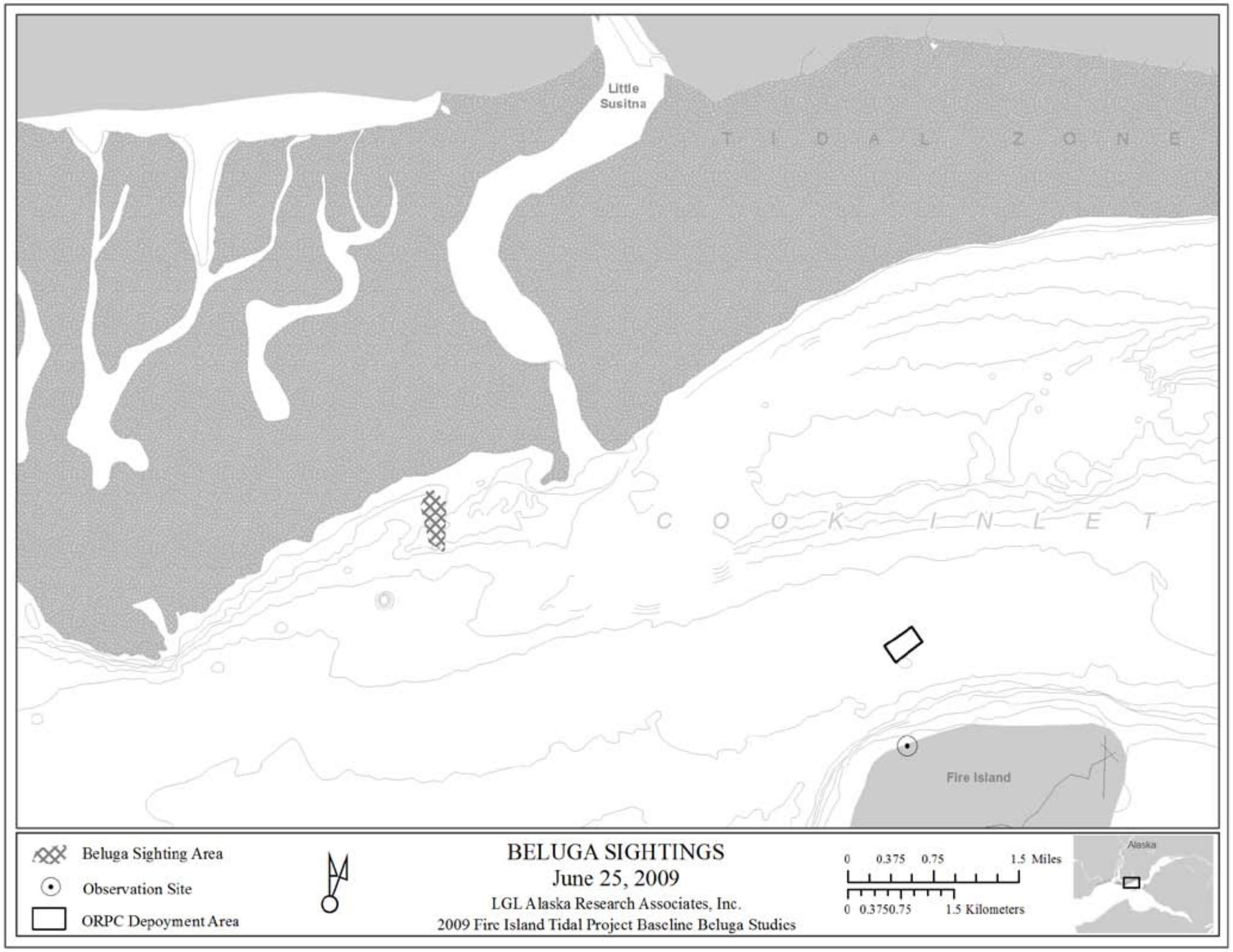

Figure B3. Locations of beluga whales sighted on June 25, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

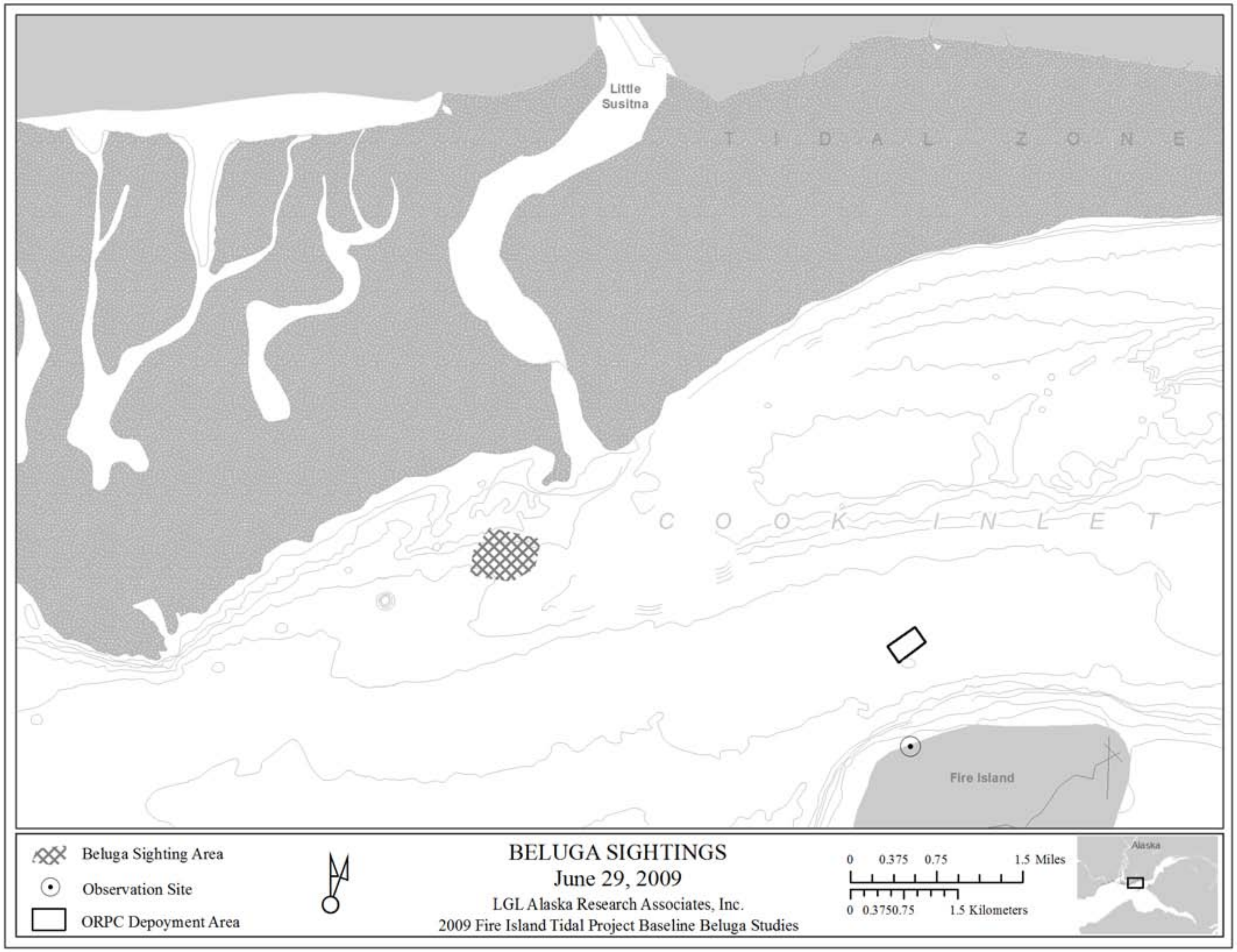

Figure B4. Locations of beluga whales sighted on June 29, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

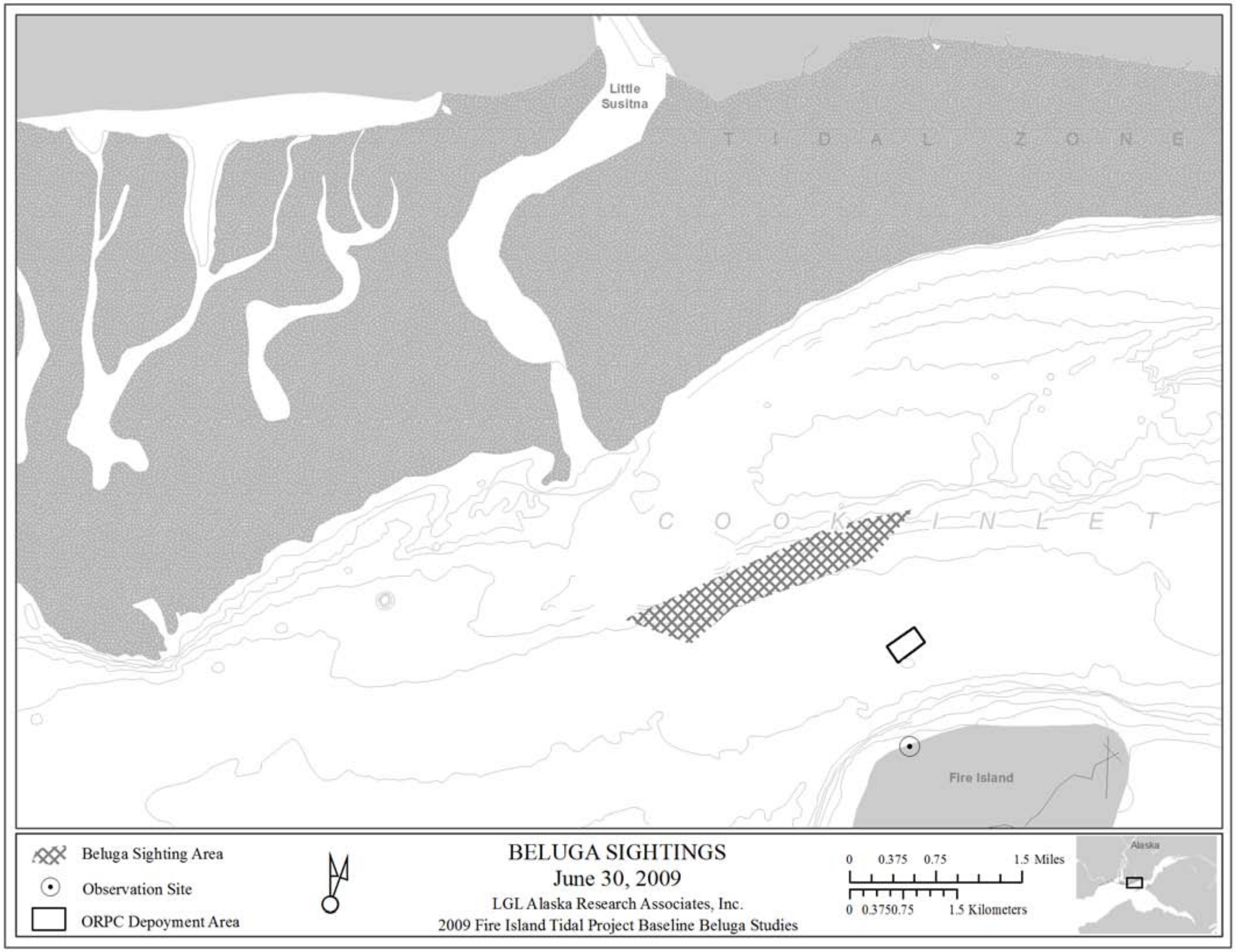

Figure B5. Locations of beluga whales sighted on June 30, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

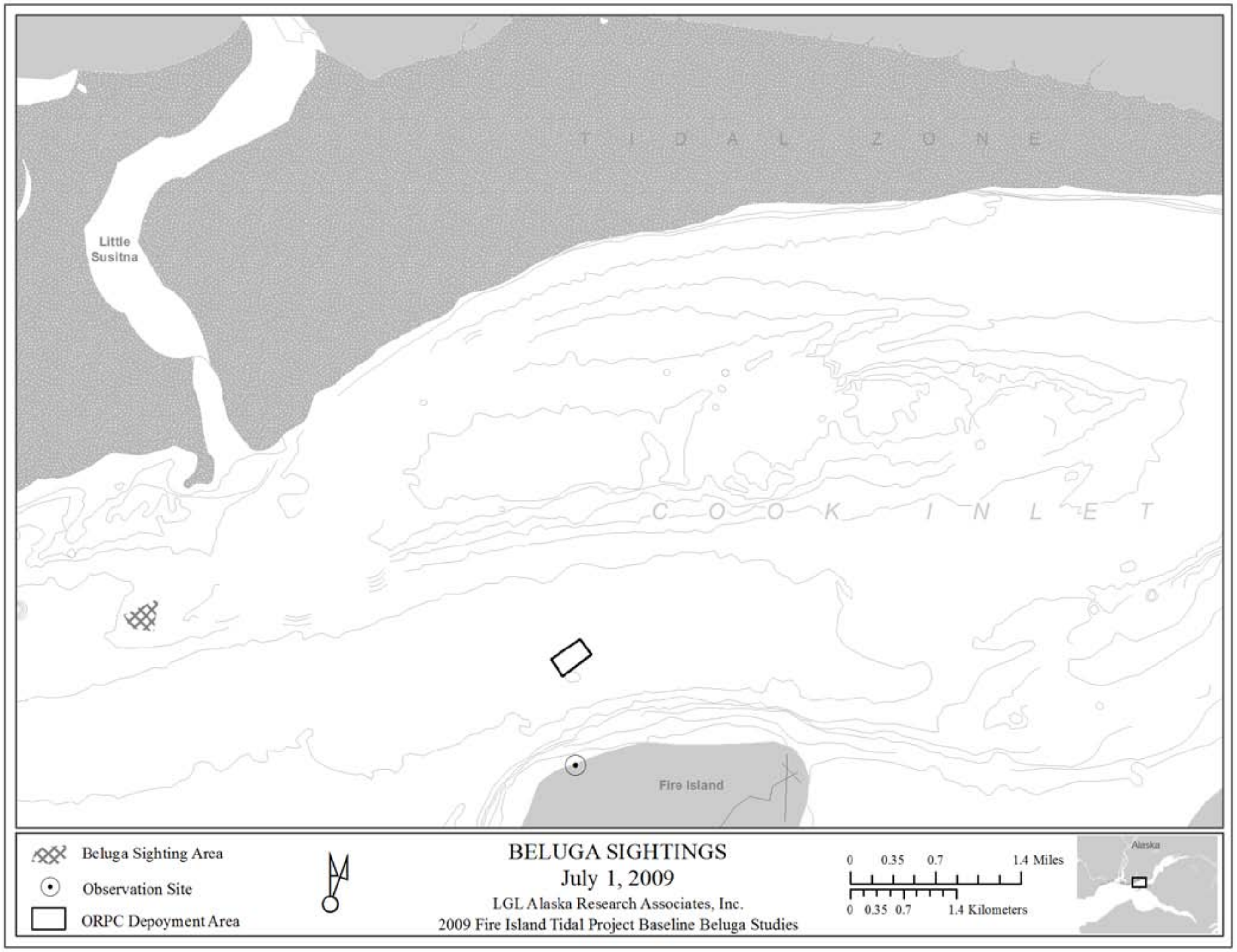

Figure B6. Locations of beluga whales sighted on July 1, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

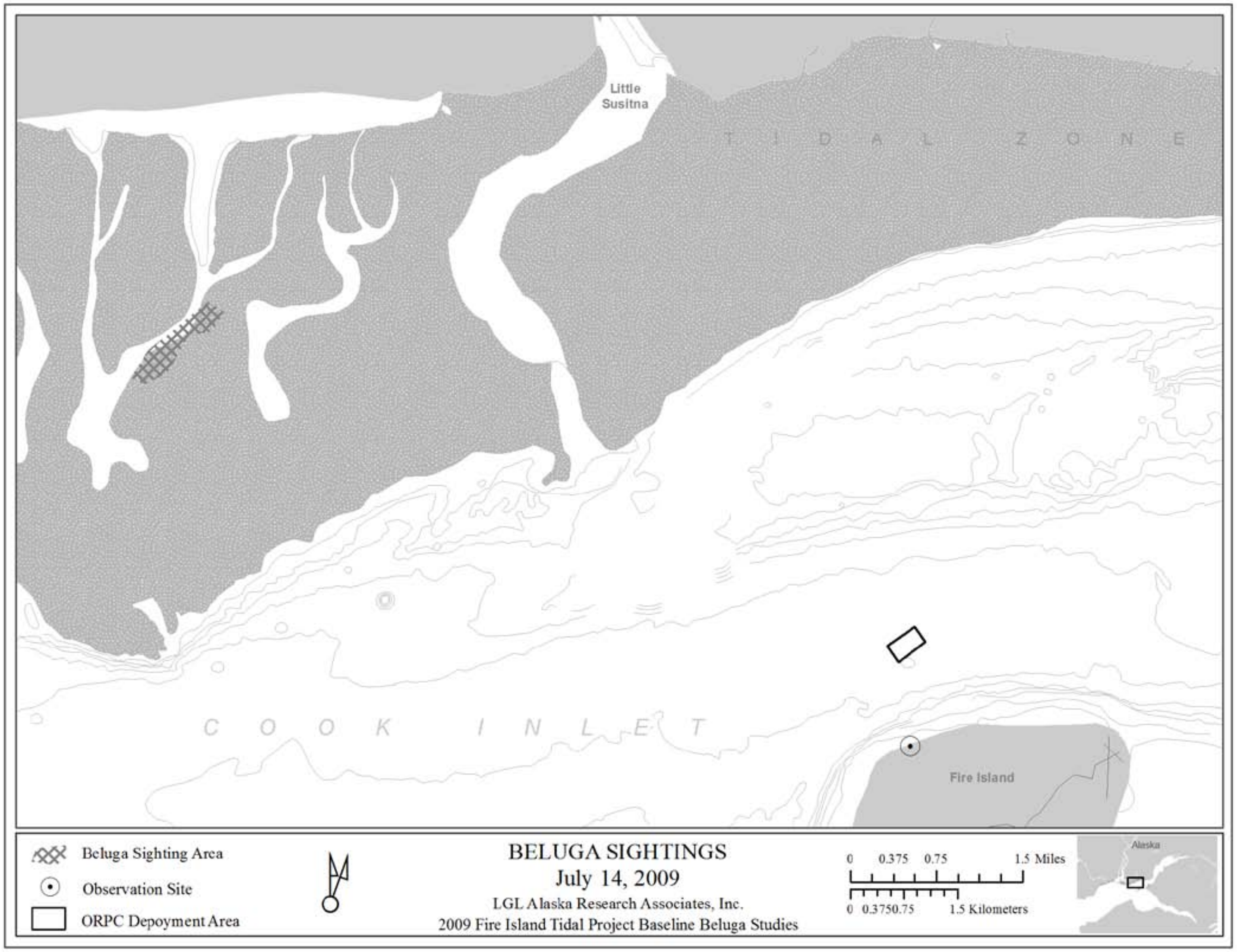

Figure B7. Locations of beluga whales sighted on July 14, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

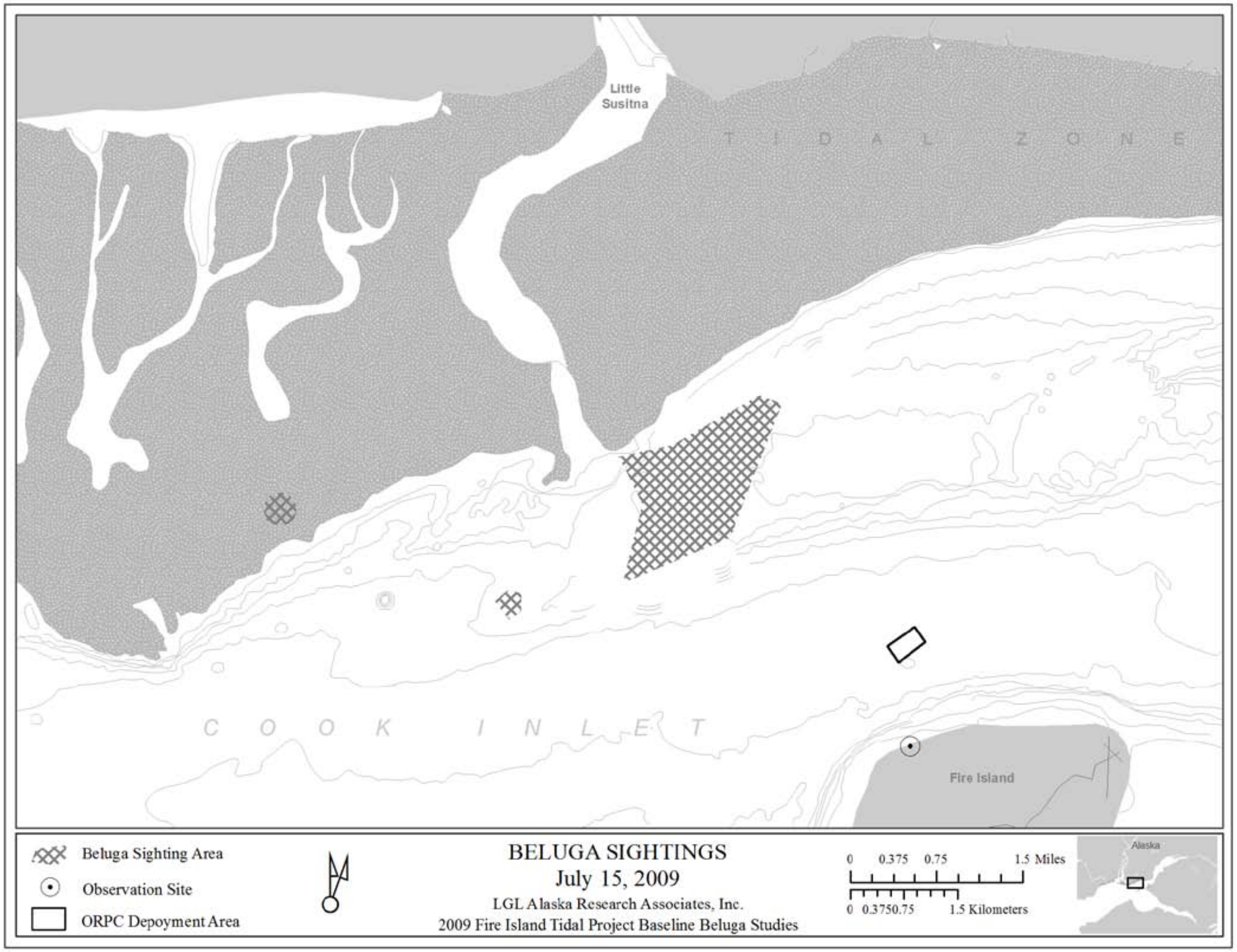

Figure B8. Locations of beluga whales sighted on July 15, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

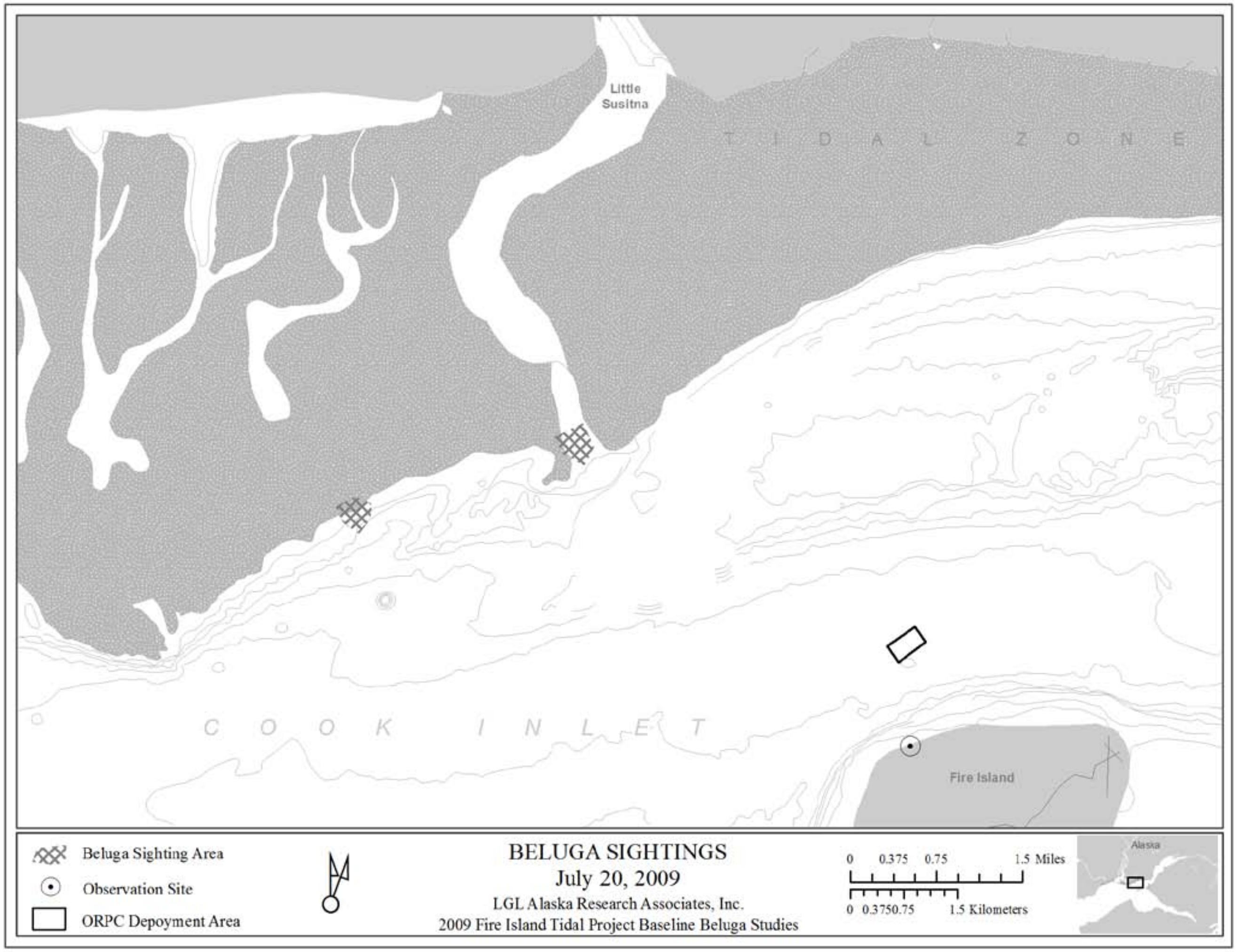

Figure B9. Locations of beluga whales sighted on July 20, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

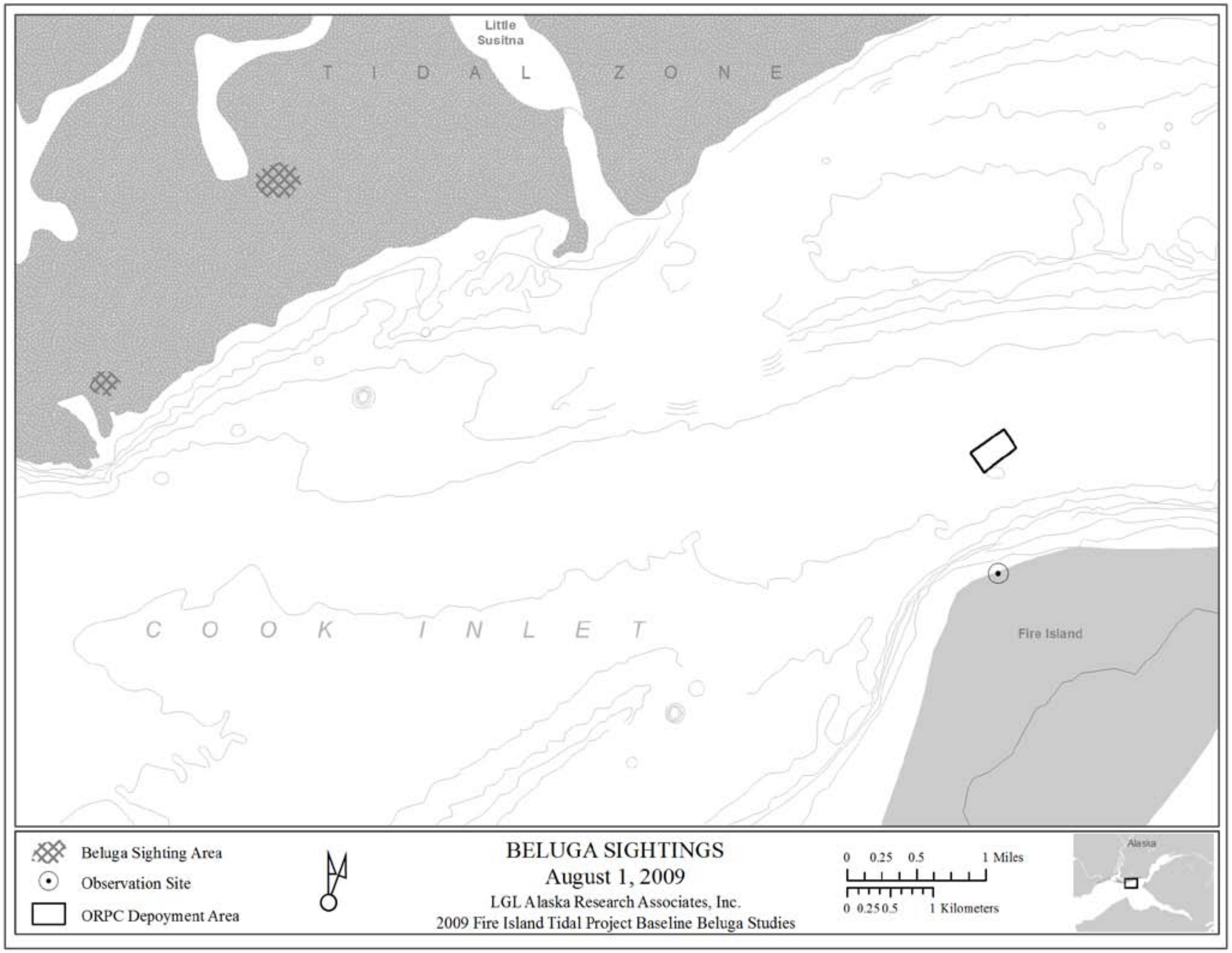

Figure B10. Locations of beluga whales sighted on August 1, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

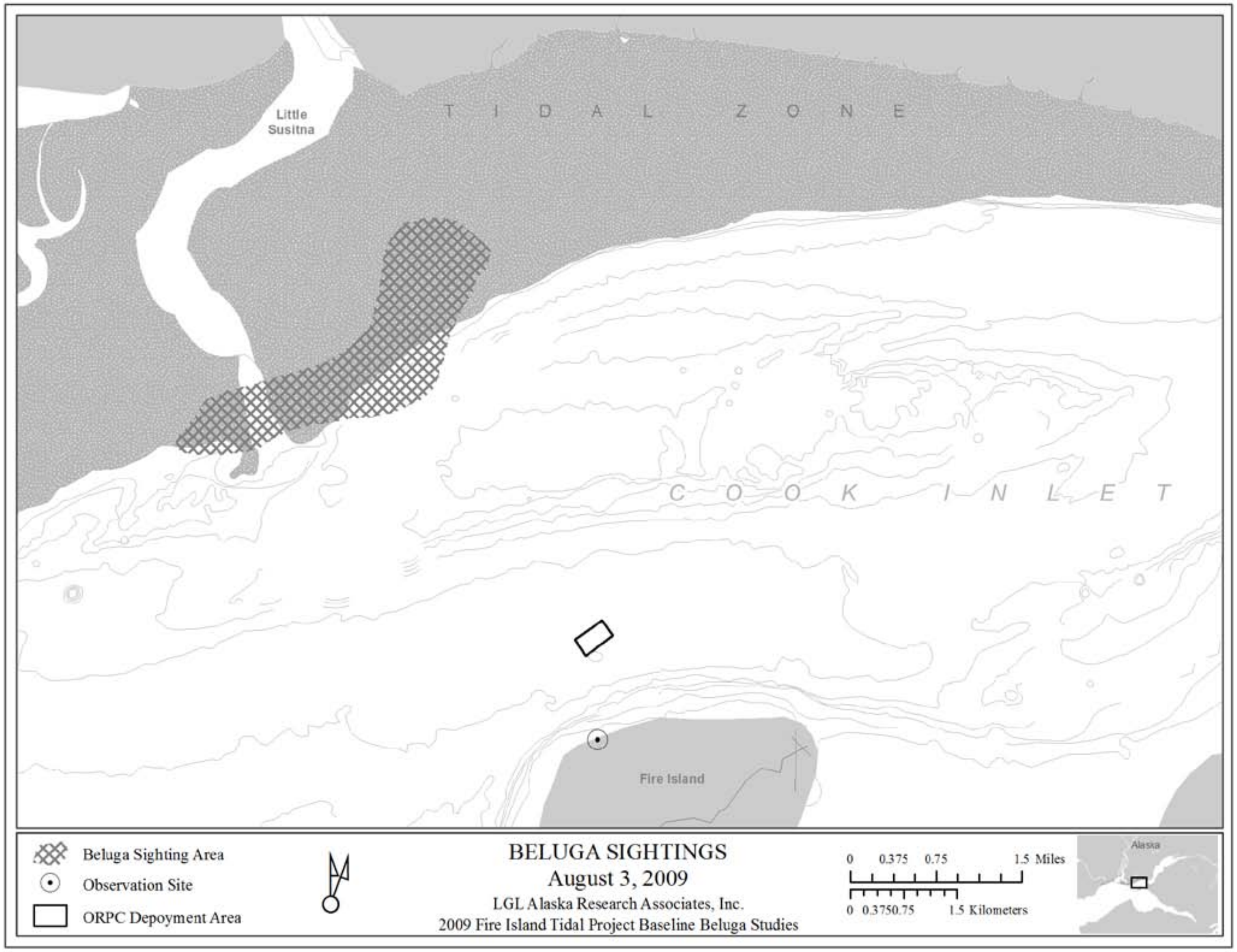

Figure B11. Locations of beluga whales sighted on August 3, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

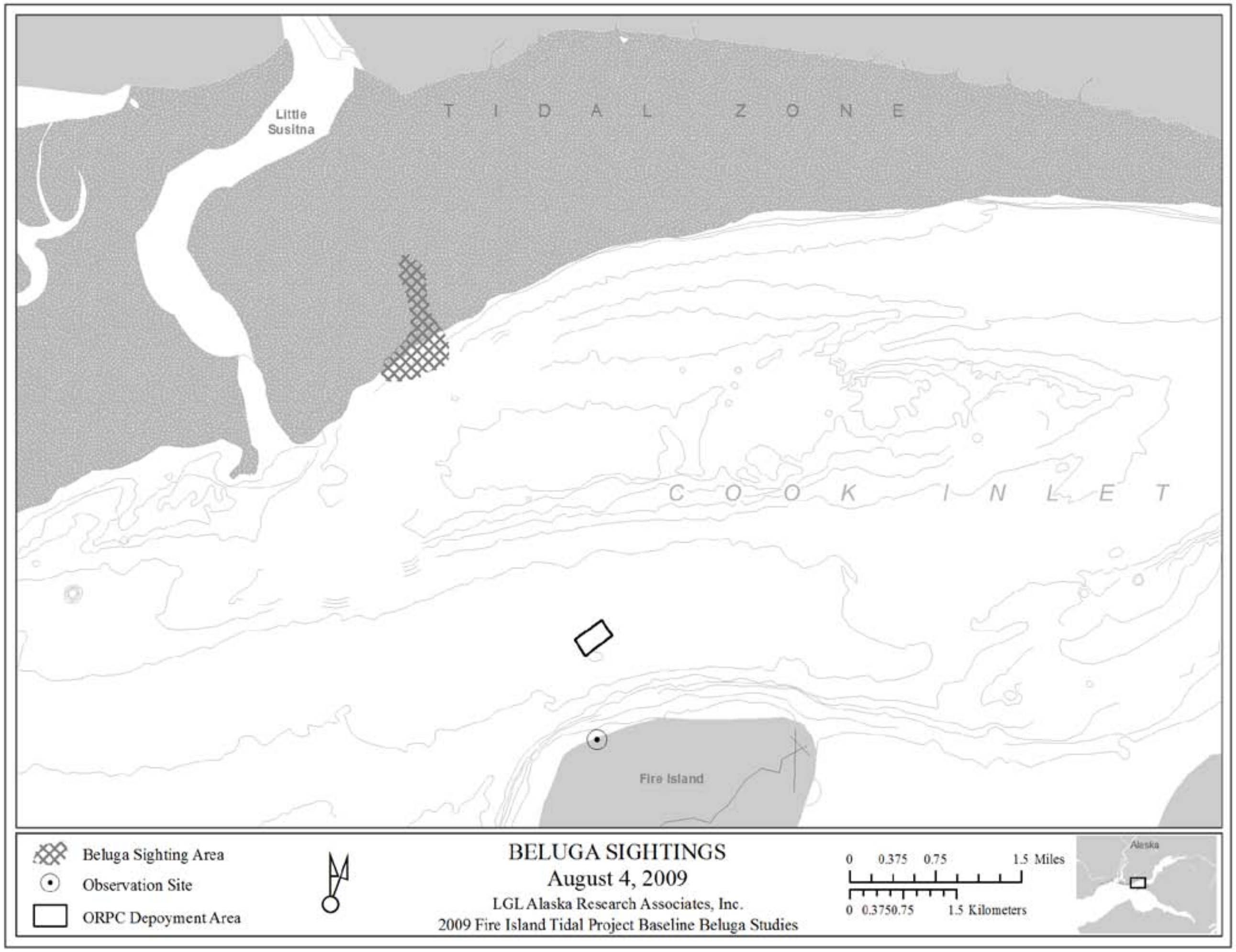

Figure B12. Locations of beluga whales sighted on August 4, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

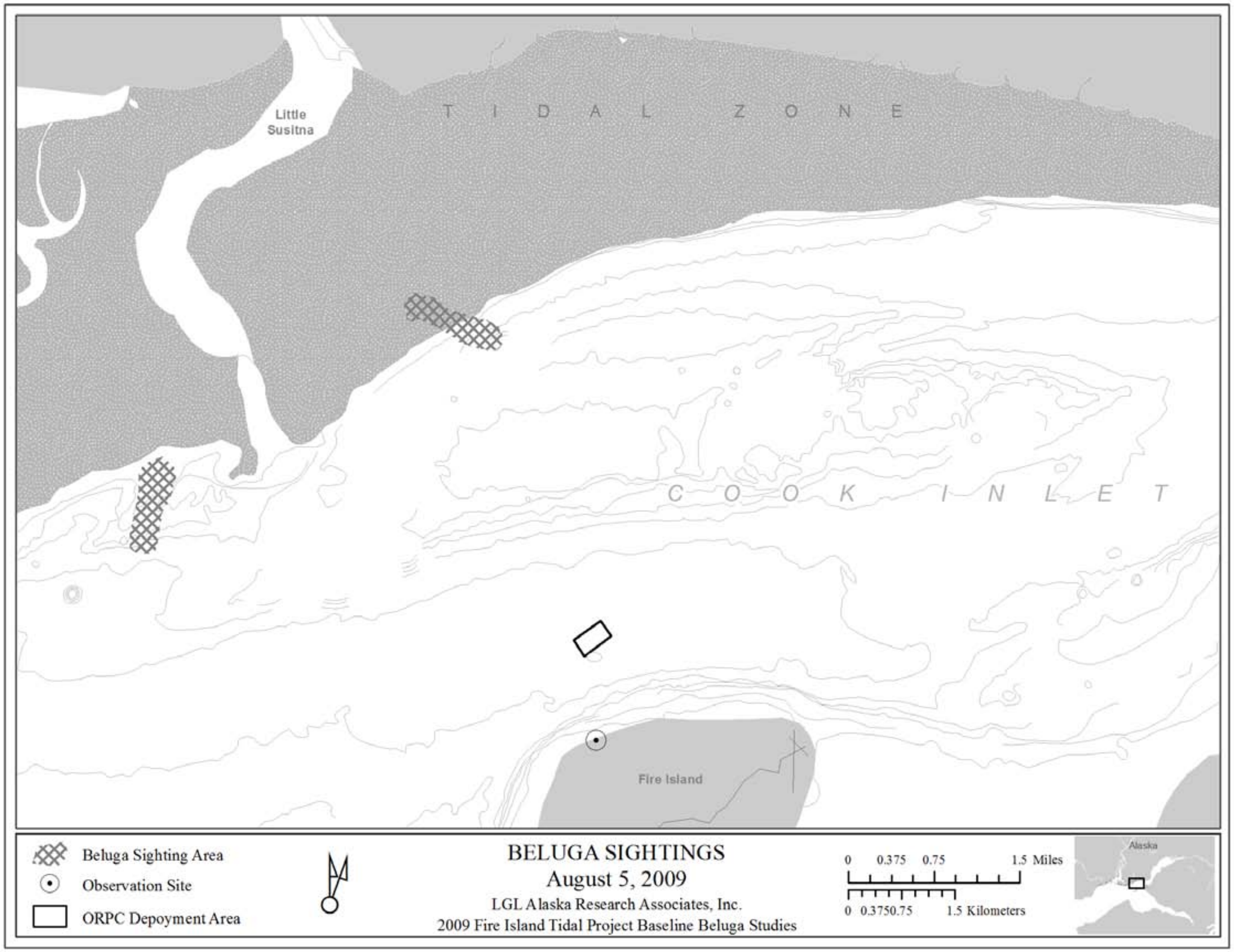

Figure B13. Locations of beluga whales sighted on August 5, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

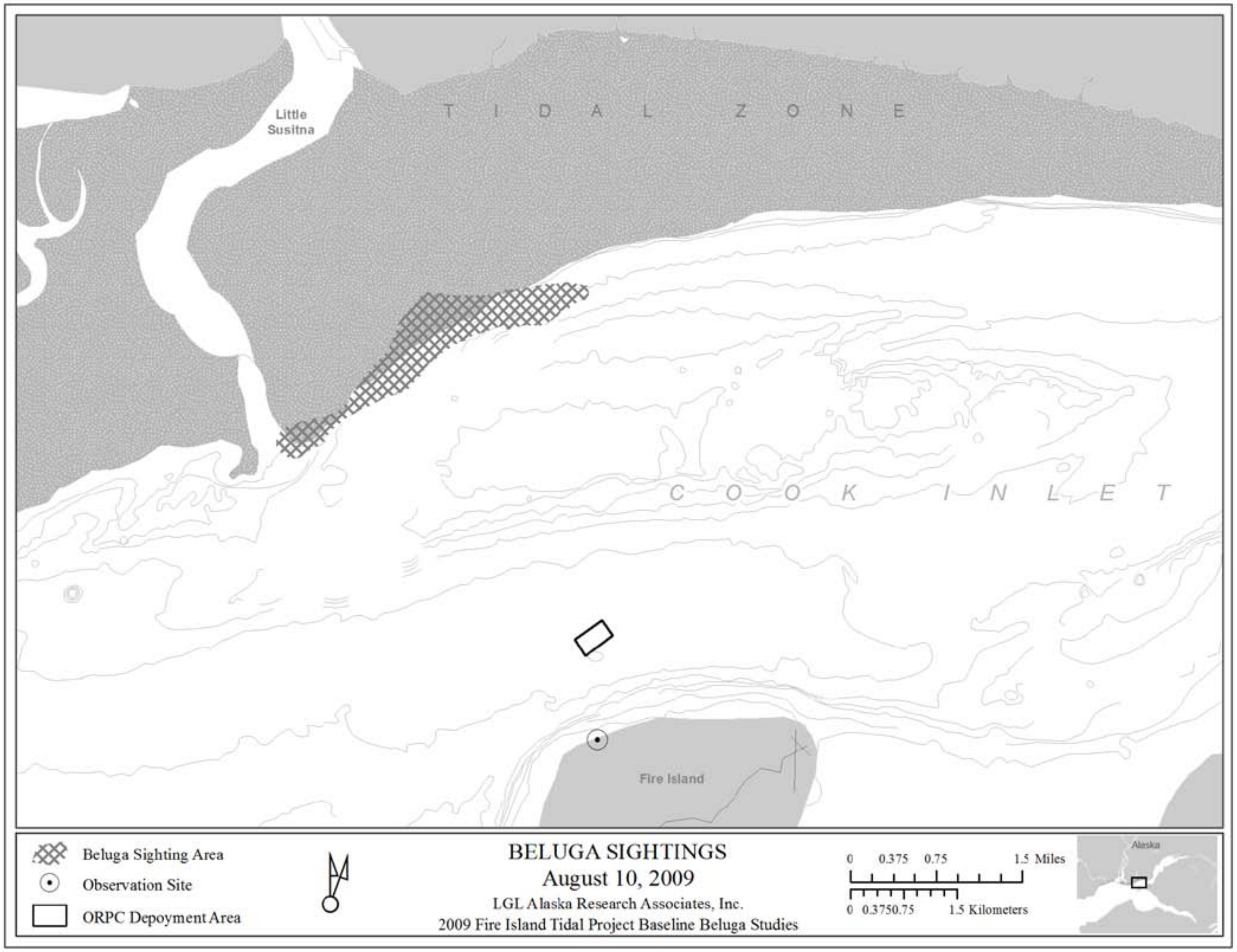

Figure B14. Locations of beluga whales sighted on August 10, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

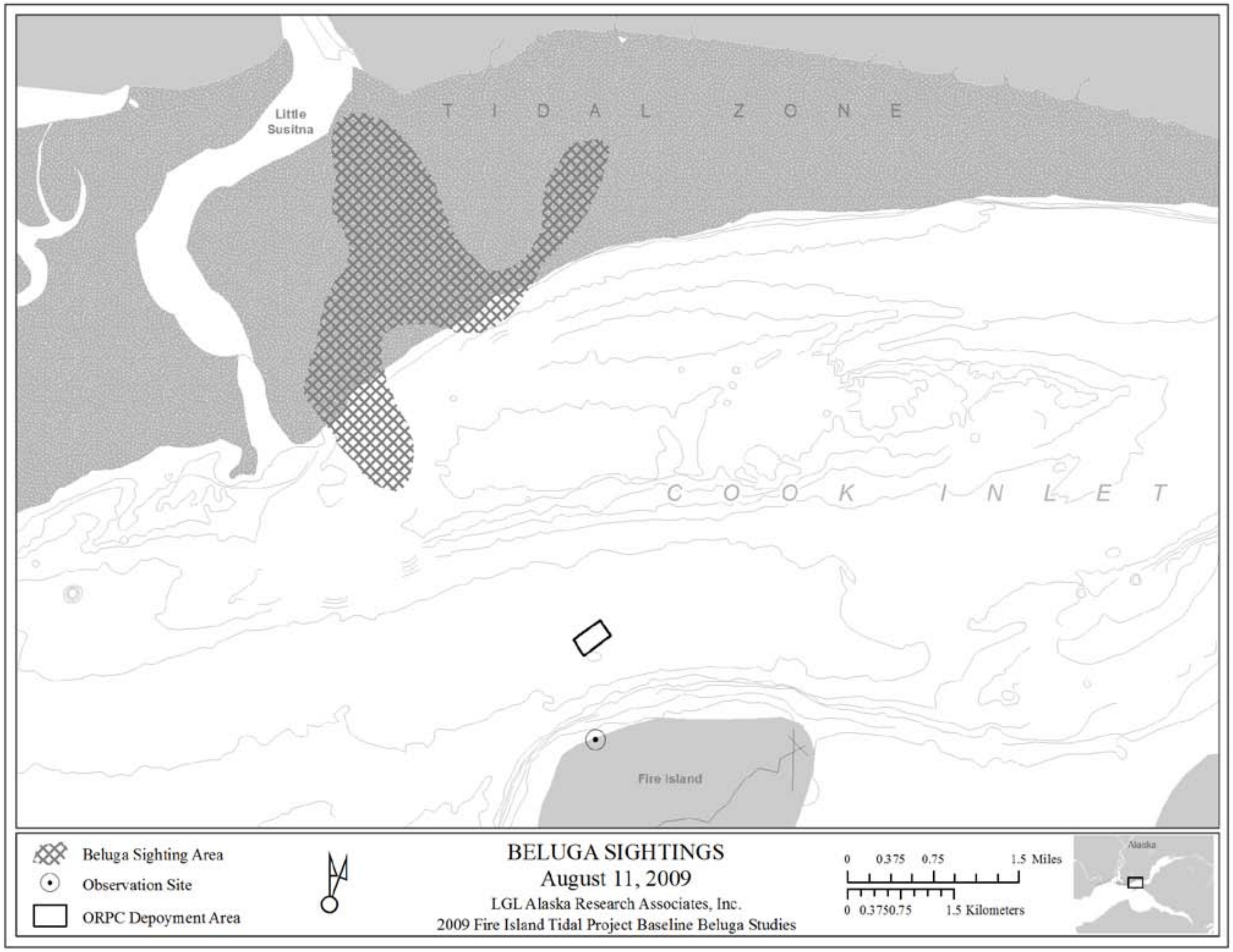

Figure B15. Locations of beluga whales sighted on August 11, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

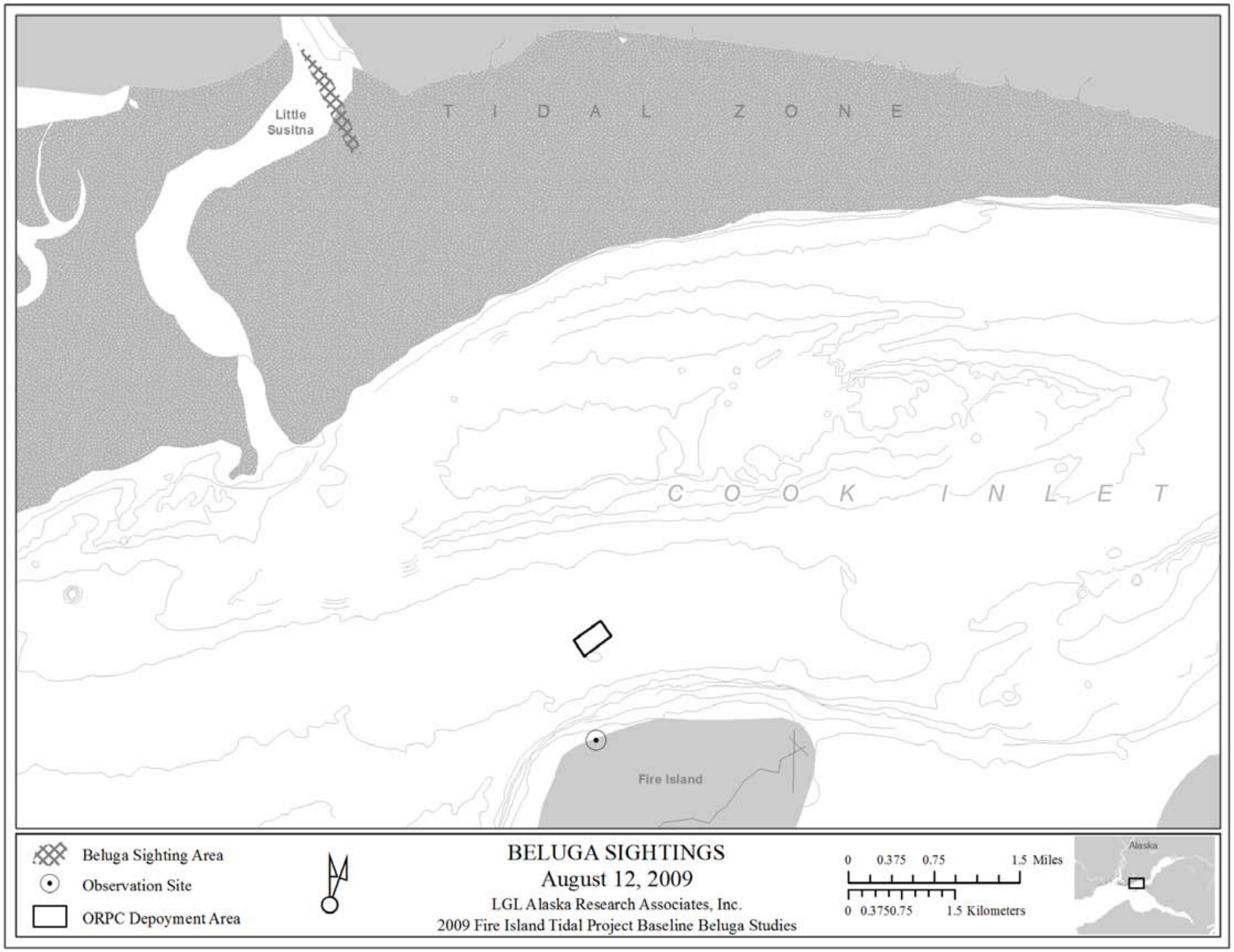

Figure B16. Locations of beluga whales sighted on August 12, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

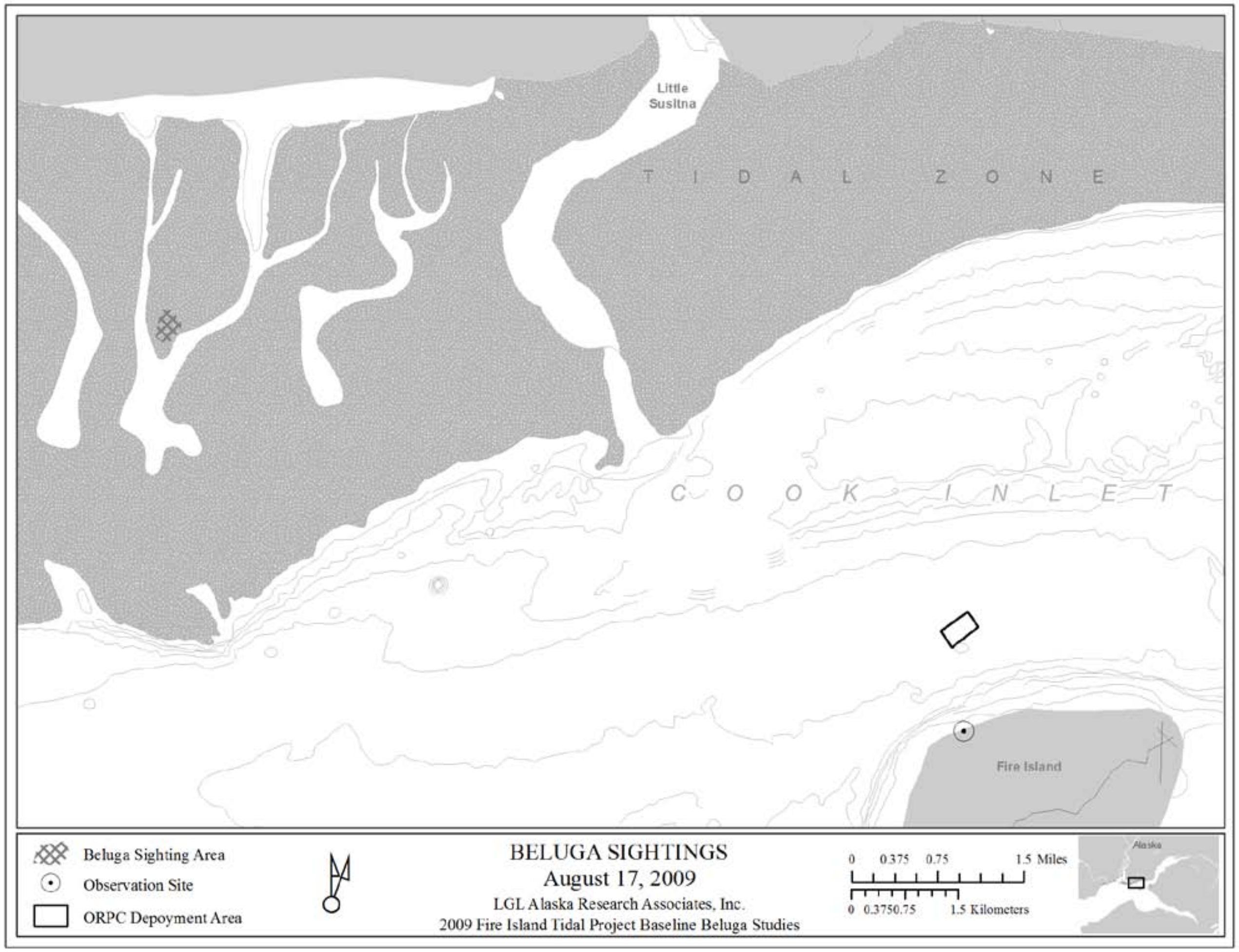

Figure B17. Locations of beluga whales sighted on August 17, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

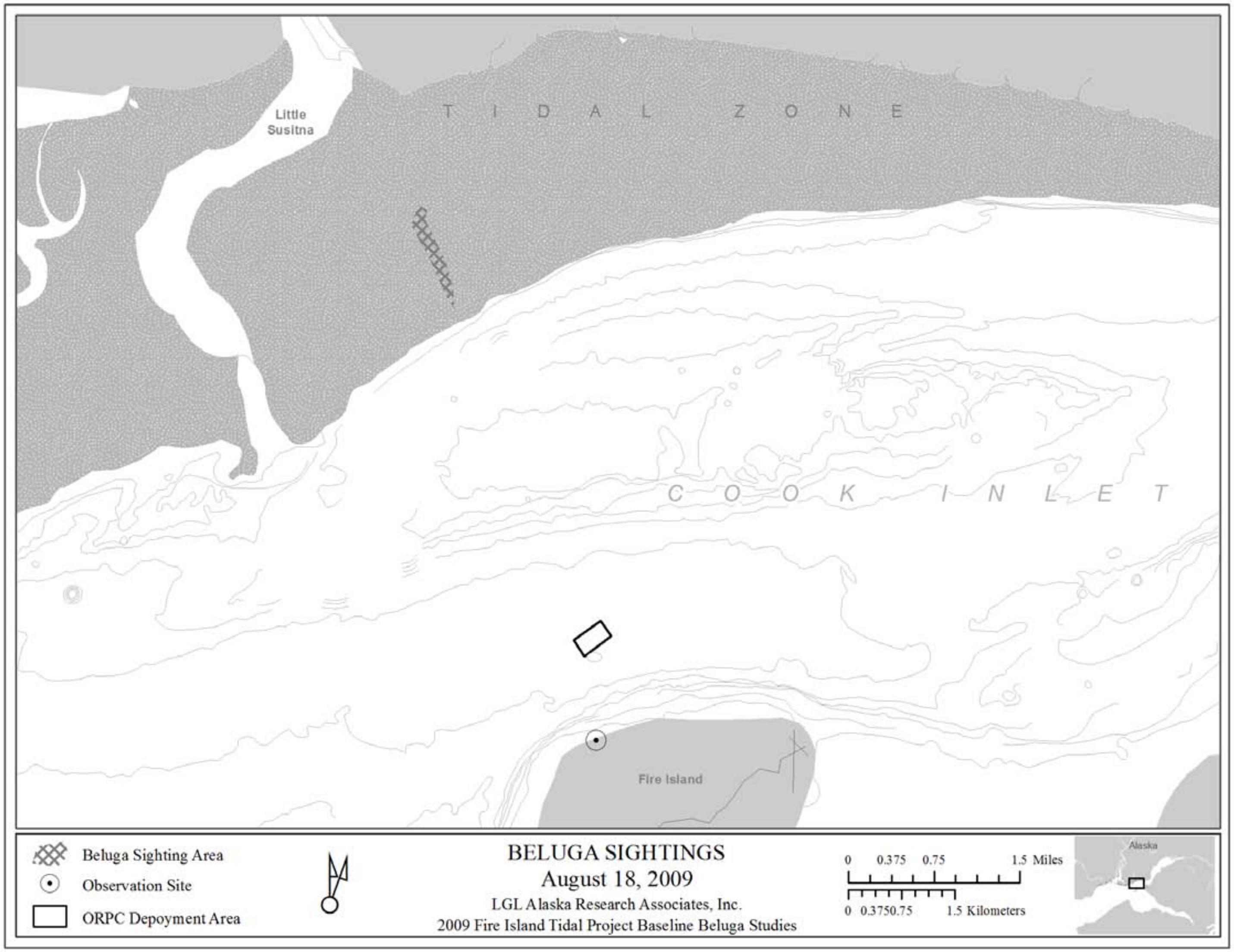

Figure B18. Locations of beluga whales sighted on August 18, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

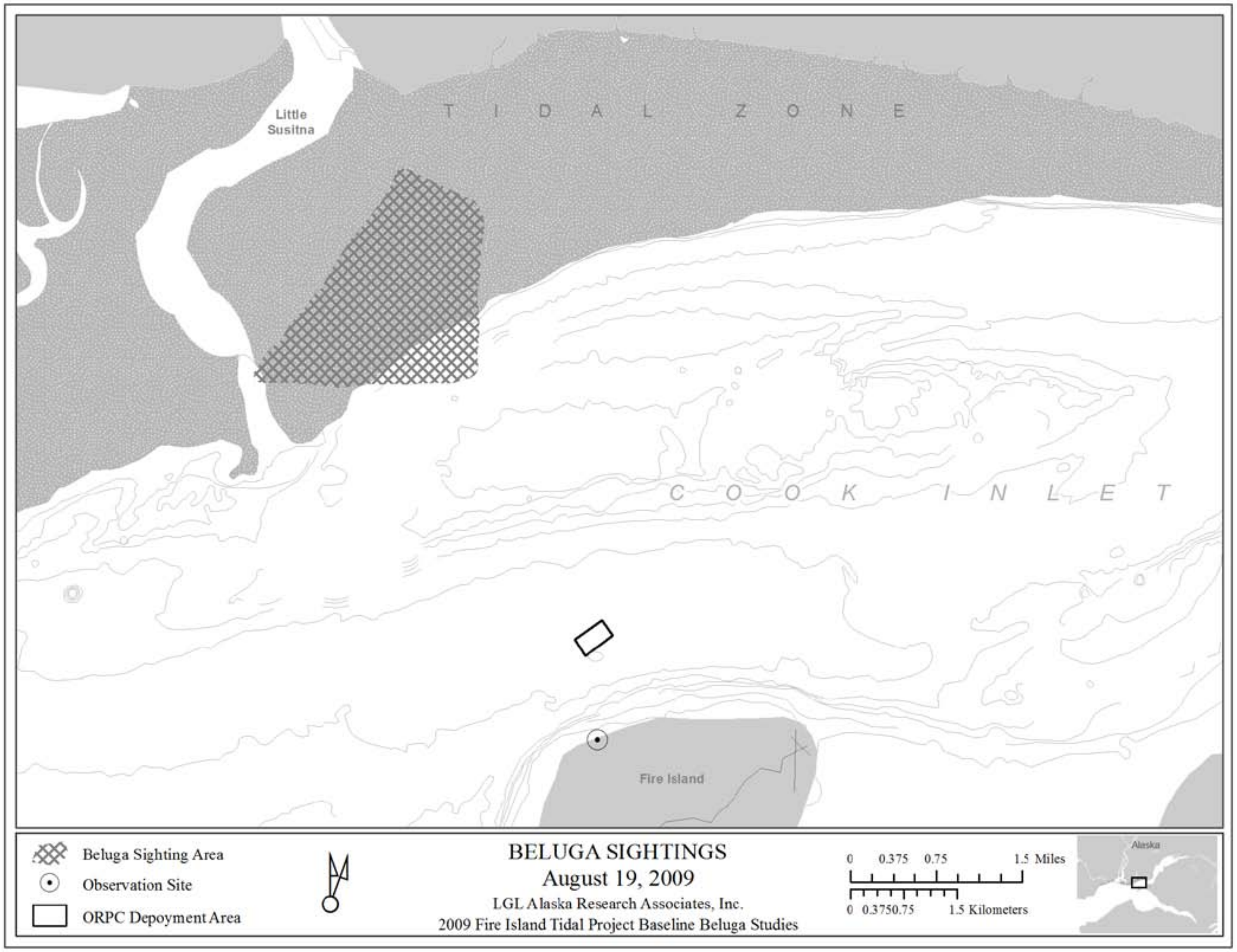

Figure B19. Locations of beluga whales sighted on August 19, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

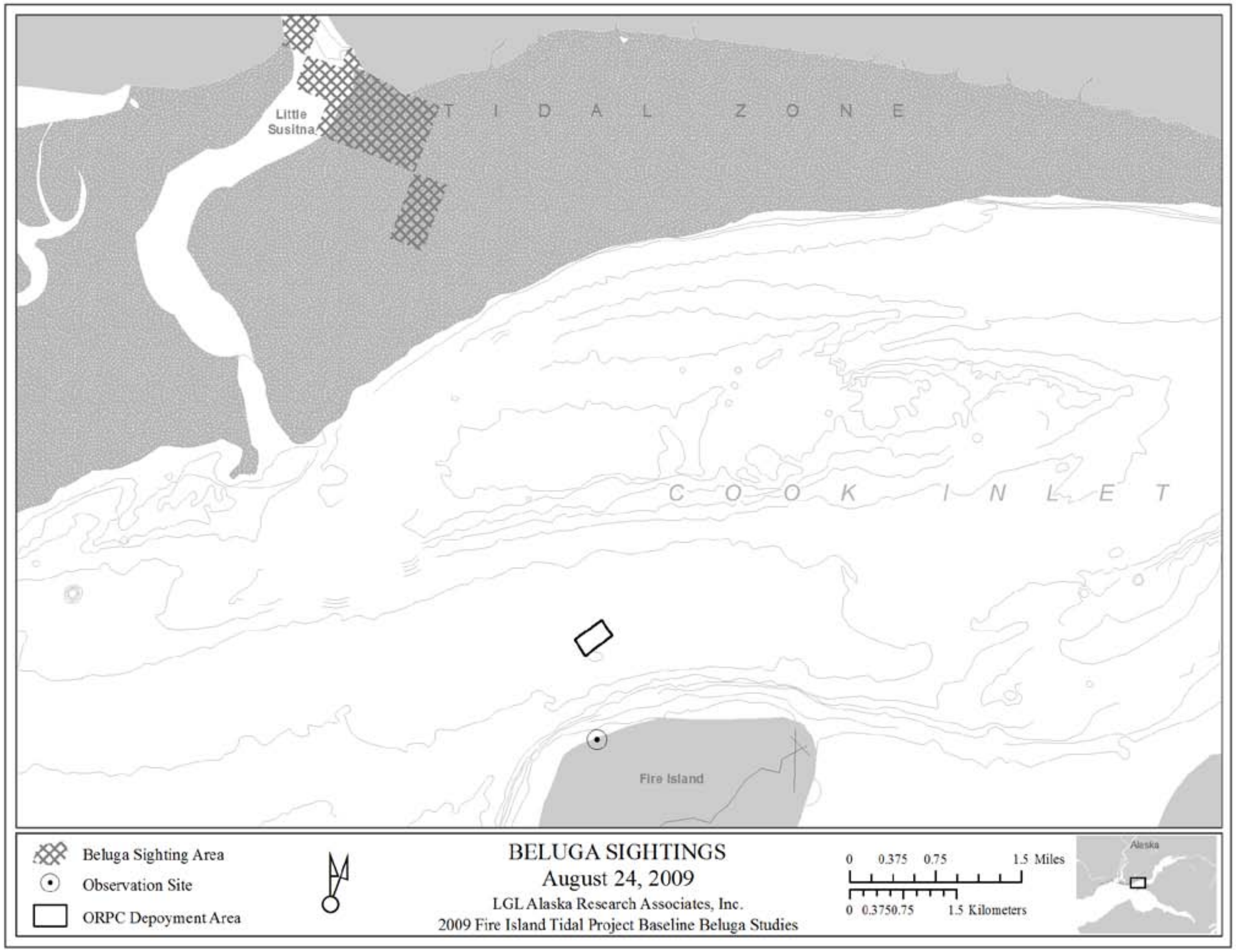

Figure B20. Locations of beluga whales sighted on August 24, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

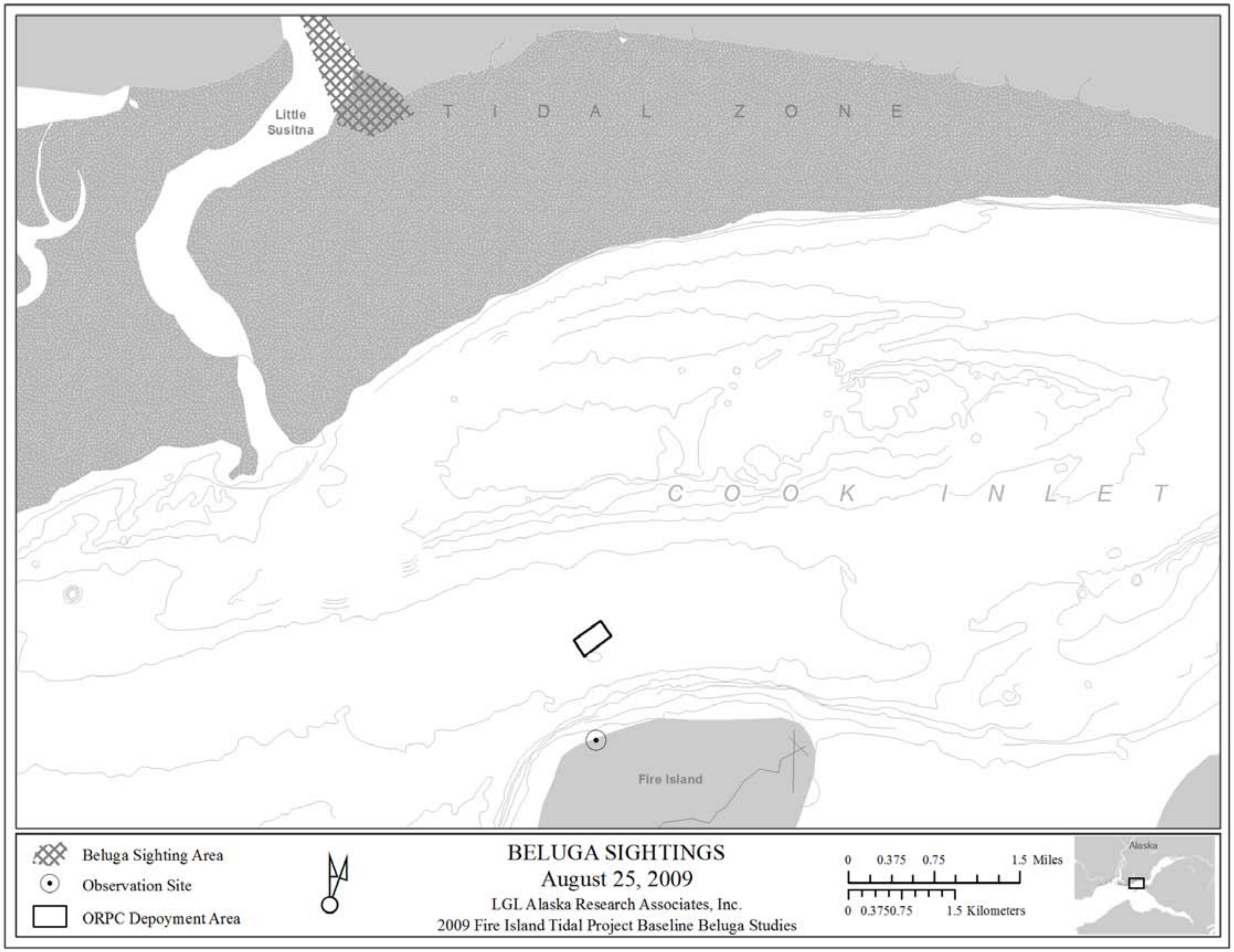

Figure B21. Locations of beluga whales sighted on August 25, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

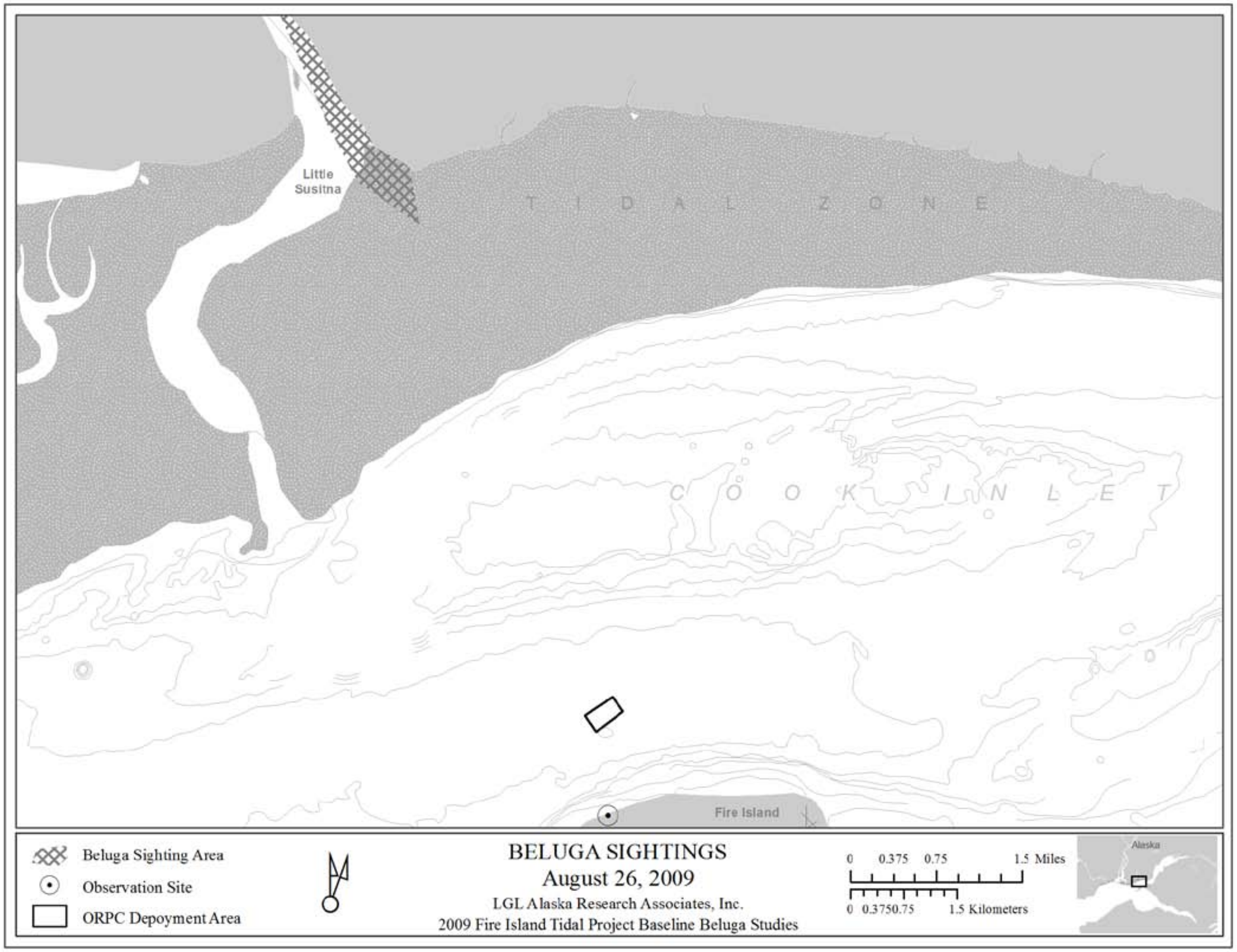

Figure B22. Locations of beluga whales sighted on August 26, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

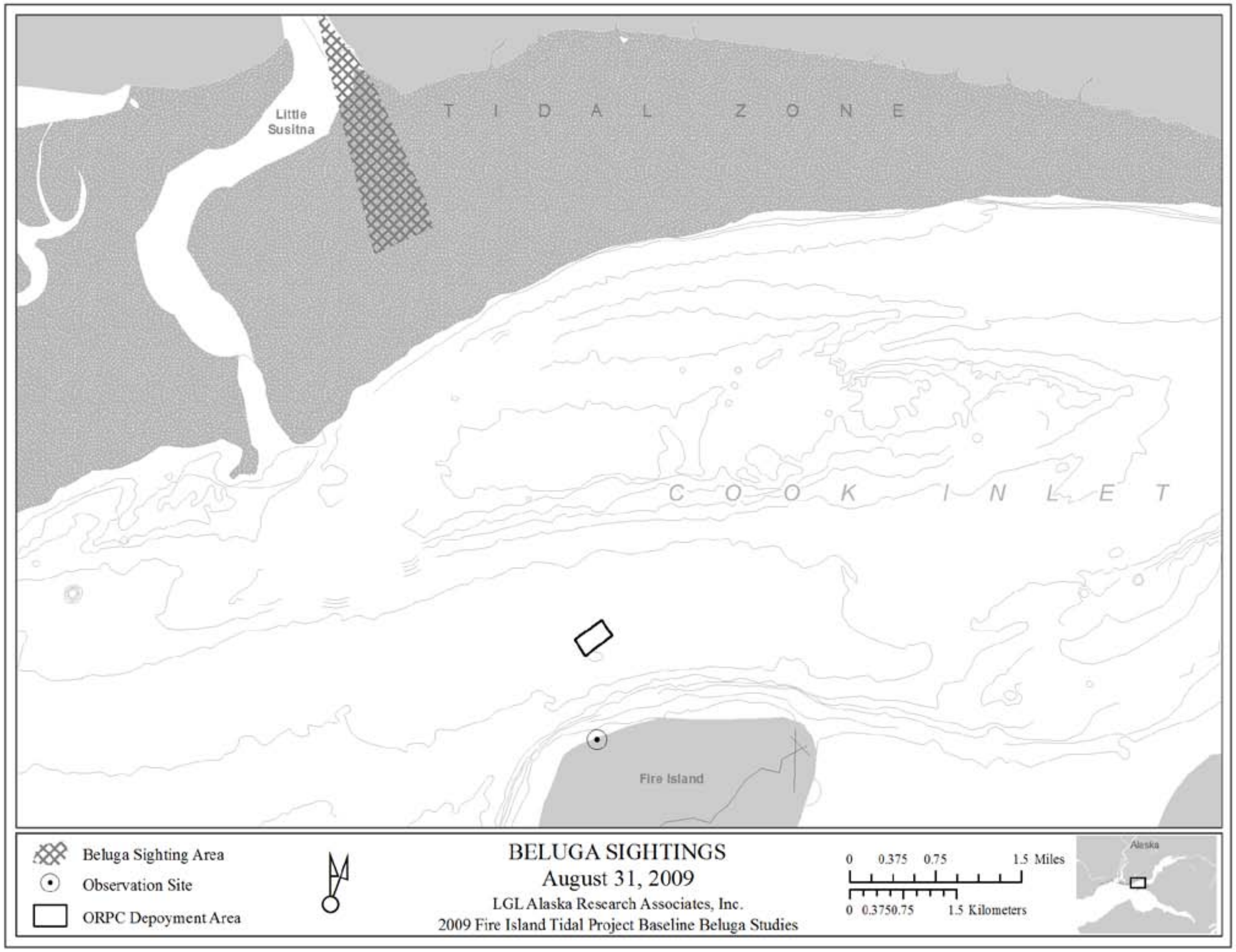

Figure B23. Locations of beluga whales sighted on August 31, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

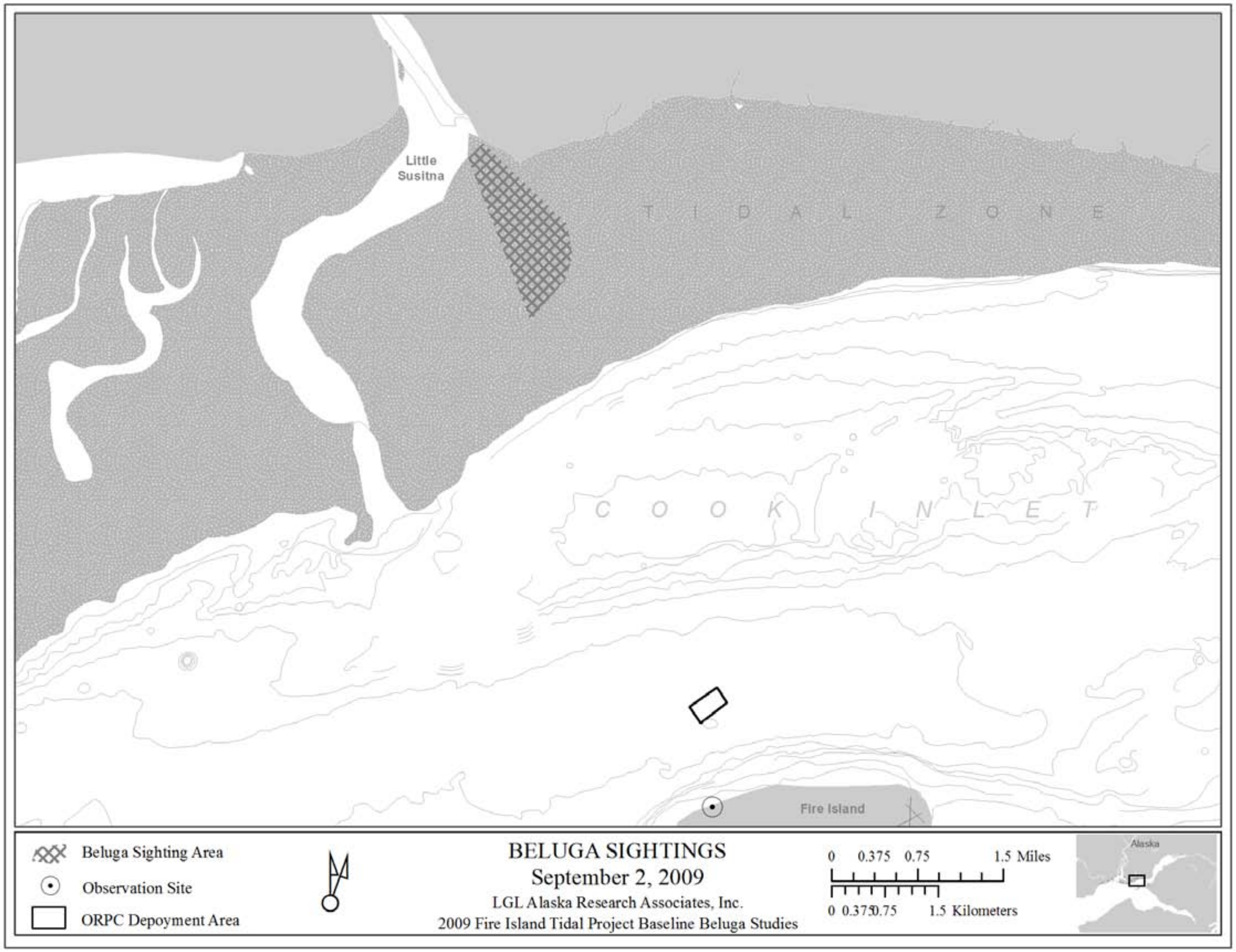

Figure B24. Locations of beluga whales sighted on September 2, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

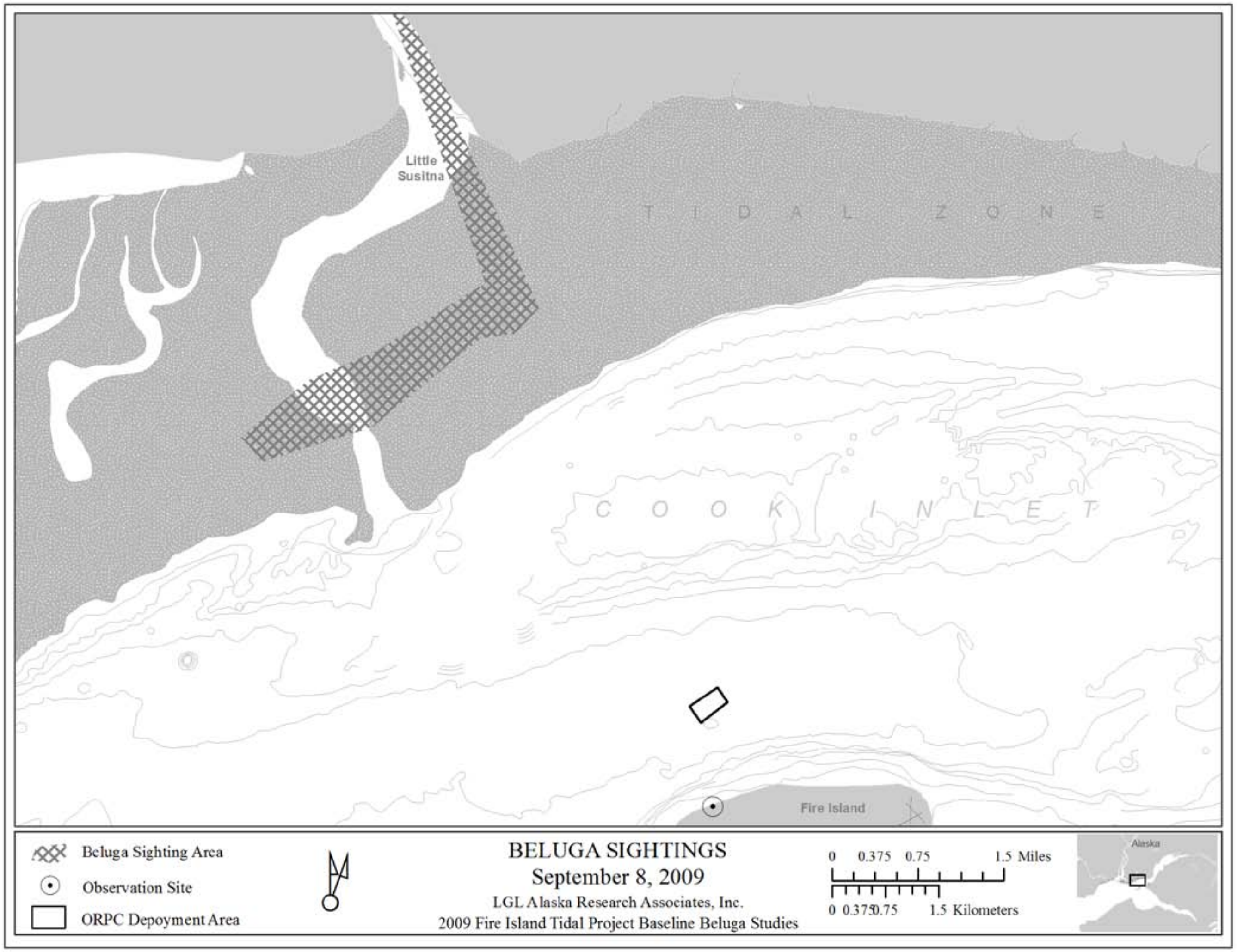

Figure B25. Locations of beluga whales sighted on September 8, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

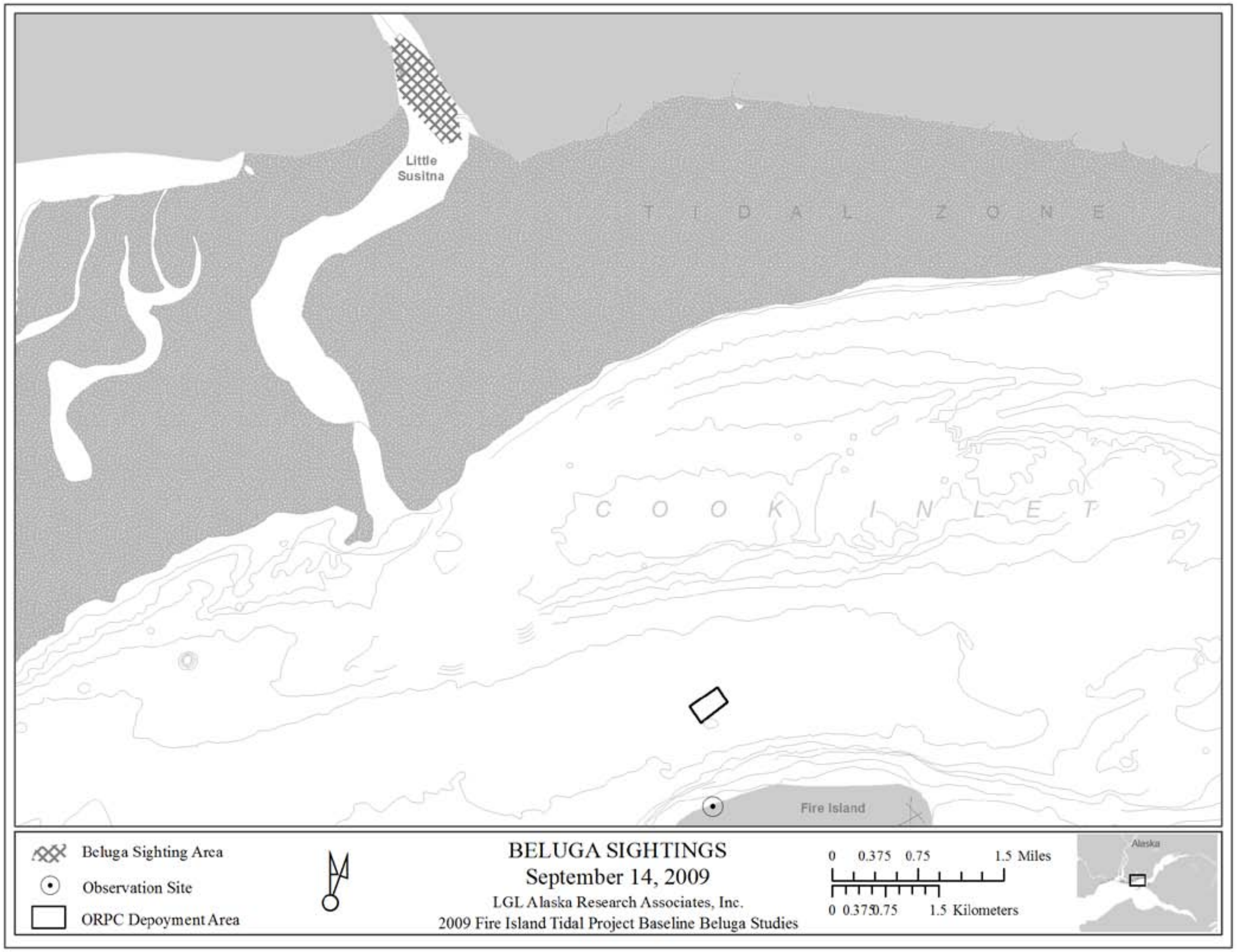

Figure B26. Locations of beluga whales sighted on September 14, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

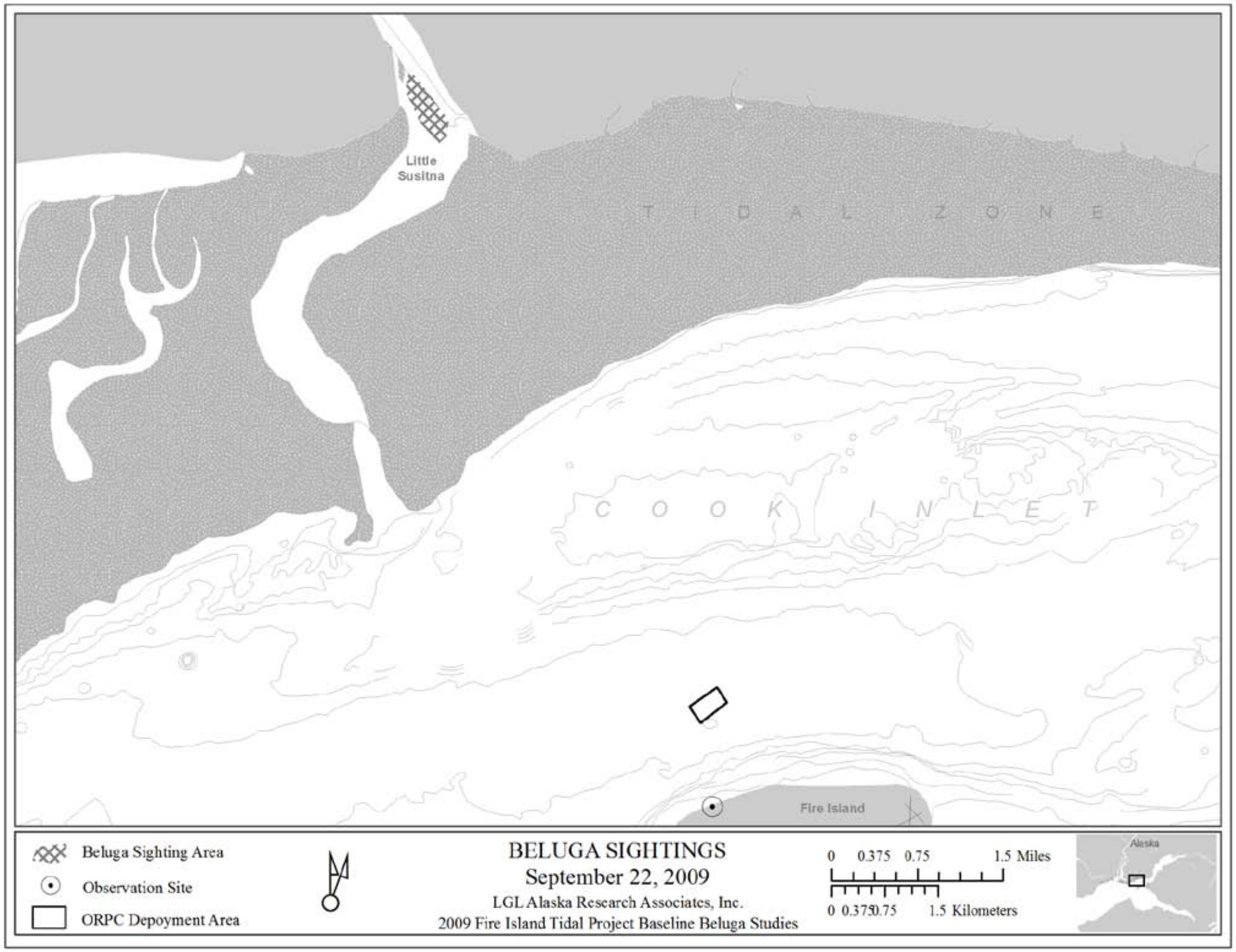

Figure B27. Locations of beluga whales sighted on September 22, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

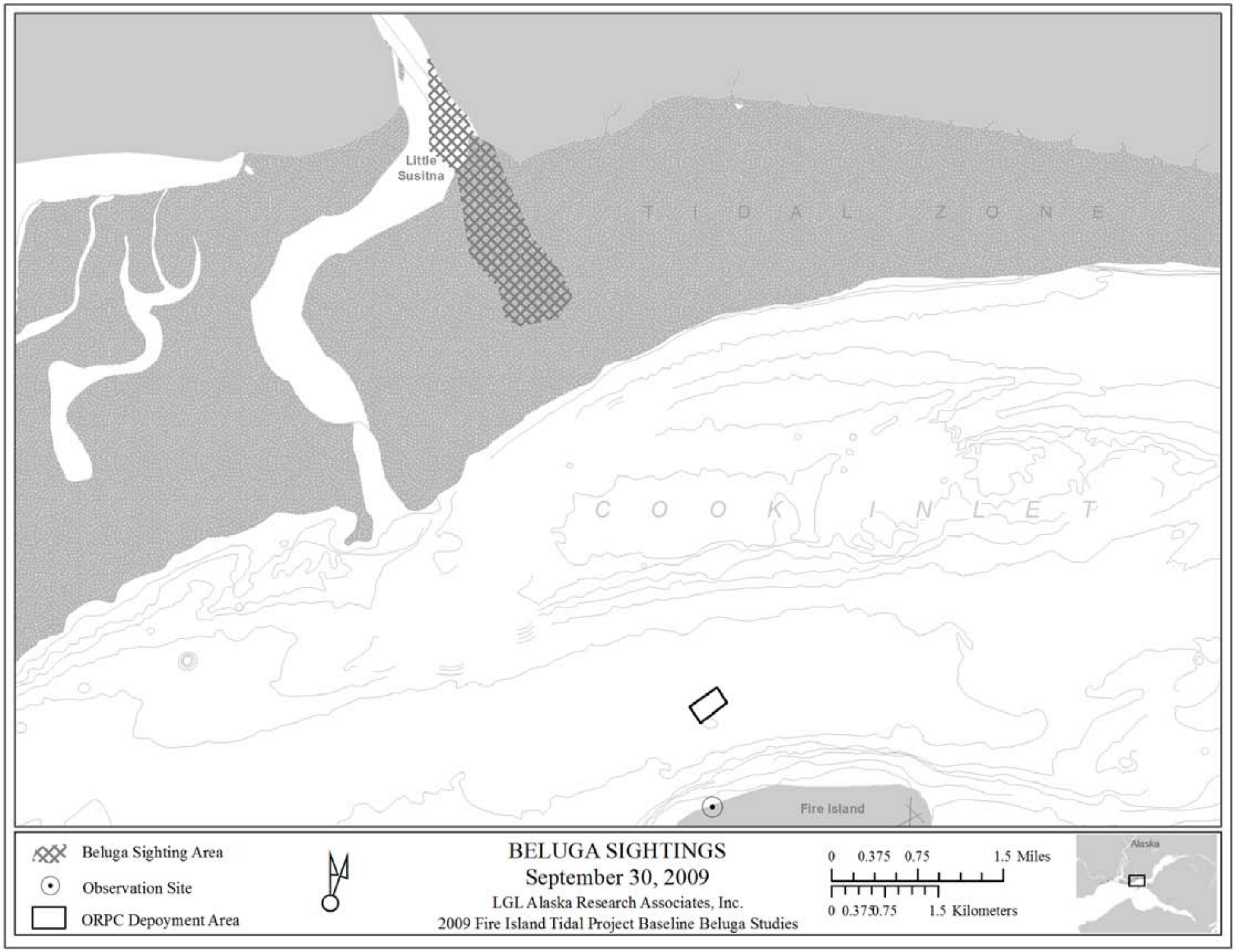

Figure B28. Locations of beluga whales sighted on September 30, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

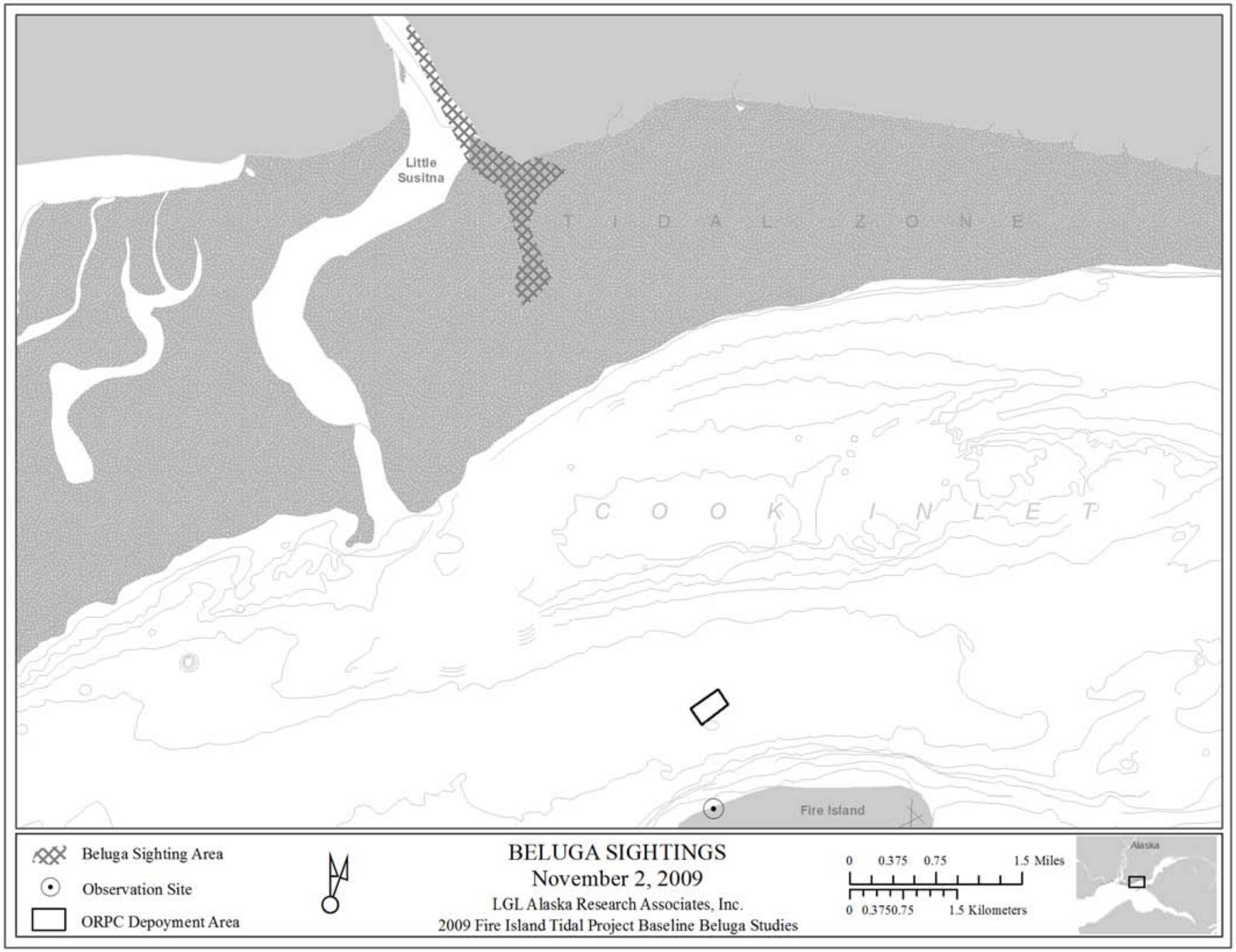

Figure B29. Locations of beluga whales sighted on November 2, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

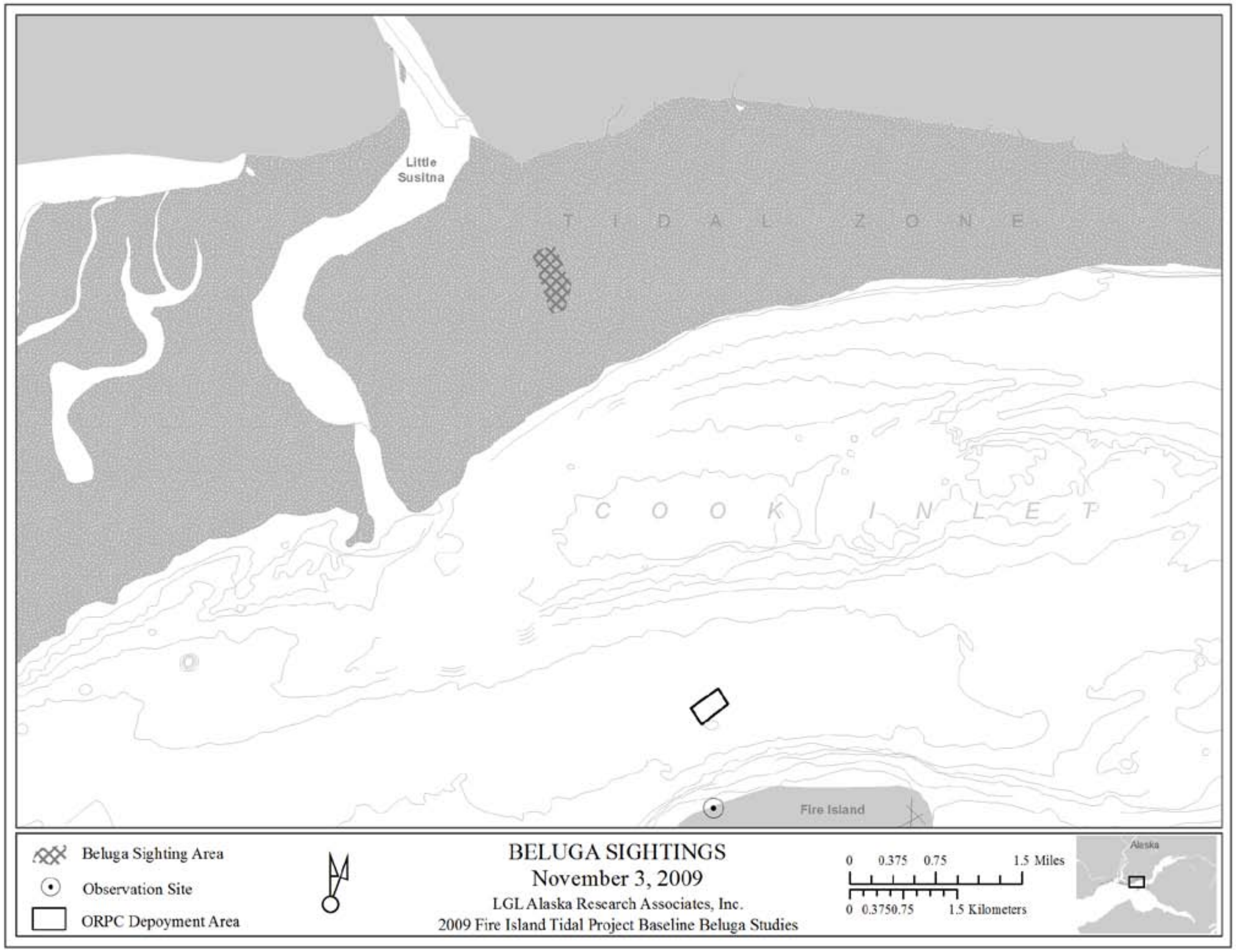

Figure B30. Locations of beluga whales sighted on November 3, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

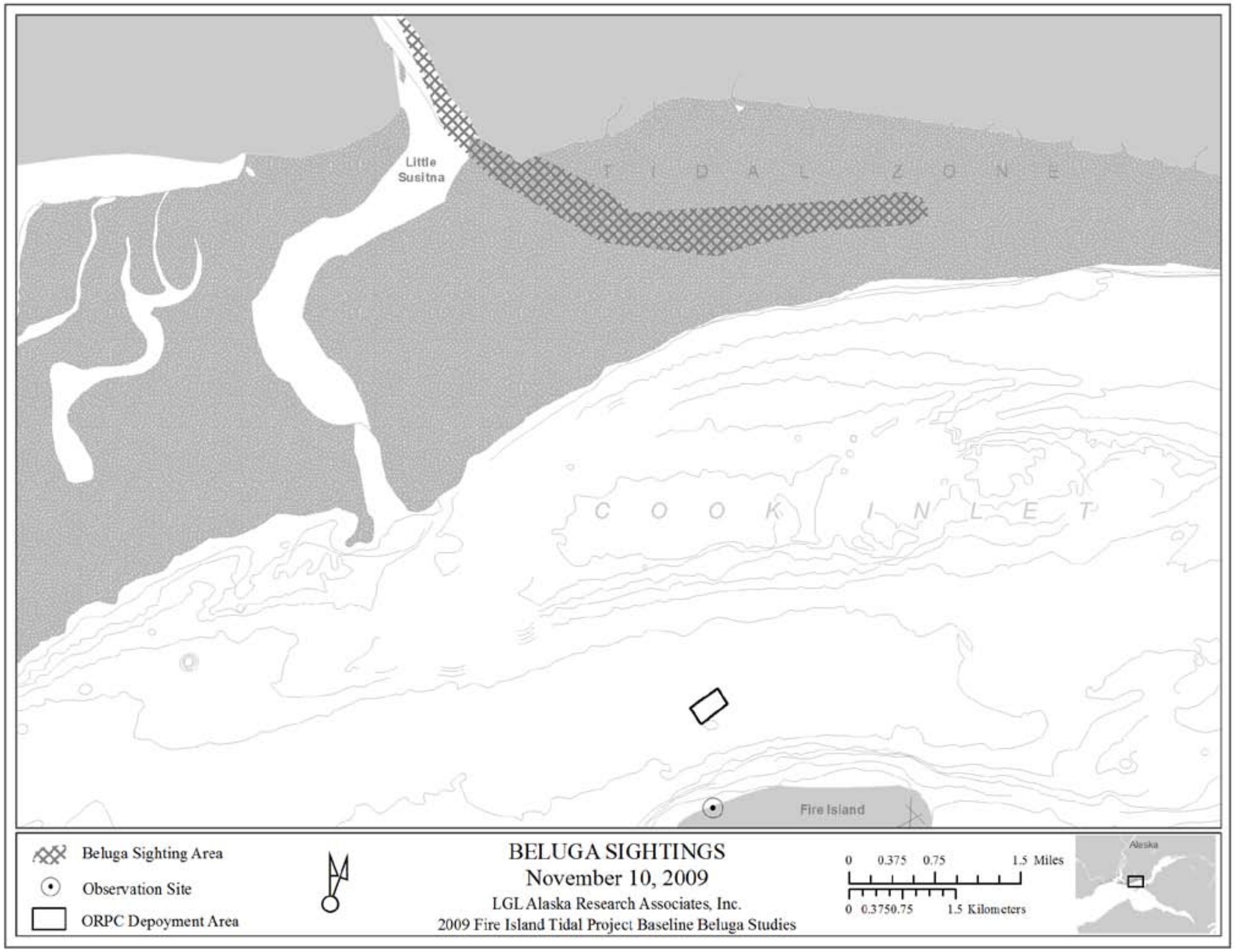

Figure B31. Locations of beluga whales sighted on November 10, 2009. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

APPENDIX C

MONITORING EFFORT BY MONTH

Table C1. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for June 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?	Comments
1	2009JUN17	11:15	14:45	3:30	2.7	6.9	4:55	23:19	No	No	Late start due to trail cutting
2	2009JUN18	10:00	14:46	4:46	9	6.2	4:57	23:17	No	No	
3	2009JUN19	11:00	14:50	3:50	0.5	4.8	4:59	23:15	Yes	No	
4	2009JUN22	10:20	15:00	4:40	5.0	-0.7	5:06	23:08	No	No	
5	2009JUN23	10:00	15:00	5:00	7.1	-1.2	5:08	23:06	No	No	
6	2009JUN24	10:00	15:00	5:00	8.5	0.1	5:11	23:03	Yes	No	
7	2009JUN25	10:40	15:43	5:03	8.6	0.0	5:13	23:01	Yes	No	Later shift due to extremely high tide preventing beach walk
8	2009JUN29	10:00	15:00	5:00	4.1	6.9	5:23	22:51	Yes	No	
9	2009JUN30	10:00	15:00	5:00	1.7	7.5	5:26	22:49	Yes	No	

Table C2. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for July 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?
1	2009JUL01	10:00	15:00	5.00	0.5	7.1	4:27	23:41	Yes	No
2	2009JUL02	10:00	15:00	5.00	1.0	5.9	4:30	23:40	No	No
3	2009JUL07	10:00	15:00	5.00	6.3	-0.3	4:35	23:35	No	No
4	2009JUL08	10:00	15:00	5.00	7.3	0.1	4:37	23:34	No	No
5	2009JUL09	10:00	15:00	5.00	8.1	0.8	4:39	23:33	No	No
6	2009JUL10	10:05	15:00	4.92	8.5	1.4	4:41	23:31	No	No
7	2009JUL13	10:00	15:00	5.00	6.9	4.2	4:46	23:26	No	No
8	2009JUL14	9:50	15:00	5.17	5.2	5.3	4:48	23:24	Yes	No
9	2009JUL15	9:47	14:56	5.15	3.4	6.3	4:50	23:23	Yes	No
10	2009JUL16	9:46	15:00	5.23	1.5	6.9	4:52	23:21	No	No
11	2009JUL20	10:00	15:00	5.00	3.4	2.1	5:01	23:12	Yes	No
12	2009JUL23	9:56	15:00	5.07	8.4	-0.5	5:08	23:06	No	No
13	2009JUL28	9:40	14:00	4.33	4.7	7.5	5:21	22:54	No	No
14	2009JUL29	9:30	15:00	5.50	2.2	7.1	5:23	22:51	No	No
15	2009JUL30	9:30	15:00	5.50	1.1	7.1	5:26	22:49	No	No
16	2009JUL31	9:21	15:00	5.35	1.3	6.3	5:28	23:54	No	No

Table C3. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for August 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?
1	2009AUG01	8:49	15:00	6.18	2.6	5.9	5:31	22:43	Yes	No
2	2009AUG03	8:00	16:00	8.00	6.0	5.4	5:36	22:38	Yes	No
3	2009AUG04	8:00	16:00	8.00	7.0	4.4	5:38	22:35	Yes	No
4	2009AUG05	7:40	16:00	8.33	8.3	3.4	5:41	22:32	Yes	No
5	2009AUG10	7:41	16:00	8.32	6.5	0.9	5:54	22:18	Yes	No
6	2009AUG11	7:40	16:00	8.33	5.3	1.8	5:56	22:15	Yes	No
7	2009AUG12	7:44	16:00	8.27	3.6	3.1	5:59	22:13	Yes	No
8	2009AUG17	8:23	16:45	8.37	3.1	7.9	6:12	21:58	Yes	No
9	2009AUG18	7:40	15:30	7.83	6.1	5.2	6:14	21:55	Yes	No
10	2009AUG19	8:00	16:00	8.00	7.6	4.8	6:17	21:52	Yes	No
11	2009AUG24	7:40	16:00	8.33	6.5	0.8	6:30	21:37	Yes	No
12	2009AUG25	7:37	16:00	8.38	4.3	2.1	6:32	21:33	Yes	No
13	2009AUG26	10:00	17:40	7.67	6.8	1.9	6:35	21:30	Yes	No
14	2009AUG31	8:07	16:07	8.00	4.2	7.0	6:48	21:15	Yes	No

Table C4. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for September 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?
1	2009SEP01	8:00	16:00	8.00	5.5	6.3	6:50	21:12	No	No
2	2009SEP02	8:05	16:05	8.00	6.8	5.5	6:53	21:08	Yes	No
3	2009SEP08	8:35	16:30	7.92	8.1	1.1	7:08	20:49	Yes	No
4	2009SEP09	8:30	19:30	11.00	7.0	6.7	7:10	20:46	No	No
5	2009SEP10	7:00	12:05	5.08	2.7	7.7	7:13	20:43	No	No
6	2009SEP14	9:00	17:00	8.00	1.0	8.0	7:23	20:30	Yes	No
7	2009SEP15	9:00	18:00	9.00	2.2	8.6	7:25	20:27	No	No
8	2009SEP16	9:00	16:00	7.00	3.8	7.2	7:27	20:24	No	No
9	2009SEP21	9:30	17:15	7.75	9.6	3.7	7:40	20:08	No	No
10	2009SEP22	9:00	17:15	8.25	8.9	2.3	7:42	20:05	Yes	No
11	2009SEP23	9:00	17:00	8.00	7.7	1.7	7:45	20:02	No	No
12	2009SEP28	9:00	17:00	8.00	1.6	7.4	7:57	19:46	No	No
13	2009SEP29	9:00	17:00	8.00	2.3	8.2	8:00	19:43	No	No
14	2009SEP30	10:40	18:00	7.33	1.1	8.5	8:02	19:39	Yes	No

Table C5. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for October 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?
1	2009OCT06	12:00	19:00	7.00	6.9	1.9	8:17	19:20	No	No
2	2009OCT07	8:20	16:20	8.00	7.2	1.5	8:20	19:17	No	No
3	2009OCT12	12:00	19:00	7.00	7.6	4.3	8:33	19:02	No	No
4	2009OCT13	8:50	18:30	9.66	1.8	7.4	8:35	18:59	No	No
5	2009OCT14	9:00	18:50	9.83	3.3	8.8	8:38	18:56	No	No
6	2009OCT19	10:35	18:30	7.92	8.4	7.0	8:51	18:40	No	No
7	2009OCT20	8:50	16:55	8.08	9.0	2.0	8:54	18:37	No	No
8	2009OCT21	10:10	18:30	8.33	9.0	4.6	8:56	18:34	No	No
9	2009OCT22	9:00	17:00	8.00	6.8	2.1	8:59	18:31	No	No
10	2009OCT26	10:15	15:00	4.66	3.2	7.6	9:10	18:20	No	No
11	2009OCT27	10:30	16:30	6.00	2.3	7.7	9:12	18:17	No	No
12	2009OCT28	10:45	16:45	6.00	1.6	8.1	9:15	18:14	No	No
13	2009OCT29	10:10	16:10	6.00	2.5	7.6	9:18	18:11	No	No

Table C6. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for November 2009.

Day	Date	Shift Start	Shift Stop	Total hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted?	Belugas Sighted within proposed Deployment Area?
1	2009NOV02	9:30	15:30	6.00	5.0	7.0	8:31	16:57	Yes	No
	2009NOV03	9:30	15:30	6.00	6.2	6.1	8:34	16:54	Yes	No
3	2009NOV04	9:35	15:35	6.00	7.3	4.6	8:47	16:51	No	No
4	2009NOV06	9:40	15:10	5.50	8.5	1.9	8:42	16:46	No	No
5	2009NOV09	10:00	15:30	5.50	7.1	4.8	8:51	16:38	No	No
6	2009NOV10	9:50	15:30	5.66	5.2	6.4	8:53	16:36	Yes	No
7	2009NOV11	9:35	11:30	1.92	2.5	6.3	8:56	16:33	No	No

APPENDIX D

BELUGA WHALE SIGHTINGS SUMMARIZED BY DATE

Table D1. Beluga whale sightings during June 2009 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calve	Unk	Total	Group #	1° Activity[1]	2° Activity[1]	Spread[2]	Direction[3]	Formation[4]	Comments	Belugas sighted within proposed Deploy-ment Area?
2009JUN19	11:25	2	0	0	0	2	1	T	U	7	W	P	This group simultaneously seen by LGL photo-id survey boat at close range, which counted a group of 24 belugas	No
2009JUN24	13:25-14:07	3	0	0	0	3	1	U	U	7-12	E	NF		No
2009JUN25	15:23-15:39	5	0	0	0	5	1	U	U	7-13	U	NF	3 belugas close together, 2 further away	No
2009JUN29	10:14-10:40	2	0	0	0	2	1	U	U	x	U	NF		No
2009JUN30	14:28-15:00	1	1	0	0	2	1	T	D	3	W	L	Gray animal may be a large calf, but can't be sure.	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**			Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**			Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**			No Formation	**NF**
				Unknown	**U**			Unknown	**U**

Table D2. Beluga whale sightings during July 2009 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calf	Unk	Total	Group #	1° Activity[1]	2° Activity[1]	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within proposed Deploy-ment Area?
2009JUL01	14:24-14:36	5	0	0	0	5	1	T	D	7	U	U	No
2009JUL14	11:13-11:23	1	0	0	0	1	1	D	M	x	V	U	No
2009JUL15	10:49-14:22	2	0	0	0	2	1	T	D	12	E	U	No
2009JUL20	14:40-14:50	60-75	0	0	0	60-75	1	D	FS	13	W	NF	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**			Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**			Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**			No Formation	**NF**
				Unknown	**U**			Unknown	**U**

Table D3. Beluga whale sightings during August 2009 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calve	Unk	Total	Group #	1° Activity[1]	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within proposed Deployment Area?
2009AUG01	10:28-11:23	50	0	0	0	50	1	U	U	V	U	No
2009AUG03	13:18-15:10	30	0	0	0	30	1	U	U	V	U	No
2009AUG03	13:55-15:55	12	0	0	0	12	2	U	U	V	U	No
2009AUG04	09:22-13:40	30	3	0	0	33	1	U	U	V	U	No
2009AUG05	12:35-14:54	50	10	0	0	60	1	U	U	V	U	No
2009AUG05	14:10-15:10	50	0	0	0	50	2	U	U	V	U	No
2009AUG10	07:55-16:00	55	0	0	0	55	1	U	U	V	U	No
2009AUG11	07:57-15:55	55	0	0	0	55	1	U	U	V	U	No
2009AUG12	07:54-15:55	18	0	0	0	18	1	U	U	V	U	No
2009AUG17	08:42-10:20	35	1	0	0	36	1	U	U	V	U	No
2009AUG18	08:06-13:47	5	0	0	0	5	1	U	U	V	U	No
2009AUG19	09:54-16:00	30	0	0	0	30	1	U	U	V	U	No
2009AUG24	09:56-16:00	15	0	0	0	15	1	U	U	V	U	No
2009AUG25	09:45-15:20	5	0	0	0	5	1	U	U	V	U	No
2009AUG26	10:25-17:16	18	0	0	0	18	1	U	U	V	U	No
2009AUG31	08:37-15:55	25	0	0	0	25	1	U	U	V	U	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**			Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**			Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**			No Formation	**NF**
				Unknown	**U**			Unknown	**U**

Table D4. Beluga whale sightings during September 2009 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calve	Unk	Total	Group #	1° Activity[1]	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within proposed Deployment Area?	Comments
2009SEP02	9:00-14:05	10	0	0	0	10	1	U	1	V	U	No	
2009SEP08	11:33-14:25	16	0	0	0	16	1	U	U	U	U	No	
2009SEP08	13:05-13:05	0	0	0	1	1	2	U	N/A	U	N/A	No	Unconfirmed
2009SEP14	14:01-16:36	25	0	0	8	33	1	U	7	V	U	No	
2009SEP22	12:30-13:08	4	10	0	0	14	1	U	7	V	NF	No	
2009SEP30	10:40-16:20	54	0	0	0	54	1	U	7	V	NF	No	

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**			Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**			Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**			No Formation	**NF**
				Unknown	**U**			Unknown	**U**

Table D5. Beluga whale sightings during November 2009 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calve	Unk	Total	Group #	1° Activity[1]	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within proposed Deployment Area?	Comments
2009NOV02	13:03-14:07	3	1	0	0	4	1	U & T	3 - 13	V & NE	NF & L	No	
2009NOV02	13:45-14:38	12	0	0	0	12	2	U & T	7 - 12	V & NE	NF & L	No	
2009NOV03	14:00	5	0	0	0	5	1	U	7	V	NF	No	Single sighting
2009NOV10	12:17-15:15	19	0	0	0	19	1	T & U	3 - 13	SW & V	NF & L	No	

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**			Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**			Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**			No Formation	**NF**
				Unknown	**U**			Unknown	**U**

Pre-Deployment Visual Monitoring for Beluga Whales in and near the Cook Inlet Tidal Energy Project Proposed Deployment Area, May-November 2010.

Final Report

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EXECUTIVE SUMMARY

South-central Alaska's Cook Inlet is home to some of the greatest tidal energy potential in the United States. It is also home to an endangered population of beluga whales (*Delphinapterus leucas*). Successful permitting and operation of a tidal power project in Cook Inlet will require a rigorous biological assessment of the potential and realized effects of the sound footprint and physical presence of tidal turbines on the distribution, relative abundance, and behavior of Cook Inlet beluga whales. In 2009 and 2010 LGL Alaska Research Associates, Inc., sponsored by ORPC, conducted a study to visually monitor beluga whale presence, relative abundance, and behavior off of the north side of Fire Island, Upper Cook Inlet, Alaska. This report presents results from 2010.

The study plan to survey for beluga whales in and near the proposed Deployment Area was developed by ORPC and reviewed by regulatory and resource agencies as part of the Federal Energy Regulatory Commission (FERC) pre-consultation process. A copy of the approved study plan is included in Appendix A. Any modifications to the original plan due to logistical constraints were made after conversations with NMFS-Alaska Region, and are discussed in this report.

The study had two primary objectives:

1. **Estimate** the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the proposed Deployment Area during ice-free months of 2009 and 2010.
2. **Provide** information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project.

ORPC is collaborating with the Alaska Department of Fish and Game (ADF&G) to share data from visual and passive acoustic detections of beluga whales in and around the proposed Deployment Area near Fire Island. Results of this collaboration will be presented in a separate report**.**

Methods

In May 2009, an observation site was selected on Fire Island that gave the maximum vantage of the proposed Deployment Area. NMFS personnel visited the site prior to the commencement of 2009 field operations and confirmed the viability of the site for making visual observations (with the caveat that vegetation obstructing the field of view be cleared from the site, which subsequently occurred). This site was also used in 2010. Observations in 2010 began on May 4 and continued until November 13. Observers were typically at the observation site two days per week. Observations were only conducted during daylight hours. All tidal stages were sampled.

Visual observations of the presence, abundance, and surface-behavior of beluga whales and other marine mammals were conducted by trained observers stationed on a cliff 64.5 m (212 ft) above the mean low water line overlooking the proposed Deployment Area. Observers surveyed for belugas from land (at the observation site), as well as from the air during flights to and from Fire Island. Observations were also conducted from a research vessel used to transport observers to and from Fire Island on a few occasions.

Land-based observers used hand-held binoculars, spotting scope, a survey grade theodolite, and the naked eye to search for belugas in the proposed Deployment Area and surrounding areas as far as the Susitna River and Point MacKenzie. Beluga locations were recorded in two ways: 1) by using a 500 m x 500 m (1,640 ft x 1,640 ft) grid-cell map of the field of view and, 2) using a theodolite and software combination.

Aerial and boat-based observers used the unaided eye, clinometer, global positioning system (GPS) unit, and a grid-cell map to locate and record beluga whales during crew-transport trips between Anchorage and Fire Island. Incidental beluga sightings were obtained by observers surveying from the beach while walking to the observation site, and from interviews with pilots. During twice-daily crew-transport flights, observers asked the pilots when and where they saw belugas during their other flights and how many belugas they saw. During visual observations for belugas, observers also searched for and recorded other marine mammals in the proposed Deployment Area and field of view. Observers measured and recorded hourly environmental conditions, as well as the presence of vessels in the proposed Deployment Area and field of view and the presence of birds on the water in or near the proposed Deployment Area. Data recorded using Pythagoras™ (a marine mammal tracking program) were imported in a Geographic Information System (GIS). The locations of all belugas were mapped relative to the proposed Deployment Area and the observation site.

Results

Visual observations were conducted for a total of 47 days (310.9 hours) between May 4 and November 13, 2010, averaging 1.7 days of observation per week. Belugas were seen on 17 of the 47 observation days, for a total of 466 sightings and an average of 1.5 sightings per hour. Belugas were seen most often and in the greatest numbers in May, and were never seen in November, although observation time in November was greatly reduced relative to other months. Belugas were seen in the proposed Deployment Area on three days in 2010, and near it on two days (near was defined as ≤2 km/1.2 m from the ce nter of the proposed Deployment Area). Belugas were most commonly seen in and around the mouth of the Little Susitna River. Belugas were seen only once during crew-transport flights in 2010, along the shore near Westchester Lagoon (in Anchorage). No belugas were observed during vessel transit. Spernak Air pilots reported seeing beluga whales in the mouths of the Beluga, Ivan, Lewis, Theodore, Susitna, and Little Susitna rivers, as well as near Port MacKenzie in Knik Arm, but not in or near the proposed Deployment Area or around Fire Island. Harbor seals were seen on only one of the 47 observation days. Apart from harbor seals (and beluga whales), no other marine mammals were seen.

Discussion

This study was a continuation of the first dedicated survey, to our knowledge, for beluga whales from Fire Island, Alaska. The primary objective of the study was to estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the ORPC proposed Deployment Area during ice-free months of 2010 and 2009. In 2010, belugas were seen on only three occasions in the proposed Deployment Area during the six and a half month observation period (May through mid-November). There were no beluga sightings in or near the proposed Deployment Area in 2009. Although whales were seen in and near the proposed Deployment Area in 2010, the majority of all sightings were located at the mouth of the Little Susitna River. This result was consistent with results from 2009 and with other studies that have repeatedly demonstrated patterns of belugas congregating in the rivers and bays of Upper Cook Inlet during the summer and fall. Belugas seen in the proposed Deployment Area were observed to be travelling between other areas.

The second objective of this study was to provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project. This objective has been met with monthly progress reports from LGL to ORPC, which ORPC in turn distributes to NMFS and FERC. Copies of these reports are publically available at http://www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm#orpc. This final report is a summary of the seven monthly reports for 2010.

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NMFS
Mandy Migura, Kate Savage, Susan Walker

Permit
Cook Inlet Region Inc. (CIRI); the local Native Corporation who owns the majority of Fire Island lands, granted a permit to allow for access to the island.

United States Coast Guard (USCG) License HSCG-Z71117-09-RP-054L was executed on June 8, 2009 to allow observers to utilize the observation site at the NW corner of the island, and amended in July to allow for the construction of an observation tower.

INTRODUCTION

ORPC Alaska, LLC (ORPC), a subsidiary of Ocean Renewable Power Company, LLC, is an Alaska-based, tidal energy technology and project development company. Ocean Renewable Power Company has developed proprietary OCGen™, TidGen™, and RivGen™ technology that will convert the energy in ocean, tidal, and river currents into emission-free electricity. In March 2007, ORPC was granted a Preliminary Permit (P-12679) by the Federal Energy Regulatory Commission (FERC) for its project site in Upper Cook Inlet; this permit expired in March 2010 and a second preliminary permit was applied for and issued to ORPC on October 13, 2010 (this permit expires on October 12, 2013). On March 31, 2009, ORPC submitted a draft application for a FERC Pilot Project License for its Cook Inlet Tidal Energy Project, which would allow ORPC to install a 5MW pilot project, in a phased approach beginning with an initial 1MW installation in 2012. This pilot project license would have duration of up to eight years. Pilot projects are small, short-term, removable projects that must be carefully monitored to ensure that there are no unacceptable adverse environmental effects. The projects are designed to be easily and quickly shut down and/or removed if such effects are encountered that cannot be mitigated. This pilot project will provide data necessary for a potential commercial scale expansion both in terms of technological viability and environmental sustainability of the project.

While Cook Inlet is home to some of the greatest tidal energy potential in the United States, it is also home to an endangered population of beluga whales (*Delphinapterus leucas*). Successful permitting and operation of a tidal power project in Cook Inlet will require a rigorous biological assessment of the potential and realized effects of the sound footprint and physical presence of tidal turbines on the distribution, relative abundance, and behavior of Cook Inlet beluga whales. A study plan to survey for beluga whales in and near the proposed Deployment Area was developed by ORPC and reviewed by regulatory and resource agencies as part of the FERC pre-consultation process. A copy of the approved study plan is included in Appendix A.

Beluga whales use sound for communication, navigation, predator/prey interactions, and hazard avoidance. Underwater sound associated with installation and operation of equipment during Pilot Project operations may temporarily alter beluga whale behavior and presence in the proposed Deployment Area. In addition, the physical presence and operation of the turbine in the proposed Deployment Area has the potential to affect the distribution, relative abundance, and/or behavior of beluga whales. Information is needed to evaluate the use of the proposed Deployment Area by belugas and to assess potential risks to belugas during deployment and operation of tidal energy modules.

Understanding and quantifying potential effects of ORPC's Cook Inlet Tidal Energy Project on beluga whales is critical to the success of the project. The Cook Inlet beluga whale Distinct Population Segment (DPS) was listed in October 2008 as endangered by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). It is also designated as depleted under the Marine Mammal Protection Act (MMPA). Critical habitat was proposed by NMFS in December 2009, with Upper Cook Inlet, including the ORPC proposed Deployment Area, proposed as Critical Habitat Type 1 (high value/high sensitivity) for beluga whales (NMFS 2009a). FERC cannot issue a hydropower license to ORPC without a Biological Opinion from

NMFS indicating that the project will not jeopardize the Cook Inlet beluga population or its critical habitat.

Numerous visual surveys of beluga whales have been undertaken in the upper parts of Cook Inlet in conjunction with environmental studies for the Port of Anchorage, Knik Arm Bridge, and Seward Highway Projects (Funk et al. 2005, Prevel-Ramos et al. 2006, Markowitz and McGuire 2007). However, limited information is available for the ORPC module proposed Deployment Area near Fire Island (Figure 1).

This report presents results from 2010 of a study by LGL Alaska Research Associates, Inc. (LGL) sponsored by ORPC to visually monitor beluga whale presence, relative abundance, and behavior in the waters off of the north side of Fire Island, Upper Cook Inlet, Alaska. This marks the second year of the pre-deployment monitoring effort, with the first year of monitoring occurring in 2009. Information presented in this report provides data that will be used to characterize pre-deployment patterns of beluga whale presence, distribution, relative abundance, and surface behavior in and near the Cook Inlet Tidal Energy Project proposed Deployment Area. Continued studies in future years have been proposed and would consist of monitoring during and after deployment of the generating equipment to determine beluga whale interaction with the OCGen™ Module and the proposed Deployment Area. Results from the pre- and post-deployment years will be compared to determine if underwater noise and/or physical presence of the module is associated with changes in beluga distribution, relative abundance, and behavior (i.e., behavior visible at the surface).

The study had two primary objectives:

1. Estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the proposed Deployment Area during ice-free months of 2010.
2. Provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project.

ORPC is collaborating with the Alaska Department of Fish and Game (ADF&G) to share data from visual and passive acoustic detections of beluga whales in and around the proposed Deployment Area near Fire Island. Passive acoustic sampling is paired with visual sampling to compare the two methods of observation and to complement the data sets of each method. Through a comparison of these data sets we will gain an understanding of how the two methods might overlap in their detections of belugas and how each might be limited. Combining visual and acoustic observations will increase our abilities to detect belugas in the Deployment Area. ADF&G uses an acoustic mooring package consisting of two types of acoustic recorders, one (the Ecological Acoustic Recorder or EAR) to record low-frequency sounds and one (the C-Pod to record high-frequency sounds). ADF&G will analyze the recorded data from the EAR/C-Pod array deployed in 2009 and 2010. LGL will analyze the visual observation data from 2009 and 2010. LGL and ADF&G will collaborate to correlate visual and acoustic data. Results of this collaboration will be presented in a separate report.

METHODS

Site Selection and Observation Schedule

A permit from Cook Inlet Region, Inc. (CIRI; the majority land owner on Fire Island) was secured on in 2009 and renewed in 2010 for observer access to Fire Island. ORPC also obtained a license from the United States Coast Guard (USCG) to use the Race Point Lighthouse Reservation lands on Fire Island (which provided a vantage of the proposed deployment site) for the observation site for investigation of beluga whale use of the area. In May 2009, an observation site was selected near Race Point that was accessible from pre-existing trails on the island, and gave the maximum vantage of the proposed Deployment Area (Figure 1). This site was confirmed as viable for the study by Kate Savage of NMFS in June 2009, and was subsequently used for the entirety of the 2009 and 2010 field seasons.

Beluga field observations in 2010 began on May 4 and continued until November 13. The 2010 observation schedule was adjusted from the 24 hour per week goal established for 2009 to a goal of two seven-hour observation days per week. This goal was reduced to one day per week during the first three weeks of August so as to allow for more observation days later in the season when, in addition to their standard monitoring effort, crews were required on site to visually monitor for belugas during the deployment of acoustic equipment in and around the proposed Deployment Area. Observations were only conducted during daylight hours, and all tidal stages were sampled over the field season.

For transportation to and from the observation site, the observation team chartered round trip aircraft service between Fire Island and Merrill Field in Anchorage, AK. Upon landing at Fire Island, the observation team hiked approximately 3 km (2 mi) through marsh, beach, meadow and woods to reach the observation site. Over the course of the season, the crew maintained two small cabins near the northeast corner of Fire Island as safety shelters in case they were stranded on the island. The crew had to remain on the island overnight once throughout the season. Observers traveled and worked in pairs due to safety concerns related to the remoteness of the observation site. The observation team traveled on a research vessel to Fire Island on one day and from Fire Island on four days because of adverse weather conditions that grounded aircraft.

Visual Observations

Visual observations of the presence, abundance, and surface-behavior of beluga whales and other marine mammals were conducted by trained observers stationed at the observation site, a bluff ~64.5 m (212 ft) above the mean low water line overlooking the proposed Deployment Area. The distance between the observation site and the center of the proposed Deployment Area was 1.25 km (0.76 mi; Figure 1). Visual observers were necessary due to the turbid water of Cook Inlet which made underwater observations (from still cameras, video cameras, or divers) unfeasible.

All 2010 beluga monitoring was conducted from a tower constructed in 2009 on an existing foundation at the site. The improved vantage for visual observations that the tower afforded was supported by NMFS personnel. The observation tower provided observers with safety from bears and moose, shelter from winds and rain, and a higher vantage that reduced the need to continually prune vegetation in order to keep it from obstructing the view of the proposed Deployment Area. The tower was 4.5 m (14.8 ft) high which, combined with the bluff height, resulted in an observer height 69.8 m (229 ft) above mean low water, and an increased field of view (Figure 2).

Beluga Sightings

Observers surveyed for belugas from land (at the observation site) and air (during flights to and from the island). Observations were conducted from a boat when vessel transit to or from the island was required. Observers also obtained incidental beluga sighting information from crew-transport aircraft pilots. Nine observers were on the observation team; all were experienced field biologists and those observers new to the project were always paired with more-experienced team members.

Land-based Observations

Observers used hand-held binoculars (7 x 50, with built-in reticles and compass), a frame-mounted spotting scope (20 x 60), a survey grade theodolite (Sokkia DT-5), and the unaided eye to search for belugas in the proposed Deployment Area and surrounding areas from the Susitna River to Point MacKenzie (Figure 1). When a beluga whale was sighted, observers recorded the time, location, group size, whale color (i.e., white, gray, or calf, defined as <2/3 adult size, usually dark gray and swimming alongside a larger beluga), direction of travel, (i.e., N, S, E, W) and behavior. Focal group behavioral information (Mann 2000) was collected including behavioral state (traveling, milling, diving, resting, and feeding) and inter-individual distance/group spread. Predominant and secondary surface-behaviors were recorded for each group sighted. A beluga had to be seen by one or both observers in order for it to be recorded as a confirmed sighting; surface disturbances (i.e., splashes or "footprints") or sounds were recorded as possible sightings. Observers noted if a beluga was seen or near in the proposed Deployment (near was defined as ≤2 km/1.2 m from the center of the proposed Deployment Area).

Locations were recorded in two ways: 1) using a 500 m x 500 m (1,640 ft x 1,640 ft) grid-cell map of the field of view and, 2) using a theodolite and software combination. LGL has developed and employed a grid system to record the locations and movements of Cook Inlet beluga whales in Upper Cook Inlet, including Knik Arm (Funk et al. 2005), the Port of Anchorage (Markowitz and McGuire 2007) and along Turnagain Arm (Markowitz et al. 2007). This system has proven effective for documenting whale group location and movements on a coarse scale (500 m x 500 m or 1 km x 1 km grids [1,640 ft x 1,640 ft or 0.62 mi x 0.62 mi]). In applying this technique, trained observers used a combination of compass bearings taken from binoculars and landmarks to place whale groups at any given time in a grid cell.

Use of a surveyor's theodolite to monitor the location and movement patterns of whales and dolphins is a well-established technique (reviewed by Samuels and Tyack 2000), and LGL has found it to be particularly effective for monitoring beluga whales' distances from, and responses to, human activities in Cook Inlet (Prevel-Ramos et al. 2006, Markowitz and McGuire 2007). During theodolite tracking sessions, data were entered directly into a laptop computer in a Microsoft® Access database. Using this technique, computer calculations made with Pythagoras™ (Gailey and Ortega-Ortiz 2000) whale-survey software provided accurate, real-time estimates of the distance of whales from the proposed Deployment Area. To ascertain the accuracy of the theodolite, in 2009 GPS tracks from a small boat were compared to the fixes taken of the same boat with the theodolite. A GIS analyst later compared the boat's GPS track line to the track line created by the theodolite and Pythagoras™ software. In instances when the theodolite was not working (e.g., dead batteries, high winds) the grid cell map was used as a backup to determine whale locations. The theodolite was the preferred means of spatial designation and the grid system was maintained as a back up.

Aerial and Boat-based Observations

Aerial observers used the unaided eye, clinometer (measures angle), global positioning system (GPS) receiver, and a grid-cell map to locate and record beluga whales during crew-transport flights between Anchorage and Fire Island in a Cessna 207 and a Cessna 107. Flights were usually at an altitude of 150-300 m (492-984 ft) at approximately 160 km/hr (99 mi/hr). Both observers scanned for belugas. When whales were detected, observers recorded the angle, altitude, GPS location, time and the number of belugas. Observers also recorded the belugas' estimated location on a grid cell map and later refined that location using the data recorded during the sighting. The flight path of the plane was recorded using the track function on the GPS receiver. Observers employed this same protocol for boat-based observations (although without integration of clinometer and altitude data) in determining whale location. The field of view from within the vessel's cabin was considerably smaller than those afforded by land-based or aerial surveys, although vessel transit was longer (30-90 minutes each way) than air transit (approximately five minutes within view of the water each way). The vessel routes passed directly through much of the land-based field of view, including passage directly through the proposed Deployment Area.

Incidental Observations

Incidental beluga sightings were obtained by observers surveying from the beach while walking to the observation site, and from interviews with pilots. During both inbound and outbound crew-transport flights, observers asked the pilots when and where they saw belugas during their other recent flights and how many belugas they had seen.

Other Marine Mammal Sightings

During visual observations for belugas, observers also searched for and recorded other marine mammals in the proposed Deployment Area and field of view. If a marine mammal was seen, observers recorded the time, location, group size, behavior, and travel pattern of the mammal. The theodolite and grid cell map were used to record the marine mammal's location. Marine mammal sightings were later mapped in the same manner as beluga sightings.

Environmental Conditions

Observers measured and recorded environmental data including air temperature, wind speed and direction, cloud cover, Beaufort sea state, visibility (i.e., ability to see far shore), angle of glare, and presence of whitecaps. Temperature and wind speed were measured with an anemometer/thermometer. Environmental conditions were recorded every hour, or when any significant changes occurred.

Vessel Sightings

During observations for belugas, observers also recorded the presence of vessels in the field of view. If a vessel was seen, observers recorded the time of day, vessel type, name, and general route, including any passage through or near the proposed Deployment Area. Vessel totals were tallied every hour. The theodolite was used to map and track vessels.

Bird Sightings

Observers noted the presence of birds on the water in or near (defined as closer than 2 km/1.2 m) the proposed Deployment Area. Species and number were recorded when possible. Bird sightings were not mapped.

Analysis

Data recorded using Pythagoras™ were imported into a Geographic Information System (GIS) using ESRI's ArcGIS 10.0. The locations of belugas were mapped relative to the proposed Deployment Area and the observation site. When the theodolite data were not available, data derived from the grid cell maps were used. Data derived both from the theodolite and the grid cells were recorded in point format as a static location.

As part of the mapping process, locations of belugas were then transposed over the 500 m x 500 m (1,640 ft x 1,640 ft) grid layer in the GIS. Cells that contained beluga locations were selected and exported as the graphical representation of the whales' locations. Using the cells to represent general areas was done in an attempt to better accommodate the dynamic nature of a whale in the water. Daily beluga sighting maps are found in Appendix B.

RESULTS

Visual Observations

Land-Based Observation Effort and Beluga Sightings

Visual observations were conducted on a total of 47 days (310.9 hours) from May 4 through November 13, 2010 (Table 1). The greatest number of observation days (10 days) and observation hours (69.4 hours) occurred in September. The lowest number of observation days (4 days) and hours (12.9 hours) occurred in November. Belugas were seen on 17 of the 47 observation days (Table 1). Belugas were seen most often and in the greatest numbers in May. Belugas were not seen in November, although monitoring effort in November was less than other study months both in number of observation days and hours of observation each day (Table 1, Figure 3).

Belugas were seen in the Proposed Deployment Area on three days in 2010; one day in May and two days in October (Table 1; Figures 4 and 5; Appendix B, C, and D). The May sighting in the proposed Deployment Area consisted of a mother and calf (Appendix D). Belugas were seen near but not in the proposed Deployment Area on two days (May 18 and September 8). The mean distance between belugas and the proposed Deployment Area was 5.4 km (3.36 mi; Table 1). Belugas were most often seen in and around the mouth of the Little Susitna River and toward the Susitna River (Figures 5-12; Appendix B, C, and D). Beluga densities for all months of observation combined were greatest at the outflow of the Little Susitna River (Figure 4).

Methods of Determining Sighting Location

Two different methods (grid-cell maps and theodolite) were used to determine the location of marine mammal sightings. Little discrepancy in beluga locations was apparent for the two methods, although it appeared that mapped locations of belugas tracked with the theodolite were at a somewhat greater distance from the observation site than those locations mapped based on estimated location/distance with grid cell (i.e., observers tended to visually underestimate distance slightly; McGuire and Bourdon 2010). In 2009, comparisons were made between the GPS tracklines from a small boat and the tracked locations of the same boat from the theodolite; tracks were found to be very similar (McGuire and Bourdon 2010).

Aerial & Boat-based Surveys

Belugas were seen only once during crew-transport flights in 2010. The sighting occurred on August 26 when a group of three white belugas was seen along the shore near Westchester Lagoon in Anchorage (Figure 13). Flight paths of crew transit to and from Fire Island in 2010 are presented in Figure 14. No whales were observed during vessel transit. Belugas were not seen from the beach by observation crews during their twice-daily walks between the runway and the observation site.

Incidental Observations

Over the course of the field season, Spernak Air pilots reported seeing beluga whales in the mouths of the Beluga, Theodore, Lewis, Ivan, Susitna, and Little Susitna rivers, as well as in Knik Arm near Point MacKenzie (Figure 15). The largest groups were seen in June at the mouths of the Susitna and Little Susitna rivers, and whales were seen most frequently at the Susitna River (Table 2). Pilots did not report seeing beluga whales in or near the proposed Deployment Area or around Fire Island.

Other Marine Mammal Sightings

Harbor seals were seen from the observation tower on only one of the 47 observation days in 2010 (Table 3, Figure 16). The harbor seals were within 2 km (1.2 mi) of the proposed Deployment Area. On June 29, an unconfirmed pinniped sighting was recorded near the Kincaid

Park shoreline of Anchorage; the pinniped was believed to have been a harbor seal. Apart from harbor seals (and beluga whales), no other marine mammals were recorded.

Environmental Conditions

Sighting conditions in 2010 were rated as good on 13.5 days, fair on 31.5 days, and poor on 2 days. Poor sighting conditions in July were due to fog, and poor sighting conditions in September were due to haze and whitecaps. Observers were able to see to the far shore (the mouth of the Little Susitna River) on all observation days in 2010. Mean wind speed was 7.0 km/hr (4.4 mi/hr), and wind speed ranged from 0-37.4 km/hr (0-23.4 mi/hr). Mean Beaufort sea state was 1.2. Mean air temperature was 12.6 ^{o}C (54.7 ^{o}F), and ranged from -3.8 to 25.8 ^{o}C (25.2 to 78.4 ^{o}F). Rain was noted on 16 days, and fog on nine days; snow was not noted on any observation days (Table 4).

Vessel Sightings

Skiffs and the ORPC research vessels were the most commonly-seen vessels in 2010. The ORPC- commissioned research vessel was engaged in work in and around the proposed Deployment Area. No vessels were observed engaging in fishing activities (Table 5).

Bird Sightings

Gulls were the most common birds on the water in or near (i.e., ≤2 km/1.2 m) the proposed Deployment Area in 2010. Three mew gulls (*Larus canus*) were identified to species. Surf scoters (*Melanitta perspicillata*), pacific loons (*Gavia pacifica*), and bald eagles (*Haliaeetus leucocephalus*) were also seen in or near the proposed Deployment Area (Table 6). Birds were rarely seen on the water in or near the proposed Deployment Area during observations, and were only sighted there on three out of 47 observation days.

DISCUSSION

This 2009-2010 study is, to our knowledge, the first dedicated survey for beluga whales from north Fire Island, Alaska. The primary objective of the study was to estimate the frequency of occurrence, relative abundance, and surface behavior of beluga whales in and near the ORPC proposed Deployment Area during ice-free months of 2009 and 2010. Belugas were seen in the proposed Deployment Area on only three days during the six and a half month observation period in 2010 (May through mid-November). Belugas were not seen in the proposed Deployment Area during the 2009 field season (mid-June through mid-November). Overall sighting rates were comparable between 2009 and 2010 (1.6 and 1.5 belugas/hour, respectively).

The low frequency of occurrence of beluga whales in the proposed Deployment Area during this study was not surprising given that other studies have consistently reported patterns of beluga whale presence in the rivers and bays of Upper Cook Inlet during the summer and fall. These studies have included aerial and boat-based surveys of Upper Cook Inlet, tagging studies, and land-based observations in Knik Arm, Turnagain Arm, and near the Chuit River (Rugh et al. 2000, 2005, 2006, 2007; Funk et al. 2005; Hobbs et al. 2005; Goetz et al. 2007; Markowitz and

McGuire 2007; Markowitz et al. 2007; Nemeth et al. 2007; McGuire et al. 2008, 2009; Shelden et al. 2008a,b,c, 2009a,b). Sighting reports from Spernak pilots were also consistent with the idea that belugas aggregate at the mouths of rivers in Upper Cook Inlet during the ice-free months.

The north side of Fire Island has neither rivers nor bays, nor does it contain "estuarine areas, or shallow areas adjacent to medium and high low accumulation streams" (Goetz et al. 2007), which are considered preferred habitat features for Cook Inlet belugas as defined by NMFS (NMFS 2009a). Belugas are known to prey on a variety of fish and invertebrates, and salmon (*Onchorhynchus* spp) and eulachon (*Thaleichthys pacificus*) have been found to be important prey species (Fried et al. 1979, Hazard 1988, Huntington 2000, Moore et al. 2000). There are no documented salmon or eulachon[1] runs on Fire Island (NMFS 2009b). They are however, known to spawn in the Susitna River and other rivers in Upper Cook Inlet in May and July (Calkins 1989).

The tracks of 15 belugas instrumented with satellite tags 1999-2003 showed belugas were sometimes in the vicinity of Fire Island, although movement patterns suggest they passed the island while transiting between other areas (Hobbs et al. 2005). Tagged belugas were tracked near Fire Island in all seasons. The primary activity of all belugas seen in the proposed Deployment Area in 2010 was travel. In 2009, belugas were not observed using waters in or near the proposed Deployment Area, for travel between areas of known occurrences (e.g., the mouth of the Susitna River and Knik Arm) or otherwise.

Our observations of beluga whale presence in and near the Little Susitna River throughout the summer and fall with a peak in August (2009) and May (2010) are consistent with patterns detected from aerial surveys by NMFS (1993-2009; Rugh et al. 2000, 2005, 2006; Shelden et al. 2008a,b,c, 2009a,b). Observers during aerial surveys flown by NMFS June 2-9, 2009 reported groups of belugas in Chickaloon Bay and the Susitna Delta (defined as the near shore area between the Beluga and Little Susitna rivers; Shelden et al. 2009a). Observers during surveys flown by NMFS August 11-13, 2009 reported groups of belugas near the Ivan, Susitna, and Little Susitna Rivers, as well as in Knik Arm (Shelden et al. 2009b). In previous years, aerial surveys (conducted annually in June, and sometimes in May, July, and August) have detected belugas off of the Susitna Delta in the summer, but not around Fire Island (Rugh et al. 2000), the only exception being two belugas reported northeast of Fire Island on June 14, 2007 (Rugh et al. 2007).

Beluga whales were reported in the Susitna Delta in May, June, July, and August, but not in September or October during boat-based surveys in May through October 2006 (Nemeth et al. 2007). Belugas were not seen as the vessel transited near Fire Island during any of these months.

[1] During the site visit to the Fire Island in May 2009, observers noted many dead (spawned) eulachon on the beach on the north side of Fire Island; it was assumed these dead eulachon were carried downstream in the Susitna or Little Susitna rivers by the current and washed up on Fire Island by the tide.

Belugas were seen from the Fire Island observation station in October 2010 but not in October 2009. The absence of beluga sightings in October 2009 was notable, particularly because belugas were again seen in November of the same year at the mouth of the Little Susitna River, and was likely an artifact of the sampling schedule and not because whales do not use this area at this time. Spernak Air pilots reported seeing whales at the mouth of the Little Susitna River on six days in October 2009 and on two days in 2010. NMFS does not conduct aerial surveys for belugas in October, and aerial-survey data for this time period are not available for comparison.

The second objective of this study was to provide information to ORPC, NMFS, and FERC on beluga whale sightings and locations relative to the Cook Inlet Tidal Energy Project. This objective has been met with monthly progress reports from LGL to ORPC, which ORPC in turn distributed to NMFS and FERC. Copies of these reports are publicly available at http://www.fakr.noaa.gov/protectedresources/whales/beluga/development.htm#orpc. This report is a summary of the seven monthly reports for 2010.

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Table 1. Monthly observation effort and beluga sightings from the Fire Island Alaska observation site in 2010.

Month	# Days of Effort	# Hours of Observation	# Days Belugas Sighted	Percent Observation Days Belugas Sighted	# Beluga Groups Sighted	# Beluga Sightings	# Beluga Sightings/Hour	Belugas in Deployment Area?	Closest Distance between proposed Deployment^ Area and Belugas (km)
May	6	42.2	5	83.30%	11	326	7.7	yes	0*
June	9	61.92	2	22.20%	3	75	1.2	no	5.0
July	6	40.62	1	16.70%	1	15	0.4	no	5.8
August	5	38.93	3	60.00%	3	22	0.6	no	5.1
September	10	69.38	4	40.00%	4	25	0.4	no	0.5
October	7	44.96	2	28.60%	2	3	0.1	yes	0*
November	4	12.91	0	0.00%	0	0	0	no	NA
2010 Total	**47**	**310.92**	**17**	**36.20%**	**24**	**466**	**1.5**		
								Mean	**5.45**

** Belugas were sighted within proposed Deployment Area*
^ Measured from center of proposed Deployment Area

Table 2. Reports of incidental sightings from Spernak Air pilots, as reported to LGL observers from May 3 to November 14, 2010.

Month	Date	Location	Number of Whales	Comments
May	21MAY2010	Susitna River	Not reported	Seen at high tide
May	30MAY2010	Little Susitna River	300+	
June	05JUN2010	Susitna River	300+	
June	16JUN2010	Theodore & Lewis Rivers	100	
June	17JUN2010	Susitna River	Not reported	
June	17JUN2010	Beluga River	Not reported	
June	17JUN2010	Lewis River	Not reported	
June	17JUN2010	Theodore River	Not reported	Seen 1/4 mile up River
June	23JUN2010	Susitna River	Not reported	Seen at southwest side of river mouth
June	23JUN2010	Susitna & Beluga Rivers	Not reported	Seen along coast between the two rivers
June	24JUN2010	Susitna River	Not reported	Seen at southwest side of river mouth
June	24JUN2010	Susitna & Beluga Rivers	Not reported	Seen along coast between the two rivers
June	24JUN2010	Ivan River	Not reported	
July	01JUL2010	Beluga River	Not reported	
July	01JUL2010	Susitna River	Not reported	
July	01JUL2010	Lewis River	Not reported	
July	01JUL2010	Theodore River	Not reported	
July	06JUL2010	Beluga River	20	
July	06JUL2010	Ivan River	15	
July	06JUL2010	Lewis River	15	
July	06JUL2010	Theodore River	15	
July	07JUL2010	Lewis River	60	
July	07JUL2010	Ivan River	15	
July	22JUL2010	Susitna River	20	
July	28JUL2010	Susitna River	136	Pilot flew over ~15 times to count
August	03AUG2010	Little Susitna River	50	
August	03AUG2010	Ivan River	"Lots"	
August	25AUG2010	Little Susitna River	"Small group"	Seen at high tide
September	01SEP2010	Susitna River	Not reported	
September	01SEP2010	Ivan River	Not reported	
September	01SEP2010	Theodore River	Not reported	
September	02SEP2010	Knik Arm	Possible sighting	Something seen moving rapidly North up Knik Arm. Not confirmed as beluga
September	02SEP2010	Theodore River	Not reported	
September	03SEP2010	Little Susitna River	25	
September	09SEP2010	Susitna River	Possible sighting	Heavy V's observed under water in SW & NE channels; no surfacing - no confirmation of sighting.

September	21SEP2010	Susitna River	15	8-10 whales seen in AM, 4-5 whales seen in PM. High tide in afternoon. Observation date not certain.
September	23SEP2010	Knik Arm (near Birchwood)	Not reported	
September	28SEP2010	Ivan River	20+	Observation date not certain
October	11OCT2010	Susitna River	20+	Seen in mouth @ 0845
October	14OCT2010	Beluga River	25+	Lots of activity and apparent play
October	14OCT2010	Little Susitna River	80	
October	14OCT2010	Ivan River	40	
October	22OCT2010	Little Susitna River	40	Seen around bend of river. Observation date not certain
October	28OCT2010	Beluga River	Not reported	Observation date not certain; may be October 29 instead
November	10NOV2010	Little Susitna River	3	

Table 3. Harbor seal sightings from the Fire Island Alaska observation site in 2010.

Month	Days of Observation Effort	Hours of Observation	Days Harbor Seals Sighted	Harbor Seal Sightings	In Deployment Area?
May	6	42.2	1	2	Yes
June	9	61.92	0	0	no
July	6	40.62	0	0	no
August	5	38.93	0	0	no
September	10	69.38	0	0	no
October	7	44.96	0	0	no
November	4	12.91	0	0	no
2010 Total	**47**	**310.92**	**1**	**2**	no

Table 4. Monthly environmental conditions from the Fire Island Alaska observation site in 2010.

Month	# Days of Observation	# Days Conditions Good	# Days Conditions Fair	# Days Conditions Poor	# Days Able to See Far Shore	Mean Wind Speed (km/hr)	Range of Wind Speed (km/hr)	Mean Beaufort Sea State	Mean Air Temperature (°C)	Range of Air Temperature (°C)	# Days with Rain	# Days with Fog	# Days with Snow
May	6	5	1	0	6	2.9	0.0 to 13.5	0.5	16.3	8.0 to 25.8	1	0	0
June	9	2	7	0	9	10.1	0.0 to 31.0	1.5	14.8	1.0 to 23.7	4	2	0
July	6	0	5	1	6	9.2	0.0 to 32.9	1.3	15.8	12.8 to 22.2	2	2	0
August	5	0	5	0	5	5.5	0.0 to 22.0	1.0	15.7	12.1 to 21.2	3	3	0
September	10	2	7	1	10	5.2	0.0 to 28.8	1.1	12.3	0.7 to 19.8	3	0	0
October	7	1.5	5.5	0	7	7.3	0.0 to 15.8	1.4	3.5	-3.8 to 7.9	3	2	0
November	4	3	1	0	4	16.0	3.1 to 37.4	1.9	1.4	-0.5 to 3.6	0	0	0
2010 Total	**47**	**13.5**	**31.5**	**2**	**47**	**7.0**	**0.0 to 37.4**	**1.2**	**12.6**	**-3.8 to 25.8**	**16**	**9**	**0**

Table 5. Monthly sightings of vessels seen from the Fire Island Alaska observation site in 2010. Vessel sightings are expressed in number of hours each vessel type was seen per month. DA refers to vessels seen in the proposed Deployment Area; non-DA refers to vessels seen outside of the proposed Deployment Area.

Month	# Days of Observation	ORPC survey boat		Tugs		Tug with barge		Skiff		Motorized Barge		Container Ship		Tanker		Other vessels		Leucas	
		DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA	DA	Non-DA
MAY	6	0	0	1	0	2	1	2	1	1	0	2	0	0	0	0	0	0	0
JUN	9	0	0	0	0	1	0	2	2	0	0	1	0	0	0	0	0	0	1
JUL	6	0	0	1	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0
AUG	5	6	0	2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
SEP	10	1	0	2	0	2	0	5	7	0	0	1	0	1	0	0	0	0	0
OCT	7	10	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	4	5	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**47**	**22**	**1**	**6**	**0**	**10**	**3**	**12**	**11**	**1**	**0**	**4**	**0**	**1**	**0**	**0**	**1**	**0**	**1**
	Combined Total	**23**		**6**		**13**		**23**		**1**		**4**		**1**		**2**		**2**	

Table 6. Monthly bird sightings seen from the Fire Island Alaska observation site in 2010. Bird sightings are reported for birds seen on the water in or near (≤ 2km/1.2mi) the Deployment Area.

Month	Days of Observation Effort	# Surf Scoters	# Pacific Loons	# Bald Eagles	# Mew Gulls	# Unidentified Gull Spp.
May	6	30	5	0	3	0
June	9	0	0	0	0	0
July	6	0	0	2	0	61
August	5	0	0	0	0	0
September	10	0	0	0	0	0
October	7	0	0	0	0	0
November	4	0	0	0	0	0
2010 Total	**47**	**30**	**5**	**2**	**3**	**61**

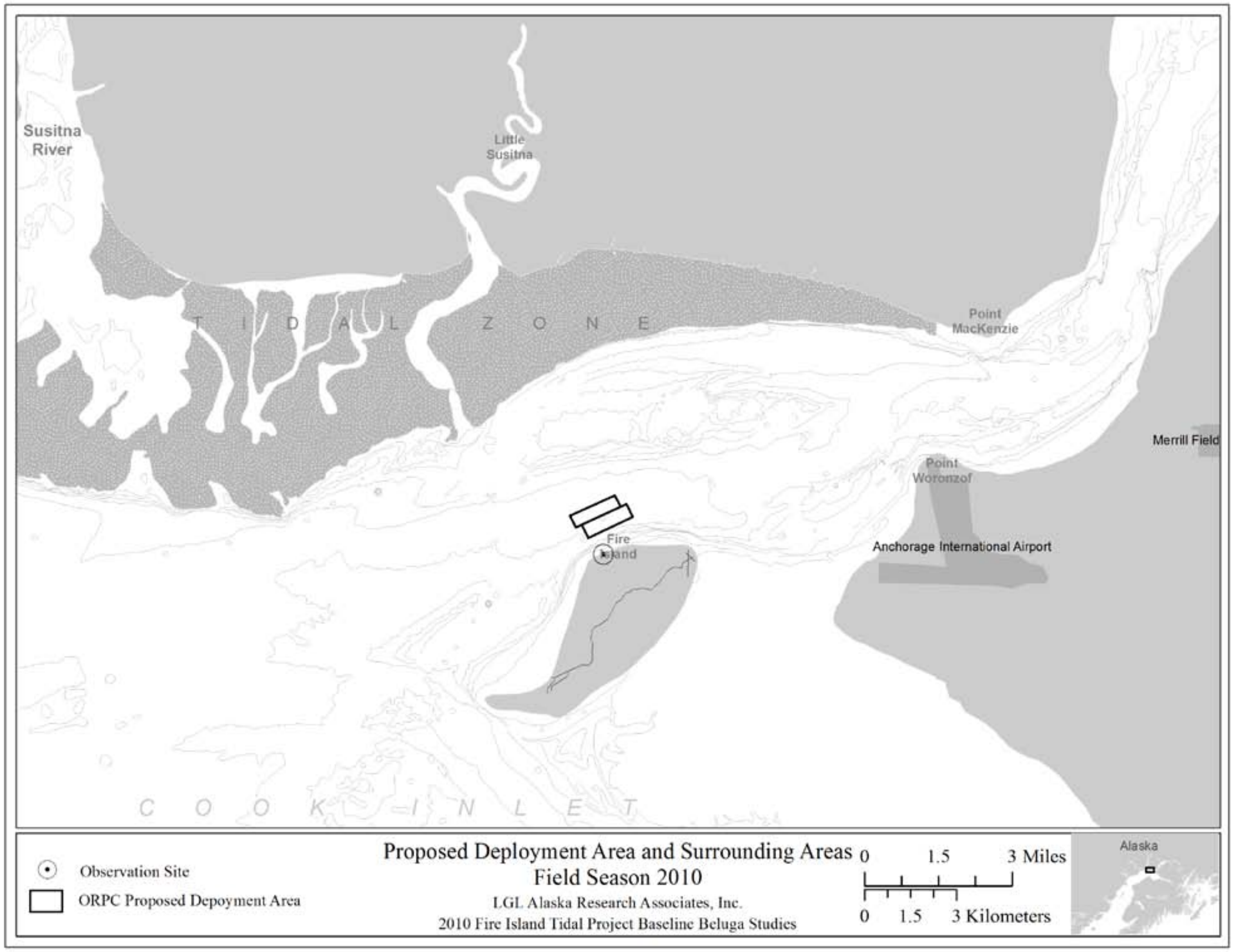

Figure 1. A map of Upper Cook Inlet showing the ORPC proposed Deployment Area, the Fire Island observation site, and major features presented in the text. Prominent areas visible from the observation site include the Susitna River to the West, the Little Susitna River to the north, and Point MacKenzie to the east.

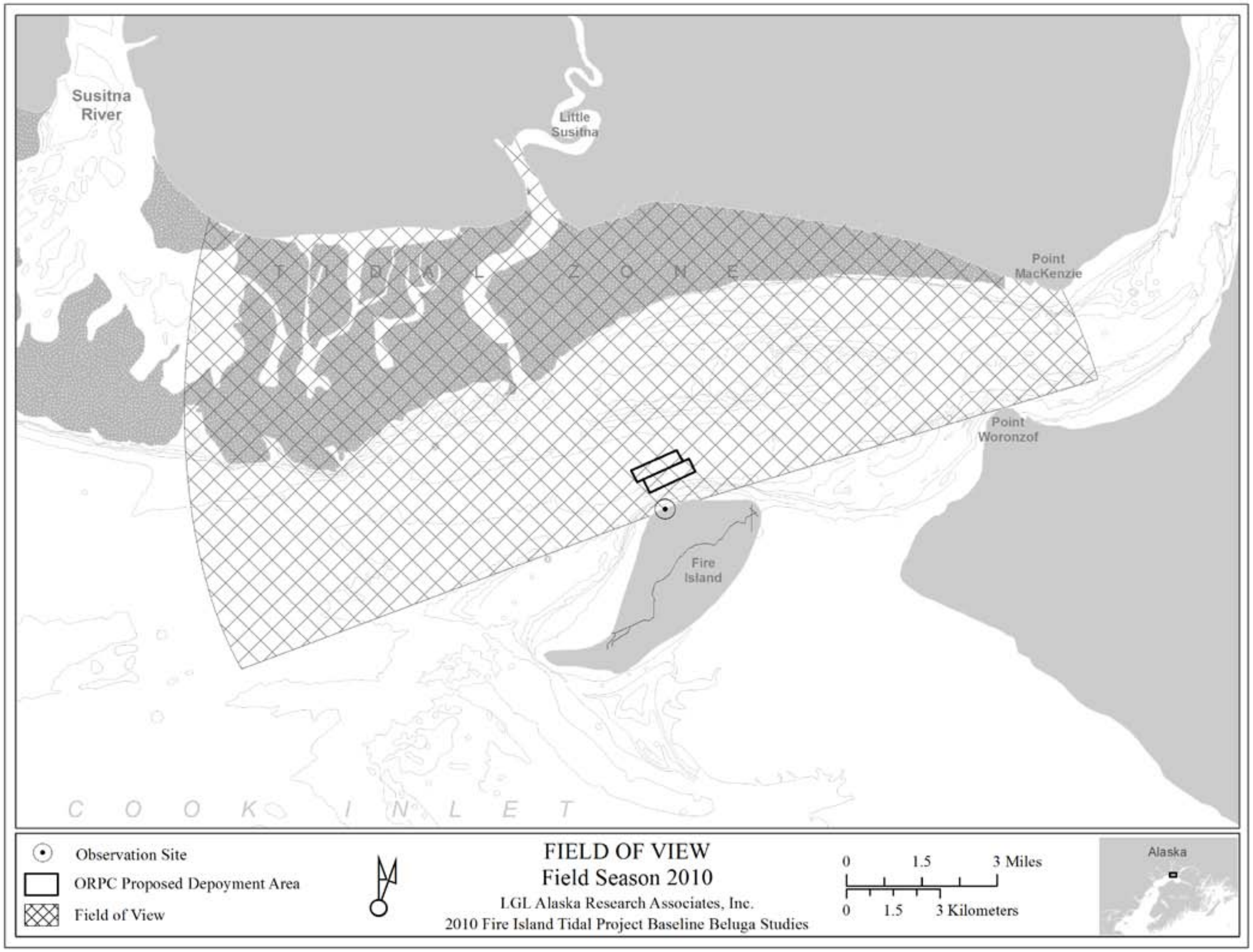

Figure 2. The maximum field of view as seen from the observation site tower and measured with the theodolite. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

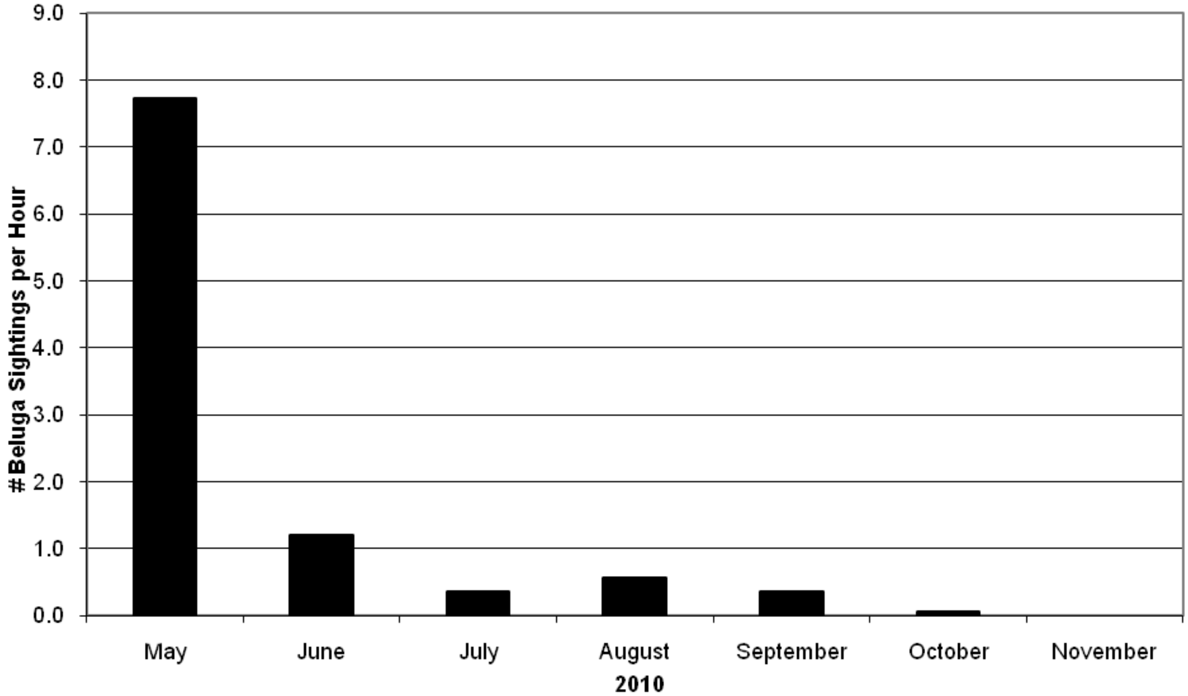

Figure 3. Number of belugas sightings per hour from the Fire Island observation site in 2010.

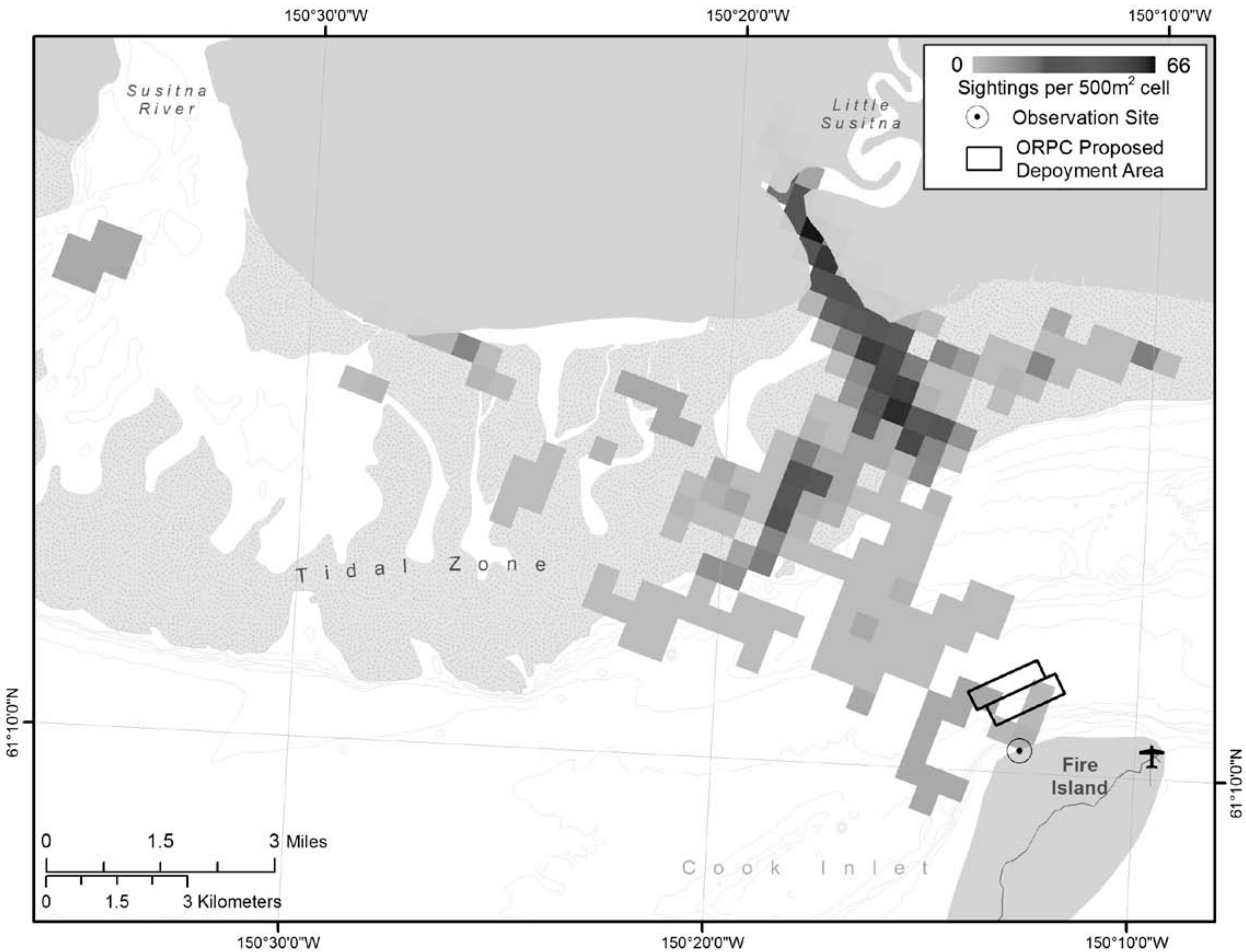

Figure 4. Density of beluga sightings between May 4 and November 13, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

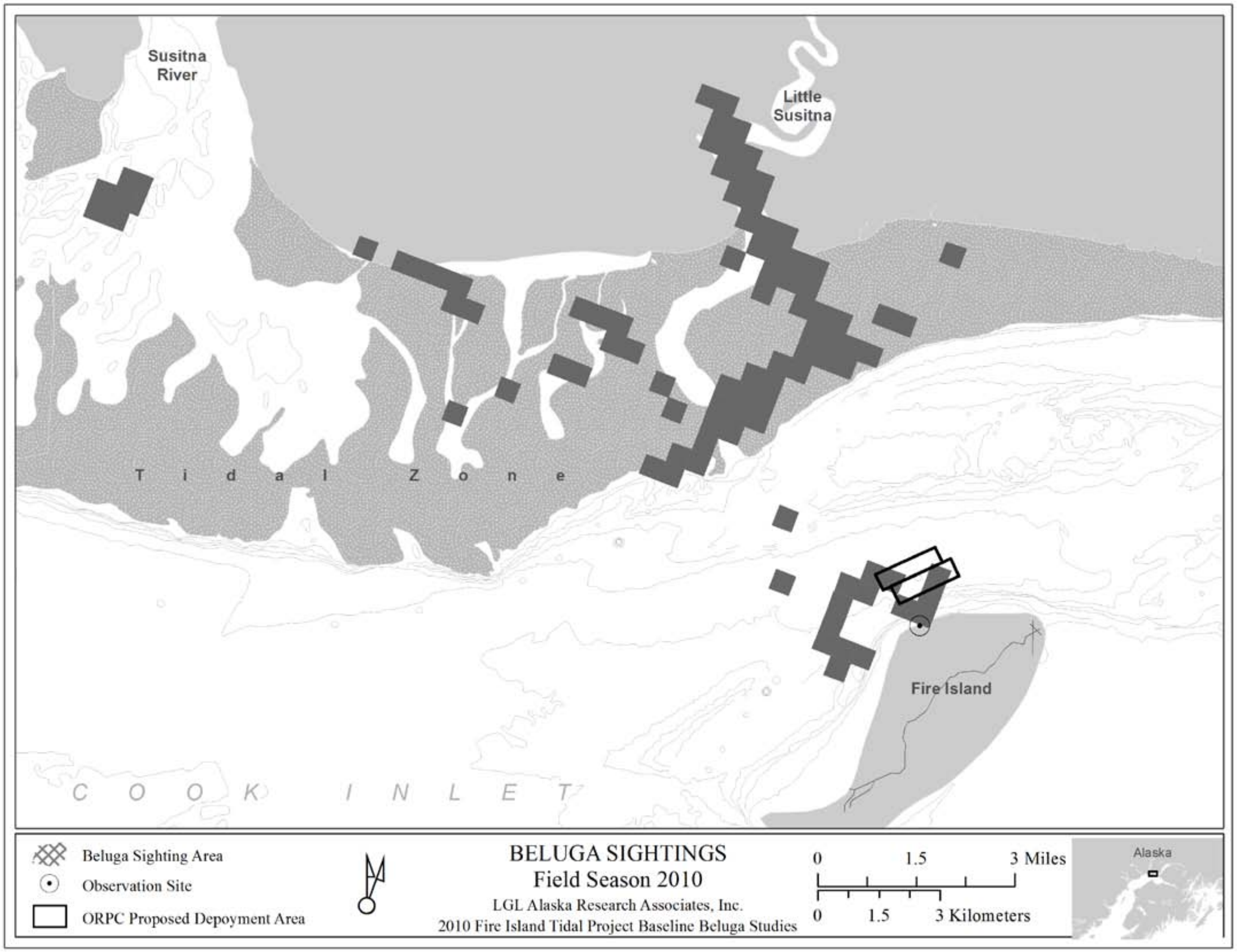

Figure 5. Locations of all beluga sightings between May 4 and November 13, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

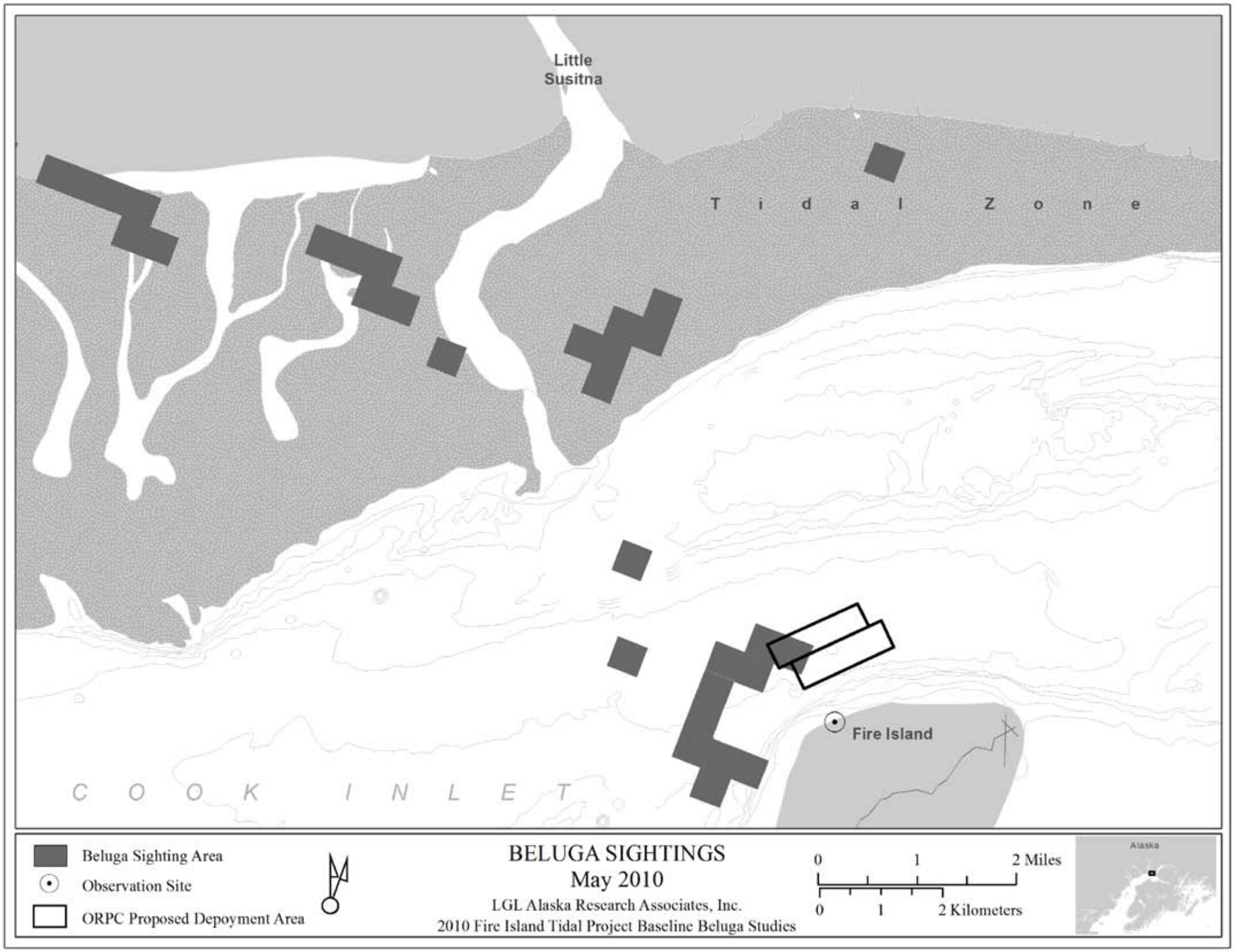

Figure 6. Locations of all beluga sightings in May 2010. Observations began on May 4. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

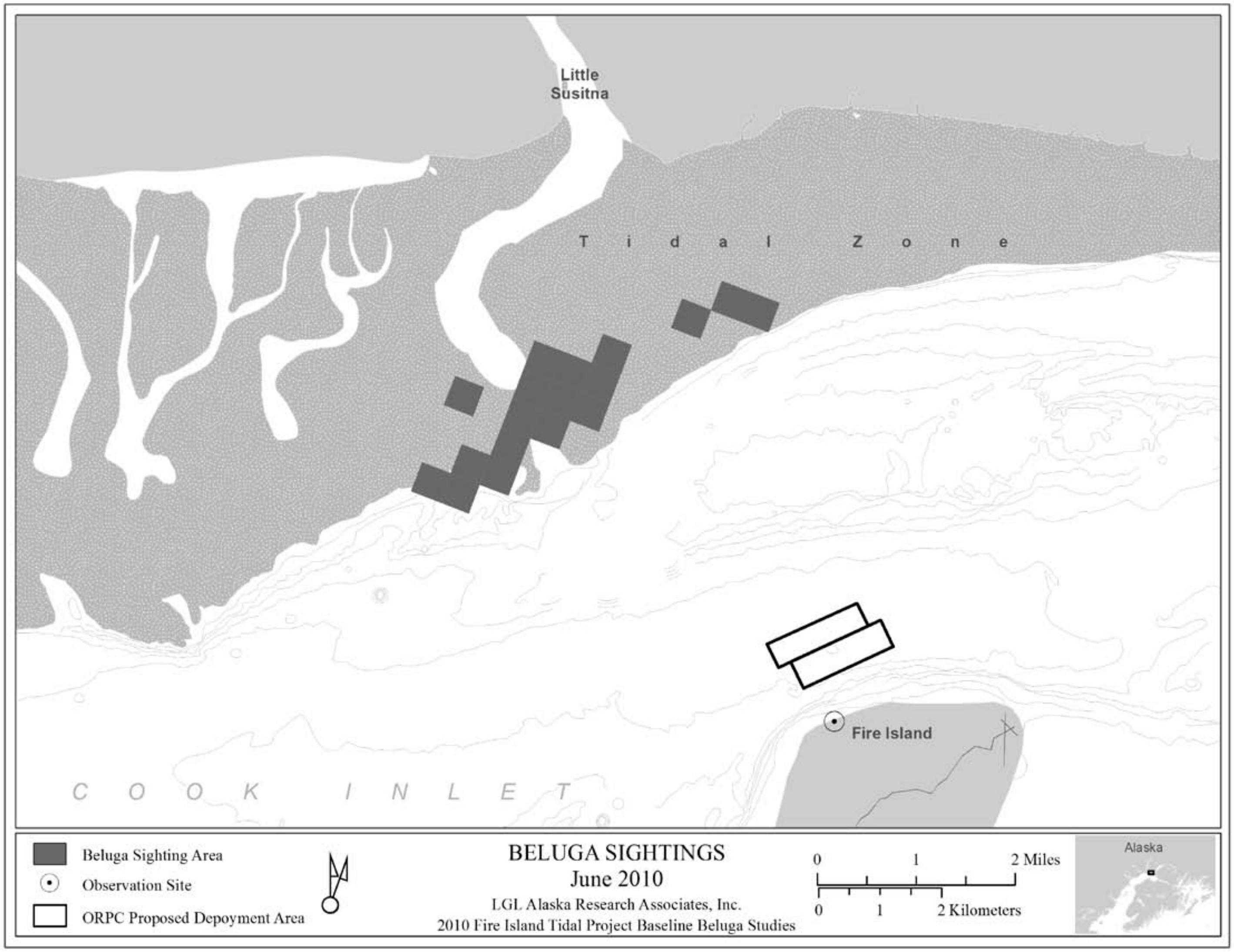

Figure 7. Locations of all beluga sightings in June 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

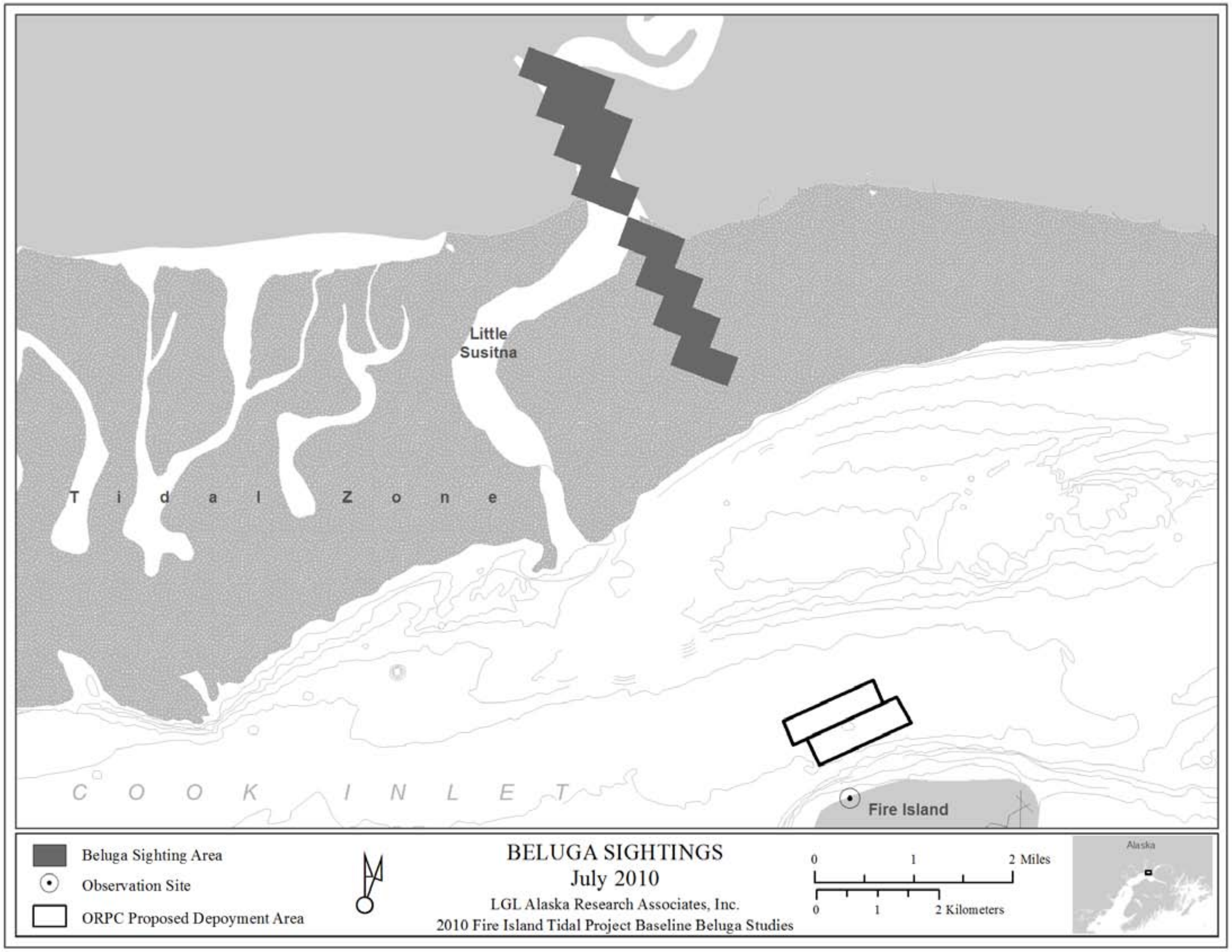

Figure 8. Locations of all beluga sightings in July 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

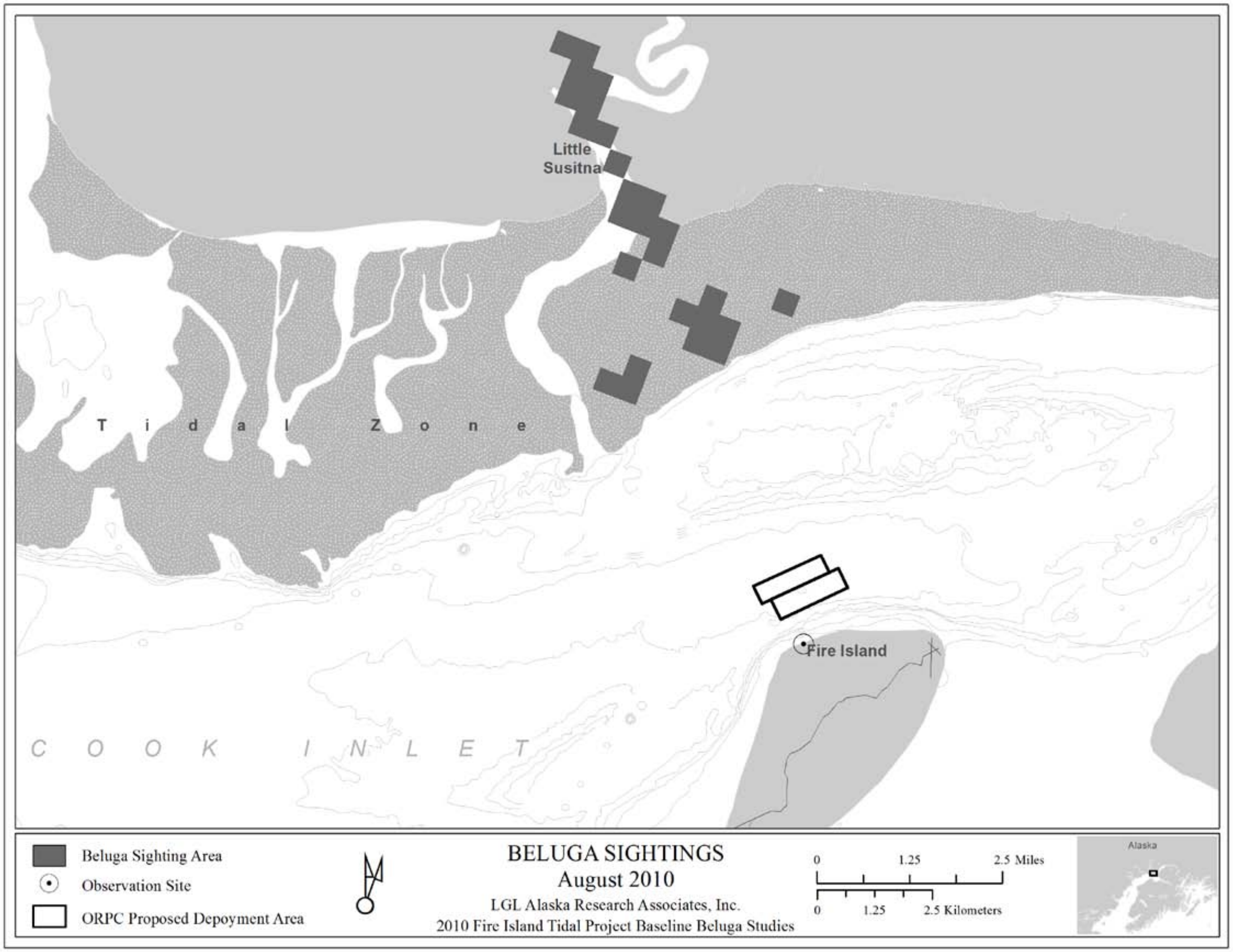

Figure 9. Locations of all beluga sightings in August 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

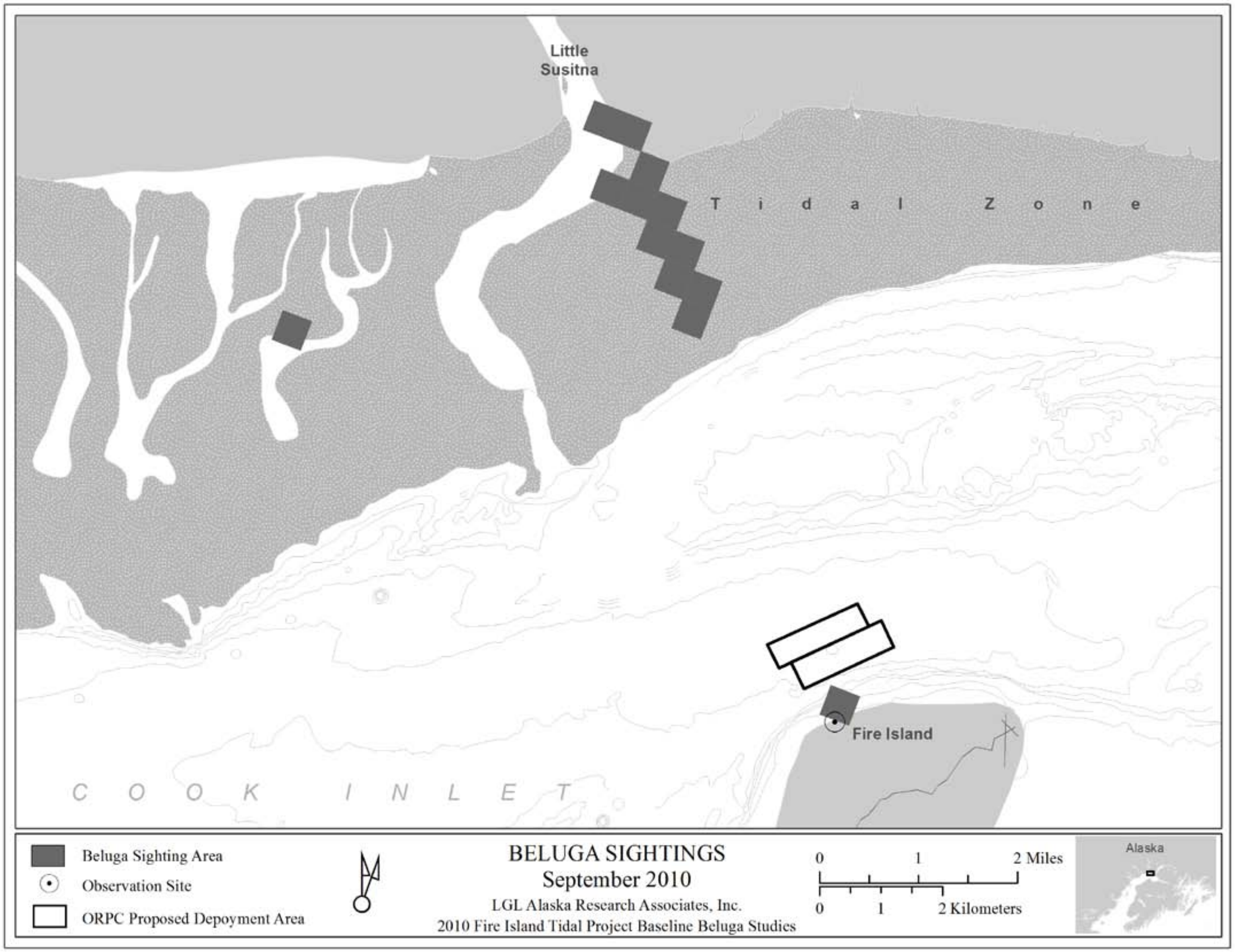

Figure 10. Locations of all beluga sightings in September 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

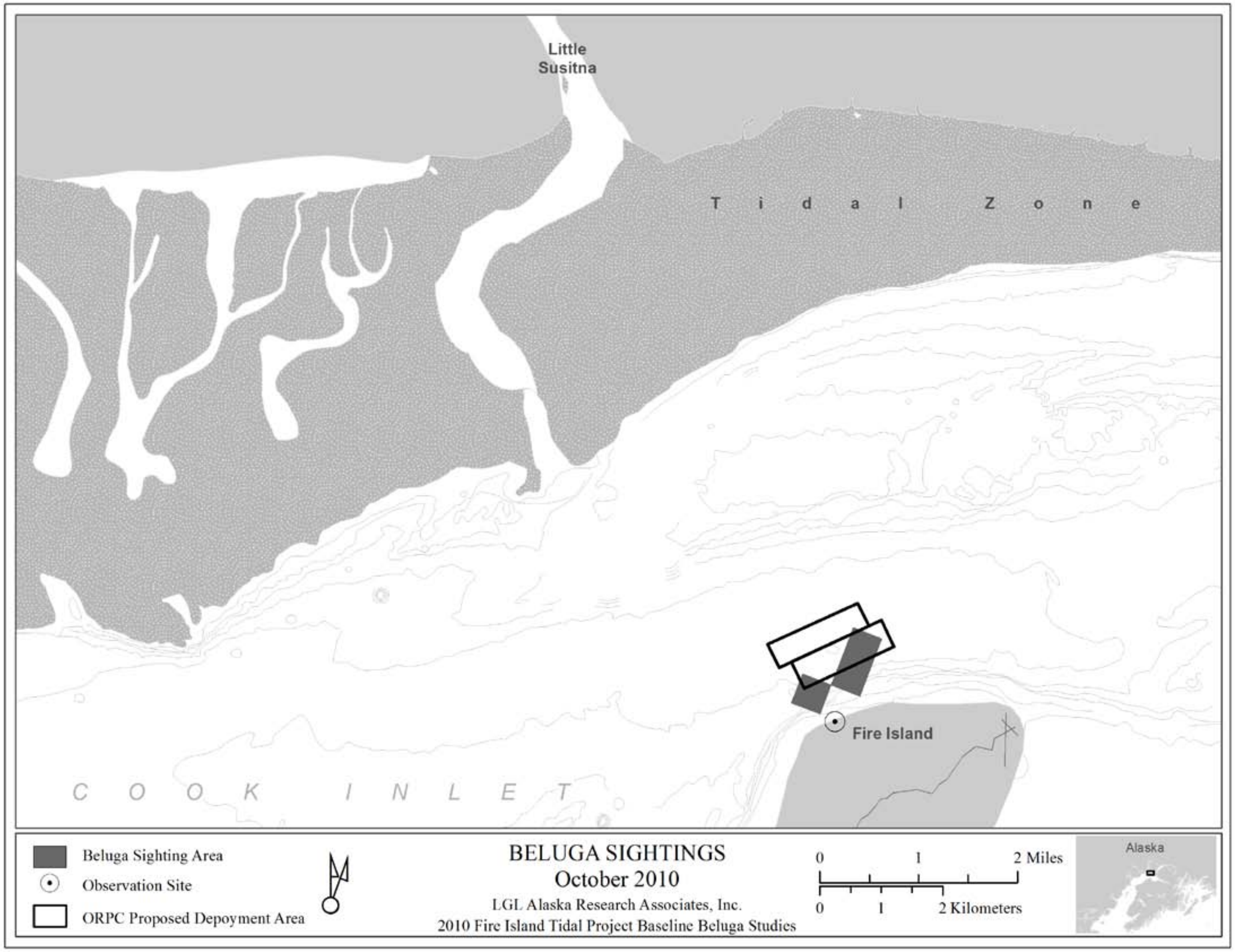

Figure 11. Locations of all beluga sightings in October 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

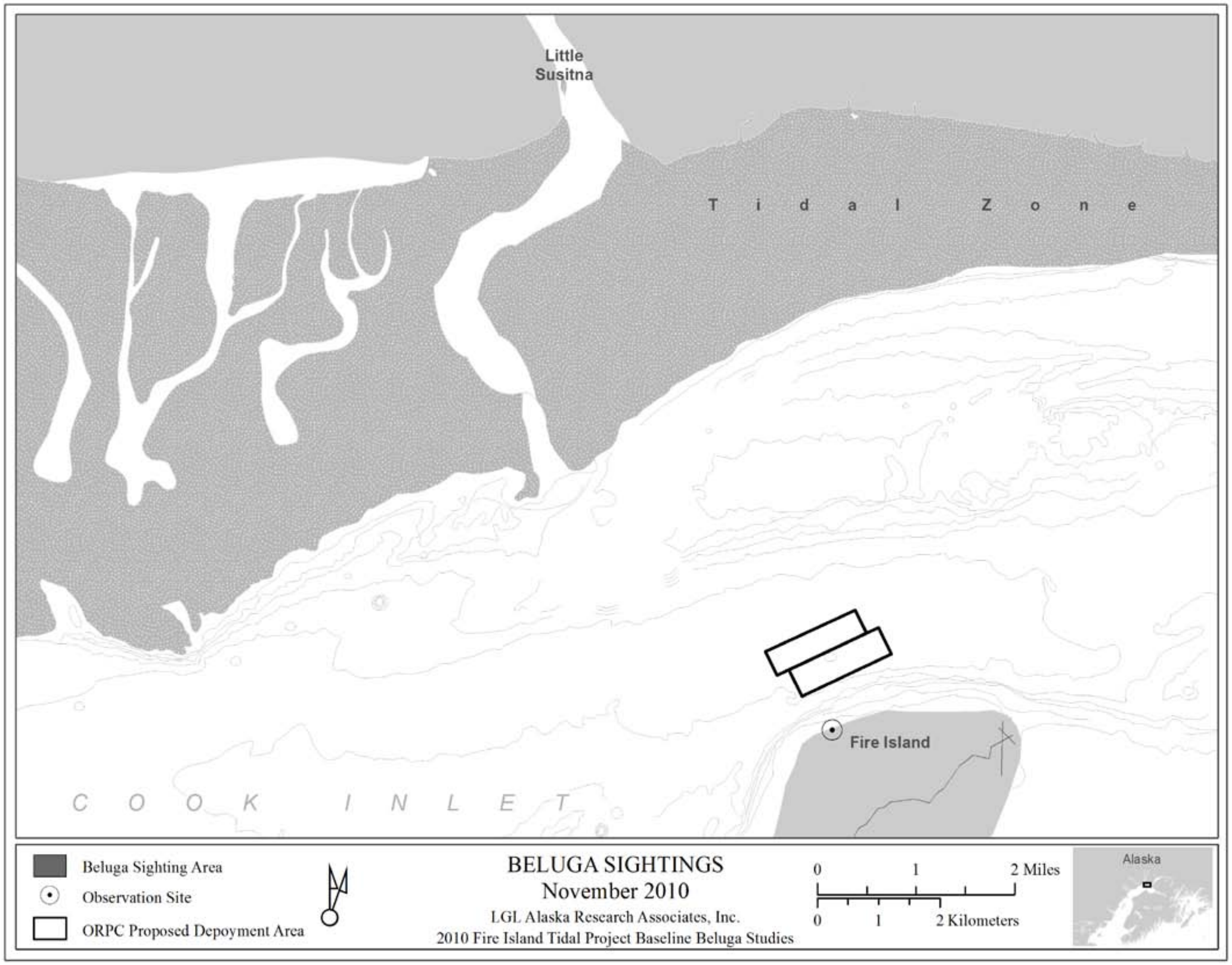

Figure 12. Locations of all beluga sightings in November 2010. Observations concluded November 13, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

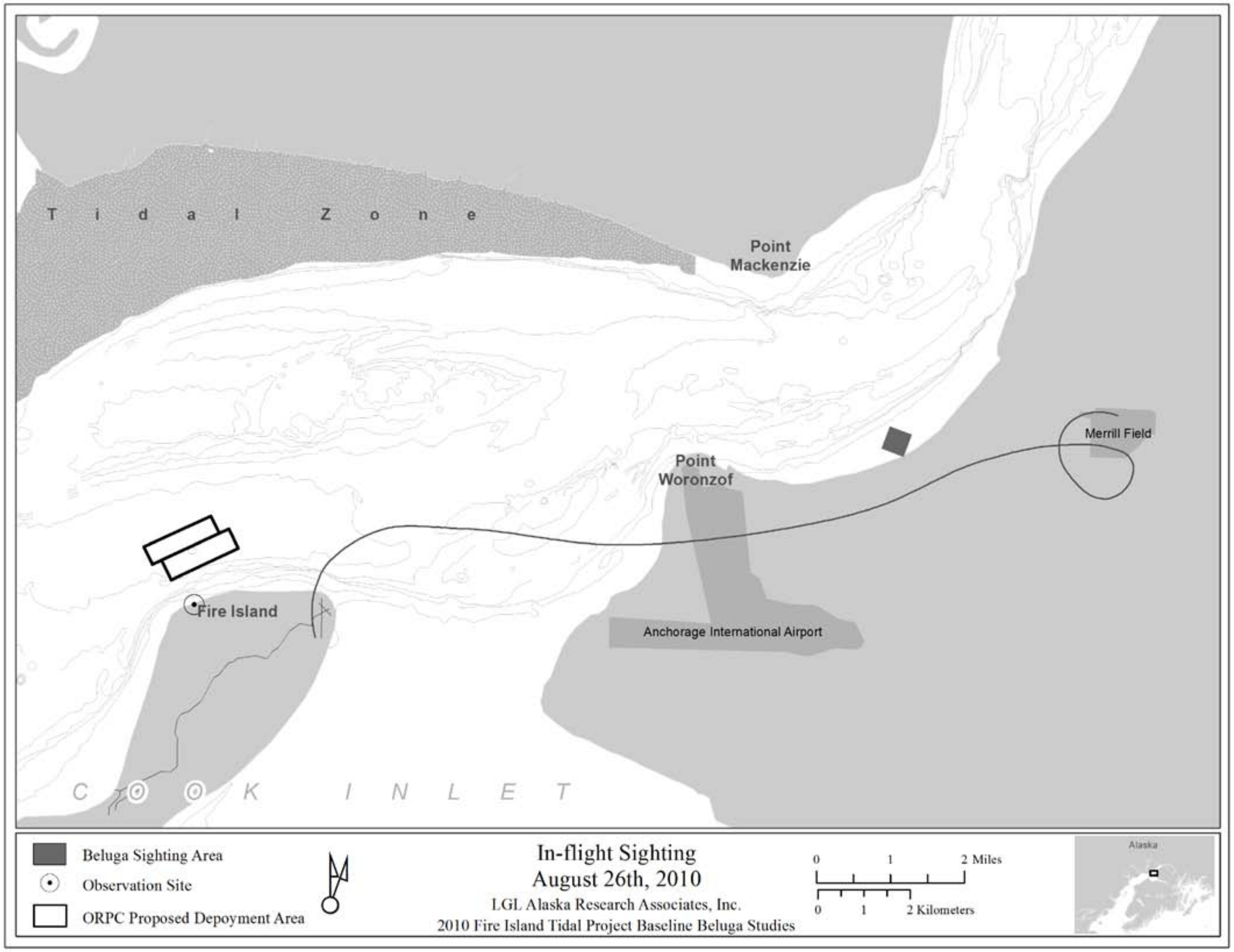

Figure 13. Location of 3 belugas sighted during a crew-transport flight on August 26, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

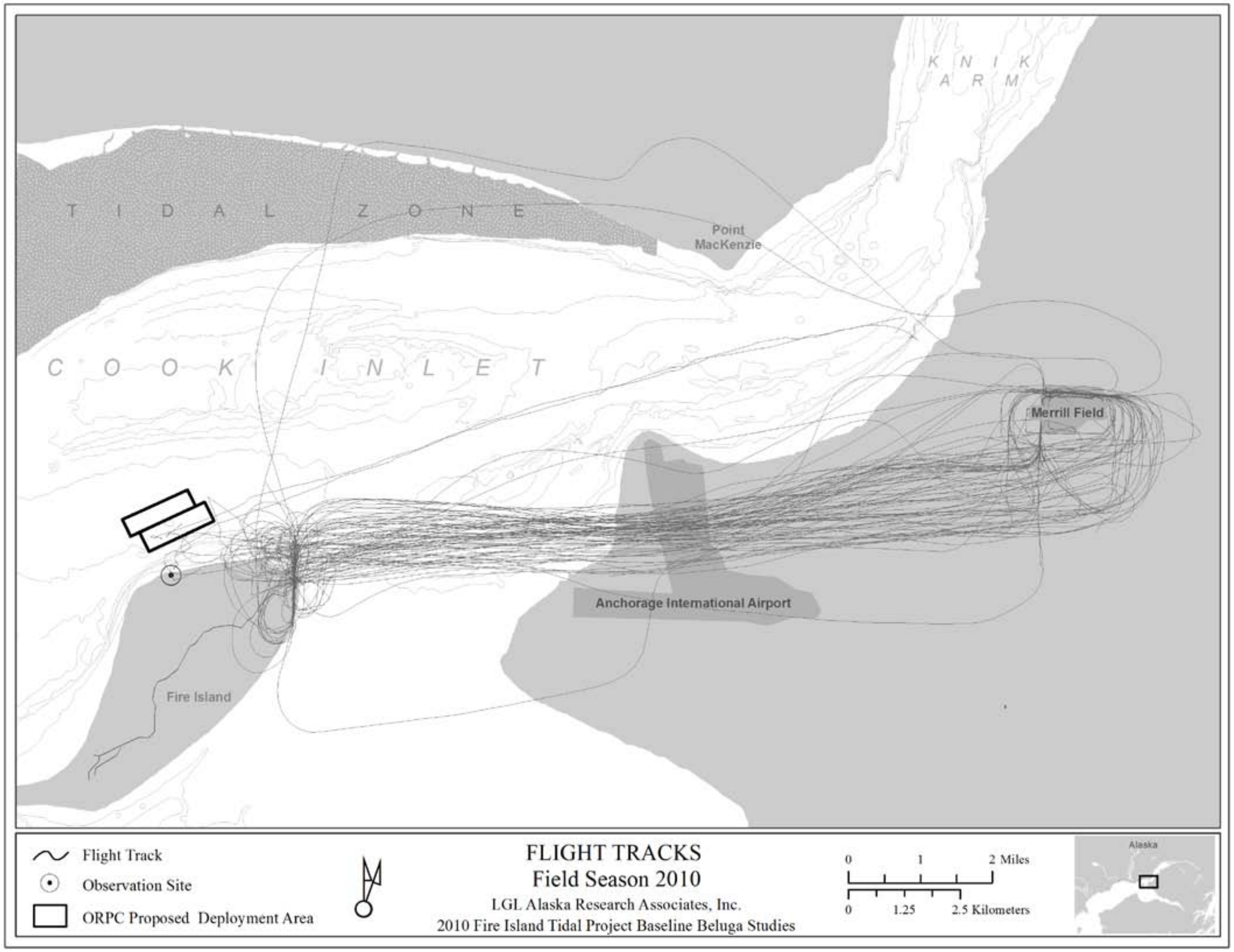

Figure 14. Tracks of crew-transport from flights and vessels, May 4, 2010 through November 13, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

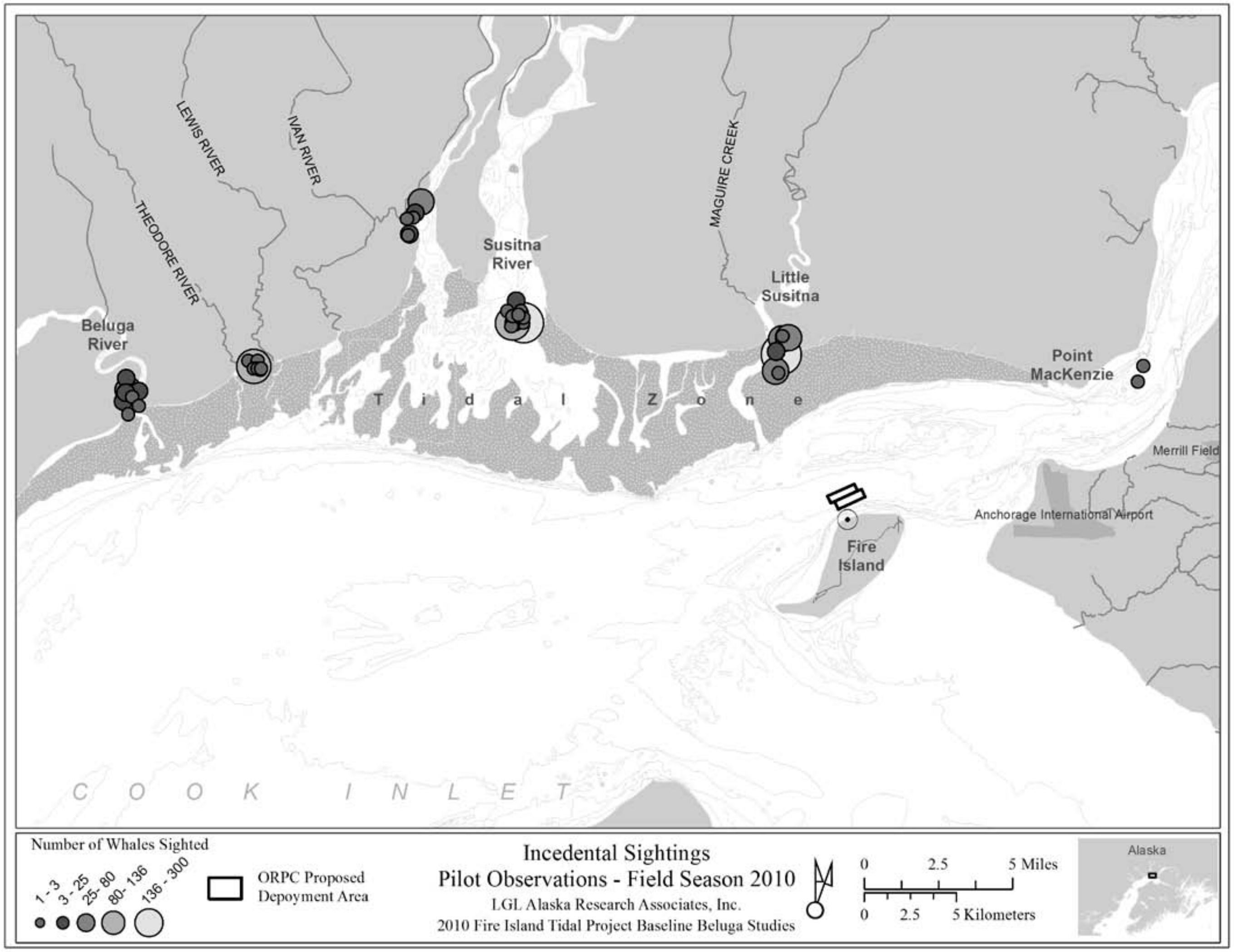

Figure 15. Location and estimated group sizes of belugas observed by Spernak Air pilots on flights other than crew transport to Fire Island, May 4 through November 13, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

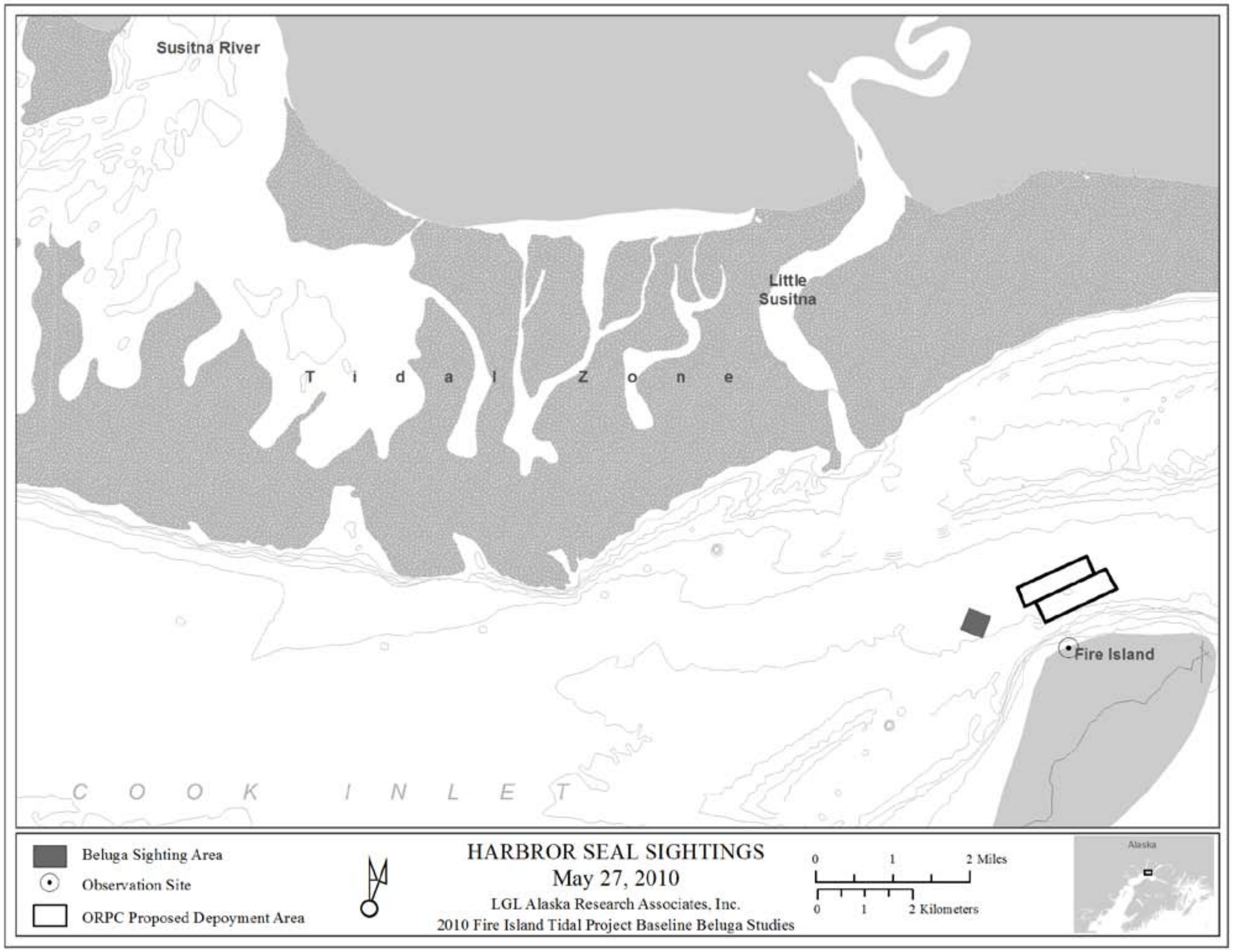

Figure 16. Locations of harbor seals sighted from May 4 to November 13, 2010. Seals were only sighted on one day (May 27). The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

APPENDIX A

ORPC ALASKA PRE-DEPLOYMENT BELUGA WHALE OBSERVATIONS STUDY PLAN – 3/23/09

1.0 DESCRIPTION OF ISSUE

ORPC Alaska, LLC (hereinafter, ORPC), a subsidiary of Ocean Renewable Power Co., is applying to the Federal Energy Regulatory Commission (FERC) for a pilot license for the Cook Inlet Tidal Energy Pilot Project, FERC Project No. 12679 (hereinafter, Pilot Project or Project). The Project will evaluate the potential for a new source of clean, renewable energy generation using tidal energy resources in Upper Cook Inlet (UCI). The purpose of the Pilot Project is to collect the engineering and environmental effects information to support the project description and environmental analysis of a larger commercial project. ORPC has developed a proprietary modular ocean current generation device, the OCGen™ Module (module). The core component of the OCGen™ technology is ORPC's proprietary turbine-generator unit (TGU), which utilizes advanced design cross-flow turbines to drive a permanent magnet generator located between the turbines and mounted on the same shaft. Multiple TGUs are combined to form one module. Each module proposed for deployment in Cook Inlet will be comprised of 4 TGUs.

The Project will consist of a phased deployment and operation of 5 modules over an expected 8 year license term. Each module has an estimated peak capacity of 1 megawatt (MW) in a 6 knot current. For the site-specific conditions in UCI, a single module will consist of two half-modules, each with 2 TGUs. The overall dimension of each half-module is approximately 91 feet (ft) (28 meter [m]) in length by 28 ft (8.5 m) high and 14 ft (4.2 m) wide. The modules will be placed approximately 42 ft (12.8 m) below the surface at Mean Lower Low Water (MLLW). ORPC plans to deploy the modules in a phased approach. During the first phase, 1 module will be deployed during May/July of 2011, pending all regulatory approvals. During the second phase, ORPC anticipates installing an additional four modules in July/August, 2012, within the designated Pilot Project Deployment Area (Deployment Area) (Figure A1).

Information on beluga whale presence, habitat use and behavior in the proposed project area is critical for evaluating potential project effects and for meeting regulatory requirements under the ESA, the Marine Mammal Protection Act (MMPA), and under FERC regulations for hydropower licensing. There have been numerous surveys of beluga whales in the upper parts of Cook Inlet as part of the environmental studies conducted for the Port of Anchorage, Knik Arm Bridge, and Seward Highway Projects (Markowitz and McGuire 2007, Ramos et al. 2006, Funk et al. 2005). However, there is limited information for the Deployment Area near Fire Island.

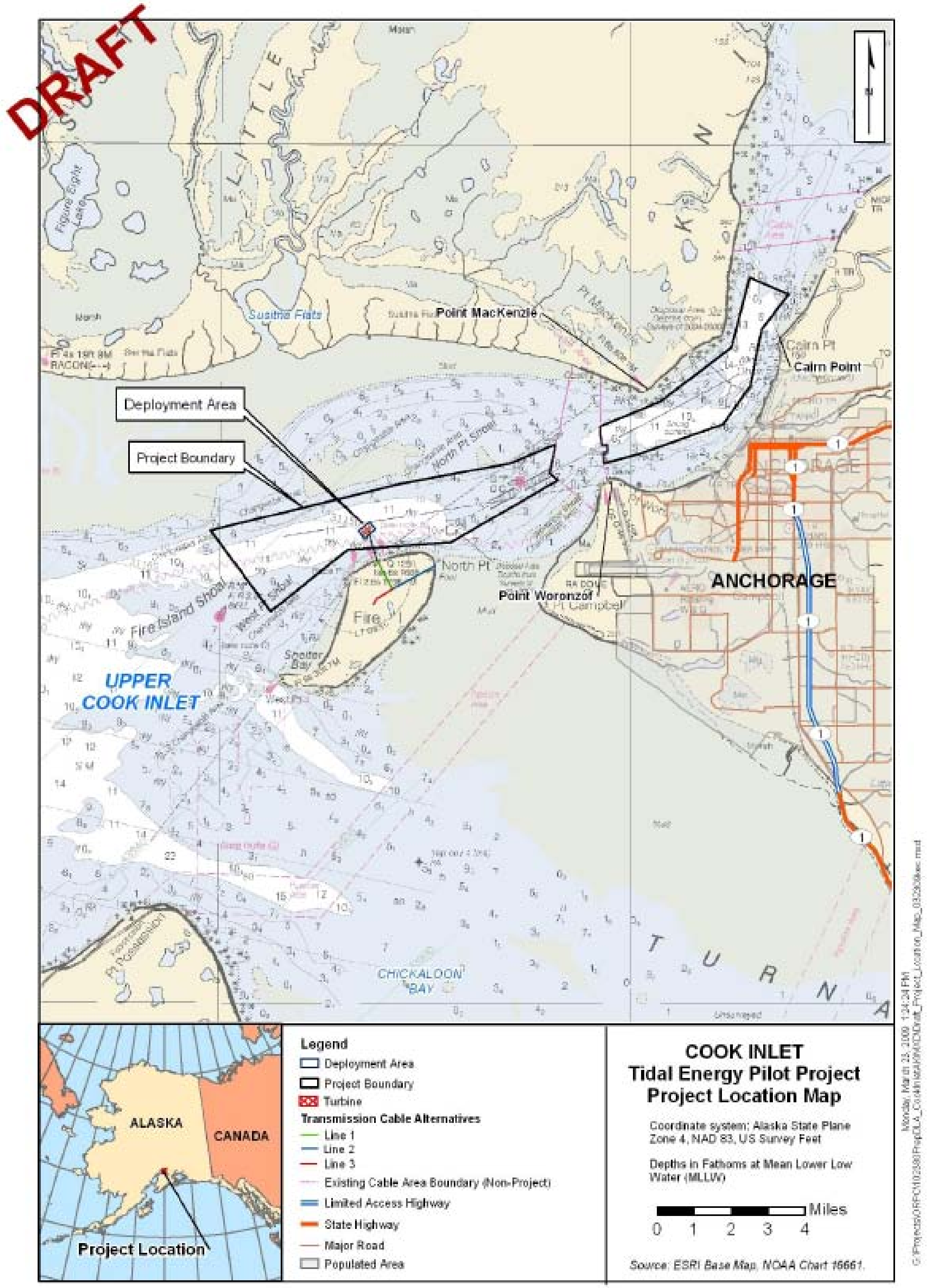

Figure A1. Project Location Map.

2.0 RELEVANT EXISTING INFORMATION

The Cook Inlet beluga whale (*Delphinapterus leucas*) Distinct Population Segment (DPS) has recently been listed as endangered by National Oceanic and Atmospheric Administration (NOAA) under the Endangered Species Act (ESA). Surveys on beluga whales in Cook Inlet documented a decline in abundance of nearly 50 percent between 1994 and 1998, from an estimate of 653 whales to 347 whales (National Marine Fisheries Service [NMFS] 2008). This decline was mostly attributed to the subsistence harvest (through 1998); however, even with the restrictions on this harvest, the population has continued to decline by 1.45 percent per year from 1998 to 2008. Annual surveys have continued since 1994, and indicate this population is not recovering (NMFS 2008).

Critical habitat has not been designated but NOAA Fisheries has designated Knik Arm as a Type 1 habitat of high value/high sensitivity for beluga whales (NMFS 2008). These areas are full of shallow tidal flats, river mouths, or estuarine areas, and are important for foraging and calving habitats. Use of this habitat varies during the year with the potential of belugas occurring within the vicinity of the Deployment Area in most months. Depending on the season, belugas can occur in both offshore and coastal waters. During the spring and summer, Cook Inlet belugas are generally concentrated near the warm, shallow waters of river mouths where prey availability is high due to seasonal fish runs. Most of the calving in Cook Inlet occurs from mid-May to mid-July in the vicinity of these warm-water river mouths (Nemeth et al. 2007). In general, belugas are more dispersed throughout the Upper and Middle Inlet during winter months rather than concentrated at river mouths. The Little Susitna River mouth and Susitna Flats, documented beluga use areas, are approximately four miles and further from the deployment area.

Beluga whales using Knik Arm and UCI are exposed to variable conditions due to the large tidal fluctuations that occur in the arm and in UCI in general. Funk et al. (2005), conducted shore-based observations of beluga whales in Knik Arm to characterize whale movement patterns and to determine important habitat locations in relation to tidal patterns. The study found that changes in water depth associated with the tidal cycle greatly influenced the habitat available, the patterns of whale movement, and the habitat used by belugas in Knik Arm (Funk et al. 2005). As the tide flooded, beluga whales typically moved into the upper reaches of Knik Arm. Whales moved south towards the Sixmile Creek/Eagle Bay area and out of the upper reaches of Knik Arm as the ebb tide began. Movements of beluga whales in Knik Arm with tides are highly predictable. Riding the tides is likely to be energetically efficient, and may decrease the chances of stranding. Prior to this there had been no published reports describing these movements or clear correlations between tidal changes and beluga distributions and habitat use in Cook Inlet (Moore et al. 2000). The influence of tides on the movement of beluga whales that reside in or use coastal estuaries in Russian waters was summarized by Kleinenberg et al. (1964). Inshore migrations by belugas occurred primarily during flood tides in areas with marked tidal fluctuations. Beluga whales were reported to migrate along the shore during high spring tides with movements into rivers driven by prey availability (Kleinenberg et al. 1964 as cited in Funk et al. 2005).

Beluga whales have been observed to feed most efficiently in summer months, possibly building up energy reserves for the winter. Belugas are reported by Native hunters to have only 2-3 inches (in) (5-7.5 centimeter [cm]) of blubber in April and May but up to 12 in (30.5 cm) in the fall (Huntington 2000). Beluga whales feed throughout the water column and on the sea floor although they appear to focus their foraging efforts at streams and rivers where fish are highly concentrated. In general, belugas usually dive for about 3-15 minutes while hunting for food. Other beluga populations inhabiting shallow coastal areas are known to make shallow dives while foraging for food (Martin et al. 2000). They can travel for about 1.5 miles during a dive and commonly dive to a depth of 66 feet (20 m) to hunt. They can dive to greater depths ranging 1,000 to 2,000 feet (305 to 610 m) at times, however greater dive depths are associated with populations that inhabit deep water and not those in relatively shallow coastal habitat (Martin et al. 2000). In the winter, Cook Inlet belugas concentrating in deeper waters in the mid Inlet (further south of the deployment area) make deep feeding dives (NMFS 2008).

3.0 NEED FOR ADDITIONAL INFORMATION

Information on the numbers, behavior, and habitat use of belugas has been collected for recent projects in UCI, north of Fire Island. A limited amount of information is available for the western reach of the proposed project area, the Deployment Area off of Fire Island. Agency staff has indicated that Cook Inlet beluga whales are known to use the habitat in the proposed Project Area (Figure A1) on a regular basis, and the vicinity of Cairn Point is an important migratory route for whales as they move into and out of Knik Arm. More localized information is needed in order to evaluate existing use of the proposed Deployment Area by belugas and assess potential risks to whales during deployment of tidal energy modules.

4.0 PRE-DEPLOYMENT STUDY PLAN

4.1 Study Plan Goals and Objectives

The primary objective of the proposed study is to assess the distribution and movement of beluga whales in the Deployment Area off the north side of Fire Island.

4.2 Study Area

The proposed study area for beluga observations is the area to the north of Fire Island, with focus on the Deployment Area (Figure A2).

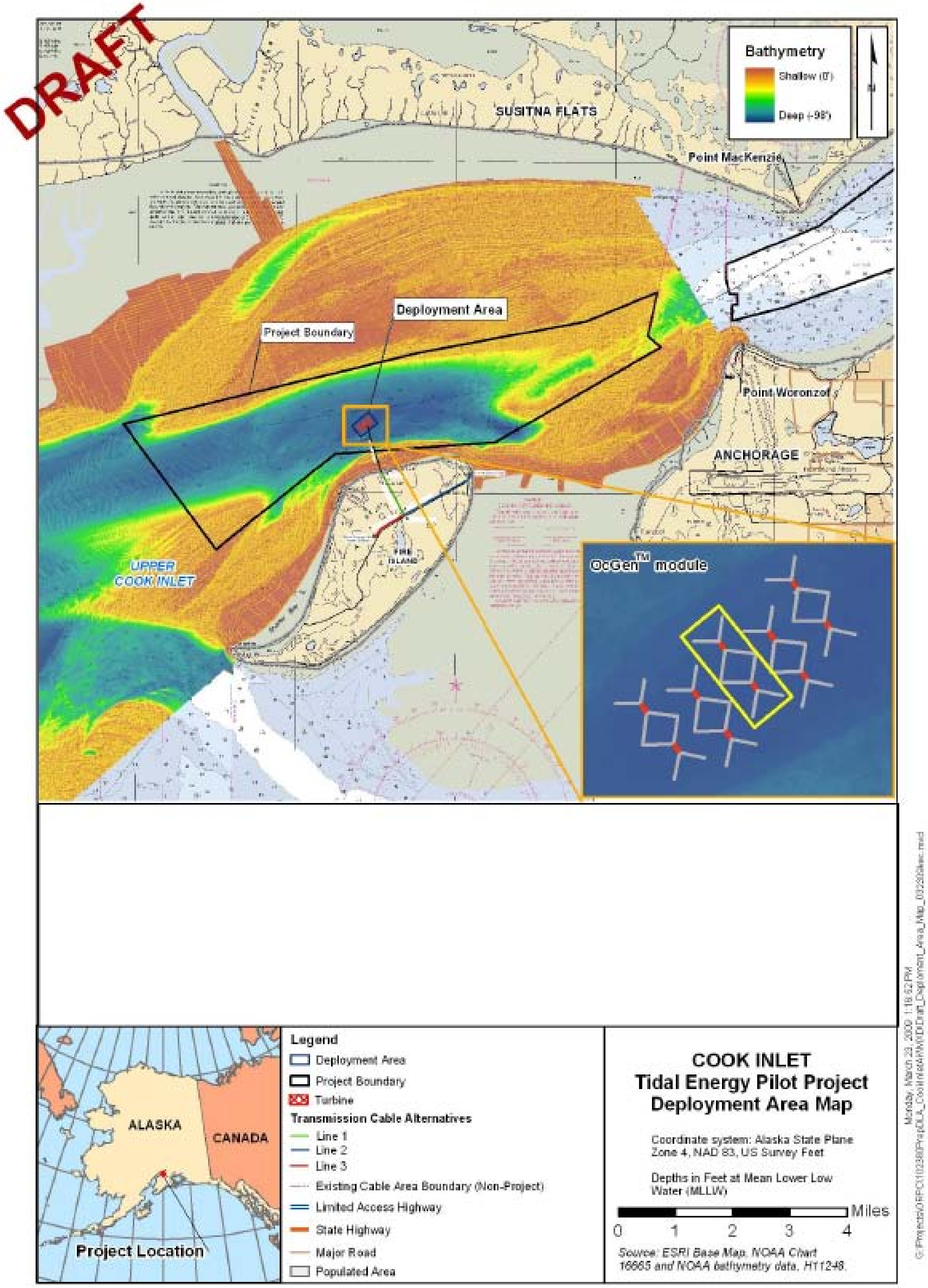

Figure A2. Deployment Area Map.

4.3 Methods

The proposed baseline monitoring study is adapted from similar shore-based visual observation studies as referenced above. The pre-deployment monitoring will take place over the course of the 2009 field season (May-November) and is expected to begin mid-late May. Given the large observation area and safety concerns on the remoteness of the area, two observers will be stationed on Fire Island.

Data collected at the monitoring stations will include: start and end time, environmental conditions (including Beaufort sea state), and beluga whale sighting information, including whale location, direction of travel, speed, group number, number and age class of whales if possible, and additional behavioral observations. Incidental observations of other marine mammals in the project area will be noted. Monitoring session frequency will coincide with habitat use patterns and will typically range from 2 to 6 days/week throughout the season (average of 4 days/week from May through November). The observer will conduct visual monitoring sessions utilizing binoculars, spotting scope, theodolite with laptop computer, and digital camera with zoom lens. Daily observations will average 6 hours with adjustments for seasonal occurrence and abundance. Photo documentation of beluga whale and other marine mammal sightings will be taken to confirm sightings. The precise location of the observation site and details of the study methodology will be refined in consultation with appropriate regulatory and resource agencies prior to initiating the survey.

4.4 Data Analysis and Reporting

Results of the beluga observations will be summarized in a draft report in December 2009. The results of the beluga observations will be incorporated into the final license application to be filed March 2010. Map figures will be created to document observation locations and photo-documentation of sightings will be provided in an appendix.

Further, the results will provide guidance to ORPC in evaluating the need for additional sites or an increased effort in development of a post-deployment beluga monitoring plan.

4.5 Schedule

The pre-deployment baseline beluga observations are expected to start mid to late May and continue through the ice-free season, possibly November, 2009. The precise location of observation sites and details of the study methodology will be refined in consultation with appropriate regulatory and resource agencies prior to initiating the survey. Results of the beluga observations will be summarized in a draft report in December 2009.

5.0 References

Funk, D.W., T.M. Markowitz, and R. Rodrigues (eds.). 2005. Baseline studies of beluga whale habitat use in Knik Arm, Upper Cook Inlet, Alaska, July 2004-July 2005. Rep. from LGL Alaska Research Associates, Inc., Anchorage, AK, in association with HDR Alaska, Inc., Anchorage, AK, for Knik Arm Bridge and Toll Authority, Anchorage, AK, Department of Transportation and Public Facilities, Anchorage, AK, and Federal Highway Administration, Juneau, AK.

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National Marine Fisheries Service. 2008. Conservation Plan for the Cook Inlet beluga whale (*Delphinapterus leucas*). National Marine Fisheries Service, Juneau, Alaska.

Nemeth, M.J., C.C. Kaplan, A.M. Prevel-Ramos, G.D. Wade, D.M. Savarese, and C.D. Lyons. 2007. Baseline studies of marine fish and mammals in Upper Cook Inlet, April through October 2006. Final report prepared by LGL Alaska Research Associates, Inc., Anchorage, Alaska for DRven Corporation, Anchorage, Alaska.

APPENDIX B

MAPS OF DAILY BELUGA WHALE SIGHTINGS

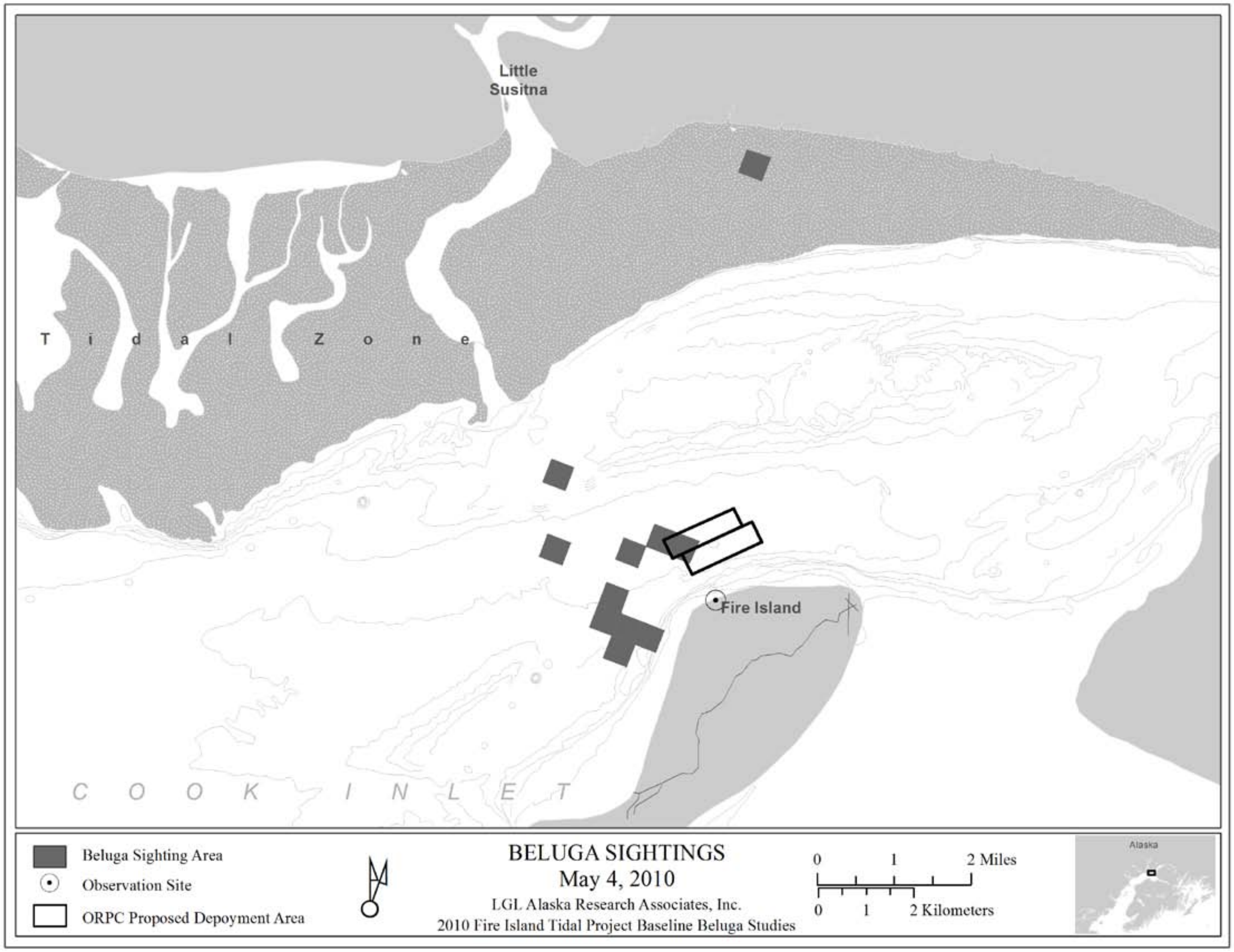

Figure B1. Locations of beluga whales sighted on May 4, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

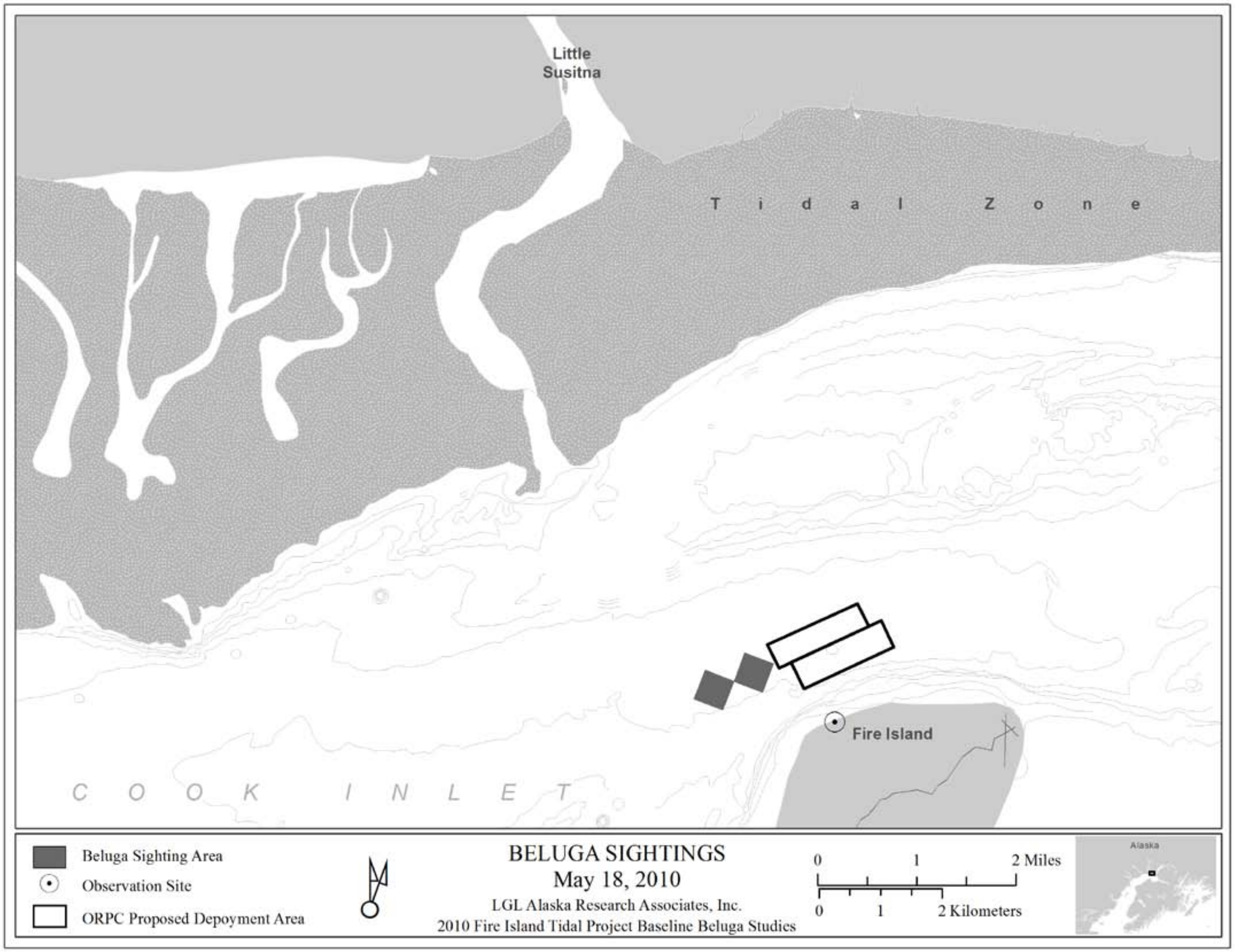

Figure B2. Locations of beluga whales sighted on May 18, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

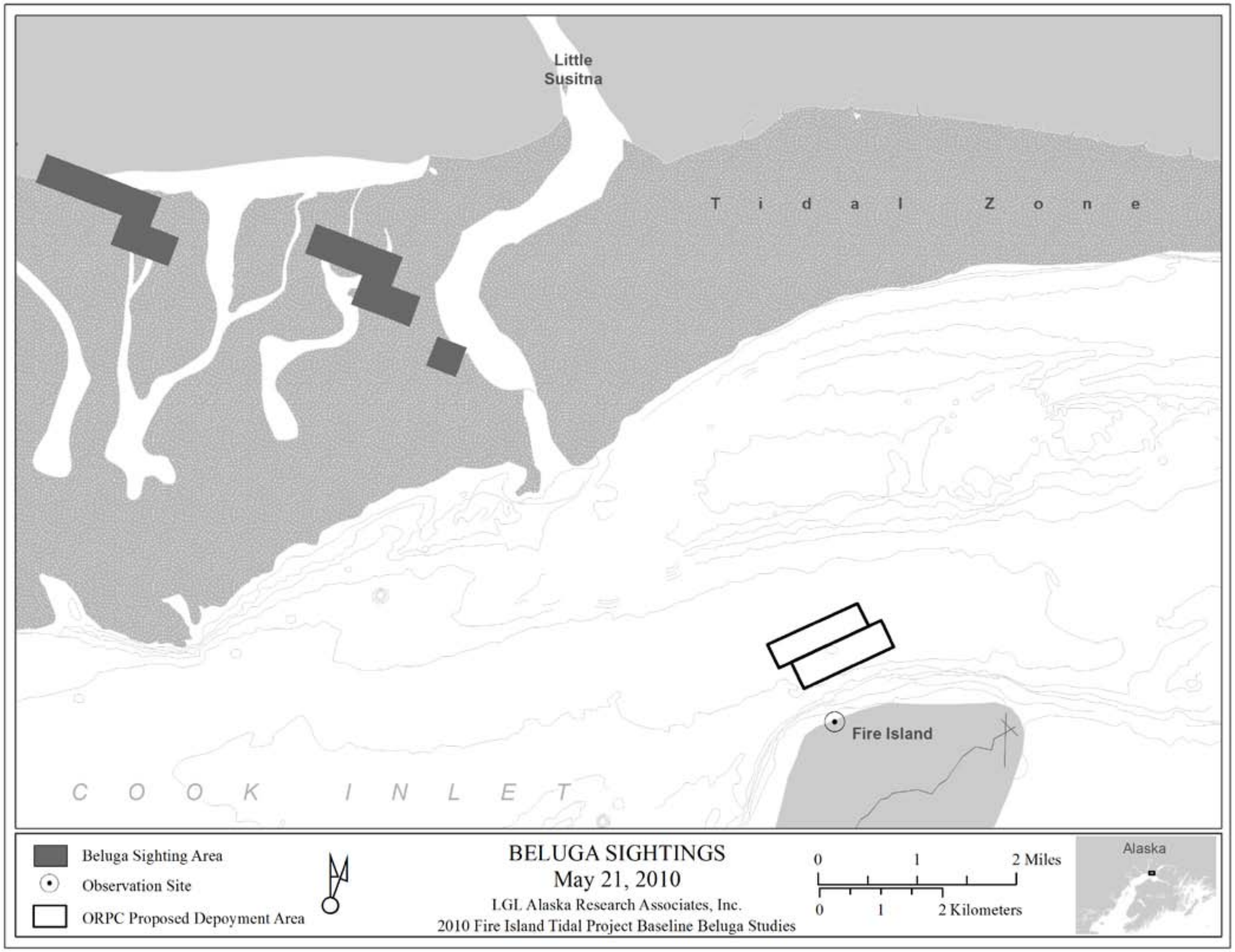

Figure B3. Locations of beluga whales sighted on May 21, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

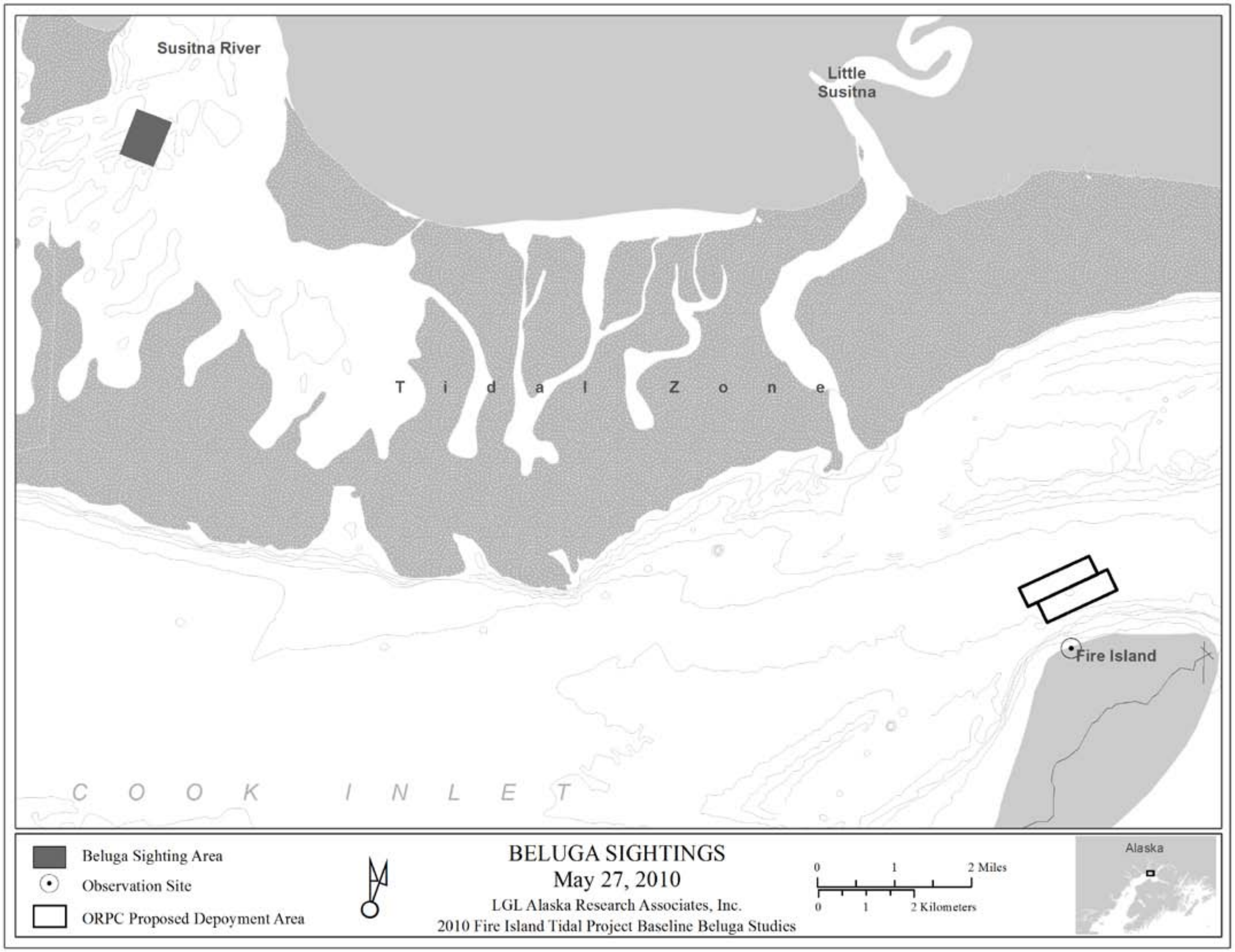

Figure B4. Locations of beluga whales sighted on May 27, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

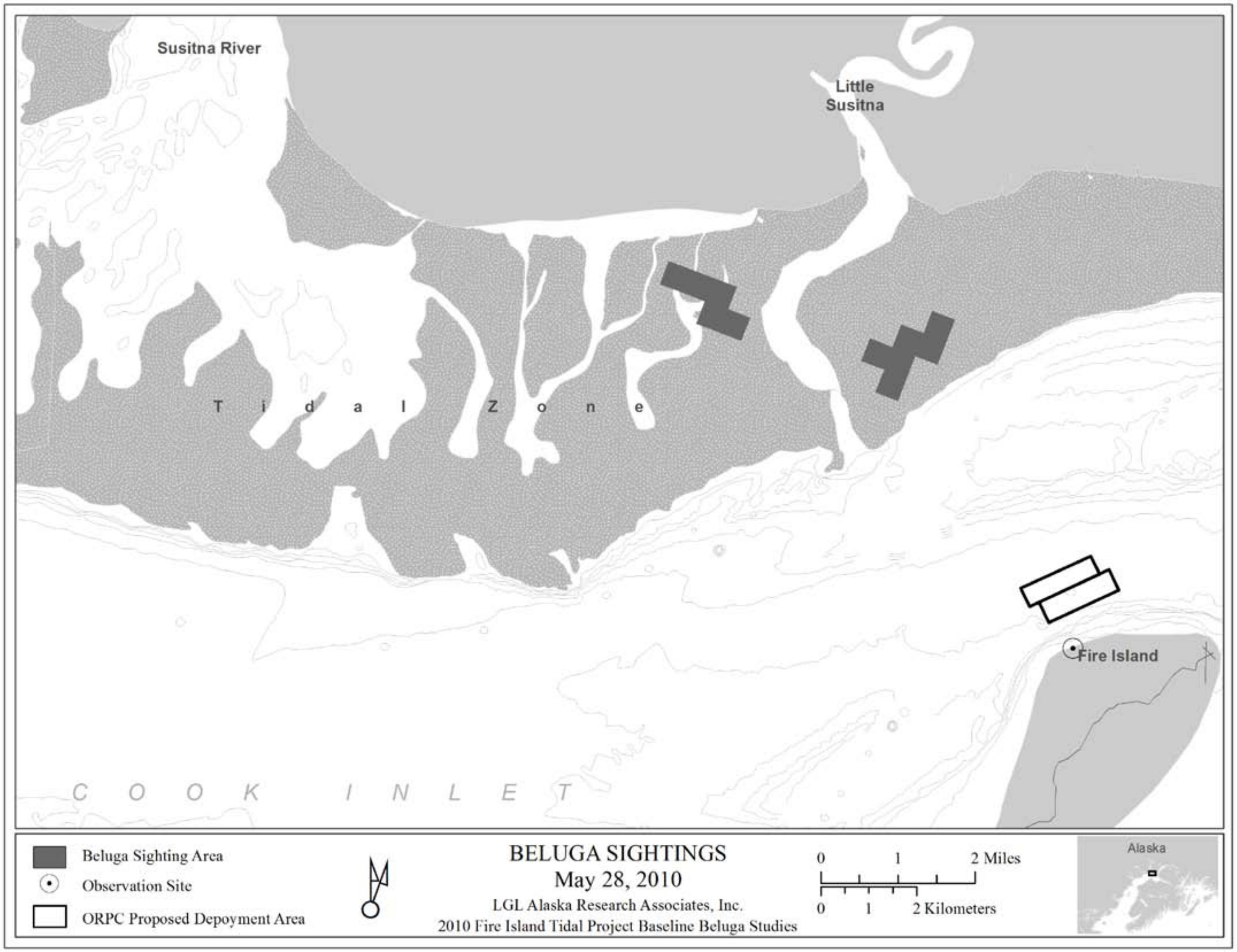

Figure B5. Locations of beluga whales sighted on May 28, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

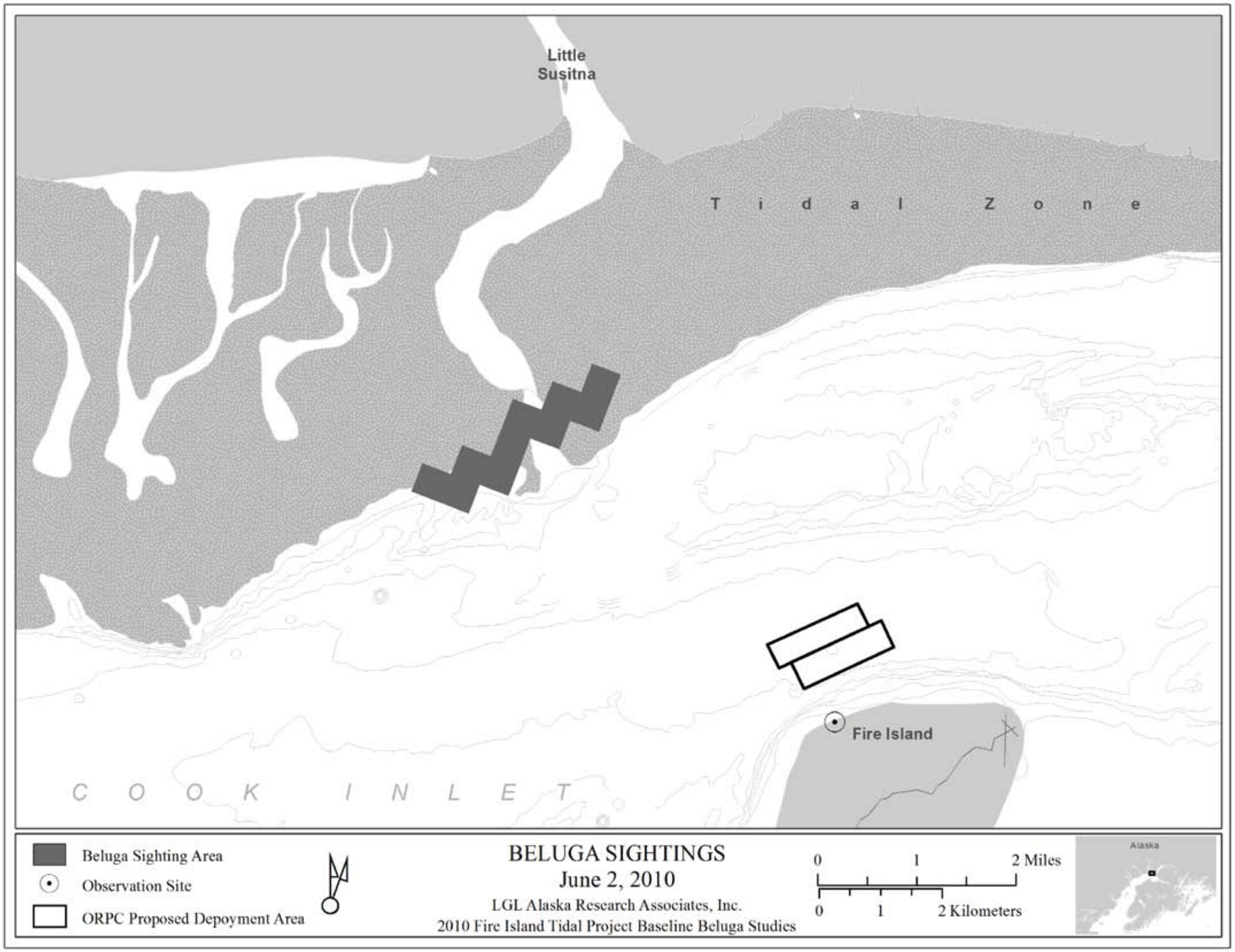

Figure B6. Locations of beluga whales sighted on June 2, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

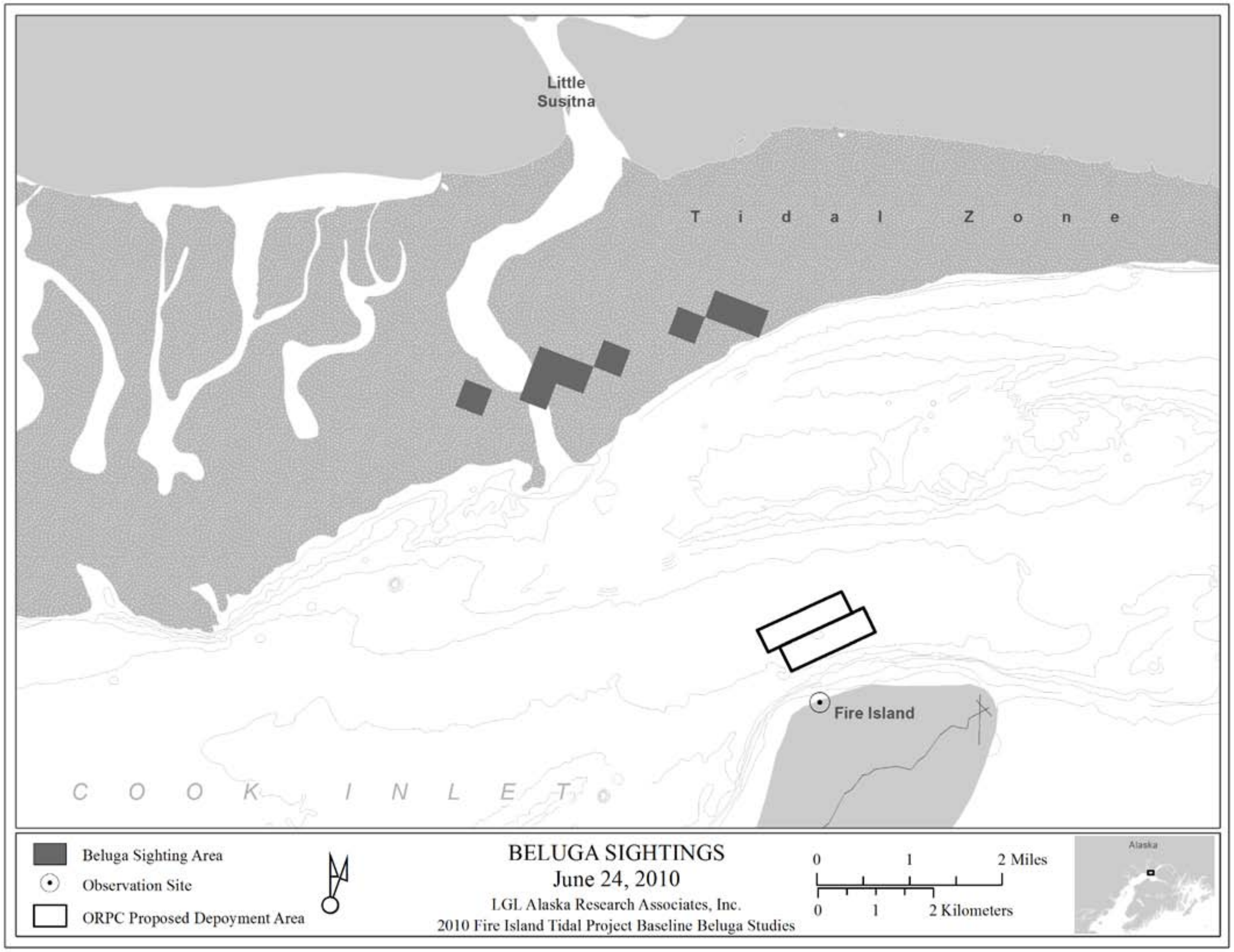

Figure B7. Locations of beluga whales sighted on June 24, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

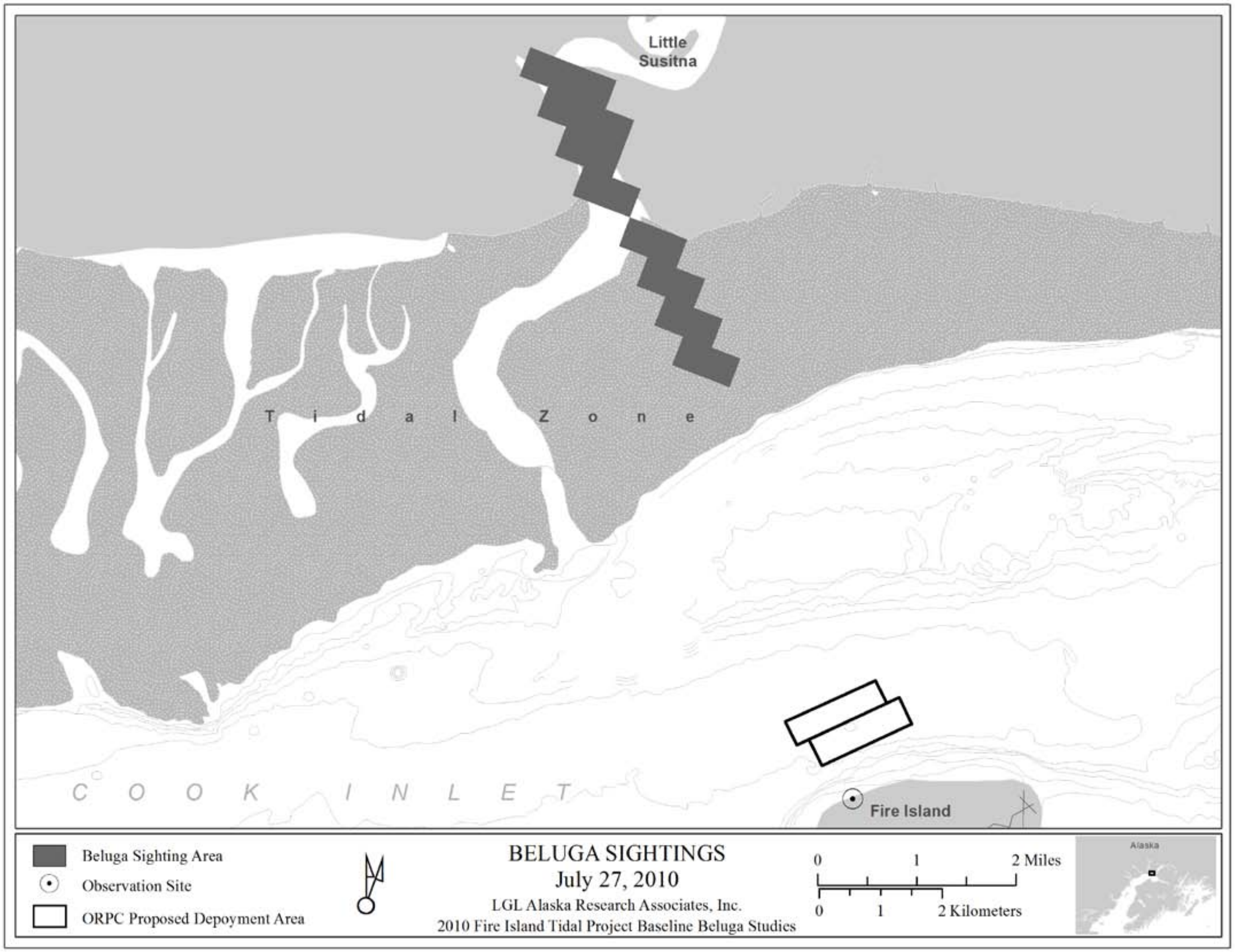

Figure B8. Locations of beluga whales sighted on July 27, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

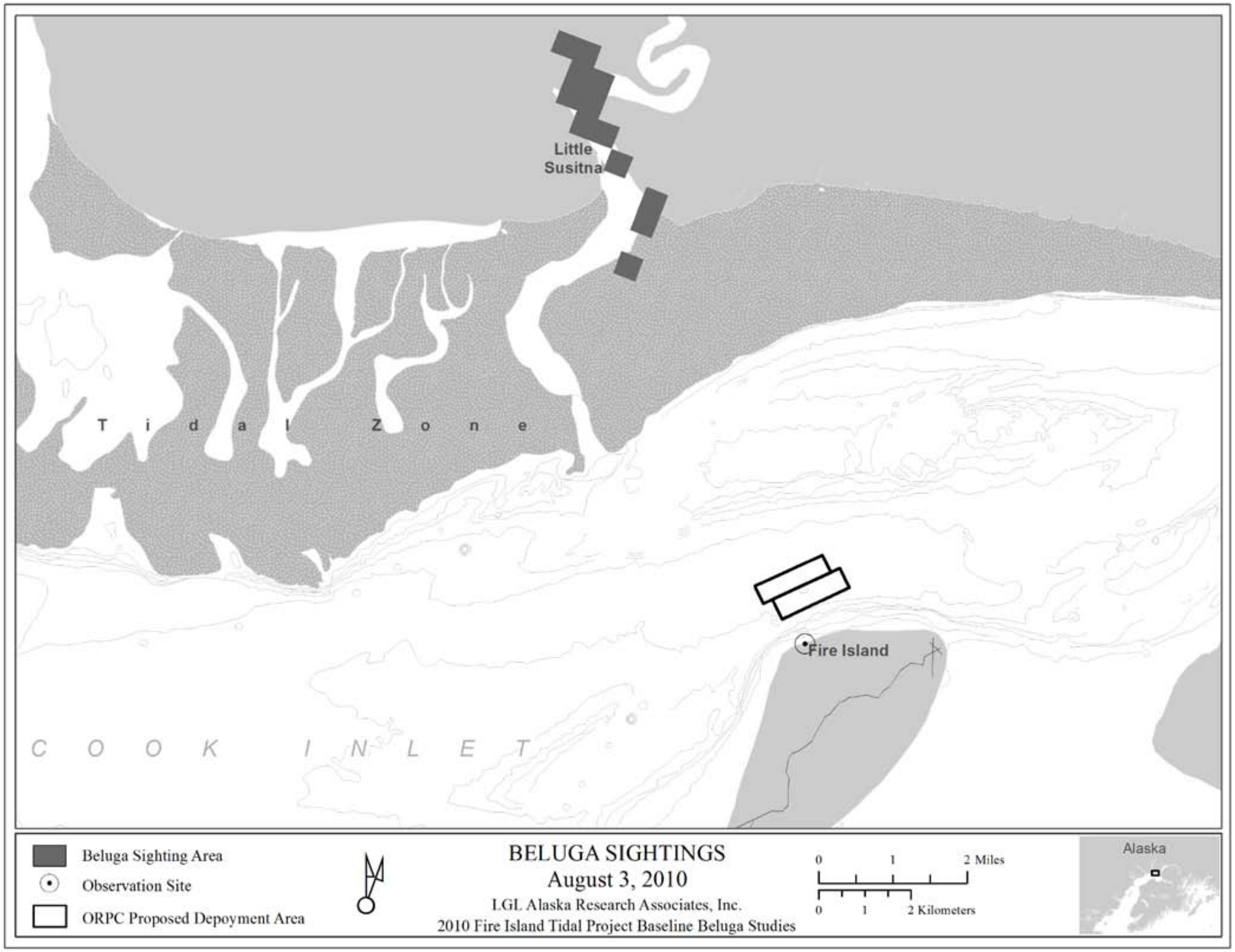

Figure B9. Locations of beluga whales sighted on August 3, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

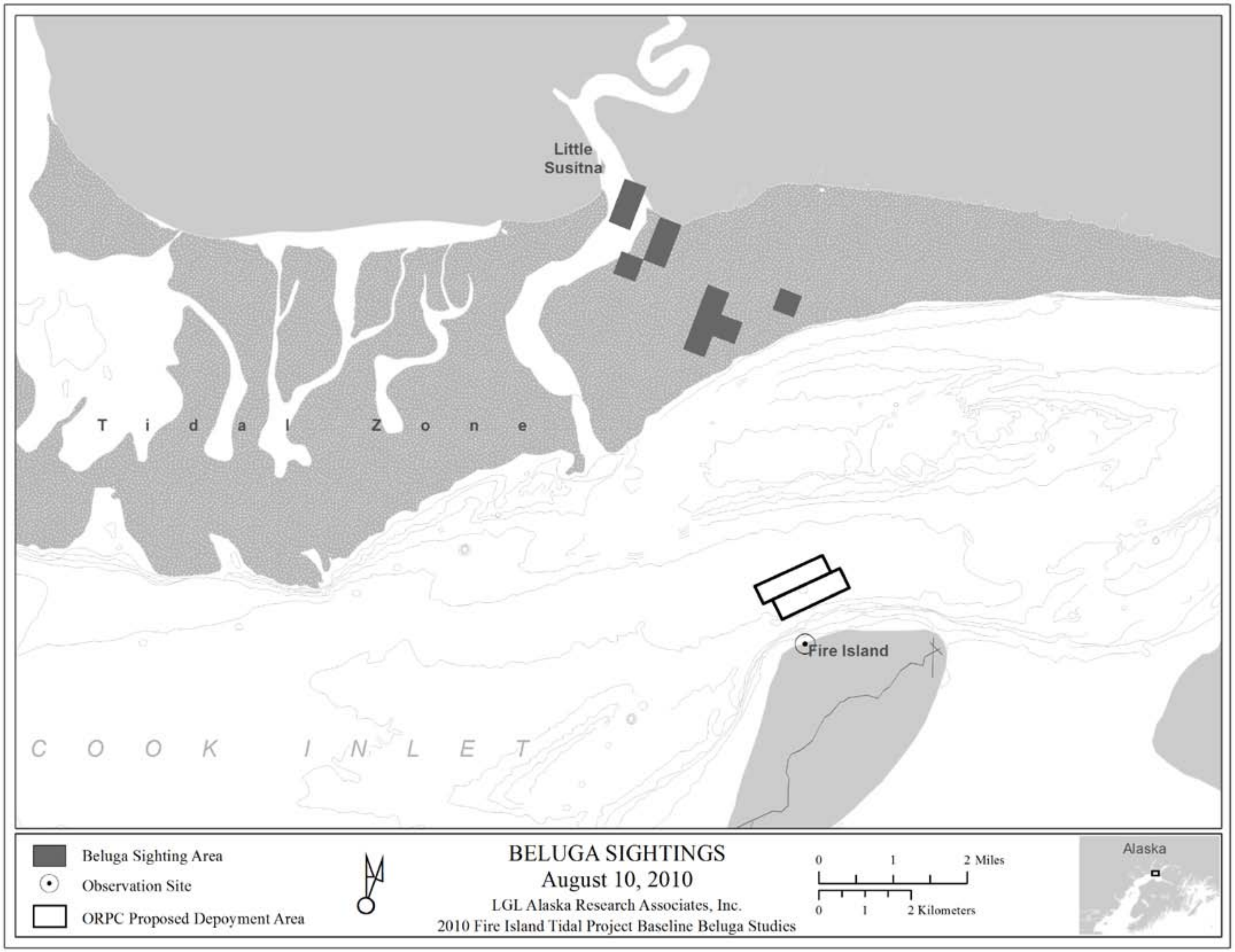

Figure B10. Locations of beluga whales sighted on August 10, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

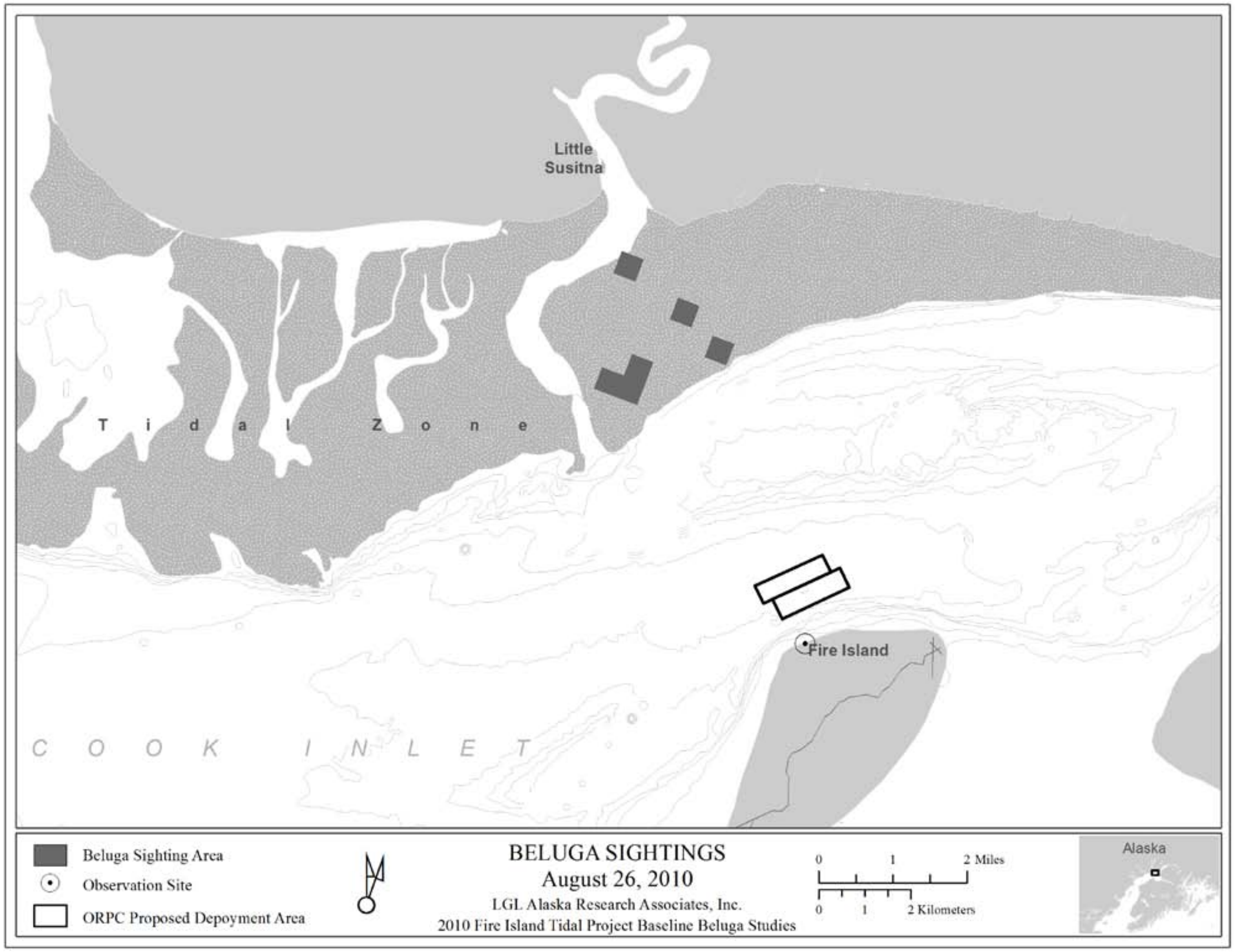

Figure B11. Locations of beluga whales sighted on August 26, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

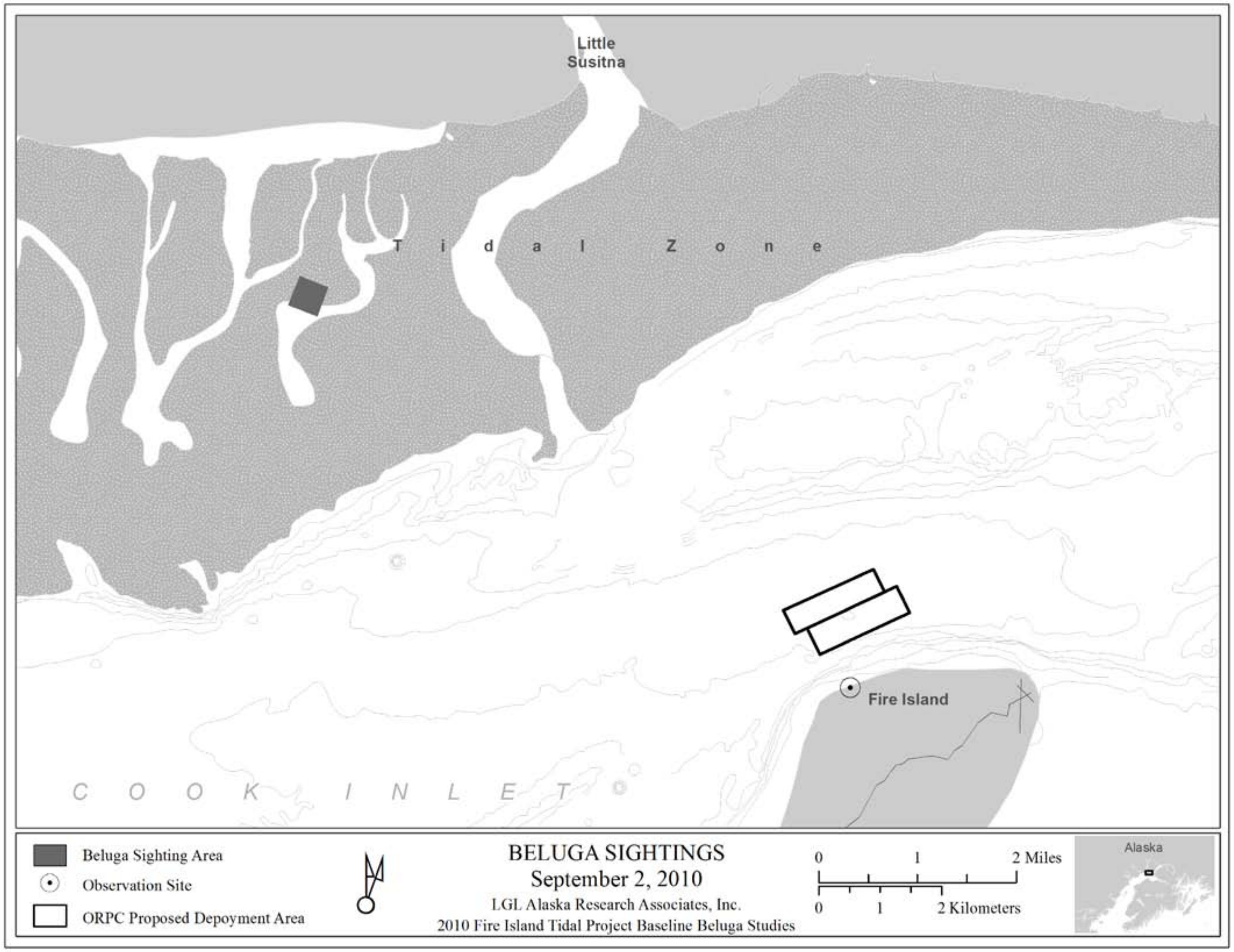

Figure B12. Locations of beluga whales sighted on September 2, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

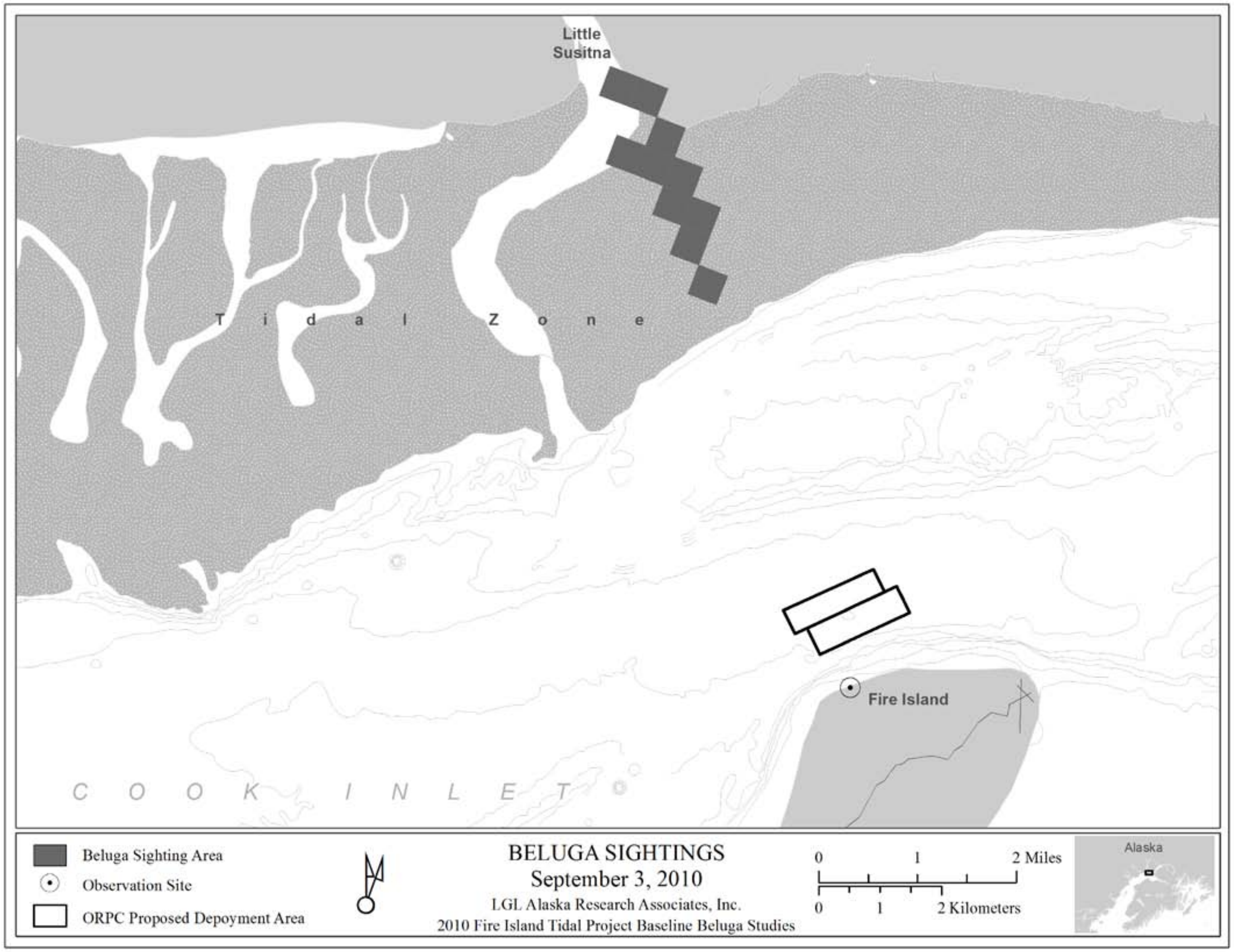

Figure B13. Locations of beluga whales sighted on September 3, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

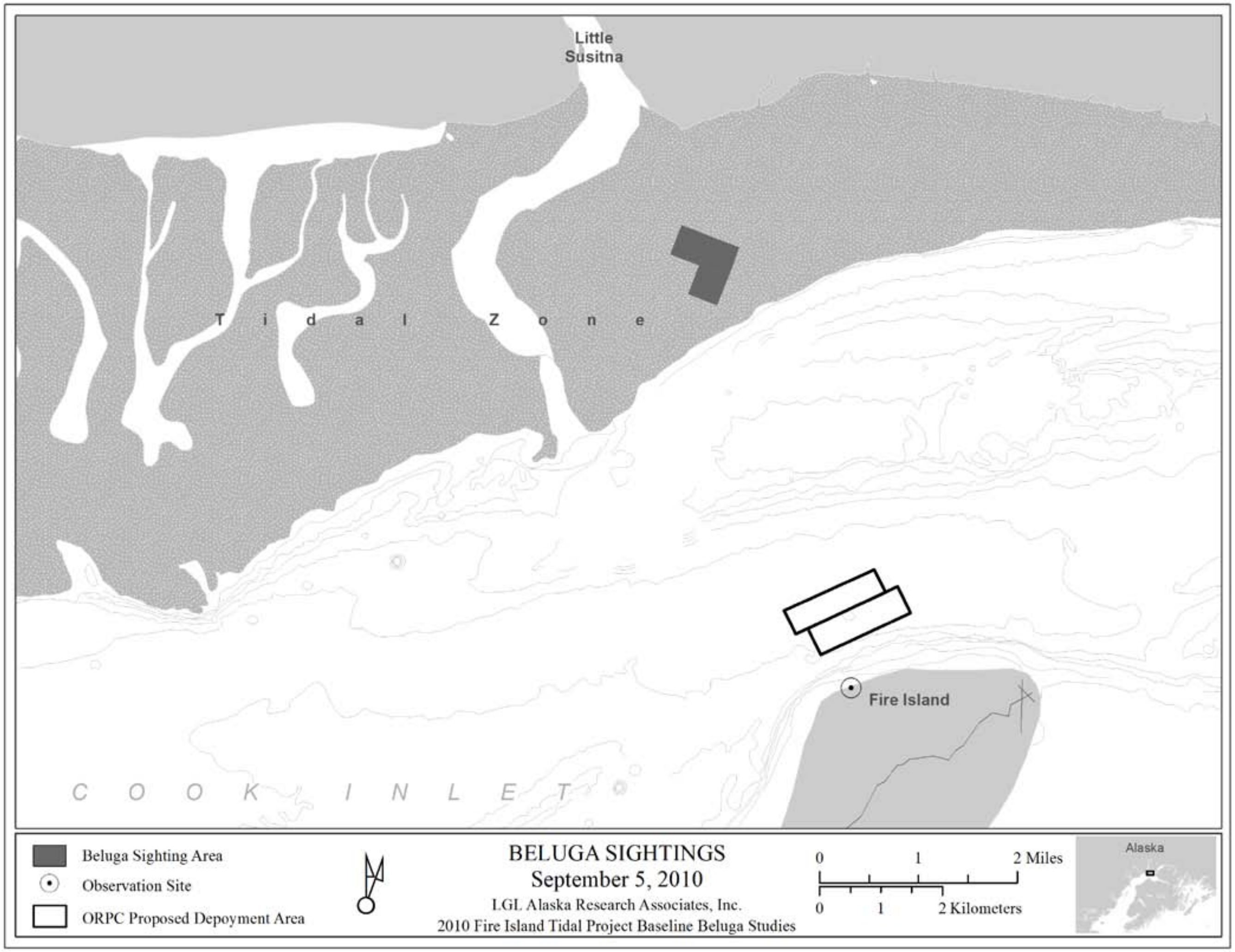

Figure B14. Locations of beluga whales sighted on September 5, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

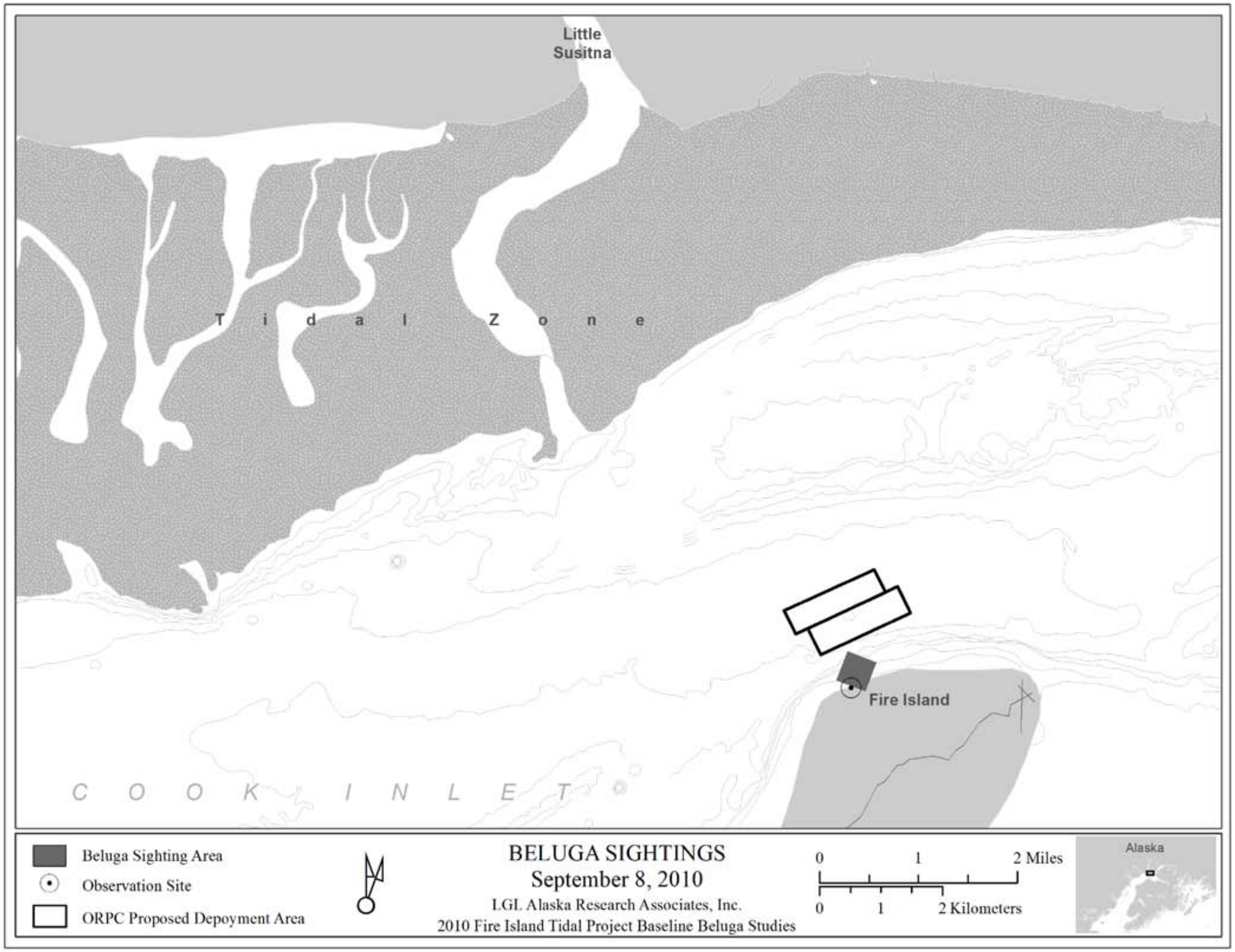

Figure B15. Locations of beluga whales sighted on September 8, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

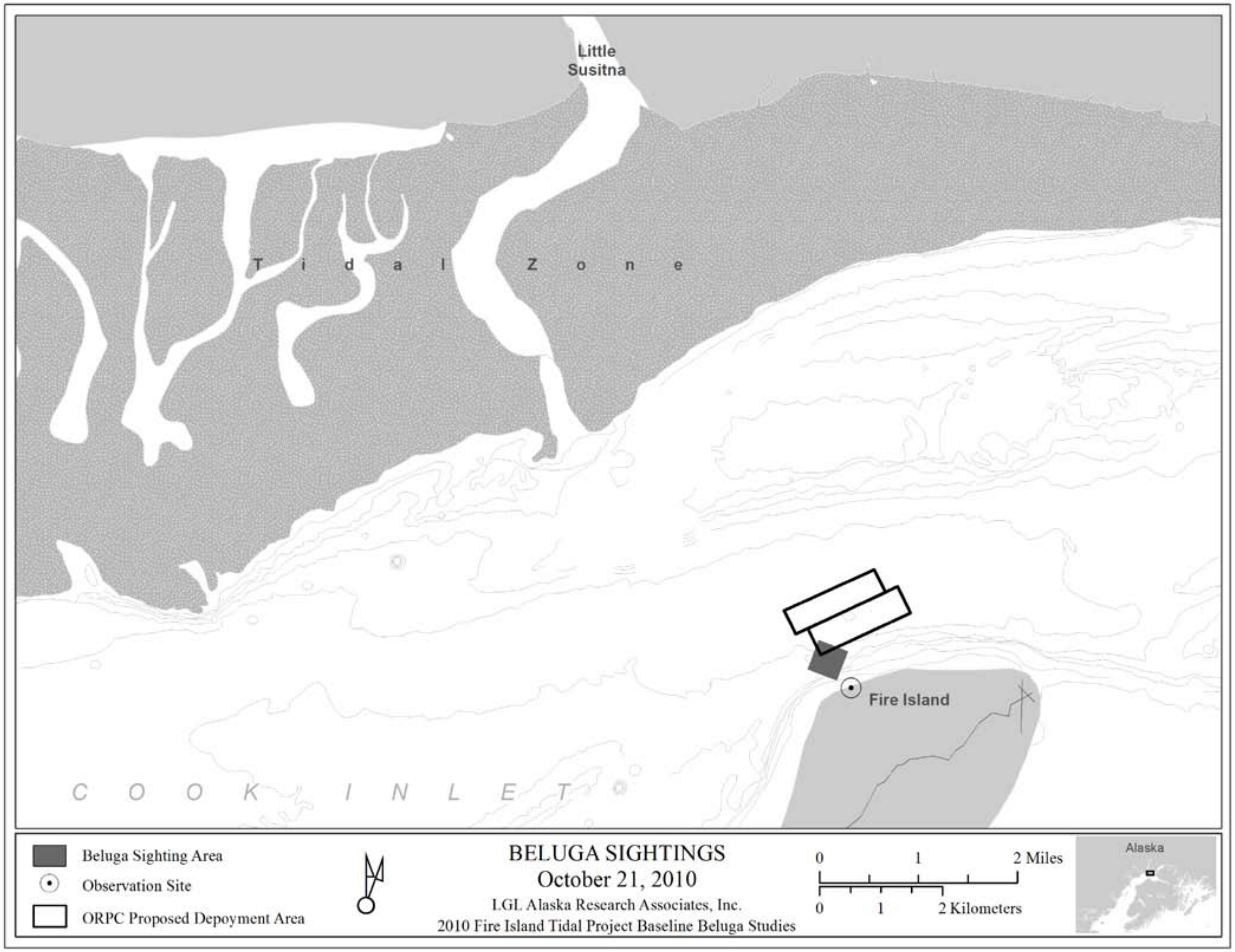

Figure B16. Locations of beluga whales sighted on October 21, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

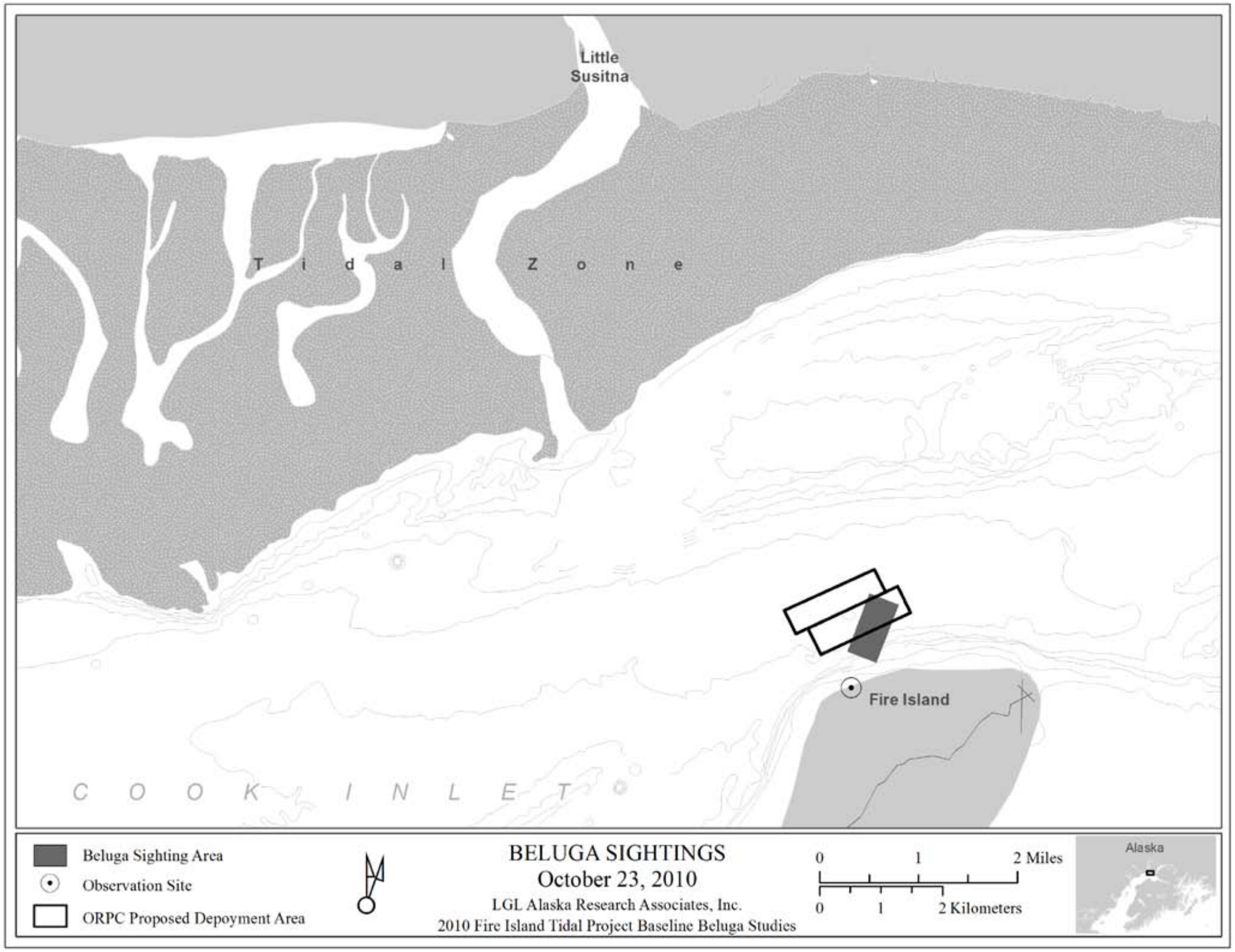

Figure B17. Locations of beluga whales sighted on October 23, 2010. The term Deployment Area refers to the proposed Deployment Area, which is subject to change upon further development of the project.

APPENDIX C

MONITORING EFFORT BY MONTH

*Table C1. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for May 2010. *Near is defined as ≤ 2km/1.2mi from the proposed Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010MAY04	9:10	16:10	7.0	5.62	3.69	5:43	22:12	Yes	Yes
2	2010MAY05	9:10	16:10	7.0	4.26	4.96	5:40	10:14	No	No
3	2010MAY18	9:13	16:13	7.0	7.68	1.48	5:06	10:48	Yes	Yes
4	2010MAY21	8:58	16:00	7.0	2.34	6.47	4:59	10:56	Yes	No
5	2010MAY27	9:10	16:20	7.2	7.81	2.61	4:46	11:10	Yes	No
6	2010MAY28	9:03	16:03	7.0	8.74	0.94	4:44	11:12	Yes	No

*Table C2. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for June 2010. *Near is defined as ≤ 2km/1.2mi from the proposed Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010JUN02	9:01	4:03	7.0	6.18	2.89	4:35	23:22	YES	NO
2	2010JUN03	8:58	4:01	7.0	4.72	4.19	4:34	23:24	NO	NO
3	2010JUN07	8:51	3:55	7.0	2.64	7.02	4:28	23:31	NO	NO
4	2010JUN08	9:03	4:05	7.0	3.37	6.95	4:27	23:32	NO	NO
5	2010JUN16	9:20	16:00	6.7	8.06	0.89	4:21	23:41	NO	NO
6	2010JUN17	9:05	15:50	6.7	6.06	2.71	4:21	23:42	NO	NO
7	2010JUN23	9:15	16:00	6.7	3.98	6.41	4:22	23:44	NO	NO
8	2010JUN24	9:15	16:10	6.9	5.64	5.04	4:22	23:44	YES	NO
9	2010JUN29	9:20	16:00	6.7	8.66	0.16	4:26	23:42	NO	NO

*Table C3. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for July 2010. *Near is defined as ≤ 2km/1.2mi from the proposed* Deployment Area.

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010JUL01	9:10	16:10	7.0	6.86	2.12	4:28	23:41	NO	NO
2	2010JUL07	9:10	16:10	7.0	2.46	7.04	4:37	23:34	NO	NO
3	2010JUL08	9:10	16:10	7.0	3.38	6.76	4:38	23:33	NO	NO
4	2010JUL13	9:30	15:30	6.0	9.9	-0.76	4:48	23:25	NO	NO
5	2010JUL19	9:05	16:02	6.9	1.14	6.89	5:01	23:13	NO	NO
6	2010JUL27	9:20	16:00	6.7	8.78	0.51	5:20	22:54	YES	NO

*Table C4. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for August 2010. *Near is defined as ≤ 2km/1.2mi from proposed the Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010AUG03	9:20	16:10	6.8	2.40	5.68	5:38	22:36	YES	NO
2	2010AUG10	9:20	16:16	7.1	9.06	1.15	5:56	22:16	YES	NO
3	2010AUG17	9:10	16:06	6.9	1.67	6.52	6:14	21:56	NO	NO
4	2010AUG26	11:07	22:20	12.2	7.17	9.09	6:37	21:28	YES	NO
5	2010AUG27	7:30	16:45	11.2	6.15	1.53	6:39	21:25	NO	NO

*Table C5. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for September 2010. *Near is defined as ≤ 2km/1.2mi from the proposed Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010SEP02	10:05	17:05	7.0	2.98	5.56	6:55	21:06	YES	NO
2	2010SEP03	9:00	16:05	7.7	1.81	6.97	6:57	21:03	YES	NO
3	2010SEP05	10:15	17:10	6.9	1.95	8.02	7:02	20:57	YES	NO
4	2010SEP06	10:16	17:15	7.0	3.22	7.93	7:05	20:54	NO	NO
5	2010SEP08	9:40	16:40	7.0	7.03	5.32	7:10	20:47	YES	YES
6	2010SEP09	10:40	17:40	7.0	6.67	6.29	7:12	20:44	NO	NO
7	2010SEP22	10:05	16:40	6.6	6.29	6.13	7:44	20:03	NO	NO
8	2010SEP23	9:36	16:30	6.9	7.32	4.99	7:47	19:59	NO	NO
9	2010SEP27	9:45	16:40	6.9	8.77	2.08	7:57	19:47	NO	NO
10	2010SEP28	9:40	16:40	7.0	8.10	2.57	7:59	19:43	NO	NO

*Table C6. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for October 2010. *Near is defined as ≤ 2km/1.2mi from the proposed Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010OCT06	9:50	16:30	6.7	4.54	8.21	8:20	19:18	NO	NO
2	2010OCT11	9:50	16:30	6.7	9.44	1.49	8:32	19:03	NO	NO
3	2010OCT15	9:40	16:30	6.8	3.63	6.07	8:43	18:50	NO	NO
4	2010OCT21	9:50	15:00	5.2	5.57	3.49	8:59	18:32	YES	YES
5	2010OCT22	9:50	17:00	7.2	6.68	6.47	9:01	18:29	NO	NO
6	2010OCT23	10:05	17:05	7.0	7.62	5.23	9:04	18:26	YES	YES
7	2010OCT25	10:33	16:00	5.4	7.81	1.95	9:09	18:20	NO	NO

*Table C7. Monitoring effort, tidal height, daylight hours, and summary of beluga sightings for November 2010. *Near is defined as ≤ 2km/1.2mi from the proposed Deployment Area.*

Day	Date	Shift Start	Shift Stop	Total Hours of Observation	Tide Height Start (m)	Tide Height Stop (m)	Sunrise (AKDT)	Sunset (AKDT)	Belugas Sighted	Belugas sighted in or near* the proposed Deployment Area?
1	2010NOV03	10:47	14:00	3.2	1.45	4.59	9:34	17:55	NO	NO
2	2010NOV11	9:41	15:00	5.3	8.36	4.1	8:56	16:34	NO	NO
3	2010NOV12	9:48	12:30	2.7	7.46	7.39	8:58	16:31	NO	NO
4	2010NOV13	11:00	12:40	1.7	7.33	7.64	9:01	16:29	NO	NO

APPENDIX D

BELUGA WHALE SIGHTINGS SUMMARIZED BY DATE

Table D1. Beluga whale sightings during May 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010MAY04	10:35-10:35	1	0	0	0	1	1	T	U	na	W	NF	No
2010MAY04	10:57-11:36	1	0	1	0	2	2	T	D	3	W	L	Yes
2010MAY04	11:26-11:26	1	0	0	0	1	3	T	U	na	W	NF	No
2010MAY04	12:13-12:13	1	0	0	0	1	4	T	U	na	SW	NF	No
2010MAY04	15:25-15:25	0	0	1	5	6	5	T	U	13	NE	NF	No
2010MAY18	10:41-10:55	2	0	2	0	4	1	T	D	3	S	U	Yes
2010MAY21	08:58-9:46	52	5	0	0	57	1	T	U	U	U	NF	No
2010MAY21	13:39-14:51	34	0	0	0	34	2	U	U	U	U	U	No
2010MAY27	11:15-11:15	100	0	0	0	100	1	U	U	U	U	U	No
2010MAY28	9:35-9:35	0	0	0	58	58	1	FS	M	>13	na	L	No
2010MAY28	13:04-16:05	0	0	0	62	62	2	T/FS	M	>13	W	L	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	T	Resting	R	<1	1	Variable	V	Circular	C
Socialize	S	Spy Hop	SH	1-3	3	Unknown	U	Parallel	P
Dive	D	Milling	M	4-7	7	North	N	Linear	L
Feeding Observed	FO	Other	O	8-12	12	South	S	Echelon	E
Feeding Suspected	FS	Unknown	U	>13	13	East	E	No Formation	NF
				Unknown	U	West	W	Unknown	U

Table D2. Beluga whale sightings during June 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010JUN02	14:32–16:00	65	0	0	0	65	1	T	U	>13	E	L	No
2010JUN24	12:45	1	0	0	0	1	1	U	U	<1	U	NF	No
2010JUN24	13:18-14:26	9	0	0	0	9	2	T	U	7	U	U	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	T	Resting	R	<1	1	Variable	V	Circular	C
Socialize	S	Spy Hop	SH	1-3	3	Unknown	U	Parallel	P
Dive	D	Milling	M	4-7	7	North	N	Linear	L
Feeding Observed	FO	Other	O	8-12	12	South	S	Echelon	E
Feeding Suspected	FS	Unknown	U	>13	13	East	E	No Formation	NF
				Unknown	U	West	W	Unknown	U

Table D3. Beluga whale sightings during July 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010JUL27	9:38-15:55	14	1	0	0	15	1	U	U	U	U	U	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**	North	**N**	Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**	South	**S**	Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**	East	**E**	No Formation	**NF**
				Unknown	**U**	West	**W**	Unknown	**U**

Table D4. Beluga whale sightings during August 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010AUG03	11:20-15:30	11	0	0	0	11	1	U	U	U	U	U	No
2010AUG10	9:35-14:33	5	0	0	0	5	1	U	U	U	U	U	No
2010AUG26	15:03-16:51	6	0	0	0	6	1	U	U	U	U	U	No

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**	North	**N**	Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**	South	**S**	Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**	East	**E**	No Formation	**NF**
				Unknown	**U**	West	**W**	Unknown	**U**

Table D5. Beluga whale sightings during September 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010SEP02	10:43	5	0	0	0	5	1	T	U	3	W	L	No
2010SEP03	11:56	10	1	0	0	11	1	U	U	U	U	U	No
2010SEP05	10:45-11:28	5	3	0	0	8	1	O	U	U	U	U	No
2010SEP08	13:53	1	0	0	0	1	1	T	U	N/A	E	N/A	Yes

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**	North	**N**	Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**	South	**S**	Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**	East	**E**	No Formation	**NF**
				Unknown	**U**	West	**W**	Unknown	**U**

Table D6. Beluga whale sightings during October 2010 are summarized by date. Unk = unknown.

Date	Time	White	Gray	Calves	Unknown	Total	Group #	1° Activity[1]	2° Activity	Spread[2]	Direction[3]	Formation[4]	Belugas sighted within or near proposed Deployment Area?
2010OCT21	11:25	1	1	0	0	2	1	T	U	1	W	N/A	Yes
2010OCT23	14:57-15:00	1	0	0	0	1	1	T	U	N/A	NE	N/A	Yes

[1] Activity				[2] Spreads (Body Length)		[3] Direction		[4] Formations	
Traveling	**T**	Resting	**R**	<1	**1**	Variable	**V**	Circular	**C**
Socialize	**S**	Spy Hop	**SH**	1-3	**3**	Unknown	**U**	Parallel	**P**
Dive	**D**	Milling	**M**	4-7	**7**	North	**N**	Linear	**L**
Feeding Observed	**FO**	Other	**O**	8-12	**12**	South	**S**	Echelon	**E**
Feeding Suspected	**FS**	Unknown	**U**	>13	**13**	East	**E**	No Formation	**NF**
				Unknown	**U**	West	**W**	Unknown	**U**

GREENERIDGE SCIENCES, INC.

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MEMORANDUM

To: Monty Worthington, ORPC AK

From: Katherine H. Kim, Robert G. Norman, Charles R. Greene, Jr.

Date: 29 June 2011

Re: Cook Inlet ambient noise report [GSI Technical Memorandum 442-2]

This is a report of a study conducted by Greeneridge Sciences, Inc., sponsored by Ocean Renewable Power Company (ORPC), to acoustically monitor the Cook Inlet Tidal Energy Project Deployment Area. This report covers recordings during October 2010 and November 2010–April 2011.

Objectives

The study has two primary objectives

1. Measure ambient sound levels in the Deployment Area west of Fire Island for extended recording periods.
2. Detect beluga whale vocalizations, specifically whistles, in the Deployment Area in Cook Inlet and estimate locations of the detected calls.

To achieve these objectives, DASARs (Directional Autonomous Seafloor Acoustic Recorders), especially designed for operation in the high-current regime of Cook Inlet, and an Acousonde omnidirectional wideband acoustic recorder were utilized. One DASAR and one Acousonde were deployed 23–25 October for operational testing. Two DASARs were deployed 13 November 2010–24 April 2011 to provide long-term, overwinter recordings.

This memorandum documents the Acousonde analyses and summarizes the results of the first objective: ambient noise measurements made by the DASARs during the overwinter recording period. The overwinter DASARs will also provide information on the second objective; however, beluga detection and localization results will be the subject of a separate report.

Acousonde

An Acousonde omnidirectional wideband acoustic recorder was co-deployed with a DASAR during the 23–25 October tests. Unlike a DASAR, an Acousonde lacks directional estimation capability, but it has a significantly higher recording bandwidth for characterizing high-frequency ambient noise and detecting additional beluga calls, if present, such as echolocation clicks. At the time of the Fall 2010 operational tests, the Acousonde was capable of sampling at a rate of up to 116.15 kHz. With the anti-alias filter enabled, as it was for the October 2010 tests, the operational bandwidth is 42 kHz. (The anti-alias filter rolls off slowly, 3-dB down at 42 kHz and 22 dB down at 100 kHz, providing some usable bandwidth above 42 kHz.) With the Acousonde's higher bandwidth comes the tradeoff of a shorter recording duration than the DASAR, so the Acousonde was configured for 25% duty cycling, recording the first 15 min at the top of every hour until its memory was completely filled two days later.

Figure 1 shows the band levels for both the DASAR and Acousonde over the full deployment period (23–25 October 2010) and calculated across various bands. For the DASAR spectral estimation results in this section, 60-s of data sampled at 5000 Hz were analyzed using a 5000-point FFT, Blackman-Harris window, and 50% overlap. For the Acousonde spectral estimation results, 90-s of data sampled at 116.15 kHz were analyzed using an 8192-point FFT, Blackman-Harris window, and 50% overlap (for the 25% duty cycle). The DASAR's operational bandwidth is dictated by (a) the 100 Hz high-pass break of the hydrophones to help decrease the influence of anticipated low-frequency noise and (b) the anti-aliasing filter cutoff frequency of 2250 Hz. The band of interest for beluga vocalizations is 1000–2250 Hz. For the Acousonde, 66 Hz and 10 kHz high-pass break frequencies and the aforementioned 42 kHz anti-aliasing filter cutoff frequency were part of its design. Calibration testing of the Acousonde resulted in development of an equalization filter to ensure a flat response from 700–7000 Hz, with the remainder of the Acousonde's response up to 42 kHz being flat. The top panel of Figure 1 compares the band levels measured by the Acousonde (red dots) and DASAR (blue line), in both cases across the DASAR band of interest, 1000–2250 Hz. There is very good agreement between the two instruments for roughly the first half of the Acousonde's deployment, after which the Acousonde consistently reports higher band levels than the DASAR. The cause for this discrepancy is unknown, but an increase in Acousonde band level variability is also evident, in some cases mimicing the broadband transients seen in the DASAR band level results (spike-like excursions in the blue line) as well as spectrogram results. The bottom panel of Figure 1 compares the Acousonde band levels across two different frequency bands: 1000–2250 Hz (red) as in the top panel and 2250–42000 Hz (green), the former representative of the band shared with the DASAR and the latter denoting the extension in bandwidth gained by use of the Acousonde. What is striking is that there is often much more energy in the 2250–42000 Hz band than the 1000–2250 Hz band, a result which is not characteristic of most (wind-driven) ambient noise. However, a strong semidiurnal pattern is evident in the higher-frequency Acousonde data, attributable to the tidal currents of Cook Inlet (Figure 2). Lacking current measurements, currents speeds throughout this report are derived from current predictions for a location southwest of the Deployment Area and with similar bathymetric conditions (Hahn 2007). As seen in Figure 2, the Acousonde's received levels (green) increase with the high currents (blue) associated with ebb and flood tides and decrease at slack tides. The heightened received levels are hypothesized to be attributable to so-called "pseudo-sound" (non-propagating acoustic signals), most notably, flow noise, as well as non-ambient sounds such as impulsive debris collisions with the recorder. The Acousonde was attached to a post welded to the DASAR's seafloor-mounted frame and its hydrophone lay just below the surface of its polyurethane encapsulation and, thus, the Acousonde's response to tidal fluctuations is not wholly unexpected.

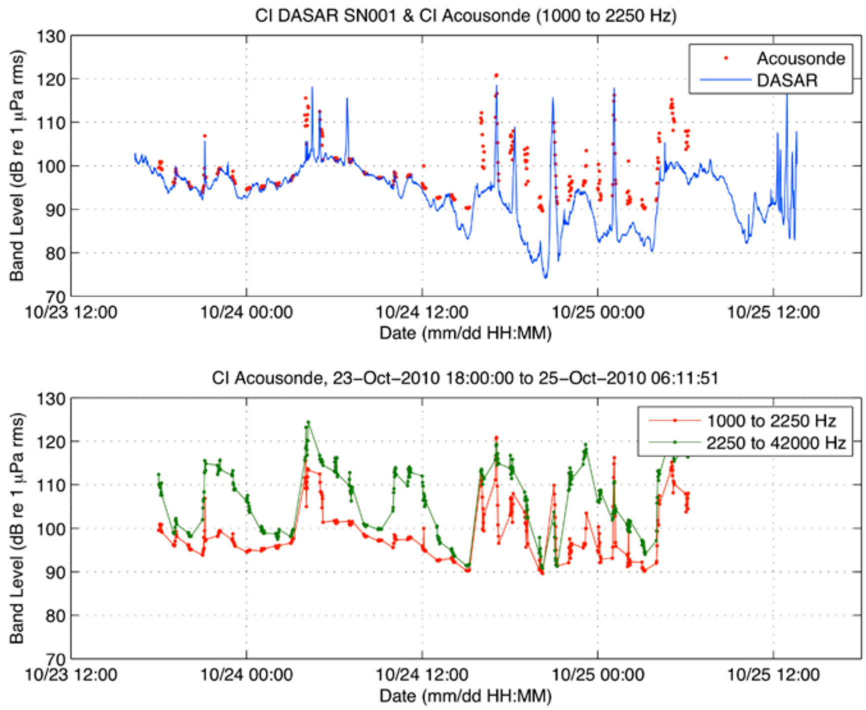


Figure 1. Band levels across different bands for the DASAR and Acousonde throughout the October 2010 deployment. The top panel compares the Acousonde (red dots) with the DASAR (blue line) for their shared band of 1000–2250 Hz. The bottom panel compares band levels for the Acousonde for the aforementioned 1000–2250 Hz band (red) with the Acousonde's band beyond that of the DASAR's (2250–42000 Hz, green). The red and green dots in the bottom panel indicate the Acousonde's measured levels at its 25% duty cycle, with linear interpolation in between measurements.

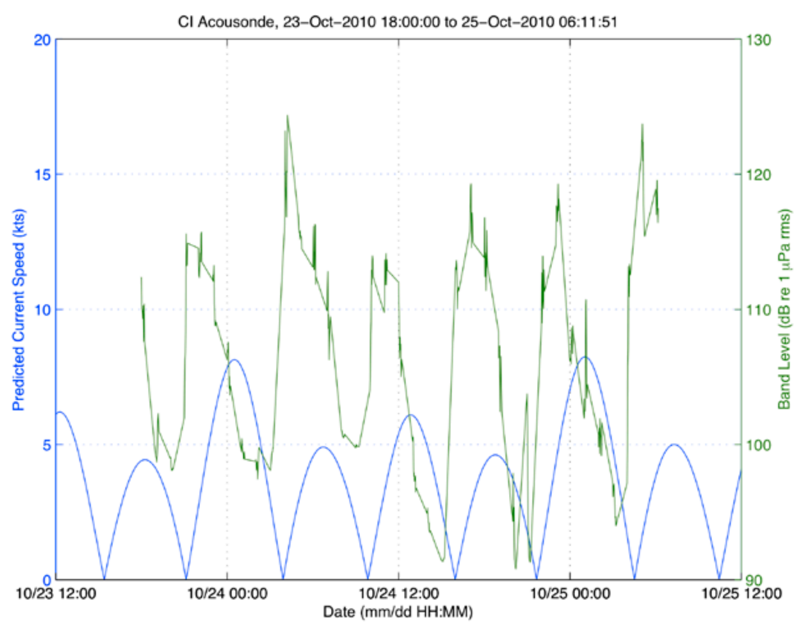


Figure 2. Acousonde band levels for 2250–42000 Hz (green) displayed with predicted current speeds (blue).

Figure 3 further conveys the influence of pseudo-sound and/or debris collisions on the Acousonde, this time in terms of sound pressure spectral density levels. The top and bottom plots represent two different times during the deployment. While the general character of the DASAR's received level curve as a function of frequency (blue) largely remains the same for different time periods, the Acousonde's received level curve (red) varies wildly. Unfortunately, lack of accurate time registration between the Acousonde and DASAR (with their independent clocks) as well as the Acousonde's relatively great distance from the DASAR (with respect to an acoustic wavelength for these higher frequencies of interest) prohibit the exploitation of multiple sensor techniques to remove uncorrelated noise contamination. Consequently, use of the Acousonde to extend the bandwidth of the DASAR is limited in such high current environments.

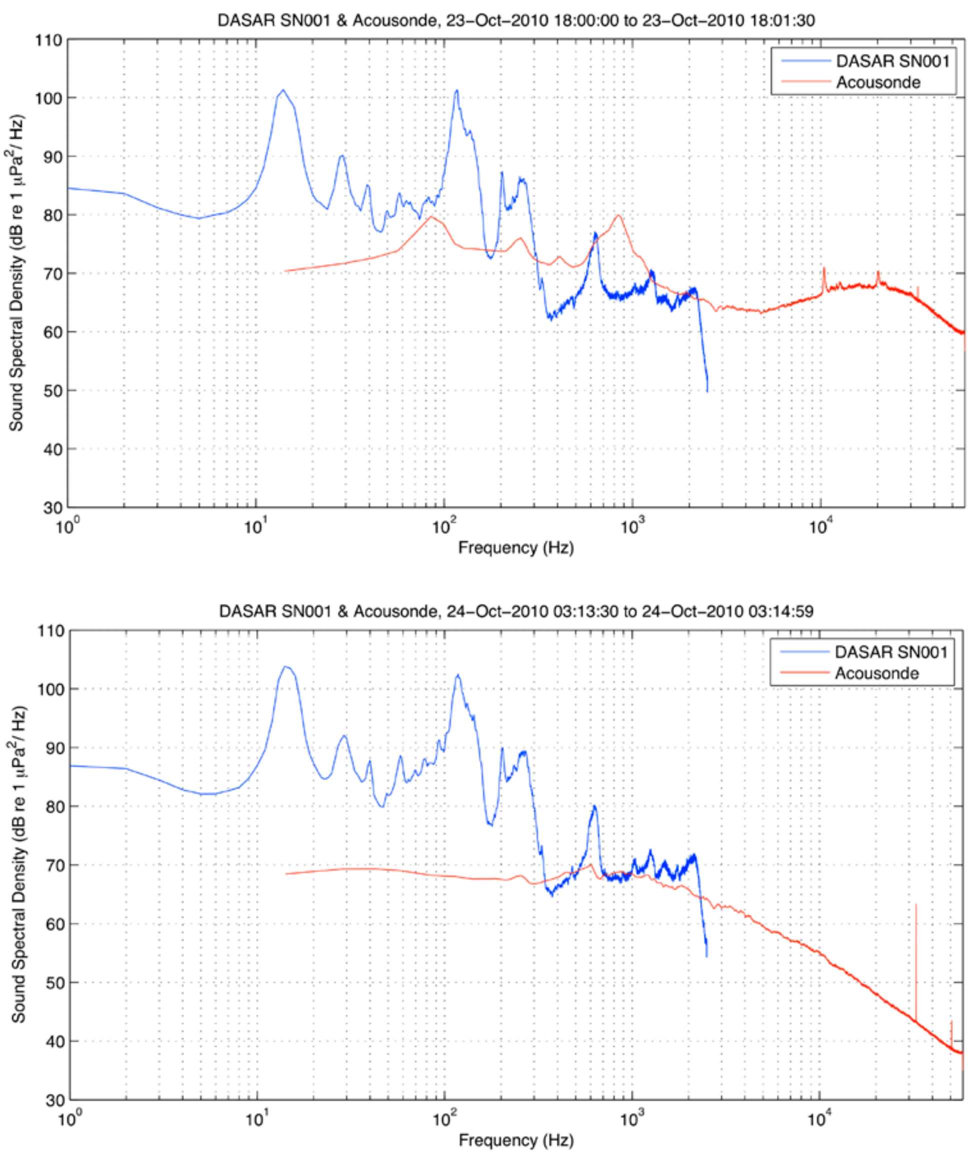


Figure 3. DASAR (blue) and Acousonde (red) sound pressure spectral density levels at time near the beginning of the Fall 2010 deployment (top) and several hours later (bottom).

DASAR (Directional Autonomous Seafloor Acoustic Recorder

In order to measure ambient noise levels over an extended period in the Deployment Area, two DASARs (SN101 and SN103) were deployed 0.74 km apart from one another off the northern shore of Fire Island at 61°10’48.5912” N, 150°12’12.499” W and 61°10’42.01” N, 150°13’0.238” W, respectively. Received sound levels recorded on the single DASAR (SN001) deployed in October 2010 were reported previously (see Greene 2010). This memorandum presents results for the two DASARs (SN101 and SN103) deployed “overwinter” from 13 November 2010 to 24 April 2011.

Figure 4 presents band level as a function of time across the entire overwinter deployment. In the interest of data compression, data from the first 60 s of every 128 MB raw acoustic data file (a period of approximately 1 hr) was utilized in the calculation. For the DASAR spectral estimation results that follow, 60 s of data sampled at 5000 Hz were analyzed using a 5000-point FFT, Blackman-Harris window, and 50% overlap. The top panel in Figure 4 shows the predicted tidal current each hour. The middle and bottom panels show the band levels from 1000–2250 Hz for DASAR SN101 and SN103, respectively. In all three panels of Figure 4, the influence of spring and neap tides occurring approximately twice a month are apparent.

A two-day close-up of band levels for the two DASARs is depicted in Figure 5. Band level is depicted in blue, and predicted current speed is depicted in green. In this higher time resolution plot (a value for every minute of acoustic data), the influence of the semidiurnal tides is evident. As current increases with ebb and flood tides, so do received levels on the DASARs. As tidal current approaches zero at slack tide, received levels similarly decrease to their lowest levels.

The two DASARs distinguished in Figure 5 exhibit slightly different degrees of tidal influence. SN101 (top) appears more impacted by tidal current than SN103 (bottom). The DASAR sensors are known to be well-matched in amplitude and phase, so individual sensor sensitivities do not account for this small difference between DASARs. The disparity may be due to the two DASARs’ different deployment locations and, consequently, small variations in local environmental conditions, *e.g.*, size and amount of gravel on the seafloor that contribute to ambient noise levels. In addition, the DASARs likely had different geographic orientations on the seafloor, *i.e.*, were rotated relative to each other, yet band levels in Figure 5 are for Hydrophone 1 in both cases. While the hydrophones are omnidirectional, they are laid in close proximity of each other (10” sensor spacing) in an equilateral triangle centered on top of a cylindrical electronics housing and under a protective plastic dome. In addition to possible distortion of ray paths over the edge of the housing, the dome might add its own refractive coloring—although these effects, if present, appear to be minimal.

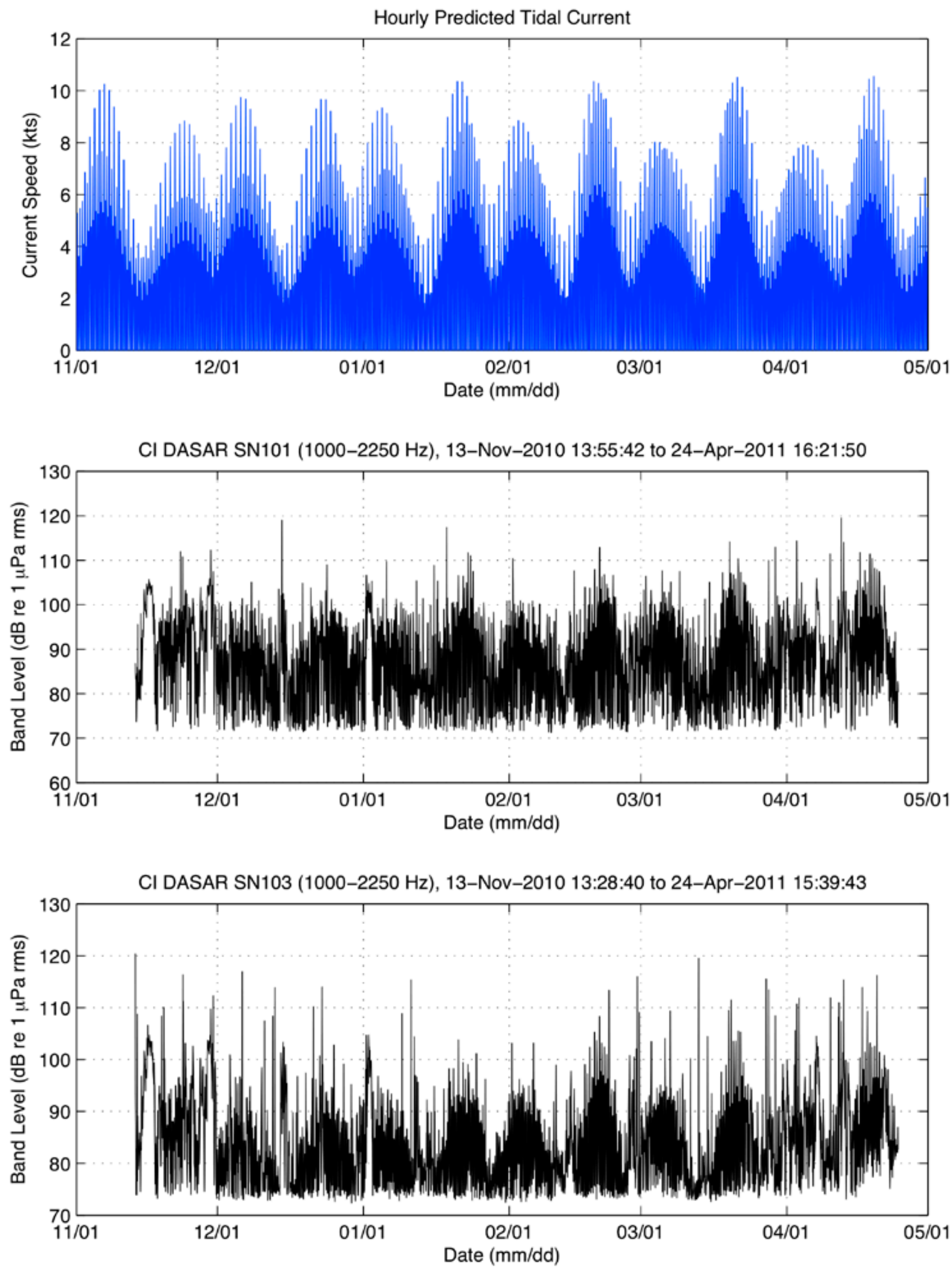


Figure 4. Tidal current (top), band level for SN101 (middle), and band level for SN103 (bottom) as a function of time across the five-month overwinter deployment period.

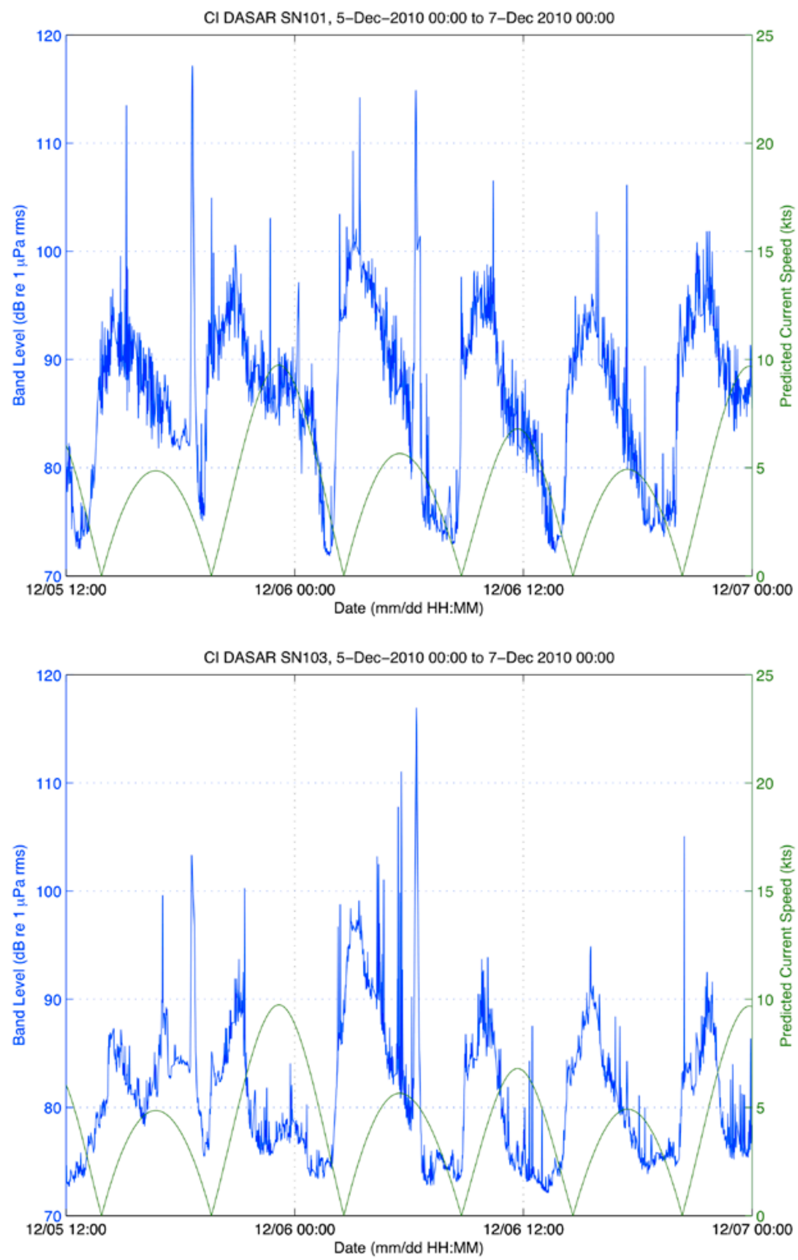


Figure 5. Band level (blue) and tidal current (green) as a function of time for the two-day period from 5–7 December 2010. Both SN101 (top) and SN103 (bottom) exhibit tidal fluctuations, SN101 more so than SN103, likely due to their different deployment locations and orientations.

Ships, aircraft, and wind-generated waves all contribute to Cook Inlet's ambient noise field in the DASAR's operating band. Transiting ships, some related to the Port of Anchorage located 19 km (12 statute miles) northeast of Fire Island, are common sound sources during the ice-free months. Aircraft overflights, associated with Anchorage International Airport located 11 km (7 statute miles) due east of Fire Island, occur regularly and were frequently present in the DASAR records from at-sea trials. Wind-generated waves are also a well-known contributor to ambient noise levels. As seen in Figure 6, winds, measured at a NOAA weather station located at the

Port of Anchorage, originated primarily from the northeast and had a median speed of 3.5 kts over the course of the overwinter deployment. Median speed for gusts was 5.4 kts and peaked at 53 kts. Periods of sustained strong winds persisted for days during the deployment period, peaking at 29.7 kts (NOAA/NOS 2011). Some of these high-wind events, for example, in mid-November, at the end of November, and in mid-December, can be directly associated with increased band levels (*cf.* Figure 4).

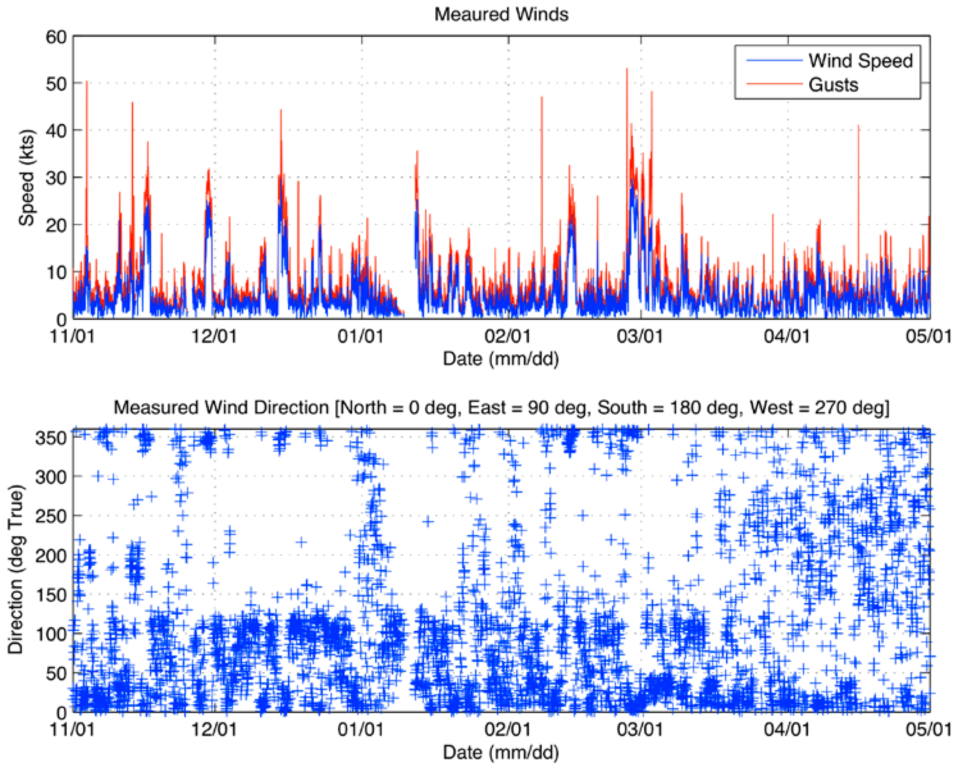


Figure 6. Measured wind speed (top) and direction (bottom) as a function of time across the five-month overwinter deployment period.

In addition to tidal current, anthropogenic sources, and wind, the onset and end of the ice season in Cook Inlet is manifest in the DASAR acoustic records. Figure 7 presents water temperature (top, green line), band level for SN101 (middle, black line), and band level for SN103 (bottom, black line) as a function of time across the overwinter deployment. In the lower two plots, the curves of green dots, each dot calculated over ~30 days to encompass spring and neap tidal variation and then connected linearly, represent the central moving median of the band levels in each respective plot. This running average of band levels mimics that of water temperature in the top panel. Figure 7 suggests that, as the ice season commenced and large pans of ice began to cover Cook Inlet, ambient noise levels decreased as vessel traffic, refraction of aircraft sounds at the air-water interface, and wind-generated waves decreased.

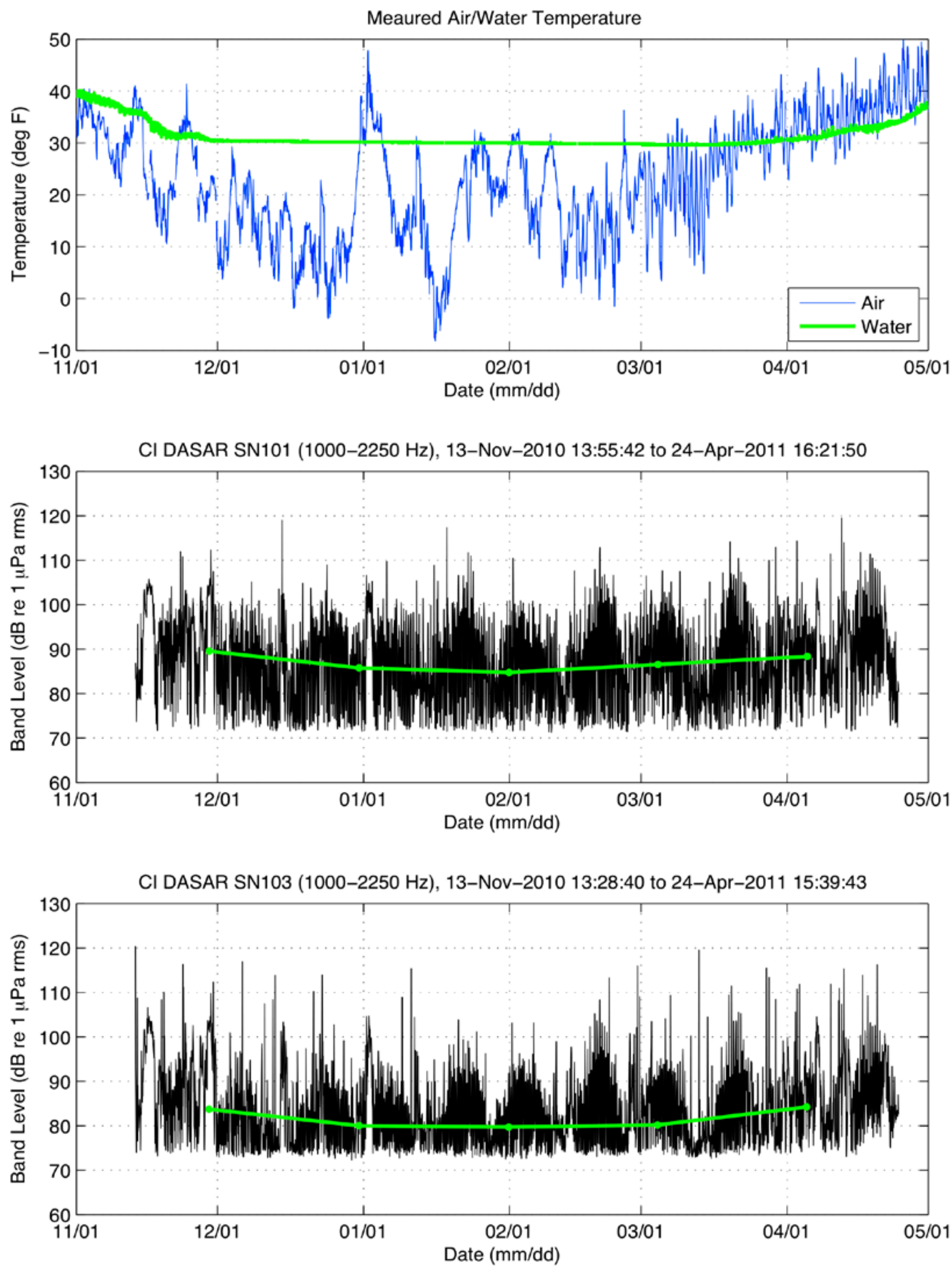


Figure 7. Water temperature (top, green line), band level for SN101 (middle, black line), and band level for SN103 (bottom, black line) as a function of time across the five-month overwinter deployment period. Central moving median values for band level are indicated by the green connected dots in middle and bottom plots.

Figure 8 shows percentile sound pressure spectral density levels measured by SN101 (top) and SN103 (bottom) for the overwinter deployment period. As with the overwinter band level calculations in Figure 4, the acoustic data set was "sampled" at the first 60 s of every 128 MB file, or about once an hour. Spectral density levels between the two DASARs are roughly equivalent. The humps in the spectra around 260 Hz and 620 Hz are mechanical resonances in the DASAR, specifically, "drum head" resonances in the top cap of the cylindrical pressure case containing the electronics. The 50^{th} percentile (median) spectral density curve corresponds roughly to Sea State 2 for SN101 and Sea State 1 for SN103. The minimum percentile spectral density curve corresponds to the approximately 40 dB re 1 $\mu Pa^2/Hz$ noise floor of the DASARs.

Percentile representations of 1/3-octave band levels for SN101 (top) and SN103 (bottom) for the overwinter deployment period are depicted in Figure 9. One-third-octave band filters are proportional bandwidth filters whose output is determined by integrating over a range of frequencies (band) to obtain the mean square pressure expected in the band. Although the frequencies labeled on the x-axis of Figure 9 are shown at equal spacing, note that the filter bandwidth of 1/3-octave bands is proportional to filter center frequency and, thus, increases with increasing frequency. The resonances seen in the spectral density levels plots (Figure 8) are also seen clearly in the 1/3-octave band level representation. Across the DASAR's band of interest for beluga whistles (1000–2250 Hz), the average 1/3-octave band level is 80.9 and 75.6 dB re 1 μPa for SN101 and SN103, respectively, 50% of the time.

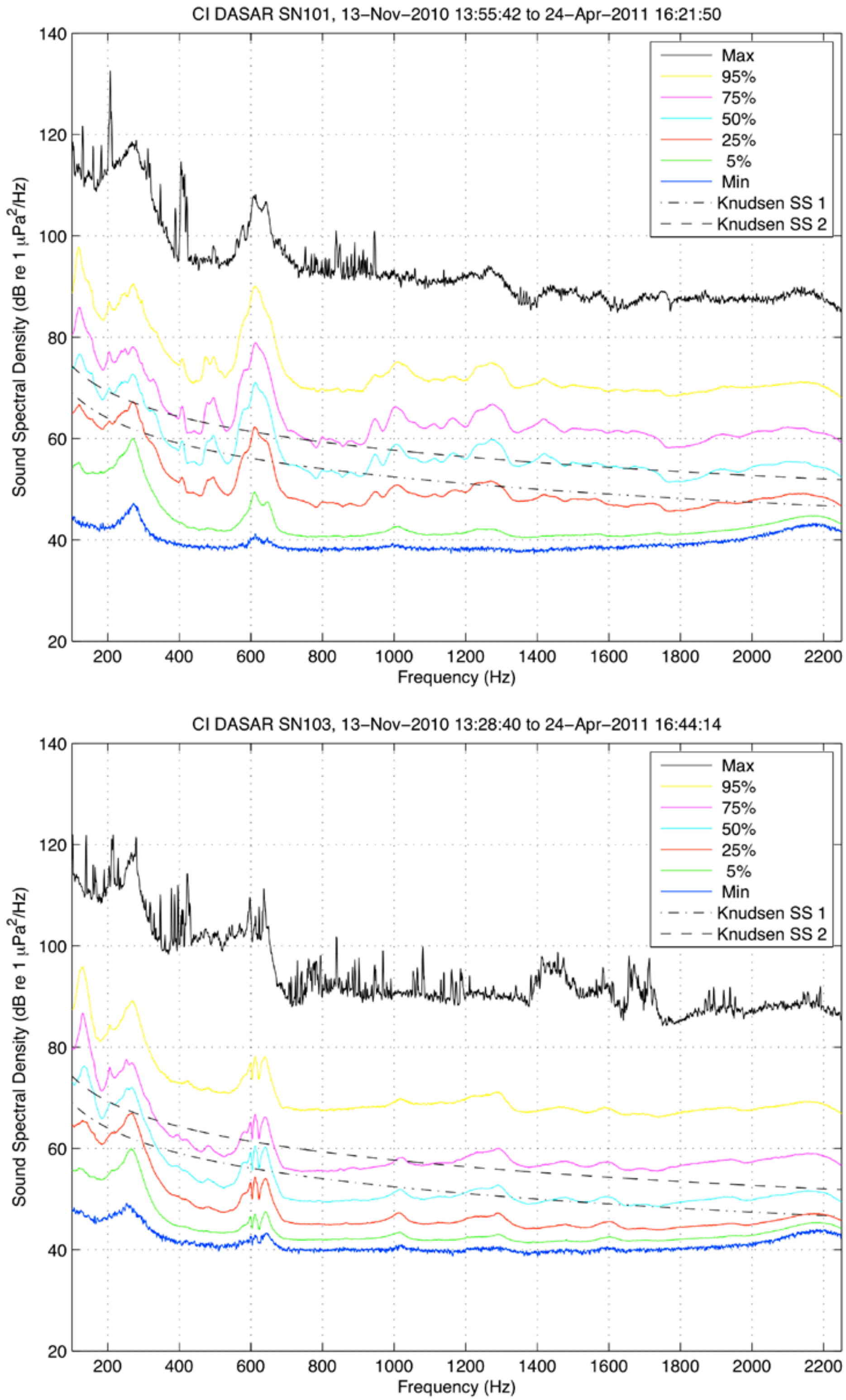


Figure 8. Percentile sound pressure spectral density levels measured by SN101 (top) and SN103 (bottom) over the five-month overwinter deployment period.

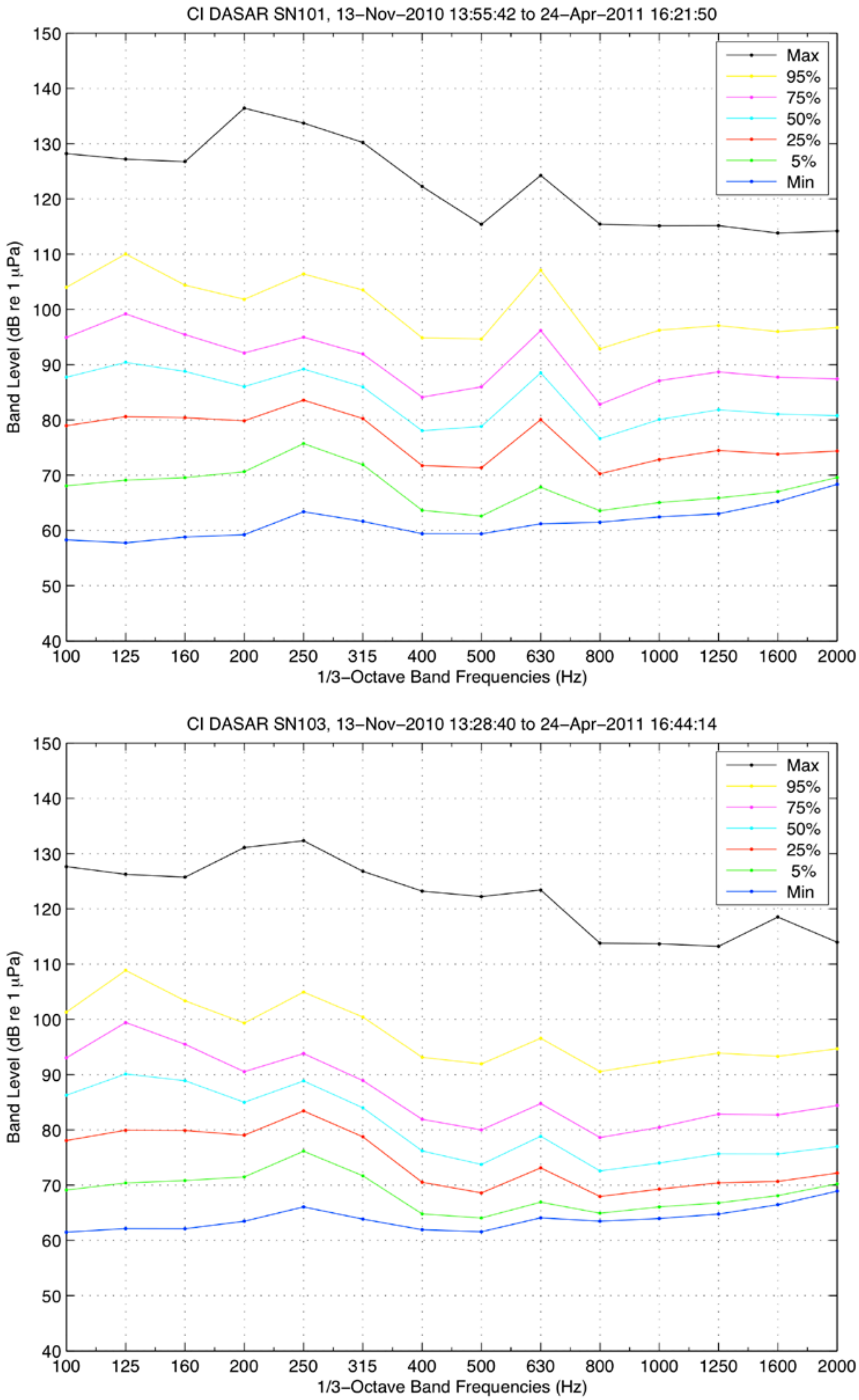


Figure 9. Percentile 1/3-octave band levels measured by SN101 (top) and SN103 (bottom) over the five-month overwinter deployment period.

Noise Contamination

The high current environment of Cook Inlet makes the region desirable for tidal power generation but, likewise, creates an extremely challenging environment for acoustic measurements. In addition to common ambient noise sources such as vessels and wind-generated waves, known contributors to sound measurements in this area include rolling gravel on the seafloor, debris striking acoustic recorders, and turbulence-induced flow noise around hydrophones. The latter two—debris collisions and flow noise—should not be included in estimates of ambient noise levels.

In Cook Inlet, debris striking acoustic recorders reveals itself as impulsive, broadband transients with energy primarily in the 1000–2000 Hz frequency range and possibly higher. Analyses of DASAR data from Fall 2010 at-sea trials indicated that such events were common in the Deployment Area.

Flow noise, often termed "pseudo-sound," is a pressure fluctuation which does not propagate at the speed of sound and decays rapidly (Strasberg 1979). Greeneridge Sciences' Cook Inlet DASARs were designed to mitigate flow noise through the use of an acoustically-transparent shroud: an 18"-diameter, 3/16"-thick dome composed of ABS plastic surrounding the three hydrophones and electronics housing.

The purpose of the aforementioned shroud was two-fold: protection against flying debris and reduction of flow noise. Both objectives appear to have been met, and the DASAR's three-hydrophone design, originally intended solely for beluga call bearing estimation, proved fortuitous in removal of contamination from ambient noise measurements.

Identifying Contamination

A well-known method of identifying pseudo-sound contamination in underwater acoustic signals is by measuring the spectral coherence between two hydrophones (Deane 2000). The magnitude-squared coherence, C_{xy}, between two hydrophones with a fixed separation is defined as:

$$C_{xy} = \frac{|S_{xy}|^2}{S_{xx}S_{yy}} = \gamma^2 \qquad (1)$$

where $|S_{xy}|$ is the magnitude of the cross-spectral density between hydrophones *x* and *y*, and S_{xx} and S_{yy} are the autospectral density of *x* and *y*, respectively. If the hydrophone separation is a small fraction of a wavelength, propagating acoustic signals (such as the desired ambient noise, in this case) will be highly correlated on the pair of hydrophones, while non-acoustic noise phenomena will produce uncorrelated pressure waveforms on the two hydrophones. In other words, because the two hydrophones are close together relative to the wavelengths of the acoustic sounds of interest, the ambient noise signal received on the two hydrophones are effectively the same. By assumption, contaminated signals are independent and, therefore, uncorrelated with each other and with the ambient noise.

The coherence, γ, of SN101 hydrophones pairs for a 60-s period on 5 December 2010 is shown in Figure 10. The top panel depicts the coherence for Hydrophones 1 and 2, the middle panel

Hydrophones 1 and 3, and the bottom panel Hydrophones 2 and 3. Coherence values near 1 indicate signals that are highly correlated; coherence values near 0 indicate signals that are highly uncorrelated. In this example, received signals are largely coherent (i.e., associated with a propagating acoustic field) across most of the DASAR band with notable dips in coherence at certain frequencies, some of which are dependent on the hydrophone pair. In addition, the “drum head” resonances at approximately 260 and 620 Hz exhibit fairly high coherence, suggesting that this particular mechanical resonance affects all three hydrophones in roughly the same manner. The degree to which flow noise and debris collisions each contribute to contamination of the ambient noise measurement is unknown. Note that Figure 10 presents just one example, and the coherence estimate varies significantly depending on the environmental conditions of a given time period.

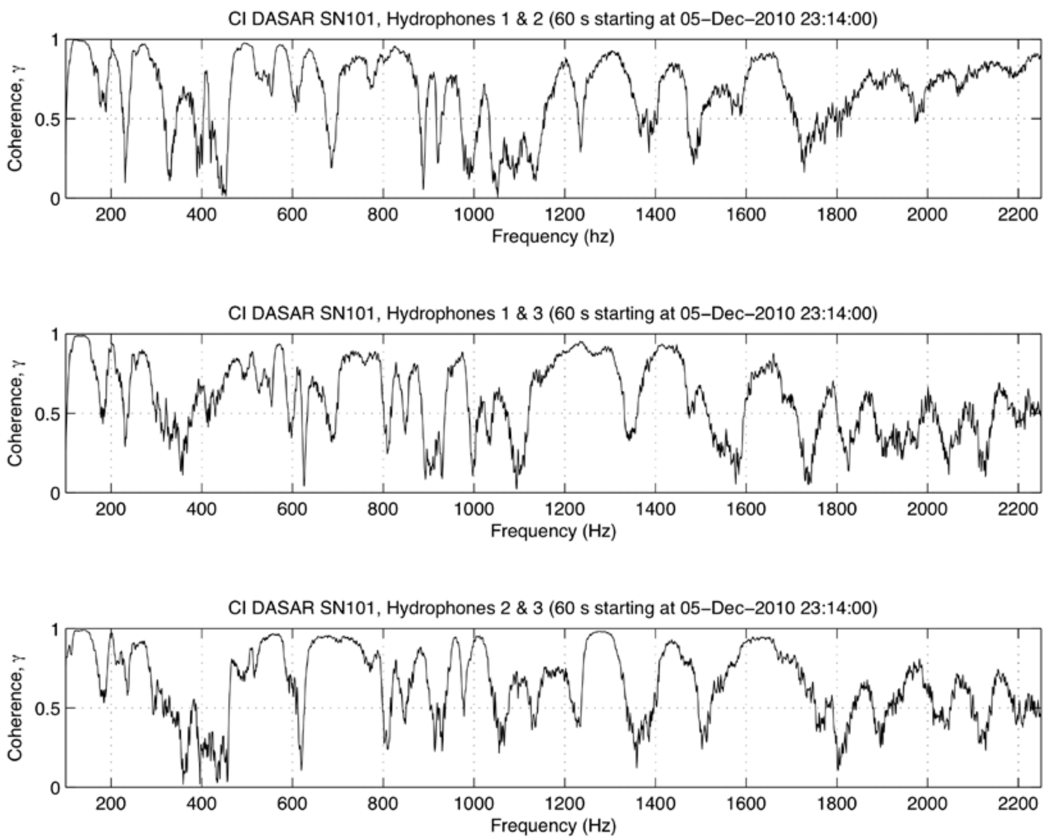


Figure 10. Coherence of SN101 hydrophones pairs for a 60-s period beginning on 5 December 2010 at 23:14 AKST.

Contamination Removal

Once the contamination is identified, it can be removed from the recorded signal through a simple correction using the coherence estimate. For sound pressure spectral density levels S_x and S_y measured by two hydrophones x and y, respectively, and coherence γ defined in Equation (1):

$$10\log S_a = 5\log S_x + 5\log S_y + 10\log\gamma \quad (2)$$

where S_a represents the sound pressure spectral density level of the true ambient noise (Buck and Greene 1980). For $\gamma > 0.9$, the correction to the average power level at the two hydrophones is less than 0.5 dB re 1 μPa^2/Hz. For $\gamma = 0.5$, the average power level is decreased by 3 dB re 1 μPa^2/Hz.

Figure 11 shows the spectral density levels (red and blue) for different SN101 hydrophone pairs (top, middle, and bottom plots) and the average spectral density level with contamination removed (black). The time period is the same as that shown in Figure 10. In comparing with Figure 10, the low coherence associated with some frequency bands results in reduced ambient noise spectral density levels at those frequencies.

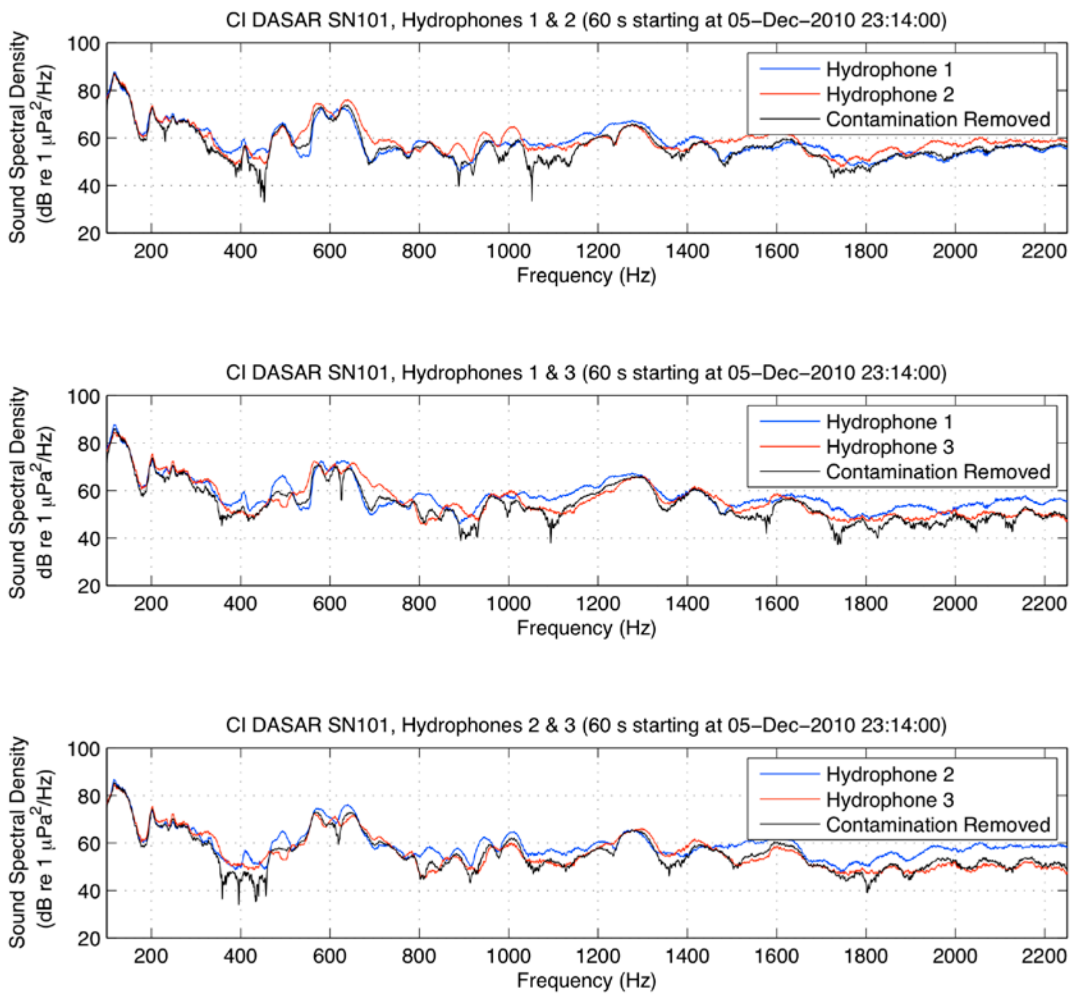


Figure 11. Spectral density levels for SN101 hydrophone pairs (red and blue) and spectral density level with contamination removed (black). Time period is the same 60-s period beginning on 5 December 2010 at 23:14 AKST shown in Figure 10.

The DASAR's three hydrophones yield three pair-wise estimates of true ambient noise levels. As alluded to previously, due to hydrophone layout and possible refractive coloring by the dome, the DASAR's orientation on the seafloor has a small but noticeable effect on received levels. Consequently, the three estimates of ambient noise were further averaged to yield a single estimate of ambient noise for a given DASAR. Figure 12 presents this final ambient noise level for the time period associated with Figures 10 and 11.

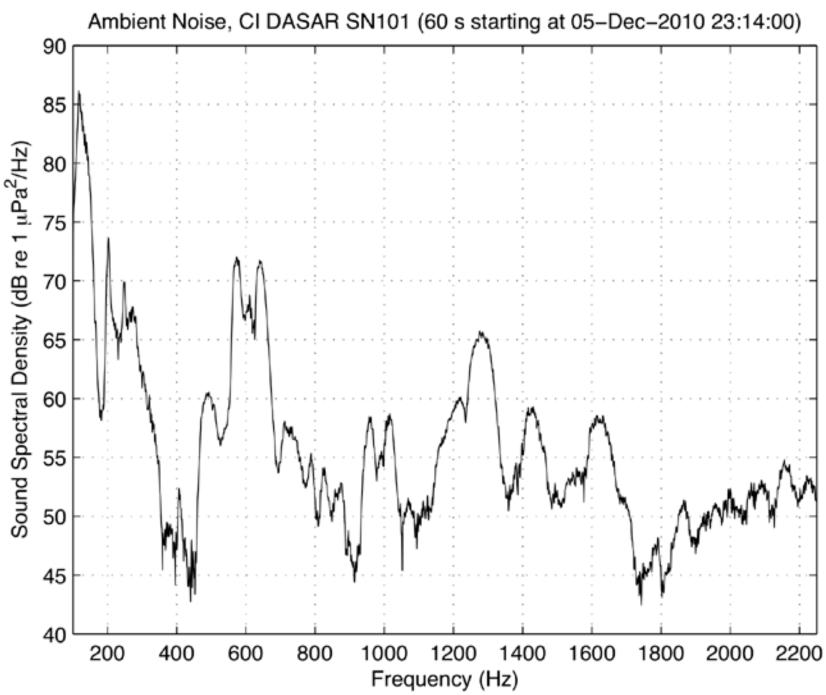


Figure 12. Ambient noise spectrum levels (contamination removed) for the 60-s time period associated with Figures 9 and 10.

Ambient Noise Spectrum Level

Utilizing the methods described in the previous section *Noise Contamination*, ambient noise levels measured by each of the two DASARs were estimated for the entire five-month overwinter period.

Figure 13 shows band level across the 1000–2250 Hz band as a function of time for SN101 (top) and SN103 (bottom), with noise contamination removed. Overall band levels are lower than in Figure 4 but time-varying characteristics at these time scales remain the same. In particular, band level variation with current speed is still evident, indicative of the tidal current's role in ambient noise levels. As current increases, the noise associated with rolling gravel, flying debris (debris collisions with the DASAR notwithstanding), and additional unidentified noise sources legitimately contribute to the ambient noise field.

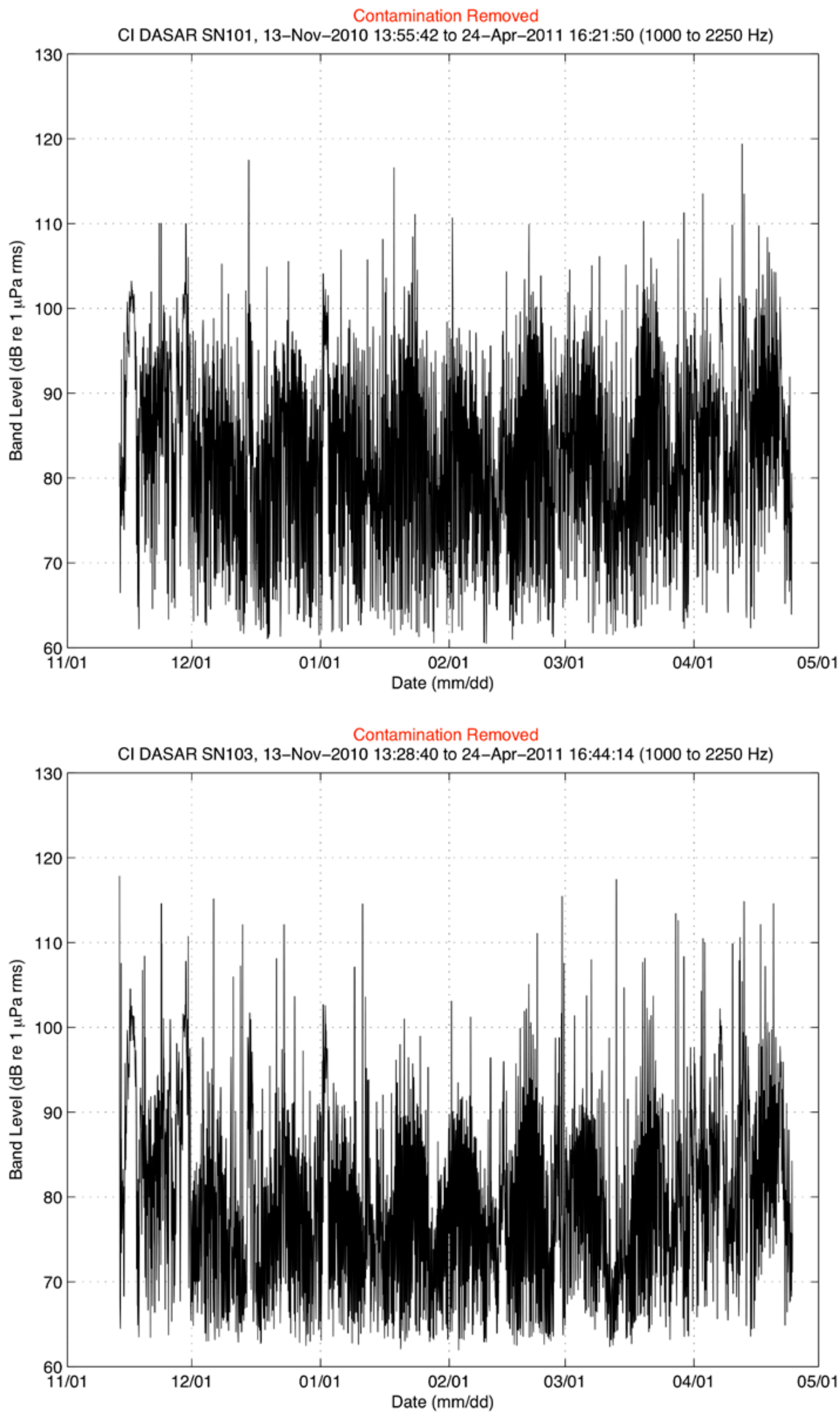


Figure 13. Contamination-removed band level for 1000–2250 Hz for SN101 (top) and SN103 (bottom) as a function of time across the five-month overwinter deployment period.

Figures 14 and 15 show the sound spectral density levels and 1/3-octave band levels, respectively, with noise contamination removed for SN101 (top) and SN103 (bottom). These figures are analogous to Figures 8 and 9. In Figure 14, note that spectral density values below approximately 40 dB re 1 $\mu Pa^2/Hz$ are an artifact of the contamination removal calculation of Equation (2). The noise floor of the DASARs is known to be around 40 dB re 1 $\mu Pa^2/Hz$, and, thus, values that fall below the known noise floor are not physically meaningful. The most notable effect of contamination removal is a decrease in spectral density levels (and, similarly, 1/3-octave band levels), particularly above 1000 Hz. Consequently, median (50^{th} percentile) spectral density levels, originally estimated to being equivalent to roughly Sea State 2 conditions, dropped to that for Sea State 1 conditions or less. Across the DASAR's band of interest for beluga whistles (1000–2250 Hz), the average 1/3-octave band level was 77.1 and 72.3 re 1 μPa for SN101 and SN103, respectively, 50% of the time—roughly 3 dB less than received levels corrupted by noise contamination. As such, the DASAR's detection capabilities in the band of interest for beluga whistles (1000–2250 Hz) can be greatly improved with contamination removed. In other words, the effective signal-to-noise ratio is increased with removal of noise contamination, and, thus, the DASARs are able to discern lower source level and/or more distant beluga calls compared to other acoustic measurement methods.

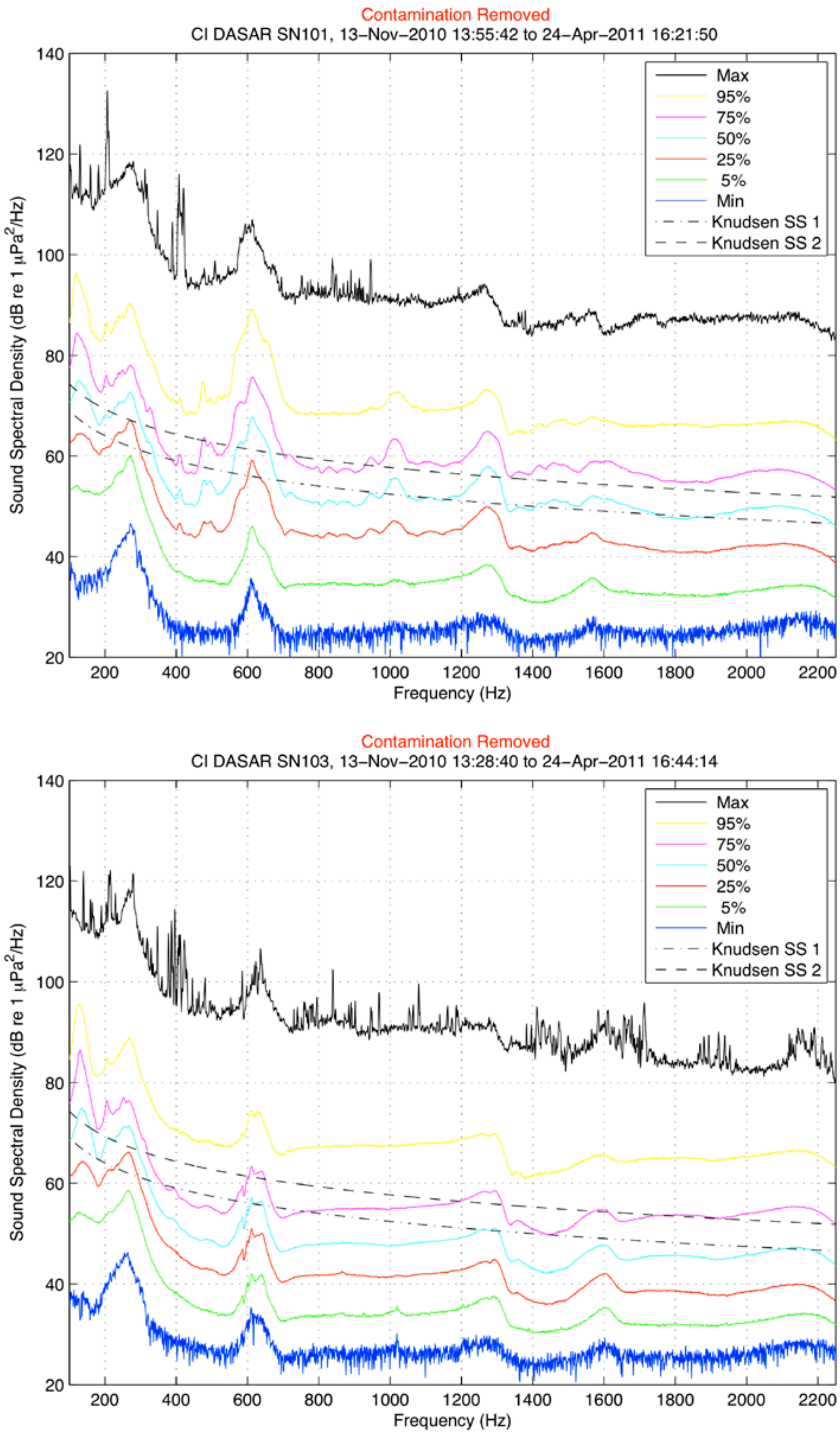
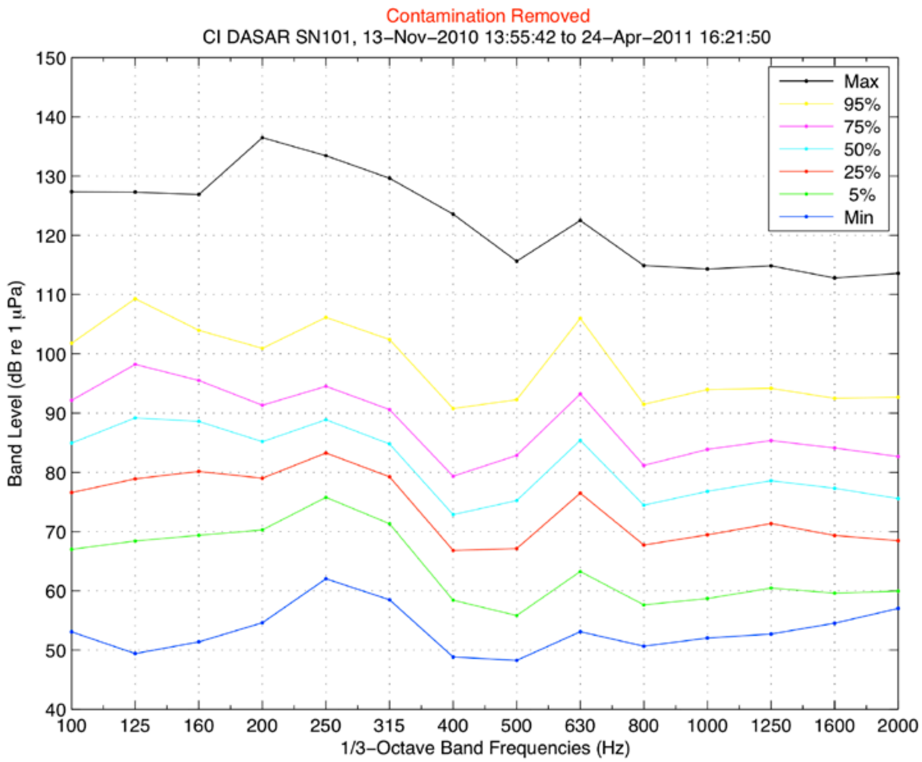


Figure 14. Contamination-removed percentile sound pressure spectral density levels measured by SN101 (top) and SN103 (bottom) over the five-month overwinter deployment period.



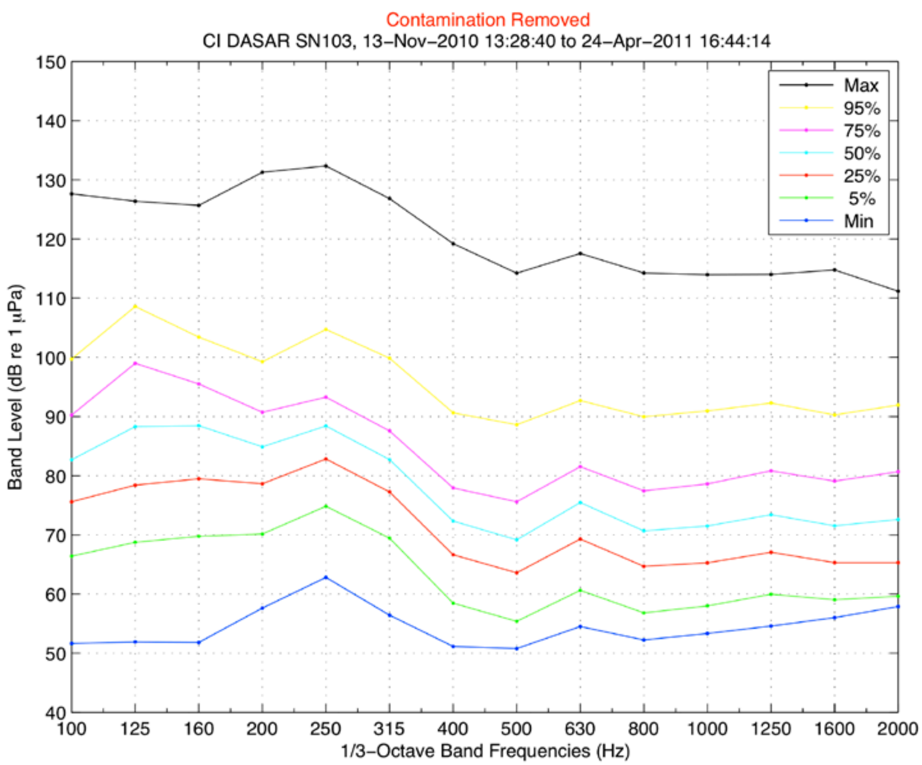


Figure 15. Contamination-removed percentile 1/3-octave band levels measured by SN101 (top) and SN103 (bottom) over the five-month overwinter deployment period.

Conclusions

Long-term, continuous, ambient noise measurements were successfully conducted in the high-current environment of Cook Inlet. Contributors to ambient noise in the Deployment Area include rolling gravel and suspended debris as a function of tidal current, anthropogenic sources such as transiting vessels and aircraft overflights, and wind-generated waves. Although the Acousonde, a high-bandwidth recorder, was adversely affected by flow noise and debris collisions associated with the area's strong tidal currents, the Cook Inlet DASAR, with its flow-noise-mitigating dome and multiple sensor configuration, reduced such noise contamination and enabled measurement of the true ambient noise field. After removal of uncorrelated signals from the sound recordings, ambient noise levels from November 2010 through April 2011 were estimated to be roughly equivalent to Sea State 1 conditions, and, in the operational band of interest for beluga whistles (1000–2250 Hz), the average 1/3-octave band level was 72.3–77.1 dB re 1 μPa half of the time.

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GSI TECHNICAL MEMORANDUM 442-6B

To: Monty Worthington, ORPC AK

From: Katherine H. Kim, Robert G. Norman, Dawn Grebner

Date: 20 January 2014

Re: East Foreland ambient noise and beluga vocalization detection report

This is a report of a study conducted by Greeneridge Sciences, Inc., sponsored by Ocean Renewable Power Company (ORPC), to acoustically monitor the Cook Inlet Tidal Energy Project's East Foreland site. This report covers (i) recordings from a one-month test deployment at the East Foreland study site from 26 September 2012 – 21 October 2012 and (ii) overwinter recordings from 21 October 2012 – 27 January 2013. As such, this report supplants GSI Technical Memorandum 442-6, which included preliminary results for the one-month test deployment only.

Objectives

The study has two primary objectives

1. Measure ambient sound levels in the Deployment Area in Cook Inlet for extended recording periods.
2. Detect beluga whale vocalizations, specifically whistles, in the Deployment Area in Cook Inlet.

These two objectives were previously met for the Cook Inlet Tidal Energy Project's Fire Island site, as reported in GSI Technical Memorandum 442-2 (Kim et al. 2011) and GSI Technical Memoranda 442-5/5B (Kim 2012, Kim et al. 2013), respectively. The same acoustic data analysis techniques were applied to the East Foreland site, the subject of this report.

Ambient Sound Levels

One-Month Test Deployment

One DASAR (SN103) was deployed at the East Foreland area of Cook Inlet on 23 September 2012. Unlike previous DASAR deployments which rely on grappling for a groundline and anchor for retrieval, the DASAR at East Foreland was tethered to shore via an armored cable. This one-month deployment served as a test deployment for a subsequent, five-month, overwinter deployment.

The DASAR recorded continuously (100% "duty cycle") from 21 September 2012 at 16:02:44 AKDT to 25 October 2012 at 16:12:18, approximately 34 days. About six days of mobilization and demobilization sounds were recorded before and after the DASAR's actual date/time on the seafloor. Results in this report exclude mob/demob sounds and are thus limited to the period 26 September 2012,00:28:31 AKDT to 21 October 2012, 09:33:24 AKDT.

Figure 1 presents band level (blue line) as a function of time across the entire one-month deployment. In the interest of data compression, data from the first 60 s of every 128 MB raw acoustic data file (a period of approximately 1 hr) was utilized in the calculation. For the DASAR spectral estimation results that follow, 60 s of data sampled at 5000 Hz were analyzed using a 5000-point FFT, Blackman-Harris window, and 50% overlap. The blue line in the upper plot of Figure 1 shows the band level from 1000–2250 Hz for DASAR SN103. The red line in the lower plot shows the predicted tidal height. The influence on band levels of spring and neap tides occurring approximately twice a month is apparent, in particular in the pattern of band level peaks. The influence of the semidiurnal tides is also evident in Figure 1, as seen in the higher-frequency cycles in band level. As current increases with ebb and flood tides, received levels on the DASAR generally increase. As tidal current approaches zero at slack tide, received levels similarly decrease, in general.

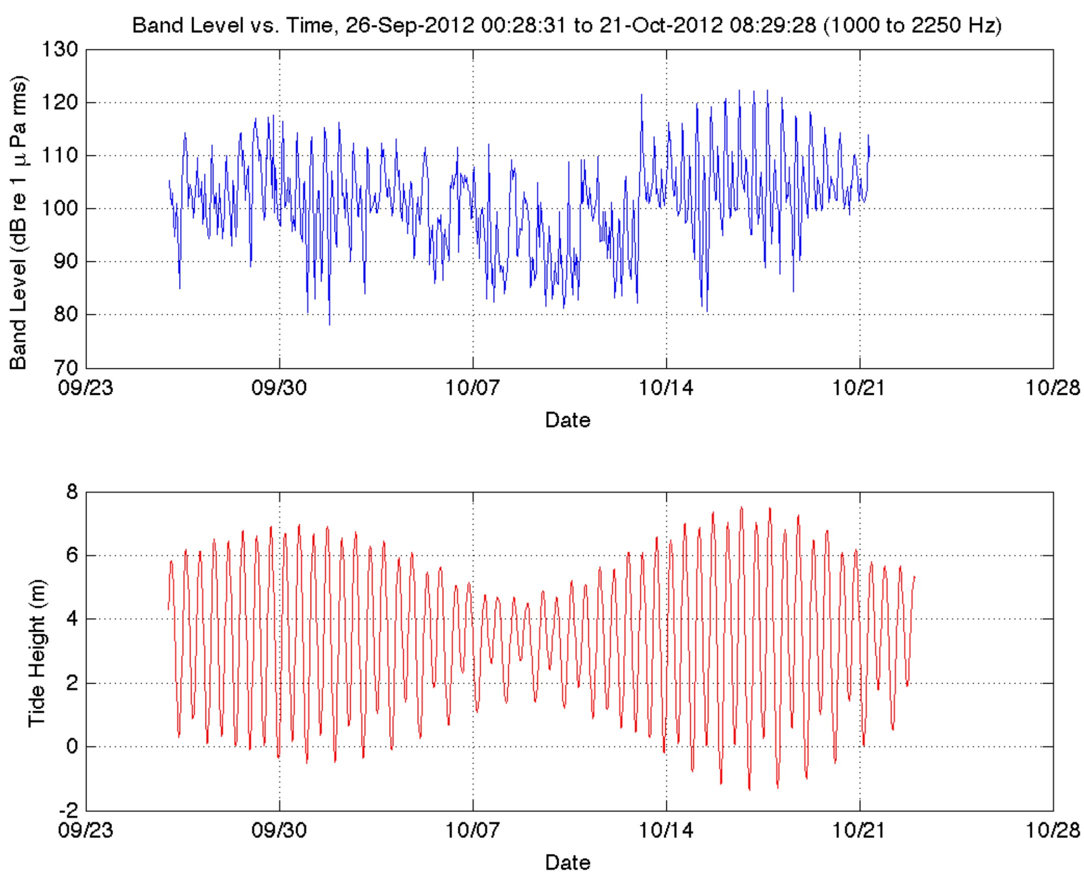


Figure 1. Band level for SN103 (blue, upper plot) and tidal height (red, lower plot) as a function of time across the one-month test deployment period.

The increased sound levels associated with high currents, as seen in Figure 1, can be attributed to rolling gravel on the seafloor, debris striking the acoustic recorders, and turbulence-induced flow noise ("pseudo-sound") around the hydrophone sensors. Although rolling gravel (as well as wind-generated waves, vessel noise, and seismic airgun activity) present in the East Foreland study area are all arguably legitimate contributors to the local soundscape, debris striking the recorders and flow noise are sources of noise not representative of ambient sound. Indeed the latter, flow noise, does not propagate in the same manner as typical acoustic pressure fluctuations and is an inherent challenge to making high-quality acoustic measurements in high-current environments.

Greeneridge Sciences' Cook Inlet DASARs' design helps to mitigate against these sources of noise contamination. First, its acoustically-transparent, ABS plastic shroud provides physical protection against flying debris and reduces flow noise both in the field. Second, its multiple hydrophones enables further reduction in pseudo-sound contamination in post-processing by exploiting the spectral coherence between two hydrophones to identify pseudo-sound contamination (Deane 2000) and then applying a correction to sound pressure spectral density levels using the coherence estimate (Buck and Greene 1980). Technical details and examples are provided in GSI Technical Memorandum 442-2 (Kim et al. 2011).

Figure 2 shows percentile sound pressure spectral density levels measured over the one-month deployment period. Figure 3 shows the percentile sound pressure spectral density levels measured over the same period but with pseudo-sound noise contamination removed. As with the band level calculations in Figure 1, the acoustic data set was "sampled" at the first 60 s of every 128 MB file, or about once an hour. The humps in the spectra around 260 Hz and 620 Hz are mechanical resonances in the DASAR, specifically, "drum head" resonances in the top cap of the cylindrical pressure case containing the electronics. The 50^{th} percentile (median) spectral density curve is shown in cyan in Figures 2 and 3. This average spectral density level at the East Foreland site is substantially higher than the average spectral density level at the Fire Island site, where the average level was in excess of 10 dB lower over a two-day period in September 2010 (Figure 2 in Greene 2010) and roughly 20 dB lower over a five-month period in November 2010–April 2011 (Figure 8 in Kim et al. 2011). The minimum percentile spectral density curve corresponds to the approximately 40 dB re 1 μPa^2/Hz noise floor of the DASARs which, by design, resides close to Sea State 0.

Percentile representations of 1/3-octave band levels for the one-month deployment period are depicted in Figure 4. One-third-octave band filters are proportional bandwidth filters whose output is determined by integrating over a range of frequencies (band) to obtain the mean square pressure expected in the band. Although the frequencies labeled on the x-axis of Figure 4 are shown at equal spacing, note that the filter bandwidth of 1/3-octave bands is proportional to filter center frequency and, thus, increases with increasing frequency. The resonances seen in the spectral density levels plots (Figures 2 and 3) are also seen clearly in the 1/3-octave band level representation. Across the DASAR's band of interest for beluga whistles (1000–2250 Hz), the average 1/3-octave band level was 95.2 dB re 1 μPa and 92.8 dB re 1 μPa (a 2.4 dB difference), for pseudo-noise present and pseudo-noise removed cases, respectively, 50% of the time.

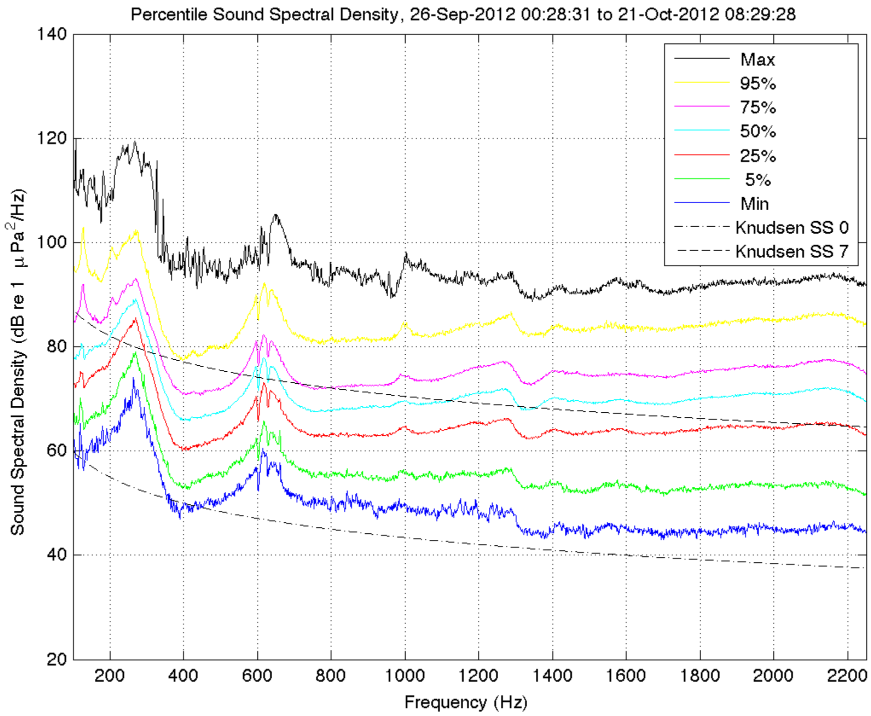


Figure 2. Percentile sound pressure spectral density levels measured by SN103 over the one-month test deployment period.

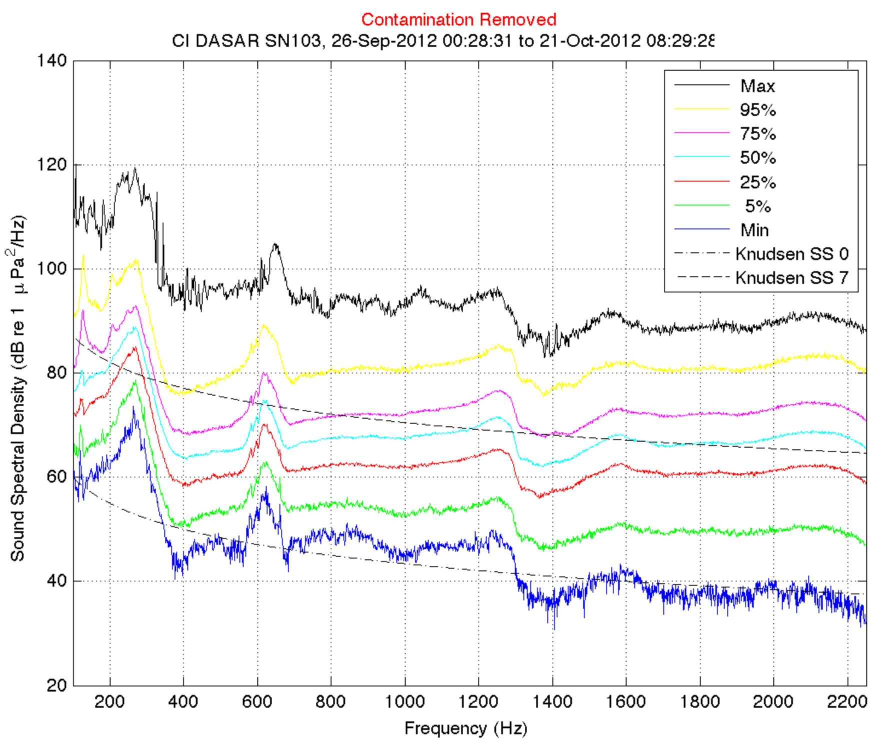


Figure 3. Percentile sound pressure spectral density levels measured by SN103 over the one-month test deployment period, with pseudo-sound noise contamination removed.

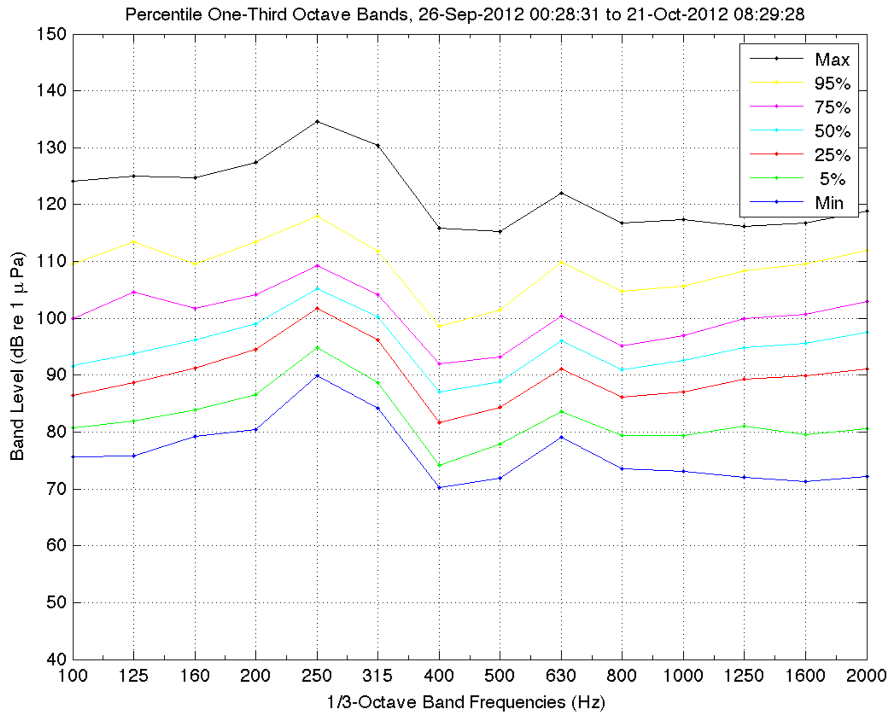


Figure 4. Percentile 1/3-octave band levels measured by SN103 over the one-month test deployment period.

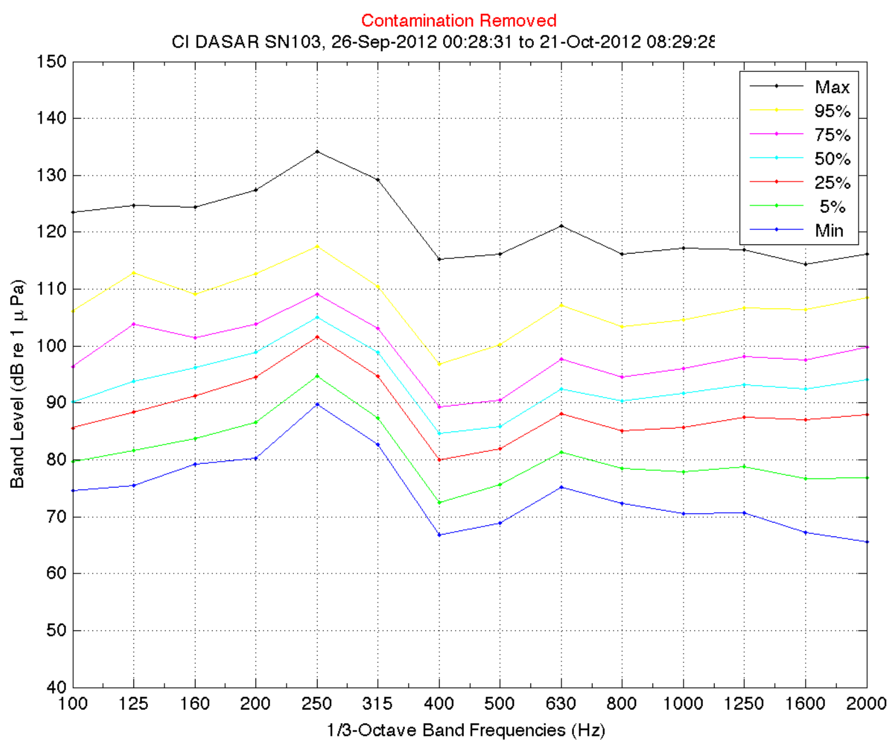


Figure 5. Percentile 1/3-octave band levels measured by SN103 over the one-month test deployment period, with pseudo-sound noise contamination removed.

Overwinter Deployment

For the proposed five-month, overwinter deployment, two DASARs (SN101 and SN102) were deployed at the East Foreland area on 21 October 2012. Like the test deployment in the previous month, the DASARs were tethered to shore via an armored cable.

DASAR SN101 recorded continuously (100% "duty cycle") from 21 October 2012 at 09:02:19 AKDT to 29 March 2013 at 03:28:13 AKDT. (Daylight saving time was in effect at the time of deployment but had ended prior to instrument retrievals. For consistency, daylight saving time is used throughout the overwinter deployment period.) Approximately six hours of mobilization sounds were recorded before the DASAR's actual date/time on the seafloor. In addition, beginning on 27 January 2013, SN101 began recording sounds reminiscent of physical disturbance to the DASAR, culminating in an unidentifiable catastrophic event around 2300 AKDT on that day (although SN101's hard drive continued to record non-acoustic "data" to disk through March). The acoustic records were consistent with the physical state of SN101 upon recovery; its plastic shroud and two of its three hydrophones had been ripped off, and the remaining hydrophone was dangling by its electrical cable. Consequently, results in this report are limited to the period 21 October 2012, 13:55:30 AKDT to 27 January 2013, 22:36:04 AKDT for SN101. The tether for SN102 was severed, presumably due to harsh environmental conditions, and SN102 was never recovered.

Figure 6 depicts the band level across the beluga band of interest (1000–2250 Hz) throughout the overwinter deployment. Compared to the one-month deployment, the association between band levels and tides is even more readily apparent over the time scale of the overwinter deployment.

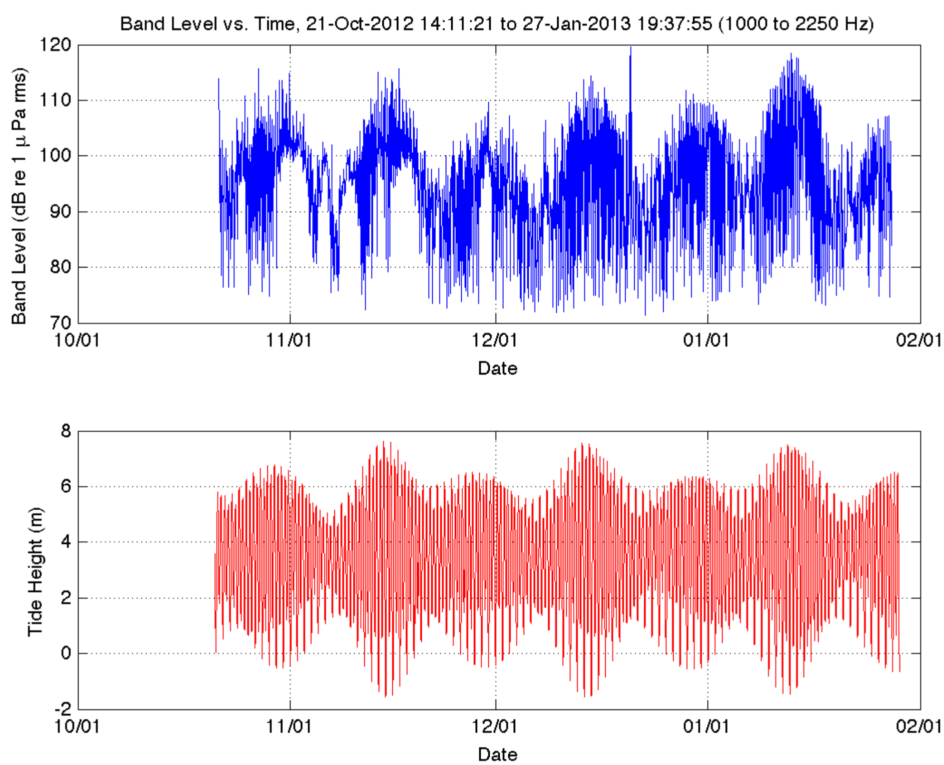


Figure 6. Band level for SN101 (blue, upper plot) and tidal height (red, lower plot) as a function of time across the overwinter deployment period.

Figures 7 and 8 show the sound spectral density levels with and without noise contamination removed, respectively. In Figure 8, note that the spectral density values below approximately 40 dB re 1 μPa^2/Hz are an artifact of the contamination removal calculation (details in Kim et al. 2011) since the noise floor of the DASARs is known to be around 40 dB re 1 μPa^2/Hz. Spectral density levels were higher than those of the Fire Island site, but the levels themselves and the difference compared to Fire Island were lower than recordings made during the test deployment one month earlier.

Percentile representations of 1/3-octave band levels for the overwinter deployment period are depicted in Figures 9 (pseudo-noise present) and 10 (pseudo-noise removed). Across the DASAR's band of interest for beluga whistles (1000–2250 Hz), 50% of the time, the 1/3-octave band level was on average 89.4 dB re 1 μPa with pseudo-noise was present and 87.3 dB re 1 μPa with pseudo-noise removed, or 2.1 dB less than received levels corrupted by noise contamination. By comparison, for the overwinter period at the Fire Island site, sound level differences attributed to pseudo-noise were 3.3 dB and 3.9 dB for the two DASARs deployed at Fire Island. This suggests that uncorrelated noise was greater at the Fire Island site than at the East Foreland site. One source of tidal data predicted that maximum tidal height at East Foreland for October 2012–January 2013 was 9.9 m and, at Fire Island for November 2010–April 2011, was a comparable 9.8 m (Hahn 2007). However, a different source of tidal data predicted significant differences in maximum tidal heights (and, thus, current speeds and pseudo-noise) between the two sites (Lutus 2011). In Lutus's model, maximum tidal height was 7.5 m at East Foreland and 10.7 m at Fire Island. The difference between the two tidal models is likely due to differences in tidal station locations in the two models coupled with the highly dynamic oceanographic environment of the two sites. Unfortunately, Lutus's model lacked predicted current data for either site. Hahn's model provided current data for three stations around Fire Island, with maximum currents varying by several knots among stations during the time period of interest. Lacking measurements of currents at DASAR deployment locations for the two sites, one can only hypothesize that the higher uncorrelated noise levels at Fire Island compared to East Foreland were due to higher local current speeds possibly encountered at Fire Island. It is possible that the location of the DASARs further offshore at Fire Island may have positioned the instruments in stronger currents that at East Foreland, even though Fire Island is known to exhibit overall lower current velocities.

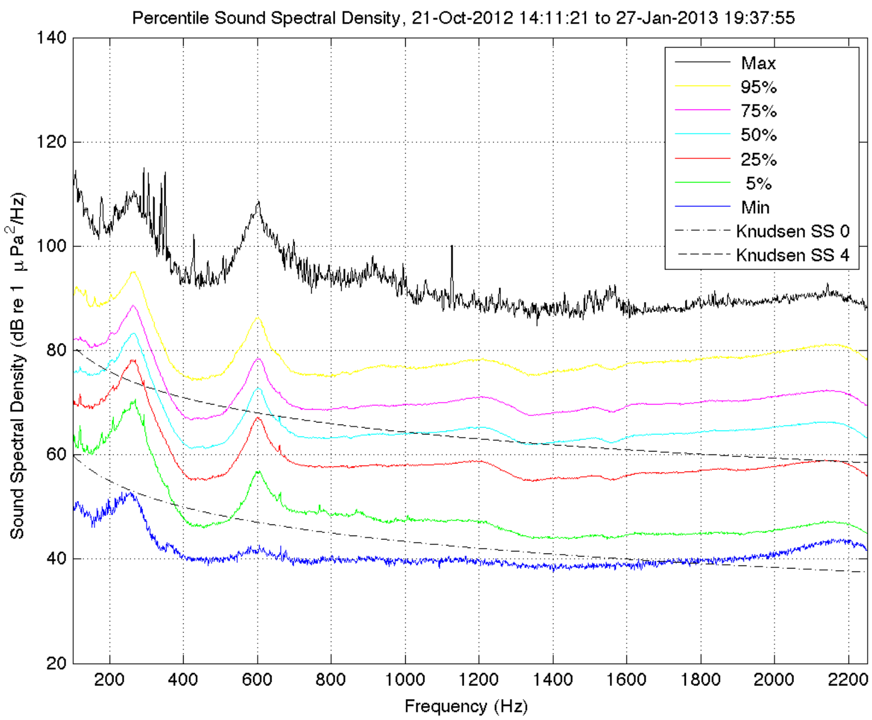


Figure 7. Percentile sound pressure spectral density levels measured by SN101 over the overwinter deployment period.

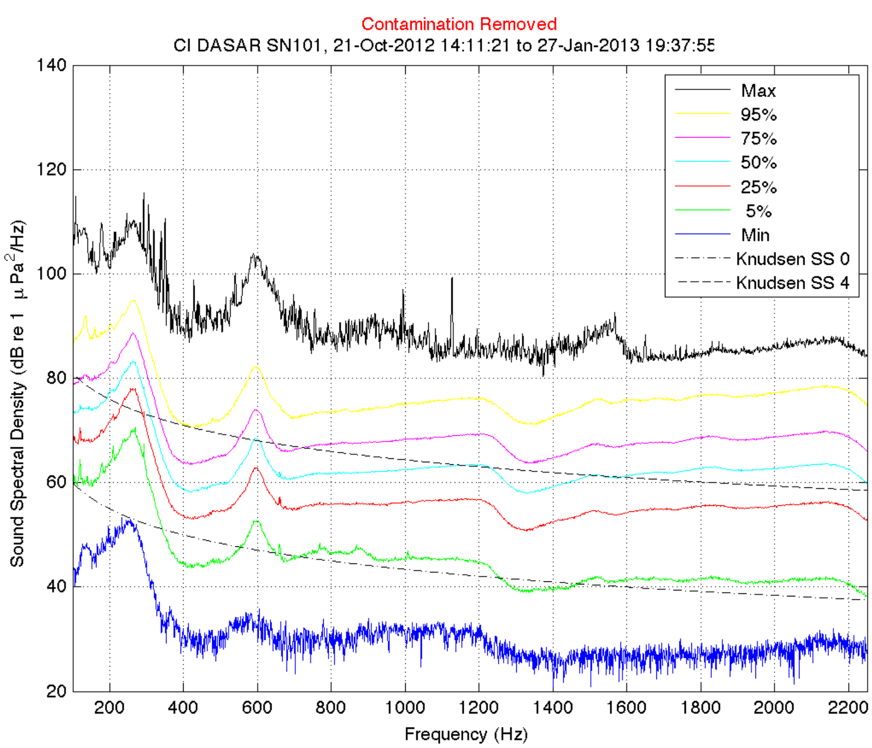


Figure 8. Percentile sound pressure spectral density levels measured by SN101 over the overwinter deployment period, with pseudo-sound noise contamination removed.

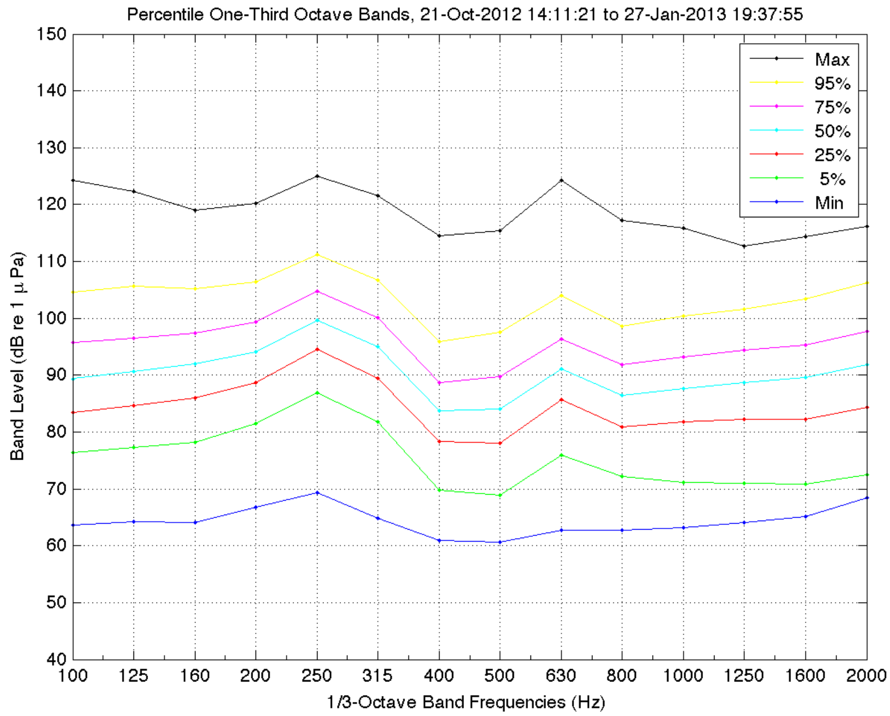


Figure 9. Percentile 1/3-octave band levels measured by SN101 over the overwinter deployment period.

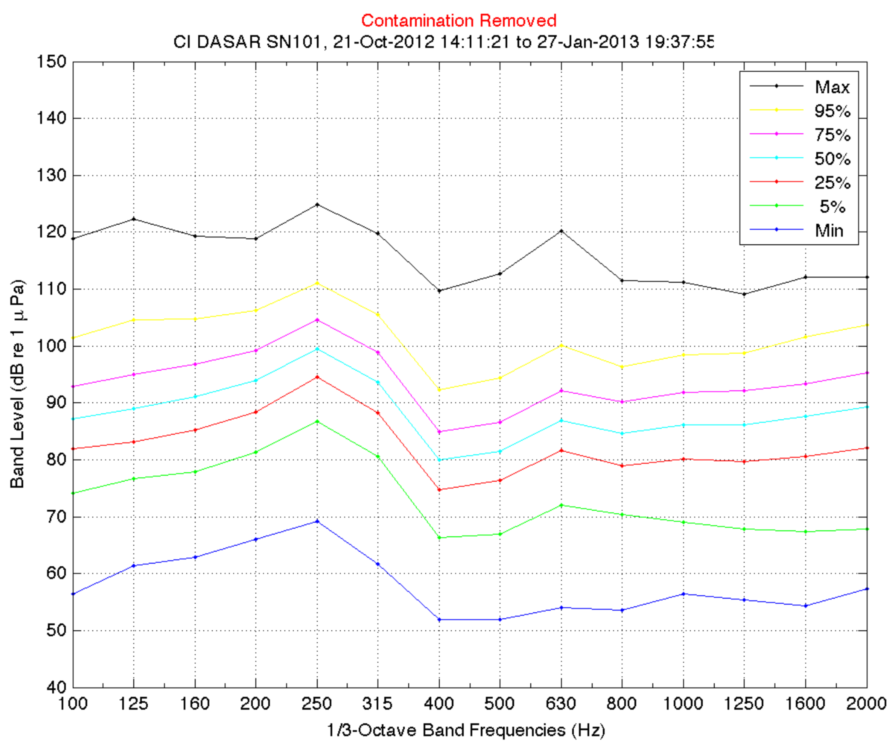


Figure 10. Percentile 1/3-octave band levels measured by SN101 over the overwinter deployment period, with pseudo-sound noise contamination removed.

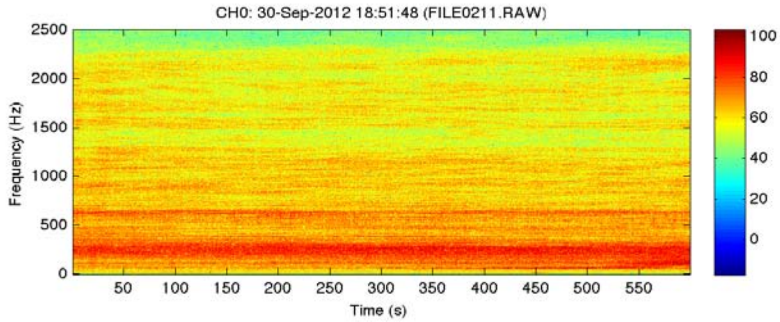
Beluga Whale Vocalizations

One-Month Test Deployment

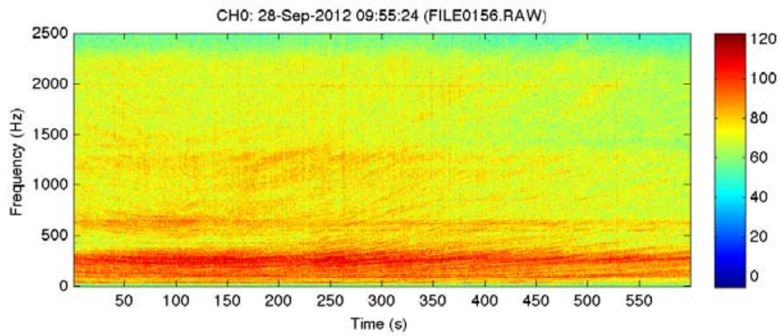
To facilitate detection of beluga whistles on such a large dataset, an automated whistle detector, previously utilized with great success in tracking dolphins off Southern California and subsequently applied without modification to the Fire Island data set, was applied to the East Foreland data set. For a detailed discussion of the detection algorithm, see Kim et al. 2006. In short, an energy detector and frequency tracker were applied to one-minute spectrograms calculated throughout the deployment period.

The same algorithm parameters utilized for the Fire Island data set were applied to the East Foreland data set. Detections that met various performance criteria — for example, exceeded a threshold of the spectrogram's mean energy plus twice its standard deviation, remained within a ±200 Hz frequency window, and met or exceeded a track length of 10 adjacent time bins— were flagged as whistles. The resultant detections were then manually reviewed. While beluga calls were detected at the Fire Island site, no beluga calls were detected at the East Foreland site during the one-month recording period. Indeed, none of the sounds recorded by the DASAR at East Foreland appeared obviously biological in nature.

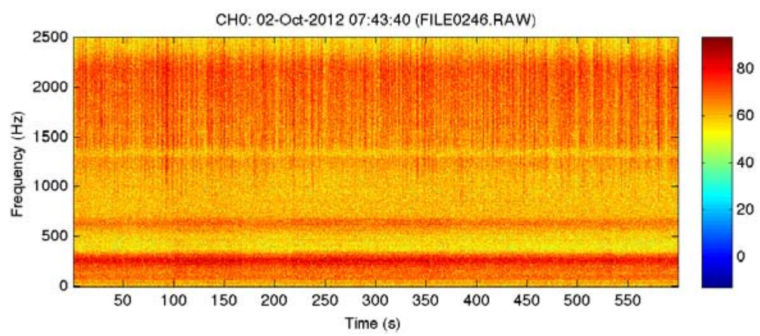
Although no belugas were detected, the examination of false alarms did give insight into the various transient sounds present at East Foreland. Examples of typical transients are shown below in Figure 11. Vessel noise (Figure 11b) and airgun pulses (Figure 11d) were the most common sources of anthropogenic transients. Out of the 29-day recording period, vessels were detected in the recordings on every day but one day (1 October), and roughly 37% of the time, based on a minimum detection duration of one minute. Airguns were detected approximately 3% of the time, on 23, 28, 29, and 30 September. The last airgun pulse was detected 43 minutes after midnight on 30 September. The airgun detections exhibited typical airgun pulse characteristics—high sound levels, short duration, repetitive, persisting on the order of hours, low but broadband frequency range, and reverberation at (presumably) longer ranges—although they had an unusually long inter-pulse interval of 24 seconds. These airgun pulses are hypothesized to originate from a three-dimensional (3D) seismic survey conducted by Apache Alaska Corporation, along the eastern side of the central Cook Inlet near the Nikiski/Kenai area through 30 September (Apache Alaska Corporation 2011, Hendrix et al. 2012). This survey utilized two source vessels, the *M/V Arctic Wolf* and the *M/V Peregrine Falcon*, equipped with 2400 cu. in. and 440 cu. in airgun arrays, which flip-flopped shots at a 12-s interval, thus, explaining the 24-s interval assuming only one source was detected by the DASAR. Further corroboration that the detected pulses originated from the Apache survey was the acoustic detections' coincidence with slack tides. As identified in the IHA application and subsequent post-survey report, marine seismic data were only acquired during low and high slack tides, approximately 2–3 hours over the tide.



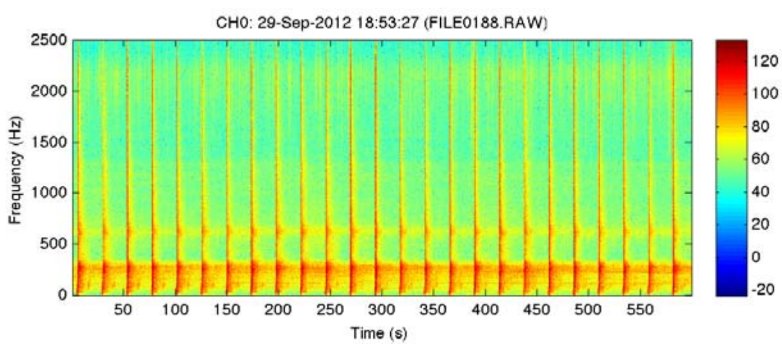
(a) Near maximum tidal current



(b) Vessel noise



(c) Impulsive noise (environmental)



(d) Impulsive noise (airguns)

Figure 11. Typical transients in the Cook Inlet environment at East Foreland.

Overwinter Deployment

Unlike the September test deployment, the overwinter deployment did result in acoustic detections of beluga vocalizations. Table 1 details the beluga event detections, where an event is a minimum of one minute in duration. Noteworthy are two long bouts of calling, each in excess of a hour, on 25 December 2013 and 9 January 2014. The spectrogram from a roughly one-minute period on 25 December is depicted in Figure 12. Time is on the x-axis, frequency is on the y-axis, and the colors represent received sound levels in units of dB re 1 µPa. Red tracks of beluga whistles are readily apparent, especially below 1200 Hz but also around 1500 Hz and 1700 Hz. Black dots indicate time-frequency cells that meet the automated detection criteria for whistles. In this example, there are few false alarms but some noticeable misses.

Date	**Time (AKST)**	**Duration (hh:mm:ss)**
12 Nov 2012	11:53:28	0:01:00
25 Nov 2012	22:58:53	0:01:00
	23:00:53	0:19:00
	23:37:53	0:01:00
26 Nov 2012	6:16:34	0:01:00
	10:39:25	0:01:00
	10:40:25	0:01:00
	10:42:25	0:03:00
	10:47:25	0:02:00
	10:51:25	0:02:00
	10:56:25	0:04:00
	11:03:25	0:02:00
	11:07:25	0:15:00
	11:24:25	0:02:00
	11:29:25	0:03:00
	11:33:25	0:02:00
	11:46:56	0:01:00
	11:49:56	0:01:00
	11:52:56	0:04:00
	11:58:56	0:01:00
	11:59:56	0:01:00
	12:00:56	0:01:00
	12:03:56	0:01:00
	12:07:56	0:01:00
	12:14:56	0:01:00
	12:15:56	0:02:00
	12:30:56	0:01:00
	13:28:23	0:01:00
1 Dec 2012	2:08:36	0:01:00

	6:53:52	0:28:46
	7:23:38	0:46:00
	8:29:22	0:01:00
	8:55:22	0:01:00
	16:38:17	0:03:00
	16:44:17	0:01:00
	16:59:00	0:01:00
	18:13:47	0:01:00
	19:38:43	0:01:00
	19:43:43	0:02:00
	19:48:43	0:01:00
	20:28:30	0:01:00
	21:01:30	0:03:00
	21:51:18	0:01:00
2 Dec 2012	0:19:59	0:02:00
5 Dec 2012	6:54:55	0:09:00
	7:16:09	0:02:00
	7:20:09	0:01:00
	7:24:09	0:03:00
	7:41:09	0:02:00
	7:44:09	0:04:00
	8:03:09	0:05:00
	8:09:09	0:15:14
	8:34:23	0:01:00
	8:35:23	0:02:00
	8:37:23	0:02:00
	8:44:23	0:10:00
	8:56:23	0:07:00
	9:05:23	0:01:00
	9:09:23	0:16:14
	9:37:37	0:01:00
	9:43:37	0:20:00
	10:26:56	0:01:00
	10:29:56	0:01:00
	10:32:56	0:02:00
	10:35:56	0:01:00
	10:37:56	0:04:00
	10:43:56	0:04:00
	10:48:56	0:03:00
	10:53:56	0:05:00
	11:01:56	0:01:00
	11:07:56	0:03:00

	11:52:11	0:04:00
	11:59:11	0:03:00
	12:04:11	0:03:00
	12:07:11	0:01:00
	12:18:11	0:13:14
	21:58:59	0:02:00
	22:04:59	0:01:00
6 Dec 2012	11:19:12	0:01:00
	18:45:39	0:01:00
	18:53:39	0:01:00
	21:24:27	0:01:00
	22:07:46	0:01:00
	22:49:10	0:01:00
	22:55:10	0:02:00
	23:00:10	0:01:00
	23:56:37	0:01:00
7 Dec 2012	0:17:37	0:01:00
	0:22:37	0:02:00
	0:25:37	0:01:00
	0:32:37	0:01:00
	11:59:04	0:03:00
	12:06:04	0:01:00
12 Dec 2012	5:41:32	0:02:00
	5:48:32	0:01:00
	6:07:18	0:02:00
	6:13:18	0:02:00
14 Dec 2012	18:16:49	0:02:00
15 Dec 2012	8:03:22	0:01:00
25 Dec 2012	15:03:38	0:02:00
	15:11:38	0:27:41
	15:39:19	1:24:44
30 Dec 2012	20:00:40	0:13:00
	21:04:48	0:01:00
31 Dec 2012	14:10:28	0:04:00
	20:35:20	0:18:00
1 Jan 2013	14:52:14	0:04:00
9 Jan 2013	15:43:14	1:12:43
14 Jan 2013	7:57:45	0:12:57
20 Jan 2013	13:29:20	0:01:00
22 Jan 2013	13:30:55	0:05:00
	14:05:41	0:10:00
	14:15:41	0:02:00

	14:18:41	0:01:00
	14:22:41	0:01:00
	15:47:22	0:01:00
24 Jan 2013	9:11:38	0:01:00
	9:22:38	0:01:00
	9:25:38	0:04:00
	9:30:38	0:06:00
	10:20:26	0:03:00
	10:24:26	0:07:00
	10:32:26	0:01:00
	10:34:26	0:01:00
	10:36:26	0:03:00
	11:16:16	0:01:00
	11:20:16	0:02:00
	11:24:16	0:01:00
	11:27:16	0:01:00
	11:29:16	0:04:00
	11:36:16	0:02:00
	11:39:16	0:01:00
	11:43:16	0:01:00
	11:53:12	0:01:00
	11:56:12	0:01:00
	13:45:02	0:01:00

Table 1. Beluga call detections during the DASAR overwinter recording period of 21 October 2012 through 27 January 2013.

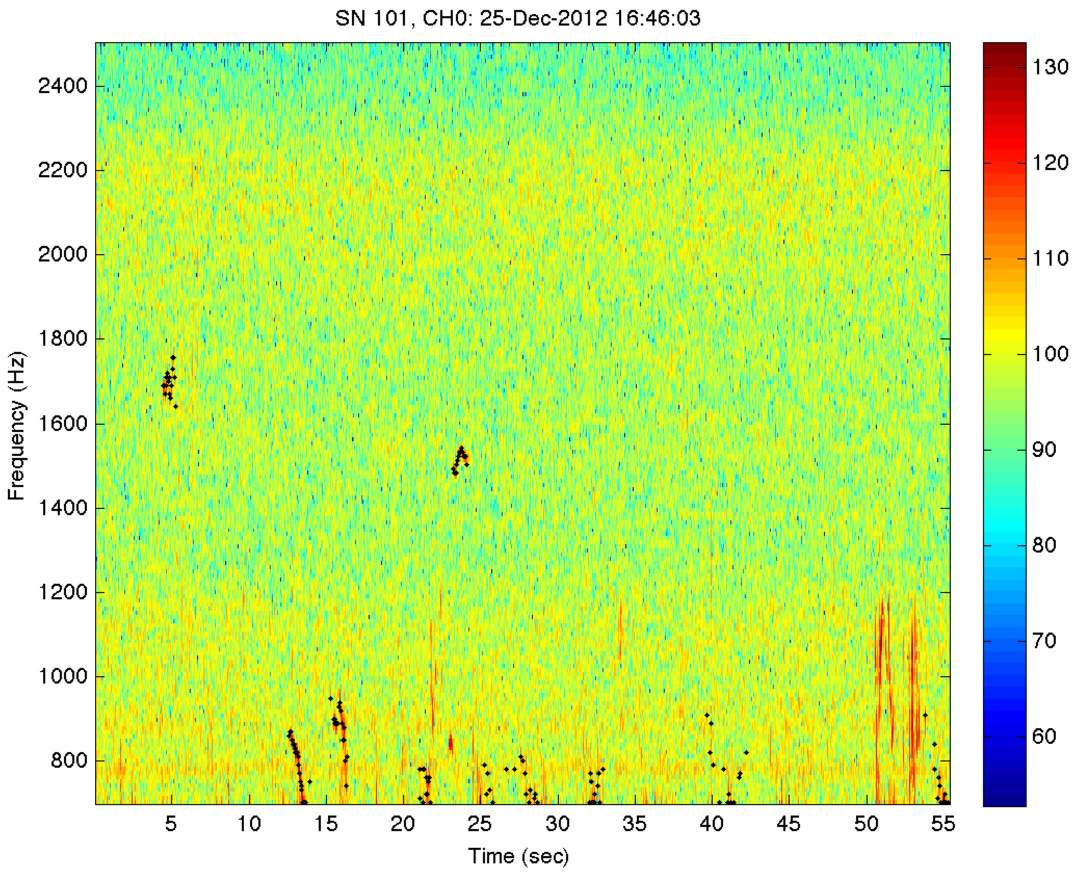


Figure 12. Typical spectrogram of acoustic data received on DASAR SN101 on 25 December 2012. Red tracks are beluga whistles. Black dots indicate potential whistle tracks flagged by the automated whistle detector.

Figure 13 summarizes the number of minutes of beluga whistles detected during each month of recordings. Regardless of the duration of a given beluga call, one minute was deemed the minimum duration logged for a single detection. No beluga vocalizations were detected in October, 76 min were detected in November, 428 min in December, and 154 min in January.

Compared to the September test deployment in which anthropogenic sounds, namely, vessels and airguns, were relatively commonplace, the overwinter deployment was characterized by ice sounds and beluga vocalizations. No airguns and no definitive vessels were detected, although possible airplanes were detected on 19 and 21 November and 4, 5, and 25 December.

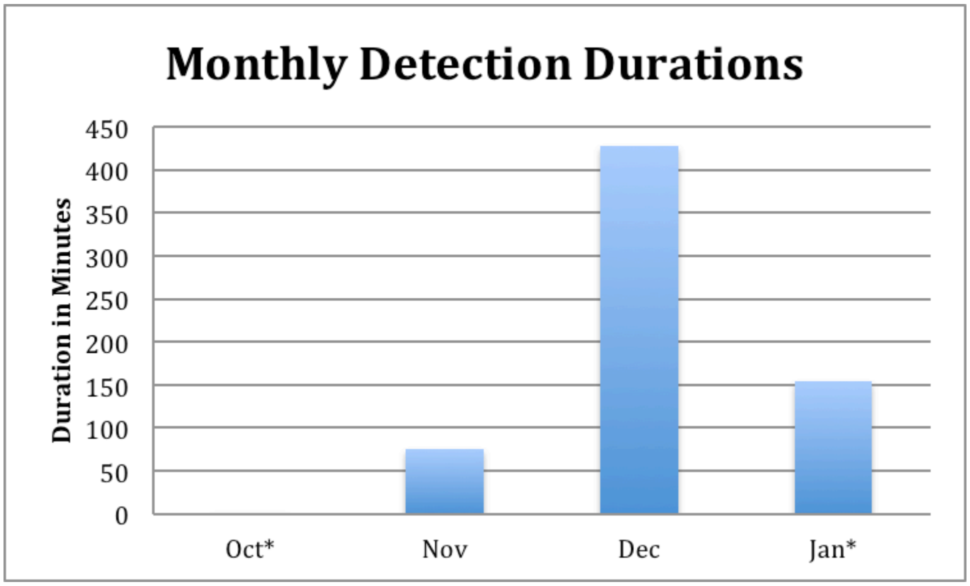


Figure 13. Duration in minutes of beluga call detections by month. *Recordings included only the last 11 days of October and the first 27 days of January.

Conclusions

The Cook Inlet DASAR successfully collected long-term, continuous, acoustic recordings in the demanding high-current environment of East Forelands. Average ambient noise levels at the East Foreland site during late September through late October were substantially higher than those at the Fire Island site for similar time frames. After removal of uncorrelated signals from the sound recordings and in the operational band of interest for beluga whistles (1000–2250 Hz), the average 1/3-octave band level was 92.8 dB re 1 µPa for the September test deployment and 87.3 dB re 1 µPa for the October–January overwinter deployment at the East Foreland site, as compared to 72.3–77.1 dB re 1 µPa for the two DASARs at the Fire Island site. The difference between sound level estimates with and without pseudo-noise contamination was 2.1–2.3 dB re 1 µPa at East Foreland and 3.3–3.8 dB re 1 µPa at Fire Island, hypothesized to be due to higher local currents at the particular DASAR deployment locations of the Fire Island site. However, the significantly higher received levels overall at East Foreland suggest that current-related and/or anthropogenic noise sources are greater contributors to the East Foreland soundscape than Fire Island's. Contributors to the East Foreland soundscape were primarily tidal/current-related sources (*e.g.*, turbulence, rolling gravel, suspended debris) and anthropogenic sources (especially transiting vessels, but also occasional airgun pulses and airplanes). Both environmental and anthropogenic noise sources appear to be more prominent at the East Foreland site compared to the Fire Island site.

Another distinction in the East Foreland acoustic data set compared to Fire Island is the monthly timing of beluga call detections, not wholly unexpected given likely seasonal differences in beluga use of the different habitats. At the East Foreland site, the maximum duration of beluga detections occurred in December with 428 min. The month prior (November) had 76 min of detections and the month following (January) 154 min. At the Fire Island site, maximum duration of beluga detections occurred in November with 529 min, followed by 172 min in April, with very few detections during the intervening months..

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GSI TECHNICAL MEMORANDUM 442-5B

To: Monty Worthington, ORPC AK

From: Katherine H. Kim, Susanna B. Blackwell. Dawn Grebner

Date: 18 November 2013

Re: *Erratum* for Cook Inlet beluga vocalization detection: 5.5-month overwinter review

This erratum consists of revisions to Table 1 of GSI Tech Memo 442-5, which was discovered to contain detections of ice noise incorrectly classified as beluga vocalizations. An independent review and reclassification of all positive detections listed in Table 1 of GSI Tech Memo 442-5 was undertaken to rectify the error. An updated Table 1 of beluga vocalizations is shown below.

Table 1. Comparison of EAR manual and DASAR automated detection during concurrent recording period of 13 Nov 2010 through 24 April 2011. All dates/times are expressed in AKST. Duration of each beluga encounter is noted parenthetically, with a minimum encounter duration of one minute. All times listed assume zero seconds, e.g., 09:00–09:05 refers to detections beginning at 09:00:00 and ending at 09:05:00. Encounters detected on both EAR and DASAR are depicted in bold and italics. [Updated from GSI Tech Memo 442-5, Table 1.]

EAR Manual vs. DASAR Automated Detection Comparison		
Date	EAR Manual Method	DASAR Automated Method
21 Nov 2010	10:19–10:29 (0:10)	08:16–08:31 (0:15)
24 Nov 2010	11:24–11:39 (0:05)	05:51–06:13 (0:22), 06:14–06:16 (0:02), 07:58 (0:01), 08:04-08:07 (0:03), 08:17–08:20 (0:03), 08:23-08:26 (0:03), 09:08-09:11 (0:03), 09:12 (0:01), 09:14-09:20 (0:06), 09:21-09:24 (0:03), 09:24 (0:01)

27 Nov 2010	***10:29–12:54 (2:25)***	***07:58–11:01 (3:03)***, 13:50 (0:01)
28 Nov 2010	***09:34–13:24 (3:50)***	***07:12–11:51 (4:39)***
30 Nov 2010		02:34–02:37 (0:03)
23 Dec 2010		19:33 (0:01)
7 Jan 2011		17:44 (0:01)
11 Jan 2011		00:17 (0:01)
24 Feb 2011		10:15 (0:01), 10:29 (0:01), 10:31–10:36 (0:05), 10:38 (0:01), 10:40–10:45 (0:05), 11:33 (0:01), 11:35–11:39 (0:04), 12:10–12:12 (0:02), 12:16 (0:01), 12:20 (0:01)
25 Feb 2011		10:41 (0:01), 10:43–10:45 (0:02), 11:00–11:02 (0:02), 11:03 (0:01), 11:29–11:31 (0:02), 11:33–11:36 (0:03), 11:38 (0:01), 11:40 (0:01), 11:42 (0:01), 11:48–11:50 (0:02), 11:51–11:53 (0:02)
26 Feb 2011		08:52 (0:01)
26 Mar 2011	23:14–00:09 (0:55)	10:16 (0:01), 11:09 (0:01), 12:02 (0:01)
7 Apr 2011	02:29–03:16 (0:47)	00:25–01:12 (0:47), 01:19–01:23 (0:04)
15 Apr 2011	02:19–02:29 (0:10)	
19 Apr 2011		20:00–20:03 (0:03)
24 Apr 2011	***04:47–08:09 (3:22)***	***05:00–06:54 (1:54)***, 12:03–12:10 (0:07)

In the initial classification of true detections versus false alarms, two classification categories were employed: (1) beluga vocalization or (2) not a beluga vocalization. For the review process, a finer-grained classification system consisting of seven categories was utilized to enable reviewers to more accurately represent the uncertainty and subjectivity inherent in the manual analysis of bioacoustic data. Those seven categories were: (1) ice or likely ice, (2) beluga, (3) possible beluga, (4) low SNR, (5) uncertain, (6) characteristic “n” or “-” at same frequency, and (7) other. Category #6 refers to an unrecognized signal that was considered to be of biological origin and occurred repeatedly throughout the data set.

Figure 1 shows the distribution of detections among these categories as a function of the number of detection events, where an event is a minimum of 1-minute in duration and contiguous minutes are treated as a single event or "encounter". By this metric, 72% of detection events previously classified as beluga should have been classified as ice. However, due to the fine time resolution of events, this metric can be misleading. Figure 2 shows the distribution of detections as a function of the duration, rather than the number, of detection events. In terms of detection duration, 44% of previous ice detections were misclassified as beluga, with 45% of detections being true beluga detections. Category #6 (characteristic "n" or "-" at same frequency), constituting 5% of detection durations, had previously been identified as beluga vocalizations due to their biological nature and their timing relative to more definitive beluga calls. The remaining four categories each consisted of 2% or less of detection durations.

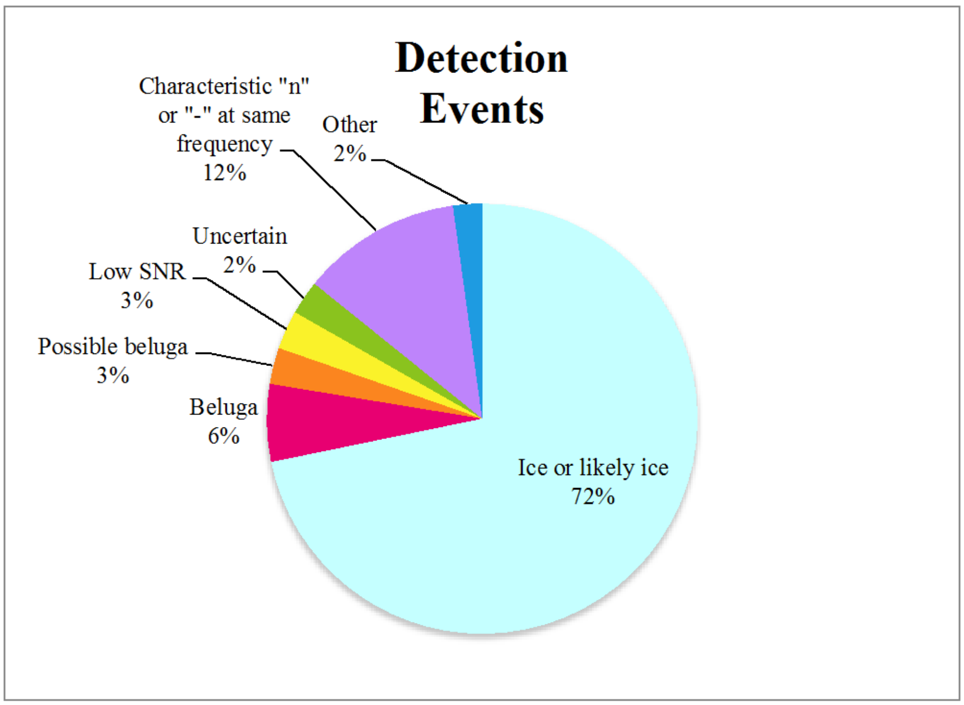


Figure 1. Distribution of detections among all classification categories utilized in the DASAR automated detection review in terms of number of detection events.

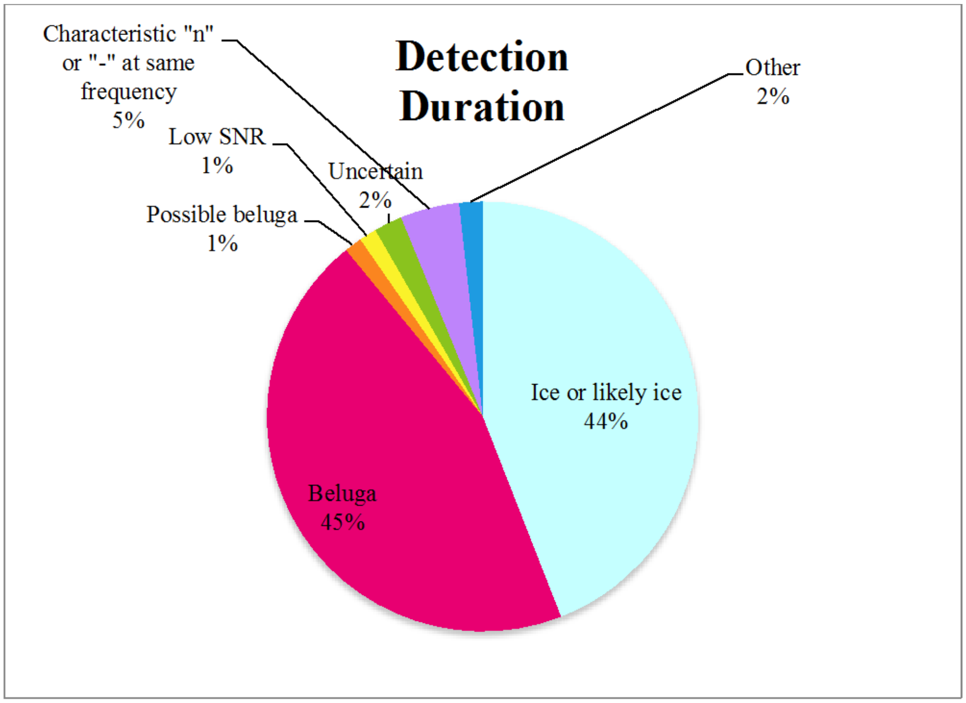


Figure 2. Distribution detections among of all classification categories utilized in the DASAR automated detection review in terms of detection duration.

To provide a more direct comparison to previous results while still recognizing uncertainty in the classification process, the aforementioned seven classification categories were subsequently reduced to three categories: (1) ice, (2) beluga, and (3) other biological or uncertain. Detections in the "characteristic "n" or "-" at same frequency" category were all grouped with "other biological or uncertain". Remaining detections in the other three categories—"possible beluga", "low SNR", and "uncertain"—were reclassified into the reduced set of categories based upon proximity in time to definitive classifications and additional reviewer notes. For example, if a "low SNR" detection occurred amidst ice detections, it was reclassified as "ice".

Figures 3 and 4 depict the distribution of detections among this reduced set of classification categories in terms of the number of detection events and the detection duration, respectively. As discussed earlier, detection duration provides a reliable metric for assessing the errors in the original classification process. As shown in Figure 4, 45% of the detections were confirmed as beluga vocalizations, 47% were reclassified as ice, and 8% were deemed either biological or uncertain in origin.

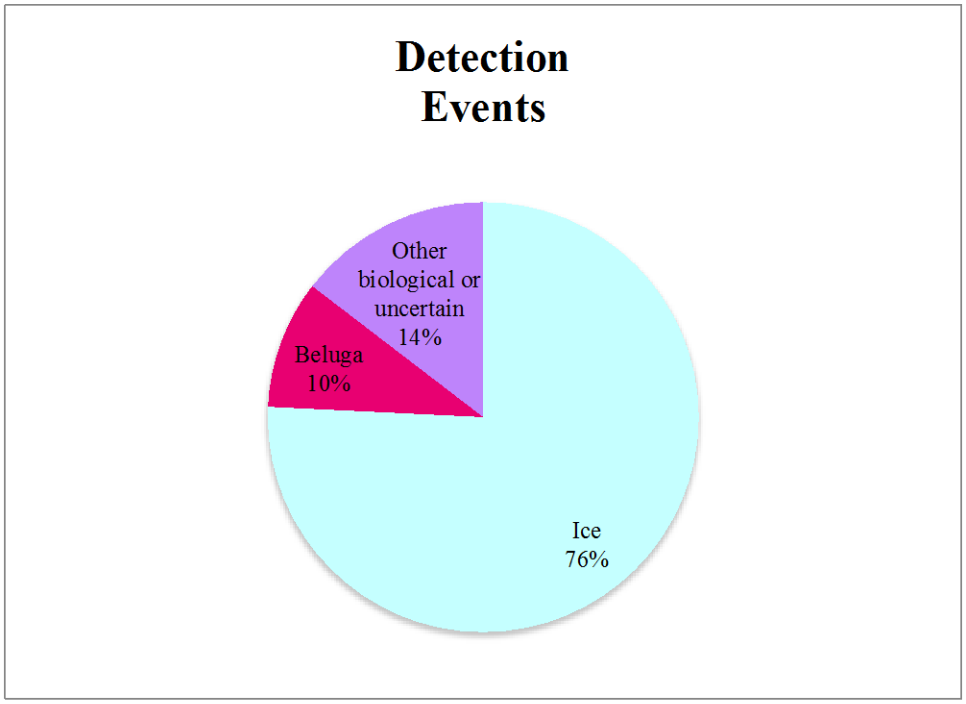


Figure 3. Distribution of detections among reduced set of classification categories utilized in the DASAR automated detection review in terms of number of detection events.

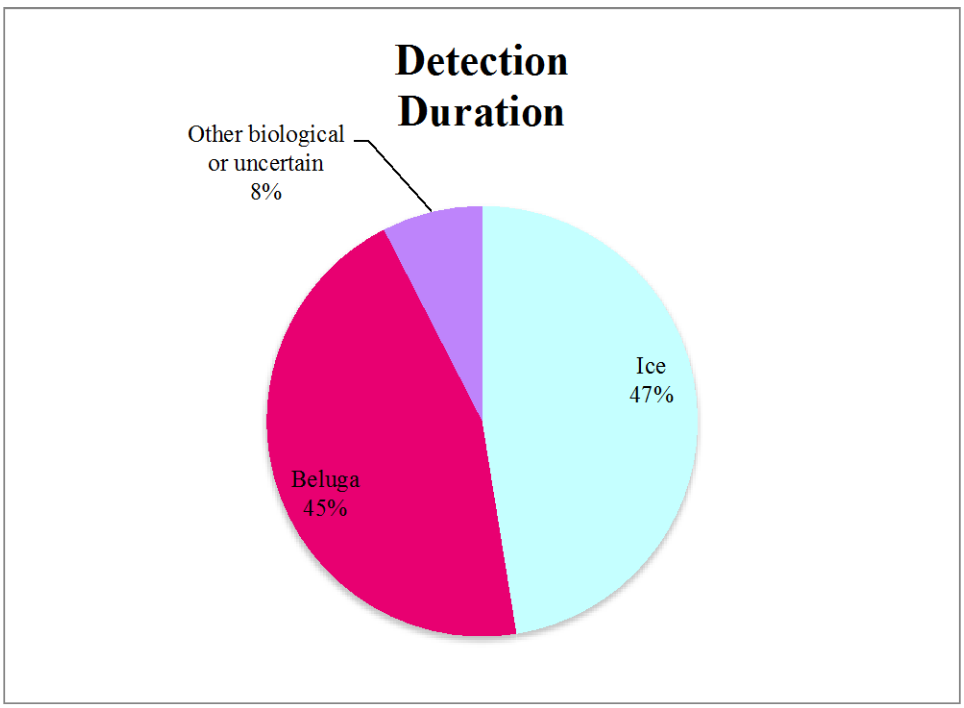
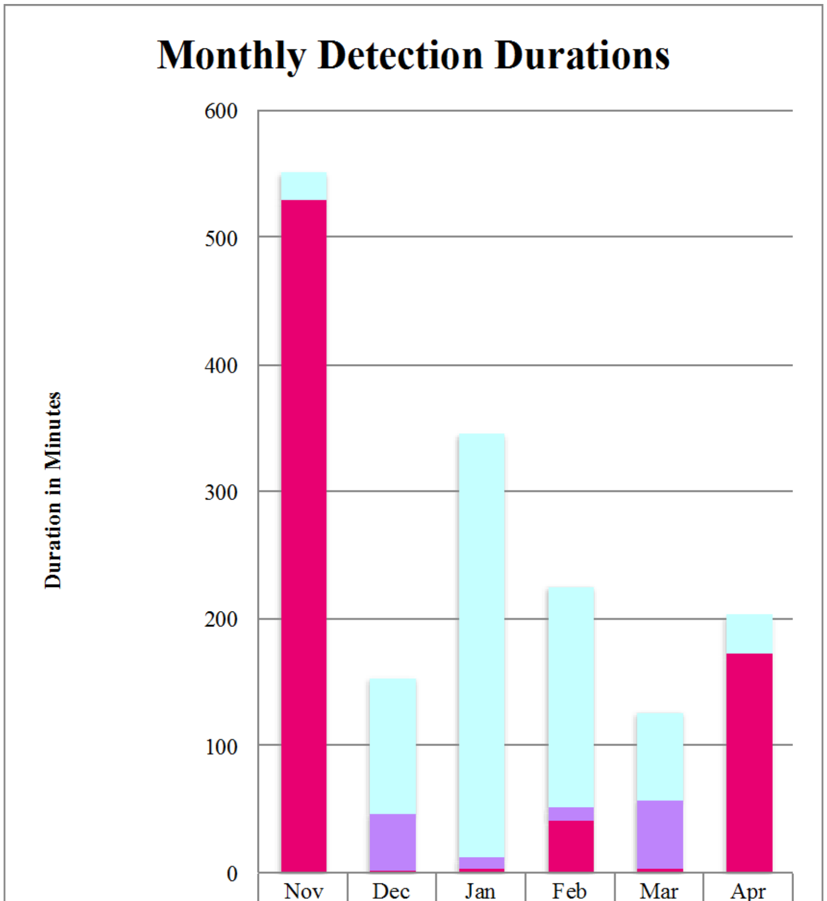


Figure 4. Distribution of detections among reduced set of classification categories utilized in the DASAR automated detection review in terms of detection duration.

Finally, Figure 5 depicts detection durations on a monthly basis. Noteworthy is that beluga vocalizations occurred in all months of recording. Out of the 5-month recording period, beluga vocalization detections peaked in November with 529 minutes. April contained 172 minutes of beluga detections. As expected, misclassification of ice occurred most frequently from December through March when ice is at its greatest concentration in Cook Inlet.



	Nov	Dec	Jan	Feb	Mar	Apr
Ice	22	107	334	174	69	30
Other biological or uncertain	0	45	8	10	54	0
Beluga	529	1	3	41	3	172

Figure 5. Distribution of detections (in minutes) as a function of month. Beluga vocalizations occurred in all months, while misclassification of ice occurred most frequently from December through March.