COLUMBUS-AMERICA DISCOVERY GROUP
and the *SS CENTRAL AMERICA*

Binu Koshy prepared this case under the supervision of Professor Peter Bell, Richard Ivey School of Business, the University of Western Ontario, solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of a managerial situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

In 1857, while carrying passengers and gold from California to New York, the *SS Central America* sank in a hurricane, taking gold bars and coins worth an estimated $400 million to the ocean floor. One hundred, twenty-eight years later, the Columbus-America Discovery Group was formed with the objective of locating, exploring, and recovering the remains of the *SS Central America*. In the summer of 1985, Thomas G. Thompson, director and founder of Columbus-America, assigned to Dr. Lawrence D. Stone the task of estimating the location of the wreck and participating in planning the search.

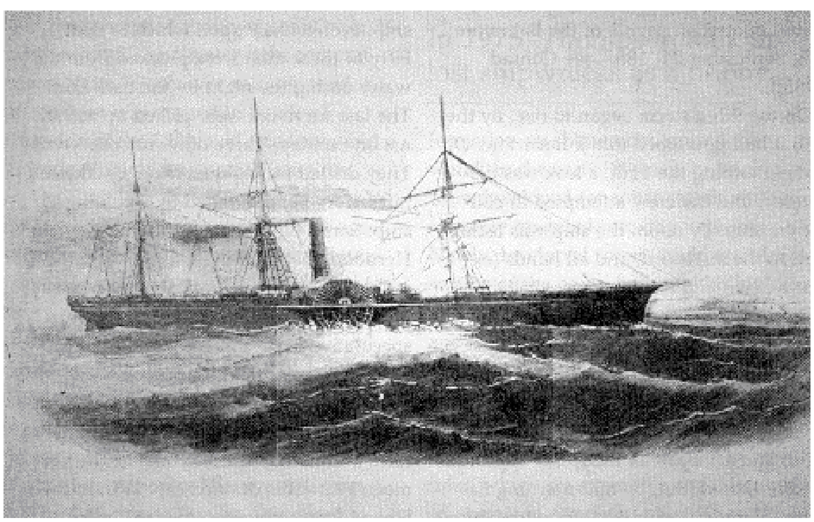

Figure 1: The *SS Central America* from a lithograph in Frank Leslie's *Illustrated Newspaper*, October 3, 1857.

The Sinking of the *SS Central America*

Between 1848 and the completion of the transcontinental railroad in 1869, the principal mode of transportation between California and the east coast of the United States was to travel by steamer from San Francisco to the west coast of Panama, cross the isthmus by train, and take a steamship to New York. In 1857, the *SS Central America*, one of the steamships operating on the Atlantic side of the Panama route, sank in a hurricane taking 425 people and an estimated $400 million worth of gold to the ocean bottom almost 8,000 feet below.

The ill-fated journey began on the 20th of August, 1857 when the mail steamer *Sonora* left San Francisco harbor carrying about 600 passengers and crew, and three tons of gold bound for New York. Arriving at the Pacific coast of Panama, the travelers were met by a train which took them to the Atlantic coast to board the mail steamer *Central America*. The *SS Central America* was a 280-foot wooden hulled steamship with two large iron side paddle wheels (Figure 1). In command was the captain of the ship, William Lewis Herndon, a commander in the United States Navy. On September 3rd, the *Central America* left Panama for New York. On the 9th a storm began to rise and by the 10th it had developed into a hurricane. On Friday morning, September 11th, a leak was discovered, and the crew attempted to bail out the ship. By 2:00 p.m. the water covered the coal and smothered the fire in the main boilers, disabling the engines. Passengers and crew bailed heroically all night, and at daybreak the storm appeared to have abated but, by Saturday morning, Captain Herndon could feel the storm rising again and realized that the ship was certain to go down.

At noon, Herndon signaled the brig *Marine* to rescue passengers from the *Central America*. Fifty-nine women and children plus 41 male passengers and crew made it to the *Marine* before evening when darkness and distance prevented further rescue efforts. At 6:30 p.m. the schooner *El Dorado* approached the *Central America*. Captain Herndon relayed his last estimated position to the captain of the *El Dorado,* and then waved the schooner away from the sinking ship and asked it to stand by until morning. The *El Dorado* drifted away in the storm. That evening, a few minutes before 8:00 p.m., Captain Herndon climbed onto the port paddle wheel of the *Central America* and fired his final rocket indicating that it was soon going down. Moments later, the ship was engulfed by the waves taking its treasure in gold bars and coins to the ocean depths.

When the ship went down, many men were dragged down by the undertow. Those that survived grabbed pieces of the wooden superstructure including doors from the ship and even a chair on which to float. That evening, about five hours after the sinking, a Norwegian sailing vessel, the bark *Ellen*, discovered the survivors and over the next eight hours managed to rescue fifty more men from the waters. Eight days and 20 hours later, the final three survivors were picked up over 400 miles north of the shipwreck after an incredible ordeal of survival on the high seas. In total, 425 people, including the captain, lost their lives.

The Civil War that followed so quickly after the loss of the *SS Central America* overshadowed this tragedy and dimmed it from historical memory. The *Central America* was, however, the most famous shipwreck of its time, comparable to the *Titanic* in this century.

The Columbus-America Discovery Group

The Columbus-America Discovery Group was formed in 1985 to conduct multi-disciplinary research, to develop sophisticated deep-ocean technology, and to locate, explore, and recover the remains of the *SS Central America*. Thomas G. Thompson, director and founder of the *Central America* Project, had an interest in shipwrecks and collected information on shipwrecks around the world. Thompson's background as an ocean engineer gave him the special knowledge concerning the latest advances in robotics, computer control technology, image processing, and other high tech advances that would make a search for a deep ocean shipwreck possible.

In the early1980s, new technologies were developed for sonar search and for remotely operated recovery vehicles. Newly developed sonar technologies could scan large areas of the ocean bottom with high resolution. Advances in robotics, fiber optics, and computers made it possible to build remotely operated underwater vehicles capable of performing a full range of archaeological recovery tasks. This technology eliminated the need for manned submersibles, which were expensive and dangerous to operate in the deep ocean, and made it economically feasible for a small, independent entrepreneur to search for and recover objects on the deep ocean floor.

In the late1970s, the *SS Central America* emerged from a selection process which had considered several potential deep water recovery projects. The *Central America* had sunk on the Blake Plateau, some 200 miles east of Charleston and 1.5 miles below the ocean surface, in an area with a flat bottom and little current. Because of the great depth, the ship was safe from damage by storms and hurricanes as well as from casual exploration by SCUBA divers or treasure hunters. In addition, this region had a very slow sedimentation rate and a lack of current which meant there was very little chance that the *Central America* would be covered by any sediment, and as a result, the wreck would provide an attractive target for side-looking sonar. The ship was known to be carrying large quantities of gold, making its location and recovery economically attractive to investors, and there was considerable historical information available about the wreck. Finally, the wreck was located off the coast of the United States so that any resulting legal problems could be handled solely through the US courts under US law.

In the early '80s Thompson began to assemble a limited partnership of private investors to finance the search for and recovery of the *Central America*. He also began to assemble the team of scientists and technicians that would carry out the project. In 1982, Bob Evans joined Tom Thompson as the second project director, and in 1985 Barry Schatz joined the effort as the third.

Finding the Wreck of the *SS Central America*

The Columbus-America Discovery Group had the following goals:

- Locate the wreck of the *SS Central America* and recover gold and historical artifacts in a responsible manner,
- Develop new technology for deep ocean exploration,
- Add to the historical knowledge of the *Central America* and its times, and
- Increase the scientific understanding of the deep ocean environment and its inhabitants.

The first issue addressed was to review and analyze all the available information and produce an estimate of the location of the *Central America*. Gathering all of the information available about the wreck was done primarily by Evans. He obtained information from newspaper accounts, many of which were given by survivors of the wreck, from ships' logs, from books written by the survivors, and from testimony given to the committee that investigated the loss. Evans organized this information into a matrix where a row in the matrix corresponded to a single account of the loss. The columns designated times. An entry at a given row and column gave a summary of what was happening at that time according to the account represented by the row. The matrix made it easy to cross check the numerous accounts and obtain information about what happened at a specific time.

Figure 2 shows a map of the general area of the *Central America* sinking. The line of dashes shows the route of the *Central America* during its last voyage. The line terminates at the position relayed by Captain Herndon to the schooner, *El Dorado*, a little over an hour before the *Central America* sank. Also shown are the estimated positions of the *Marine* when she sighted the *Central America* at noon on the day of the loss, and the *Ellen* at 8:00 a.m. the next morning as she was recovering survivors. Near the *Ellen* position is the location of the wreck as estimated by Captain Badger, a passenger on the *Central America* who was rescued by the *Ellen*.

The information appeared to cluster into three self-consistent scenarios, each with different levels of uncertainty. The first scenario based on the position given by Herndon; the second based on the position of the *Marine* when it sighted the *Central America*; and the third based on the celestial fix taken from the *Ellen* at 8:00 a.m. Sunday morning. Each scenario had to be examined more thoroughly to determine the accuracy of its information.

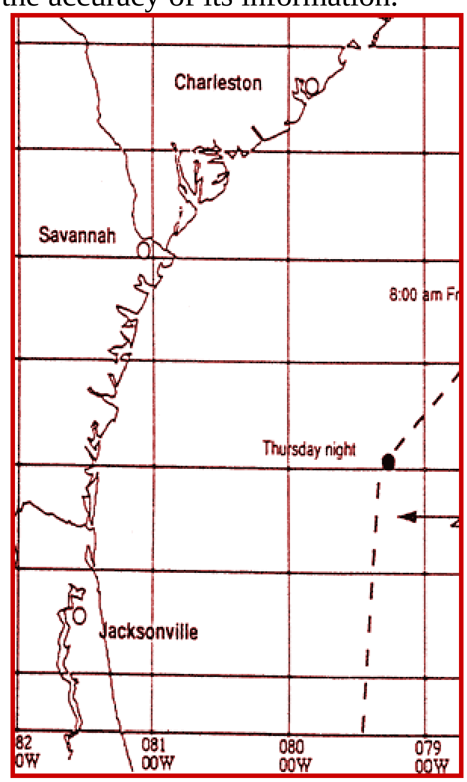

Figure 2: The area where the *SS Central America* sank.

Central America Scenario

The primary piece of information in the *Central America* scenario is the position of the *Central America* passed by Captain Herndon to the *El Dorado*. The position was relayed in the midst of the storm just an hour and a half before the ship sank. This raises the immediate question of when and how this position was taken. The only methods for estimating one's position at sea were to obtain a celestial fix, or to dead reckon from the last fix. By studying the accounts of the disaster, Evans determined that there was a clearing in the storm on Saturday morning around 7:00 a.m. at the time of a lunar meridian. Evans also determined that Herndon returned his navigational instruments to the cabin of a passenger on the *Central America* at 8:00 a.m. on Saturday morning. On the basis of this evidence the team surmised that Herndon had taken a celestial fix at 7:00 a.m. on Saturday morning and that the position relayed to the *El Dorado*, 31°25'N, 77°10'W, was this fix.

[Note: Positions are given in terms of degrees and minutes of latitude (North) and longitude (West). Each degree is divided into 60-minute intervals. In the region of the wreck, each degree of latitude represents about 60 nautical miles (nm), and each degree of longitude about 52 nm.]

How accurate was this fix, and what did it tell about the location of the *Central America* when it sank 13 hours later? The fix was presumably taken using a sextant to determine the altitude of the meridian of the moon measured in degrees from the horizon, with a chronometer used to estimate the Greenwich mean time at which the meridian occurred. Standard navigational tables provide the angular height of the moon's meridian measured from the equator. From these data, latitude and longitude can be computed.

The accuracy of the fix relayed by Captain Herndon was determined by analyzing the errors in the navigational method he used. In particular, the observed path of the moon had a rather broad apex making it difficult to determine the exact point of the meridian when using a sextant, and this adds significant uncertainty to the longitude estimate, with the result that the uncertainty in longitude was estimated to be more than four times greater than the uncertainty in latitude. Characterizing the uncertainties in the estimation of latitude and longitude as normally distributed with mean zero, Barry Belkin of Daniel H. Wagner Associates provided the following estimates of the standard deviations, σ_{lat} and σ_{lon}, of Herndon's fix (expressed in nautical miles):

$\sigma_{lat} = 0.9$ nm and
$\sigma_{lon} = 3.9$ nm.

Of course the *Central America* did not stay stationary during the time between the celestial fix at 7:00 a.m. and her sinking at 8:00 p.m. that evening. During this time her engines were disabled and no sails hoisted, and she was at the mercy of the winds and currents. In order to account for her movement during this time, the team estimated her drift. There were two components of drift:

- Drift due to the ocean current
- Drift due to the effects of wind on the ship (leeway).

The ocean current during the storm had to be estimated indirectly. In order to determine if there was a direction to the current at the time of the loss, the team reviewed the path of the three men who drifted for eight days on a raft before being picked up by a passing ship. This evidence indicated a generally northeasterly direction to the current.

The team also looked at ocean current data from that region during the past 130 years. The ocean current is the sum of two types of currents, the geostrophic current and the wind-driven current. One can think of the geostrophic current as the current that would be present if there was no wind. In order to estimate the geostrophic current, the team used ocean current readings that were taken in the month of September in the region from 30°N to 32°N and 76°W to 78°W and spanning the period from the early 1850s to 1974. The region was broken into sixteen 30-minute by 30-minute rectangles. Within each rectangle, the team computed the mean and empirical covariance of the data points lying in the northeast quadrant (because on the days surrounding the sinking the current was in a generally northeasterly direction). This produced bivariate normal distributions with mean vectors having a speed of up to 1.5 nautical miles per hour (kts) in the northeast direction (Appendix 1). The team took these bivariate normal distributions as their best estimate of the distribution of the geostrophic current during the loss of the *Central America*.

To estimate the wind acting on the ocean surface, Evans returned to the ships' logs and survivors' accounts to find estimates of wind speed and direction during the two days preceding the loss of the *Central America* (Appendix 2). To account for the uncertainty in these estimates, the team modeled the winds as having a bivariate normal distribution with mean equal to the value obtained by Evans and a covariance matrix that allowed the wind to vary by as much as 45 degrees from its mean. Roland W. Garwood of the Naval Postgraduate School used his computer model of wind-driven current to estimate the current that would have been produced by the winds as estimated by Evans. Garwood produced estimates for each six-hour period from 7:00 a.m. on Saturday to 1:00 p.m. on Sunday (Appendix 3). The resulting currents had speeds ranging from 0.2 to 0.4 knots. The uncertainty in these estimates was represented by a bivariate normal distribution with a variance of 0.1 knots in each direction. To obtain the distribution of the total ocean current, the team computed the distribution of the vector sum of the geostrophic and wind-driven current.

The direct action of wind on a ship also contributes to drift (leeway). The leeway factor is the fraction of the wind velocity that is converted to drift as a result of the wind acting on the area of a ship that is above water. Using blueprints of the *Central America*, the leeway factor was estimated to be 3%. Multiplying this by the wind velocity produced the leeway on the *Central America*.

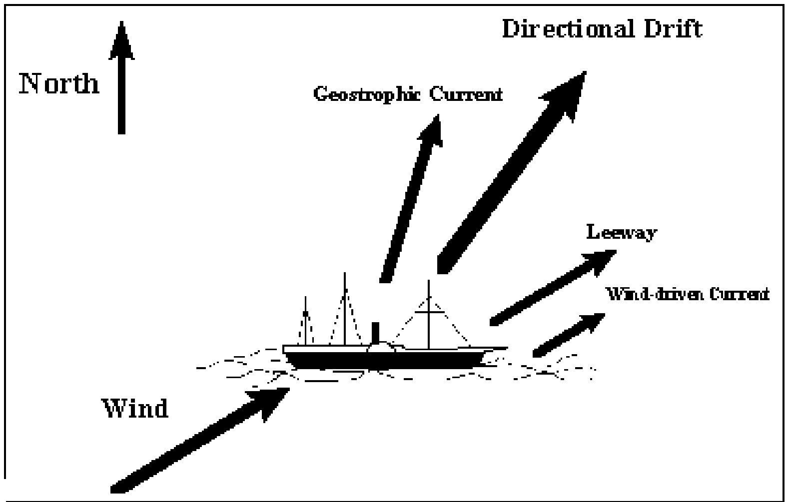

Figure 3: Forces acting on the SS Central America

Ellen Scenario

For the *Ellen* Scenario, the project team used the position of the *Ellen* at 8:00 a.m. on Sunday when she was recovering survivors from the *Central America*. The approach was to drift the survivors backward to the time of the sinking of the *Central America* to obtain an estimate of the position of the wreck. At 8:00 a.m. on Sunday, the captain of the *Ellen* took a celestial fix using a meridian of the moon. The recorded position was 31°55'N, 76°13'W. Uncertainty analysis yielded standard deviations of σ_{lat} = 0.9 nm and σ_{lon} = 5.4 nm. Since people in the water have no leeway, their drift is determined solely by the ocean current. To produce this backward drift, the team set the leeway factor to zero and multiplied the mean vectors for ocean current by minus one drifting the survivors backward to 8:00 p.m. on Saturday when the *Central America* sank.

Marine Scenario

At 12:45 p.m. on Saturday, the *Marine* sighted the *Central America*. Captain Burt of the *Marine* reckoned his position to be 31°40'N, 76°50'W. The best estimate of the last time that Burt made a celestial fix was at 6:00 a.m. on Friday. For most of the time between this fix and the sighting of the *Central America*, the *Marine* was being driven by the storm under little or no sail. The team estimated the leeway of the *Marine* at four percent and applied the wind velocities for that period of time to estimate that the *Marine* traveled 77 nm since the last fix. They also assumed that the error in dead reckoning a position is no more than 25 percent of the distance traveled since the last fix. This resulted in an uncertainty that was circular normal with standard deviation of nine nm in each direction.

As well, the team also accounted for the distance of the *Marine* from the *Central America* at the time of the sighting. The *Marine* heaved to near the *Central America* at 1:30 p.m., 45 minutes after the sighting. Assuming that the maximum speed of the *Marine* was eight knots, they calculated that the *Central America* was between one and six miles from the *Marine* at the time of the sighting.

The *Central America* was sighted off the lee bow of the *Marine*. The *Marine* was reported to be running before the wind which was from the SW at this time. As a consequence they estimated the *Marine* to be heading NE and the lee direction off the bow to be ENE = 67.5°. They added an uncertainty of ±60° about this direction.

Combining the Three Scenarios

The team looked at each scenario as a whole to determine if there was corroborating evidence that strengthened the credibility of that scenario. As an example, the position estimated by Captain Badger, a passenger on the *Central America*, was very consistent with the *Ellen* scenario. Lieutenant Matthew Maury made an estimate of the location of the wreck based on the information that he had collected in his report to the Secretary of the Navy. This position also supported the *Ellen* scenario. The celestial fix on which the *Ellen* scenario was based was taken after the storm had passed on a ship that was in no danger of sinking. This position was written in the ship's log. By contrast, Herndon's position, on which the *Central America* scenario was based, was passed verbally to the *El Dorado* in the middle of a storm shortly before the *Central America* sank.

When combining the three scenarios the team assigned a percentage to each scenario. The percentages represented the relative credibility of the scenarios and were required to add to 100. They averaged the three sets of percentages to produce the scenario weights. The results were: *Central America* 23%, *Ellen* 72%, and *Marine* 5%. The *Ellen* received the highest weight or credibility for the reasons discussed above. The information in the *Marine* scenario was so uncertain that the team gave it a low weight but did not discard it entirely.

With historical information in hand, the Columbus-America Discovery Group set out to develop a probability map of the location of the remains of the *SS Central America*. Once this map had been developed, the team turned to developing an efficient search plan that would produce a high probability of finding the *Central America*.

Developing A Search Plan

Fred Newton of Triton Technology was given the task of designing a sonar search that would produce a high probability of finding the *Central America*. The plan had to provide specific directions for performing a search and serve as a basis for estimating the amount of time, effort, and money necessary to assure a high probability of success.

The side scan sonar to be used in the search for the *Central America* was towed behind the search vessel moving at two nautical miles per hour and covered a swath of 2,500 meters on either side. Newton estimated the probability of the sonar detecting the wreck as a function of the lateral range of the sonar from the target. Over most of the 2,500 meter range, the signal-to-noise ratio (SNR) produced a detection probability of 0.99. At ranges close to the sensor, increased reverberation from the ocean bottom caused the SNR and the probability of detection to drop. At the outer reaches of the 2,500 meter range, the SNR and the probability of detection also dropped.

Since the ocean bottom was some 7,000 to 10,000 feet deep in the search area, the sonar had to be towed from the search ship using a long cable; it was, therefore, desirable to minimize the number of course changes required. Along with the towing cable, a coaxial cable was to be used to relay the sensor responses back to the ship where they would be recorded on an optical disk and displayed on paper.

When developing the search plan, Newton had to take into account the lateral range function for the sensor, the probability of gaps between swaths, and the amount of probability covered by the swath of the sensor. With this in mind he set out to design a plan that would yield a high probability of success in the most efficient way possible.

Where were the remains of the *SS Central America*? How could the wreck be found? How long would a search take? Was success guaranteed?

APPENDIX 1

Historical Ocean Currents (in kts)

Latitude	Longitude	Expected Value of Easterly Current	Expected Value of Northerly Current	Variance Easterly Current	Variance Northerly Current	Covariance
3115.0 N	07715.0W	0.104	0.278	0.545	0.511	0.287
3145.0 N	07715.0W	0.878	1.017	0.663	0.803	0.524
3215.0 N	07715.0W	1.513	1.518	0.713	0.627	0.266
3115.0 N	07645.0W	-0.0773	0.00239	0.285	0.416	0.206
3145.0 N	07645.0W	-0.0609	0.0407	0.394	0.529	0.185
3215.0 N	07645.0W	0.380	0.441	0.355	0.393	0.215
3115.0 N	07615.0W	-0.0796	0.0214	0.296	0.577	0.140
3145.0 N	07615.0W	0.0491	0.0350	0.234	0.387	0.0893
3215.0 N	07615.0W	0.206	0.203	0.451	0.431	0.255

APPENDIX 2

Wind Synopsis (as prepared by Bob Evans)

The individual perspective and nautical experience of each observer were considered when making these estimates of approximate wind speeds and directions. All the raw data were of a subjective nature and while many other variations in the interpretation of this storm are possible, the data represent a reasonable estimate of the conditions experienced on the *SS Central America* during the storm in which she sank.

Day	Time	Wind Direction	Wind Speed
10 Thursday	12:00 pm	NE	35 knots
	1:00 pm	NE	36
	2:00 pm	NE	37
	3:00 pm	NE	38
	4:00 pm	NE	40
	5:00 pm	NE	42
	6:00 pm	NE	44
	7:00 pm	NE	45
	8:00 pm	NE	47
	9:00 pm	NE	49
	10:00 pm	NE	50
	11:00 pm	NE	51
11 Friday	12:00 am	NE	52
	1:00 am	NE	53
	2:00 am	NE	54
	3:00 am	NNE	55
	4:00 am	NNE	56
	5:00 am	NNE	57
	6:00 am	NNE	58
	7:00 am	NNE	60
	8:00 am	NNE	65
	9:00 am	NNE	70
	10:00 am	NNE	75+
	11:00 am	N	75+
11 Friday	12:00 pm	NNW	75+
	1:00 pm	NW	70
	2:00 pm	NW	65
	3:00 pm	NW	64
	4:00 pm	NW	63
	5:00 pm	NW	62
	6:00 pm	NW	61
	7:00 pm	WNW	60
	8:00 pm	WNW	60
	9:00 pm	WNW	60
	10:00 pm	WNW	59
	11:00 pm	WNW	58
12 Saturday	12:00 am	WNW	56
	1:00 am	WNW	55
	2:00 am	WNW	52
	3:00 am	W	48
	4:00 am	W	45
	5:00 am	W	40
	6:00 am	WSW	35
	7:00 am	WSW	35
	8:00 am	WSW	34
	9:00 am	WSW	33

APPENDIX 2 (continued)
Wind Synopsis (as prepared by Bob Evans)

Day	Time	Wind Direction	Wind Speed
12 Saturday	10:00 am	WSW	32
	11:00 am	SW	30
12 Saturday	12:00 pm	SW	30
	1:00 pm	SW	30
	2:00 pm	SW	30
	3:00 pm	SW	29
	4:00 pm	SW	28
	5:00 pm	SW	27
	6:00 pm	SW	26
	7:00 pm	SW	25
	8:00 pm	SW	25
	9:00 pm	SW	25
	10:00 pm	SW	25
	11:00 pm	SW	25
13 Sunday	12:00 am	SW	25
	1:00 am	SW	25
	2:00 am	SW	25
	3:00 am	SW	25
	4:00 am	SW	25
	5:00 am	SW	25
	6:00 am	SW	25
	7:00 am	SW	25
	8:00 am	SW	25
	9:00 am	SW	25
	10:00 am	SW	25
	11:00 am	SW	25

APPENDIX 3

Wind Blown Current Estimates

Date and Time	East (kts)	North (kts)	Variances (kts^2)
12 0700	0.37	0.45	0.10
12 1300	0.69	-0.49	0.10
12 1900	-0.23	-0.65	0.10
13 0100	-0.37	0.23	0.10
13 0700	0.44	0.30	0.10