APPENDIX II
SPATIAL RESOLUTION

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The following discussion has been prepared to provide an overview of the potential sources of error in the placement of various features on the charts prepared for this report. It also addresses the resulting accuracy of data placement and the methodology used to attempt to minimize the errors.

System Accuracy and Potential Sources of Error

The following is not intended as an in depth study of all possible sources of error. It is intended to address the major sources and to indicate the level of resolution possible, given the equipment and survey parameters.

a. Navigation System

The navigation system used has a stated 90% confidence level of less than one meter. The base station methodology insured that the accuracy of the base station locations are known to a much greater precision than one meter. Coupled with the Kalman filtering techniques and multi-threaded, multi-tasking employed by the WinFrog INS it is reasonable to assume that the one-meter circular error probable (cep) of the GPSCards represents the limit of accuracy of the positions generated. WinFrog also used GPS phase correlation techniques to determine the vessel velocity. The resulting velocities were used as part of the Kalman solution to restrain excursions caused by GPS signals outside the 90% confidence level, which may well have resulted in a one-meter solution to a higher confidence level.

b. Shot Positioning and Timing

A secondary potential source of error for surveys of this type is a result of timing errors in the airgun shot cycle of the multi-channel system. With a shot interval of 3.125 meters, as used in this survey, significant errors in shot spacing can occur if the navigation system is occupied with other tasks. Traditionally this problem has been avoided by setting a shot time interval that is monitored over a number of shots to determine if the required shot distance is being obtained. The shot timing is then adjusted as necessary to best approximate the correct shot distance. The major drawback of this methodology is the lack of response to short term fluctuations in vessel speed and course, which result in the shot spacing varying considerably from ideal.

By using a fast update rate and a single thread in a multi-threaded, multi-tasking environment to control shot timing, the WinFrog package is able to control shots purely on actual distance traveled along the line. WinFrog also used GPS phase correlation techniques to very accurately assess the vessel velocity, which was included in the Kalman matrix to limit excursions caused by noisy and/or incorrect GPS signals (i.e. those outside the 90% confidence level). Due to the high priority of the tracking thread, the shot distance was maintained within a reported 20 cm for almost all the survey. Note that this figure is not really a measure of the positioning accuracy of the shot, but represents the cumulative timing errors throughout the system. It can be stated, therefore, that the total cumulative errors in the WinFrog INS system for shot timing are much lower than the effect of overall DGPS system accuracy.

c. Towing Geometry

Due to the small size of the vessels used for this survey, it was not possible to deploy sophisticated acoustic solutions for positioning the source and receiver(s). Offsets were calculated from field measurements of the length of tow leaders deployed. It was assumed that the various items were offset from the navigation antenna in the reciprocal of the course made good. This approximation is reasonable in conditions where the vessel course is not changing too quickly, but it is still an approximation. Due to the short setback distances and protected areas of operation, it is reasonable to assume that the course made good was a good approximation of the actual situation. Visual observation in the field indicated that even the tail buoy of the multi-channel streamer stayed within a few degrees of the course made good, except when the vessel was maneuvering to avoid obstacles. Assuming that 5 degrees is a reasonable figure for the maximum error in all but the worst circumstances, the resulting positional errors would be approximately one and two meters for the Geopulse and MCS airgun surveys respectively.

d. Reflection System Horizontal Resolution

The resolution of the reflection system is a function of the shot interval. The best possible accuracy is obtained when a feature can be determined to occur at a single shot. Even in this case the uncertainty in the horizontal plane is at least plus or minus one shot (i.e. the horizontal sampling interval). In the case of this MCS airgun survey this figure is 3.125 meters. For the Geopulse system the figure is dependent upon the vessel speed as the system was cycled at a period of 400 milliseconds. Survey speed for the Geopulse survey was typically 3 to 4 knots which would result in sample intervals of between 0.5 and 0.75 meters. In order to minimize the potential positioning errors, the locations of features within 100 milliseconds of the seafloor were always determined from the geopulse data to take advantage of the higher horizontal resolution.

e. Out-of-Plane Reflections

A problem with almost all acoustic reflection systems is determining the actual source of a particular reflection point. The assumption used during interpretation is that the reflection points are in the plane of a line joining the source and receiver. The actual situation is that the source generates an approximately hemispherical acoustic pattern. The receivers typically have a pattern of sensitivity (to -3bD points) in the form of a cone approximately 50 degrees across track by 30 degrees along track. As a result of these patterns, it is possible for the returns to come from an interface that is offset horizontally and/or vertically from the expected return from below. Without three dimensional ray path modeling, it is difficult to estimate quantitatively the effects of out-of-plane reflectors on the data placement. However, it is possible to draw some general conclusions as follows:

1. As long as there are no steeply dipping reflecting horizons, the effects are limited to smearing of the return, resulting in a loss of resolution with little spatial positioning error.

2. In the case of steeply dipping horizons and/or faulting, it is possible that the first arrival at the hydrophone from a horizon is the out-of-plane reflection. Presuming that this return is considered to be the "true" reflection, the result will be an error in the vertical position and possibly an error in the along line position of the feature.

3. These errors are minimized by using a fast repetition rate, which results in superior horizontal resolution.

f. Data Frequency Content

The major concern for this report is error in horizontal positions of the features mapped. Sections a-e above address these issues. There is also a question of the vertical accuracy and resolution of the two systems used. The vertical resolution of the system is directly related to the frequency content of the data. The frequency content varies both as a function of the systems used to collect the data and as a function of the depth in the section. The systems used, including processing sequences, may be characterized in terms of acoustic penetration as follows:

System	Seafloor	100 ms	700 ms
Geopulse	1,000 Hz	500 Hz	n/a
Airgun	500 Hz	300 Hz	100 Hz

The vertical resolution is related to the frequency in that the maximum possible resolution is ¼ wavelength. In practice it is only possible to interpret the data to ½ of a wavelength. Using assumed velocities, the results can be summarized as follows:

System	Seafloor	100 ms	700 ms
Sound Velocity	1500 m/s	1550 m/s	1800 m/s
Geopulse (1/4 wave)	0.375 m	0.775 m	n/a
Geopulse (1/2 wave)	0.75 m	1.55 m	n/a
Airgun (1/4 wave)	0.75 m	1.29 m	4.5 m
Airgun (1/2 wave)	1.5 m	2.58 m	9.0 m

The above figures represent the best resolution of the data set. There are also potential sources of vertical placement error resulting from incorrect data migration in processing of the airgun data due to incorrect velocity assumptions, as well as the out-of-plane errors mentioned above.