[GC]Essentials of Streamer Marine 3-D Surveys*

By
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General Statement

Two different methods have been used in recent years for seismic data acquisition offshore.

- The more common of these uses hydrophones deployed in a streamer or streamers towed behind a vessel at a depth of a few meters, while the vessel moves at a speed of four or five knots.
- In the other technique, the recording sensors are deployed on the ocean floor and are connected to a stationary recording vessel. These bottom-referenced systems are called ocean bottom cable (OBC), or ocean bottom seismic (OBS).

This article concentrates on marine 3-D survey design using towed streamers. An prior article by Mike Galbraith (Search and Discovery Article #40139 (2004)) dealt with the geophysical issues related to spatial sampling (bin size) and fold, so these will not be repeated here.

Data Acquisition

Typical data acquisition uses from four to 16 streamers per vessel, with either one or two airgun source arrays. Most modern boats can tow six or more streamers with a total length of streamers between 50 and 75 kilometers.

With long streamers, fewer are deployed (e.g., six streamers of 8500 meters each), while with shorter streamers many more are possible (e.g., 16 of 4500 meters each; Figure 1). Longer streamers are being used more frequently today because of both deeper targets and improved imaging requirements in areas with complex geology, such as sub-salt structures in the Gulf of Mexico. Both increased streamer length and the number of streamers increase the amount of time taken for line changes.

Figure 1. The PGS Ramform Victory towing 16 streamers.

Because most marine surveys are recorded with the boat traveling in straight lines, survey orientation is still problematic. In areas with rapidly varying velocity fields, conventional wisdom now recommends the longest source-to-receiver axis being aligned in the strike direction. This minimizes the raypath complexity -- and thus makes the normal moveout more hyperbolic.

Subsurface illumination also is normally improved with strike acquisition. However, because the natural spatial sampling of streamer marine systems is typically finer in the inline direction than in the crossline direction, strike acquisition results in coarser spatial sampling in the dip direction. This spatial sampling must be adequate to sample the geology or aliasing will occur. This may mean that overlapping, interleaved boat passes may be necessary in order to achieve sufficiently fine crossline sampling.

Another problem is that, in complex geology, there are not necessarily true dip and strike directions, and therefore any survey orientation may result in imaging difficulties in the data-processing stages. Higher density surveys with improved wavefield sampling can provide significant improvements in the imaging processes.

The natural inline spatial sampling of most streamers is fixed at 12.5 meters or less; this is adequate for almost all geologic environments. Varying the crossline sampling to allow for geologic dip has a significant impact on survey costs; a reduction in streamer spacing means more boat passes will be required. Therefore, the decision to acquire the survey in the dip or strike direction is a major factor in determining the cost of the survey, with dip acquisition normally being preferred from a cost standpoint.

However, the size and shape of the survey and additional issues related to tides, currents, and obstructions (e.g., platforms, shallow water along coastlines, and reefs) also will complicate the decision. In general, fewer boat traverses through the area with longer lines is preferable to more, shorter lines, since the ratio of recording time to line-change time is greater.

Towing multiple streamers close together can lead to operational difficulties. A common method to achieve smaller crossline sampling has been to use two source arrays with wider streamer separation. Since the source arrays are fired alternately, the shotpoint sampling on each shotline is doubled, and the recorded fold for each common mid-point line is halved. This leads to coarser offset sampling in each bin, which can result in degraded performance of some data processing algorithms, such as multiple attenuation. Single source acquisition provides higher trace density and more uniform offset distributions.

Another imaging consideration for marine surveys is the difference in source to receiver azimuths at the boundary between data recorded on adjacent boat passes when recorded with traditional "race-track" shooting (Figure 2a). It has been shown that these can result in shadow zones with inadequate subsurface illumination, leaving both structural and amplitude errors in the data volume. Alternative recording methodologies, such as anti-parallel recording (Figure 2b), can help minimize these problems.

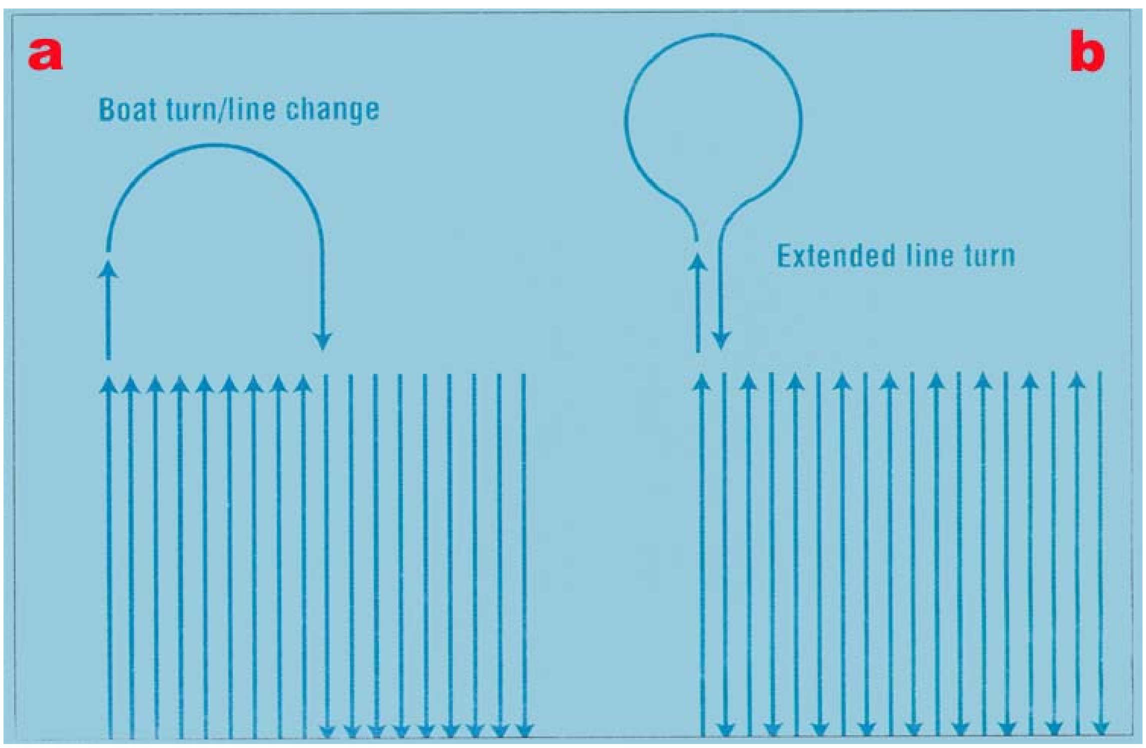

Figure 2. a. Traditional "race-track" shooting can result in shadow zones with inadequate subsurface illumination, leaving both structural and amplitude errors in the data volume. b. Alternative recording methodologies, such as anti-parallel recording, can help minimize these problems.

Because of the need for higher resolution images and improved structural and stratigraphic interpretations, higher density surveys are being acquired more frequently. These surveys typically have smaller spatial sampling and higher fold, with much better offset distributions.

For time-lapse 3-D surveys, often called 4-D, it has been shown that minimizing the differences in the pre-stack offset and azimuth attributes between the base and monitor surveys is very important in reducing the seismic differences caused by the data acquisition:

- One method to achieve this is the use of steerable streamers to better match the streamer feathering of the monitor survey to that of the base survey.
- Another method repeats source locations, which, together with an overlapped shooting configuration, using additional outer streamers, improves azimuth preservation. The use of additional outer streamers on the base survey with overlapped recording contributes to more uniform offsets and azimuth distributions.

Also, by using a more closely spaced streamer configuration, source-receiver azimuths and offsets can be repeated very accurately.