

GC 3-D Design Philosophy – Part 1: Target Size*

Bob Hardage¹

Search and Discovery Article #40661 (2010)

Posted December 17, 2010

*Adapted from the Geophysical Corner column, prepared by the author, in AAPG Explorer, September, 2010, and entitled “First of a Series: 3-D Design Philosophy”. Editor of Geophysical Corner is Bob A. Hardage (bob.hardage@beg.utexas.edu). Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director. Click for remainder of series: [Part 2](#) [Part 3](#) [Part 4](#)

¹Bureau of Economic Geology, The University of Texas at Austin (bob.hardage@beg.utexas.edu)

General Statement

The geometry of onshore 3-D seismic recording grids is based on five parameters: source-station spacing, receiver-station spacing, source-line spacing, receiver-line spacing and recording swath size. At each prospect, these design parameters can be specified by answering four simple questions:

- What is the narrowest lateral dimension of the geologic target that is to be imaged?
- What is the depth of the shallowest target?
- What is the depth of the deepest target?
- What stacking fold is required to create an acceptable image at the depth of the principal target?

The first three questions can be answered if the geology of the prospect is known. The fourth question can be answered by examining local seismic data or by guessing. Once these four questions are answered, the methodology described in this four-article series allows many onshore 3-D seismic surveys to be designed without having to use commercial design software.

About this series: Some of the more technical aspects of 3-D seismic design, such as ensuring that there are proper azimuth and offset distributions between source-receiver pairs, are not considered in this simple treatise on first principles of 3-D survey design. The intent is to describe a method that allows non-geophysicists to plan simple 3-D surveys – and to recognize flaws in proposed 3-D programs. The design procedure is diagrammed on [Figure 1](#).

Narrow Targets and Stacking Bins

The horizontal resolution provided by a 3-D seismic image is a function of the trace spacing within the 3-D data volume. As the separation between adjacent traces decreases, horizontal resolution increases. At the conclusion of 3-D data processing, each trace in a migrated 3-D seismic data volume is positioned so that it passes vertically through the midpoint of a small area called a stacking bin or image bin ([Figure 2](#)). These stacking bins can be square or rectangular, depending on an interpreter's preferences.

The trace spacing in a given direction across a 3-D image is the same as the horizontal dimension of the stacking bin in that direction. As a result, horizontal resolution is controlled by the areal size of stacking bins. The imaging objective dictates how small a stacking bin should be. Smaller bins are required if the resolution of small stratigraphic features is the primary imaging objective.

As a general rule, there should be a minimum of three stacking bins – and preferably four bins – across the narrowest feature that needs to be resolved in a 3-D data volume so that the targeted anomaly is expressed on three or four adjacent seismic traces. A variation in seismic reflection character on three to four adjacent traces is usually noticed by interpreters; anomalous reflection behavior on fewer traces tends to be ignored, or may not even be seen when viewing a 3-D data volume.

For example, if the interpretation objective is to image meandering channels that are as narrow as 100 meters, then stacking bins should have lateral dimensions of approximately 25 meters or less ([Figure 3](#)), which would cause a 100-meter channel to affect at least four adjacent traces. One of the first 3-D design parameters to define is the physical size of the stacking bin that should be created. That bin size, in turn, can be determined by first developing a stratigraphic model of the target that is to be imaged and using that model to define the narrowest feature that needs to be seen. Once this minimum target dimension is defined, stacking bins having lengths and widths that are about one-fourth of this minimum target width should be created if the target is to be recognized in a 3-D data volume.

Source and Receiver Station Spacings

Geophysical texts show that the dimension of a 3-D stacking bin in the direction that receiver lines are deployed is one-half of the receiver-station spacing along the receiver lines, and the dimension of a stacking bin in the direction that source lines are oriented is one-half of the source-station spacing along the source lines.

Thus, when a choice is made about the narrowest target that must be imaged, not only have the dimensions of stacking bins been determined, but source-station and receiver-station spacings also are defined.

Because of the 2-to-1 ratio between station spacings and stacking-bin dimensions, source-station and receiver-station spacings should be one-half (or less) of the narrowest horizontal dimension that needs to be interpreted from 3-D data.

Referring to [Figure 1](#), we have now defined parameters – source-station and receiver-station spacings – required for the first calculation step of the 3-D design process.

Summary

One appeal of the 3-D seismic design philosophy described here is that the design procedure uses geological concepts to guide the selection of geometrical parameters – the first concept being the physical size of the smallest stratigraphic feature that the seismic data must image. This non-mathematical approach to 3-D seismic design is intended for nongeophysicists – and it produces good 3-D images for most geologic problems that do not involve severe structural dip. Where rock units have steep dips or where large changes in rock velocity across fixed horizontal planes, a more rigorous calculation of station spacing should be made using commercial 3-D design software.

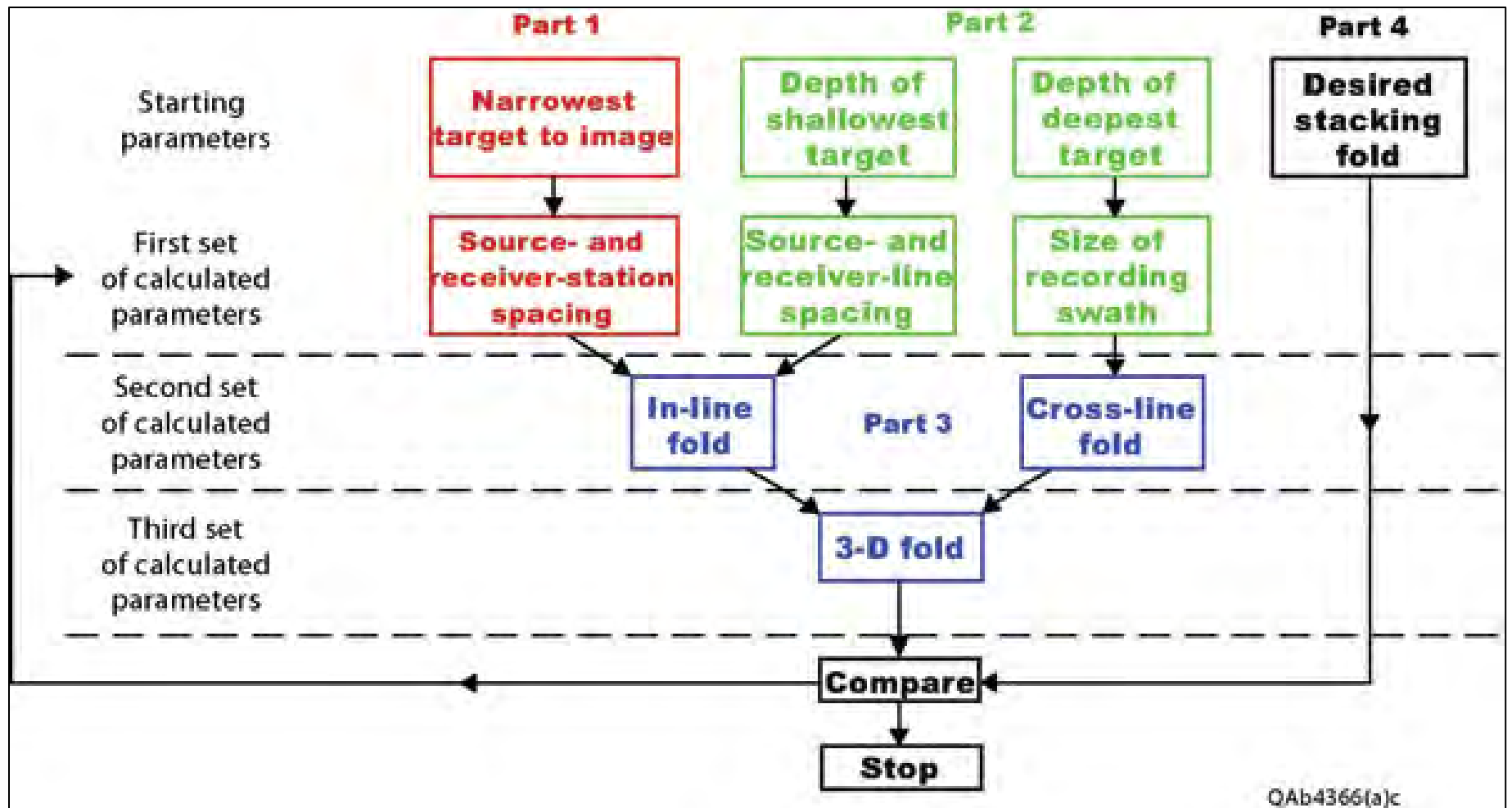


Figure 1. Planning steps that can be followed to design 3-D seismic acquisition geometry. There is no single procedure for designing a land-based 3-D survey. Each prospect offers different design challenges, and 3-D designers follow various preferred computational steps. The method discussed here is logical, easy for non-geophysicists to understand and can be used for many 3-D seismic prospects. The method will be presented as a four-article series, with the topic of each article color coded on the chart. This paper deals with part 1 of the methodology.

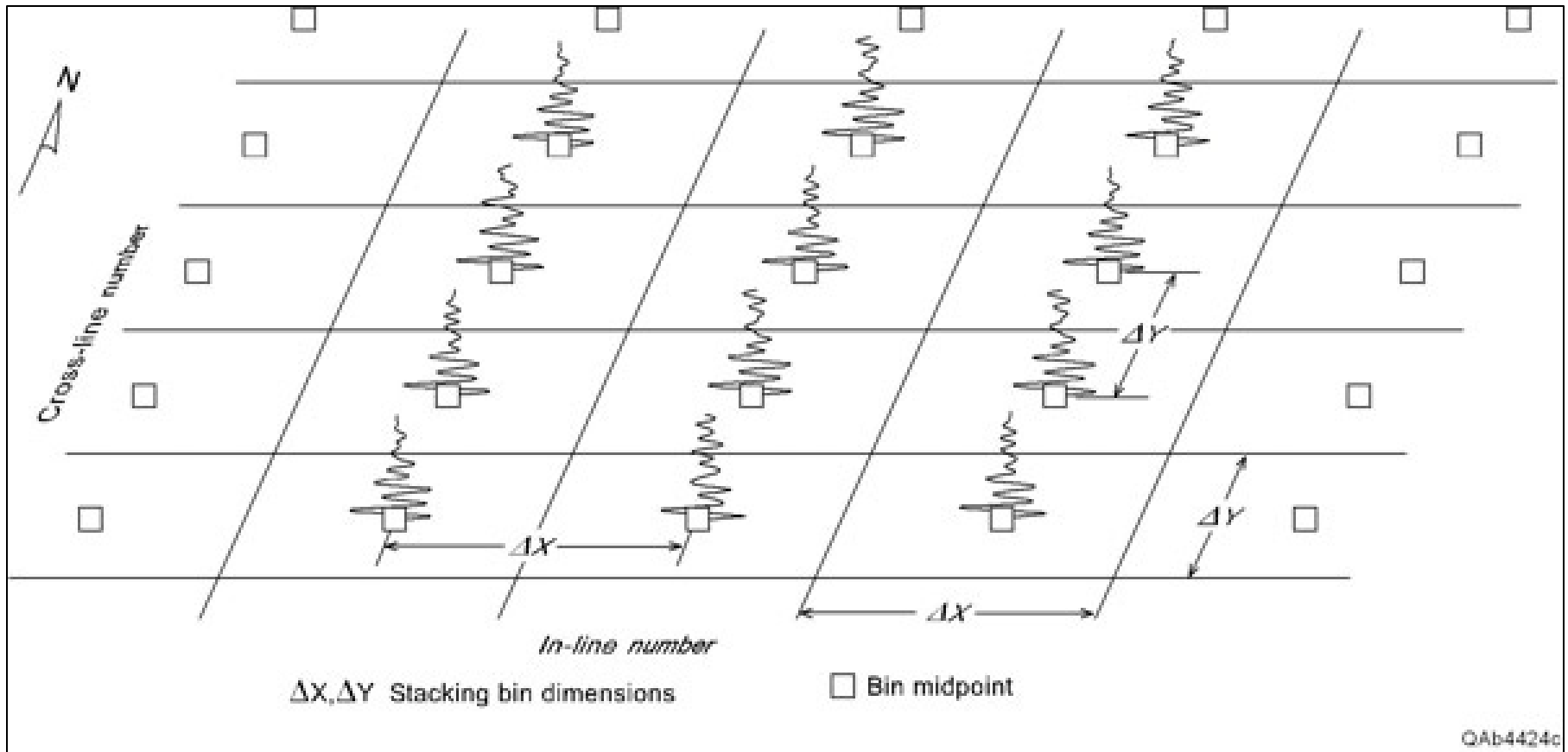


Figure 2. The area spanned by a 3-D seismic image is divided into a grid of small, abutted subareas called stacking bins. In this illustration, each stacking bin has lateral dimensions Δx and Δy . At the conclusion of 3-D data processing, a single seismic trace passes vertically through the midpoint of each stacking bin. The horizontal separations between adjacent processed traces in a 3-D data volume are Δx and Δy , the same distances as the dimensions of the stacking bins. The term in-line used here is defined as the direction that receiver cables are deployed, which is north-south in this example. In-line coordinates thus increase from west to east. Cross-line refers to the direction that is perpendicular to the orientation of receiver cables; thus cross-line coordinates increase from south to north.

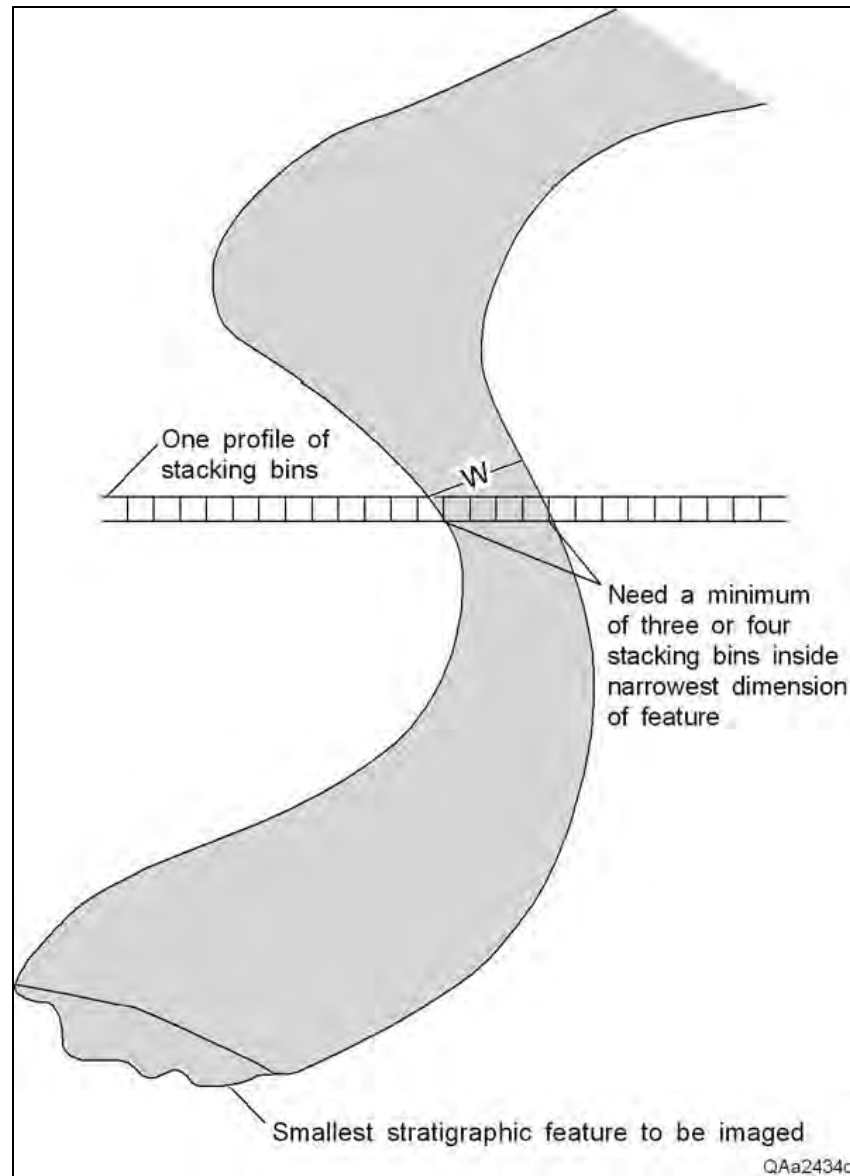


Figure 3. Example of a narrow feature that needs to be seen in a 3-D image. The first parameter that has to be defined in this 3-D seismic design method is the smallest (narrowest) horizontal dimension of a feature that must be seen in the 3-D data volume. For purposes of illustration, it is assumed the narrowest feature that is to be interpreted is a meander channel. At least three, and ideally four, stacking bins (seismic traces) must lie within the narrowest dimension W of this channel if the channel is to be reliably seen in the seismic image during workstation interpretation. Once this minimum channel width W is defined, the dimensions of the stacking bins are also defined, those bin dimensions being no wider than $W/3$, and ideally, they should be $W/4$ or less.