A Stakeless Method for Land Seismic Surveying

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Summary

A new method has been developed that provides an innovative solution to problems commonly associated with conventional land seismic surveying. "Stakeless surveying" dramatically improves operational procedures by eliminating the need for stakes and flagging while providing a higher level of positional accuracy for each seismic point. Using this technique requires some modification to receiver deployment and source navigation procedures. This technology provides multiple benefits without increasing program costs.

Introduction

Surveying has long been an important component of 3D seismic acquisition. While survey methods have evolved with improvements in technology, the standard technique has been to mark points with stakes and/or flagging prior to recording operations. This leads to numerous problems resulting from the time lag between surveying and recording.

Problems with Conventional Methods of Seismic Surveying

The 3D seismic technique on land requires locating and surveying numerous source and receiver positions on the ground. The point markers are usually required to remain on the ground for long periods of time before being utilized. This often results in missing, damaged or hard to find markers due to various circumstances including:

- Inclement weather conditions
- Livestock and/or wildlife feeding
- Agricultural activity
- Cyclic vegetation growth

On lands administered by the U. S. Bureau of Land Management (BLM), source line surveying is required months ahead of seismic recording to allow time for completing an archeological assessment. In extreme cases, survey crews must revisit the project area to refresh flagging and stakes, resulting in additional costs and interfering with scheduling.

In addition to these problems, there are positioning issues that impact data accuracy. Theoretically, seismic energy originates from a source point (drill hole or center of vibrator array) and is recorded at a receiver point (center of geophone array). These points are often not equivalent to the locations surveyed. Reasons for this include:

- Drills can't access the surveyed point, especially in heliportable or heavily-wooded operations
- Weather conditions may cause the relocation of vibrator points
- Vibrators often have to be offset from a point so vibrator operators can see the stake (figure 1)
- Permit conditions may change
- Receiver arrays may not be properly positioned in conditions of rough terrain or heavy vegetation

Several of these conditions require undesirable re-surveying, increasing the likelihood of scheduling problems and data errors. After the recording phase of the project is completed, all stakes and flagging used on the program must then be retrieved and transported offsite. This method of conducting a separate survey and seismic recording effort results in two unrelated sets of data that require integration in the processing center.

Stakeless Survey Method

A solution to many of the issues presented is surveying simultaneously with drilling or recording operations. This eliminates the need for stakes or flagging, provides more accurate positioning of seismic points and increases productivity. By combining Global Positioning System (GPS), Geographic Information System (GIS) and navigation technology into a system for seismic acquisition, a robust solution is created.

Stakeless Source Operations

For vibrator operations, each unit is equipped with a GPS receiver and a computer-based navigation system. Individual vibrator array locations programmed into the system (figure 2). Corrections are applied to compensate for the difference in the GPS antenna position and vibrator pad location. GPS base stations, providing Real Time Kinematics (RTK) corrections are set up throughout the project.

During production, the operator navigates to a source point and positions the unit as close to the desired location as conditions allow. While the vibrator point is being recorded, the GPS units are gathering data. In the time the point is recorded, a center of gravity (COG) for the array has been computed (figure2) and the value sent back to the recorder. Locations of each vibrator, along with a "breadcrumb" trail depicting each unit's travel path are also logged. When the system detects a vibrator has entered an avoidance zone, visual and audio alarms are activated. A similar system is installed in the recorder or at base camp for monitoring the locations and progression of the vibrators. Any other GPS-equipped vehicles on the project can also be monitored.

A slightly modified version of the system is used in heliportable-drill operations to account for the unique requirements of this method. These include determining the length of the long line, drill stem height and helicopter to ground azimuth, all of which are required for the positional calculation (figure 3). The process includes navigating to a pre-programmed source point, determining the best drill location using a ground spotter, placing the drill and recording the position. A benefit of this system is the ability to record a redundant position when retrieving the drill unit.

Stakeless Receiver Operations

The receiver layout is done in two phases. The first consists of a helicopter navigating to and placing equipment bags at specified drop locations. This eliminates having to mark drop locations on the ground with flagging and creates a visual "trail" of bags along a receiver line. The next phase is standard geophone deployment except with a GPS-equipped surveyor just ahead of the layout crew. The surveyor navigates to a receiver point, spray paints a dot on the ground at the center of the array and records the position. In the case of an inline array, the surveyor can also navigate to and mark the beginning of the array.

Stakeless Survey Quality

The stakeless survey method provides more accurate seismic point positions than conventional survey techniques by recording actual array center locations. State-of-the-art GPS receivers, RTK corrections and standard survey controls are employed. A survey specialist manages and quality controls all survey data. An advantage to this system is the near real-time feedback loop both for points needing re-surveying and for correlating survey data to recording logs.

Stakeless Survey Economics

The cost of stakeless surveying compares favorably to that of conventional surveying and is often more economical. All stakeless survey projects to date (over a four year timeframe) have been completed at equal or less cost than conventional surveying. The stakeless method eliminates most survey consumables and clean up labor. Also, there is no need for costly refreshing of stakes and minimal need for re-surveying. Offsetting this somewhat is the requirement for GPS units and computers in each vibrator along with system development costs. Since costs vary depending on project conditions, the economics of each program must be considered on a case-by-case basis.

Example

The Simpson Gulch 3D seismic project located in the Green River Basin of Wyoming provided ideal conditions for stakeless survey operations with a vibrator source. The terrain consisted generally of wide open prairie with minimal vegetative cover.

The project area occupied BLM-administered lands almost exclusively. Archeological studies were required before source lines and vehicle access trails could traversed. Instead of conventionally surveying and staking source positions, the team of archeologists used handheld GPS units for navigation and access route location.

The stakeless survey method was successfully implemented on the Simpson Gulch program, with over 24,000 source points recorded and 8000 receiver locations deployed. During the processing stage of reconciling the geometry, only 24 (0.1%) of the source point positions were modified – a remarkable achievement on a land 3D seismic program.

Conclusion

The application of modern technology to land seismic surveying has resulted in an innovative navigational technique providing substantial quality and productivity benefits over conventional surveying methods. As the stakeless survey method becomes more widely used, we will realize longer-term benefits such as improved safety statistics and reduced environmental impact. To fully exploit it's potential, the system must be utilized in more challenging operating environments.

Acknowledgements

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For Further Reading

Elkington, G., Lansley, R. M., Martin, F. and Utech, R., 1995, Uses of GIS data in 3-D seismic designs and acquisition, 65th Ann. Internat. Mtg: Soc. of Expl. Geophys., 957-959.

Wilson, B., 1998, Solving problems in land and transition zone positioning, 68th Ann. Internat. Mtg: Soc. of Expl. Geophys., 129-132.

Figures

Figure 1. Inline vibrator positions. In the picture on the left, the vibrator operator must offset the unit in order to see the stake. The diagram on the right depicts an overhead view of an inline vibrator array showing the offset to the surveyed stake position.

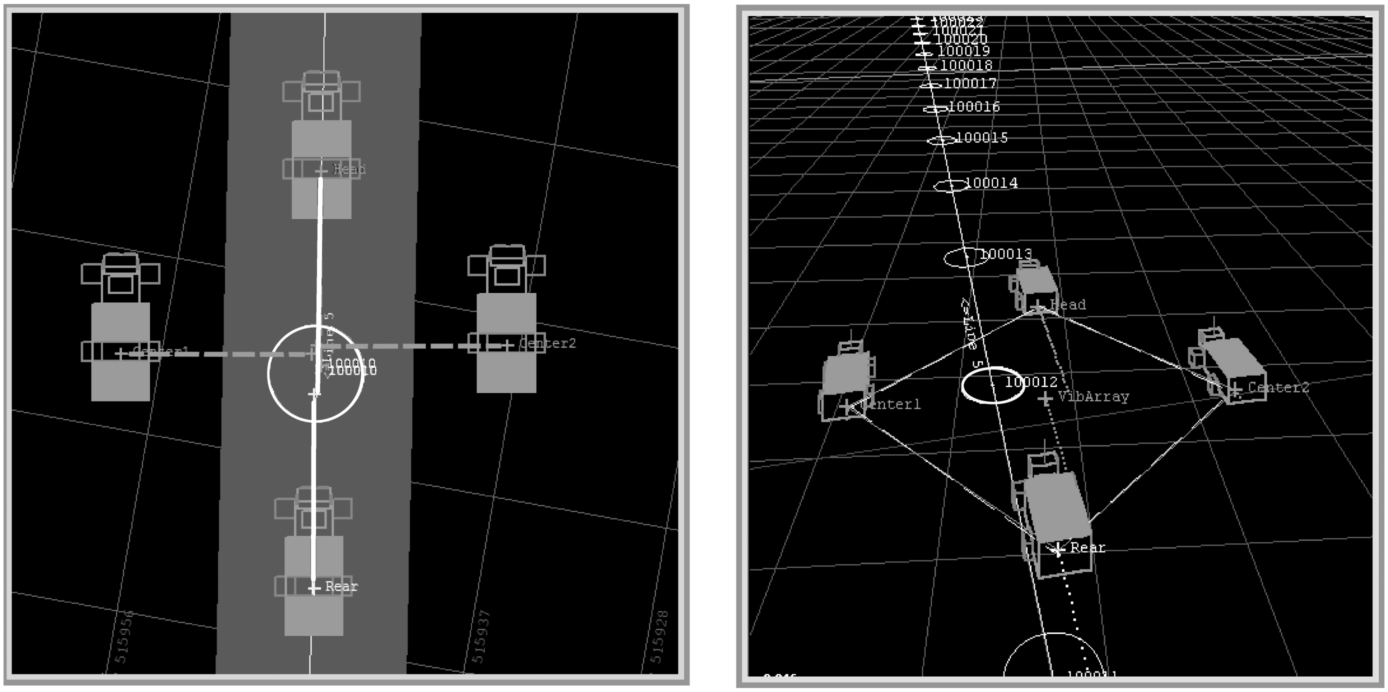

Figure 2. Vibrator navigation screens. An overhead view on the left shows the vibrators positioned in a parallelogram. The center of the circle is the preplan position for the source point. A view of the projected path is shown on the right. Note that even though the center of the vibrator array is deviated from the target circle, the computed array center or COG is recorded.

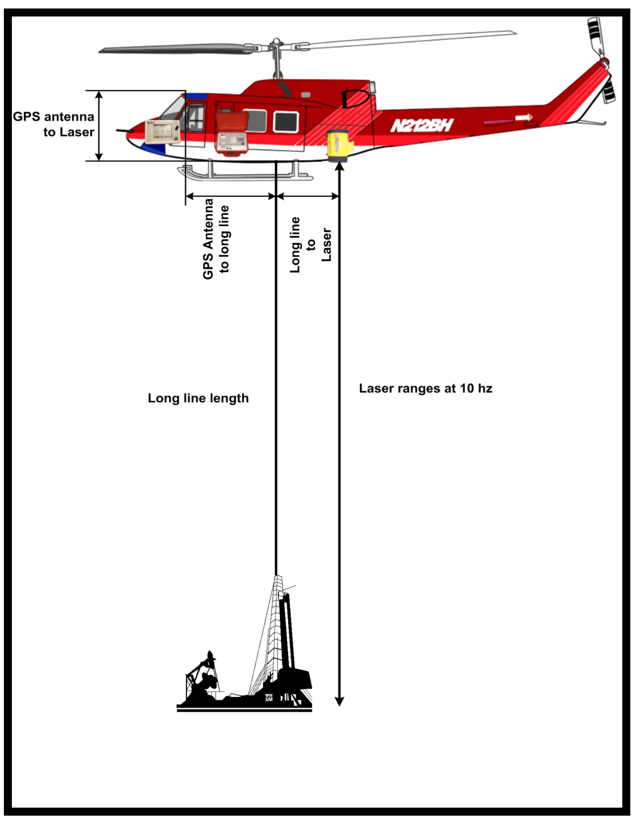

Figure 3. Airborne surveying with a helicopter simultaneously positioning a portable shothole-drilling rig. Components of the system needed to compute ground position are shown.