A field comparison of 3-C land streamer versus planted geophone data
Gabriela M. Suarez* and Robert R. Stewart, The CREWES Project, University of Calgary

Summary
A land streamer survey was successfully conducted by the CREWES Project in an area located in the foothills of the Canadian Rocky Mountains. The land streamer experiment was composed of two 3-C receiver lines located side-by-side: the land streamer and a planted geophone. Comparison of raw shot gathers, amplitude spectra and stacked sections showed that the vertical channel data quality was found to be similar for both datasets, while the radial channel data was found to have highest quality for the planted geophone. The bandwidth of the P-P reflections was close to consistent for the individual datasets and had a good correlation between both of them. For the P-S case there was no consistency on the land streamer dataset or correlation with the conventional dataset.

Introduction
Over the past two decades, high-resolution seismic methods have become popular for resolving a wide variety of geological, engineering, and environmental problems (van der Veen et al., 2001). Investigations such as these require the imaging of shallow targets (<300 m) using densely spaced sources and receivers, which are usually distributed over short acquisition spreads. However, using the traditional technique of planting geophones in the ground and physically moving cables in a CDP roll-along is costly, labour and time-consuming, especially for SH-wave surveys with their requirement for smaller spatial sampling (Pugin et al., 2004). To address some of these issues, towed land-streamer systems have been in use since the 1970s.

A land streamer could be defined as an array of geophones designed to be towed along the ground. This idea comes from the seismic marine industry, where large volumes of high-resolution data are recorded using marine streamers. However, the first tests on land were restricted to ice or snow (snow streamer) both of which provide smooth sliding surfaces suitable for long streamer use and a good geophone coupling (van der Veen et al., 2001). The concept of a towed land cable was patented by Kruppenbach and Bedenbender (1975; 1976).

Numerous successful case studies have been presented during the last three decades, helping to improve the near-surface image of the subsurface (van der Veen et al., 1998, 1999, 2001; Pugin et al., 2004; Ivanov et al., 2006; Lorenzo et al., 2006; Inazaki, 2006; Speece et al., 2007). To further develop this technology, especially for converted waves surface acquisition techniques, the CREWES Project acquired a 3-C land-streamer system. The first experiment was conducted during summer 2007 in the Priddis area located southwest of Calgary. The objective of this first attempt was to image the first 50 m of the subsurface, tests the capabilities of this acquisition technique and proposed future improvements that need to be undertaken to achieve better quality seismic data (Suarez and Stewart, 2007). A second test was conducted in the same location during March 2008 but with the objective of doing a side-by-side comparison of a planted 3-C geophone line and a land streamer line. This paper describes the second experiment and discusses the results of the comparison from both acquisition systems.

Location
The survey area was located about 5 km from the town of Priddis in the foothills of the Canadian Rocky Mountains, southern Alberta. Our geophysical test site is also home to the University of Calgary’s Rothney Astrophysical Observatory. This area has been a location of extensive shallow VSP experiments by the CREWES project (Wong et al., 2007) and a 3D seismic survey. It is a University of Calgary geoscience test site.

Description of the survey
A side-by-side multicomponent seismic line configuration oriented nearly E-W was used for the test. The test consisted of a 200 m planted-geophone seismic line, a 20 m land streamer system and a 400 m source line. For the 2D “conventional line” were used 200 3-C geophones at a 1 m spacing. A land streamer configuration (1 m; 60 channels, 20 m total) was used over the grass-covered surface, with a 10 times cable roll with no overlapping, to reach the 200 m length of the comparison line.

The basic land streamer system consisted of a base plate, tow webbing, top plate and an ATV used as the towing device (Figure 2). The top plate is drilled to use 3/8- inch screw to adapt 3-C geophones (Figure 2). Its major characteristics are the non-stretch woven belts on which geophone units are mounted to form a multichannel geophone array, and the non-planted coupling of geophone units in contact with the terrain through metallic baseplates, which enables to move easily the geophone array up to the next position (Inazaki, 2006).
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The multicomponent survey employed a vibroseis source and multicomponent geophones (Figure 4). The source was an IVI Envirovibe (18,000lb) with a 4 times vertical stack sweeping from 10 to 250 Hz sweep with an 11 seconds listening time. The planted receivers were 10 Hz 3-C geophones that were being recorded at a 1 ms sampling rate by a Geometrics Geode recording system with 60 channels (land streamer), and an ARAM-ARIES recording system (“conventional line”). The source points were at a 10 m spacing and were subsequently repeated 10 times, corresponding each time to one roll of the land streamer system. The first and last source points were located 100 m off the receiver line, to have 300 m in offset for the first and last source points shortening that offset by 10 m each time until reaching the shortest offset of 200 m, which corresponds to the location when the source is in the middle of the receiver line.

In total, 40 shot locations were acquired, 200 receiver stations, 10 land streamer positions and a total line length of 400 m for the source line and 200 m for the receiver line. Processing

After acquisition, the coincident data sets were passed through the same processing sequence using identical processing parameters. The survey geometry resulted in a maximum fold of 8 for the vertical and for the radial channel sections.

The crucial step during the processing was the rearrangement of the datasets to make them equivalent. Because the land streamer data was acquired along 10 runs of the same source line, the different segments has to be put together, numbered, sorted and a geometry assign to it to make it look as a 200 m seismic line. For the conventional line, the same process has to be done because of the 10 times acquisition of the same line. For every run the equivalent traces to the land streamer corresponding to every run were chosen, the same receiver locations were killed and the same numbering, sorting and geometry was assign to it.

After generating stacked sections, the data was sorted to the common receiver gather domain and additional processing was applied to it with the objective of improving the signal-to-noise ratio for doing frequency analysis. Shot gathers and stacked sections

In Figure 3, the response of the various geophones of the vertical, radial and transverse channels for a raw shot gather are compared.

Vertical channel: Unprocessed source gathers recorded with the streamer and the conventional line are similar (Figure 3). The signal-to-ambient noise level is higher for the geophone planted line. On the raw shots for both datasets it is difficult to observe reflections as a consequence of the prominent coherent noise along the line, but differences are observed in the signal characteristics of the airwaves. They are strongest in the conventional data and weakest in the streamer data, probably because the latter suppress slightly the higher frequency signals (van ver Veen et al., 2001).

An average Fourier amplitude spectrum was calculated on a raw shot gather for a window corresponding to a signal only area (Figure 4). With this analysis is seen how the source gathers recorded with both systems are very similar: peaks and troughs match reasonably well up to 110 Hz.

The few reflections existent in this area are reasonably well imaged on both stacked sections (Figure 5); however the land streamer section looks more contaminated with noise. There is a considerable difference in amplitude between the sections but the same events between 75 and 300 ms can be observed.

Radial channel: The results for the radial channel are not as satisfactory as for the vertical channel. The unprocessed source gathers in the land streamer look noisier and the
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Events do not look very coherent as in the conventional dataset (Figure 3). The quality of the first breaks is poor for the land streamer.

The same Fourier analysis was done in the radial channel (Figure 4). Surprisingly, peaks and troughs match reasonably well up to 140 Hz.

In the stacked sections for the radial channel the main reflections are present but they are not continuous throughout the line for the land streamer dataset (Figure 6). They are considerable differences in amplitude, events and signal-to-noise ratio for these two sections, where the quality of the streamer dataset is of much lower quality than for the vertical channel case.

Figure 3: Raw shot gathers from conventional line (top), and land streamer system (bottom). Vertical channel (left), radial channel (center) and transverse channel (right).

Frequency Analysis of the receiver gathers

Signal bandwidth may depend on receiver location (i.e. its location along the receiver line) and receiver depth. However, geophone coupling and the quality of the geophone planting might be a controlling factor in the variation of the signal bandwidth as well, variation in bandwidth across the receiver line are considered to indicate variations in geophone coupling (Cieslewicz and Lawton, 1998).

The relationship between frequency content, receiver location and geophone coupling can be depicted by plotting the spectra data in three dimensions with contour plotting. For every receiver gather of every dataset, a separate frequency spectrum was calculated in the appropriate time window, creating a matrix that represent location along the receiver line; the rows represent frequencies from zero to nyquist; and each individual cell contains decibels below maximum amplitude of the frequency spectra. The analysis of both datasets were subtracted to analyze the differences of changes in bandwidth along the line (Figure 7 and 8).

Vertical channel: Between geophones of the two acquisition systems, the frequency spectra has a reasonably correlation between frequencies in the range 40-80 Hz. For low frequencies, amplitude attenuation is less for the land streamer than for the conventional line. For high frequencies, attenuation is higher for the streamer than for the planted dataset.

In the data, 70 Hz contamination can be seen, this should be consistent between all the receiver stations, but in the plot the consistency is better for the land streamer than for the other dataset where is only noticed at some segments of the line. This evidence is another indication of better receiver coupling for the land streamer in this frequency range.

Radial channel: Figure 8 show contoured plots of the difference in frequency spectra of converted-wave reflections for both datasets as recorded on the radial channel. For the radial channel there is a poor correlation between the frequency spectra of both datasets. The planted geophones do not have as great a variation in bandwidth across the receiver line as the land streamer phones. These observations indicate that for the converted-wave the
geophone coupling was better for the geophone planted line.

Conclusions

A comparison between a 3-C land streamer and a 3-C planted-geophone line was undertaken. The analysis indicates that for the vertical component the datasets show similar events and characteristics. This result corroborates the potential and versatility of this system and the reduction of time and labor for land seismic acquisition operations.

The land streamer system recorded high-resolution seismic data on a grass covered hill. Its geophone-to-ground coupling was good and very close to be matched with the geophone planted line for the vertical channel but no for the radial and transverse channels.

Employing a vibratory source improved the acquisition speed and offered the possibility of generating repeatable signals that were necessary to complete our experiment.

The raw shot gathers for the vertical channel were alike, showing the same characteristics for the noise, the first breaks and the reflections. For the radial and transverse channel the results suggested that even when the main reflections are shown it is not an equivalent dataset to the geophone planted.

The processed stacked sections showed the existence of seismic reflections in the area and corroborated the same results as the raw shot gathers.

Figure 5: Comparison of stacked sections in the vertical channel for the conventional line data (top) and for the land streamer data (bottom).

Figure 6: Comparison of stacked sections in the radial channel for the conventional line data (top) and for the land streamer data (bottom).

Figure 7: Difference plot of the frequency analysis of the vertical channel for the conventional line and land streamer data.

Figure 8: Difference plot of the frequency analysis of the radial channel for the conventional line and land streamer data.