



A Report On Land Streamers: The Last Geophone You Will Ever Plant?

Seismic surveying gives some of the best sub-surface images of any geophysical technique. Since the ground supports a wide variety of particle motions, there are many different types of seismic waves, all which carry information about the subsurface.

But the improved resolving power of seismic imaging comes with some costs. Surveys can be time consuming and labor intensive, particularly for measuring the reflected portion of the wavefield. High resolution surveys can require great care planting geophones to ensure good coupling necessary for high-frequency recording.

The seismic marine industry is capable of recording large volumes of high-resolution data that have long been the envy of land geophysicists. While land surveys involve tedious hours slogging through swamps, dragging across deserts and sometimes spending as much as 5 minutes to plant a single geophone in hardpan or hard rock, marine surveys are conducted by effortlessly dragging hydrophone streamers behind boats. The coupling between the streamer and the water is excellent and the 'mobile array' permits the collection of massive amounts of high-frequency data that produces some of the best seismic images recorded.

Marine streamers have been so effective that there is widespread interest in developing a similar concept for land. There are many challenges to overcome: higher background noise, cross coupling between geophone elements, geophone misorientation, mechanical wear not to mention logistics concerns like dodging traffic on roads. But because the earth supports many different modes of vibration, land streamers have some attractive benefits. Not only can land surveys measure P waves, but also shear waves and surface waves, vibration modes that do not propagate in a marine environment. The measurement of surface waves with land streamers may be particularly appropriate since surface waves can be as much as an order of magnitude larger than body waves. And unlike the kilometer long streamers deployed in marine surveys, streamers for shallow land surveys can be relatively short and have very closely spaced geophones, a requirement for shallow surveys that currently makes their cost prohibitive for many applications.

Several innovators have been exploring the use of land streamers, and we bring you a brief report on their activities:

- Alan Green, ETH Switzerland
- Carsten Ploug, COWI, Denmark
- Andre Pugin, Illinois Geological Survey
- Rick Miller, Kansas Geological Survey
- Jorgen Ringgaard, Ramboll, Denmark
- John Clark, Bay Geophysical, Traverse City Michigan
- Mats Svensson, Tyréns Infrakonsult AB, Sweden
- Marvin Speece, Curtis Link, Pat Miller and Jack Kruppenbach, Montana Tech and PFM Manufacturing



COWI's Land Streamer and MiniVibe II Source

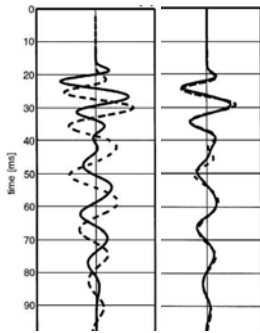


The long and winding road: Ramboll's land streamer moves fast and avoids permits

ETH, Switzerland

One of the earliest and most thoroughly documented land streamers was built by the Institute of Geophysics at ETH in Switzerland, as discussed in van der Veen and Green, 1998, and van der Veen et al., 2001. This land streamer is constructed using self-orienting gimbale geophones weighted with 1 kg housings. The housings are separated by 1 m and mounted on the underside of a rubber sheet. This configuration decouples the geophones from each other, but allows them to dig a small trench to improve contact in softer soil.

The group at ETH first made a thorough comparison of the differences between traditionally planted geophones and their land streamer. This included comparisons on a variety of surface conditions: undisturbed ground, in a shallow trench, on soft soil (meadow), on hard packed gravel and on asphalt. Results were encouraging and



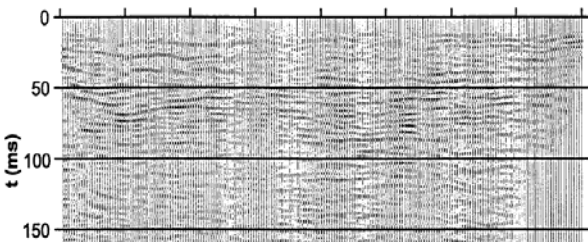
Comparisons between planted and unplanted geophones on the surface (left) and planted and unplanted geophones in a shallow trench.

suggest that in many conditions, coupling similar to planted geophones can be obtained by increasing the weight on each phone or by tilling a small depression in which the phones can lie.

Equally encouraging were ETH's estimates of labor reduction when using a land streamer. The Institute typically uses 5-6 people for operating a 96 channel survey: one recorder, two on the seismic source, two laying and

moving cable and one running an auger for drilling shot holes if an explosive source is used. With the land streamer, they were able to reduce the crew by 30-40%

and increase ground coverable by as much as 100%. Further savings could be obtained by using an impulsive or swept surface source that requires no drilling.

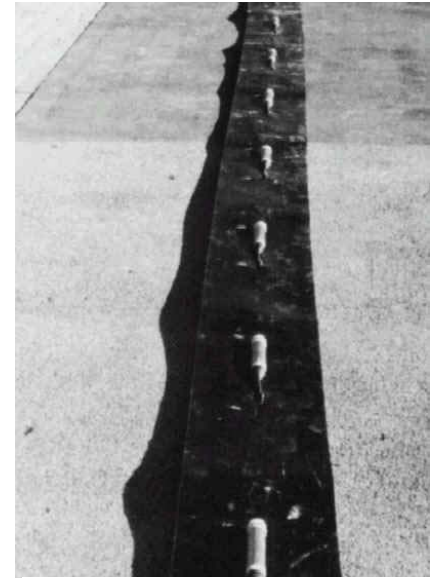


The difference between planted geophones and the land streamer are subtle even in a processed section

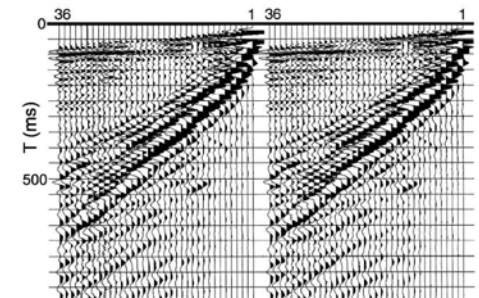
Although differences do exist between the planted and dragged geophones, the original character of the data appears well preserved. Shot records on various surfaces reveal only subtle variations. Similarly, van der Veen et al. present a plot of the differences between the land streamer and conventional sections that shows only small values.

The article also recommends that some possibilities exist for either collecting pseudo-3D data by acquiring multiple parallel lines, or even

towing multiple parallel streamers for true 3-D acquisition. Although the practical logistics of towing a 3-D array on land would have to be addressed, the cost saving suggested by van der Veen et al.'s 2-D experiments suggest that 3-D land surveying for shallow targets may be practical.



The ETH land streamer deploys gimbale geophones on a rubber mat to reduce cable snags



Shot records comparing spiked geophones (left) and the land streamer (right) yield almost identical results

COWI, Denmark

An ingenious land streamer has been devised by Dr. Carsten Ploug at COWI in Lyngby, Denmark. Dr. Ploug worked with Pro-Seismic to develop his streamer which consists of self-orienting gimbaled phones. The 200 m long streamer is equipped with 95 geophones, separated 1.25 to 2.5 m along the cable. The differentiated geophone spacing with short spacing close to the vibrator facilitates improved data quality in the shallowest part of the subsurface while achieving the ability to acquire data from more than 1 km in depth due to the 200 m maximum offset.

The land streamer is primarily developed for deployment on paved roads. The gimbaled geophones are, however, towed off the main streamer on drop leads, facilitating data collection on dirt roads as well, because it allows each geophone to rest on more stable ground before each record is taken. In addition to the cost-effective advantage of the land streamer system, acquisition on public roads does not require special permitting to cross private or restricted areas.



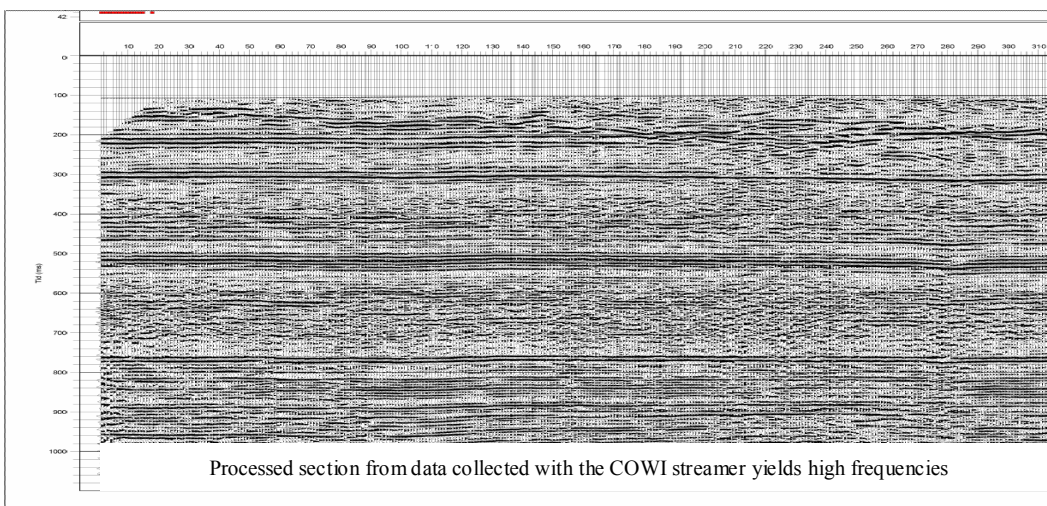
Wood blocks level streamer on pavement and reduce wear



Gimbaled geophones on drop leads orient geophones and improve data quality on dirt roads

Dr. Ploug utilizes an IVI MiniVibe II for both towing the streamer and as the energy source. Geometrics Geodes are used for recording the data and for correlating in real time. High-speed hardware correlators are included in each box and any number of channels can be correlated in less than 1 second. The smaller correlated data sets speed data transmission back to the host PC (in this case a laptop computer), so many more shots can be taken each day. An unstack feature allows noisy shot to be rejected and repeated without significant loss of survey efficiency.

It is hard to argue with the quality of Dr. Ploug's data. Shown here is a stacked CDP section with frequencies in excess of 100 hz and penetration to over 1.0 second. Data were taken in Denmark in southern Jutland as part of a study to map deeply buried groundwater aquifers.



Processed section from data collected with the COWI streamer yields high frequencies

More than 150 km seismic acquisition in 2002 is a testament to the reliability of the COWI system. Dr. Ploug and his system are available worldwide for consulting and data collection. The total seismic system includes the MiniVib II and land streamer concept as well as a distributed system with Geometrics Geodes and

traditional seismic cables and geophones. The entire system is packed in a 40 feet container which may be shipped world-wide. Contact: Dr. Carsten Ploug, cpl@cowi.dk, +45 4597 1469.

Illinois Geological Survey

Andre Pugin, at the Illinois Geological Survey, is well known for meticulous processing and careful acquisition of some of the best reflection data profiles published. Andre has extended his skills to higher volume data collection using a land streamer designed for collecting both shear and compressional wave data.

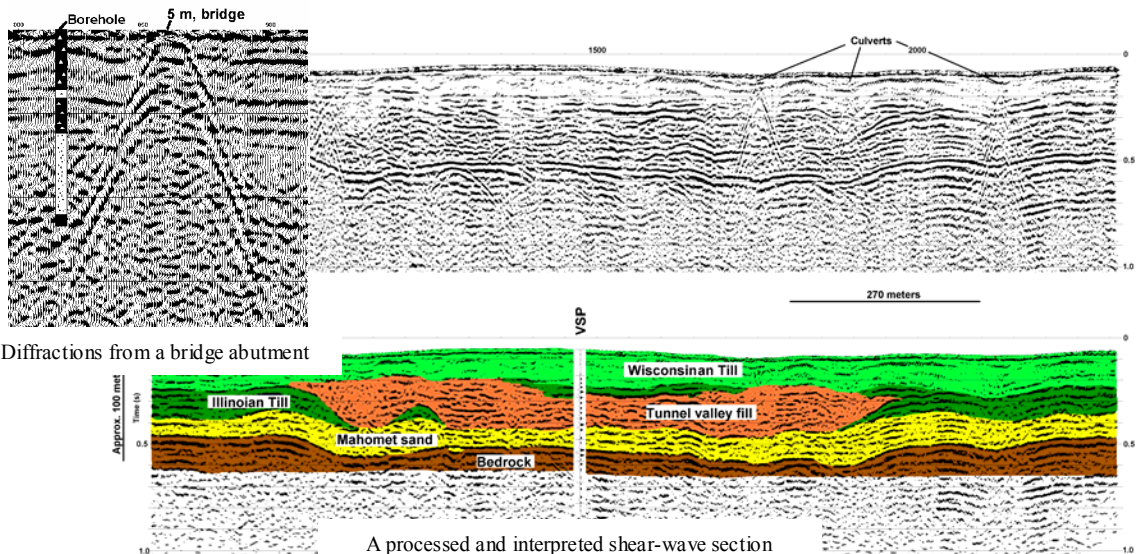


One focus of the Illinois Geological Survey involves the detailed study of aquifers and contamination from soil gas. A land streamer allows collection of enough data to map large areas quickly and efficiently.

Andre uses an impulsive source and finds that a simple hammer is often all that is needed to give data as deep as 1 second. The slower propagation speeds of shear waves yield improved resolution for characterization of lithology. In the seismic sections below, several lithologic units are visible. What is remarkable is evidence that this technique measures a sufficiently wide range of frequencies to detect culverts and bridge abutments close to the surface.



The IGS high frequency, high production rate seismic source, caught mid-swing.



Kansas Geological Survey

The KGS has long been known as a center for innovation in shallow seismic surveying. KGS scientists have been prolific, and a continual stream of new ideas, new inventions and new techniques have been introduced to the geoscience community. Not surprisingly, the KGS has also been experimenting with land streamers to accompany their research into the use of the dispersive characteristics of surface waves. However, besides using surface waves as a new tool to map stratigraphy, Rick Miller, Jianghai Xia and Choon Park have been exploring other characteristics of surface waves for imaging lateral discontinuities such as zones of reduced shear strength and even voids and tunnels.



The KGS streamer is constructed from a fire hose. Shown here is the KGS recording system, consisting of a 240 channel StrataView mounted on an all-terrain vehicle.



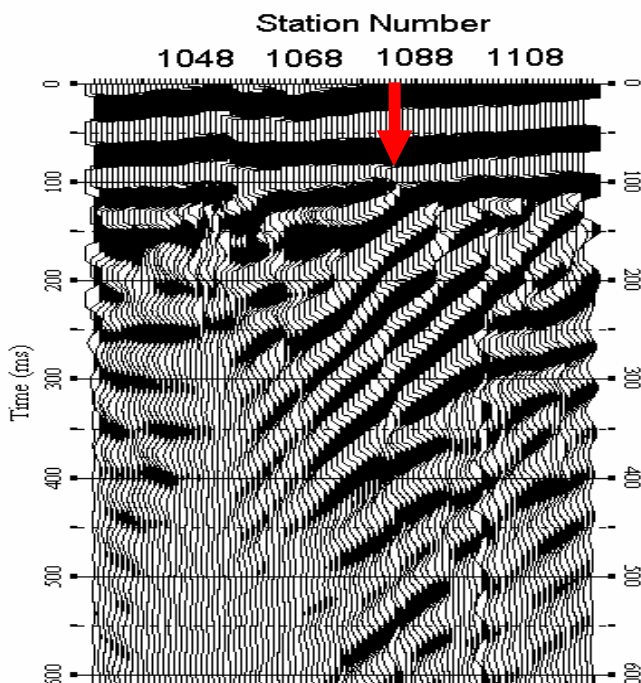
Geophones are mounted to a weighted cutter that creates a trench for better coupling

The KGS streamer takes a different approach to coupling than other streamers. The geophones are mounted inside a piece of heavy-duty fire hose. Instead of a spike base, each geophone is screwed into a clever three-pointed 'cutter' that carves a groove into the surface that it is being dragged over. Loose dirt is pushed aside and light vegetation is sliced,



Weight can be added to the interior of the streamer to compensate for ground conditions

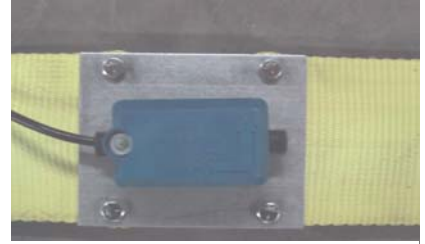
leaving firmer ground that improves coupling. Chain is added for additional weight, depending on the surface. The fire hose protects the cable, reduces tow noise, isolates each receiver pod, and is strong enough to be pulled by a tractor.



Rick uses both impulsive and swept sources to generate surface waves. In some of their studies, the KGS finds that surface waves not only have dispersive characteristics but can behave like body waves by reflecting and scattering from discrete discontinuities like pipes and tunnels. In the figure opposite, a diagonal wave pattern beneath the arrow highlights surface waves reflected from a buried drug tunnel on the U.S. Mexico border.

Bay Geophysical

John Clark at Bay Geophysical, located in Traverse City, Michigan, has developed a P & s-wave land streamer that is based on an initial design by Dr. Tomio Inazaki at the Geological Survey of Japan. This streamer utilizes a fabric strap as the tow device and steel plates as the coupling devices and works well on paved roads and smooth surfaces.



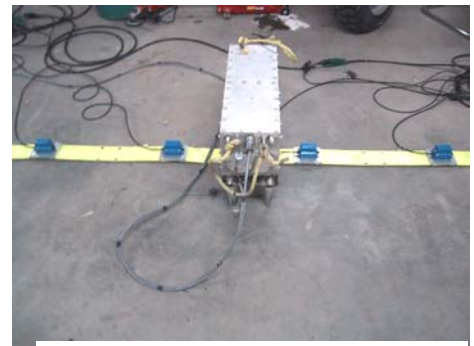
Geophones are mounted to a fabric strap



Bay's land streamer on a gravel road, imaging the subsurface using energy from Bay's shear-wave vibrator

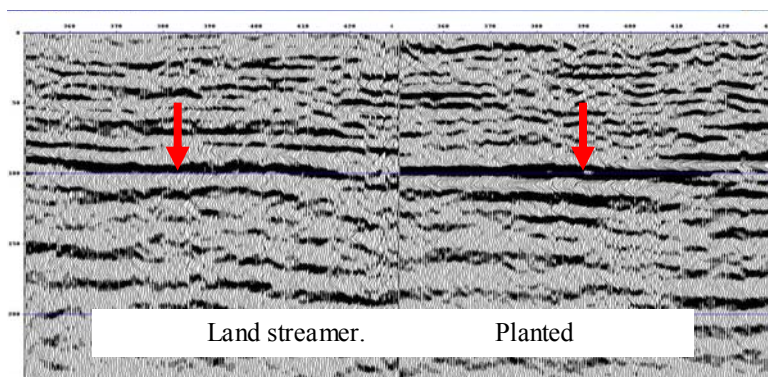
Geophones are housed in an Oyo GeoSpace 2-component case which is capable of accommodating either two orthogonal horizontal geophones or a vertical and a horizontal geophone. The aluminum plate at the top provides a means of attaching the geophone to the bottom plate while simultaneously insuring that the majority of the transducer mass is kept close to the ground. Unlike other designs, John's streamer can be configured with geophone spacings of 1-5 feet in increments of 1 foot. The streamer is sectionalized, each section 25 feet in length.

Coupled with Bay Geophysical's patented micro- vibrator, this device has thus far proven to be effective for the acquisition of shear wave reflection seismic data. The portability of the vibrator allows for split spread application. To date, this streamer has been tested solely in the shear wave mode of application. The streamer and vibrator are portable enough to be deployed from small vehicles and transported by air.

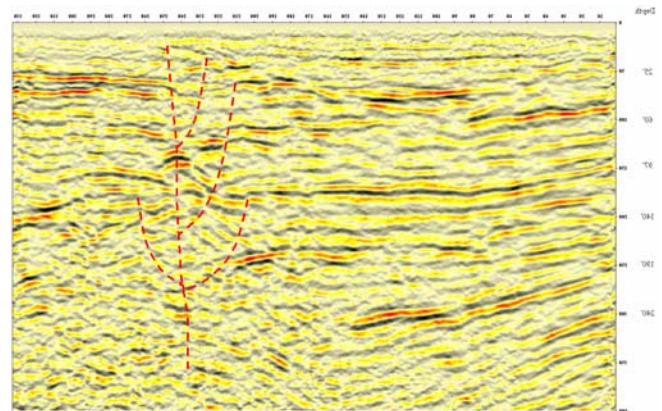


Bay Geophysical's shear-wave high-resolution vibrator.

A comparison of land streamer and geophone collected data is shown below from a site in southern Illinois. This data comparison was obtained during the first production test of the land streamer. The bright reflection at 100 milliseconds is a coal seam approximately 50 feet deep. The land streamer data is the section on the left. While there were some minor differences in reflection signature between the geophones and the land streamer, the sections were sufficiently similar to warrant additional acquisition with the streamer.



To date, the streamer has been tested against geophones in several locations around the United States including Florida, Illinois, Michigan, California, and Nebraska. The seismic section



opposite is a section from urban Los Angeles, California, taken in an area where there was severe vehicular and pedestrian traffic. The micro-vibrator/land streamer combination effectively overcame the ambient noise to depths of at least 200 feet.

RAMBØLL - Denmark

RAMBØLL started development of a new seismic land streamer in year 2000. They are now using their third generation of streamer and they have acquired more than 200 kilometers of shallow high-resolution seismic data during the last 2 years.

RAMBØLL can choose from a selection of several streamers with different geophone spacings, which can be combined to build an acquisition spread containing 30 to 102 channels. The streamer sections are combined from job to job to optimize the spread to the target.

RAMBØLL's streamers use conventional p-wave geophones. Data are recorded on a 64 channel StrataVisor NZ seismograph combined with two 24-channel Geode recording modules. A 3500 kg Minivibe made by Industrial Vehicles provides high frequency source energy up to 550Hz.



Data acquisition has been executed mainly on roads ranging from freeways to dirt roads - some in very bad shape with a soft sandy surface. RAMBØLL does not employ expensive gimbaled geophones, relying instead on 'sledged' which keep the geophones in the desired orientation. The sledges have sharp edges, which cut a small trench into unpaved roads to insure good coupling.

RAMBØLL finds the performance of the streamers is almost identical to traditionally planted geophones along the road margins. Land streamers dramatically reduce the costs of data acquisition and when the acquisition is done on roads, no permitting with landowners is required. With 10-meter shot interval the average daily production is about 2.5 km and this is done with field crews of only 2-3 persons.

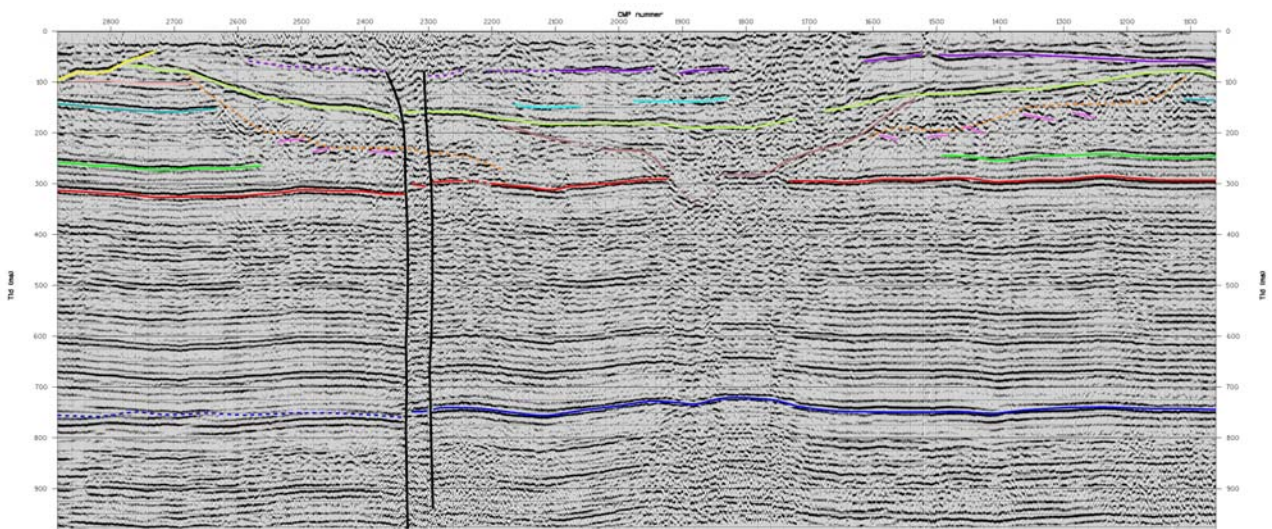
For further information, please contact Thomas Vangkilde-Pedersen at ph. +45 4598 6781 or e-mail: tvp@ramboll.dk or visit their homepage: www.ramboll.com.



The long and winding road. Ramboll's land streamer moves fast and avoids permits



MiniVibe source completes Ramboll's non-invasive seismic system



Seismic section showing a 4 km wide and 300 m deep buried quaternary valley in Denmark. The high-resolution section shows several generations of erosion and signs of glacial tectonic deformations along the slopes of the valley as well as an underlying fault system.

Tyrens

Tyréns, located in Sweden, has a rich history of innovation in the civil engineering industry. Following this inventive tradition, they have developed a 24-channel land streamer with a simple and elegant design. The main application for the streamer is to collect and interpret seismic surface waves. These data are processed and interpreted using the popular MASW technique, utilizing software written by the Kansas Geological Survey.

Standard 4.5 Hz OYO/Geospace geophones are mounted on metal plates (approx 4 kg) with a spacing of 1 m, connected to a synthetic fibre band. A Geometrics Geode seismograph and a laptop are used for data collection. For the actual test a sledgehammer is used as the seismic source, with an offset of 5 m.



A simple metal plate provides good coupling for Tyrens surface wave surveys

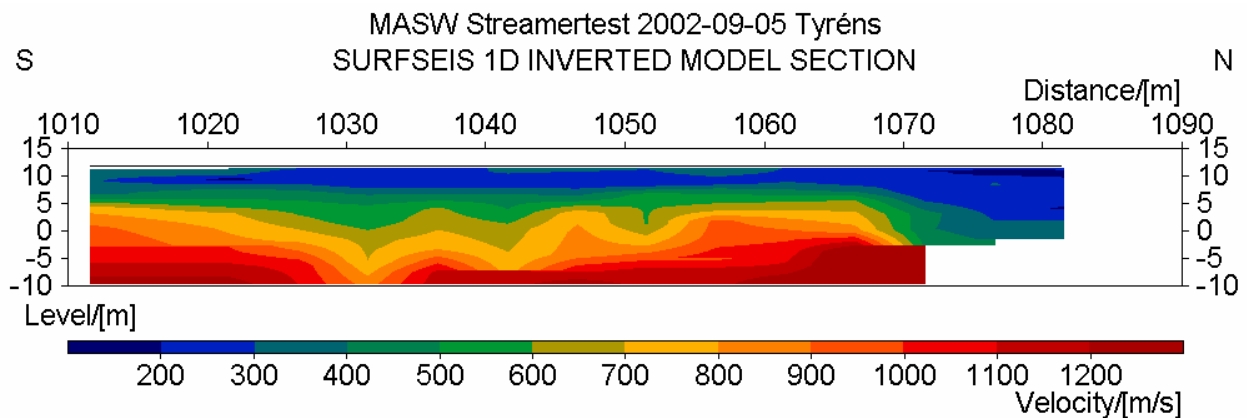


Tyréns land streamer undergoing initial testing

Initial tests of the system, presented here, were performed in an urban area in Malmö, Sweden. Ground correlation is provided using soil sampling and comparison to vertical seismic profiling surveys.

The resulting shear wave velocity profile shown below correlates well with the general stratigraphy interpreted from other data in the area - 5 m of clay till, 5 m transition zone with highly fractured limestone and more competent limestone below. The interpreted shear wave velocities are also well in accordance with shear wave velocities determined by VSP tests in the area.

For more information, contact Mats Svensson at mats.svensson@tyrens.se



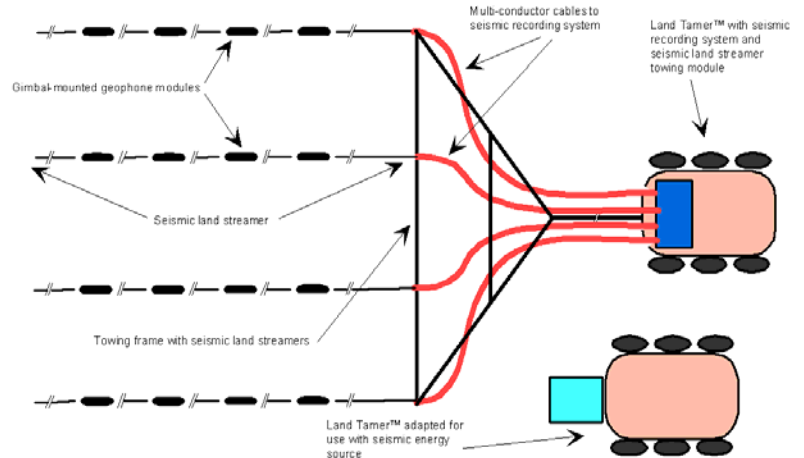
Montana Tech and PFM Manufacturing



PFM's Land Tamer is the platform chosen for the tow vehicle

The group at Montana Tech has been thorough in evaluating their design with respect to geophone coupling, and appear to be pursuing a configuration similar to the group at ETH. Gimbaleed geophones are mounted on the underside of a long rubber sheet with cables on the upper side to avoid tangles. Comparisons of spiked geophones versus land streamer configurations show significant differences when the gimbaleed geophones are placed directly on a soft surface like grass, but when on wet sand, asphalt or snow, coupling is almost identical. A final capping rubber sheet covers the top cables, making the system very robust.

Easily the most ambitious land streamer system to date is being constructed by Montana Tech under the direction of Marvin Speece, Curtis Link, Pat Miller and Jack Kruppenbach, an early pioneer of land streamer development and operation. This four streamer, 96 channel 3-D array will be towed behind an all-terrain vehicle and deployed using winches in true marine fashion to allow reduced setup time.



Four streamers are deployed from the back of the tow vehicle. A separate system vehicle deploys the source and can move independently of the receiver array.



A weighted rubber mat, similar in construction to the ETH design, is used to eliminate cable tangles and improve coupling

The Future

High-resolution seismic data acquisition is expensive and time consuming. Land streamers appear to provide a fast and comparatively economical method to collect the large volumes of data at close sensor spacings required to resolve near-surface velocity structure and provide a seismic image of the subsurface. It is clear that coupling is a major issue, but used prudently in situations where sensors can make good contact, land-streamers can provide excellent results. This is particularly true when reflections are already coherent and anomalies generated by the streamers are more obvious. Perhaps the use of multiple streamers would allow identification of localized coupling problems.

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