Wine country 3-D: Cable-less seismic acquisition in Mendoza Province, Argentina
Mike Yates*, Jeff Reck, Marty Smithey, Apache Corporation

Summary
After several years of anticipation and planning, in 2009 Apache was awarded the second of two exploration licenses in the Cuyo basin of Argentina, allowing the initiation of a long-anticipated two-survey 3-D seismic program. Despite their proximity the surveys were very different; one was in open, almost desert-like, terrain and the other was through the world-famous wine country of Mendoza.

Introduction
The two programs, “Alto Verde” and “Escalera”, lay about 50km apart; one to the south of Mendoza, and one to the east. Both were close to small towns, Tunuyan and San Martin respectively, both connected by major highways to Mendoza itself, simplifying the supply, transportation and accommodation of a field crew.

Based on initial scouting, the first survey, Alto Verde, appeared relatively uncomplicated. It consisted of 364 km² of open land dominated by dry scrubby brush land and low dunes, crossed by a highway and a river, and occupied by about 50 landowners. The area is surrounded by oilfield activity and had been crossed by several 2-D seismic lines, so the locals were somewhat used to seismic crews working in the area. From the outset Alto Verde was perceived as a “warm-up” for the second survey, Escalera, which would be the main event, and the reason Apache believed that a cable-less recording system was essential to success in Mendoza. As it turned out, cable-less technology played a large part in the success of the Alto Verde survey also.

In contrast, just 50 kilometers to the north-east, Escalera’s 220km² surface area was heavily developed for agriculture and divided amongst approximately 8,400 landowners many of whom grow grapes for the famous wineries of Mendoza province. Managing a seismic program with the environmental sensitivity of the area, along with irrigation systems, numerous small neighborhoods, and the close proximity of the town of San Martin was to become a major project for Apache’s permitting and local relations staff, as well as for the exploration team.

Cabled or Cable-less recording?

The first survey designs laid out for Escalera by Apache had been performed in 2005, well before the appearance on the market of the nodal, or autonomous, cable-less systems available in 2010. It had been clear from the outset that Escalera would be a challenging survey using a conventional cable-based system due to the small land parcels and irregular parcel size and geometry.

Apache’s prior experience with a conventional system in agricultural areas of Argentina suffered heavily from lost time spent navigating small farms trying to connect cables, high levels of theft and vandalism of cables, boxes and batteries, all of which added millions of dollars to the project due to stolen and damaged equipment, lost- and stand-by time.

A cable-less system would give complete layout flexibility with no dependence of one station on its neighbor; it would still be prone to theft and vandalism, but with the advantage that the theft of boxes would not stop the entire crew. Despite there being no such system in Argentina at the time, cost analysis at the start of the project suggested that the cost of shipping and system rental would more than offset potential losses, and Apache’s proposal to introduce this technology to Argentina played a key part in winning government approval for exploration work in such highly sensitive areas. An existing agreement between Apache Corp. and Inova Geophysical gave access to the FireFly cable-less seismic acquisition system, and this was the system selected for the program.

Initial survey designs and satellite imagery application

Based on target definitions and geophysical data derived from reprocessing existing 2D data, a set of basic requirements was established for each survey. Starting from lead polygons defined by the exploration team and from concession boundaries, calculated migration apertures were added to ensure imaging of each survey’s objectives.
and thus two surface outlines were created. These outlines, when draped on satellite imagery, permitted the first evaluation of the land enclosed within each, and how the local land-use would affect survey layout and operation and how survey design might be modified to optimize acquisition efficiency.

In Alto Verde, having the final outline and imagery enabled examination of survey division into zippers to allow recording with a limited amount of ground equipment. Initial layouts with N-S receiver lines were scrapped in favor of a layout rotated -30° that reduced the average line length and allowed the zipper division to follow the river thus requiring the vibrators to cross the river just once during the survey. The lack of cables between receiver stations removed the need for any equipment to cross the river, and thus removed a major hazard to personnel at the same time.

The land use pattern in Escalera was chaotic, with no prevailing direction for land parcels, few of which were larger than a couple of hectares. A grid of roads running approximately NE-SW and spaced approximately 600m apart was the only viable source grid, which left the problem of threading receiver lines through the vineyards in such a way to achieve the mix of seismic trace offset, azimuth and coverage required to image Apache’s objectives.

Using a nominal receiver line separation of 480m and station separation of 60m, a grid of receivers was dropped onto the survey area, being aligned with a visually selected dominant line direction approximately normal to the road layout. The receiver line was then virtually chained along field boundaries to create a layout achievable with a cabled system wired for 60m station intervals.

**Escalera final design, permitting and GIS applications**

The availability of a cable-less system removed many of the design constraints imposed by the need to connect adjacent stations by cable, added flexibility to layout operations by removing the need to deploy lines in any sequence, and allowed layout crews to follow the most efficient route instead of being forced to deploy sequential stations along a line. The entire survey layout was repeated, this time moving each station from its original grid location to a field boundary using an inline snap-to-grid. This process, which maintained the in-line receiver station distance on the grid, reduced the total number of receiver stations in the Escalera survey by 5%.

Apache was very fortunate in that the local government maintained a GIS database of land parcels and landowners; without this data the task of identifying landowners and contacting them would have been virtually impossible. Based on the intersection of the pre-planned receiver stations and the owner polygons, a “short-list” of 1,000 landowners on whose land receivers actually lay was created as a starting point for the permit process. Once the permit process was well under way, the GIS database was used for two more functions; to prioritize landowners based on how many receiver stations lay on their land (as opposed to parcel size, which is less relevant) and also to allow a visual inspection of receiver stations based on permit status. Many permits were removed from the short-list by simply moving the affected receivers a few meters cross-line across a fence, from a no-permit to a permitted parcel.

**Source testing and parameter selection**

The last seismic surveys shot in the Escalera area were 2D and were recorded almost 30 years ago using 16x16 s sweeps per VP from 3 Mertz M-9 vibrators. These had hold-down weights of 21,900 pounds and 1980’s control systems, hence it was essential to evaluate the necessary source effort before committing to final acquisition.
parameters and submitting budgets for a survey expected to use 62,000 pound vibrators with the latest control systems.

In October 2009 an opportunity arose to test source and receiver performance on two test lines, one in each of the two areas. In Escalera, the test line was positioned to allow the eventual tie of the upcoming 3D data to the closest existing well while in Alto Verde a long stretch of private road within the project area was selected.

The outcomes of the two tests were very different; in Escalera, the smallest source effort tested, a single vibrator, 8 second sweep, 40% drive would produce data clearly showing reflections from target depths, whereas in Alto Verde anything less than 4 vibrators sweeping at 80% for 20 seconds did not produce a viable record. For Escalera a single 12s sweep with two vibrators was selected as it offered the required signal to noise levels, and would allow the flexibility of running four fleets each of 2 vibrators. For Alto Verde, a single 30 second sweep was selected, using 4 vibrators.

Mobilization

The mobilization of the FireFly system from Houston to the project site in Argentina was no trivial task. Following detailed inventory of every component of the system it was shipped to Argentina and unpacked at the seismic base in San Martin. The first days of the program were very busy; while surveying was completed, radio towers were erected and equipped, the radio network established, batteries charged, recorder firmware upgraded, vibrator electronics replaced, and personnel trained in the operation of a system brand new to the country and of course to the crew.

Field operations – Alto Verde

On starting deployment of the system in Alto Verde another obstacle became apparent that was not present when the area was scouted – the two lane highway crossing the NW corner of the program area was being expanded to a divided, 4-lane highway. Fortunately, the cable-less system allowed this obstacle to be easily negotiated by allowing station skids to be defined on-the-fly, and avoiding the need for any line cables to cross the area being worked by bulldozers, graders, and other heavy equipment that could have proved difficult with a cabled system. Permit issues were easily resolved in a similar way, as any issues with a particular landowner could be quickly addressed by moving stations off that person’s land and redeploying them in a permitted area.

Field operations - Escalera

Adopting a wireless acquisition system not only liberates the design from the limitations of cables, it also permits different approaches to field operations and roll of equipment. Conventional spread roll with a cabled system is influenced by the need to connect stations to their neighbors and then connect adjacent lines by a transverse...
Wine country 3-D: Cable-less seismic acquisition in Mendoza Province, Argentina

line to the recorder. Adopting this type of spread generally means rolling receiver lines in a cross line direction while shooting or sweeping a series of relatively short salvos in the centre of the active spread, thus losing time in between salvos while shooters or vibrators reposition to the next salvo.

In Escalera, access along the roads that formed the source lines was excellent, but access between lines was very limited, so a new roll was needed that allowed each road to become a salvo, thus maximizing the available points and minimizing move-up time. Instead of a set of complete receiver lines allowing the acquisition of a salvo of shots, a series of receiver salvos laid out would allow the acquisition of a complete shot line, in this case one of the roads in its entirety with no detours. This approach required an inline roll of the receiver spread which was not an issue for the cable-less recording system and was possible without moving the recorder.

Despite 24-hour security patrolling the spread, theft and vandalism were rife toward the end of the project when more equipment was deployed close to San Martin and surrounding neighborhoods. Over one hundred stations of equipment were stolen or damaged at a significant cost. This cost, however, is believed small compared to the time that would have been lost if the crew was forced to stop recording every time a station was damaged, as would be the case with a cabled system. Although the data in each stolen station unit was lost, there was sufficient redundancy in the design and the general data quality was sufficient that this did not adversely affect the final product.

Conclusions

Recent advances in technology have created tools and techniques ideally suited to the planning and execution of complex 3-D surveys in sensitive areas such as those discussed here. The flexibility of cable-less technology on these projects allowed the acquisition of these two surveys on time and on budget. At the time of writing Apache was starting the drilling program based on the results of these two seismic surveys.

Acknowledgments

Apache would like to thank Global Geophysical Services, Inova, Ion, Enrique Segura and Alan Stark for their imagination and dedication in developing and executing these seismic programs, and Spatial Energy for the provision of all satellite imagery that aided the design and operation of both programs.