GEOGRAPHIC INFORMATION SYSTEMS FOR SEISMIC LINE OPTIMIZATION

Harnessing Spatial Data and LIDAR

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Ideal conventional seismic survey design creates regularly sampled source and receiver lines to produce high fold data with consistent offset distribution. A "text book" orthogonal seismic grid with evenly sampled perpendicular source and receiver lines, however, is impossible to achieve due to many physical and non-physical factors. In Alberta Canada, seismic design and acquisition is often adversely affected by geographic, ecologic, environmental, cultural and political concerns. Adjusting for these restrictions within traditional seismic design methods creates non-orthogonal sparsely sampled poorly offset distributed seismic data unsuitable for both acquisition and interpretation

However detailed use of Geographic Information Systems for seismic pathway design can produce high fold, high trace count, offset rich seismic data even where adverse conditions exist. In this paper, we look at a small section of a survey acquired by Explor in Northern Alberta where GIS methodology was successfully used to pre-design seismic pathways.

GEOGRAPHIC INFORMATION SYSTEMS

GIS for short

Geographic information refers to spatial data collected in an area of interest. This spatial data is combined in a Geographic Information System (GIS) which provides a framework to support project planning, decision making, survey navigation, and project management. Current GIS are also internet and cloud capable adding a high level of utility for field operations.

SURVEY LOCATION

Somewhere in Northern Alberta

Our select survey area covered approximately 32 km2 in Northern Alberta Canada. The survey was acquired between December 2016 and January 2017 with average temperature of -16C (3.2F) and lows of -33C (-27.4F). These low temperatures are advantageous as frozen ground aids baseplate-ground coupling for better signal transmission for seismic vibrators.

SLOPE OVERLAY

Comparison Between Pre & PostPlot

HIGH RESOLUTION IMAGERY

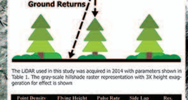
40 x 40 cm resolution

High resolution imagery with 40x40 cm accuracy was purchased for the area. As you can see, the imagery shows lush green summer, however, the survey was conducted in winter. High resolution imagery is good for verification of roads, buildings, boundaries, powerlines, and other utilities. Below are photos taken on the ground when survey was underway.

LIDAR - BARE EARTH

Hillshade 3x Height Exageration

Lidar (also called LIDAR, LiDAR, and LADAR) is a surveying method that measures distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Applications of LiDAR to land acquisition include, slope analysis, survey efficiency, hazard identification, map creation, radio communication, and logistical / safety planning



The LiDAR used in this study was acquired in 2014 with parameters shown in Table 1. The gray-scale hillshade raster representation with 3X height exaggeration for effect is shown

Point Density	Flying Height	Pulse Rate	Side Lap	Res.
2.2	1550 m	130 kHz	50 %	1x1 m

SLOPE

Slope Classification

Slope Classification
Degrees

- Clear: 0 - 8 - Vibe.
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 30 - No Vibe.
- 30 - 90 - No Drive

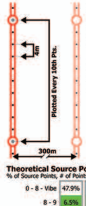
Manual Classification

Mini-vibrators were chosen as the seismic source for their low environmental footprint relative to heaver vibrators, versatility for high-resolution acquisition and agility in movement on the ground. However, these vibrators have limitations which make GIS essential for pre-planning source positions. Mini-vibrators are prone to toppling over if they attempt to shake on ground over and above certain angles. Large pieces of equipment on their sides are, as one might imagine, hazards to be avoided.

To ensure vibrators remain upright during acquisition, a schema based on slope degrees was formulated using years long field experience by several vibrator seismic supervisors. Three main categories were developed; "Vibe." (0 and 8 degrees), "No Vibe." (11-30 degrees) and "No Drive" (30-90 degrees).

THEORETICAL DESIGN

Maximum Coverage with Design Limitations



The first pass theoretical seismic line layout was designed as an orthogonal high-density acquisition with 4-meter source spacing and 300-meter source line separation (Figure to the Left). This design resulted in 27755 sources in our area of interest. Statistical spatial analysis of the sources points within the classified slope are shown below.

These parameters fulfil regulations that are in place in Alberta for environmental, ecological and local considerations. This type of layout is of course idealized and expected to change upon operations commencement.

Theoretical Source Point Analysis
% of Source Points, # of Points

Slope	%	# of Points
0 - 8 - Vibe	47.9%	13287
8 - 9	6.5%	1810
9 - 10	6%	1661
10 - 11	5.4%	1511
11 - 30 - No Vibe.	33.1%	[illegible]
30 - 90 - No Drive	1%	300

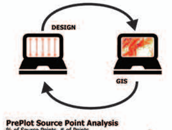
52.1% Questionable

Total Source Points in area of interst: 27755

PREPLOT (POST MOVE)

Results of Design / GIS Cycle Before Field Operations

To better position the lines, a manual process was devised where the seismic vibrator supervisors and GIS analyst worked together in-office to reposition the seismic lines to take slope and accessibility into consideration. This process took many hours (and much coffee).



PrePlot Source Point Analysis
% of Source Points, # of Points

Slope	%	# of Points
0 - 8 - Vibe	71.7%	17002
8 - 9	7.1%	1690
9 - 10	5.2%	1232
10 - 11	4.1%	966
11 - 30 - No Vibe.	11.8%	2803
30 - 90 - No Drive	0.1%	15

20890 Possible

Total Source Points in area of interst: 23708 (Theoretical Design 27755)

0 — 0.38 — 0.75 — 1.5
Kilometers
NAD 1983 UTM Zone 11N

Cartographer: Christopher Harrison 180506

POSTPLOT

Survey Completed

The seismic survey was acquired and PostPlot source points exported for analysis below. The postplot analysis shows that 73% of the points were viable for vibeing. But here is the kicker, all 25505 source points were acquired... BOOM!

PostPlot Source Point Analysis
% of Source Points, # of Points

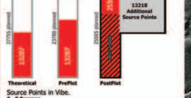
Slope	%	# of Points
0 - 8 - Vibe	73.3%	18693
8 - 9	6.8%	1722
9 - 10	6.1%	1544
10 - 11	4%	1042
11 - 30 - No Vibe.	9.8%	2504
30 - 90 - No Drive	0%	0

All 25505 Vibe Points Were Acquired

Total Source Points in area of interst: 25505 (Theoretical Design 27755)

Comparative analysis of the points are shown below.

Theoretical vs. PrePlot vs. PostPlot
Total source count



Source Points in Vibe.
0 - 8 Degrees

FUTURE DEVELOPMENT

Next Steps for Seismic Optimizaiton

From harnessing better imagery to automatic line positioning, the future of GIS seismic design integration is bright.

ASPECT

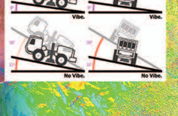
Slope Classification

Aspect
Value

- Flat (-1)
- North (0-22.5)
- Northeast (22.5-67.5)
- East (67.5-112.5)
- Southeast (112.5-157.5)
- South (157.5-202.5)
- Southwest (202.5-247.5)
- West (247.5-292.5)
- Northwest (292.5-337.5)
- North (337.5-360)

Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. The values of the output raster will be the compass direction of the aspect.

For seismic surveys, aspect can be harnessed to help vibrators avoid side-slope vibrating and navigation while maximizing up-slope vibrating and navigation. Integrating aspect may change slope classification to be direction dependant increasing over all seismic efficiency.



LIDAR - CANOPY

Lidar Classification

Forest canopy density and height are used as variables in a number of environmental applications, such as biomass estimation, vegetation coverage, and biodiversity determination. Canopy density, or canopy cover, is the ratio of vegetation to ground as seen from the air. Canopy height measures how far above the ground the top of the canopy is. Lidar can be used to determine both of these variables.

Tree Type & Height
Simplified

Canopy Value

- ≤1.5
- ≤5.4
- ≤10.4
- ≤14.8
- ≤18.5
- ≤22.1
- ≤60

Canopy height can be used to help navigate through dense forest, or even around dense forest as needs require. If colour infrared imagery is also harnessed, tree type, tree health, underbrush type and health can also information navigation.

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