OIL & GAS BEST MANAGEMENT PRACTICES

Seismic Exploration

Yukon
Energy, Mines and Resources

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Specific BMPs for specific problems cannot be given since solutions will, of necessity, be site and issue specific. Narrative BMPs are given indicating the type of measure which may be useful. Technical engineering prescriptions on how to build specific works or devices are beyond the scope of this project and the assistance of consulting engineering firms is recommended if you do not know how to construct, maintain or operate the relevant BMP or device.

Mention of trade names, commercial products or machinery does not constitute endorsement, or recommendation for use.

This guide is intended to provide users with up-to-date information about best management practices for oil and gas exploration on the Yukon Landscape but this project should not be considered as complete. There are both known and unknown sources of data which have not yet been incorporated and topics which have not yet been treated or addressed. These topics and data will be incorporated and new versions of the documents uploaded as time and resources permit.

By their very nature many specific BMPs soon become obsolete as “better” BMPs become available but the concept and the identified objectives behind the examples remain valid.

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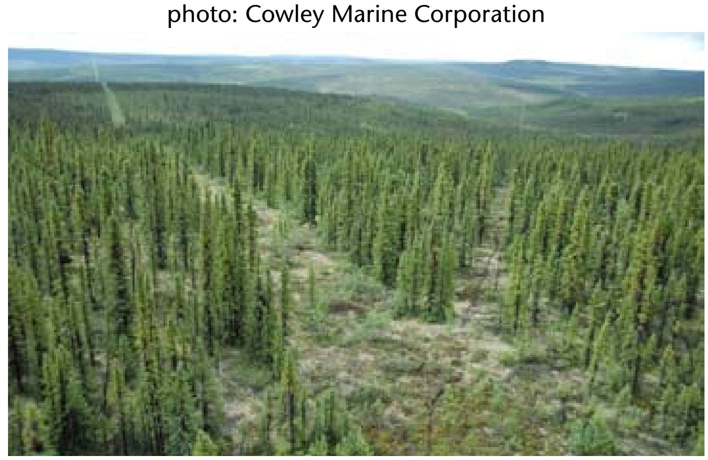
1. Objectives

Objectives of implementing best management practices for ground based seismic exploration in Yukon:

- Reduce net footprint persistence of corridors on the landscape;
- Reduce creation of new public access and associated impacts on wildlife;
- Reduce surface disturbance and soil erosion thereby reducing reclamation needs and promoting natural regeneration;
- Reduce creation of travel corridors for predators (i.e., wolves);
- Manage the access needs of industrial, commercial, recreational and subsistence users;
- Reduce timber fibre loss;
- Ensure Fish and Wildlife and Habitat Management needs are met;
- Control the introduction of invasive and foreign plant species;
- Ensure heritage resources are identified, avoided and protected; and
- Allow access to areas for geophysical exploration which cannot tolerate the impact of conventional seismic.

Hand cutting a seismic line
photo: Lorrnel Consultants

Low ground pressure vehicle
photo: Cowley Marine Corporation

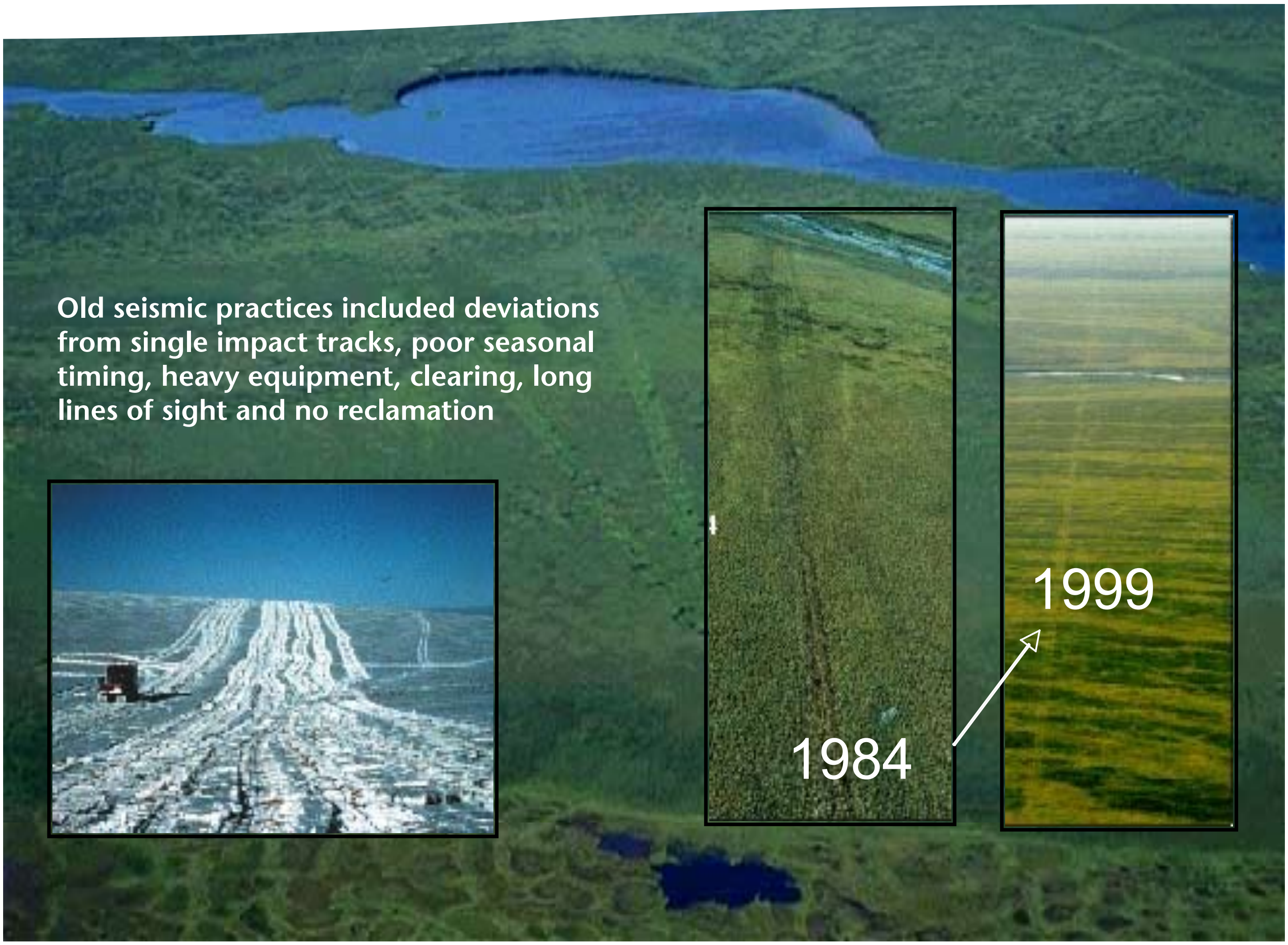


Seismic line circa 1970
North Yukon Seismic Line Regeneration Study

2. Rationale

Seismic Exploration Legacy

In northern Canada and Alaska evidence of seismic exploration remains from the 1960's. Although some studies have been carried out on the regeneration of these lines, the reason many of them still remain as both a visual scar and evidence that there has been a change of some sort on habitat and groundcover varies with the conditions under which the line was constructed in the first place.



What we do know is that the width of the line, weight of equipment, type of track or wheel, time of year, compaction by number of times used, amount and degree of soil/duff stripping and mixing, presence of discontinuous or continuous permafrost, presence of water or ice rich thaw unstable soils, depth of water cover in the spring resulting from compaction, type of groundcover (e.g. lichens, moss, sedges, grasses, shrubs, trees, etc) , type of habitat, and access by humans are all factors behind the continuing presence of some of these lines. As such, best management practices should strive to ensure that this legacy is not continued with modern seismic exploration practices.

Tote road - multiple tracks

Thaw unstable ground - unknown linear feature

Modern winter seismic exploration techniques leave very little evidence behind in the summer. This photo shows the summer after effects of the previous winters' work

photos: Courtesy K. Williams Chevron/Texaco

Mackenzie Delta winter Nodwell accessed 3D Seismic program

Cumulative Effects and Thresholds of Disturbance

In jurisdictions where exploration activity is high, the cumulative effects of these seismic exploration lines, no matter if they successfully regenerate in a short time span or long time span, are particularly apparent where certain species, such as caribou, are more sensitive to habitat disturbance or human presence. Both the direct removal and indirect removal of habitat (fragmentation, avoidance) are causative in terms of effect on wildlife. Avoidance can often be measured in terms of both the footprint itself (e.g., camps and seismic lines) as well as a distance from that footprint. In addition, human presence creates both direct (mortality due to vehicle collision, hunters and poachers, ingestion of harmful substances, nuisance issues such as scavenging at camps resulting in animals being deliberately killed) and indirect (avoidance due to noise, smell, dust, activity) affect. Finally the change to the landscape can result in the movement of humans and wildlife into an area not previously accessed or utilized by others species. Examples include the travel by wolves down access corridors and the movement of certain ungulates into areas creating either competition for resources or becoming attractant to predator species. As such best management practices should strive to reflect these well documented disturbance effects.

Low impact seismic practices reduce the need for clearing and creation of long line of sight corridors by utilizing combinations of satellite technology, meandering lines and smaller equipment as well as technologies to discourage human use

3. Context

Ecological impacts of Conventional Seismic Practices

The movement of oil and gas exploration and development activity into basins with little to no exploration activity, especially away from the existing infrastructure such as the Dempster and Alaska Highway corridors, will demand some creative thinking into how to move heavy loads across the landscape without creating roads or linear footprints. Although much of the activity will occur in the winter months (especially on taiga and tundra) when snow and ice protect the ground surface, vehicles that can negotiate rough terrain while exerting little pressure on the ground surface will provide critical support for off-road oil and gas operations.

In terrain that is sensitive to vehicle and equipment weight such as muskeg, tundra and wetlands, the type and size of tires or tracks, the proximity of the vehicle to the ground, including cat blades and mushroom cups, and the weight of the vehicle are important considerations. Moving equipment across large expanses of the landscape where no road access exists includes a responsibility, not only to avoid direct ecological effects but to also prevent indirect effects including habitat fragmentation and isolation, linear edge effects on vulnerable species, and induced human access.

Depending on the technique used, the location, and the reclamation practices of the day, many seismic lines cut over the past 40 years have not fully regenerated to pre-disturbance conditions. There are a variety of reasons including soil and root disturbance, soil horizon mixing, exposure and melting of thaw unstable ground, creation of depressions and pooling of water due to excess vehicle weights, scraping of the duff layer, competition with other plant species, use of non-native plants for reclamation, and regeneration by non-native plants accidentally introduced through such things as inadequately washed equipment. A key issue can also be the continued use of seismic lines as access routes for ongoing activities such as hunting and recreational access which slows down or prevents rehabilitation and successful regeneration.

photos: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

Specific effects are listed below.

Disturbance to wildlife

- Disturbance of wildlife and alteration of wildlife behavior from dynamite blasting, machinery noise, human presence, smells and waste/camp management.
- Line of sight effects such as alteration in predator-prey interactions and species variation. For example; wolves may use seismic lines to gain access through forested areas to habitat and prey not normally accessible; some ungulate species such as deer, moose and muskox, may use seismic lines to gain access to areas resulting in competition with other species such as caribou; these new species with greater abundance, variation or concentrations may in turn attract predator species into the same areas; some scavenging species such as bears, foxes, martins and wolverines may be attracted via cutlines into camp.
- Behaviour of crews and operating practices at camps can lead to an increase in bear/human interactions.

Well defined animal path on a seismic line
photo: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

Cumulative Effects

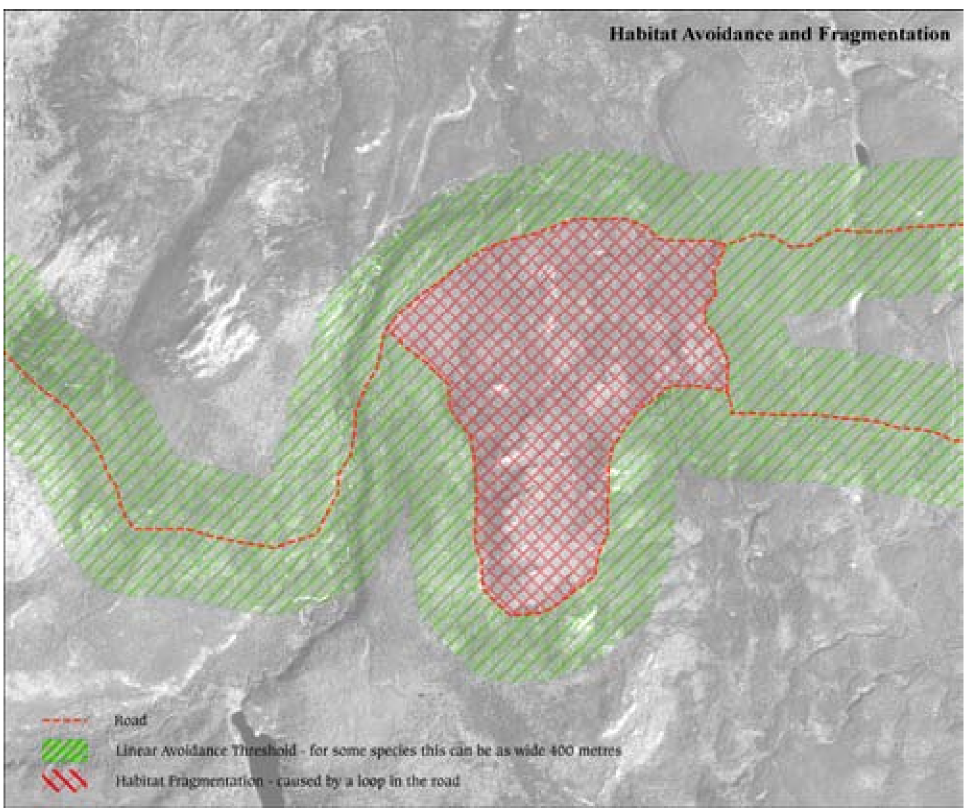
- Without adequate regeneration, seismic activities can result in a progressive loss of mature forest and alteration of forest structure in forested areas and cumulative loss of all habitat types within the region. The timing of regeneration will depend on many factors specific to the type of damage, methods used, recovery times, regional conditions and effort made.

Direct and Indirect Habitat Loss

- Direct loss of habitat includes land removed for the short or long term as a result of an industrial footprint and includes both the linear and non-linear features (such as camps and staging areas) common to seismic exploration.
- Indirect loss of habitat includes avoidance of habitat in the vicinity of seismic lines for a period of time by some species, such as caribou, and can result from a variety of factors including human presence, smell and sound as well as fear of predation due to landscape changes. As well, certain species such as song birds and furbearers will react to the "edge effect" of seismic lines in forested areas. It is important to note that smaller and less active intrusive features will cause correspondingly less responses.

Habitat fragmentation caused by 3 seismic lines intersecting
photo: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

- Habitat fragmentation such as construction of loops in roads/lines can result in an effective loss of habitat for species that avoid seismic lines or crossing of seismic lines for the period of time the avoidance threshold is met. This will vary by species and with such things as human presence, width and type of clearing.



Access Legacy

- Seismic lines and other linear features provide access routes into the forest and onto the landscape for all-terrain vehicles, snowmobiles, and off-road trucks. This can lead to increased hunting and poaching, indirect disturbance due to human presence, noise, light, smell etc, and can have significant adverse effects on soil and vegetation resulting in delays to regeneration.

Old Crow winter road

Disturbance to Hydrology

- Effects of road/trail construction can include increased stream sedimentation, bank erosion, barriers to fish passage, destruction of aquatic habitats, and alteration of drainage patterns.

Stripping for road construction on a north facing slope with underlying permafrost resulted in significant thaw activity and movement of sediments into a waterbody

4. Best Management Practices

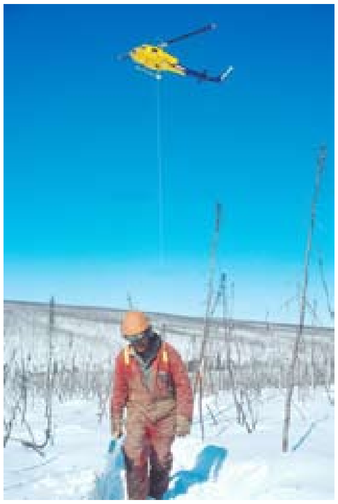
Summary of Best Practices for Seismic Exploration

- Low-impact seismic practices are recommended for all geophysical exploration activity in the Yukon. Low-impact seismic refers to approaches that reduce the footprint and effect of seismic exploration activity including losses of merchantable forest. Low Impact and Micro Impact seismic practices can help reduce the immediate and cumulative effects of seismic exploration practices on the landscape. See The Evolution of Seismic Line Clearing.

- For much of the Yukon underlain by permafrost or discontinuous permafrost and/or saturated conditions, winter only activity is recommended. Use of ground-based mechanical activity during summer months should be avoided unless using existing roads, trails, landings or natural openings or using specialized ground based equipment such as less than 2.5 metre mulchers.

- Recommended maximum line widths are less than 5.5 m, with typical receiver lines 1.75 m wide and source lines between 2.5 m and 5.5 m wide. When resource values at risk are present in the area such as caribou, recommended line widths should be as narrow as possible with meanders and offsets using hand cut walk-through methods or mulching and with equipment utilizing existing roads and trails.

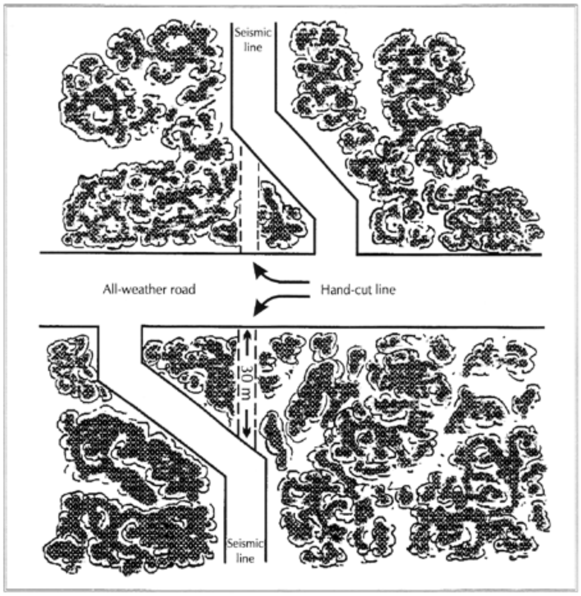
- Other techniques such as use of satellite technology (GPS), helicopter transport of seismic drilling equipment, meandering narrow cutlines, avoidance techniques designed to minimize disturbance to ground cover and vegetation and use of hand cutting and/or small mechanical equipment are tools intended to achieve footprint reduction. Line width will depend on cutting method, equipment type, timber type and density, ground cover conditions and snow cover depths. Safety considerations will also dictate width of lines and spacing of helicopter landing sites.



- Seismic lines should be cut using a variety of techniques such as hand cutting, mulching and avoidance cuts (canopy is left intact with clearing done at height appropriate to cutting or surveying methods). Non-mechanical line cutting methods such as handcut and limbing (1 – 2.5 m), low ground pressure mechanical cutting methods using “Cats” (3 – 5.5 m) and mechanical cutting using mulchers or hydro-axe (1.75 – 5.5 m) are all tools for reducing effect and footprint.

- Line of sight mitigation can be created by meandering of lines, moose blinds, and doglegs at intersections.

- Where meandering lines cannot be cut (e.g. where equipment may cause damage with wheel or track turns, or where other factors such as safety, or fire hazard require straight lines) or where existing lines are re-used, other mitigation tools should be used. These include creating barriers at regular intervals on the line to prevent wildlife and human movement upon project completion, ensuring that roads are inaccessible through creation of barriers such as gates, use of lakes as a start point for winter construction (effective only in off season and non-frozen conditions), and signage identifying the area as under regeneration (not very effective without a monitoring presence).



dogleg

Human view of blocked seismic line

Slash roll back

Snow fence

Predator view of blocked seismic line

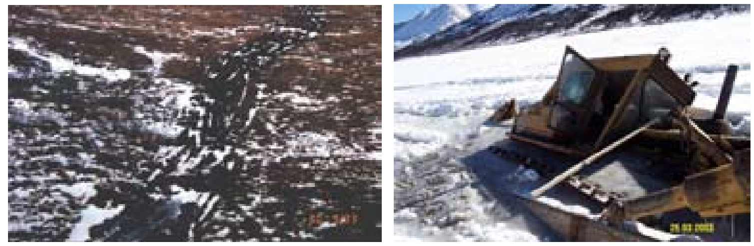
Use of lakes as a start point for winter construction
photo: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

- Key to fast regeneration, reduction in access legacy and the prevention of changes in wildlife use is ensuring that ground cover is disturbed as little as possible. Line width is one factor but the other is the compaction of the soil or groundcover on the lines, disturbance of soil/duff and exposure of permafrost or thaw unstable soils with high moisture content to thawing.

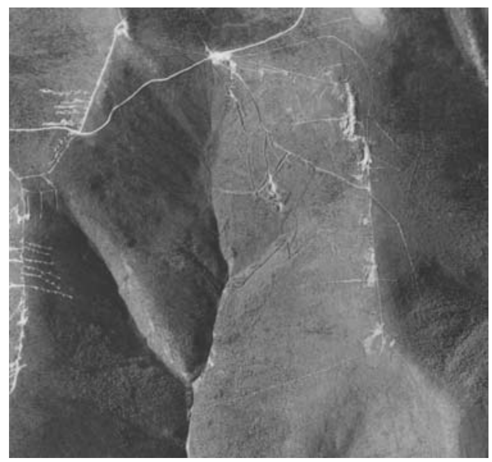
Disturbance of duff layer

- It is important to recognize thaw unstable ground and permafrost and to recognize the difficulty of moving conventional heavy equipment over this landscape type. Avoidance cutting and maintaining of shade and insulating soil/duff layers will increase the likelihood that natural conditions will remain stable. Use of mulchers or hand clearers instead of cats and bulldozers and reducing ground pressure will help maintain the insulation of the ground cover.

Signage notifying users of area about caribou concerns.
photos: Outback Group, Coal Lake Rd, Whitehorse, Yukon



View of unstable soils



Permafrost presence often means routes are only used once and a new route must then be created

Parallel lines created on a travel route. Cause likely poor consideration of ground conditions or seasonal timing Eagle Plains area north of the Dempster highway

photos: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

- Wildlife may sustain injuries from long splintered stumps left after brushing, especially in secondary growth if re-using existing right-of-ways. Moose and caribou have been found with long splinters of wood imbedded in their lower legs. Brushing should therefore be carried out in a manner that cleanly cuts vegetation near to or at ground level. See the interactive right of way brushing presentation.

- Disturbance of the soil and ground cover are minimized through the use of vehicles with low ground pressure, mushroom cups or blade covers to reduce duff/topsoil disturbance, and seasonal timing that avoids wet or soft ground conditions.

CATCO low ground pressure vehicle during ConocoPhillips Canada, Mackenzie Delta low ground pressure vehicle trial. Photo ConocoPhillips Canada

Mushroom cup

Blade cover
photo: Colt Geomatics

- Non-native invasive species may be inadvertently introduced into an area with crews and equipment. This can displace and even eliminate native flora and fauna. Workforces should be discouraged or prohibited from introducing pets, livestock and other animals. Because vehicles and machinery may carry exotic seeds and animals, vehicles and machinery that have been used in areas outside of project sites should be cleaned prior to commencement of work. A quarantine system that inspects and cleans all incoming supplies prior to their use should be developed. See Yukon Invaders.

Foxtail Barley is problematic to agricultural producers and because of its barbed awns, can work its way into the eyes, nose, gums and throats of both domestic and wild animals

White Sweet clover is a highly invasive species which rapidly colonizes gravelly well-drained soils such as roadsides, waste areas and river banks

photos: B. Bennett, Yukon Environment

- The behavior and operating practices of seismic and survey crews is an important component of impact mitigation. It is important that the rational for certain operating practices are well understood by crews and activities are monitored. Ensuring that crews are aware of potential wildlife interaction concerns and the results of abandoning food remains and drink containers in the bush is very important. In areas where traplines or wilderness outfitting camps already exist, careless disposal of garbage or treatment/ feeding of wildlife by seismic and survey crews can lead to habituated bears and other scavengers that may cause potentially deadly consequences for future wildlife and human interactions in the region. Ensuring that crews receive bear awareness certification and providing reusable lunch and drink containers to reduce the chances of littering are recommended practices.

Human bear interaction

Bear in garbage

Ensure temporary camps are managed in such a way as to discourage wildlife interest and reward (strict camp rules regarding feeding wildlife, managing cooking facilities and food wastes, electric fences, deterrent guidelines etc.)

- Hunting, fishing, trapping and collection of non-forest timber products such as wild mushrooms and medicinal plants can lead to decreased populations of local species, alteration of ecological function and biodiversity in the area due to changes in keystone species and effects on subsistence needs of residents. Workforce activities should be controlled and monitored to prevent this.

Yukon wild morrell mushrooms

- Air traffic and flight plans should be designed to recognize sensitive periods such as migration, nesting and mating seasons. Operators must also be aware of other land and resource users in the area such as wilderness tourism operators (Wilderness Tourism Best Practices), outfitters, trappers etc. and avoid overflights that would have a detrimental effect on those land and resources users. A guide to flying in sheep country offers good insight into species specific concerns.

- Historic resources exist throughout the Yukon landscape in all terrains including mountain tops, and under water. Even minor disturbance of the ground surface can impact on archaeological sites. Increased activity in a previously isolated area may see the loss of irreplaceable objects that are part of Yukon's history. The effects of projects, activities and land disposals on historic resources must therefore address protection of documented heritage and make provision for avoidance of undocumented resources through planning, heritage potential modeling, and historic resource impact assessment. See Historic Resources Best Practices.

Potential Primary Impacts

Issues and Potential Primary Impacts	Best Management Practices
Seismic lines & grids • Damage to vegetation, permafrost and surface hydrology • Disturbance to wildlife and human populations from vibroseis machine vibrations and shot-hole drilling • Erosion and changes in surface hydrology from unplugged or improperly plugged shot holes and seismic lines (cleared vegetation)	• Schedule operations during least sensitive periods, avoiding migration, nesting and mating seasons • Shot-hole methods should be considered in the place of vibroseis machinery where vegetation cover is required and where access is a concern. Ensure that the charge is small enough and deep enough to avoid cratering. Consider aquifer protection and suitable plugging. Use offsets to avoid specific sensitivities. Ensure that misfired charges are disabled and removed • Mobilize clean-up crews after operations • If using vibroseis machinery on soft ground, avoid excessive compaction from vehicles and baseplate • Ensure appropriate handling and storage of fuels and hazardous materials (e.g., explosives) • Cut seismic lines by hand to minimize disturbance • Minimize the width of corridors to ensure compatibility with operational, health and safety requirements • Do not cut trees greater than 20 centimeters (8 inches) in diameter • Minimize clearing of vegetation and insulating layers. Leave in place smaller vegetation, topsoil, root stock, seeds and endangered or protected species and species used by local communities for commercial or subsistence use • Maintain isolation from access routes and communities

Issues and Potential Primary Impacts	Best Management Practices
Helipads/airfields • Short-term disturbance of habitats from helipad clearings; disturbance of wildlife populations from noise (impacts usually local and short-term)	• Use helicopters within safety limits where minimization of ground transport and effects are required (e.g., access, clearing). • Construct helipads to reduce disturbance consistent with operational, health and safety requirements. • Assess lowest impact location for helipads and flight paths. • Schedule operations during least sensitive periods, avoiding migration, nesting and mating seasons. • Be aware of others land and resource users in the area such as wilderness tourism operators, outfitters, trappers etc. and avoid overflights that would have a detrimental effect on those land users. • Maintain buffers between helipads and airfields and travel corridors and use areas to reduce visual and noise effects.
Other infrastructure • Erosion and changes in surface hydrology • Vegetation cleared, disturbing local habitats	• "Minimize the footprint." Use and share existing infrastructure to the extent possible to avoid or reduce road construction and clearing. • In clearing vegetation, use hand-cutting techniques to the extent possible, thereby avoiding the use of heavy machinery.
Drainage • Erosion and changes in surface hydrology, causing short- and possible long-term changes in local habitats	• Take topography, natural drainage and site runoff patterns into account. Ensure adequate drainage away from streams, rivers and other waterways.

Issues and Potential Primary Impacts	Best Management Practices
Erosion (topsoil loss) • Impedes ability of habitats to revegetate, causing possible long-term damage to affected area • Siltation of waterways, with negative impacts on aquatic and marine environments	• Take topography, natural drainage and site runoff patterns into account. Ensure adequate drainage • Stabilize all slopes, revegetating with native species to reduce/avoid erosion where practices have impacted vegetation (avoid) • Break-up compacted surfaces and replace topsoil, brash, seed source, leaf litter, etc.
Site clearance • Erosion and changes in surface hydrology • Vegetation cleared, disturbing and fragmenting local habitats	• Select site to reduce effects on environment and local communities and to minimize the need for clearing, using existing infrastructure • Choose site to encourage natural revegetation by indigenous flora and fauna and to avoid the removal of vegetation, topsoil and seed source for decommissioning
Base camp construction • Wastes, fires and discharges (sewage) impact local habitats • Destruction of habitats through creation of access routes to base camps and creation of base camp sites (potentially long term) • Short-term disturbance of local habitats from base camp light, noise, smell and other activities • Potential for negative interaction with nearby communities	• Minimize the size of camps and facilities consistent with operational, health and safety requirements • Reduce waste and control waste disposal (solids, sewage) • Discourage workforce from interaction with nearby communities • Prepare contingency plans for spillages, fire risks, etc. • Keep the workforce within defined boundary and to the agreed access routes • Light sources should be properly shaded and directed onto site areas • Educate workforce on environmental concerns and design and implement policies to protect biodiversity

Issues and Potential Primary Impacts	Best Management Practices
Traffic • Short-term disturbance of habitats from traffic; short-term disturbance of wildlife populations from noise • Compaction of soils and changes in surface hydrology • Killing or maiming of local wildlife	• Use existing infrastructure to the extent possible to avoid or reduce road construction and clearing • Be aware of seasonal concerns relating to road use such as poor winter driving conditions and visibility, migration of wildlife across roads to winter or summer habitats and revise driving patterns and control accordingly • Keep traffic to the absolute minimum requirements for operations • Impose and enforce speed limits and provide driving guidelines for vehicle operators • Treat (water) road surfaces to manage dust • Allow only authorized employees access to site(s) transportation
Noise • Short-term disturbance to wildlife from noise	• Minimize extraneous noise sources and use adequate noise attenuation on engines.

Potential Secondary Impacts

Issues and Potential Secondary Impacts	Best Management Practices
Access roads • Erosion and changes in surface hydrology • Vegetation cleared, disturbing local habitats	• Maintain isolation from access routes and communities • Consult local authorities and other stakeholders regarding preferred locations, using spatial analysis and regional planning to ensure activities do not lead to secondary impacts • Block and control all access to the project site and concession areas • Choose the site to encourage natural rehabilitation/regeneration by indigenous flora and fauna; avoid removing vegetation and topsoil; preserve topsoil and seed source for decommissioning • Select site to minimize effects on environmental and local communities; minimize clearing • Use existing access, if available • Avoid loops in roads, which can isolate and fragment habitat • Use "dog-legs" and other low impact techniques to discourage access
Non-native species introduction • Displacement or elimination of native flora and fauna	• Prohibit the workforce from introducing pets, livestock and other animals • Because vehicles and machinery may carry exotic seeds and animals, clean vehicles and machinery that have been used in areas outside of project sites prior to commencement of work • Develop a quarantine system that inspects and cleans all incoming supplies prior to their use. See invasive plants

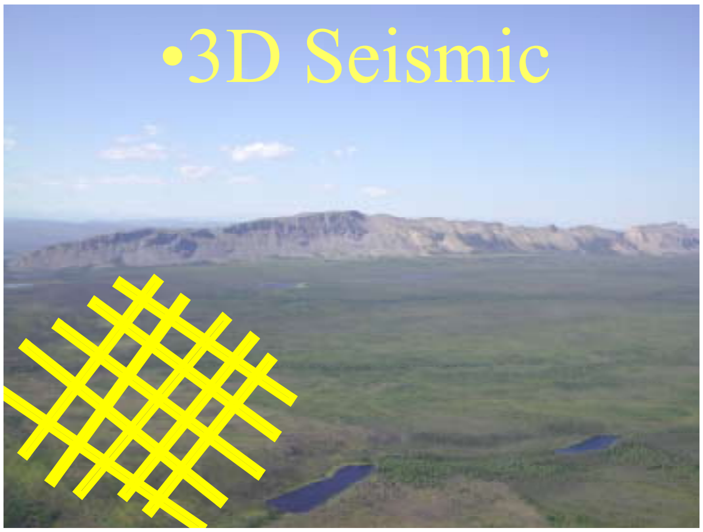
Issues and Potential Secondary Impacts	Best Management Practices
Opening new areas • Immediate effect on local habitats, with wider effect possible unless access is prohibited (possibly long term) • Increased pressure on flora and fauna populations	• Through spatial analysis or regional planning with local stakeholders, select the site to minimize effects on environment and local communities and to reduce the need for clearing • Use existing infrastructure to the extent possible to avoid or reduce road construction and clearing • Create offsets for any habitat that cannot be restored
Hunting/poaching • Elimination or decreased populations of local species. • Ecological alterations through removal of keystone species such as predators • Effect on subsistence needs of residents	• Control workforce activities (e.g., hunting, poaching and interaction with local populations) • Work with local authorities and communities to monitor and control hunting and poaching arising from new access in operations areas
Wildlife Interactions • Change in behavior of scavenger and predator species in area • Negative wildlife/human interactions • Destruction of wildlife	• Ensure crews are aware of potential wildlife interaction concerns and the results of behavior such as abandoning food remains and drink containers in the bush • Provide bear awareness certification • Provide reusable lunch and drink containers in order to reduce garbage and littering in the bush and abandonment of food remains. • Ensure temporary camps are managed in such a way as to discourage wildlife interest and reward (strict camp rules regarding feeding wildlife, managing cooking facilities and food wastes, electric fences, deterrent guidelines etc.)
Gathering non-timber forest products (NTFPs) • Increased pressure on flora and fauna populations • Ecological alterations through removal of keystone species	• Prohibit workforce from gathering NTFPs. (eg. mushrooms) • Work with local authorities and residents to monitor and control collection of NTFPs that stems from new access to operation areas

5. Description of Geophysical Exploration

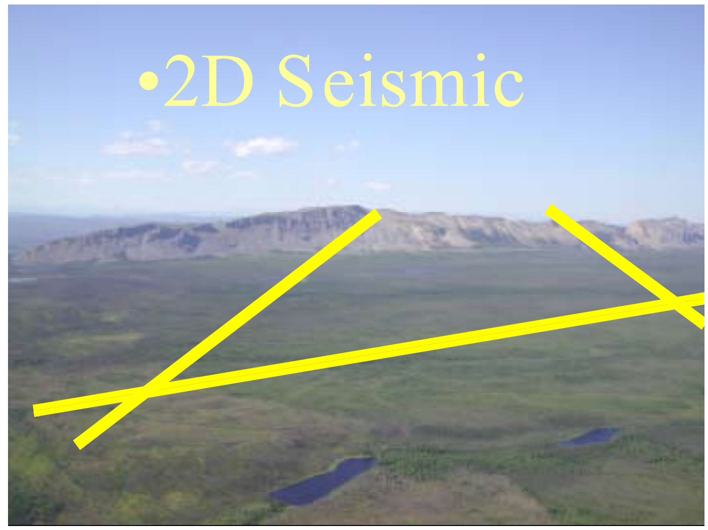
Conventional practices

Seismic (or geophysical) exploration is used to identify and map oil and gas geological structures prior to drilling. The technique is based on analyzing how sound waves are reflected from subsurface structures. http://www.chevron.com/products/learning_center/primer/

Seismic Exploration is used to get information on what is underground so exploration companies know where to drill for oil and gas. There are two types:



3D - a grid is laid out – lines are shorter, but closer together and cross each other



2D - long lines are cleared – sometimes many km long

Winter 3D seismic program in the Mackenzie Delta, NWT
photo: K. Williams, Chevron/Texaco

2D seismic photo
photo: North Yukon Yukon Government Seismic Line Regeneration Study

Traditionally a long wide linear corridor, up to 6-8 m in width (anything wider than 5.5 metres and cut in a straight line is currently considered to be conventional) is cleared (photo 1). Depending on the terrain, seismic lines might be cut using a combination of techniques that change with such things as proximity to water, or steep terrain.

Conventional lines are often cleared of vegetation and stumps. This clearing method is done for two reasons, first to enable an optically surveyed straight line and second, to bring in the large heavy equipment needed for this type of exploration (photo 2).

Conventional and narrow mulched lines side by side.
photo: Lorrnel Consultants

Vibroseis is heavy

Truck-mounted drilling equipment is then used to drill a series of holes at defined locations along the corridor (photo 3) for the placement of dynamite charges which are the source of the seismic sound waves (see vibroseis section for alternative seismic sound wave generation). The dynamite charges are sequentially exploded and the reflected sound waves are recorded at the surface using portable recording equipment (photo 4,5).

Shot holes

In the final step computers are used to amalgamate the sequential recordings into a seamless cross-sectional representation of the subsurface.

Low-impact seismic

Low-impact seismic refers to approaches that reduce the footprint and effect of seismic exploration activity including losses of merchantable forest. Changes in both survey methods and type of equipment available has allowed a change in approaches to seismic exploration over the past 30 years.

Typically maximum line widths are less than 5.5 m, with typical receiver lines 1.75 m wide and source lines between 2.5 m and 5.5 m wide. Seismic lines are cut using a variety of techniques such as hand cutting, mulching, avoidance cuts (canopy is left intact with clearing done at height appropriate to cutting or surveying methods) and meandering lines.

Seismic lines are cut using a variety of low impact techniques including avoidance cuts and meandering

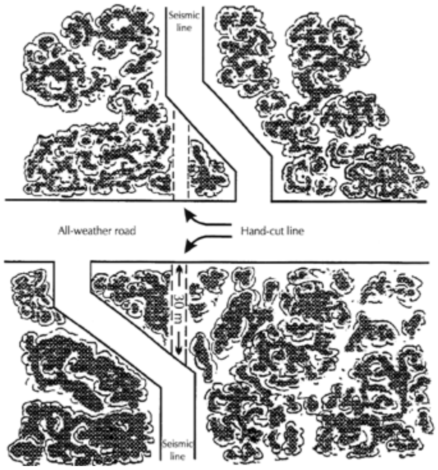
Meandering line

Walking into helidrill site

1.75 m mulched line

Avoidance cut

Line widths less than 3 m require the use of "envirodrills". Line of sight mitigation is created by meandering of lines, moose blinds, and doglegs at intersections.



Dog leg

Envirodrill

Disturbance of the soil and ground cover are minimized through the use of vehicles with [low ground pressure] (1), mushroom cups (2,3) or blade covers (4) to reduce duff/topsoil disturbance, and seasonal timing that avoids wet or soft ground conditions (5,6).

photo: Crowley Maritime Corporation 1

mushroom cup 2

mushroom cup 3

4

Blade cover photo: Colt Geomatics

Saturated ground conditions 5

Soft ground conditions 6

Non-mechanical line cutting methods such as handout and limbing (1 – 2.5m), low ground pressure mechanical cutting methods using cats (3 – 5.5m) and mechanical cutting using mulchers or hydro-axe (1.75 – 5.5m) are all tools for reducing effect and footprint.

Tracked and low pressure vehicles minimize duff layer disturbance but costs are approximately 30-50% higher than conventional depending on line width and timber density.

Hydroaxe
photo: Mike Doyle, Canadian Association of Geophysical Contractors (CAGC)

Helicopter – assisted seismic

- Employed during the recording phase to support ground activities (i.e., move equipment).
- The equipment is deployed to the ground locations using a helicopter and a long line.
- Ground access is still required for the other phases (surveying, line cutting etc.).
- Eliminates the requirement for vehicles to travel along receiver lines.

Helicopter – portable seismic

- Generally considered to cause the lowest habitat impact.
- Helicopters used extensively on the project for deployment of equipment and personnel.
- Shot holes are drilled using lightweight heli-portable drill rigs.
- Lines are usually hand-cut or minimal cut (under canopy cutting), with foot access only.
- Minimal ATV access.

Heli-portable drill being flown into Eagle Plains, Yukon.
photo: Devon Canada.

Foot access on seismic line

- Distance between drill sites varies depending on program parameters. Typical spacing between source points are approximately 100 m. Drill sites (drop zones) require 4-7m diameter clearings, depending on the tree canopy. Natural open areas or existing clearings are used when possible, but some new drop zones may be required.
- Heli-pads are required for drop-off pick-up and safety of personnel. Heli-pads are approximately 35m in diameter and are located every 1 km. Natural open areas or existing clearings are used when possible, but some new heli-pads may be required. Costs can be approximately 150% – 300% higher than conventional.

Using a natural clearing for a helicoptor landing, Eagle Plains, Yukon.
photo: Devon Canada

Mechanical-cut lines

- Line cleared by vehicle mounted equipment (e.g., dozer, "cat", gyrotrack, mulchers, hydro-ax).
- Line widths range from 1.75m to 7m.

Low ground pressure 2.75 metre mulcher

Light weight low ground pressure mulcher for narrow seismic lines, soft (muskeg) and hilly terrain fitted with 1.75 metre rotovator drum

Operating in steep terrain

Mulched line

Mulcher selectively removing trees

Photos courtesy of Bear Slashing www.bearslashing.com

Hand-cut lines

- Hand-cut lines typically involve 4 man crews, using chain saws or other hand-held cutting device.
- Hand-cut lines are typically 1.75m in width and can be straight or avoidance (meandering).

Chainsaw crew hand clearing a seismic line.
Photo: Lorrnel Consultants

- Approximate a narrow, infrequently used hiking trail.
- The risk of erosion is minimal (stumps left in place), therefore seeding typically not required.
- A minimum 1.5m width may be required by workers compensation board to allow for stretcher access, unless additional medics on ground with crews (see safety).
- Hand-cut methods are typically used in the following instances:
  - o Heli-portable seismic.
  - o 3D program receiver lines.
  - o Riparian management zones (adjacent to stream crossings).
  - o Line-of-sight mitigation technique (dogleg) crossing major public access routes.
  - o Identified wildlife corridors.
  - o Other sensitive areas.
- Typically 150% cost of mechanical cut lines, although costs are very site specific.

Under-canopy cutting/ minimal impact line

- Involves hand-cut, meandering lines, minimal cutting of shrubs, limbing of trees, and zero to minimal breaks in skyward canopy. “Hazard” trees may be felled for safety reasons, or line will deviate to safe side of the hazard.
- This technique is appropriate for receiver lines only. Minimal impact lines are too narrow and “enclosed” (no breaks in the canopy) to provide access for drilling equipment.
- Associated with heli-portable seismic, although may also be used in sensitive areas.
- Essentially “zero” impact, lines are considered to be zero meters in width, trail not identifiable after one growing season.
- Requires advanced positioning technology, Global Positioning System (GPS) or inertial guidance technology.
- The reduced line width necessitates additional safety risk management.
- Relatively new technique, not practicable everywhere.
- Costs higher than mechanical cut programs by approximately 200%.

Stream crossings

- A snowfill may be used as temporary stream crossing. The snow is free of debris and the water is frozen to the bottom.
- An ice bridge may be used as a temporary crossing for larger streams and rivers. The water body is generally not frozen to the bottom.
- A log fill may be used as an alternative to portable free span bridges.
- Stream crossings are constructed in a manner that; will not cause disturbance to the stream banks, preserve the riparian environment and eliminate fish mortality.
- Stream crossings are designed to prevent erosion and sediment load increases.

Survey – Global Positioning Systems (GPS)

- Conventional survey required a line of sight. GPS technology can accurately produce survey lines/shot hole and receiver line locations (3D) without having line of sight providing the canopy does not prevent the GPS equipment from receiving positioning data from a constellation of satellites.

Survey – Inertial Navigation System (INS)

- Inertial guidance surveying uses a combination of mutually orthogonal accelerometers to detect pitch roll and yaw. This system may use limited updates from satellites but is not dependant on continually receiving positioning data from a constellation of satellites.
- Allows seismic line (source and receivers) to be produced without requiring a line of sight.

Survey – Light Detecting and Ranging (LIDAR)

- Method of evaluating and surveying an area from the air. This system provides detailed information about the surface topography and vegetation heights.
- Provides precision survey "pixels" that can be used to navigate under canopy in order to position seismic lines with minimal disturbance of vegetation.
- Can create precise Digital Elevation Models (DEM) which can be incorporated as a seismic planning tool and for future development planning.

All terrain vehicles

- ATVs can be used as transportation for survey, line cutting, drilling/loading shot holes, QA/QC of receivers and recording equipment, line cleanup etc.
- In some cases drilling/loading shot holes may be done with ATV's.
- Typically require a 2.5m line, or open canopy to drive down but does not have to be line of sight.

Shot hole drills

- The type of drill used in an area will depend on the access, the line width and terrain.
- The drills in increasing widths are as follows: hand drills, heli-drills, enviro-drills, buggy drills, wheeled tandem drills, Nodwell drills, and finally large buggy drills.
- In some cases the ground pressure of the equipment is a limiting factor.
- Drilling costs increase as line widths decrease.

Hydro-axe (Gyrotrack/ Mulchers/ Mowers)

- Mechanical cutting systems which clear brush and small to medium sized (10" and under) trees and reduces them to wood chips and mulch. The mulch is left on the line. Allows reduced line widths and may speed revegetation.
- There may be some issues with mulch being too deep, limiting natural re-growth. As well, depending on the limiting factors to natural revegetation such as sun (especially in the north) mulch may be an impediment to natural re-growth. There is some concern that the chip-path provides a good trail attractive to public.
- Lines are typically between 1.75 and 5.5 m wide.

Mulcher selectively removing trees

Conventional seismic line (5-8 m wide)

Low impact mulcher Cut Seismic (2.5 m wide)

photo: Lorrnel Consultants

Old mulching technology

New mulching technology

First pass mulched seismic line

Completed mulched line

1.75 m wide mulched line

photos: The Canadian Association of Petroleum Producers, Evolving Approaches to Minimize the Footprint of the Canadian Oil and Natural Gas Industry (Case Study 13, Suncor Energy Inc, Lorrnel Consultants)

Vibroseis

- Terrain and near surface conditions may make vibroseis the preferred geophysical exploration technique (e.g., frozen muskeg, presence of subsurface sand and gravel deposits).
- Typically not used in areas with steep terrain. In project - site specific cases vibroseis equipment may be lifted/ winched into a steep terrain area.
- Large Vibrators on 2D lines may require up to 6.5m wide lines depending on tree density and snow loads. On a 3D source line the vibrators generally require 4.5m lines. Smaller vibrators (mini-vibes) typically require a 3m line. Mini-vibes are usually not applicable for geological targets in excess of 1000m.

Use of Old Lines

- Existing lines may or may not be used, depending on level of re-growth and current use (i.e., disturbing a recovering line may not be allowed by regulator or community, can be more difficult to clear because of dense bush caused by a change in vegetation community and/or the line may now be used for another purpose such as trapping).
- Existing lines may not meet the technical objective of the survey (well ties, shot point ties, geometry constraints).

Old lines may or may not be used depending on level of re-growth

photos: Canadian Wildlife Service/Ducks Unlimited, Yukon Government Seismic Line Regeneration Study, North Yukon

Safety

- Narrower, meandering lines may result in reduced access, which introduces additional safety issues such as longer response times for emergency medical care.
- In some cases, WCB regulations may regulate a minimum line width for worker safety.

Reference: CAPP/CAGC geophysical exploration practices, CAPP Evolving Approaches

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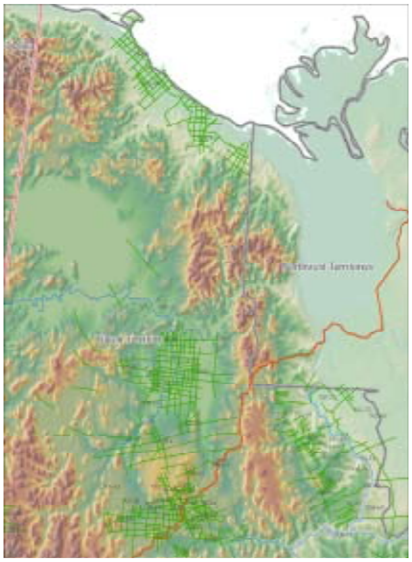

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