R. Schneider

4. The Petroleum Sector Today

Overview of the Petroleum Industry in Alberta

In 2000, Alberta's oil and gas infrastructure consisted of 103,806 operating wells, 293,799 km of pipelines, and 684 gas plants (ARD, 2001: 33). Alberta also has a large petrochemical industry that upgrades raw petroleum resources into ethylene, methanol, ammonia, and other derivative products. In 2000, Alberta produced 55% of Canada's conventional oil, 83% of natural gas, and 100% of bitumen and synthetic crude oil (ARD, 2001: 14).

In 2000, Alberta exported more than $35 billion of oil, gas, and petroleum byproducts, representing 62% of all provincial exports (ARD, 2001: 14). Disposition of Alberta's oil production in 1999 was 58% to the United States, 14% to the rest of Canada, and 27% for use within Alberta (ARD, 2000: 2). Disposition of Alberta's natural gas in 1999 was 47% to the United States, 31% to the rest of Canada, and 22% within Alberta (ARD, 2000: 3).

There are approximately 950 active oil and gas companies in Alberta (ARD, 2001: 33). Although large integrated companies and senior producers account for only about 5% of the companies (NRC, 1995), they produce the majority of the oil and gas in the province (Fig. 4.1; Table 4.1). Consequently, they are responsible for the majority

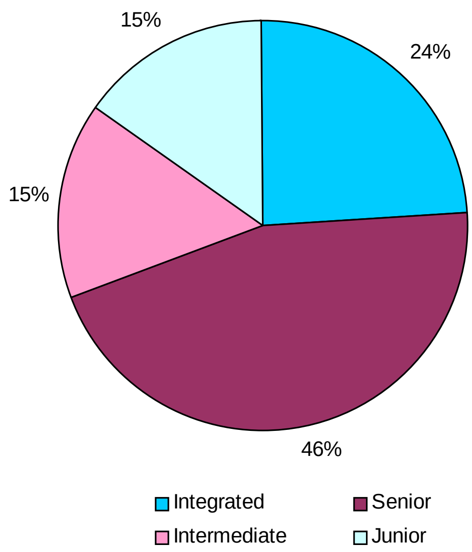


Fig. 4.1. Oil and gas production in Canada in 1994 by company category. Junior < 0.5; Intermediate = 0.5-1.5; Senior > 1.5 mm3/year. Source: NRC, 1995.

Table 4.1. Ranking of the 11 largest petroleum companies operating in western Canada, by proved oil and gas reserves in 2000[1].

Company	BOE[2](millions)
Imperial	1,919
ExxonMobil	1,916
Can. Nat. Res.	1,035
PanCanadian	1,017
Shell	817
Husky Energy	799
Petro Canada	763
Gulf	753
Talisman	612
Alberta Energy	596
Suncor	585

[1]Data from company annual reports (Canadian operations). International and off-shore reserves were excluded (except ExxonMobil).

[2]BOE = Barrel of oil equivalent.

of the environmental impacts associated with oil and gas activities. However, the impacts of junior producers may be disproportionately high relative to their production rates. This is because junior companies lack the resources of larger companies for implementing the highest standard of environmental practices and they are less exposed to public and regulatory scrutiny (Marr-Laing and Severson-Baker, 1999).

Industry expenditures are fairly evenly divided between exploration, development, extraction operations, and royalties (Fig. 4.2). In 1999, capital expenditures by the energy industry were almost $11 billion, representing over 30% of total capital investment in the province (ARD, 2000: 5; PCF, 2000). Approximately 70,000 people are directly employed in Alberta's upstream petroleum industry (SC, 2002).

In the fiscal year 2000/2001, provincial revenues from oil and gas royalties, tenure sales, and fees totalled an unprecedented $10.7 billion, representing 50.5% of total provincial revenues (ARD, 2001: 74) (Fig. 4.3). In the three previous years the petroleum sector contributed an average of 25.3% of provincial revenues (PCF, 2000).

Tenure System

Petroleum deposits are found throughout Alberta except in the Shield Region in the northeast corner of the province (Fig. 4.4). Most petroleum resources in Alberta, particularly in forested regions, are owned by the Crown. Private companies are able to extract these resources through tenure agreements with the government, administered by Alberta Energy. These tenure agreements,

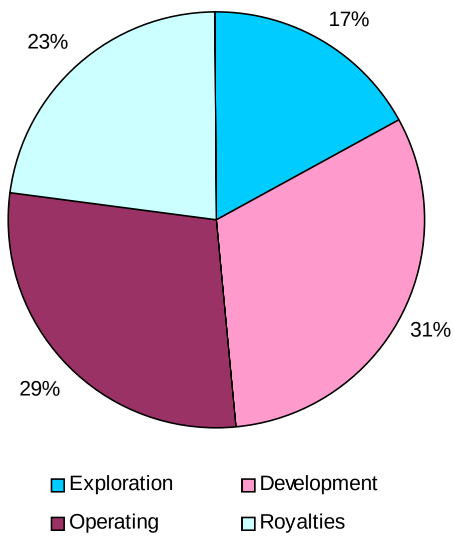


Fig. 4.2. Petroleum industry expenditures in Alberta in 1999, by type. Source: CAPP, 2000.

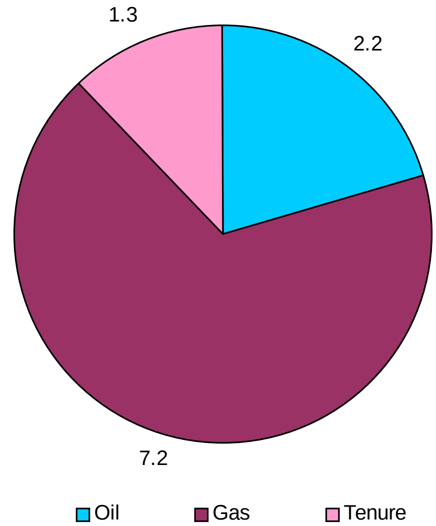


Fig. 4.3. Government revenue from oil and gas royalties and tenure agreements in Alberta in 2000/2001 ($ billions). Source: ARD, 2001.

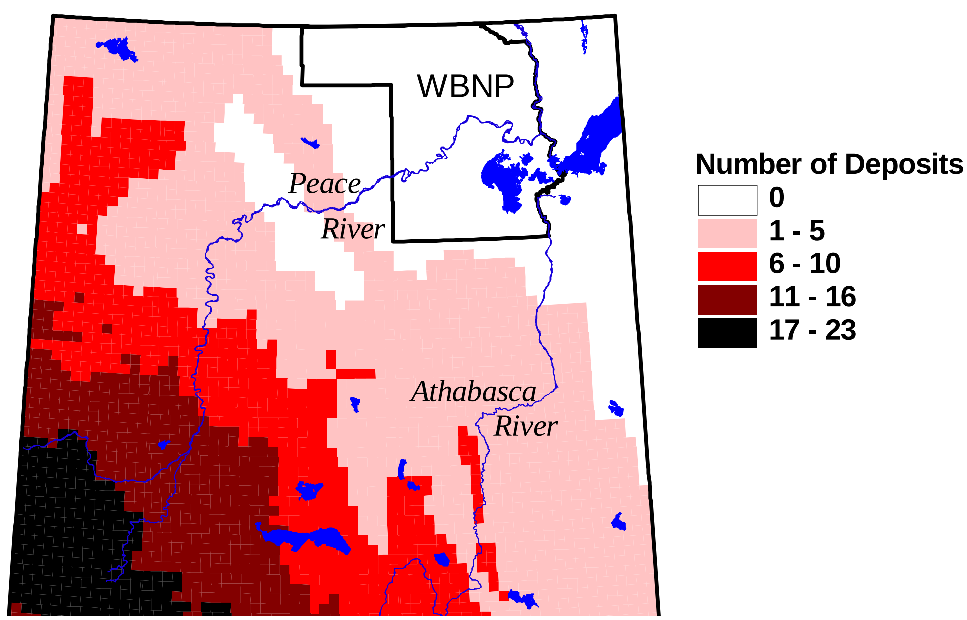


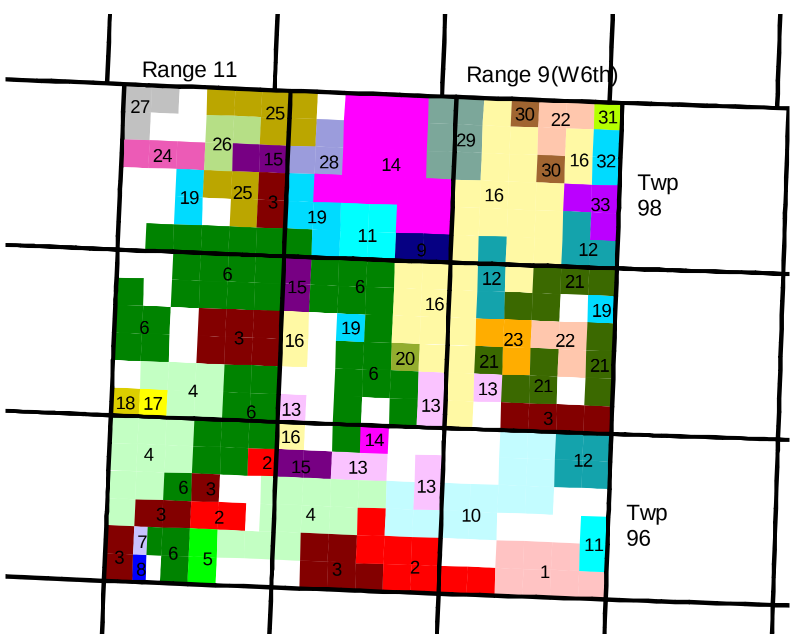
Fig. 4.4. Oil and gas deposits in northern Alberta. Multiple deposits are present in most locations, within different geological formations. Source: ERCB, 1992.

known as subsurface mineral rights, give companies the exclusive right to drill for and extract oil and gas in a specified area (GOA, 2000a, sec. 4). The rights may apply to all deposits within the specified area, or may be restricted to specific depths or type of product (oil or gas). Mineral rights do not include rights to surface access. Companies must separately obtain licences and approvals for surface activities such as seismic exploration, drilling, pipeline development, and road construction.

Mineral rights are generally awarded through an open competitive bidding process termed a “land sale”. Companies may nominate parcels of land of interest to them for inclusion in a sale, but the rights ultimately go to the highest bidder. In 2000, the average price the government received for mineral rights was $275/ha (AE, 2001a).

By government regulation, parcels of land offered at land sales cannot exceed one township in size (GOA, 2000a, sec. 7). In practice, most offerings are substantially less than this maximum. Consequently, regional landscapes are typically composed of a patchwork of tenure holdings of many different companies (Fig. 4.5).

A key stipulation of petroleum tenure agreements is that companies must initiate exploratory drilling within a specified initial period (maximum = five years) (GOA, 2000a, sec. 14-16). If a site is proved to be productive then the agreement is continued indefinitely, otherwise the rights are returned to the Crown. In practice,



1. Pancanadian
2. Petrostar
3. Northstar
4. Shell
5. Silverhawk
6. Poco
7. Cnd. Landmaster
8. Ulster
9. Chevron
10. Encal
11. Cnd. Coastal
12. Stampede
13. Rigel
14. Imperial
15. S.E. Sim
16. Talisman
17. Amoco
18. Home
19. Scott
20. Heritage
21. Morrison
22. Pembina
23. WLSC
24. Charter
25. Cnd. Hunter
26. Renaissance
27. Norcen
28. Maverick
29. Chauvco
30. Bancroft
31. Reid-Bicknell
32. Merdan
33. Petland

Fig. 4.5. Typical distribution of oil and gas leases in northern Alberta. Company names are listed to the right of the figure (data current to 1997). (Map: Forest Watch Alberta)

companies often buy mineral rights for strategic reasons, but ultimately do not develop them. Also, many sites are drilled but found to be unproductive. As a result, over 75% of mineral rights revert back to the Crown for potential resale (AE, 1996: 18).

The Interdepartmental Crown Mineral Disposition Review Committee reviews proposed sales of mineral rights to identify potential impacts on the environment. However, *"The Committee does not conduct a detailed environmental assessment at this stage, because the posting and disposition of mineral rights, in and of itself, does not entail an environmental impact. The pertinent issue at the disposition stage is whether the posting is subject to Integrated Resource Plan land-use restrictions, or any other access restrictions. . ."* (AE, 1996: 18). In practice, mineral rights for sensitive wildlife habitat areas and protected areas are routinely posted for sale, with notification that certain restrictions on surface access will apply (e.g., AE, 2001b).

Achieving sustainable management of the forest as described in the *Alberta Forest Conservation Strategy* (AFCSSC, 1997) requires long-term regional planning that integrates all industrial users and limits cumulative impacts. The petroleum tenure system in Alberta, as currently structured, constitutes a significant barrier to achieving this goal. A fundamental problem is that the awarding of mineral rights is largely disconnected from regional planning. As a result, planning initiatives must contend with companies that already have tenure agreements in place, for which they have paid substantial sums of money. Ecosystem-based planning is further hindered by regulations that limit tenure agreements to small parcels of land and that force rapid exploitation of the resource. A comparison between the tenure system used for the petroleum industry and that of the forest industry is provided in Table 4.2.

The recent *Special Places 2000* process provides an example of how the aforementioned factors can and do impede changes in land-use policy. First, because tenure agreements are small, most candidate protected areas involved many different oil and gas companies, resulting in negotiations that were slow and complex. Second, companies with tenure agreements in candidate protected area sites vigorously opposed any attempt to limit their activities in these sites, by virtue of their existing "rights". Finally, given ample financial resources and the dependence of the province on oil and gas revenues, the oil and gas industry was able to mount a powerful lobby effort. As a result of these factors, the *Special Places* process was completed with minimal impact on the oil and gas industry. The Foothills Ecoregion, where conventional oil and gas deposits are most abundant, remains 98.1% unprotected; 89% of parks in Alberta are less than 50 km^2 in size (i.e., largely accessible to companies via horizontal drilling); and oil and gas extraction in all new protected areas can continue under the provisions of tenure agreements in place prior to the site's establishment (AE, 1998; ACD, 2001). Future ecological forest management initiatives designed to integrate the petroleum and forestry industries and to limit cumulative industrial impacts will face similar challenges.

Seismic Exploration

Current Practices

Seismic (or geophysical) exploration is used to identify and map oil and gas deposits prior to drilling. The technique involves the production of sound waves at the surface, recording the waves

Table 4.2. Comparison of tenure regimes between the forest industry and the petroleum industry in Alberta.

	Forestry FMA Holders	Forestry Quota Holders	Petroleum Industry
Cost of tenure agreement	No cost	No cost	Tenure agreements sold by auction
Size of tenure agreement	Usually several thousand square kilometres	No fixed land holding; government determines where harvesting will occur	Up to one township in size (92 km^2); most are much smaller
Forest management responsibilities	Defined in tenure contract; includes requirement for public involvement	Government has primary responsib-ility	No forest management responsibilities defined in tenure agreement
Company planning horizon	100 years	20 years	5-10 years
Term of agreement	20 years; renewable	20 years; renewable	Must drill in 2-5 years; indefinite continuation if productive
Public involvement	Public advisory committees	Government responsibility	Notify public of activities; respond to complaints

that are reflected from underlying features, and interpreting these reflections to produce a computer model of subsurface geological structures. Seismic exploration is conducted by specialized firms under contract to oil and gas producers and the findings normally become proprietary information of the producer. Some seismic companies will also conduct surveys in promising areas on speculation, and then sell the information to one or more producers at a later date.

Conventional seismic operations in forested regions involve the following steps. First, a long linear corridor, six to eight m in width, is cleared using a bulldozer (GOA, 1998, sec. 43; Fig. 4.6). Then truck-mounted drilling equipment is used to drill a series of holes at defined locations along the corridor for the placement of dynamite charges (the usual source of seismic sound waves). The dynamite charges are sequentially exploded and the reflected sound waves are recorded at the surface using portable recording equipment. In the final step a computer is used to amalgamate the sequential recordings into a seamless cross-sectional view of the subsurface. A complete seismic survey of an area typically involves a series of seismic lines running parallel to each other, usually at a distance of 400 m or more between lines.

Currently in Alberta, so-called *low-impact seismic* is becoming widely adopted for use in

Fig. 4.6. Conventional seismic operations in Alberta involve the creation of long linear access corridors using bulldozers. (Photos: R. Schneider, left; C. Wallis, right)

forested areas. *Low impact seismic* is characterized by seismic lines that are an average of five-metre wide and that follow a meandering course between dynamite shot points (LAD, 1999: 14). The intent is to reduce the loss of merchantable forest by avoiding valuable stands as much as possible. *Low impact seismic* also seeks to minimize disturbance of the soil and ground cover through the use of vehicles with low ground pressure (LAD, 1999: 14).

Although *low-impact seismic* represents an improvement over conventional seismic, the five-metre lines still result in a significant industrial footprint, and they still provide access into the forest. A further reduction in impact can be achieved through the use of so-called *enviro-drills*, which are shot-hole drills mounted on specially designed all-terrain vehicles that require only two-metre corridors for access. New satellite positioning systems and inertial guidance systems (Schlumberger, 2001) enable shot points to be located without surveying, making it easier to cut meandering access routes for drilling equipment. The cost of using *enviro-drills* is currently higher than conventional methods (Table 4.3), but this cost differential should disappear once enviro-drills become widely available and operators become experienced using them. Furthermore, damage fees that must be paid to forest companies for loss of timber are reduced when *enviro-drills* are used, offsetting the cost of their use.

Vehicle access routes can be eliminated en-

Table 4.3. Relative cost of various seismic techniques in northern Alberta in 2000.

Technique	Cost per metre[1]
Truck-mounted drills	$3-5
Enviro-drills	$10-14
Heli-drills	$40 and up[2]

[1]Estimates provided by Western Geco, Calgary, AB.
[2]Cost is highly dependent on flying distance and terrain.

tirely by using heli-portable drills and recording equipment. However, 1.5-m hand-cut lines are still required to enable workers to lay down recording equipment. Although equipment is lowered to shot-hole sites by cable, helicopter landing sites must be available at regular intervals for safety reasons. More often than not, natural or industrial clearings are available for this purpose. Currently, *enviro-drills* and heli-portable drills are mostly being used in restricted areas, primarily along the East Slopes.

The seismic techniques described above provide a series of cross-sectional views of the earth — one slice for each seismic line. Advances in computer modelling have also made it possible to combine individual cross-sectional views into a full three-dimensional representation of the subsurface. However, to be used for 3D, seismic lines need to laid out in a grid pattern and at a closer spacing than for conventional 2D seismic. The use of 3-D techniques in Alberta is increasing, particularly for the steam extraction of in-situ oil sands deposits and for recovering residual oil from old reservoirs of conventional oil.

Ecological Impacts

In fiscal year 1999, the most recent year for which data are available, 101,000 km of seismic lines were approved in the Green Zone. Of these, 71,000 km involved new cutlines, and 30,000 km involved existing cutlines (Alberta Environment, unpublished data). The total length of seismic lines approved in the Green Zone is now over 1.5 *million* km (ECA, 1979: 28; AEP, 1998: 75).

Given conservative estimates of line widths, the area of forest harvested by seismic operations in the Green Zone from the start of operations in the 1950s to 1976 was 234,700 ha (ECA, 1979: 28). This compares with a harvest of 255,692 ha by the forest industry in the same region from 1956 to 1976 (ECA, 1979: 28). Because only a fraction of the wood from seismic operations is salvaged (being of the wrong species or age class, or impractical to haul out), the impact of seismic is largely additive to that of the forest industry.

In recent years the rate of harvesting by the forest industry has increased substantially, but so has the rate of seismic exploration. Consequently, the proportional impact of both industries is still similar. For example, on the Weyerhaeuser Edson FMA the annual average harvest from 1997 to 2001 was 1400 ha by the forest industry and 1083 ha by the petroleum industry (Varty, 2001). On the Alpac FMA the current rate of harvest is 16,000 ha/year by the forest industry and 11,000 ha/year by the petroleum industry (Pope, 2001).

A study in northeast Alberta has demonstrated that only 11.9% of seismic lines older than 20 years (n=62) were sufficiently regenerated to meet Alberta Forest Regeneration Survey Standards (MacFarlane, 1999). Similar rates of failure of forest regeneration have been described in the East Slopes (Revel et al., 1984). A combination of several factors is likely responsible for the observed failure in regeneration, including bulldozer damage to root systems, competition by grass species, ongoing disturbance by all-terrain vehicles and snowmobiles, and insufficient light penetration (Revel et al., 1984; MacFarlane, 1999).

Because regeneration is inadequate, seismic activities result in a progressive loss of mature forest and alteration of forest structure. Given the high rates of seismic activity in the Green Zone, the cumulative loss of habitat is substantial. These direct losses are magnified by the avoidance of habitat in the vicinity of seismic lines by some species, such as caribou (Dyer et al., 2001). Habitat effectiveness is further reduced by the extensive fragmentation of forest stands that results from seismic activity (Fig. 4.7).

Fragmentation reduces the abundance of large contiguous patches of forest that are required by forest-interior species (Bender et al.,

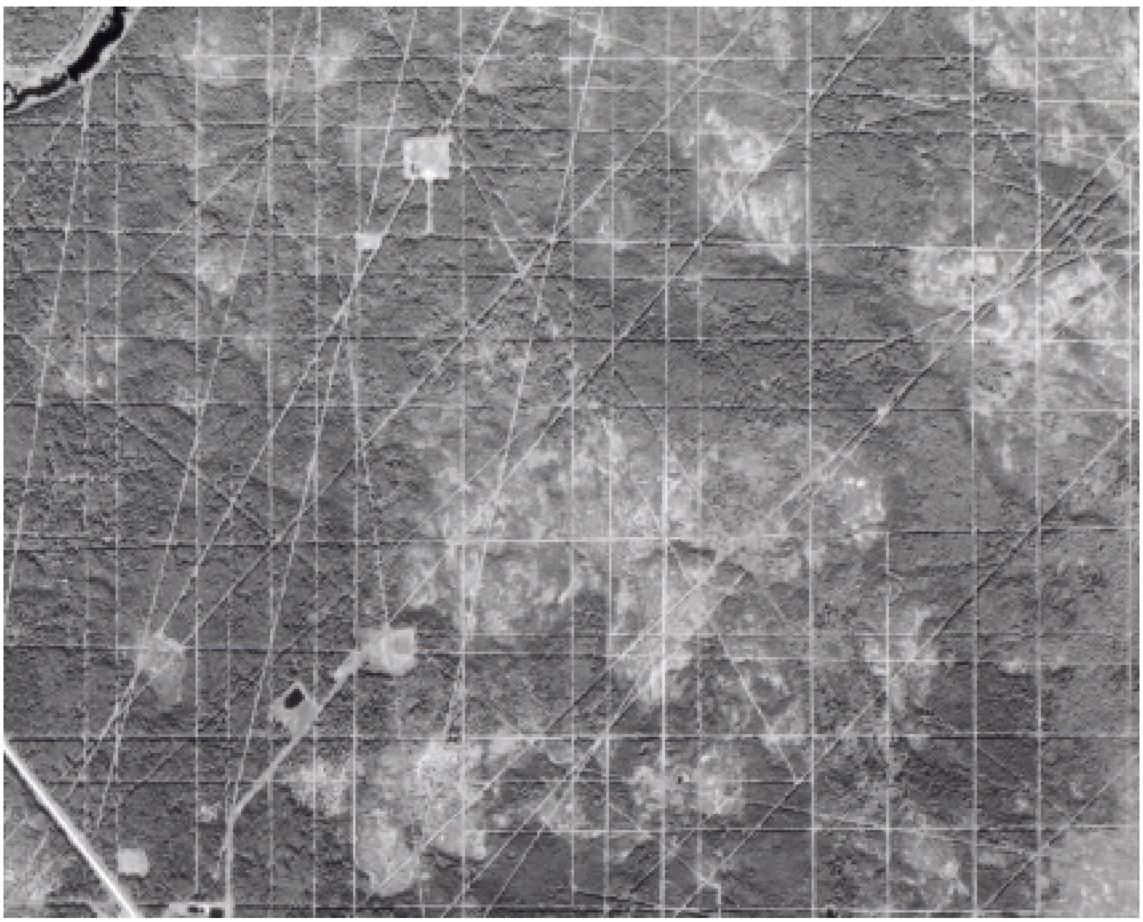


Fig. 4.7. Aerial photo illustrating the high density of seismic lines (white lines) present in many parts of Alberta's boreal forest (Twp 107, Rge 9, W6th; dimension of photo = 2.4 x 3 km; taken in 1992). (Air Photo Services, Alberta Sustainable Resource Development)

1998), and increases reproductive failure in birds due to nest predation and cowbird parasitism (Burke and Nol, 2000).

Seismic activities have several additional ecological impacts:

1. Increased access. Seismic lines provide access routes into the forest for all-terrain vehicles, snowmobiles, and off-road trucks. This leads to increased hunting and poaching and can have significant adverse effects on soil and vegetation, effectively delaying regeneration (CAPP, 1999a: E-3).
2. Damage to aquatic systems. Deleterious impacts include increased stream sedimentation, bank erosion, barriers to fish passage, destruction of aquatic habitats, and alteration of drainage patterns (CAPP, 1999a: D-13).
3. Alteration in predator-prey interactions. Wolves are able to move faster along seismic lines than in the forest and this has been associated with increased predation pressure on caribou (James, 1999).
4. Damage to soil. Deleterious impacts include compaction and mixing of soil horizons by heavy equipment, erosion, and soil cratering from shot holes that are not properly filled (CAPP, 1999a: F-3).
5. Disturbance of wildlife. Clearing operations and dynamite explosions can disturb wildlife, particularly during nesting and calving periods (CAPP, 1999a: D-3). Repeated disturbances can result in significant energy losses by increasing movement rates during the winter when food supplies are limited (Bradshaw, et al., 1998).
6. Introduction of aggressive weed species into the forest (CAPP, 1999a: F-15).

Regulatory Framework

Oil and gas exploration is generally not permitted in East Slope Prime Protection lands or protected areas (AE, 1996: 16). However, "grandfathering" clauses permit exploration when required to develop mineral rights that were acquired prior to an area being designated as protected (AE, 1996: 16).

To conduct a seismic program a company must obtain an *Exploration Approval*, administered by Alberta Sustainable Resource Development (GOA, 1998, sec. 9). Applications pertaining to public land must be accompanied by *Geophysical Field Report*, which provides site-specific details as to how environmental issues will be addressed during the clearing, operating, and reclamation phases of the geophysical program (LAD, 1999: 3). A company does not need to hold mineral rights for an area to obtain an *Exploration Approval.*

The intent of the *Geophysical Field Report* is to have the applicants outline how they plan to meet the relevant environmental standards, instead of having the government address these details in the form of approval conditions (LAD, 1999: 3). The submitted application is reviewed by various government departments, including Lands and Forest Service, Fish and Wildlife, and Land Administration, to check for deficiencies. By law, the government must provide a response within ten working days (GOA, 1998, sec. 11).

The *Geophysical Field Report* includes the following elements (LAD, 1999: 6-16):

1. Description of ground conditions. It is expected that operations in northern muskegs will be done under frozen ground conditions.
2. Identification of areas of concern (e.g.,

parks, critical wildlife zones, and areas subject to Integrated Resource Plans). These areas generally have special operating rules.

3. Watercourse crossings. All crossings must be identified and measures for mitigating environmental concerns must be explained.
4. Buffer zones. Buffers, where operating restrictions apply, are required around aquatic features (10-45 m) and designated wildlife protection corridors (50-100 m).
5. Water bodies. Restrictions on drilling and use of dynamite may apply, depending on the type of water body.
6. Existing seismic lines. Existing lines must be used if they are parallel and within 400 m, unless justification for an exemption can be made. In practice, successive seismic surveys often run in different directions, resulting in high local densities of lines (Fig. 4.7).
7. Proposed access. Access to the survey site should normally be achieved using existing roads, trails, and seismic lines.
8. Line type and width. *Low impact seismic* is now generally required in areas of merchantable forest. Conventional seismic remains acceptable in muskeg areas.
9. Timber management. Plans should include measures to minimize losses of merchantable timber. Salvage of timber may be required for conventional seismic programs, but *low impact seismic* programs are exempt.

After one year the survey site is inspected to ensure that environmental regulations were followed. If the site is acceptable a *Letter of Clearance* is issued, absolving the company of any further responsibility for the site. Companies are not required to reforest the site, though some sort of vegetation cover must be present to prevent erosion (LAD, 2000).

From the perspective of sustainable forest management, the regulatory framework governing seismic activities is fundamentally deficient in two respects. First, given that *Geophysical Field Reports* must be reviewed by multiple government departments (that are typically short-staffed) it is inconceivable that a thorough environmental review can be accomplished within the allotted ten-day period. As observed by the Environmental Council of Alberta (1979: 27),

> *The emphasis on haste that the [petroleum] industry has adopted over the years seems to have been accepted by the government. This is not conducive to good planning, which requires time to evaluate a proposed program or development.*

A second deficiency of the regulatory framework is that it is focussed on local and short-term issues, and not on sustainability of the forest as a whole. In particular, there are no regulations that limit the overall rate of harvest or require that the forest be regenerated. Neither is there any requirement that seismic activities be integrated with the long-term harvest plans of forestry companies that share the same land base. In fact, forestry companies have no control over exploration activities that occur on the land base they are charged with managing. As a consequence, efforts by forestry companies to achieve ecological forest management targets are critically hindered.

In addition to the general deficiencies described above there are also problems with individual regulations. However, a comprehensive review of the adequacy of the individual regulations governing seismic activities is beyond the scope of this book.

Drilling and Production

Current Practices

As with seismic exploration, most drilling is conducted by specialized companies that market their services to producers (PCF, 1999: 39). However, a few of the larger producers still own and operate their own drilling rigs. The cost of drilling is a function of depth, ranging from about $100,000 for a shallow well (450 m) on the prairies to more than a million dollars for a deep well (4000 m) in the foothills (PCF, 1996: 3).

The first step in drilling is the construction of an access road capable of handling large volumes of heavy truck traffic. Drilling rigs are large complex structures that are designed to be disassembled and moved from site to site (Fig. 4.8). Transport of a large rig can involve up to 50 semi-trailer trucks (PCF, 1999: 39). Additional truck traffic is generated by the transport of workers and supplies, including fuel, water, food, specialty chemicals, and drilling mud. It is also necessary to clear an area at the drilling site for the assembly of the rig and to facilitate the local movement of workers and equipment. Well site clearings of one hectare are typical in forested regions in Alberta (LAD, 2001: 10).

Drilling involves about 75 workers in total per typical well, working in round-the-clock shifts, seven days a week (PCF, 1999: 42). Though many technological refinements have been made in recent years, the drilling process is still based on the movement of a rotating bit through rock. A fluid called mud lubricates the bit and removes rock cuttings, stabilizes the hole, and controls the pressure in the wellbore. The mud is a suspension of chemicals and minerals in water or oil.

Once the oil or gas reservoir is reached, the well casing is cemented in place and a well head is installed to regulate the flow of product. Gas usually flows under its own pressure, though a compressor may be required to boost the pressure for pipeline transport. The extraction of crude oil is more complicated, and in most cases some form of pumping is required. Many wells also require "stimulation", by physical or chemical means, so that oil can move more easily through pores or fractures in the reservoir. A common method of stimulation involves the injection of concentrated acids under pressure into the rock formation (PCF, 1999: 48).

Fig. 4.8. Conventional oil drilling rig and support equipment. (Photo: Al-Pac)

The primary recovery techniques described above are able to recover an average of only 20% of the oil in a reservoir (PCF, 1999: 49). Therefore, a variety of enhanced recovery techniques are generally utilized, the nature of which is determined by the type of oil involved. For light oil (i.e., low density and viscosity), the most common enhanced recovery technique is infill drilling, which simply means drilling more wells into the same reservoir so that the oil does not have to travel as far to reach a wellbore. New directional drilling techniques permit multiple wells to be drilled from a common drilling pad, reducing the environmental impact of infill drilling.

Other enhanced recovery techniques involve the injection of water or natural gas to maintain reservoir pressure and push the oil out of the rock (PCF, 1999: 49). More advanced techniques include the injection of natural gas liquids, such as propane, into the reservoir to dissolve into the oil and reduce its viscosity, thereby aiding its release from the rock. Even with enhanced recovery techniques, the average recovery for light oil is not much more than 30% (PCF, 1999: 49).

In heavy oil fields and in-situ oil sands (Fig. 2.17), enhanced recovery generally involves the application of heat. Without heat the oil is simply too thick to be extracted. The most common technique is called steam-assisted gravity drainage which uses parallel pairs of horizontal wells for steam injection and oil recovery (PCF, 1999: 49). Steam recovery is far more intensive than conventional oil extraction because it involves batteries of closely spaced wells, it requires large quantities of water and power for generating steam, and it makes extensive use of 3D seismic surveys (AEC, 1999).

The oil sands deposits in an area of approximately 37 townships north of Fort McMurray (Fig. 2.17) are sufficiently close to the surface to be directly mined. Discussion of oil sands mining is beyond the scope of this book; however, suffice it to say that mining represents the most intensive and environmentally damaging method of oil extraction in the province.

Once a well has been brought into production it is generally tied into a pipeline system to transport the product to processing plants of various types. The construction of pipelines involves further clearing of linear corridors to provide access, and trenching for the laying of pipe. Regular ground or aerial patrols of pipelines are required to ensure that pipeline integrity is continually maintained. Consequently, forest regrowth along pipeline right-of-ways is prevented for the life of the pipeline through mechanical or chemical means (CAPP, 1999b: E-14).

Whereas oil is generally transported in raw form to refineries near major population centres for processing, most processing of natural gas is done at gas plants located near production areas (PCF, 1999: 60). Consequently, a large proportion of the 684 gas plants in Alberta are located within forested areas. The processing of gas involves the separation of natural gas (methane) from the raw gas stream which includes heavier hydrocarbons (e.g., ethane and propane), water vapour, and other gases. When hydrogen sulphide is present (sour gas), it is also removed, usually at larger facilities.

In the past, all-weather roads to well sites had to be maintained to provide access for well monitoring, maintenance, and repairs. However, through advances in automation and telemetry, it is now possible to monitor wells remotely (PCF, 1996: 6). Consequently, gas wells, which require minimal maintenance, can now be serviced by helicopter, and access roads can be removed

(BCC, 2001: 25). However, this is not yet a common practice. Because oil wells generally have pumps and other equipment that require regular maintenance, remote service of oil wells is difficult and is not yet being implemented.

The typical lifespan of a well is about 25 years, though many wells produce for longer periods. If a producing well is no longer economical to operate the well bore is plugged with cement and the site is reclaimed. A similar process is followed for new wells that are found to be dry (i.e., not capable of producing commercial quantities of oil or gas).

Ecological Impacts

As with seismic lines, it is not the impact of individual wells that is of primary concern, but the cumulative impact of all wells. In 2000 alone, 11,898 new wells were drilled in Alberta (AE, 2001c). The cumulative area of existing wells in the Boreal Forest Natural Region, as of 1997, has been estimated to be over 886 km^2 (AEP, 1998: 75). Furthermore, each well has a road leading to it and frequently a pipeline right-of-way leading away from it (Fig. 4.9).

The clearing of trees associated with the construction of well sites, access roads, and pipelines is associated with the same list of ecological impacts described for seismic lines (CAPP, 1999c: D-3). Although the total amount of clearing is less than that associated with seismic exploration, the local impact is substantially greater. For example, caribou avoid wells to a distance of 1000 m, which is four times the avoidance distance for seismic lines (Dyer et al., 2001). Roads provide faster access for more types of vehicles and cause more erosion and greater disruption of drainage patterns. Finally, well sites, roads, and pipeline right-of-ways are essentially permanent features of the landscape, given their prolonged use and slow regeneration after decommissioning.

In addition to general landscape impacts associated with deforestation, there are ecological impacts related to the contamination of soil and water. Such contamination reduces soil and water quality. Furthermore, many contaminants are classified as hazardous and may be toxic or carcinogenic (AEUB, 1996: App. 7.4). The major types of soil and water contaminants are (AEUB, 1996: App. 7.4):

- subsurface products including hydrocarbons, saline water, and heavy metals;
- drilling mud and associated chemicals and minerals;
- concentrated acids used for well stimulation and other “process chemicals”;
- industrial fluids (solvents, fuel, lubricants); and
- sewage and garbage.

Contamination of soil, surface water, and groundwater with the aforementioned products occurs in a variety of ways, including (CAPP, 1999c: sec. E):

- oilfield waste disposal by spreading on land and roads (both are officially condoned practices, with minimal oversight: AEUB, 1996: sec. 16.2);
- underground leakage during drilling due to faulty well casings;
- spills and continuous leaks during operations;
- faulty storage structures;
- improper transport and disposal of wastes; and
- pipeline failures.

Drilling and production are also associated with reductions in air quality through the release of various of gaseous emissions. Some of these

Fig. 4.9a. Aerial photograph illustrating well sites (pale squares), access roads (thick lines), and seismic lines (Twp 51, Rge 9, W5th; dimension = 0.8 x 1.2 km; taken 1992). (Photo: Air Photo Services, Alberta Sustainable Resource Development)

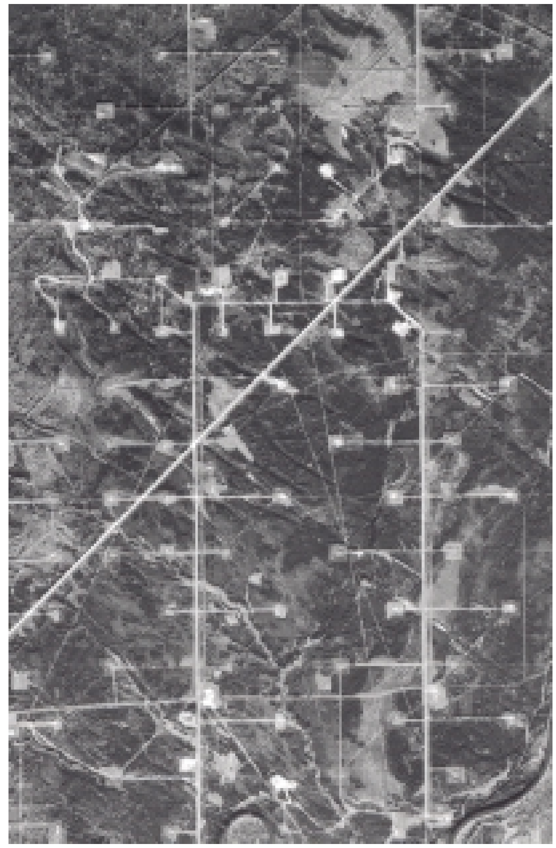


Fig. 4.9b. Aerial photograph illustrating the distribution of well sites (pale squares), and access roads at smaller scale (Twp 48, Rge 9, W5th; dimension = 4.7 x 7.3 km; taken 1994). (Photo: Air Photo Services, Alberta Sustainable Resource Development)

emissions, such as benzene and carbon monoxide, are directly toxic (CAPP, 1999c: C-35). Others, such as sulphur dioxide and nitrogen dioxide, are responsible for acid rain deposition (Schindler, 1998). Methane and carbon dioxide are important greenhouse gases. Alberta has the highest greenhouse gas emissions in Canada, largely as a consequence of energy-sector activities (EC, 1997). Not surprisingly, public concerns about petroleum industry emissions are very high, particularly among rural residents (Marr-Laing and Severson-Baker, 1999).

Sources of gaseous emissions include the following (CAPP, 1999c: Sec. C):

- leaking and flaring of gas produced as a byproduct of oil production (Fig. 4.10);
- well blowouts;
- glycol dehydrators, used to remove water

Fig. 4.10. Flaring of gas. (Photo: Canadian Parks and Wilderness Society - Edmonton)

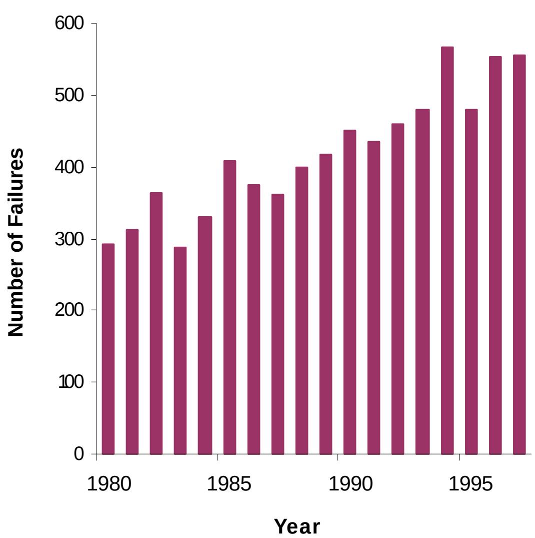


Fig. 4.11. Number of oil and gas pipeline failures in Alberta, 1980-1997. Source: AEUB, 1998.

vapour from the gas stream (primary source of benzene emissions);

- test flaring of new gas wells;
- flaring of gas and sulphur recovery at gas processing plants;
- inadequate storage and handling facilities;
- oil spills and leaks and disposal of oil wastes via spreading on land and roads; and
- pipeline failures (Fig. 4.11).

A final issue of note is the diversion and use of freshwater for enhanced oil recovery. This includes pumping water into reservoirs to maintain reservoir pressure and the generation of steam for steam-assisted gravity drainage. Although water is recycled as much as possible, both techniques involve large net inputs of freshwater over time. In 2001, Alberta Environment gave oil and gas companies permission to inject 230 billion litres of freshwater down well bores — enough water to supply the city of Red Deer for 25 years (Nikiforuk, 2002). The use of fresh groundwater by the petroleum sector is currently exceeded only by municipalities (Table 4.4). Concern has been expressed that this rate of use of freshwater, which

Table. 4.4. Annual allocation of fresh ground-water in Alberta in 2001.

Sector	Cubic Metres	Percent
Municipalities	48,365,779	29.5
Oil recovery	42,604,001	26.0
Agriculture	28,089,236	17.1
Commercial	23,634,898	14.4
Fish management	9,386,905	5.7
Other industrial	5,414,923	3.3
Recreation	4,957,436	3.0
Other	1,552,247	0.1
Total	164,005,425	100.0

Source: Alberta Government, cited in Nikiforuk, 2002.

is set to increase as the industry expands, will jeopardize the provincial supply of freshwater required for other human needs (Marr-Laing and Severson-Baker, 1999; Nikiforuk, 2002).

Regulatory Framework

Subsurface mineral rights do not provide petroleum companies with the right to conduct activities on the surface. On public lands, companies must separately obtain a *Mineral Surface Lease* and related agreements in order to drill wells and construct roads and pipelines (GOA, 2000b, sec. 76). These agreements are administered by Alberta Sustainable Resource Development. As with seismic exploration, drilling and production are not permitted in certain areas, such as protected areas, unless grandfathering clauses exist.

Pursuant to subsection 7(2) of the *Dispositions and Fees Regulation* (GOA, 2000b), forestry companies that hold tenure rights in an area must provide written consent before a *Mineral Surface Lease* can be issued. In practice, this legal avenue for managing the activities of petroleum companies has never been exercised by forestry companies. Presumably, this is because the government retains contractual rights to remove lands from forest management areas as required for industrial purposes.

Applications for a *Mineral Surface Lease* must be accompanied by an *Environmental Field Report* (LAD, 2001) in which applicants identify environmental issues and describe acceptable methods for addressing them. Applications are reviewed by various government departments and, unless deficiencies are noted, approvals are provided within 15 working days (Graham, 2001). The key elements of the *Environmental Field Report* are:

- identification of “areas of concern”, where special management rules apply;
- timber salvage;
- well site development;
- access road construction (route, size, type); and
- watercourse crossings.

Before drilling can proceed a company must also obtain a well licence from the Alberta Energy and Utilities Board. The role of the Board is to ensure that energy resources are developed in a responsible and efficient manner. One of the ways it does this is by regulating the spacing of wells. Normally, oil wells are spaced at one per quarter section of land and gas wells at one per section, unless it can be shown that additional wells are necessary “*to provide capacity to drain the pool at a reasonable rate*” (GOA, 2001, sec. 4.020 and 4.040).

For conventional wells on public land the Energy and Utilities Board generally accepts that all surface issues have been resolved through the *Mineral Surface Lease* process (AE, 1996: 19). Consequently, routine applications are normally approved in less than five working days (CAPP, 1999c: B-7). Intensive steam-assisted gravity drainage projects, oil sands mines, and other large projects generally require an Environmental Impact Assessment prior to approval. However, none of the proposed oil sands projects (totaling tens of billions of dollars) have been declined, in spite of the fact that defined limits on regional cumulative impacts do not exist.

The Energy and Utilities Board is also responsible for ongoing regulation of active wells, including the regulation of emissions and handling of wastes. As scientific evidence of the harmful effects of pollution mounts, there is growing concern that the existing regulatory framework governing operations is inadequate (Marr-Laing and Severson-Baker, 1999: 1). There is additional concern that existing regulations are not being effectively enforced, as a consequence of recent government downsizing (Marr-Laing and Severson-Baker, 1999: 1). The most serious deficiencies include unacceptable levels of gas venting and flaring, unacceptable levels of benzene release from gas plants, inadequate standards for the handling of oil field wastes, and inadequate regulation of groundwater resources. These issues are reviewed in detail in a recent paper by the Pembina Institute (Marr-Laing and Severson-Baker, 1999).

The decommissioning and reclamation of well sites is administered by the Alberta Energy and Utilities Board and by Sustainable Resource Development. The objective of the reclamation process is to "*return the specified land to an equivalent land capability*" (GOA, 1999: sec. 2). This is narrowly interpreted to mean that the site must be capable of growing trees, but restoration of the original forest is not required. Consequently, well sites are normally reseeded to grass (LAD, 2001: 10). Other reclamation requirements include the removal of contaminants, restoration of the original topography, and restoration of soil conditions (AEP, 1999). Once reclamation has been completed the company is awarded a Reclamation Certificate, absolving it of further responsibility for the site. In the Green Area, government inspection of reclaimed sites is not mandatory, but instead is based on an audit system (GOA, 1999: sec. 6.2).

A more detailed review of specific regulations pertaining to drilling and production is beyond the scope of this book. However, it is important to note that the same general deficiencies I described for seismic exploration apply to the regulation of oil and gas wells. Even though the construction of oil and gas wells and associated infrastructure have a tremendous impact on the structure and integrity of the forest, there are no regulatory or policy limits on the annual rate of forest clearing, no requirements for reforestation, no thresholds for cumulative impacts, and no requirements for integrated long-term planning with the forest industry intended to maintain forest sustainability. Instead, the regulatory framework is focussed on mitigating industrial activities on a case by case basis with minimal review and no recognition that the forest has a finite capacity to meet the needs of multiple industrial users.

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