Sustainable Energy Solutions

A *Peak* into the Future

Potential Landscape Impacts of Gas Development in Northern Canada

June 2005

Peggy Holroyd and Hal Retzer

REPORT

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Acknowledgements and Disclaimer

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The content of this report is entirely the responsibility of the Pembina Institute and does not necessarily reflect the views of those acknowledged above.

Throughout this document both metric and Imperial units are used. Decisions regarding which units to use in each section were made based on what the authors felt would be most familiar to the reader.

About the Authors

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Peggy Holroyd works as an Environmental Policy Analyst with the Pembina Institute's Energy Watch Program reviewing Environmental Impact Assessments for new oil and gas projects, and identifying cumulative impacts of gas development in the Yukon and Northwest Territories. A Northerner herself, she has experience with and has studied political and socio-economic issues in small Northern communities. Ms Holroyd graduated with a degree in International Development from the University of Calgary, including a minor in Northern Planning and Development through the Arctic Institute of North America.

Hal Retzer
Hal Retzer has 22 years' experience in engineering, operations and project management in the gas gathering and processing industry and is currently a consultant in the oil and gas industry. His experience includes project management, design, construction and commissioning of numerous gas processing facilities ranging in size from small ($50,000) to large ($300 million). Mr. Retzer has previously been involved in field operations, business operations, health, safety and environment (HS&E), training and management of a field and head office staff of 350 people for a large gas gathering and processing company. More recently, Mr. Retzer has applied his working knowledge of the gas industry to model the extent of gas field development in the North.

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Introduction

This paper illustrates the potential physical footprint of gas development in three fields within northern Canada's sedimentary basins: the Mackenzie Delta, Colville Hills and Peel Plateau.

In this study *ALCES*®, a landscape-scale simulation model, was used to estimate the footprint in the three fields of typical gas development over the next 30 years. The model was also used to explore alternative management scenarios that apply several "best practices" currently used in the gas industry.

This project was commissioned by the Canadian Arctic Resources Committee (CARC) and the Canadian Parks and Wilderness Society (CPAWS), Yukon and Northwest Territories chapters.

Rationale for the Study

Renewed interest in developing the oil and gas resources of northern Canada presents peoples of the North with economic opportunities as well as significant social and environmental risks. With large-scale development proposals submitted and pending, it is imperative that Northerners have access to quality information and develop a sound understanding of the oil and gas industry in order to make informed decisions about the potential environmental impact of these developments.

The need for this study is consistent with that identified by a variety of sources, including the expert panel that participated in the 2004 CPAWS–Yukon Science Workshop. Similarly, Northerners who have taken part in the Pembina Institute Northern Oil and Gas Capacity Building workshops have consistently called for this type of study to be undertaken prior to major oil and gas development.[1]

Northerners have been provided with little information that illustrates potential scenarios for oil and gas development over a 30- to 50-year time period. Similarly, information about the potential cumulative, long-term ecological, economic, and social impacts of full-scale natural gas exploration and development is limited. The emphasis to date has been on individual gas projects (e.g., a seismic project, an exploration drilling project, the Mackenzie Gas Project[2]). Such projects represent only one stage of a much larger development process. This project is intended to provide Northerners with an estimate of the extent and pace of gas field development that could occur if known and potential reserves of gas hydrocarbons are developed.

A series of GIS maps of current and forecast gas developments in the three study areas have been included in Appendix A. This will provide Northerners with a visual tool to help them evaluate the density of seismic lines, wells, roads, pipelines, gas plants, compressor stations, gas plants, and gas transmission lines on the land. The maps could be used in land use planning and to raise community awareness about the potential impacts of oil and gas development.

This technical document will be complemented by a public report that includes a qualitative discussion of the environmental impacts associated with gas development.

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[1] Ongoing since 2002, over 100 individuals have attended the Pembina Institute's Northern Oil and Gas Capacity Building Workshops.
[2] Mackenzie Gas Project Web site: www.mackenziegasproject.com/index.asp

The scope of this study did not allow a quantitative assessment of the environmental impacts associated with potential gas development in the three study areas. However, based on the modeled footprint developed from this study, the authors suggest this would be a valuable next step.

Other projects have been undertaken to assess the long-term impacts of development in the North. In January 2005, Canadian Arctic Resources Committee (CARC) released a series of maps that plot potential development in the Mackenzie Delta and the Colville Hills as suggested in a report submitted with the Application and Environmental Assessment of the Mackenzie Gas Project (MGP).[3] Each map depicts a different snapshot in time. This study here complements, reinforces and expands upon the discussion of cumulative effects as presented in CARC's report *Mapping Study of the Cumulative Effects of the Mackenzie Gas Project*.

Objectives

Based on current oil and gas reserve estimates and development proposals, this study aims to provide Northern communities with a 'picture' of potential cumulative gas development in three regions of the North. This information is intended to serve as a useful tool for communicating the scope and scale of potential gas development to Northerners.

The study results will be used to

- provide decision makers with information about the potential nature and extent of the footprint associated with gas development in the event that the Mackenzie Valley pipeline is built.
- raise public awareness about the footprint and environmental impacts associated with gas development.
- encourage discussion on industry "best practices" that may be used to reduce the footprint of development.

Study Areas

The study models the general pattern of gas field development over the next 30 years based upon proven and potential reserves and development plans for

- the Mackenzie Delta, Northwest Territories (onshore only)
- the Colville Hills, Northwest Territories (Sahtu region)
- the Peel Plateau, Yukon Territory.

The study does not identify the exact location of well sites or pipelines, but rather gives a representation of the overall density (e.g., percent of land under development). To identify exactly where a particular well or seismic line would be located requires detailed knowledge of the subsurface geology and is outside the scope of this study.

This study has incorporated existing gas development into the model based on the most recently available information.

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[3] Gilbert Laustsen Jung Associates Ltd. 2004. *Mackenzie Gas Project: Gas Resource and Supply Study*. A study prepared for Imperial Oil Resources Ventures Limited, www2.ngps.nt.ca/applicationsubmission/index.html

Methods

The ALCES Model

The ALCES model was chosen as the tool to analyze the gas reserves data. ALCES (an integrated landscape management tool) is intended "to deliver a strategic-level landscape simulation that allows resource managers to understand the strategic consequences and opportunities associated with land use practices within regional landscapes."[4] The ALCES user can consider typical land use trajectories on a landscape, track the ecological footprint of development over time, and consider the consequences of select land use practices. Data on plausible land use trends are stored and then used to run future scenarios. ALCES runs through a software program called STELLA.[5]

The ALCES model is used extensively in Western Canada, including by the Department of Energy in Alberta. Industry users include Golder and Associates, AMEC Environmental and Syncrude Canada.[6] The model has been used several times in the North, including by the Department of Indian and Northern Affairs in the NWT and Yukon, and the Department of Resources, Wildlife and Economic Development in the NWT.

Hubbert/Naill Approach

Within the energy module of ALCES, there is the option to build scenarios that are user-defined or that use the Hubbert/Naill Life History Approach for reserve depletion. This project uses the Hubbert Naill Approach.

In the 1950s, petroleum geologist M. King Hubbert stated that a decline in oil and gas discoveries per foot of exploratory drilling would occur over time, causing oil and gas production to peak and then decline over time. This statement was based on the assumption that there is a finite amount of reserves in a given area. The life cycle of oil and gas production over time would then resemble a bell curve, where "the stock of proven reserves of natural gas rise, peak and fall over time, and the stock of unproven resources falls monotonically due to depletion."[7] In 1972, Roger Naill created a model of US natural gas discovery and production that confirmed the hypothesis of M. King Hubbert.[8]

The methodology initiated by Hubbert makes it possible to estimate production rates, number of wells, length of pipelines, and length of seismic lines based on an estimate of known gas reserves for a particular gas field. In general, the analysis starts with the known gas reserves, either proven or potential. From this, the rate at which proven (or potential) gas is brought into production (i.e., the discovery rate) and annual production rates (based on the usage rate) are determined. The number of producing wells is then established using a well coefficient, which is the ratio of producing wells per volume of proven reserves.

[4] Stelfox, B. 2004. ALCES Presentation, at ALCES Training Workshop, University of Calgary, December 6, 2004.
[5] www.iseesystems.com/
[6] *Past and Current ALCES License Holders and Users*, www.foremtech.com/products/pr_alces_map.htm
[7] System Dynamics Society. Undated. *Introduction to System Dynamics,* online book, www.systemdynamics.org/DL-IntroSysDyn/refmod.htm
[8] System Dynamics Society. Undated. *Introduction to System Dynamics,* online book, www.systemdynamics.org/DL-IntroSysDyn/ch6.htm

Throughout this study the terms “proven gas” and “unproven (or potential) gas” are used. Proven gas is natural gas that is known to exist because it was discovered during drilling. Unproven gas is natural gas that could exist based on the interpretation of sub-surface geology. Both proven gas and unproven gas are often cited to a certain confidence level.

Modeling Assumptions

This study modeled industrial footprints for most of the major land uses expected in the development of a gas field: wells, well pads, well access roads, pipeline gathering systems, well site dehydrators, well site conditioning facilities, field compressor stations, on site camps, helicopter pads and seismic lines. The assessment did not include gravel borrow pits for road and infrastructure construction, landfills, or gas plants.

The study assumes that major gas transmission pipeline capacity is sufficient to transport all available gas at the well head and, therefore, does not limit production.[9]

Study Areas

The three study areas — Mackenzie Delta, Colville Hills, and Peel Plateau — were chosen as areas with known development opportunities.

Physical surface areas of the study regions were extrapolated from documents that reported on associated reserve estimates. For the Mackenzie Delta and Colville Hills, this information came from the 2004 report by Gilbert Laustsen Jung Associates Ltd. entitled Mackenzie Gas Project: Gas Resource and Supply Study (hereinafter called the GLJ Report).[10] For the Peel Plateau this information came from the National Energy Board's 2000 report, Petroleum Resource Assessment of the Peel Plateau, Yukon Territory, Canada.[11]

The Mackenzie Delta is located where the Mackenzie River empties into the Beaufort Sea. The study area for the delta includes the anchor fields as identified in the Mackenzie Gas Project (MGP) application as well as the remaining areas of the delta that have known gas reserves. Offshore areas were excluded from the analysis, yet contain almost twice as many reserves as do onshore areas.[12]

Colville Hills is located northeast of Norman Wells. The study area for Colville was drawn to include the Significant Discovery Licenses in Colville and the lands between each, for a total of approximately two million hectares to correspond with the area of reserves in the GLJ Report.[13]

The Peel Plateau is located in northeastern Yukon, bordered to the north by the Mackenzie Mountains and to the east by the Richardson Mountains. For study purposes, GIS maps were used to divide the Peel Plateau into the Peel Plain and Disturbed Belt given that there are significantly different potential reserves in each area that could result in different concentrations of development.

Maps of the study areas and data sources for the maps are included in Appendix A.

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[9] See *Discussion* section on production for explanation of how pipeline capacity would affect study results.

[10] Gilbert Laustsen Jung Associates Ltd. 2004. Mackenzie Gas Project: Gas Resource and Supply Study. A Study Prepared for Imperial Oil Resources Ventures Limited, www2.ngps.nt.ca/applicationsubmission/index.html

[11] National Energy Board. 2000. *Petroleum Resource Assessment of the Peel Plateau, Yukon Territory, Canada.* For the Oil and Gas Resources Branch, Department of Economic Development, Government of the Yukon.

[12] GLJ Report, p. 57–59.

[13] GLJ Report, p. 37

Current Surface Developments

Current surface developments such as existing seismic lines and well sites are included in the analysis. Based on GIS information, existing developments within the study areas are summarized below. Other pre-existing land disturbance such as roads and utilities are not incorporated into the modeling. A comparison of modeled development versus current development to-date has been included in the discussion section.

Table 1. Current Surface Developments

	Existing Seismic Lines (km)	Existing Well Sites
Mackenzie Delta (onshore including anchor fields)	21,041	119
Colville Hills	2,428	17
Peel Plateau	1,715	19

Proven and Unproven Reserves

Mackenzie Delta

In the Mackenzie Delta, proven and unproven reserve estimates were taken from the GLJ Report. For the three anchor fields proposed in the Mackenzie Gas Project, this study based the measure of proven reserves from figures taken from Table 5 of the GLJ Report: Onshore Mackenzie Delta — Discovered Recoverable Marketable Gas Resources.[14]

Table 2. Proven Gas Reserves in Parsons Lake, Taglu and Niglingtak Anchor Fields

Anchor Fields	Parsons Lake	Taglu	Niglingtak	Total
Proven Reserves Billion cubic metres ($10^9 m^3$)	63.6	79.9	20.3	163.8
Proven Reserves Trillion cubic feet (TCF)	2.25	2.82	0.72	5.79

For rest of the Mackenzie Delta, outside the anchor fields, both proven and unproven reserves were used. The reserve numbers for the Mackenzie Delta (Basin Margin and Listric Fault Zone) were calculated based on the discovered resources reported in Table 5 of the GLJ Report and on the undiscovered resources reported in Table 19 of the report.[15] Within ALCES, the reserves in the three anchor fields were subtracted from the reserves in the whole Mackenzie Delta to reflect the concentration of reserves in the anchor fields and to ensure a more accurate estimate of development in the Mackenzie Delta outside of the anchor fields.

Table 3. Proven and Unproven Gas Reserves in the Mackenzie Delta

Mackenzie	Table 5:	Table 19:	Total	Proven	Total Reserves

[14] GLJ Report, p.17. The reserves numbers for the Mackenzie Delta are for a P50 (or 50%) confidence level.
[15] GLJ Report, p.59.

Delta	Proven Onshore Reserves	Unproven Reserves	Proven and Unproven Reserves	Reserves in Anchor Fields	Less Reserves in Anchor Fields
Reserves 10^9m^3	210	198	408	163.8	244.2
Reserves TCF	7.41	6.99	14.4	5.78	8.62

Colville Hills

Gas reserve estimates for the Colville Hills were taken from Table 7 of the GLJ Report. The best estimate of total resources was 185.4 10^9m^3 (6.58 TCF) and includes both proven and unproven reserves in the area.[16]

Peel Plateau

Reserve estimates for the Peel Plateau are taken from the National Energy Board's 2000 report, *Petroleum Resource Assessment of the Peel Plateau, Yukon Territory, Canada*. These same reserve estimates are also used in the Yukon Government's 2001 report on the Peel Plateau, *Background Geological Information*.[17] These numbers remain unproven as, to date, there have not been any significant discoveries in the Peel Plateau region.

This study looked at the Peel Plateau's two main plays: the Disturbed Belt and the Plains Area. The Disturbed Belt, with three times the reserves of the Plains Area, could have a higher density footprint than that of the Plains region.[18]

Table 4. Unproven Gas Reserves in the Peel Plateau

Peel Plateau	Disturbed Belt	Plains Area	Total
Reserves 10^9m^3	48.0	16.5	64.5
Reserves TCF	1.70	0.58	2.28

Discovery and Usage Rate

The discovery rate is the percentage of proven and/or unproven gas that becomes available to be produced each year as compared to the total reserves presumed to be available. In ALCES, a discovery rate of 20% annually was assumed for the fields most likely to be developed first (i.e., those with proven reserves currently proposed for development, such as the anchor fields as part of the MGP application) and 15% for the fields with a longer development timeline (i.e., Colville Hills and Peel Plateau).

The usage rate is the percentage of proven gas that is produced each year as compared to the total reserves presumed to be available. Usage rates for all areas were assumed to be 18% annually. This is consistent with the predicted usage rates in the GLJ Report[19] and approximately matches the decline rates each proponent has published in their respective sections of the MGP

[16] The reserves numbers for Colville Hills are also for a P50 (or 50%) confidence level.
[17] www.emr.gov.yk.ca/oilandgas/ra
[18] The reserves for Peel Plateau as taken from the National Energy Board Petroleum Resource Assessment report are the mean numbers, which correspond to a P39 (or 39%) confidence level.
[19] See GLJ Report, p. 54. Final decline rates of 18–23% from each field, production plateau at four to five years.

application. For example, the decline rates for Taglu range from 16% to 23% per annum as reported in Table 3.4 of the MGP Application, *Application for Approval of the Development Plan for Taglu Field — Project Description,* submitted by Imperial Oil Resources Ltd. to the National Energy Board.

Based on these discovery and usage rates, reserves will be depleted in approximately 25 to 30 years, yielding maximum yearly production between years four and eight. The timing of depletion and rates of peak production as determined in this study are consistent with those predicted in the GLJ Report.[20]

Well Rate

The well rate is a ratio of successful wells drilled per volume of proven gas reserves. In this study, the number of anticipated initial producing wells for each of Taglu, Niglintgak and Parsons Lake was divided by the initial proven reserves for each anchor field, respectively. Rates ranged from a low of four wells/TCF for Taglu to a high of eight wells/TCF for Niglintgak. An average rate of six wells/TCF was assumed for the rest of the Mackenzie Delta. Well rates for Colville Hills and Peel were set at eight and seven wells/TCF respectively, assuming that more wells will be required to deplete the reserves due to their dispersed nature.

Seismic Lines

Seismic development was estimated based on a ratio of kilometres of seismic lines to number of drilled wells. Since the number of drilled wells is a function of the proven reserves, the seismic ratio also becomes a function of proven reserves. To determine this ratio the total distance of seismic lines created was divided by the total number of drilled wells (successful and dry) from 1995 to 2002 for Alberta, British Columbia and Saskatchewan. The findings were as follows:

Table 5. Ratio of Kilometres of Seismic Lines to Number of Drilled Wells, 1995 to 2000, Alberta, British Columbia and Saskatchewan

	Km of seismic lines/drilled well
Alberta[21]	10
British Columbia[22]	17
Saskatchewan[23]	8

The data for these areas are complete and current, representing recent seismic practices. The results have been adjusted to account for those wells or seismic programs applied for but not drilled or completed.

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[20] See GLJ Report, p. 55. Figure 31 shows production plateau in years four to eight.
[21] Alberta well information from EUB Statistical Series 57: Field Surveillance Provincial Summaries, 1999/2000 and 2002; www.eub.gov.ab.ca/BBS/energystats/EUBactivity/fieldactivity/default.htm. Alberta seismic data from personal communication with Dave Bartesko, Laurice Block and Evelyn Finley, Alberta Sustainable Resource Development, Public Lands and Forests Division, 20 January 2004.
[22] British Columbia data from Oil and Gas Commission, Activity Level, Industrial Activity, OGC Activity Report (Other); www.ogc.gov.bc.ca/sitemap.asp
[23] Saskatchewan well data from Industry and Resources, Mineral Statistics Yearbook, 2001, p. 210, Historical Summary of Exploratory and Development Wells Drilled. Updated for 2002 by Saskatchewan Industry and Resources (Myron Sereda). The yearbook is not available online but can be purchased; www.ir.gov.sk.ca/Default.aspx?DN=3732,3620,3384,2936,Documents. Saskatchewan seismic data from personal communication with R. Troyer, Manager, Sedimentary Geodata, Saskatchewan Industry and Resources, 16 January 2004.

As the British Columbia gas industry is relatively young and reflects current seismic practices, the British Columbia average of 17 km/drilled well was used in this study to predict future development in the North.

Seismic lines vary between 1.5 and 8 metres in width.[24] Given that a five metre-width is considered low impact for seismic lines, this study conservatively assumed the use of this width in future development, as shown in Table 6.

Pipelines

Every producing gas well requires a pipeline. The ratio of kilometres of pipeline per producing well is a function of the number of wells in a given area. For this study, a ratio of 9 km of pipeline per well was used and this was based on calculating the total pipeline length divided by the number of wells as proposed for the anchor fields in the MGP application. The results as calculated from the MGP application for the anchor fields are summarized in Table 6.

Treed areas are typically cleared of vegetation to allow access to the pipeline. Taking the figures directly from the MGP application, the width of these pipeline corridors are 30 metres for all fields except the Taglu Anchor Field, which was set at 40 metres. These widths considerably exceed those typical of Alberta and British Columbia, which average 15 to 20 metres.

Wells per Pad

For the Mackenzie Delta, this study assumes the use of multi-well pads similar to that proposed by the MGP for the anchor fields. Most gas well sites in the southern parts of the NWT and Yukon, and in southern Canada in general, are single well pads. Multi-well pads are economically feasible in the Mackenzie Delta because the reserves there contain a large amount of gas relative to the amount of surface land area, and there is also an extensive amount of surface water.

Based on the dispersed nature of the reserves for Colville Hills and Peel Plateau, a more traditional development has been assumed with a single well per pad.

Roads

For wells drilled on single well pads such as for Colville Hills and Peel Plateau, the length of roads will be similar to the length of pipelines. This is based on the premise that each producing well pad requires a road, just as each producing well pad requires a pipeline. For these two areas, then, the linear footprint for roads has been assumed to be the same as that for pipelines, namely, 9 km per well pad. This is a conservative estimate because roads are built to access every well, whether dry and successful, whereas pipelines are only built to access successful wells.

For wells on multi-well pads, such as is assumed for the Mackenzie Delta study area, the length of roads required is significantly reduced per well as most access is via air transport and most drilling equipment is hauled in over temporary ice and winter roads. The MGP application cites about 2.5 km of roads per well pad; the same figure has been used in this study for multi-well pads. It is likely that, as more well pads get built, proponents will want to construct more

[24] Schnieder, R. 2002. *Alternative Futures: Alberta's Boreal Forest at the Crossroads.* Edmonton: Federation for Alberta Naturalists, p, 48–49.

permanent roads between well pads to avoid helicopter costs. Hence, the assumption of 2.5 km per well pad is conservative.

The width of roads has been assumed to be 30 metres with no overlap with other linear disturbances.

Table 6. Model Inputs Summary

	Mackenzie Delta (onshore only, no anchor fields)	Colville Hills	Peel Plateau	Mackenzie Taglu Anchor Field	Mackenzie Niglintgak Anchor Field	Mackenzie Parsons Lake Anchor Field
Discovery Rate[25]	0.15	0.15	0.15	0.2	0.2	0.2
Usage Rate[26]	0.18	0.18	0.18	0.18	0.18	0.18
Well/TCF Proven[27]	6	8	7	4	8	7
Drilling Success Rate[28]	0.3	0.3	0.2	0.4	0.4	0.4
Seismic Lines (km/drilled well, including dry)	17	17	17	17	17	17
Gathering System: (km/producing well or well pad)[29]	9	9	9	9.7	13.7	3.8
Access Roads: km/ well pad	2.5	9	9	2.5	2.5	2.5
Area per Well Pad (including dehydrator) (ha)	4.2	2.5	2.5	5	4.3	2.3
Number of Wells per Pad	6	1	1	6	6	12
Width of Gathering System Right of Way (m)[30]	30	30	30	40	30	30
Width of Roads (m)	30	30	30	30	30	30
Width of Seismic Lines (m)	5	5	5	5	5	5
Lifespan of All Infrastructure (years)	30	30	30	30	30	30

[25] Discovery rate: the rate at which gas reserves are discovered; e.g., a discovery coefficient of 0.2 means that 20% of the unproven gas reserves are discovered each year.
[26] Usage rate: the rate at which proven gas is produced each year, similar to the decline rate of a field; e.g., a usage rate of 0.18 means 18% of the proven gas is produced each year.
[27] Well/TCF: the number of successful wells drilled per year for a given volume of remaining proven gas. The numbers shown above for Taglu, Niglintgak and Parsons Lake are calculated from information provided in the MGP application.
[28] Drilling success rate: the ratio of successful wells to the sum of successful and unsuccessful wells.
[29] Includes an allocation of the gathering system from each field to the Inuvik gas plant.
[30] Width of gathering system right-of-ways for Taglu, Niglintgak and Parsons Lake are taken from the MGP application.

Results

Figure 1 shows the modeled production profile over time for each of the study areas. The purpose of plotting the production profile from the model is to validate it against other production profile data. A valid production profile is important as it sets the rate of development for the entire gas field.

Figure 2 shows the actual production profiles for Fort Liard and Pointed Mountain. These profiles depict two of the actual producing areas in the North and are used as a point of comparison with the modeled profiles.[31]

Figures 3A and 3B show the number of wells drilled per year, including both dry and successful wells, as well as the cumulative number of wells over time. The graph for the Mackenzie Delta includes onshore development only and does not include the proposed MGP anchor fields. Developments in the Mackenzie Delta including the anchor fields are quantified in Table 7.

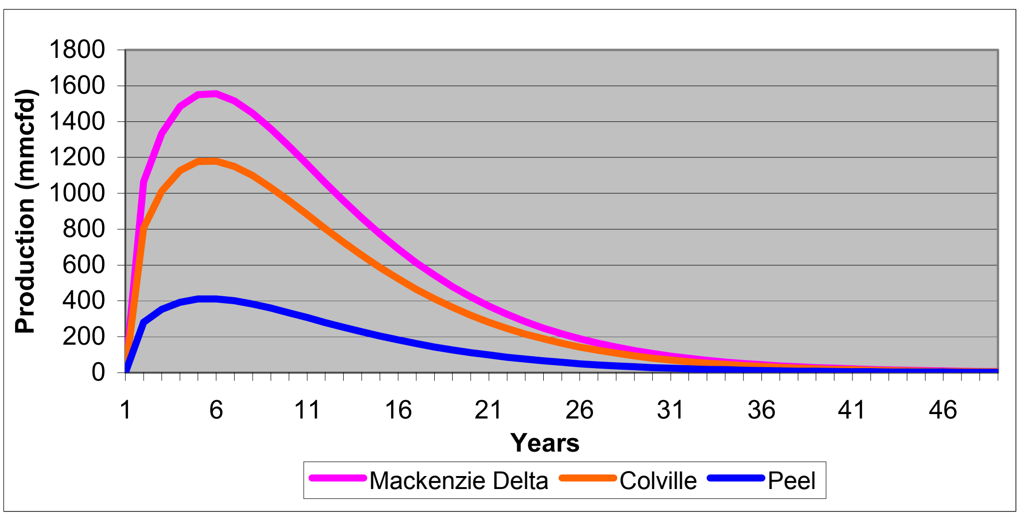
Figures 4A and 4B show the linear and surface area industrial footprints for the study areas.

Figures 3a, 3b, 4a and 4b are results directly from the model and do not include the existing footprint of seismic or wells. Existing seismic and wells have been included in Table 7.

Table 7 shows the infrastructure requirements such as the number of wells and well pads, kilometres of seismic lines, pipelines and well pad access roads, and the calculated area and linear densities for each of the study areas. Table 7 includes existing seismic and well footprints.

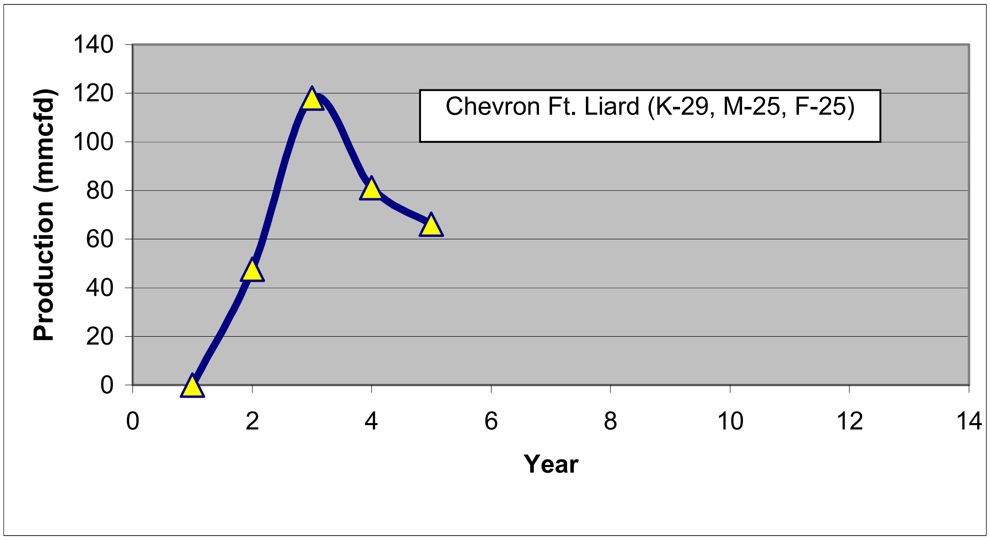
These results are presented in this section and further examined in the following *Discussion* section.

Figure 1. Modeled Production Profiles



[31] Pointed Mountain production numbers are taken from the National Energy Board Public Production Statistics provided by Trena Barnes, Data Coordinator, Exploration and Production. Ft. Liard production numbers are taken from www.ainc-inac.gc.ca/oil/ann/ann2003/dev_e.html.

Figure 2. Examples of Actual Production Profiles



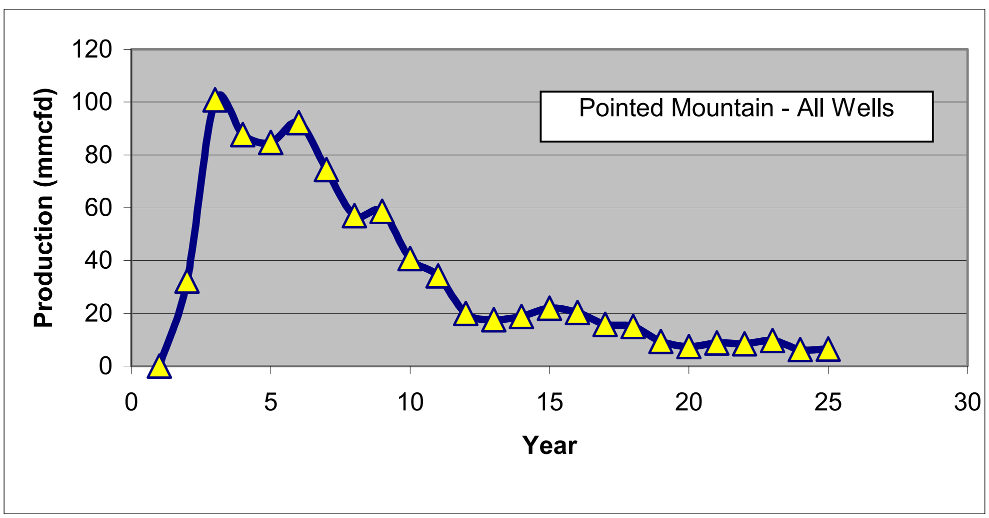


Figure 3A. Well Profiles (Yearly and Cumulative) for Colville Hills and Mackenzie Delta

Colville Hills **Mackenzie Delta**

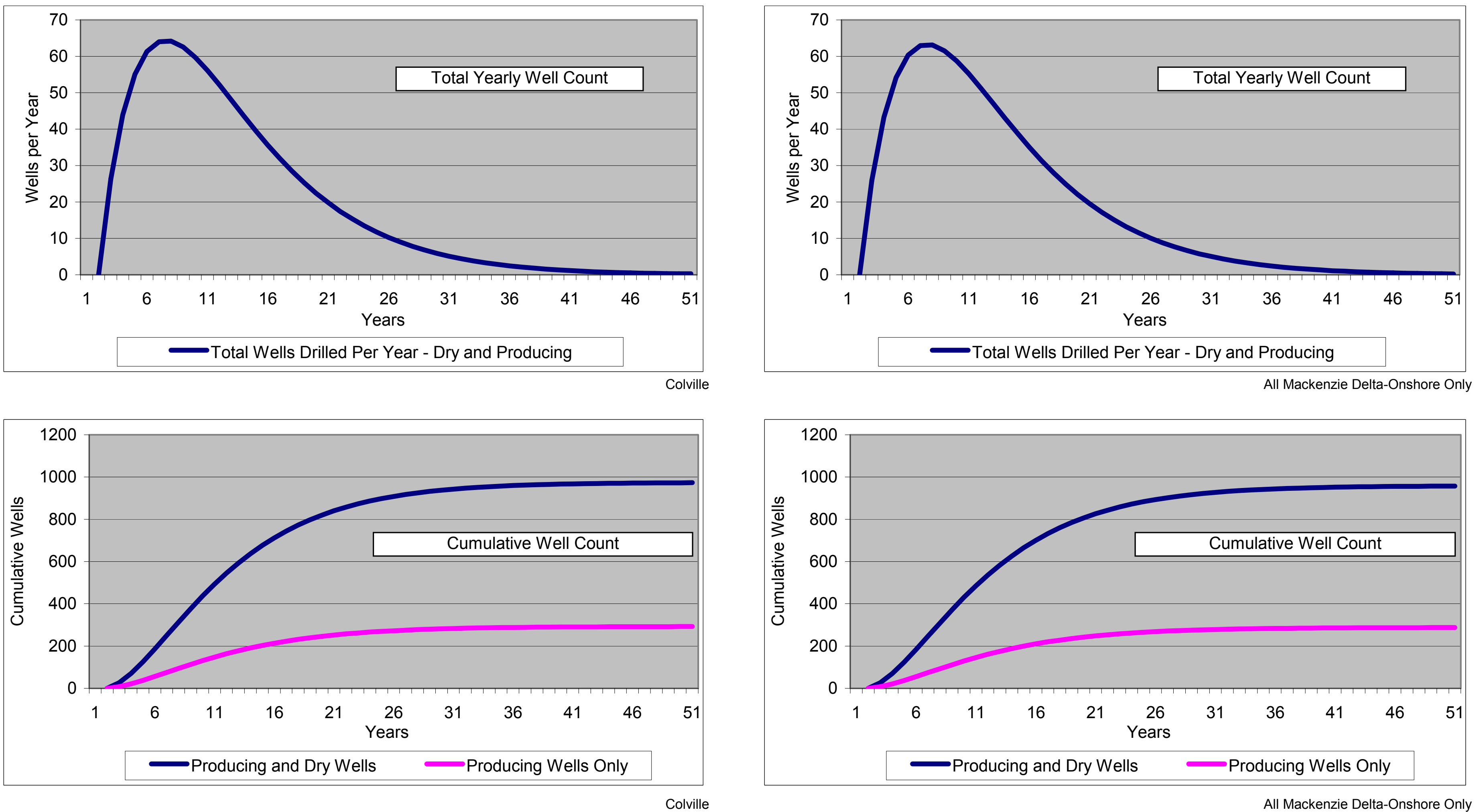
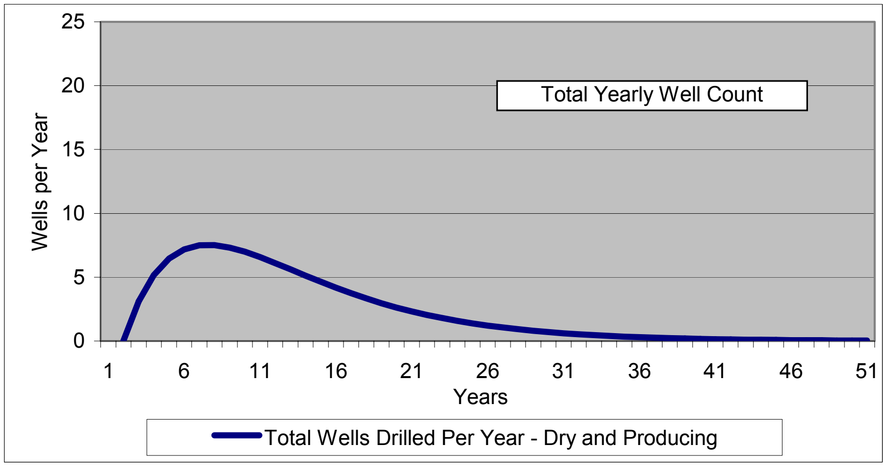
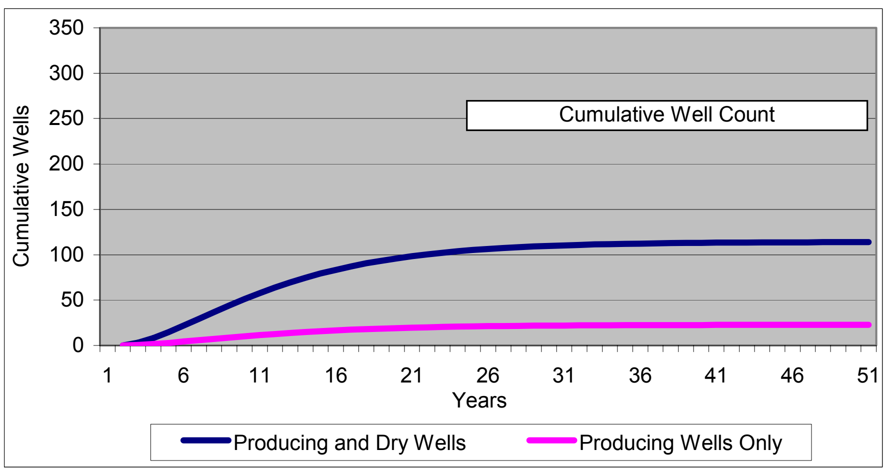


Figure 3B. Well Profiles (Yearly and Cumulative) for Peel Plain and Peel Disturbed Belt

Peel Plain

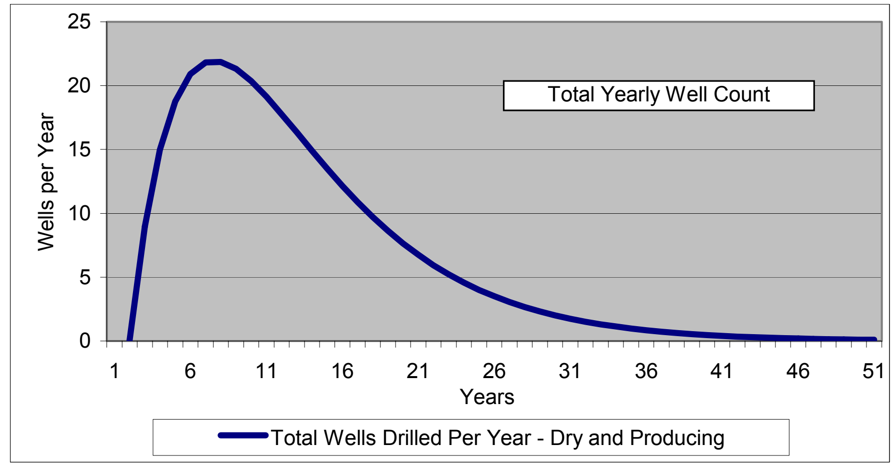


Peel- Plains

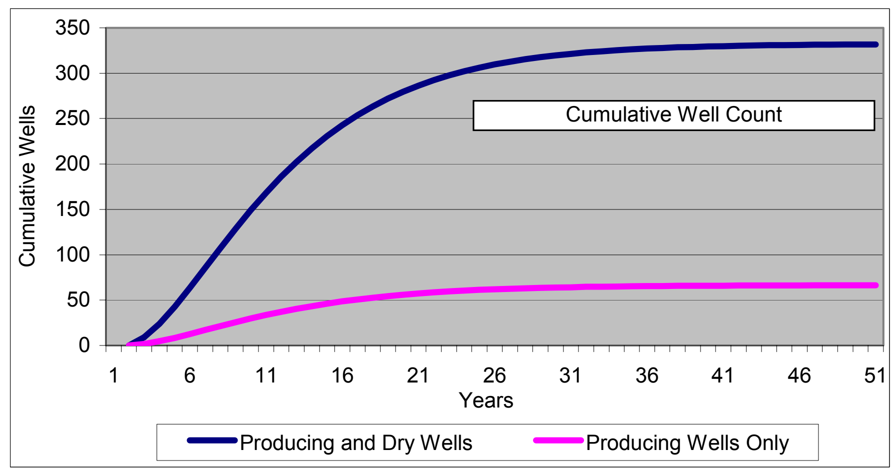


Peel- Plains

Peel Disturbed Belt



Peel Plateau- Disturbed Area



Peel Plateau- Disturbed Area

Figure 4A. Linear and Surface Area Disturbances in Colville Hills and Mackenzie Delta

Colville Hills **Mackenzie Delta**

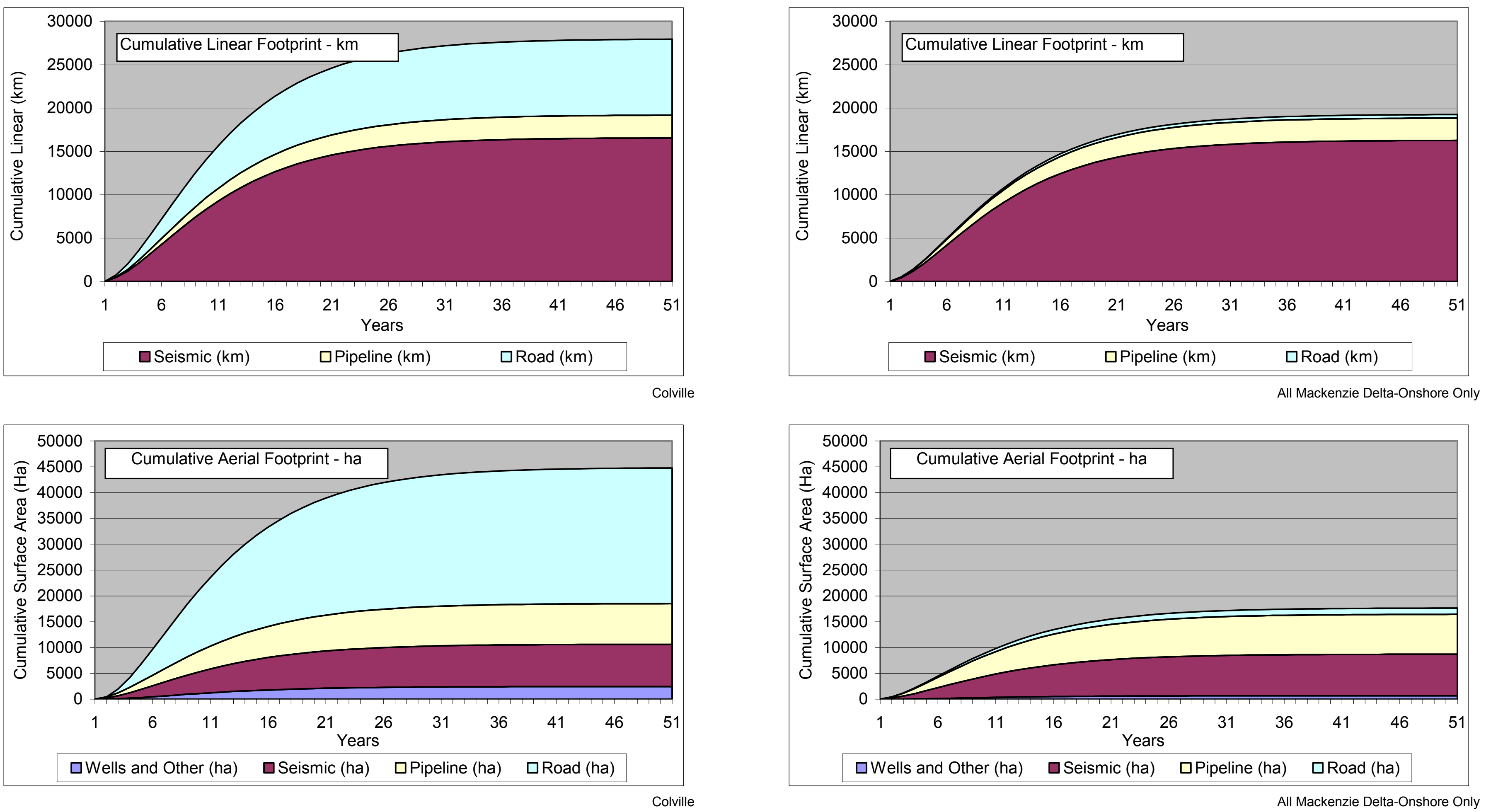
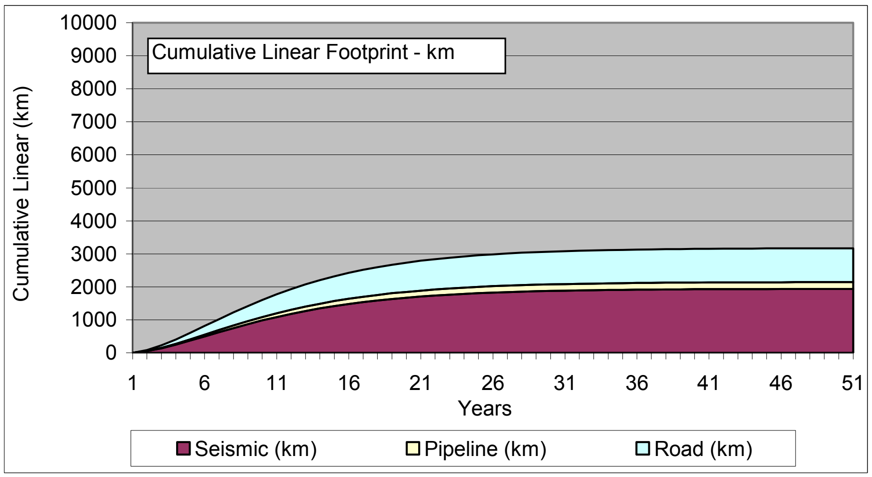


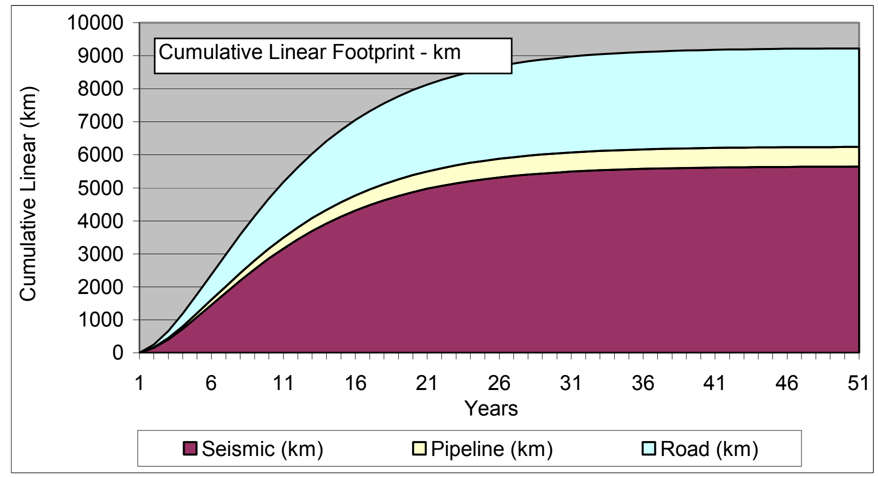
Figure 4B. Linear and Surface Area Footprints in Peel Plain and Peel Disturbed Belt

Peel Plain

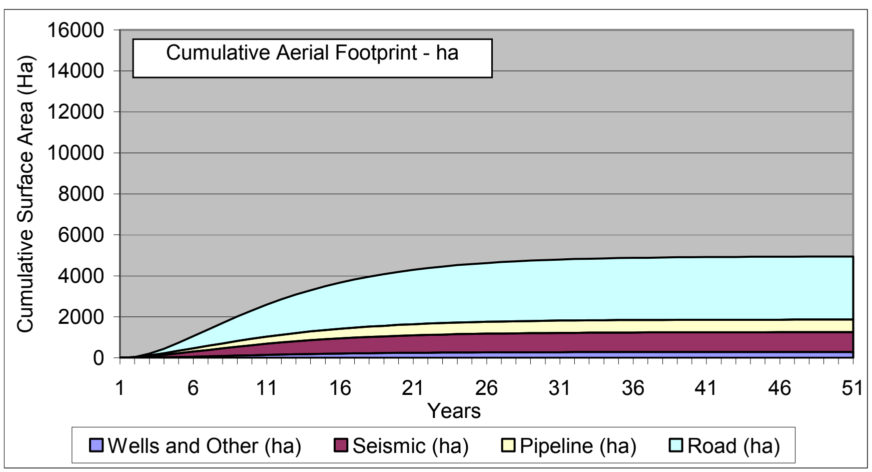


Peel- Plains

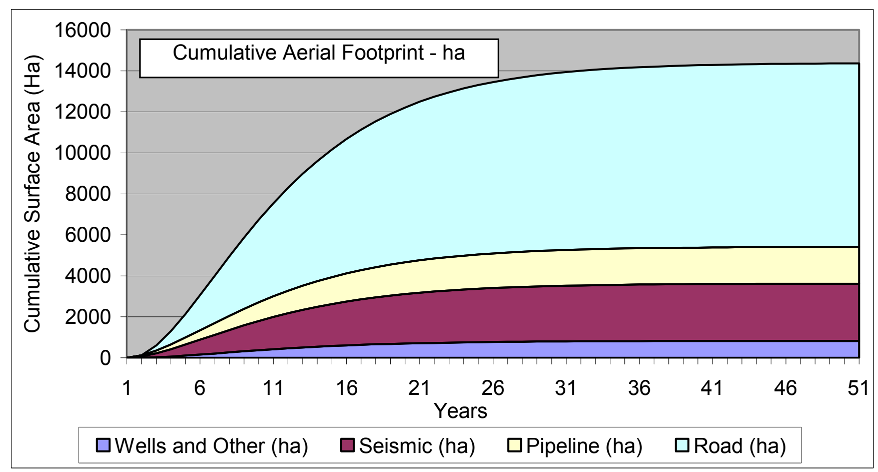
Peel Disturbed Belt



Peel Plateau- Disturbed Area



Peel- Plains



Peel Plateau- Disturbed Area

Table 7. Infrastructure Requirements for Each of the Study Areas (includes existing and modeled)

	Mackenzie Delta (onshore only, no anchor fields)	Mackenzie Delta (onshore only, anchor fields included)	Colville Hills	Peel Plateau (both areas combined)	Mackenzie Taglu Anchor Field	Mackenzie Niglintgak Anchor Field	Mackenzie Parsons Lake Anchor Field
Total Wells	1,051	1,502	964	453	155	79	217
Total Well Pads	274	331	964	453	26	13	18
Km of Seismic	36,927	44,625	18,592	9,119	2,651	1,347	3,700
Km of Pipelines	2,523	3,893	2,567	784	605	434	331
Km of Roads	389	532	8,557	3,920	65	33	45
Total Hectares (ha) Disturbed	38,885	48,760	45,229	20,418	3,663	2,712	3,529
% of Surface (ha) Footprint	2.8	3.4	2.3	Average: 1.6 Disturbed Belt: 2.4 Plains: 0.9	60.2	74.0	10.3
Linear Footprint (km/km^2)	2.9	3.4	1.5	Average: 1.1 Disturbed Belt: 1.6 Plains: 0.6	54.6	49.5	12.0

Discussion

This study examines potential cumulative development impacts in the Mackenzie Delta, Colville Hills and Peel Plateau if proven and unproven gas reserves are developed over the next 30 years.

Historically, proponents of oil and gas development in the North have not analyzed the cumulative scenarios that could unfold if all of the reserves in a particular area are developed. This study attempts to create such an analysis.

Production

Figure 1, above, shows the modeled production profile over time for each of the study areas. All of the developments follow a production bell curve pattern over time similar in shape to that predicted by the GLJ Report for the anchor fields,[32] and similar to actual developments in the Chevron Ft. Liard and Pointed Mountain fields (see Figure 2).[33] Within the first ten years production rises quickly and then peaks, after which a steady decline continues until the field is depleted. As the model demonstrates, the production profile is the key determinant of the pace of development for wells, pipelines, gas plants, roads and seismic lines.

The production profiles generated by the model assume that the capacity of the gas transmission line or the Inuvik gas processing facility (proposed in the Mackenzie Gas Project) does not curtail production from the individual fields. If production were curtailed, the production profiles would rise to a plateau and stay flat until the gas deliverability from the field declined to a point below the capacity limitation. A normal decline would then occur. While the total production over the life of the fields would not change, the rate of gas production would be reduced in the early years and each field would produce gas over a longer period of time before its reserves would be depleted.

Wells

The annual and cumulative numbers of wells drilled in each study area are shown in Figure 3. These are the cumulative number of wells required to deplete the reserves for each area. The Mackenzie Delta and Colville Hills well counts are nearly identical. While Colville Hills has fewer reserves than the Mackenzie Delta, the model applied a higher well coefficient for Colville Hills based on the assumption that more wells will be required to deplete the reserves in this area due to their dispersed nature. Although the total number of wells for both the Mackenzie Delta and Colville Hills are similar, the number of wells pads for the Mackenzie Delta is about one-sixth that of Colville Hills due to the use of multi-well pads (see Table 7).

The effect of the drilling success rate is clearly illustrated by the difference between the total number of producing wells drilled versus the total number of producing and dry wells drilled. Areas with larger reserves generally require more wells to fully deplete the reserves. For example, the Mackenzie Delta, which has close to four times the gas reserves of the Peel Plateau, is predicted to require approximately 1,000 wells, whereas the Peel Plateau will only require about 434 wells to deplete all of the reserves (see Figures 3A and 3B).[34] Peak drilling activity is

[32] See Figures 31 through 35 of GLJ Report.
[33] Pointed Mountain, located in southeast Yukon, is one of the original producing gas fields in the North. The field is now fully depleted and shut-in. Chevron's Ft. Liard wells are some of the more productive wells in the Ft. Liard area.
[34] Mackenzie Delta, excluding the anchor fields.

predicted to occur in years seven through nine, at which time more than 60 wells could be being drilled in each of the Mackenzie Delta and Colville Hills areas.

Assuming additional reserves are not found over the life of the field, the model predicts that the number of wells drilled per year will decline over time. In practice, as fields are developed and more seismic, well bore and "offset" drilling data are gathered, the reserve estimates for a given area often increase.[35] Hence the results as presented here are likely conservative.

The model predicts an average production rate per producing well in the early years of up to 80 million cubic feet per day (mmcfd) per well. By the time each study area is close to depletion, average production per well drops to less than 1 mmcfd. This is consistent with actual production history in other highly prolific fields. For example, some wells in the Fort Liard area are very productive with early year production rates as high as 70 mmcfd.[36] In contrast, the entire Western Canadian Sedimentary basin in Alberta, which is now mature, has an average production per producing well of less than 0.2 mmcfd.[37]

It could be argued that the well coefficients used in these models are only suitable for fields with very high reserves concentrated in small areas (the basis for the well coefficients came from the MGP application for the anchor fields). As an example, the Peel Plateau, which has about the same number of reserves as Taglu but spread out over an area 150 times as large, could possibly have a much higher well coefficient. If the well coefficients were doubled, then the number of wells would double and the initial well production would halve. In the absence of better initial deliverability data for the three study areas (i.e., there are no proven gas reserves for the Peel Plateau), the well coefficients were left as above resulting in a conservative analysis.

The number of wells that could be drilled in the future in the Peel Disturbed Belt area (332) is about three times that in the Peel Plains area (121), because there are roughly three times as many reserves in the Disturbed Belt.

Cumulative Linear and Surface Area Footprint

Figure 4 shows the linear and surface area footprint for each study area. The footprint is the amount of the land's surface companies use to develop gas reserves. It includes the area taken up by seismic lines, gathering systems, roads, wells, well site camps, and well site equipment.

This footprint has two components. The first measures the actual surface area (hectares – ha) cleared and disturbed. The second measures linear footprint (kilometres per square kilometre – km/km^2) and the spread of gas infrastructure across the landscape.

Even though the Colville Hills reserves are smaller than those in the Mackenzie Delta, linear and surface area development for Colville Hills is greater. This is primarily due to the assumption that single well pads will be built in Colville Hills, while multi-well pads will be used in the Mackenzie Delta. Compared to multi- well pads, single well pads require more pipelines and more roads to be built to more locations. The linear seismic footprint is similar for both areas.

[35] For example, on a province-wide basis, the Alberta EUB Statistical Series ST98-2004, "Alberta Reserves Outlook and Supply/Demand Outlook 2004–2013" and the "Historical and Potential Reserve Growth in Oil and Gas Pools in Saskatchewan" in *Summary of Investigations 2004, Volume 1, Saskatchewan Geological Survey* both show that gas reserves generally increase in the early years of development.

[36] The Chevron Ft. Liard well M-25 had 66 mmcfd of production in its first full year of operation. It is one of the highest producing wells in the area.

[37] Figure 4.21, Page 4-25 of the Alberta EUB Statistical Series ST98-2004, "Alberta Reserves Outlook and Supply/Demand Outlook 2004–2013," shows that there are about 79,000 wells producing 150 x 10^9 m^3/year of gas, which yields an average daily production per well of 0.184 mmcfd.

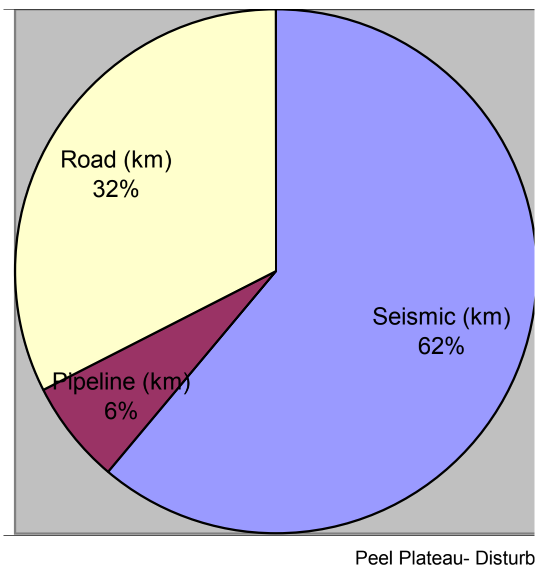
In the Colville Hills and Peel Plateau, each well, whether dry or producing, requires a road. Unless these roads are reclaimed (especially roads to dry wells), they represent a significant portion of the overall footprint on the landscape. Fewer kilometres of pipelines are required than roads because pipelines are only built to producing wells.

For all areas, seismic lines make up the majority (60%) of the overall linear footprint. However, once all disturbances are converted to a physical surface area, seismic lines take up a smaller portion of the footprint (19%) due to their relatively narrow width compared to roads and pipelines. See, for example, the pie charts below depicting disturbance data for the Peel Plateau.

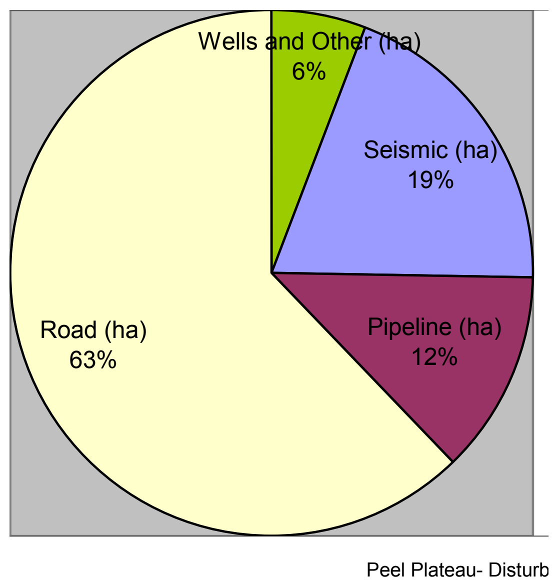
The surface area of seismic lines may be smaller than other infrastructure but their impact to wildlife can be greater. For many animal species habitat loss from linear disturbance such as seismic lines exceeds the surface area footprint of natural gas development.

Figure 5. Surface Disturbance Data

Peel Plateau Disturbed Belt
Linear Disturbance (km/km^2)



Peel Plateau Disturbed Belt
Surface Area Disturbance (% ha)



The footprint of existing development in the study areas pales in comparison to the footprint of potential development. Comparing existing (Table 1) to modeled wells and seismic lines (Figures 3 and 4), the number of existing developments is only a small proportion of the total number predicted to emerge over the life of the study areas. The one exception to this is in the Mackenzie Delta, where 21,041 km of seismic lines are already present (47% of total seismic kilometres), most of which were created in the 1970s and early 1980s. The authors expect that many of these existing seismic lines will be redone over the next 10 to 20 years using newer seismic technology. As such, the existing seismic and the modeled seismic footprints are additive.

Table 7, above, shows the modeled results of the overall surface impacts at the end of the life of the gas reserves for the three study areas.

Once again it is clear that the two areas with the highest reserves (Mackenzie Delta and Colville Hills) will experience the largest footprint of development. The use of multi-well pads and helicopter operation for the Mackenzie Delta will, however, likely result in a considerable reduction in the number of well pads and permanent roads required.

This study found that the footprint densities in the anchor fields would be considerably higher than those in other areas because of the relatively small surface area and very large concentrations of gas reserves in the anchor fields. The model is likely over predicting the amount of footprint in the anchor fields as it hasn't taken into account all of the duplicate or overlapping use of infrastructure (in particular pipelines) that are possible where there are large reserves over small surface areas. However, even with these considerations, the model does indicate that these landscapes would be intensively developed and greatly modified by the time reserves are fully depleted. The differences in density of development in the Mackenzie Delta are clearly visible on the maps in Appendix A.

The total surface area disturbed in each study area, except in the anchor fields, ranges from 1.6 to 2.7%. Linear disturbances range from 1.1 km/km^2 to 3.4 km/km^2. These figures are associated with the main components of new gas development and do not include the additive impacts from other industries such as logging, mining, electrical transmission or other utility impacts, or previous oil and gas activities.

The disturbances due to gas development are typical of other mature fields already developed in Alberta and northeastern British Columbia. Sawyer and Haskins calculated a linear disturbance density for the Boreal Forest Natural Region that varies from 0 km/km^2 in protected areas to 5 km/km^2 in areas affected by a network of roads, seismic lines and pipelines, which are a result of the activities of several resource extraction industries.[38] Seismic lines are the largest contributor to linear disturbance; disturbance due to seismic lines alone has been found to be as high as 4 km/km^2 in some Alberta townships.[39] In comparison to these previous studies, the results of this study are conservative and may even under-represent the actual linear disturbances of future mature Northern gas fields.

[38] Alberta Environmental Protection. 1998. The Final Frontier: Protecting Landscape and Biological Diversity within Alberta's Boreal Forest Natural Region. Edmonton: Alberta Environmental Protection, p. 127.

[39] Stelfox, J.B., and B. Wynes. 1999. A Physical, Biological and Land-use Synopsis of the Boreal Forest's Natural Regions of Northwest Alberta. Peace River, AB: Daishowa-Marubeni International Ltd.

Best Practice Options

“Best practices” are technologies, techniques, and government policies that have been thought to reduce environmental damage. They do not eliminate the harm of natural gas development; nor the need for careful planning and management of when and where natural gas development occurs.

Colville Hills was used as a case study to explore how particular best practices might affect the total footprint of development. This section of the report is a hypothetical exercise to explore the ways that different industry practices may be used to reduce the footprint of development. It is assumed here that the best practice options would be feasible 100% of the time in the Colville Hills. In many instances, best practice options are site specific.

The model assumes the application of the following practices individually and then collectively:

- reducing the width of seismic lines from five to two metres
- increasing the number of wells per pad from one to six
- overlapping seismic, road and pipeline corridors by 50%
- reclaiming disturbed land in an average of 15 years

According to the base development scenario outlined above, this study predicts that close to 30,000 km of linear disturbance will occur in Colville Hills over a 30-year timeframe. This linear disturbance, coupled with disturbance from the placement of well pads, will result in a total surface disturbance of 45,229 hectares of the total study area, which is two million hectares. Table 8 illustrates the decrease in linear and surface disturbance that could be realized if certain best practices were employed.

Table 8. Changes in Surface Footprint with Best Practice Scenarios for Colville Hills

	Base Scenario	Best Practices Scenario	Total Ha Footprint: Base Scenario	Total Ha Footprint: Best Practices Scenario	%Total Surface Footprint (ha): Best Practices Scenario	Total Linear Footprint (km/km^2): Best Practices Scenario	% Surface Area Footprint Reduced Due to Best Practice
Base Scenario	As modeled	n/a	n/a	n/a	2.26	1.49	n/a
Width of Seismic lines (metres)	5	2	45,229	40,446	2.12	n/a	11
Number of wells per pad	1	6	45,229	21, 949	1.10	n/a	53
Overlap of seismic, road and pipeline development (%)	0	50	45,229	32,341	1.61	0.76	29
Reclamation Average Lifespan of all infrastructure (years)	permanent	15 yrs	45,229	24,614	1.10	1.31	47

These results show that the use of best practices has the potential to significantly reduce linear and surface area disturbance. The largest change is shown by the increased number of wells per pad which reduced the surface area footprint by 53%. Reducing the width of seismic lines decreased the overall surface area footprint by 11%. Overlapping the seismic, road and pipeline development by 50% reduced the surface area footprint by 29% and linear footprint by half. If the disturbed areas could be reclaimed in an average of 15 years, the surface area footprint would be 47% smaller and the linear footprint would be 12% reduced at the end of the 30 year period.

Reclamation that occurs concurrently with the extraction of the resource could significantly reduce the footprint of development at the end of the life of the field. However, to realize the full benefits of reclamation, proponents must properly reclaim the landscape by reforesting both roads and abandoned industrial sites. If these areas are not properly reclaimed, they can be continually accessed by off-road vehicles and invasive non-native species of plants can take hold. In the North, a short growing season and limited nutrients in the soil to support plants mean that reclamation is more difficult than in southern climates. Failure to properly reclaim areas can lead to permanent changes to plant and animal communities.

As evidenced in the Mackenzie Delta results, the use of winter roads for initial drilling and helicopter access for on-going operations reduces the overall footprint; however, to ensure the ongoing benefit of the initial construction of winter roads, surface impacts due to such construction must be negligible (i.e., no vegetation impacts, etc.). The repetitive use of winter roads to service the well sites can introduce a surface impact over time; such use can damage permafrost and slow the recovery of affected vegetation. Roads can also inhibit wildlife movement. Though the use of helicopter access reduces the surface footprint by reducing roads, it introduces other potentially negative impacts such as noise pollution.

There are other best practices not modeled here that could be considered. For example, pipeline and road widths could be reduced. In this study, a pipeline width of 30 metres was modelled to be consistent with the proposed width in the MGP application; however, pipeline widths in many parts of Alberta and British Columbia are as narrow as 15 to 20 metres. While reducing pipeline and road widths would not affect linear density (km/km^2), it would proportionately decrease the surface footprint (ha).

Conclusions

This model demonstrates a rapid rate of gas development and a large linear and surface area footprint of development in the North.

The findings suggest that Northerners can expect industrial development to increase significantly over a period of 10 to 20 years and then, unless more reserves are found, decline. The model shows that the rate of development and ultimate footprint will be similar to other mature gas fields in Western Canada's Sedimentary Basin that are now fully developed and that have left a significant surface disturbance on the landscape.

This study has shown that the use of currently available best practices can reduce the footprint of development considerably, although the impact of gas development can never be entirely eliminated. The best available practices should be continuously employed and improved to reduce the ecological impacts of development. The modeling approach used in this study could be a tool used by regulators and companies to evaluate the effects of different and improved exploration, development and operational practices.

The results from this study are likely conservative for the following reasons:

- Offshore reserves were not included in the study.
- Historically, more gas reserves are discovered as fields are developed. This in turn leads to more development.
- Should the MGP pipeline be constructed, gas producers will have the critical piece of infrastructure needed to economically bring their gas to market. As a result, proponents will be more willing to explore more fields, thus leading to additional discoveries and subsequent production. There is an economic incentive to keep the pipeline full to its maximum capacity.
- When existing fields go into decline, new fields such as offshore gas, other reserves not yet discovered, and possibly offshore gas hydrates could be developed and tied into existing pipelines. For example, in southern Alberta, gathering and processing capacity once used for conventional gas is now being used to produce unconventional gas resources, such as coalbed methane.
- The liquid line from the Inuvik gas processing facility could potentially open up oil production in the North by providing a means to transport oil to southern markets.
- The assessment did not include gravel borrow pits, landfills, or gas plants.
- The study does not consider the impact from other industries such as logging, mining, or electrical transmission.
- The use of multi-well pads may not always be feasible, thus increasing the footprint considerably.

This study does not aim to predict the future; rather, it simply demonstrates a logical outcome of projected activity based on trends. Plausible development scenarios have been generated that can be used in discussions of stakeholder objectives and can contribute to more informed decision making.

Recommendations

This study provides a foundation on which to assess the impacts of gas development on wildlife, air quality, climate change, traditional resource use, local economies, culture and other values. Such assessments are necessary to more fully quantify the direct and indirect effects of development activities. A further study is required to better assess the socio-economic impacts, the ecological impacts and the response of various species to development.

In many areas of the North there is still the opportunity to choose where natural gas development can occur and which areas will be free of industrial development. Given the potential for rapid rate of development, there is strong reason to set aside conservation lands before natural gas development begins.

Natural gas development can have a very large impact on the environment. Development, which consists of activity and infrastructure, can cause environmental disturbances to land, soil, water, wildlife, and vegetation. While not explained in detail in this report, the potential environmental and human health impacts of gas development need to be assessed in greater detail.[40]

This study can be used as a base from which to begin to quantify the cumulative environmental impacts of development. This study's results, in combination with scientific research on the adverse effects on wildlife, plants and ecosystems, will provide a clearer picture of cumulative environmental effects of gas development in the North. The United Nations has developed the GLOBIO model, which, using recent scientific studies on wildlife, plants and ecosystem, relates the probability of impact to plants and animals based on their proximity to human infrastructure. GLOBIO provides a tool to examine effects of permanent infrastructure on species population viability and suggests buffer zones for various infrastructure types. This tool can be used to examine the environmental effects of development that are larger than the direct footprint.[41]

The model used in this study could be run for a wider range of scenarios and a greater number of reserves. Model assumptions were kept conservative and the results do not show the worst case scenario of development. When more information is available on potential development in the study areas, the model should be run again to reflect this new information.

Models that project a full 'picture' of cumulative development are accessible to regulators, decision makers, and individuals. Information is readily available on the pattern of typical gas development. This study, or other studies like this, could be used to examine the impacts of policies, regulations and best practices on potential development scenarios, and then used to plan appropriate management and mitigation. With a full picture of cumulative development, and an understanding of cumulative impacts associated with development, Northerners will be able to assess trade-offs and risks, and attempt to balance current competing objectives and related decisions that will affect Northern ecosystems and communities into the future.

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[40] For more information on the potential environmental impacts of gas development, see the Pembina Institute series of primers, *Environment and Energy in the North*, available at www.pembina.org.
[41] www.globio.info

Appendix A: Study Area Data Sources and Maps

Data Sources for Base Maps

Mackenzie Delta

Communities	Northwest Territories Digital Atlas 2002 (WWF) *Toponymy Program, Prince of Wales Northern Heritage Centre, Government of the Northwest Territories, 2002.*
Roads	Northwest Territories Digital Atlas 2002 (WWF) *Northwest Territories Centre for Remote Sensing, Dept. of Resources, Wildlife and Economic Development, Government of the Northwest Territories, 2002.*
Rivers/Lakes	Northwest Territories Digital Atlas 2002 (WWF) *National Atlas of Canada Base Maps © 2000. Government of Canada with permission from Natural Resources Canada.*
Wells	National Energy Board, 2001, 2002, 2003
Seismic	Northwest Territories Digital Atlas 2002 (WWF) *Frontier Geological and Geophysical Operations Reports, Operations Business Unit, National Energy Board, 2001.*
Pipelines	Northwest Territories Digital Atlas 2002 (WWF) *Digitized by WWF-Canada from various publicly available maps, 2001*
Oil and Gas Rights	Northwest Territories Digital Atlas 2002 (WWF) *Reproduced with permission from the Minister of Indian and Northern Affairs Canada, 2002.*
Mackenzie Delta Anchor Fields	Northwest Territories Digital Atlas 2002 (WWF) *A subset of the oil and gas rights data set (covering only SDL 019, 030, 032 and 063).*
Mackenzie Delta Plays	Digitized by CPAWS – Yukon from the GLP Report

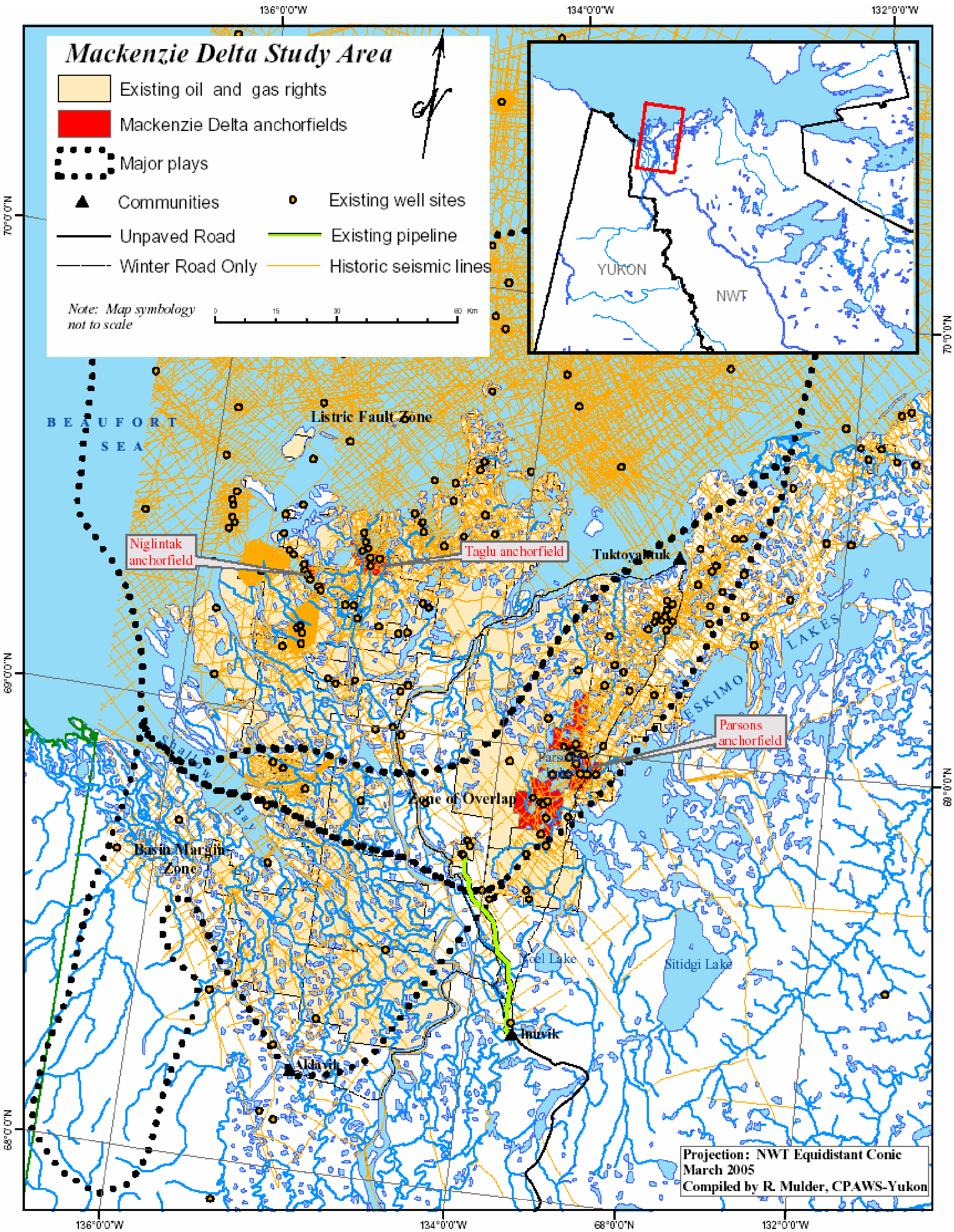
Colville Hills

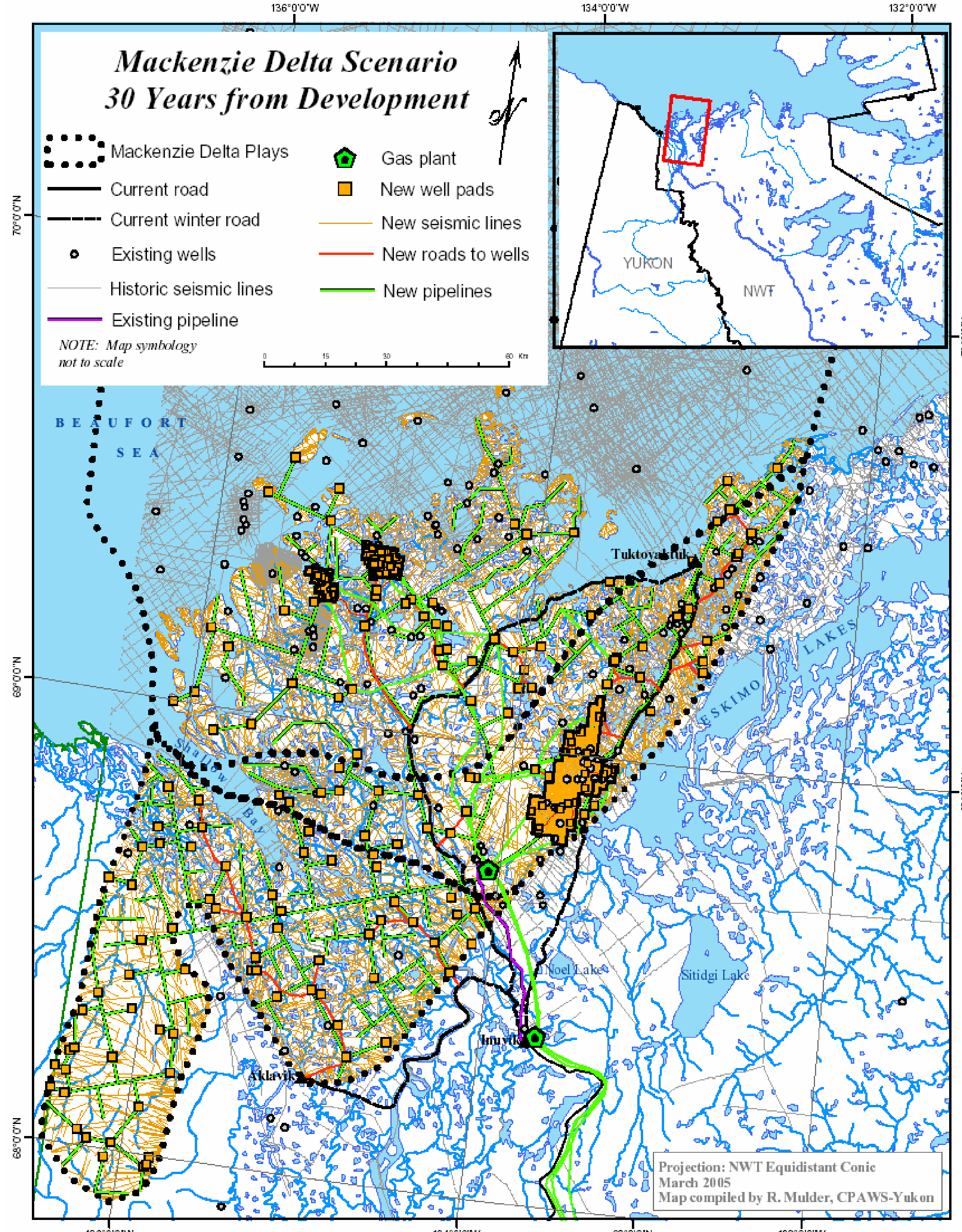
Communities	Northwest Territories Digital Atlas 2002 (WWF) *Toponymy Program, Prince of Wales Northern Heritage Centre, Government of the Northwest Territories, 2002.*
Roads	Northwest Territories Digital Atlas 2002 (WWF) *Northwest Territories Centre for Remote Sensing, Dept. of Resources, Wildlife and Economic Development of the Northwest Territories, 2002.*
Rivers/Lakes	Northwest Territories Digital Atlas 2002 (WWF) *National Atlas of Canada Base Maps © 2000. Government of Canada with permission from Natural Resources Canada.*
Wells	National Energy Board, 2001, 2002, 2003
Seismic	Northwest Territories Digital Atlas 2002 (WWF) *Frontier Geological and Geophysical Operations Reports, Operations Business Unit, National Energy Board, 2001.*
Oil and Gas Rights	Northwest Territories Digital Atlas 2002 (WWF) *Reproduced with permission from the Minister of Indian and Northern Affairs Canada, 2002.*
Colville Hills Anchor Fields	Northwest Territories Digital Atlas 2002 (WWF) *A subset of the oil and gas rights data set (covering only SDL 023 and 024).*

Colville Hills Study Sites	Digitized by CPAWS – Yukon from hand-drawn boundaries delineated to encompass two million hectares of reserves to match the GLJ reserves

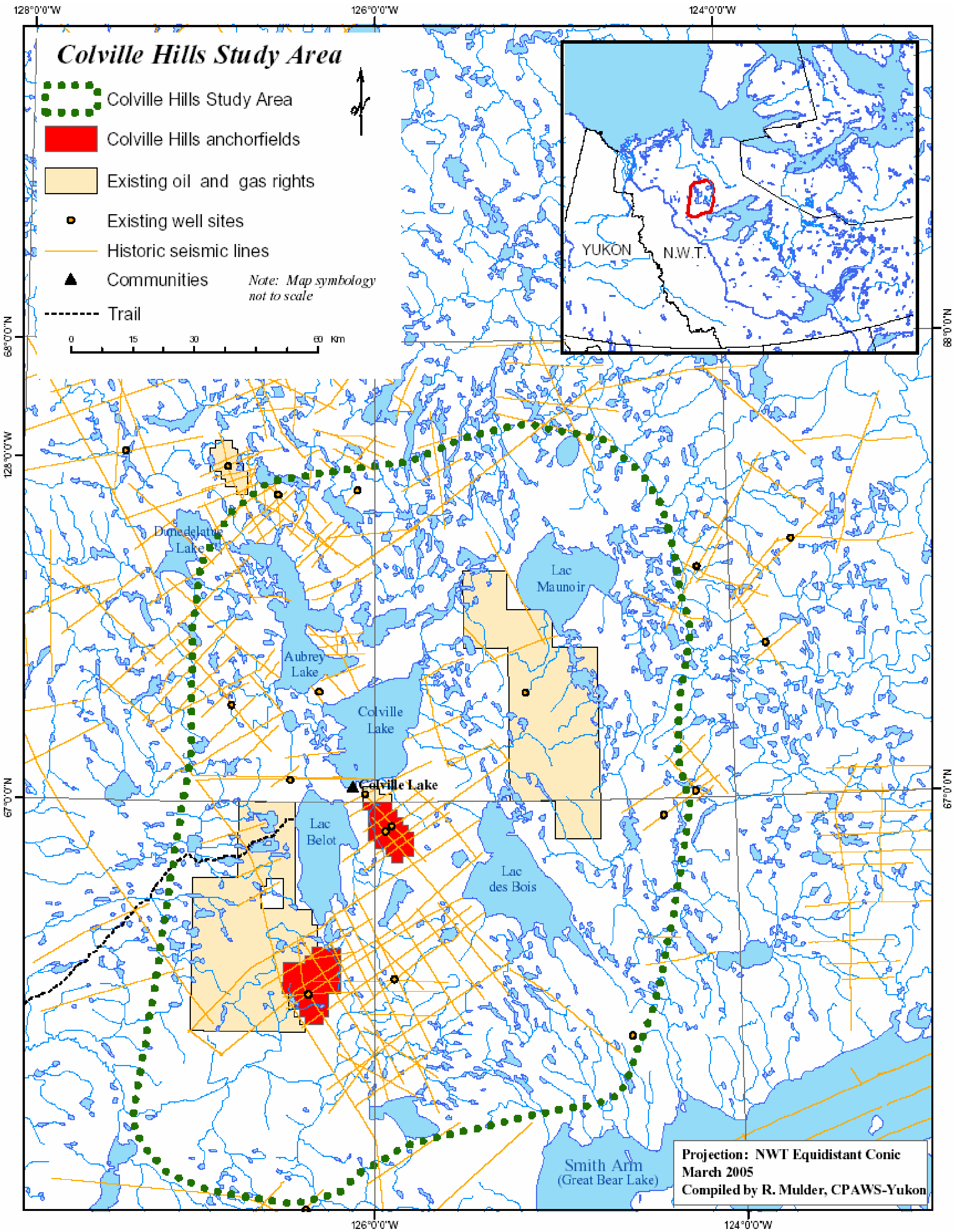
Peel Plateau

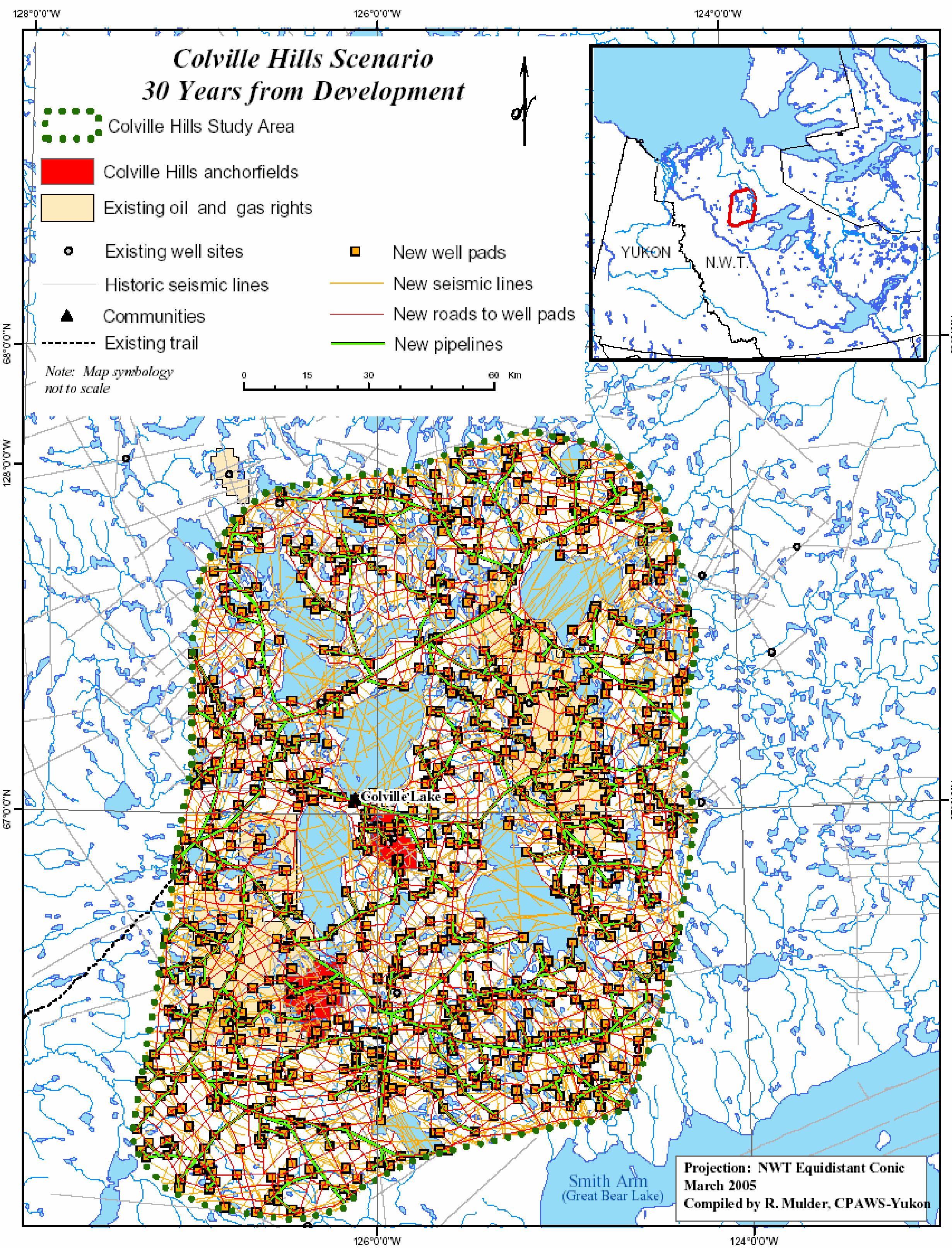
Rivers/Lakes	Digital Chart of the World (DCW) data compiled by NATO at 1:1 million scale (NAD 83)
Wells	Oil & Gas Management Branch, Department of Energy, Mines and Resources, Yukon Government
Seismic	Oil & Gas Management Branch, Department of Energy, Mines and Resources, Yukon Government
Oil and Gas Rights	Oil & Gas Management Branch, Department of Energy, Mines and Resources, Yukon Government
Peel Plateau Study Areas	Digitized by CPAWS – Yukon, based on Peel Plateau boundaries. Oil & Gas Management Branch, Department of Energy, Mines and Resources, Yukon Government


Mackenzie Delta Study Area
Existing oil and gas rights
Mackenzie Delta anchorfields
Major plays
Communities
Existing well sites
Unpaved Road
Existing pipeline
Winter Road Only
Historic seismic lines
Note: Map symbology not to scale
YUKON
NWT
BEAUFORT SEA
Listric Fault Zone
Niglintak anchorfield
Taglu anchorfield
Tuktoyaktuk
ESKIMO LAKES
Parsons anchorfield
Zone of Overlap
Basin Margin Zone
Shallow Bay
Inuvik
Aklavik
Noel Lake
Sitidgi Lake
Projection: NWT Equidistant Conic
March 2005
Compiled by R. Mulder, CPAWS-Yukon
136°0'0"W
134°0'0"W
132°0'0"W
70°0'0"N
69°0'0"N
68°0'0"N

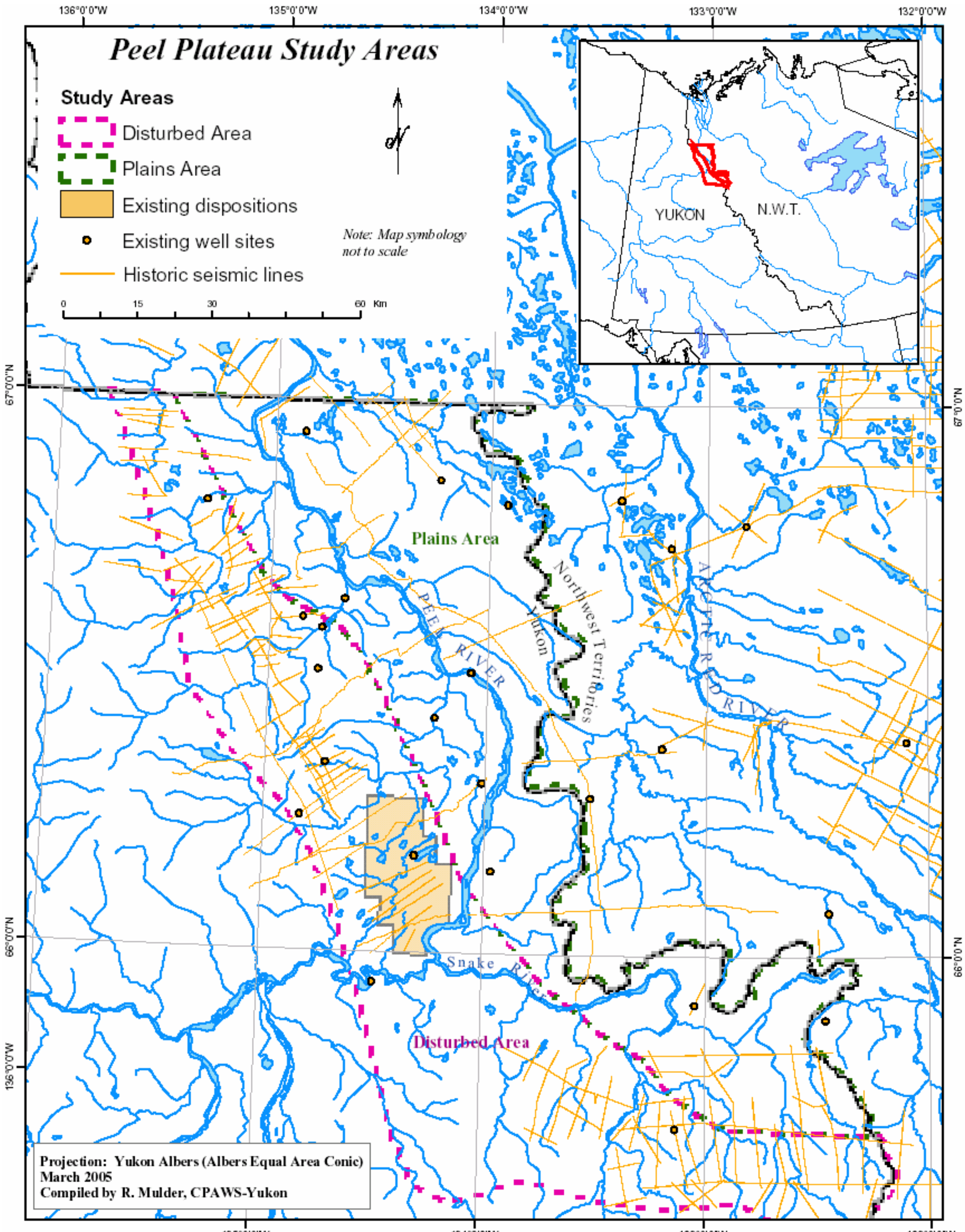


Mackenzie Delta Scenario
30 Years from Development
Mackenzie Delta Plays
Current road
Current winter road
Existing wells
Historic seismic lines
Existing pipeline
Gas plant
New well pads
New seismic lines
New roads to wells
New pipelines
NOTE: Map symbology not to scale
YUKON
NWT
BEAUFORT SEA
ESKIMO LAKES
Tuktoyaktuk
Shallow Bay
Noel Lake
Sitidgi Lake
Inuvik
Aklavik
136°0'0"W
134°0'0"W
132°0'0"W
70°0'0"N
69°0'0"N
68°0'0"N
Projection: NWT Equidistant Conic
March 2005
Map compiled by R. Mulder, CPAWS-Yukon

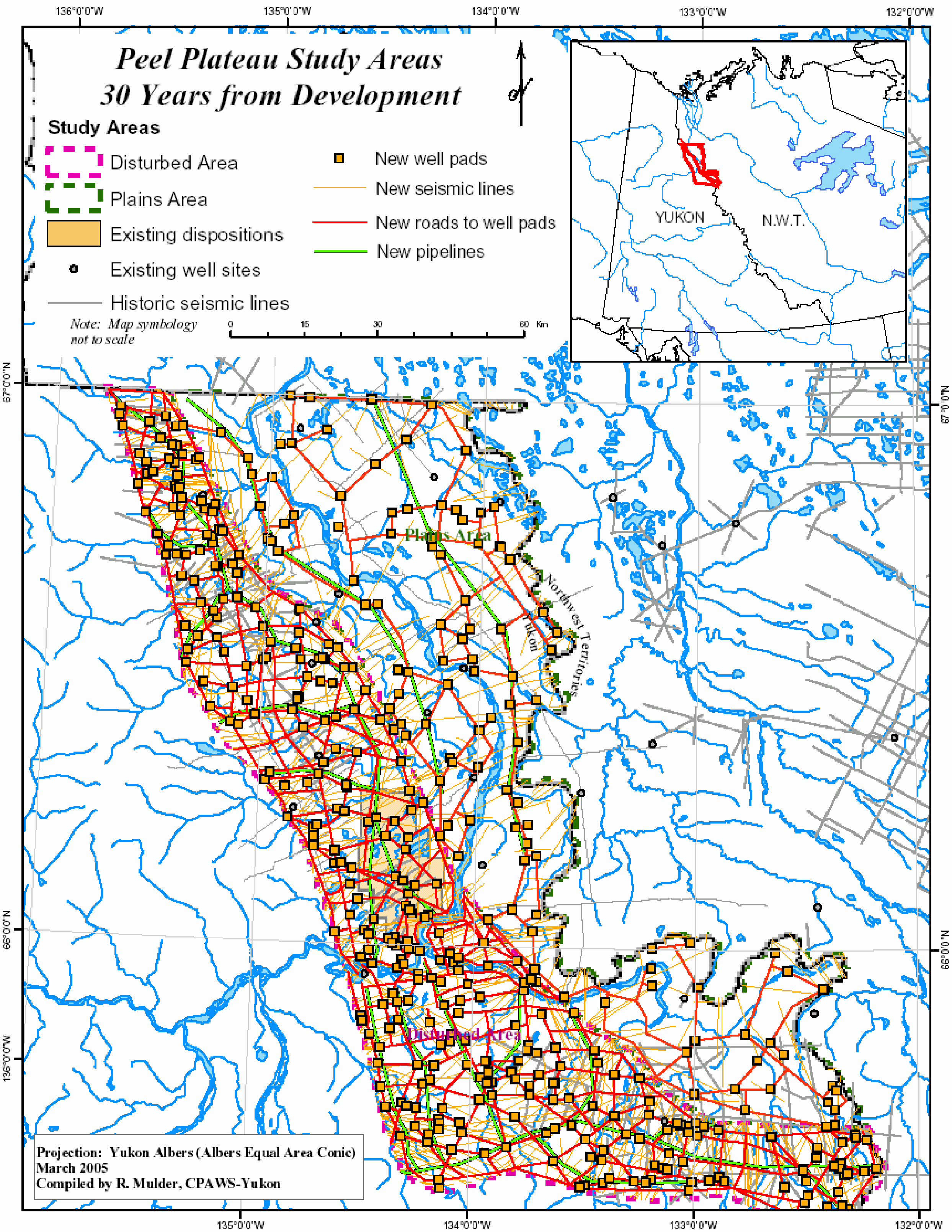

128°0'0"W
126°0'0"W
124°0'0"W
Colville Hills Study Area
Colville Hills Study Area
Colville Hills anchorfields
Existing oil and gas rights
Existing well sites
Historic seismic lines
Communities
Note: Map symbology not to scale
Trail
0 15 30 60 Km
YUKON
N.W.T.
68°0'0"N
67°0'0"N
Lac Maunoir
Aubrey Lake
Colville Lake
Colville Lake
Lac Belot
Lac des Bois
Smith Arm
(Great Bear Lake)
Projection: NWT Equidistant Conic
March 2005
Compiled by R. Mulder, CPAWS-Yukon



Colville Hills Scenario
30 Years from Development
Colville Hills Study Area
Colville Hills anchorfields
Existing oil and gas rights
Existing well sites
Historic seismic lines
Communities
Existing trail
New well pads
New seismic lines
New roads to well pads
New pipelines
Note: Map symbology not to scale
0 15 30 60 Km
YUKON
N.W.T.
Colville Lake
Smith Arm
(Great Bear Lake)
Projection: NWT Equidistant Conic
March 2005
Compiled by R. Mulder, CPAWS-Yukon
128°0'0"W
126°0'0"W
124°0'0"W
68°0'0"N
67°0'0"N



Peel Plateau Study Areas
Study Areas
Disturbed Area
Plains Area
Existing dispositions
Existing well sites
Historic seismic lines
Note: Map symbology not to scale
0 15 30 60 Km
YUKON
N.W.T.
Plains Area
PEEL RIVER
Yukon
Northwest Territories
ARCTIC RED RIVER
Snake River
Disturbed Area
Projection: Yukon Albers (Albers Equal Area Conic)
March 2005
Compiled by R. Mulder, CPAWS-Yukon
136°0'0"W
135°0'0"W
134°0'0"W
133°0'0"W
132°0'0"W
67°0'0"N
66°0'0"N


Peel Plateau Study Areas
30 Years from Development
Study Areas
Disturbed Area
Plains Area
Existing dispositions
Existing well sites
Historic seismic lines
New well pads
New seismic lines
New roads to well pads
New pipelines
Note: Map symbology not to scale
0
15
30
60 Km
YUKON
N.W.T.
Plains Area
Northwest Territories
Yukon
Disturbed Area
Projection: Yukon Albers (Albers Equal Area Conic)
March 2005
Compiled by R. Mulder, CPAWS-Yukon
136°0'0"W
135°0'0"W
134°0'0"W
133°0'0"W
132°0'0"W
67°0'0"N
66°0'0"N