Cortex Consultants

Modelling Cumulative Impacts in the Peace-Moberly Tract

Analysis of the Base Case Scenario

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prepared for: **Peace Moberly Tract Sustainable Resource Management Planning Table**

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Summary

The Peace-Moberly Tract (PMT) is approximately 1,090 square kilometres of land lying between Moberly Lake and the Peace River, and intersecting the Lower Moberly, Hudson's Hope, Boucher, Gething and Upper Moberly landscape units. At the present time the PMT is relatively undisturbed by human development.

The Saulteau and West Moberly First Nations have identified the PMT as an area of special interest and a Sustainable Resource Management Plan (SRMP) process is currently underway to help define how the Crown land and resources of the PMT will be used in the future.

This project was undertaken to support the development of the SRMP by developing a spatial modelling framework capable of projecting disturbances associated with resource development and applying it to a PMT development scenario.

The development scenario (termed the base case) represents the *status quo* management situation – that timber harvesting and natural gas development proceed as scheduled or limited by current plans, commitments, and regulations. In general, landbase definitions and forest management assumptions follow the last timber supply review. Assumptions around the spatial distributions, extent and rates of exploration and development of natural gas in the PMT are based on analyses of similar gas field developments in areas surrounding the PMT.

In general, the model adequately represents timber development and harvesting (Figure S1) and gas development and production in the PMT (Figure S2).

It is difficult to interpret the effects of disturbances of both industries together, since land and road usage, regeneration times, reclamation standards, and durations of disturbances are significantly different between the two industries. Therefore we have evaluated the impacts associated with each industry separately by simulating each industry independently, as well as together.

Cumulative impacts on two of the environmental indicators identified by the planning table—percent of area cleared and density of linear features (winter and all –season roads, pipelines)—are presented in Figures S3 and S4. Note that the cumulative cleared area attributable to timber harvesting and gas development and production does not exceed 5.5% over the 50-year projection. Similarly the density of linear features does not exceed 1 kilometre per square kilometre.

Our analysis shows that forestry and gas development will result in a significant and sustained increase in cleared areas, linear features and stream crossings in the PMT under base case assumptions. The onset of some impacts associated with forestry will be more rapid and have a larger magnitude than gas development, but are subject to greater fluctuations from decade to decade—in particular, periods of road development and harvesting are interspersed with periods of low disturbance. Compared with forestry, environmental impacts associated with gas development appear relatively lower and increase more gradually, but are sustained over the 50 year simulation.

The sum of the impacts reported for the scenarios simulating each industry independently are greater than impacts reported for scenario simulating both industries together. This indicates that overlap of developments and access reduces the disturbances that one might predict from independent consideration of each industry.

Figure S1. Forecast harvest from the PMT.

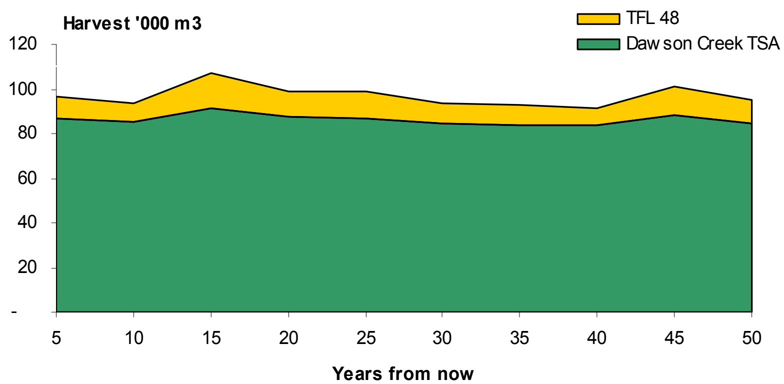


Figure S2. Average projected number of exploration and production wells drilled within the PMT study area

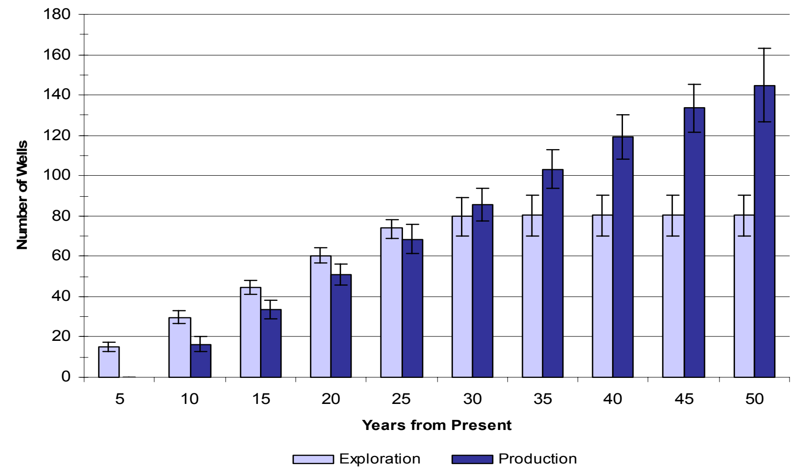


Figure S3. Mean projected percent cleared area within PMT study area boundary. Units are percentage of total area that is cleared.

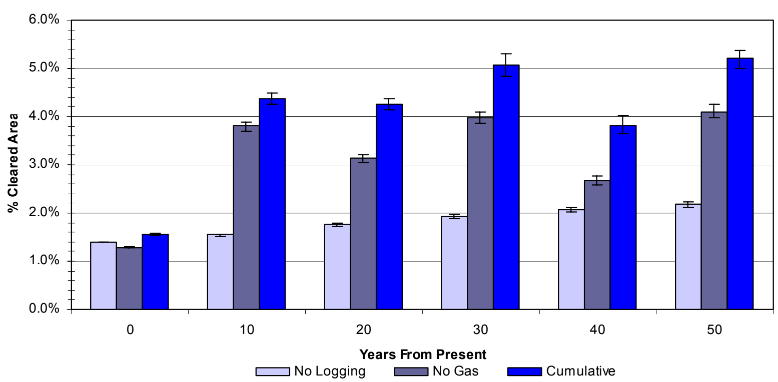
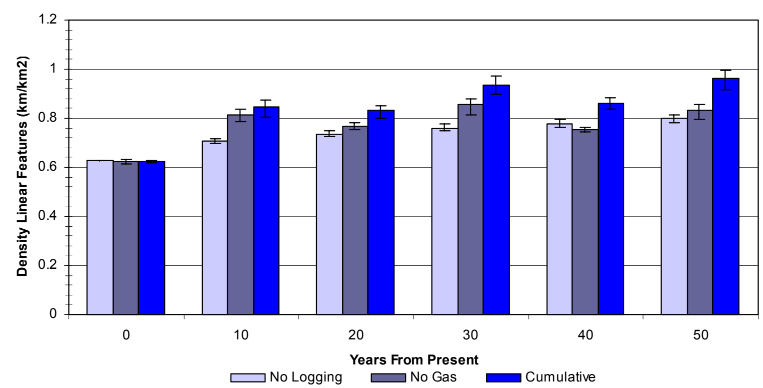


Figure S4 Mean projected densities of linear features (winter roads, all season roads and pipelines) within the PMT study area. Units are km of linear features per square km.



.Note: Error bars represent upper and lower 90th percentile of 50 replicate simulations.

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1.0 Introduction

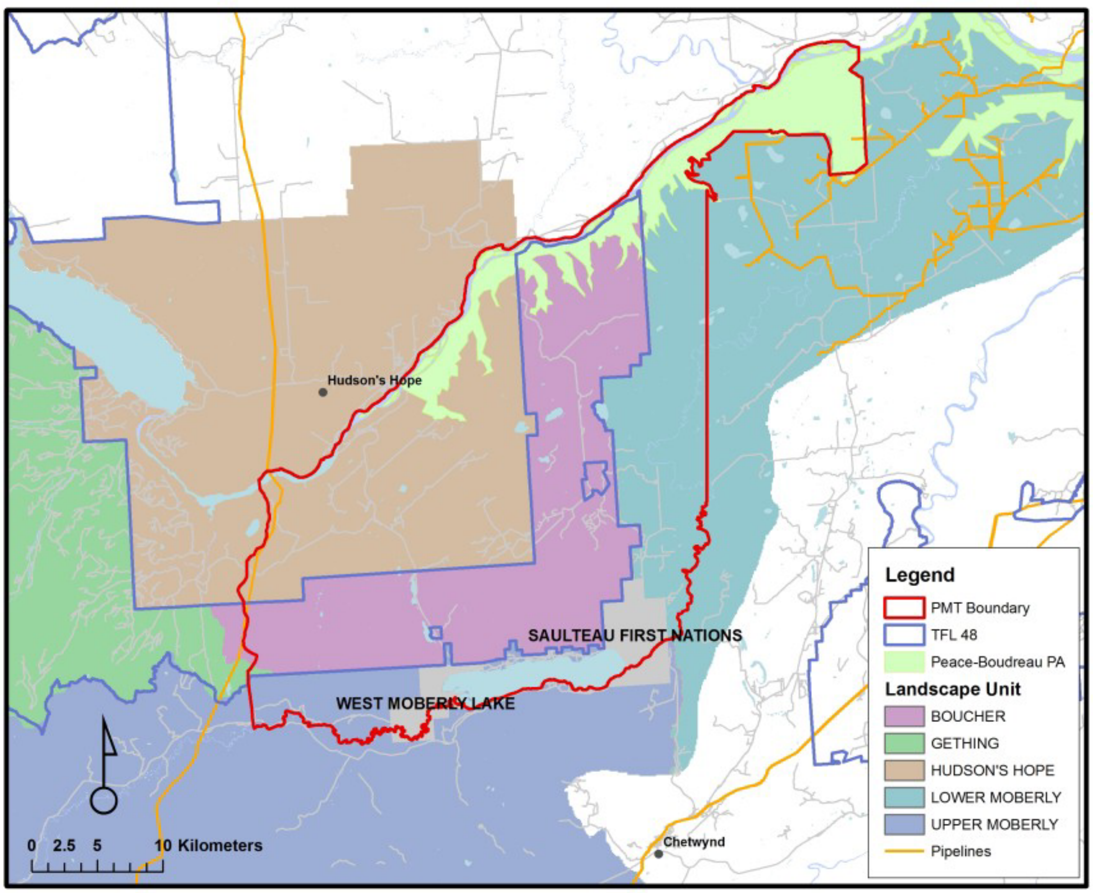
1.1 Background

The Peace-Moberly Tract (PMT) is approximately 1,090 square kilometres of land lying between Moberly Lake and the Peace River (Figure 1), and intersecting the Lower Moberly, Hudson's Hope, Boucher, Gething and Upper Moberly landscape units.

The Saulteau and West Moberly First Nations have identified the PMT as an area of special interest. The proximity of the PMT to these communities allows the use of the area for various cultural activities, including the benefits of hunting, trapping and fishing as assured under Treaty 8.

The study area is mostly forested, containing commercially valuable timber as well as potential oil and gas resources. A significant portion of the PMT is suitable for agricultural purposes. A portion of the plan area falls within the municipal boundaries of the Town of Hudson's Hope. Furthermore, the community of Chetwynd is nearby and the PMT lands are used by the residents for recreational and commercial purposes.

Figure 1. Location of Peace-Moberly Tract study area.



At the present time the PMT is relatively undisturbed by human development. A Sustainable Resource Management Plan (SRMP), is currently underway to help define how Crown land and resources of the PMT will be used in the future.

This project was undertaken to support the development of the SRMP by:

- developing a spatial-temporal modelling framework (PMT-CI model) capable of projecting disturbances associated with resource development
- identifying and forecasting quantitative indicators suitable for assessing cumulative impacts on environmental, cultural, and socio-economic values, and
- applying this framework to the Peace-Moberly Tract (PMT) Planning Area

This document reports the results of the analysis of a base case scenario using the PMT-CI model. Sections 2 and 3 describe the simulated development of the timber and gas resources, respectively. The purpose of these sections is to establish the validity of the model for each of the disturbance processes. The cumulative effects on selected environmental indicators of the disturbance processes are presented in Section 4.

1.2 Model Overview

The PMT-CI model and base case analysis scenario were designed to demonstrate the potential impacts of timber and natural gas exploration and development on indicators related to stakeholder values identified as having significant importance in the PMT. Identified stakeholder values include aspects of terrestrial and riparian ecosystems, wildlife habitat, cultural and heritage sites, and the economic benefits of timber harvesting and natural gas extraction.

The PMT-CI simulates forest harvesting, natural gas exploration and development, and access infrastructure (roads and pipelines) development, under various management assumptions specified in scenarios. It is a simulation model with stochastic variables that represent uncertainty about current and future conditions, and multiple replicate simulations are required in order to capture the range of possible outcomes in the results. The PMT-CI model is explained more fully in Appendix A, and the Base Case Scenario assumptions are explained in Appendix B.

The PMT-CI forecasts quantitative indicators of the cumulative impacts of development on environmental and socio-economic values for a particular scenario. It tracks the rate and extent of development, the state of the forest, and the levels of infrastructure required to access developments at any time. Indicators are presented as the mean and estimates of variance between replicate simulations. These indicators are described in detail in Appendix C.

There is considerable uncertainty in the extent and location of the gas resource, and in the rates of it's exploration and development. Therefore the model estimates the probability of disturbance, and, of course, its accuracy is only as good as the accuracy of the information that goes into the model.

Furthermore, the model projects the future state of the forest landbase under the anthropogenic disturbance agents only. It does not predict natural disturbances (e.g., fire or MPB) which could also have a significant effect on future states.

This incompleteness of the model together with the inherent uncertainty of the process of gas exploration and development, implies that the results of a modelled scenario should interpreted relative to another scenario, rather than interpreted literally.

Finally, the PMTCI is a strategic model that informs policy development and is not an operational planning tool. The objective of scenario analysis with the model should be to refine the domain experts' judgment – it does not replace critical thinking.

2.0 Timber Development and Harvesting

This section presents results summarizing the timber harvest levels and the state of the residual forest—constraints limiting harvesting, seral-stage distributions, and inventory levels—obtained under the management assumptions of the base case scenario.

2.1 Volumes Harvested

Mean annual volumes harvested within the TSA and TFL portion of the PMT study area boundary are presented in Table 1. Overall, harvest volumes in the PMT average 96,826 m^3 per year. Although harvest targets for the TSA are set for the larger study area (all LU's intersecting the PMT), volumes harvested remain relatively constant with an average annual volume harvested of 86,219 m^3. Mean annual harvest volumes in the TFL are more variable and range from 7,116 m^3 to 15,953m^3.

Although the area of productive forest in the TSA is similar in size to the TFL (29,866 ha and 26,294 ha, respectively), the harvested volume in the TSA averaged over 8 times than what was harvested in the TFL. Area harvested in the TSA averaged 1320 ha per year, while only 190 ha per year in the TFL.

Table 1. Mean annual volume harvested in the portion of the Dawson Creek TSA and TFL 48 located within the PMT study area.

	Mean Annual Volume Harvested (m^3)		
Years From Present	**TSA**	**TFL**	**Total**
5	86,684	10,291	96,974
10	85,060	8,262	93,322
15	91,214	15,953	107,167
20	87,209	11,832	99,041
25	86,602	12,141	98,743
30	84,171	9,099	93,270
35	83,836	8,683	92,519
40	84,146	7,116	91,261
45	88,388	12,712	101,099
50	84,880	9,979	94,859

2.2 Limiting Constraints on the State of the Residual Forest

Areas within the Timber Harvesting Land Base (THLB) constrained by non-timber resource objectives are summarized for current (initial) conditions in Table 2. Note that areas are reported for the larger study area that includes all LU's intersecting the PMT boundary. Area constrained is the area made unavailable for harvesting in order to satisfy the constraint specified for that zone. The net area is the total area made unavailable to satisfy the constraint in that zone minus the area overlapping in other zones. The % constrained area is the net area made unavailable divided by the total area of that zone in the THLB.

Table 2. Limiting constraints for non-timber resource objectives reported for current conditions.

Zone	Constraint	%		Threshold		THLB ha	Area Constrained Net ha	Total ha	% Constrained
Visual Quality Objectives									
IRM	min	67	above	3	m	82969	0	0	0.0%
VQOm	min	80	above	5	m	4652	1099	1105	23.6%
VQOpr	min	90	above	5	m	7943	5421	5441	68.3%
VQOr	min	95	above	5	m	2216	1656	1658	74.7%
VQOp	min	99	above	5	m	117	84	85	72.0%
Landscape Level Biodiversity									
BWBSmw1Int	min	13	above	100	yrs	14432	0	0	0.0%
BWBSmw1Low	min	13	above	100	yrs	98142	3538	3892	3.6%
BWBSwk1Int	min	13	above	100	yrs	558	70	70	12.6%
BWBSwk1Low	min	13	above	100	yrs	7196	0	0	0.0%
BWBSwk2Low	min	13	above	100	yrs	1965	0	0	0.0%
ESSFmv2Int	min	9	above	250	yrs	16052	1439	1439	9.0%
ESSFmv2Low	min	9	above	250	yrs	743	57	91	7.7%
ESSFmv4Low	min	9	above	250	yrs	308	8	9	2.6%
ESSFmvpInt	min	9	above	250	yrs	13	0	0	0.0%
SBSwk2Int	min	9	above	250	yrs	28721	2517	2527	8.8%
SBSwk2Low	min	9	above	250	yrs	2289	236	256	10.3%

2.3 Seral Stage Distributions

Seral stage distributions for productive forests in both contributing and non-contributing areas located within the PMT study area boundary are presented in Figure 2. Areas are reported for each harvest partition (conifer leading, deciduous leading and small pine leading) for the TSA and the TFL 48 separately.

Age class distributions in both the portions of the PMT in the TSA and TFL remain mostly consistent over time. This indicates that harvest levels are not set too high and that forest cover constraints are maintaining representation of mature and old seral stages.

In conifer leading stands within the TSA there is a drop in mature coincident with an increase in old growth. This can be attributed to both a reduction of mature stands that get harvested, but also to mature stands in non-contributing areas transitioning to old growth. The PMTCI model does not simulate the effects of natural disturbances, and stands in the non-contributing landbase continue aging undisturbed over the length of the simulation.

With deciduous leading stands in both the TSA and TFL there is a decrease in mid seral stands and an increase in both young stands as these stands become merchantable and are harvested, and in mature stands as mid seral stands in the non-contributing landbase transitions to mature.

The majority of small pine leading stands are classified as either mature or old, and the effects of harvesting of these stands is negligible.

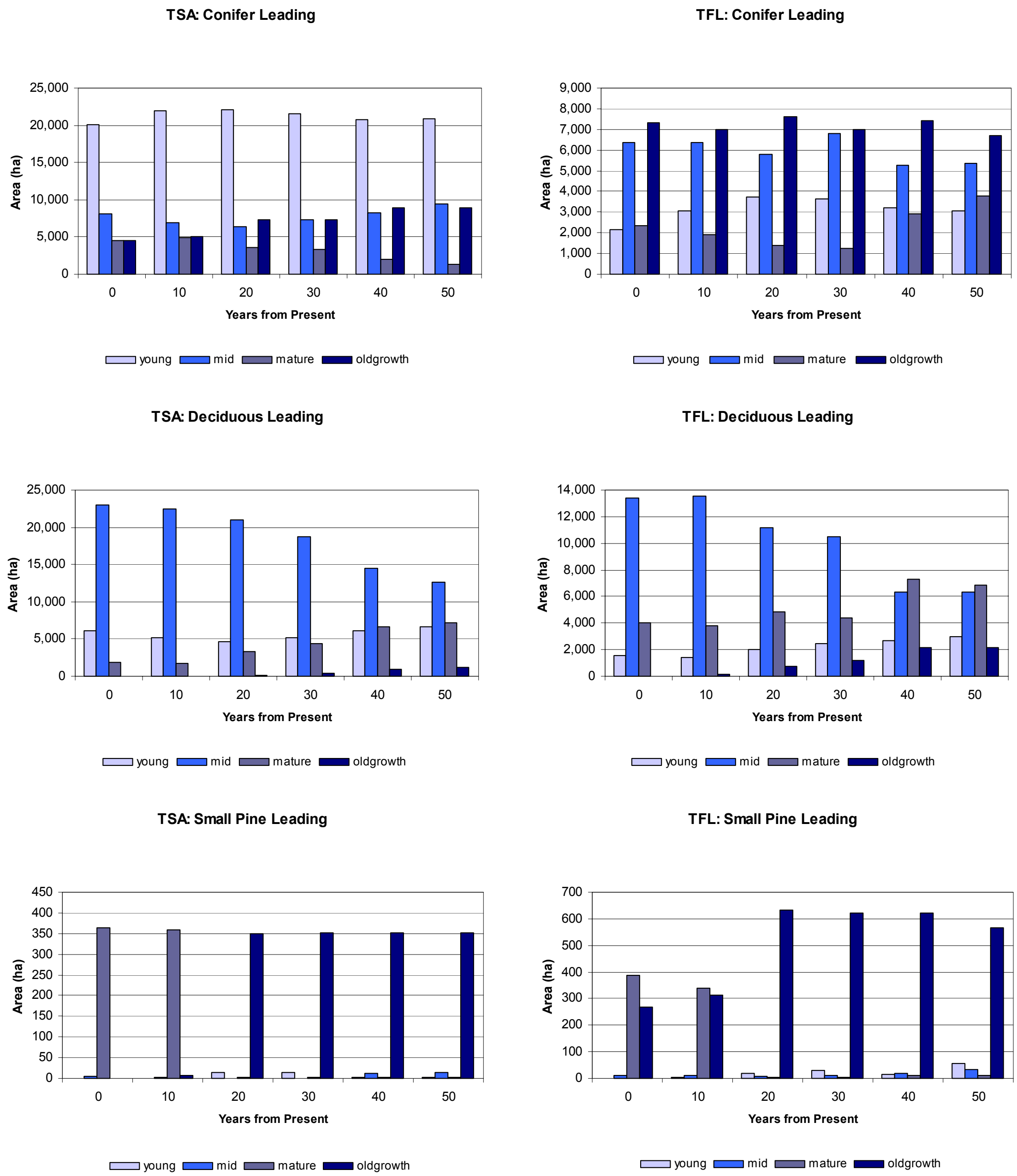


Figure 2. Projected area in young, mid, mature and old growth seral stages for conifer leading stands, deciduous leading stands and small pine stands in the portions of the TSA and TFL located within the PMT study area.

2.4 Inventory Levels

The volume of standing merchantable timber within conifer leading, deciduous leading and small pine leading stands located in the THLB inside the PMT study area are presented in Figure 3. The total growing stock remains mostly level over the 50 year simulation period, suggesting that the short and mid term harvest levels used in the base case analysis are sustainable. Conifer leading stands remain stable at 3.6 million m^3, deciduous leading stands remain stable at approximately 4.6 million m^3, and small pine stand increase slightly to over 210,000 m^3.

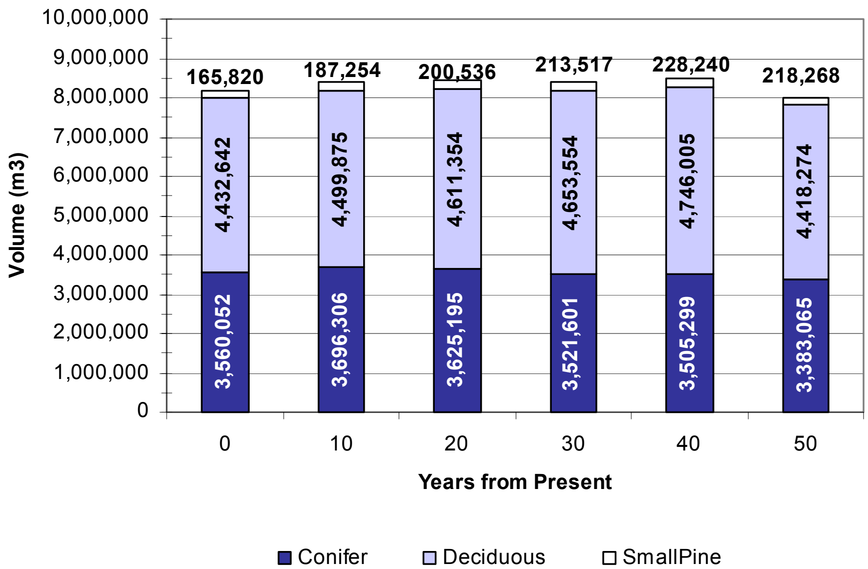


Figure 3. Standing merchantable volume (age > minimum harvest age) in the timber harvesting landbase within the PMT study area.

Figure 4 shows the standing merchantable timber volume in the portions of the TSA and TFL located in the PMT. Growing stock in the TSA appears to be declining, while increasing slightly in the TFL. This suggests that the harvest levels specified for the TSA may be too high to be sustainable. However, since the TSR II analysis, inventory adjustments have been made (based on VRI Phase II). These adjustments were not applied to the inventory used in this analysis. The decline in growing stock after the second decade may be attributable to underestimated productivity in the inventory and growth and yield projections, which has since been corrected in the VRI Phase II inventory adjustments.

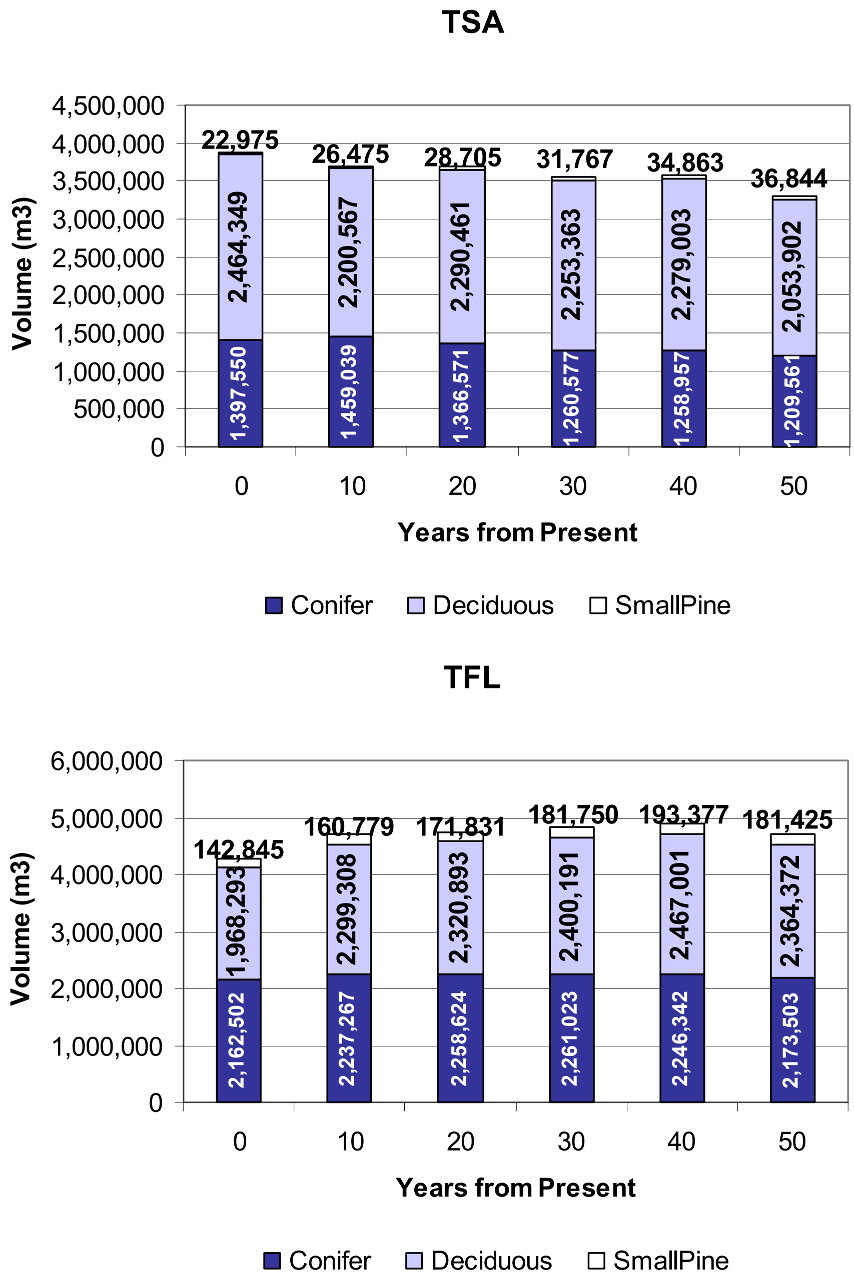


Figure 4. **Standing merchantable volume (age > minimum harvest age) in the timber harvesting landbase within the portions of the TSA (top) and TFL (bottom) located in the PMT study area.**

3.0 Gas Exploration and Development

This section summarizes the PMTCI model's simulated exploration and development of natural gas in the PMT and compares the model's indicators of development to values specified in the Ministry of Energy and Mines (MEM) development scenarios for the region.

3.1 Number of Wells

Generally, correspondence between the numbers of well predicted by the PMTCI model and the MEM scenario is very high (Table 3). The overall numbers of exploration wells predicted by the model are within 2% of those predicted in the MEM scenario. Differences are slightly greater when comparing numbers of production wells, with MEM scenario predicting between 4 - 8% more wells than the PMTCI model. These differences can be attributed to the slightly different approaches used to determine the numbers of production wells.

In the MEM scenario, the expected number of production wells in each case class is based on average numbers of production wells observed for analogous gas plays in areas adjacent to the PMT (e.g., low = 1.5, medium = 6, high = 20). The simulation model determines the number of production wells by first assigning a target gas reserve value to each case (e.g., low = 6 BCF, medium=20 BCF, high = 100 BCF), and then accumulating adjacent sections of land until the cumulative gas reserve value assigned to each section meets or exceeds the target value for the case. The gas reserve value assigned to each section is based on a random value selected from a normal distribution with a mean of 8 and a standard deviation of 0.8 (assuming two leases per section with one well per lease). This value was determined as the average of the number of expected wells in a case divided by the expected gas reserve value for the case (e.g., low = 6 BCF/1.5wells, medium = 20/6, high = 100/20).

Table 3. Comparison of average expected numbers of exploration and production wells, and expected well densities (wells/km^2) determined by the PMTCI simulation model (mean of 50 replicates) and those calculated from the MEM scenario specification shown in brackets.

Play Type	N Exp Wells	N Prod Wells	Total	Expected Density (wells/km^2)
Monias	22.9 (24)	49.12 (51.48)	72.02 (75.48)	0.15 (0.16)
Foothills	39.1 (40)	95.76 (104)	134.86 (144)	0.35 (0.37)
Central	18.6 (18)	26.68 (29.25)	45.28 (45)	0.2 (0.2)
Total	80.6 (82)	171.66 (185)	252.26 (264)	0.23 (0.24)

3.2 Well Productivity

The proportion of exploration classified as drill and abandon, or in low, medium or high case classes are consistent between the simulation model and the MEM scenario specification (Table 4).

Table 4. Comparison of the proportion of exploration wells classified as drill and abandon, low, medium and high cases classes between the model simulations (mean of 50 replicates) and proportions calculated from the MEM scenario specification shown in brackets.

		Case Class		
Play Type	**D&A**	**Low**	**Med**	**High**
Monias	0.68 (0.67)	0.16 (0.19)	0.72 (0.7)	0.12 (0.11)
Foothills	0.59 (0.6)	0.19 (0.21)	0.70 (0.69)	0.11 (0.10)
Central	0.74 (0.75)	0.23 (0.2)	0.69 (0.67)	0.08 (0.13)

3.3 Rate of Development

Forecast rates of natural gas development in the PMT are shown as the mean cumulative number of exploration and production wells drilled (Figure 5), and the percentage of the total number of wells expected to be drilled (Figure 6). In the base case scenario, numbers of exploration and production wells drilled each year are controlled by a random variable to account for expected uncertainty in rate of natural gas exploration and development in the PMT. The numbers of exploration and production wells drilled in each year were drawn from uniform distributions ranging between 2 - 5, and 2 - 4, respectively (see Appendix 2).

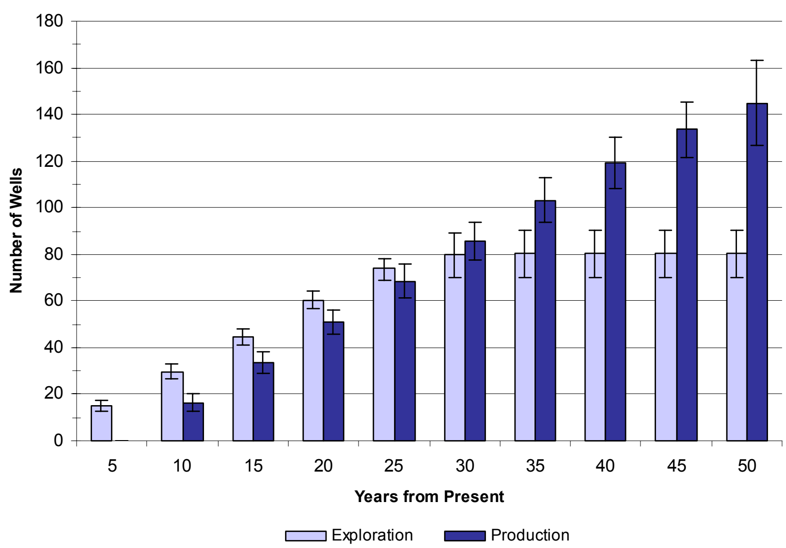


Figure 5. Average projected number of exploration and production wells drilled within the PMT study area. Error bars represent upper and lower 90th percentile of 50 replicate simulations.

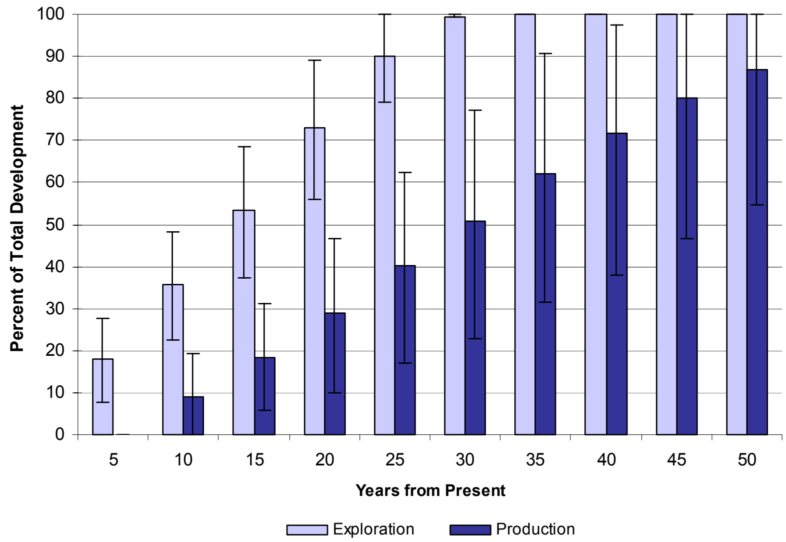


Figure 6. Average projected percentage of the total expected exploration and production wells drilled within the PMT study area. Error bars represent upper and lower 90th percentile of 50 replicate simulations.

Invariably, all exploration wells are accessed and drilled within 30 years. Because not all exploration wells drilled identify successful cases, variability in the rate of development of successful cases (i.e., drilling of production wells) is greater. Within 50 years, the average number of production wells drilled is 145, or approximately 87% of the extent of conventional development. Note that there is a large degree of variability around rates and numbers of wells drilled, and at least 10% of replicates drilled 100% of production wells by year 45. Variability in the projected numbers of wells drilled over time highlight the large uncertainty in rates of exploration and development of natural gas resource in the PMT.

3.4 Development by Play

Tables 5 and 6 show the average projected numbers of exploration and production wells drilled by play type over time. Numbers of wells drilled in the Monias play area are nearly half that drilled in the Foothills play area, even though the Monias comprises 43% of the PMT study area, whereas the Foothills is only 36%. This is because the expected number of exploration wells in the Foothills play area is 40, whereas in the Monias it is only 24. Also, the probability of identifying a successful case is greater in the Foothills than in the Monias (pCOS = 40% for Foothills, pCOS = 33% for Monias).

Table 5. Projected number of exploration wells drilled (mean ± standard deviation) in the Monias, Central and Foothills play areas located within the PMT study area.

Exploration Wells	Play Type		
Years from Present	Monias	Central	Foothills
5	4.1 ±2	3.6 ±1.5	7.3 ±2.4
10	8.1 ±2.9	6.8 ±1.9	14.7 ±3.1
15	12.1 ±3.6	10.4 ±2.8	22.3 ±3.9
20	16.5 ±3.7	14 ±3.1	29.4 ±4.4
25	20.3 ±3.8	17.2 ±3.4	36.4 ±5.4
30	22.6 ±4.5	18.6 ±3.8	38.9 ±5.6
35	22.8 ±4.6	18.6 ±3.9	39.1 ±5.5
40	22.8 ±4.6	18.6 ±3.9	39.1 ±5.5
45	22.8 ±4.6	18.6 ±3.9	39.1 ±5.5
50	22.8 ±4.6	18.6 ±3.9	39.1 ±5.5

Table 6. Projected number of production wells drilled (mean ± standard deviation) in the Monias, Central and Foothills play areas located within the PMT study area.

Production Wells	Play Type		
Year	Monias	Central	Foothills
5	0 ±0	0 ±0	0 ±0
10	4.2 ±4.2	3.2 ±3.2	9 ±9
15	8.1 ±8.1	5.3 ±5.3	20.1 ±20.1
20	12.5 ±12.5	8.3 ±8.3	30.1 ±30.1
25	17.1 ±17.1	11.5 ±11.5	39.7 ±39.7
30	21.6 ±21.6	14.3 ±14.3	49.5 ±49.5
35	26.7 ±26.7	16.8 ±16.8	59.4 ±59.4
40	31.3 ±31.3	19.4 ±19.4	68.7 ±68.7
45	35.4 ±35.4	21.4 ±21.4	76.9 ±76.9
50	39.2 ±39.2	22.7 ±22.7	83 ±83

Projected well densities in the PMT study area increase in a non-linear fashion from 0.02 wells/km^2 in the first decade to just over 0.1 wells per km^2 in fifth decade (Figure 7). Densities are highest in the Foothills play area (0.15 wells/km^2), and lowest in the Monias play area (0.07 well/km^2). As with well numbers, well densities in the Monias play area are half than in the Foothills. Variability in well densities is large across all play areas, and increases with time.

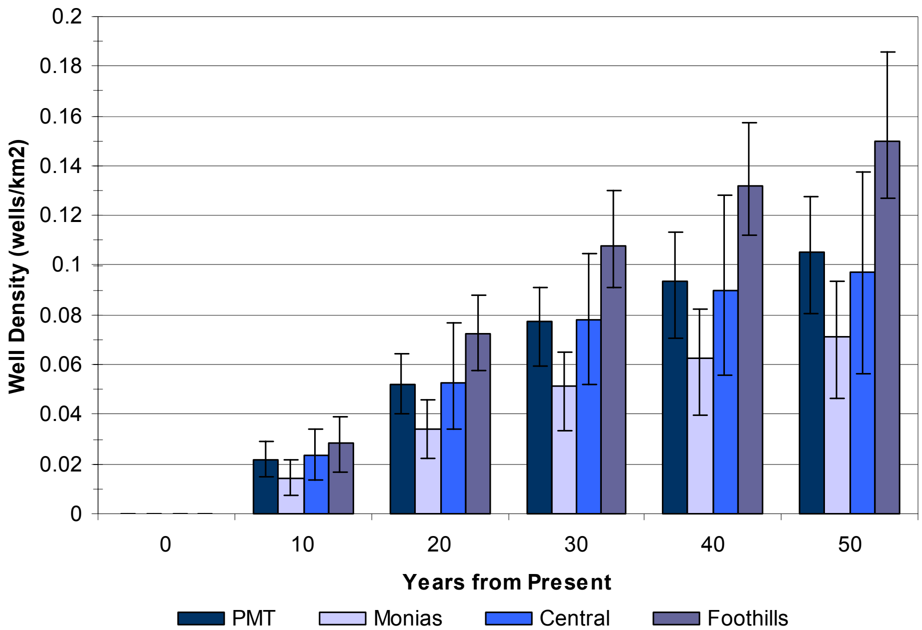


Figure 7. Mean projected well densities (number of wells per square kilometer) in the PMT study area (black) and within the Monias (white), Central (hatched) and Foothills (gray) play type areas. Error bars show upper and lower 90th percentiles of 50 replicates.

4.0 Cumulative Impacts on Environmental Values

This section presents the results showing the impacts of forestry and natural gas exploration and development in (1) the PMT study area; (2) in area with very high capability for moose habitat; (3) and in area within draft management area 1. Summaries within these three areas were chosen in order to illustrate overall impacts in the PMT, environmental impacts, and impacts on culturally significant areas, respectively. Table 7 shows the area within each moose habitat capability class within the PMT study area boundary, and Table 8 shows the area within each of the draft management units.

Table 7. Summary of area classified by moose habitat capability within the PMT study area boundary.

	Very High	High	Moderate	Low	Very Low	Non-Habitat	Total
Area (ha)	73,715	7,050	588	20,056	2,828	2,801	107,038
Percentage	68.9%	6.6%	0.5%	18.7%	2.6%	2.6%	100%

Table 8. Area within draft management area zones within PMT study area boundary.

	Draft Management Areas					
	Unclassified	First Nations Reserve	MA1	MA2	Pending	Total
Area (ha)	55,066	3,816	18,972	20,510	8,674	107,038
Percentage	51.45%	3.57%	17.72%	19.16%	8.10%	100%

In order to separate the effects of each industry on cumulative impact indicators, three scenarios were compared: (1) projected natural gas exploration and development with no forest harvesting (no logging); (2) projected forest harvesting, but with no natural gas exploration and development (no gas); and (3) projected both forest harvesting and natural gas exploration and development (cumulative).

The first indicator described below is the projected area that is in a cleared state. Cleared areas are areas that are disturbed, i.e., regeneration delay, and include cutblocks, well pads, 3D seismic lines, roads and pipelines. This indicator is measured as the percentage of the study area in a cleared state.

The second indicator is the density of linear features. This indicator is measured as the km of linear feature divided by the area within summary strata (km/km^2). Linear features include winter roads, all season roads and pipelines.

The third indicator shows numbers of crossings of fish bearing streams by all season and winter roads. This indicator is measured as the number of stream crossings divided by the length of streams within the summary strata (crossings/ km streams).

4.1 Cleared Areas

For current conditions approximately 1.3% of the PMT study area boundary is cleared areas (Figure 8). In area with very high capability for moose habitat 1.6% of the area is cleared (Figure 9), and in draft management area 1, only 1% of the area is in a cleared state (Figure 10). Across all summary strata, for the scenario with gas and forestry combined the projected percentage of cleared areas does not exceed 6%, but remains above 3% after the first decade.

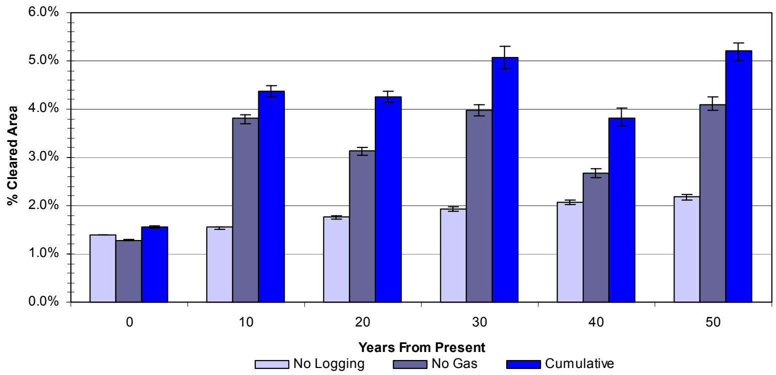


Figure 8. **Mean projected percent cleared area within PMT study area boundary. Units are percentage of total area that is cleared. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

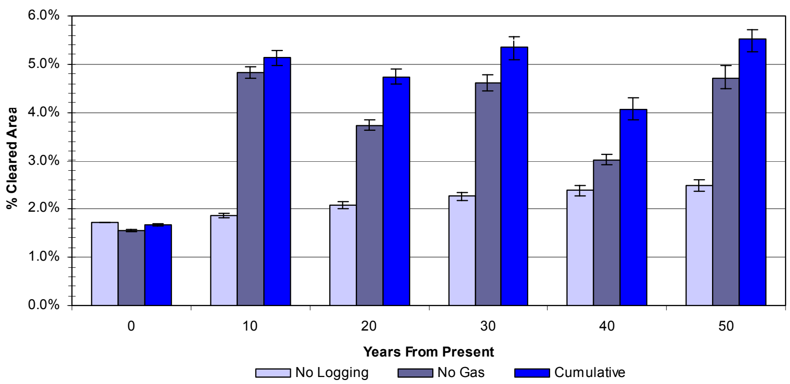


Figure 9. **Mean projected percent cleared area within very high capability for moose habitat. Units are percentage of total area that is cleared. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

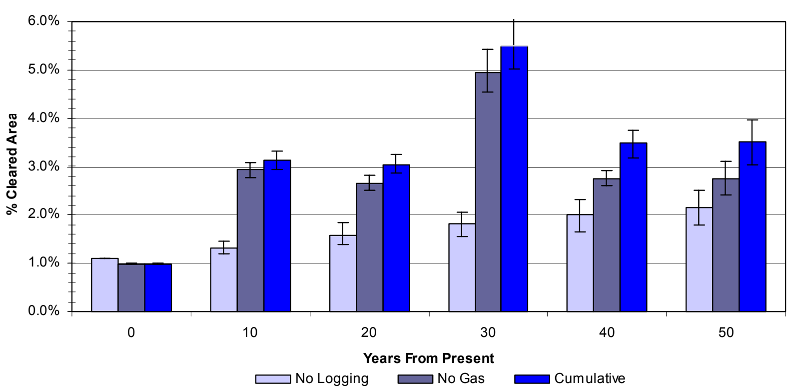


Figure 10. **Mean projected percent cleared area within draft management area 1. Units are percentage of total area that is cleared. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

Within areas with very high capability for moose habitat, percentages are only slightly higher than in the PMT as a whole. This is because very high moose capability covers nearly 70% of the PMT. Note that current forestry cutblocks or well sites are not included in the summary of current conditions (t=0), so the percent cleared areas for current conditions is likely underestimated.

Comparing the three scenarios, it is evident that the majority of cleared areas can be attributed to forestry developments. However when combined, the total percentage of cleared areas for the gas only and forestry only scenarios is greater than cleared areas for the scenario with both industries operating simultaneously. This indicates an overall reduction in cleared areas, attributable to overlap in developments, than if both industries were operating separately.

Generally, cleared areas attributed to gas development increase gradually from time zero, whereas cleared areas associated with forestry increase rapidly and fluctuate between time periods. This is because of the assumption that production well pads and all season roads accessing them are in place for the life of the scenario, whereas harvest blocks and winter roads accessing them regenerate within 2 years. Hence, cleared areas associated with forestry are not cumulative over time, whereas oil and gas are.

4.2 Density of Linear Features

Figures 11 to 15 show the projected density of linear features for the area with the PMT boundary, area with very high capability moose for habitat and area in draft management area 1. For current conditions the overall density of linear features (roads and pipelines) in the PMT study area boundary is 0.63 km/km^{2}. (Figure 11), 0.73 km/km^{2} in very high capability moose habitat (Figure 12), and 0.44 km/km^{2} in draft management area 1 (Figure 13). Projected densities of linear features in all three summary areas are generally greater for forestry than natural gas development, except in decade 4 where gas development contributes a higher density than forestry. Variability between replicate simulations is least in the larger PMT study area boundary, and greater in the smaller Draft Management Unit 1. Furthermore, compared to the scenario with no gas development, variability is greatest for the scenario with gas development only (i.e., No Logging), indicating greater uncertainty in the location and extent of linear features required to access gas developments, and that this uncertainty increases when results are considered at finer scales. As with the cleared areas indicators, when gas development and forestry are simulated together, the projected densities of linear features are less than the combined values of scenarios where each industry was simulated separately. The results suggests that coordinated development between industries could result in a substantial decrease in impacts associated with linear developments than if each industry operated independently.

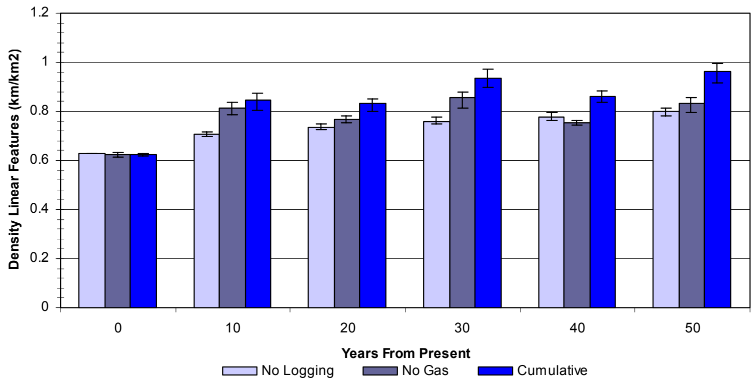


Figure 11. **Mean projected densities of linear features (winter roads, all season roads and pipelines) within the PMT study area. Units are km of linear features per square km. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

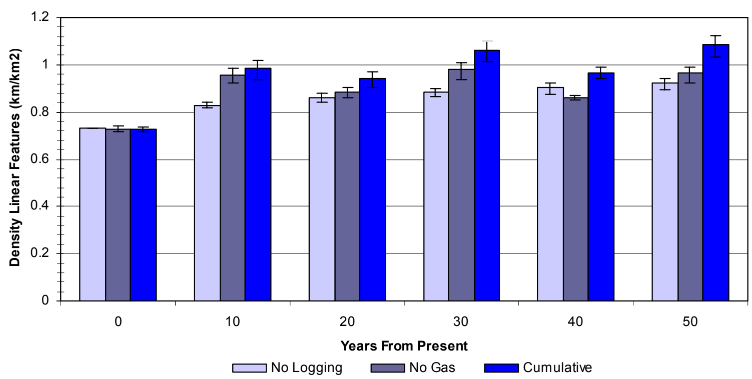


Figure 12. **Mean projected densities of linear features (winter roads, all season roads and pipelines) within area with very high capability for moose habitat. Units are km of linear features per square km. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

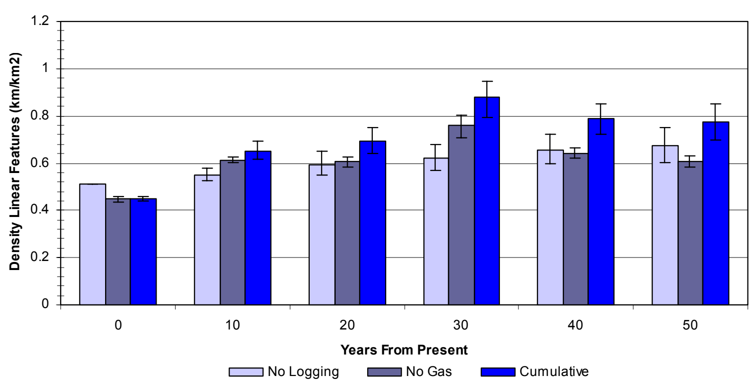


Figure 13. **Mean projected densities of linear features (winter roads, all season roads and pipelines) within draft management area 1. Units are km of linear features per square km. Error bars show the upper and lower 90th percentiles of 50 replicate simulations.**

4.3 Fish-Bearing Stream Crossings

Figures 14 to 16 show the projected numbers of crossings of fish bearing streams by all season roads for the area with the PMT boundary, area with very high capability moose for habitat and area in draft management area 1. For current conditions the number of stream crossings per km of stream in the PMT is 0.25 crossings/km (Figure 15), higher in area with very high capability of moose habitat (0.3 crossings/km; Figure 19), and lowest in draft management area 1 (0.2 crossings/km; Figure 20). Since, it is assumed that all season roads are developed only to access production wells for natural gas development, there is no increase in the number of stream crossings by all season roads in the scenario that simulates forestry only. Generally, numbers of stream crossings increase gradually to around 0.325 – 0.375 crossings /km within the three summary zones. As with linear density measurements, variability between replicate simulations increases as the size of the summary zone decreases, indicating uncertainty in the location and extent of gas resource.

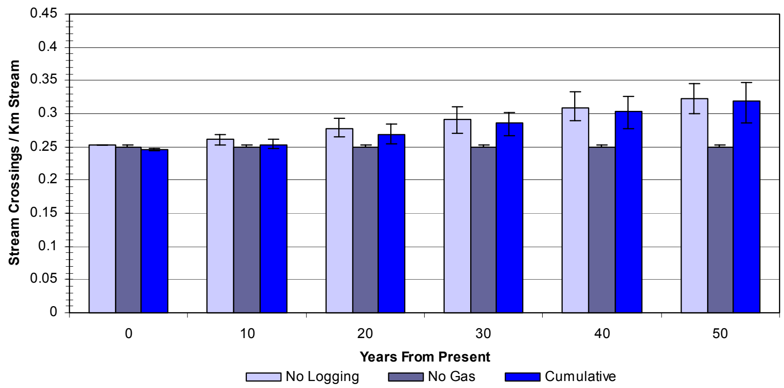


Figure 14. Mean projected crossings of fish bearing streams by all season roads in the PMT study area boundary. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.

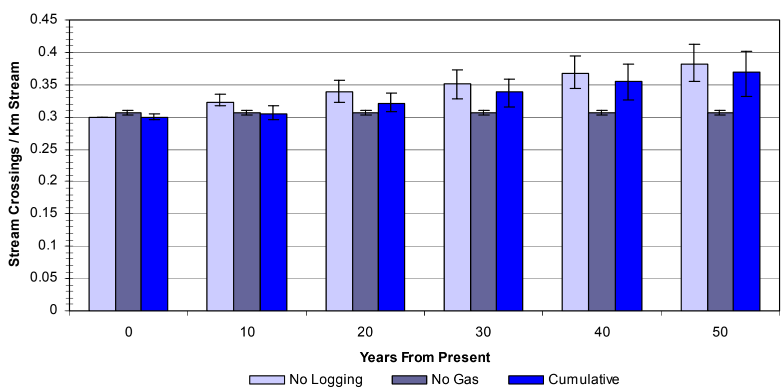


Figure 15. Mean projected crossings of fish bearing streams by all season roads in areas with very high capability moose habitat. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.

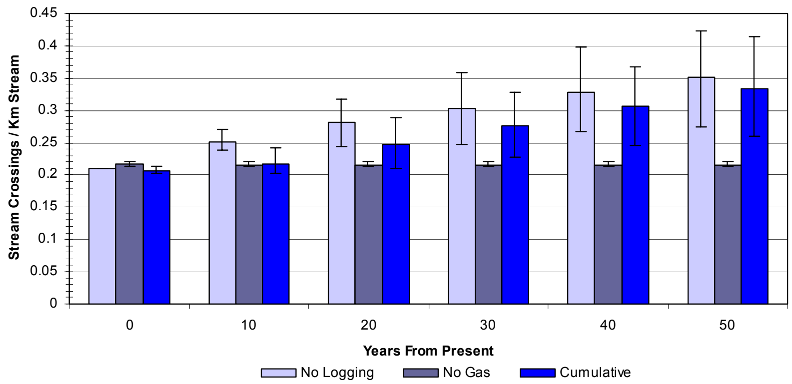


Figure 16. Mean projected crossings of fish bearing streams by all season roads in draft management unit 1. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.

Figures 17 to 19 show the projected numbers of crossings of fish bearing streams by winter roads for the area with the PMT boundary, area with very high capability moose for habitat and area in draft management area 1. For current conditions the number of winter road stream crossings per km of stream in the PMT is 0.5 crossings/km (Figure 17). Crossings are more numerous in area with very high capability of moose habitat (0.6 crossings/km; Figure 18), and least numerous in draft management area 1 (0.35 crossings/km; Figure 19). Winter roads are assumed to be developed to access both exploration wells and harvest cutblocks. However, if a successful case is identified by an exploration well, then the access road is converted to an all season road. Unsuccessful exploration wells, and the winter roads accessing them are assumed to be reclaimed within 4 years. Thus, the number of winter road stream crossings attributed to gas exploration increases and then remains constant as exploration wells are drilled and unsuccessful ones are reclaimed. The increase in numbers of winter road stream crossings attributable to forestry developments is greater and fluctuates between 0.57 – 0.8 crossings /km within the PMT boundary. Note the greatest fluctuation in winter road crossings within the draft management area 1, with a large increase in decade 3 (Figure 19). This indicates a timber stand with high priority in 30 years within this zone.

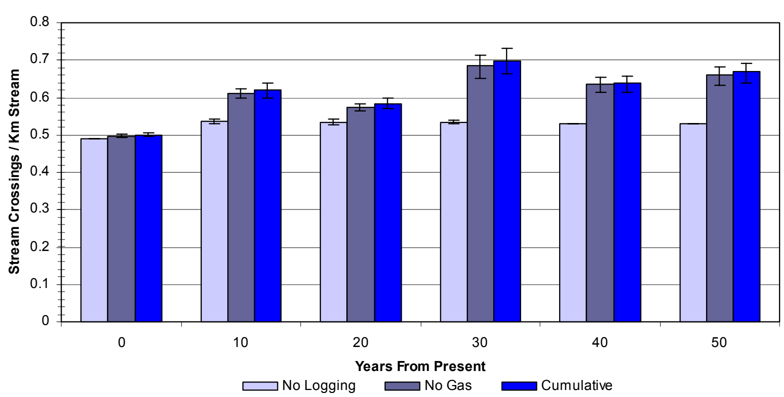


Figure 17. Mean projected crossings of fish bearing streams by winter roads in the PMT study area boundary. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.

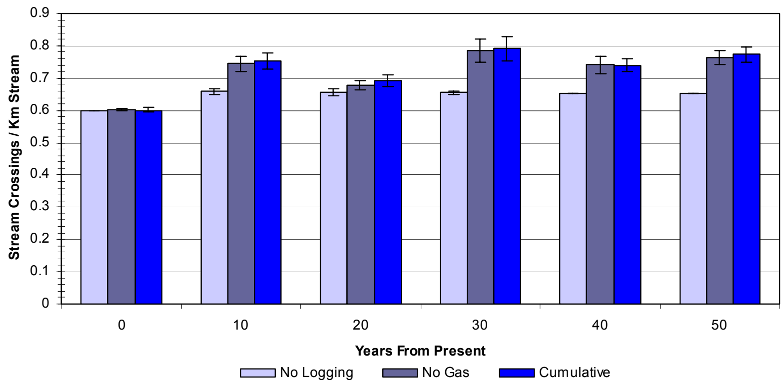


Figure 18. **Mean projected crossings of fish bearing streams by winter roads in areas with very high capability for moose habitat. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.**

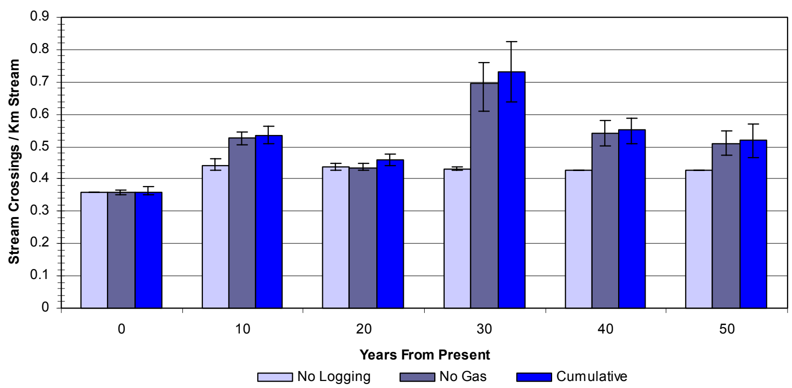


Figure 19. **Mean projected crossings of fish bearing streams by winter roads in draft management area 1. Units are numbers of stream crossings per km of stream. Error bars show the upper and lower 90th percentile of 50 replicate simulations.**

4.4 Spatial Distribution of Disturbance

The probabilities of disturbance on the PMT during the fifth decade are shown in Figures 20 (cleared area) and Figure 21 (linear infrastructure). Each figure is presented for (a) gas exploration and production only, and (b) timber development and harvesting only.

The disturbance (both clearing and linear) generated by the exploration and production of gas appears more dispersed across the PMT in the fifth decade than the disturbance generated by timber harvesting. This is due to the random placement of gas infrastructure by the model, (subject to the input parameters controlling well densities and spacing, and the cost surface controlling placement of well sites and linear infrastructure), and its persistence on the landbase, relative to timber harvesting disturbances. The probability of cleared areas attributed to gas exploration and development are higher in the south west (Foothills) play area. This is because number of wells drilled and probabilities of success are expected to be higher in this play area, than further northeast. Locations with high probabilities of cleared areas for the forestry-only scenario indicate high priority timber stands that are merchantable during this time period.

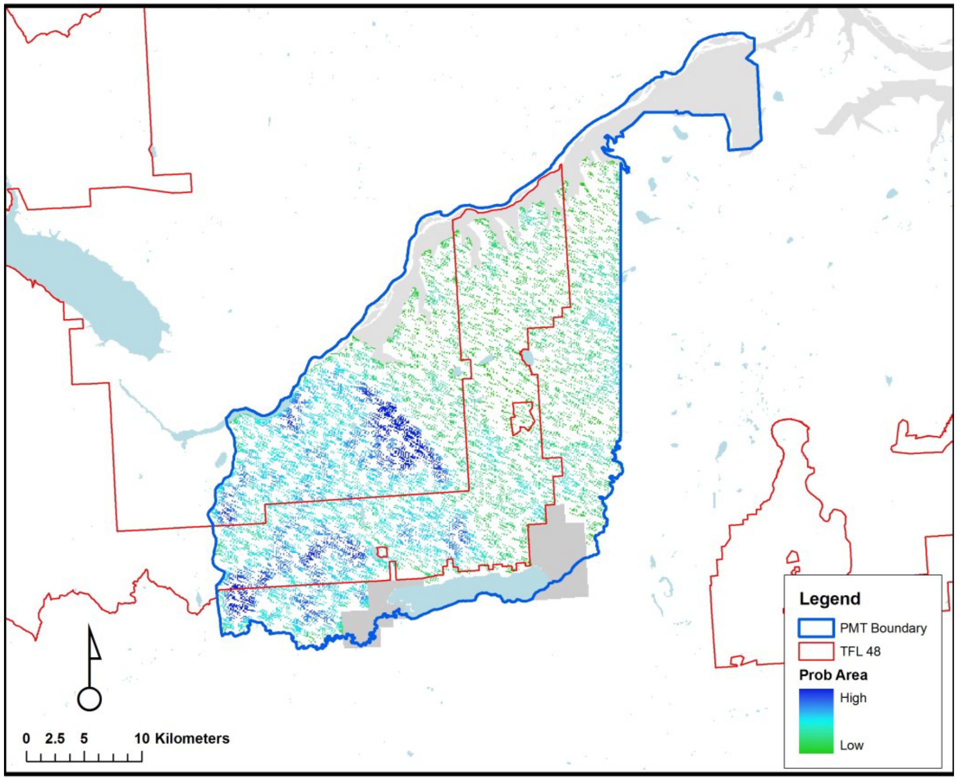
The probability of linear disturbance shows the number of times a road or pipeline passes through a particular part of the study area, when summed over all replicate simulations. Linear features link new or existing developments to the existing linear infrastructure (i.e., at t = 0). For the gas-only development scenario, most areas have a non-zero probability of linear disturbance, but areas with highest probabilities are in locations in close proximity to existing corridors (Figure 21 a). Probabilities decrease with increasing distance from existing roads and pipelines, and are very low or zero in areas defined with high cost (e.g., water bodies, riparian corridors, first nations reserves, etc.). This suggests that the current and future location of main access corridors in the PMT will have a large effect on the location of linear infrastructures to access gas exploration and development.

Conversely, in the forestry-only scenario, a large proportion of the study area has low or zero probability of linear disturbances, and areas with high probabilities are located either on, or near existing roads, and are clustered in areas surrounding merchantable timber stands with high priority for harvesting during this time period (Figure 21 b).

Comparisons in spatial patterns of disturbance probabilities between the two scenarios illustrates consequences of uncertainty, and assumptions about the persistent and cumulative nature of gas development and associated access infrastructure. Because of shorter regeneration delays on harvest blocks and winter access roads, disturbances associated with harvesting are ephemeral, and most likely to be located in regions with high value timber. By comparison, production wells and associated access infrastructure are assumed to be in place over the entire simulation period. This, combined with uncertainty in placement of production wells, results in non-zero disturbance probabilities that are distributed across a larger area.

Figure 20. Probability of a cleared cell (0.25 ha) after 50 years of development (base case scenario). A cell is considered cleared if the combined area cleared within a cell > 50% of the total area of the cell.

a. Gas development and production only.



b. Timber development and harvesting only.

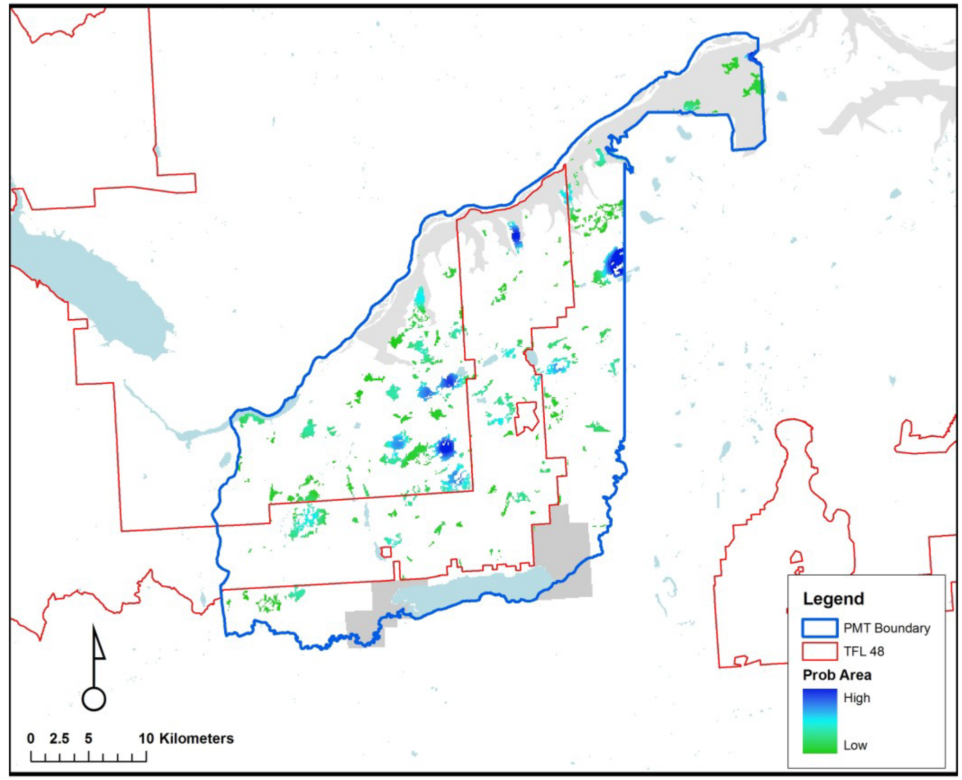
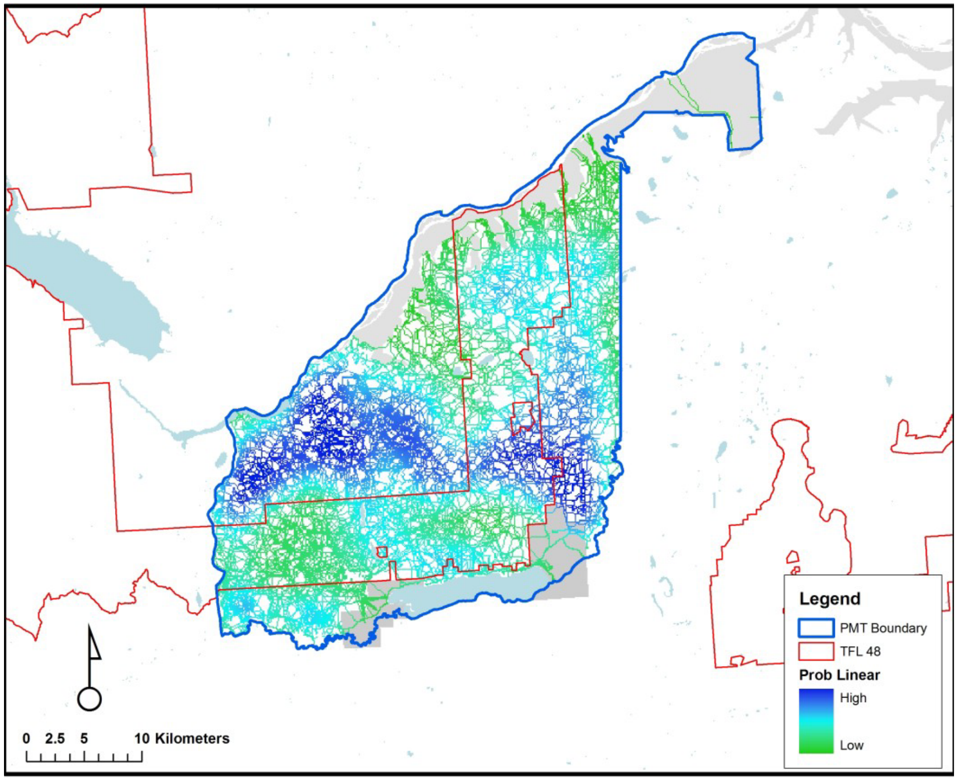
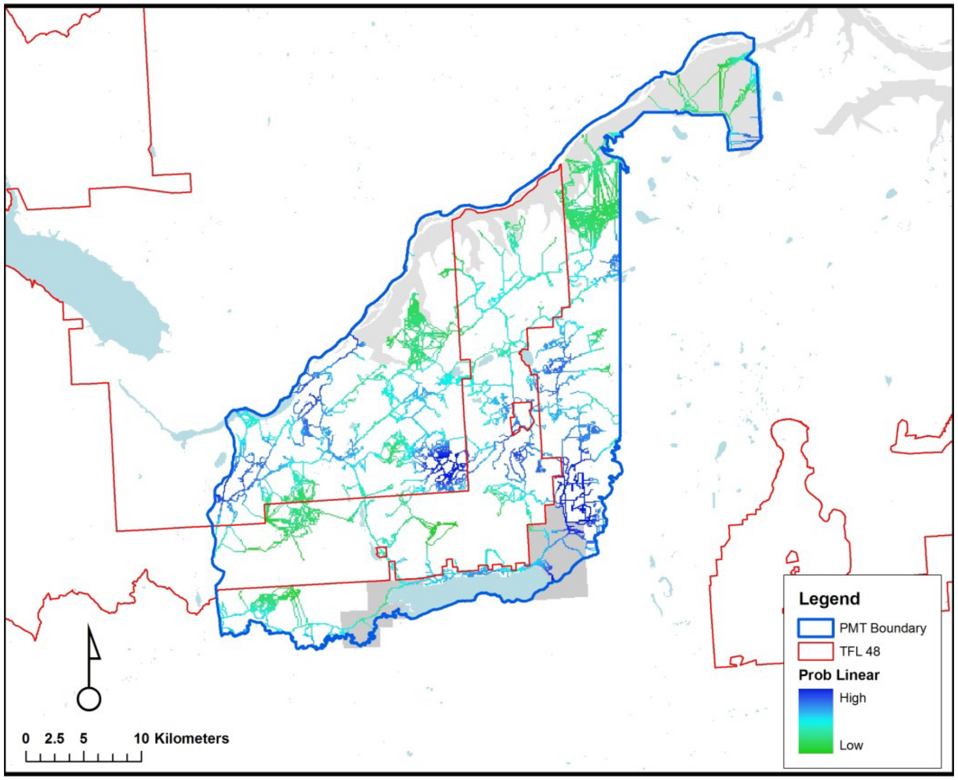


Figure 21. Probability of a linear development within a cell (0.25 ha) after 50 years of development (base case scenario). A linear development is an all-season or winter road, or a pipeline.

a. Gas development and production only.



b. Timber development and harvesting only.



5.0 Conclusions

Our analysis shows that forestry and gas development will result in a significant and sustained increase in cleared areas, linear features and stream crossings in the PMT under base case assumptions.

The onset of some impacts associated with forestry will be more rapid and have a larger magnitude than gas development, but are subject to greater fluctuations from decade to decade—in particular, periods of road development and harvesting are interspersed with periods of low disturbance. Compared with forestry, environmental impacts associated with gas development appear relatively lower and increase more gradually, but are sustained over the 50 year simulation.

It is difficult to interpret the effects of disturbances of both industries together, since land and road usage, regeneration times, reclamation standards, and durations of disturbances are significantly different between the two industries. Therefore we have evaluated the impacts associated with each industry separately by simulating each industry independently, as well as together. The sum of the impacts reported for the scenarios simulating each industry independently are greater than impacts reported for scenario simulating both industries together. This indicates that overlap of developments and access reduces the disturbances that one might predict from independent consideration of each industry.

The uncertainties associated with gas development parameters are specified at broader scales (3 major play areas in the PMT), and the variance in output results that are summarized at those scales should be a direct consequence of the variances specified in the inputs. When results are summarized over areas that are smaller than the zones used to specify gas development parameters, the degree of variance in the outputs will be greater since spatial placement of gas leases are distributed with uniform probability within the broader defined zones. However, we contend that we are justified in summarizing impacts associated with gas developments at these scales since resulting patterns of disturbances are not totally random. Spatial influence of the cost surface will affect the placement of wells (300m setbacks) and routings of roads and pipelines (least cost paths through the cost surface). Furthermore, the projected locations of access infrastructure will also depend strongly on the locations of existing roads and pipelines, and locations of forestry developments in that time period.

The base case scenario analysis represents one possible future under a set of assumptions that best represents status quo. In order to demonstrate how different management policies will effect rates of development and levels of associated impacts, and therefore provide information on the possible effectiveness and impacts associated with different management policies, it will be necessary to explore alternate scenarios.

References

B.C. Ministry of Forests. 2002. Dawson Creek Timber Supply Area Analysis Report.

Canadian Forest Products. 2005. Sustainable Forest Management Plan 4 for Tree Farm License 48.

Fall, A. 2002. The SELES Spatial Timber Supply Model. Internal Ministry of Forests Report.

Appendix A –The Peace Moberly Tract Cumulative Impacts Model

A.1 Overview

The PMT-CI model framework simulates forest harvesting, natural gas exploration and development, and access infrastructure development (roads and pipeline), and is designed to find a feasible schedule of development given sets of assumptions about (1) expected rates of development and the extent of associated disturbances, (2) constraints controlling rates of development, and (3) constraints controlling levels of impacts on identified values. The model is spatial, and developments are laid out according to assumptions about spatial pattern of developments. Also, map coverage's representing economic, cultural and/or environmental values can be incorporated, so that spatial locations of developments can be manipulated to minimize costs, or maintain impacts below specified thresholds. It is a simulation model with stochastic variables that represent uncertainty about the rates and future locations of development activities, and should therefore be considered a strategic model that informs policy development, rather than an operational planning tool.

The rates and patterns of timber harvesting are controlled by specified harvest levels, harvesting priority rules, and forest cover and adjacency constraints typical of timber supply modelling. Rates of natural gas exploration and development are controlled by random variables specifying the expected numbers of wells drilled each year. Exploration wells are located, accessed and drilled first. Development of production wells follows after successful cases have been identified through drilling of exploration wells. Some horizontal flexibility is afforded to well placement to enable overlap with high priority harvest blocks, and to avoid high cost areas. Although not implemented in the base case analysis, the model is also capable of constraining rates and patterns of natural gas exploration and development in order to maintain impacts below specified thresholds.

The model spatially locates roads and pipelines to access developments by connecting developments to existing infrastructure along least cost paths along a cost surface. At each time period, the resulting road and pipeline network is the minimum required to connect all developments to existing roads or pipelines.

A.2 Forest Harvesting Sub-model

The forest harvesting sub-model is based on the SELES spatial timber supply model (Fall, 2002). This model was originally designed as a spatial analog of FSSIM and is intended to match the results of the TSR analysis when applied under the same management assumptions. The forest harvesting sub-model consists of three landscape events (stand aging and succession, inventory analysis, and forest harvesting) described in more detail below.

The stand aging and succession event increments the stand age at each time step and updates age class, stand height, and seral-stage information. It also facilitates the switch to managed analysis units upon stand regeneration.

The inventory event performs an inventory analysis at each step and tracks the amount of forests above and below thresholds specified for each forest cover constraint within relevant zones (see

Appendix B). Where cover constraints are in violation, older stands are made unavailable before younger stands.

The harvesting event performs harvesting in available cells and simulates the allocation of cutblocks. Within the TSA harvest targets are specified as an allowable annual cut (AAC). Sustainable harvest levels for the portion of the TSA within the study area are specified as volumes and were approximated for the landscape units intersecting the PMT based on methods described in Appendix B.

Available stands are limited to areas in the THLB, eligible resource emphasis zones, within minimum distance of roads (if access constraints are enabled), within minimum distance of recent cutblocks (if adjacency is enabled), and stands older than minimum harvest age. Stands identified as available are then ordered in terms of priority. Harvest priority for available cells is relative oldest first (age relative to minimum harvest age). Stands identified in forestry development plan cutblocks are assigned higher priority to ensure they are harvested first. Cutblocks are then selected with block sizes chosen from a uniform distribution ranging between 10 and 80 ha. As the block is harvested, forest state layers are updated and tracking variables are incremented. The THLB is reduced by 2% to account for new access roads and within block development. Harvesting continues until the harvest target is met, or forest cover constraints become violated.

The harvesting model is applied differently for the area within TFL 48. Harvesting is limited only to the portion of the TFL within the PMT boundary. Spatially delineated harvest blocks scheduled in 10 year intervals for 70 years into the future were provided by the TFL-holder, Canadian Forest Products (Canfor). These harvest blocks are consistent with Canfor's sustainable forest management plan (Canfor 2005), and thus we assume that the area identified for harvesting at each time period is consistent with current management assumptions, does not violate forest cover constraints, and that harvest levels are sustainable. Harvest targets within the TFL are therefore area-based, and for each time period, are determined by dividing the area within all cutblocks for the current decade by the base time-step.

A.3 Natural Gas Exploration and Development Sub-model

The natural gas exploration and development sub-models are designed to operate together with the harvesting and access management sub-models. The conceptual model and parameter estimates comprising this model are based on consultations with the Oil and Gas industry and an aspatial development scenario for the PMT developed by Ministry of Energy and Mines.

The model supports four play types: Monias, Central Plains, Foothills, and unconventional coal bed gas. Because of uncertainty in the economic feasibility in the PMT, a scenario including unconventional CBG development was not simulated. Within the PMTCI model natural gas exploration and development is modeled in two separate processes: 1) well placement and spacing, and 2) exploration and development.

A.3.1 Uncertainty and the Development Processes

The model is designed to find a feasible spatial schedule of natural gas development over time, subject to constraints on rates of development (currently maximum number of wells drilled per year and well densities/spacing). Although not implemented in the base case analysis, rates and patterns of development can also be constrained to maintain tracking indicators below specified thresholds (e.g., to minimize impacts on identified values).

Within the PMT the location and extent of natural gas reserve pools and associated wells is uncertain, and is specified as a uniform probability across the play area (Figure A1). Placement of exploration wells, successful cases, and associated production wells depends on random variables drawn from distributions with a specified range of uncertainty (see Appendix B). The potential characteristics of conventional gas development in the PMT can be estimated by analyzing nearby developed gas fields in geological structures similar to those in the PMT. These analyses provide parameters for expected numbers of exploration wells, probabilities of a success, and expected frequency of successful cases by size class.

The resulting spatial pattern of development is probabilistic and multiple iterations are required for each development scenario in order to capture the range of possible outcomes. Impacts associated with natural gas exploration and development (e.g., well-pads, roads, pipelines, and 3D seismic) are tracked for each iteration and summary statistics are presented as averages bounded with estimates of variance over all replicates.

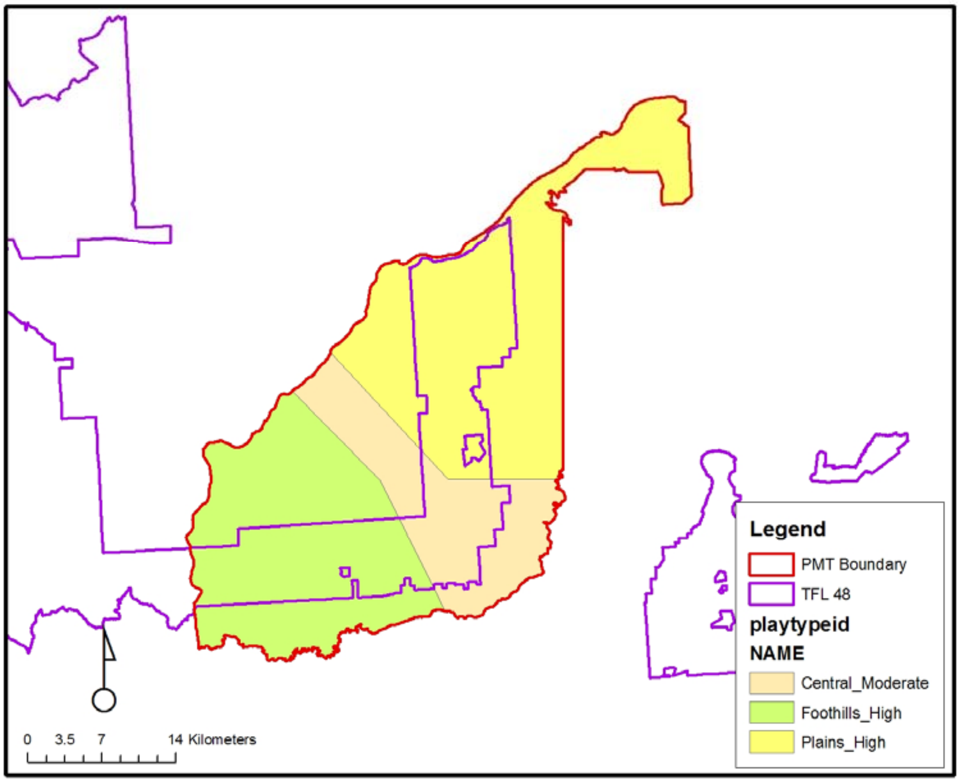


Figure A1. Location of the Plains (Monias), Foothills and Central conventional gas play type zones used to model natural gas exploration and development in the PMT.

A.2.2 Well Placement and Spacing

An exploration event identifies the location and extent of gas reserve pools (cases) within each play type over the entire planning horizon. Multiple replicates are generated to represent range of variability. This is executed once at the beginning of the simulation and is independent of forest harvesting.

A preprocessing step is required to generate the spatial distribution of gas wells in each gas play type. The result represents the full extent of conventional gas development for a particular replicate simulation. Initially, the PMT study area is divided up into equal areas the size of one section of land. The centres of each section are then connected into a triangulated network. This provides an efficient data structure for identifying gas reserve pools.

Each section is assigned as either containing exploration well, or not, with a probability based on the expected number of exploration wells in that play type. Sections containing exploration wells are then evaluated based on a probability of success to determine whether a successful case is present. Successful cases are assigned to one of 3 case classes (low, medium, high) based on a specified probability distribution (pCOS). The total size the case is then determined based on its classification by selecting a value from a normal distribution (pTargetValue; Table 3). See Appendix B for details on default parameter values.

The shape and extent of each case is determined based on the random assignment of a potential gas value to each section of land. Adjacent sections of land are added to the one containing the exploration well, with higher value sections added first, until the combined reserve value of all sections in the cluster is equal to the predetermined target size. In this way, contiguous clusters of sections representing the area containing the case are identified. A directional bias can be incorporated in order to mimic linear trends in reserve pools lying along linear trapping structures. If available, a resource potential map can be used to bias the assignment of resource values to sections with resource potential, thereby increasing certainty of the location of the gas resource.

This process is repeated for a specified number of replicates, resulting in a set of independent representations of the overall pattern and extent of the oil and gas reserve in the PMT.

A.2.3 Exploration and Development

The development event selects and drills wells sites. Exploration wells are drilled first and accessed by winter road. If an exploration well identifies a successful case, then identified cases are selected randomly for activation. Exploration wells within successful cases are converted to production wells and addition production wells are drilled in subsequent time periods. Production wells are accessed by all-season road and pipeline. Active production wells within the case are identified and prioritized based on incremental value and incremental costs of adding the well to the network. Production wells are then accessed by all-season roads and drilled in order of priority. Unsuccessful exploration wells and winter access roads can be reclaimed and after regeneration delay their impacts are no longer counted. Production wells and associated infrastructure remain in place over the entire simulation.

Indicators are measured and reported at each time step. These include numbers and densities of exploration and development wells drilled (by play type), the percent of the total expected development completed, length and densities of roads and pipelines created to access well sites, and area affected by seismic activity.

Natural gas exploration and development is simulated concurrently with forest harvesting. The rate of development is controlled by number of exploration and production wells drilled in each year. Exploration wells are drilled and accessed first. At the end of each time step, those exploration wells identifying successful cases are converted to production wells, and the case is activated. Once active cases are present, production wells are then located randomly sections of land belonging to the active case.

In each time step the number of exploration and production wells to be drilled is determined from a random value selected from a uniform distribution. The location of a well pad is selected randomly from within the section of land containing the well to be drilled. Under current assumptions, up to two wells can be drilled in the same section. If the location falls within a high cost area, then an alternate area may be selected within the specified set back distance.

Although not currently included in base case model assumptions, the model is capable of controlling the rates of natural gas development based on limiting constraints. For example, drilling can stop or slow if impact indicators exceed a specific threshold.

A.4 Road and Pipeline Access Sub-model

At each time step, all extant wells and harvest blocks are linked to existing road and pipelines along least cost paths following a cost surface. The access model creates the minimum amount of roads and pipelines required to link all new developments to each other and to existing access infrastructure. It is therefore assumed that at any given time, the roads and pipelines created by the model can be no less than what is required to access developments existing at that time period. Cutblocks and exploration wells are linked to existing roads by new winter roads. Production wells are linked to existing all season roads by new all season roads, and are also linked to existing pipelines by new pipelines. The assumption is made that roads and pipelines in place now will remain in place in future time periods.

Appendix B – Base Case Scenario Assumptions

The following section describes the model assumptions for the base case scenario with respect to forest harvesting, natural gas development and road and pipeline development. Generally, landbase definitions and forest management assumptions follow the last timber supply review (TSR II, MoF 2002). Assumptions around the spatial distributions, extent and rates of exploration and development of natural gas in the PMT are based on analyses of similar gas field developments in areas surrounding the PMT. This analysis is summarized in Appendix A.

B.1 Forest Harvesting Model Assumptions

B.1.1 Timber Harvesting Land Base

Forest harvesting is assumed to occur only in the area defined within the timber harvesting landbase (THLB). The THLB defined for the TSA portion of the PMT boundary was based on FC polygon database provided by BC Ministry of Forests. This was the same THLB definition used for TSR II and is represented as proportional inclusion factors (MoF 2002). The THLB defined for the portion of TFL48 located within the PMT boundary was based on a polygon coverage provided by Canfor, which also included spatially delineated harvest blocks scheduled in 10 year intervals for 70 years into the future. Within TFL48, all exclusions are represented spatially as either in or out of the THLB. Table B1 provides a summary of areas located with the PMT study area boundary.

Table A1. Summary of area THLB within PMT study area boundary

Unit	Non-THLB (ha)	THLB (ha)	Total Productive
Dawson Ck. TSA	20,592	29,866	50,458
TFL48	10,268	26,294	36,562
PMT Study Area	30,860	56,160	87,020

B.1.2 Resource Emphasis Areas

Non-timber resource objectives are represented in the model through the application of forest cover constraints. Areas subject to the same forest cover constraints are aggregated into resource emphasis areas. Constraints are then applied to each REA independently, thus ensuring that the areas contributing towards satisfying a given constraint are distributed across the landbase. Forest cover constraints are applied in the TSA portion of the study area and follow TSR II assumptions.[1] These include objectives for maintaining visual quality and landscape level biodiversity within the productive forest (Table B2 and B3). Table B4 lists the criteria used in the model to assign stands to seral stage classes.

[1] Forest harvesting in the TFL occurs only in scheduled cutblocks in which harvesting is assumed to meet non-timber resource objectives.

Table B2. Visual quality objectives and corresponding areas within the productive forest in the portions of the TSA and TFL within the PMT study area.

Unit	Constraint	Dawson Ck. TSA (ha)	TFL48 (ha)	PMT Study Area (ha)
Not in VQO		32,031	1,024	33,055
Integrated Resource Mgmt	minimum 67% above 3 m	10,757	33,901	44,658
Modification VQO	minimum 80% above 5 m	891	110	1,001
Partial Retention VQO	minimum 90% above 5 m	4,056	1,366	5,422
Retention VQO	minimum 95% above 5 m	2,387	45	2,432
Preservation VQO	minimum 99% above 5 m	336	116	452
Total (ha)		50,458	36,562	87,020

Table B3. Landscape level biodiversity objectives for biodiversity emphasis options areas located within the productive forest in the portions of the TSA and TFL in the PMT study area.

Unit	Constraint	Dawson Ck. TSA (ha)	TFL48 (ha)	PMT Study Area (ha)
BWBSmw1Int	minimum of 13% above 100 yrs	4,252		4,252
BWBSmw1Low	minimum of 13% above 100 yrs	44,473	28,269	72,742
BWBSwk1Int	minimum of 13% above 100 yrs	726		726
BWBSwk1Low	minimum of 13% above 100 yrs	600	7,554	8,154
SBSwk2Int	minimum of 9% above 250 yrs	387		387
SBSwk2Low	minimum of 9% above 250 yrs	20	739	759
Total		50,458	36,562	87,020

Table B4. Seral stage class definitions used in the PMTCI model.2

BEC	NDT	early (yrs)	mid (yrs)	mature (yrs)	old (yrs)
ATun	5	0 – 39	40 – 119	120 - 249	>250
BWBSmw1	3	0 – 19	20 - 79	80 - 99	>100
BWBSwk1	3	0 – 19	20 - 79	80 - 99	>100
BWBSwk2	3	0 – 19	20 - 79	80 - 99	>100
ESSFmv2	2	0 – 39	40 – 119	120 - 249	>250
ESSFmv4	2	0 – 39	40 – 119	120 - 249	>250
ESSFmvp	5	0 – 39	40 – 119	120 - 249	>250
ESSFwc3	1	0 – 39	40 – 119	120 - 249	>250
ESSFwcp	5	0 – 39	40 – 119	120 - 249	>250
ESSFwk2	1	0 – 39	40 – 119	120 - 249	>250
SBSwk2	2	0 – 39	40 – 99	100 - 249	>250
BWBS_d	3	0 – 39	40 - 99	100 - 139	>140

[2] Based on biodiversity guidebook class definitions.
(http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/biodiv/biotoc.htm)

B.1.3 Harvest Levels

Typically sustainable harvest levels are determined through timber supply analysis, which aims to find harvest levels that ensure a stable growing stock over the mid and long term. Since the PMT study area includes only a portion of the larger Dawson Creek TSA sustained yield unit, it was not appropriate to determine harvest levels following this approach. Therefore sustainable harvest level were approximated from the existing allowable annual cut (AAC) set for the TSA in the last TSR.

The harvesting model operates on a larger study area than the PMT boundary, defined as the extent of all Landscape Units intersecting the PMT boundary (see figure 1). A sustainable harvest level for the portion of the Dawson Creek TSA intersecting the larger PMT study area was determined by computing the proportion of the TSA harvest volume targets expected within the PMT, based on the proportion of the merchantable timber volume in the PMT study area in each analysis unit:

$$AAC_{PMT} = \sum_{i=1}^{n} \left(\frac{V_{PMT,i}}{V_{TSA,i}} \cdot \frac{V_{TSA,i}}{Vt} \cdot AAC_{TSA} \right),$$

where:

$V_{PMT,\,i}$ is the merchantable volume for each analysis unit *i* in the PMT;

$V_{TSA,\,i}$ is the merchantable volume for each analysis unit *i* in the TSA;

Vt is the total merchantable volume for all analysis units in the TSA;

AAC_{TSA} is the annual allowable cut for the TSA.

Table B5 lists area and volumes, and harvest levels derived for the portion of the TSA within LU's intersecting the PMT study area. Sustainable harvest levels for the TSA portion of the PMT (i.e., in all LU's intersecting the PMT boundary) were estimated to be 462,778 m^3/yr. The AAC is divided among three partitions conifer (169,400 m^3), deciduous (215,000 m^3), small pine (7,785 m^3) and represents approximately 1.5%, 2.2% and 0.9%, respectively, of the total standing volume in each partition within the study area. Harvest levels are held constant out to the simulation horizon (50 years).

Table B5. Area and volumes for the Dawson Ck. TSA, and the portion of the TSA intersecting the larger PMT study area

All Productive in TSA	Dawson TSA	PMT TSA	% Difference
Area (m^2)	1,829,933	308,017	16.8%
Growing Stock (m^3) [3]	121,458,320	21,499,408	17.7%
Merch Vol (m^3)	114,407,888	20,282,185	17.7%

[3] Note the Dawson Creek TSA Analysis Report (MOF 2002) reports growing stock at 140 mi m3, with 98% in merchantable stands

AAC (m^3)	**2,078,000**	**391,583**	18.8%
Coniferous			
Area (m^2)	1,003,630	181,128	18.0%
Growing Stock (m^3)	72,866,627	11,029,146	15.1%
Merch Vol (m^3)	69,054,885	10,661,311	15.4%
AAC (m^3)	**1,098,000**	**169,404.9**	15.4%
Deciduous			
Area (m^2)	527,615	116,351	22.1%
Growing Stock (m^3)	37,349,513	9,600,126	25.7%
Merch Vol (m^3)	34,172,104	8,750,881	25.6%
AAC (m^3)	**880,000**	**214,397**	24.4%
Small Pine			
Area (m^2)	298,688	10,538	3.5%
Growing Stock (m^3)	11,242,180	870,136	7.7%
Merch Vol (m^3)	11,180,900	869,993	7.8%
AAC (m^3)	**100,000**	**7,781**	7.8%

B.1.4 Model assumptions for Harvesting Model

The forest cover data and volume projections are based on analysis units and growth and yield projections as specified in the last timber supply review (MoF 2002). Since the last TSR, adjustments (based on VRI Phase II) have been made to the volume estimates in the inventory. The adjusted forest cover data and growth and yield information was not available for this analysis.

Table B6 summarizes additional assumptions in the harvesting sub-model. Stands greater than minimum harvest age, and that are unconstrained by visual quality objectives and landscape level biodiversity objectives are made available for harvesting are processed in order of priority. Harvesting priority is relative oldest first. In the base case analysis, harvesting priorities are not influenced by the cost surface, but have the capability to be. A 2 year regeneration delay is assumed on both forestry cutblocks and winter access roads, and it is assumed these areas regenerate to productive forest and do not contribute as impacts following this period. No explicit adjacency constraints are assumed (i.e., no min green-up time for adjacent cutblocks). Note that without adjacency rules, harvesting may result in placement of adjacent harvest blocks, where the total cleared area exceeds then 80 ha maximum. No access constraints area assumed (i.e., no minimum distance to road criteria). Where available, forestry is assumed to share access roads with those created for natural gas developments.

Table B6. Model assumptions for forest harvesting in the base case analysis

Assumption	Description
Study Area	All LU's intersecting the PMT boundary Lower Moberly, Hudson's Hope, Boucher, Upper Moberly
THLB and forest cover constraints	THLB definition as per TSR II (MoF 2002) VQO's and Landscape Level Biodiversity only Targets, thresholds and seral stage definitions as per TSR II
Harvest Levels - Dawson Creek TSA	approximated harvest targets based on proportion of merchantable volume in each analysis unit within the PMT Harvest targets specified for three partitions: Coniferous, Deciduous, Small Pine As per PA13, harvesting of deciduous partition occurs within the both the TSA and TFL
Harvest Levels - TFL 48	Harvest targets for conifer stands in TFL 48 are based on area within 10-year FDP harvest block polygons provided by Canfor Harvesting in TFL48 occurs only within the PMT boundary
Harvest Priority	Relative oldest first priorities are not influenced by cost surface
Block size	selected from uniform distribution ranging from 10 – 80 ha
Regeneration Delay	2 year regeneration delay on forestry cutblocks 2 year regeneration delay on winter access roads
Adjacency	No explicit adjacency (i.e., no min green-up time for adjacent cutblocks) Note, this may result in harvesting of adjacent blocks, which may increase block size above 80 ha.
Access Constraints	no access constraints (i.e., no minimum distance criteria) shared access with oil and gas developments (i.e., use existing all season or winter roads, but only build new winter roads to access cutblocks)
Base Time Step	5 years
Reporting Interval	10 years

B.2 Gas Exploration and Development Assumptions

Based on analysis of adjacent gas fields, we expect that of the 24 exploration wells drilled in Monias (Plains) play area, 33% will identify successful cases. Of the 40 exploration wells drilled in the Foothills play area, 40% will identify successful cases, and of the 18 exploration wells drilled in the central play areas, 25% will identify successful cases (W. Walsh pers. comm.; Table B7). Natural gas exploration and development is limited to the area identified as available for exploration and development (B. Purdon pers. comm.; Table B7; Figure B1). Well spacing is assumed to be one exploration well lease per section of land (1600 x 1600 m), and up to two production well leases per section for successful cases (Table B7). For all three play areas we expect that 20%of the identified cases will have a reserve size of less than 6 BCF (low), 70% of cases will be 20 BCF (medium), and 10% of cases will be 100 BCF (high).

We assume where available, natural gas development will share access roads with forestry. In the base case analysis, drilling of wells are not limited by minimum distance to roads criteria. In each time period, all existing well sites are linked to existing infrastructure (i.e., the current network of roads and pipelines). Exploration wells are built accessed by winter roads; all season roads are built to access production wells. Pipelines are built to link production wells to existing pipelines.

Drilled and abandoned exploration wells and the winter roads built to access them are assumed to be reclaimed to planted seed mixtures or natural re-vegetation after 4 years. Once reclaimed, it is assumed that they no longer contribute to cleared areas or linear features impact indicators. Once drilled, production wells and the all season roads and pipelines built to access them are assumed to be in place for the entire simulation.

Table B7. Model assumptions for oil and gas development in the base case analysis

Assumption	Description
Study Area	PMT study area boundary (excluding areas listed below) Three play types: Foothills, Central, Monias-Plains Type Coal bed gas type play not be included in the base case scenario
Areas excluded from exploration	Peace River Watercourse Peace-Boudreau PA Lakes >300m in diameter FN Reserves
Spacing - Exploration	One lease per section One well pad per lease
Spacing – Production	Two leases per section One well pad per lease
Number of exploration wells	Monias: 24, foothills: 40, central: 18
probability of success	Monias: 0.33, foothills: 0.40, central: 0.25
expected distribution of case sizes (for all play areas)	20% low, 70% medium, 10% high
Area impacted by 3D seismic	0.000791 ha seismic/ ha exploration
Number of exploration wells per year	random value selected a uniform distribution ranging from 2 to 5
Number of exploration wells per year	Production wells per year (for successful cases) - random value selected a uniform distribution ranging from 2 to 4
Access and Infrastructure	Shared access with forestry No access constraints (i.e., no minimum distance criteria) Use existing all season or winter roads Build new winter roads to access exploration wells Build new all season roads to access production wells Build new pipelines to link production wells existing pipelines
Set backs (horizontal flexibility)	wells can be drilled in all areas except those excluded from exploration (see above) move wells up to 300m to area with lowest impact (see cost surface descriptions below)
Depletion rates	no depletion of production wells
Regeneration Times	drilled and abandoned exploration wells and winter roads to access them are assumed to be reclaimed after 4 years (i.e., no longer contribute as impacts) drilled production wells are in place for the life of the simulation
Base Time Step	5 years
Reporting Interval	10 years

Conventional - Plains - East side of PMT

1.5 prospects as follows:

	Low case			Medium Case			High Case		
Chance of Success	0.2			0.7			0.1		
Units		m2	ha		m2	ha		m2	ha
Reserves (BCF)	<6			20			100		
# wells per success	1.5	12675	1.3	6	50700	5.1	20	169000	16.9
Area per success (Section)	1 Section			3 Sections			10 Sections		
Pipeline	No Pipeline	0	0	Pipeline & Road	236772	23.7	Pipeline & Road	789240	78.9
Compressor	No Compressor	0	0	Half a Compressor	8450	0.8	1 Compressor Station	16900	1.7
3 D Seismic per success	No 3D Seismic	0	0	1.5 Sections 3D Seismic	62400	6.2	5 Sections 3D Seismic	208000	20.8
2 D seismic left	2D Seismic	1328400.0	132.8		1328400.0	132.8		1328400.0	132.8
Sub-total		*1341075*	*134.1*		*1686722*	*168.7*		*2511540*	*251.2*

Number of expected successes			1.6			5.5			1
Total area (ha) impacted w/o 2 D & expl wells			**2**			**199**			**94**
Total area impacted (ha)			**454**						
% total area impacted			**0.62**						
Reserves (BCF)			**121**						

Assume		
	m2	ha
3D / section = (((1600/450*4.5)*1.25)*1600)*1.3	41600	4.2
Total 2D in plains area = 1.5*1600*8 *36*4.5	3110400	311.0
2D Impacted to-date =600*1000*4.5*.66	1782000	178.2
2D left	1328400.0	132.8
2 wells/lease		
~600km 2DSeismic in PMT already		
Total number of Exploration Wells		24
Chance of Success		0.33

Given/Assumptions		**Units**
Lease size is 130 m x 130 m (same for a compressor)	16900	m2
No. m2 in a ha	10000	m2
Spacing of a seismic line	450	m/Section
Width of a seismic line	4.5	m
2D seismic is 1.5 lines/section		
Add 1 seismic line for every 4 of 3 D (multiply by 1.25)	1.25	-
30% mark up on 3D (multiply by 1.30)	1.3	-
1.2 km of road/well	1200	m
1.2 km of pipeline/well	1200	m
All season road ROW is 20 m wide	20	m
Winter road ROW is 10 m wide	10	m
Winter roads are used 33% of the time		
Pipeline ROW is 15 m wide	15	m
Pipeline & roads over lap 70% of the time		
Pipeline & road 70% overlap weighted mean	27.9	m

Analogy: Monias

847 km of seismic
189 km of road
71 tied in wells (including 11 exploratory) (appears to be 1 well/lease)
297 km pipeline
average road/well 2.7 (we estimated 1.2km/well at 2 wells/lease and Monias has single well lease)
average pipeline/well 4.2 (this double our estimate)

Figure B1. Scenario for a Monias/Plains conventional gas development in the east side of the PMT

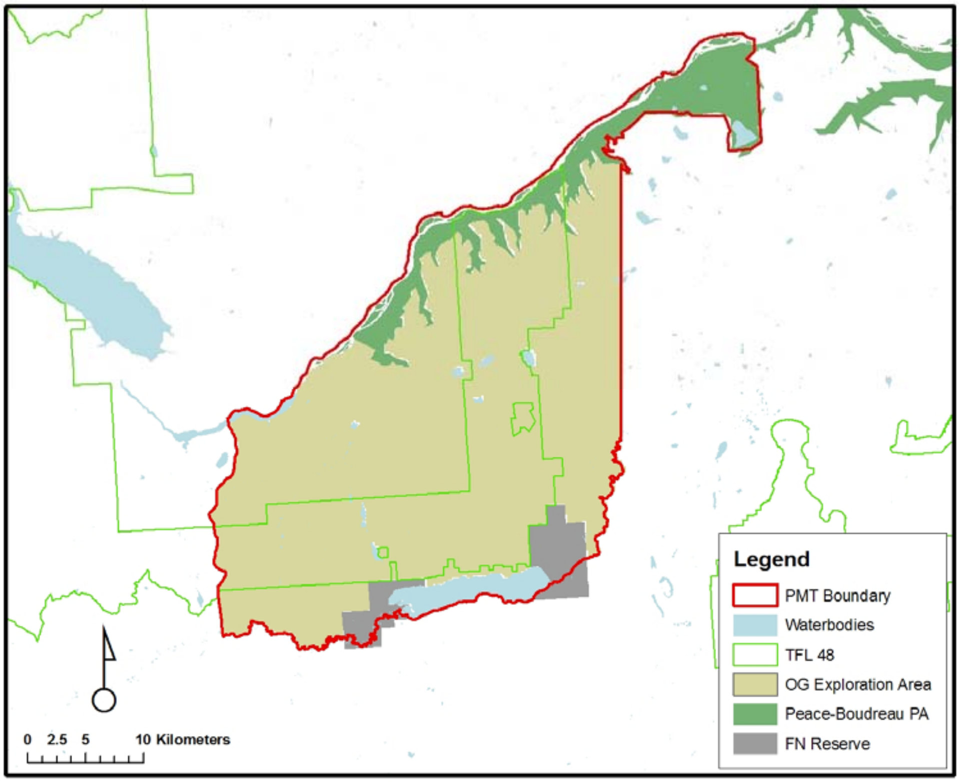


Figure B2. **Area available for oil and gas exploration and development (shown in beige). Excluded areas were FN reserves, water bodies > 300m diameter, Peace Boudreau PA, and Peace River (B. Purdon pers. comm.).**

B.3 Road and Pipeline Access Assumptions

The following describes the methods used to identify and classify the existing road infrastructure within the PMT. Table B8 lists sources of road line work made available for the modelling exercise. Features within these coverage's were interpreted and classified into winter access only and all season access roads according the criteria listed in Table B9. Trails were excluded from the resulting road coverage. Figure B3 shows the location of the current network of winter and all season roads used in the modelling analysis.

Table B8. Available road feature database

Name	Filename
TRIM transportation features	ttransport_pmt.shp
MOF forest tenure roads (new system)	rds_ften_pmt.shp
Canfor existing roads	rds_cfp_exist.shp
Canfor Proposed roads	rds_cfp_propose.shp
OGC Petroleum development roads	tpdr_pmt.shp

Table B9. Reclassification of existing road feature database for spatial modeling in PMT.

ReClass	Acccess	Sources	Selected Features
Paved roads	year-round	TRIM transportation features	all features classes specifying "paved"
Gravel roads	year-round	TRIM transportation features	all features classes specifying "gravel"
Forest development roads	year-round	MOF forest tenure roads	all features not previously classed as "Gravel roads"
Forest development roads	year-round	Canfor existing roads	all features not previously classified
Forest development roads	winter-only or uncertain	TRIM transportation features	all features classes specifying "road.unimproved"
Forest development roads	winter-only or uncertain	Canfor Proposed roads	all features not previously classified
Petroleum development roads	year-round	OGC Petroleum development roads	all features not previously classified
Trails	quad only	TRIM transportation features	features classes specifying "trail" or "road.overgrown"

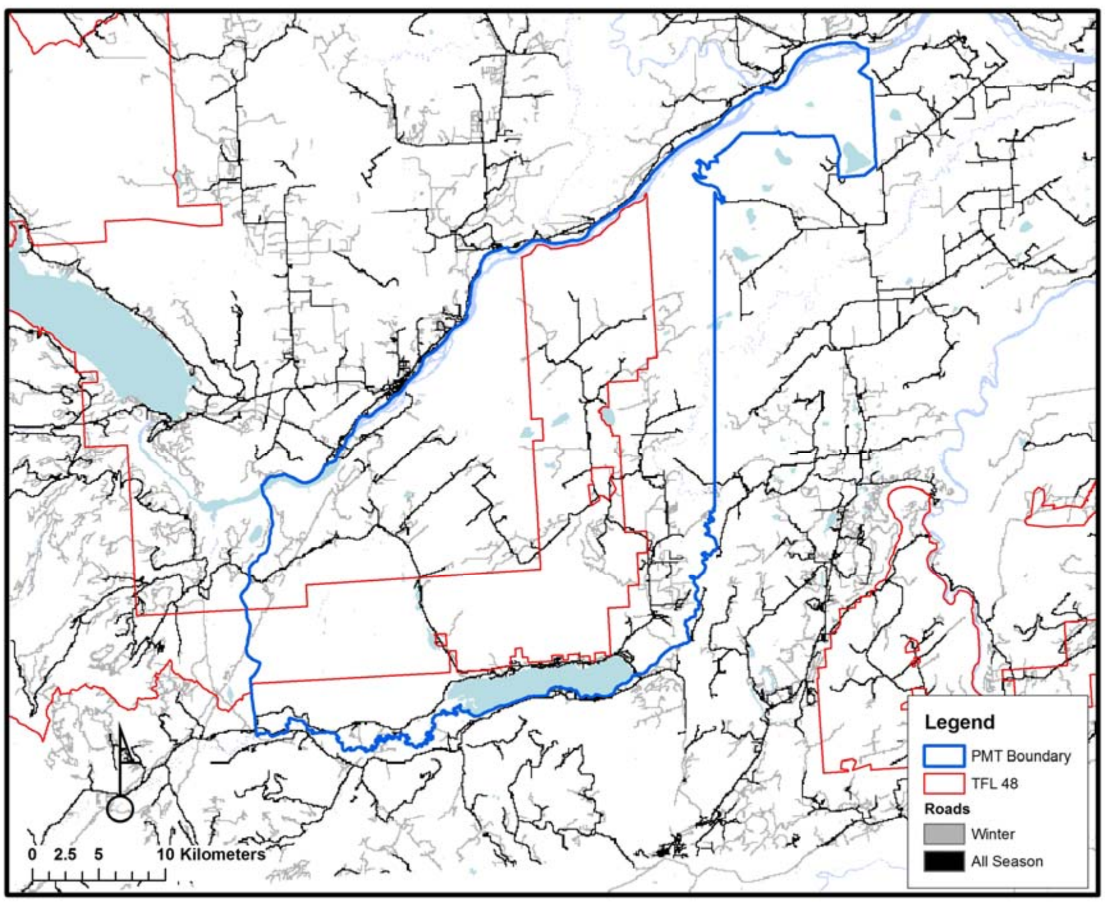


Figure B3. Location and classification of road network for the PMTCI model.

B.4 Base Case Cost Surface

The model's spatial behaviour (development and location of roads, pipes, harvest areas and well sites) is also a property of the scenario, representing policy constraints on development. These restrictions and preferences are represented in the model as a cost surface. Cost surfaces are used by the model to influence the location of roads and pipelines, and the placement of well sites. Under base case model assumptions, forestry and oil and gas development were not directly constrained by features represented in the cost surfaces. Rather, the cost surfaces effect the spatial location of well pads and roads and pipelines in the model in following the ways:

Well Setbacks - A 300m setback rule is applied for locating well pads, so that wells are placed within the lowest cost location within 300 m of originally selected location.

Infrastructure - Well pads and cutblocks are linked to existing infrastructure along roads and pipelines that follow the least cost path across the cost surface. In areas with uniform cost, the least cost path would be a straight line.

The cost surface does not altogether exclude wells, roads or pipelines from high cost areas. Rather, placement of developments (excluding harvest blocks) favor the lowest cost alternative where possible. For example, if a well-pad and an existing pipeline were separated by an area with uniform cost, then the connecting pipeline would follow a straight line. If a lake were located between the well pad and an existing pipeline, the connecting pipeline would follow the least cost route around the lake. However, if a river were located between the well pad and an existing pipeline, the connecting pipeline would still cross the river because there would be no alternate lower cost route. Figures B4 and B5 show features used to define cost surfaces.

Figure B4. Location of sensitive area features used in the cost surfaces

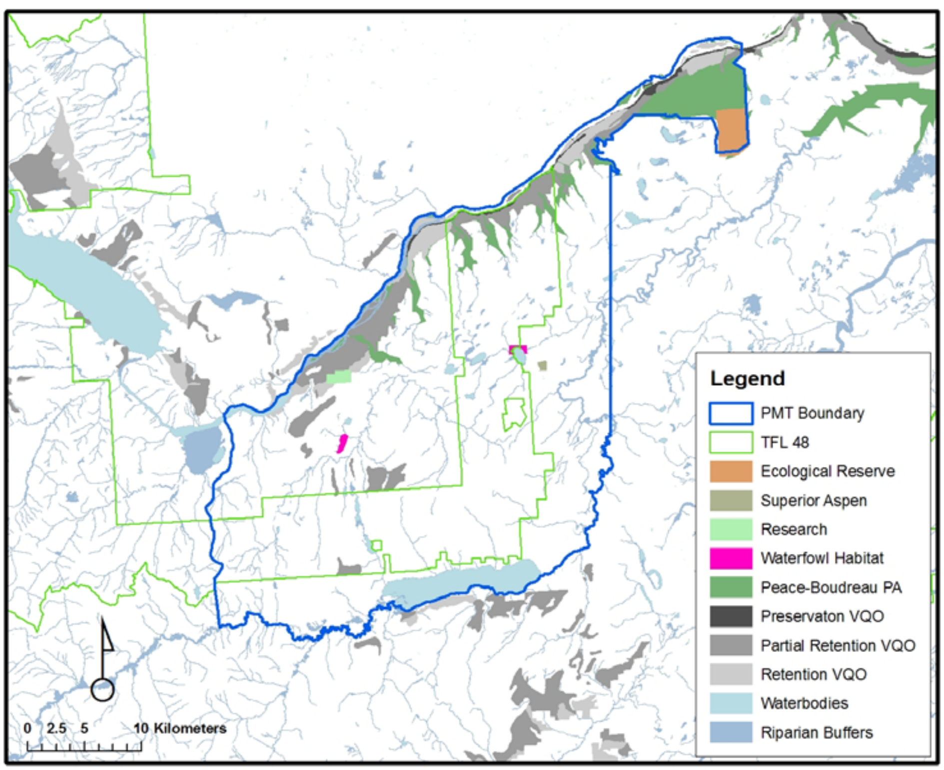
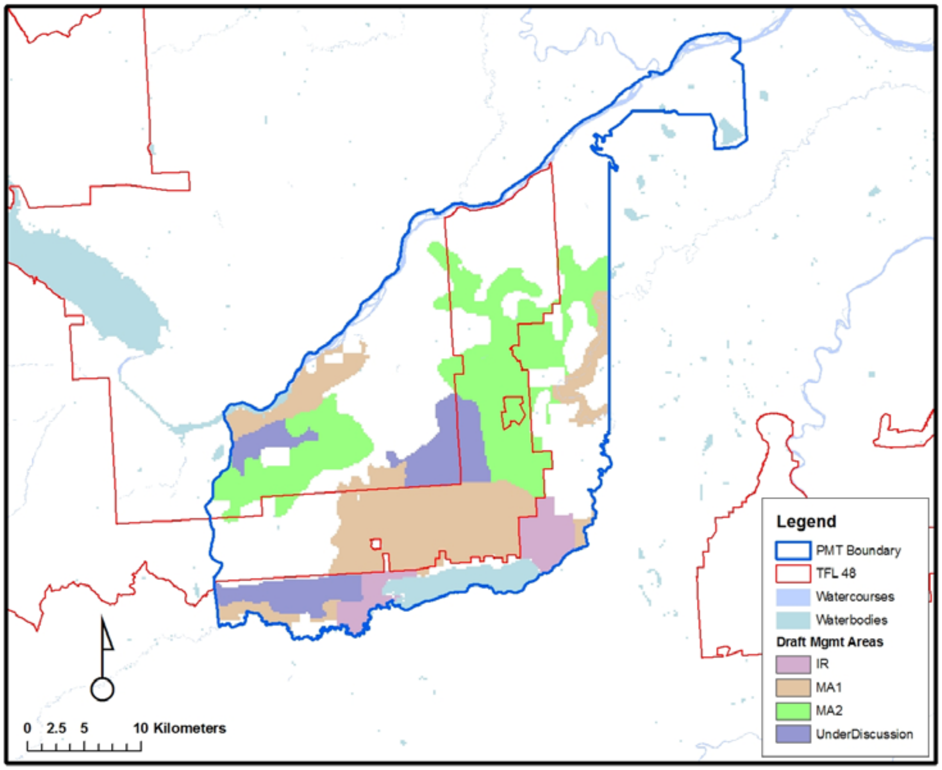


Figure B5. Location of draft management areas

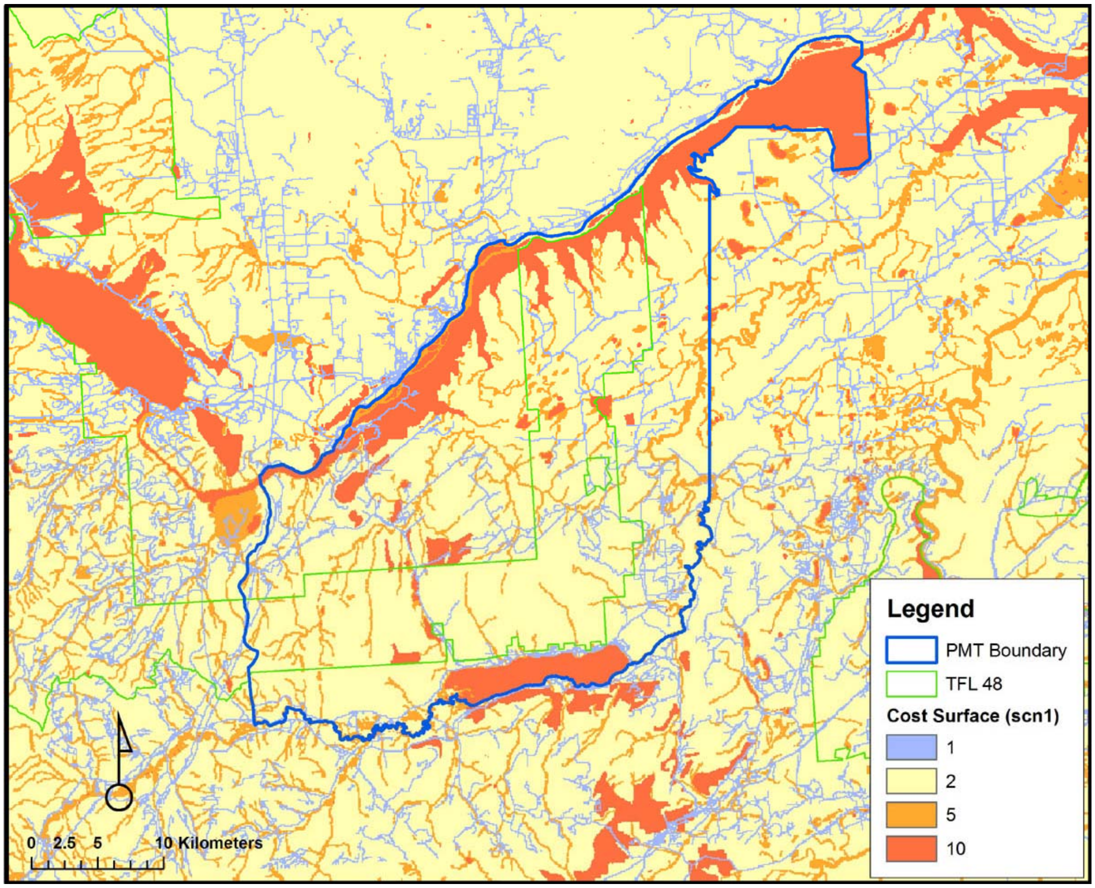


Spatial features and assigned values used to create the cost surface are listed in Table B10. Sensitive areas were assigned a cost value of 10. These included all lakes and major river corridors, waterfowl sites, parks and protected areas, research reserves, ecological reserves and superior aspen clones. Also included were protection, retention and partial retention visual quality zones. All existing roads and pipelines were assigned lowest cost, and rivers and lakes were assigned a cost of 5. The complete cost surface for the base case scenario is presented in Figure B6.

Table B10. Cost surface representing current management with avoidance of sensitive areas

Feature	Cost	Data Source
Existing Roads/Pipelines	1	see appendix 3
Non-sensitive areas	2	n/a
Rivers and Streams (RMZ)	5	ddc_rip_buf.prj
Lakes and Major River Corridors	10	waterbodies_trim_pmt.shp
Waterfowl Sites	10	trump_swans2005.shp
Parks and Protected Areas	10	pbdreau.e00
VQO (P, PR, R)	10	ddc_vqo.shp
Research Reserves	10	sensitive_tenures.shp
Ecological Reserves	10	sensitive_tenures.shp
Superior Aspen Clones	10	sensitive_tenures.shp

FigureB6. Cost surface for base case with sensitive areas, base case scenario



Levels of disturbance are tracked over time by indicators measuring variables representing impacts associated with development. These include density of linear features, density of well sites and area cleared (total surface disturbance), and are reported out by various stratifications of the landbase. Additionally, spatial outputs are produced as probability surfaces representing the frequency in which a particular area was disturbed over all replicate simulations.

Since no disturbances occurs at time = 0, indicator values for all scenarios are equal, and are representative of baseline conditions for the study area. Over time, differences in indicators values between scenarios reflect the different values represented in the cost surfaces.

Appendix C – Model Indicators

C.1 Modelling Indicators

Model indicator tables are provided as tab delimited text files. Indicator values for multiple replicates are recorded consecutively in the file. Summary statistics can be computed using pivot tables in MS Excel (or MS Access for larger files). Although indicators are reported for the entire study area (including all LU intersecting the PMT), indicator summaries presented in this report are reported out for the area within PMT Boundary only.

C.1.1 Natural Gas Development Indicator (oGasDevelopment.txt)

This file includes output of variables tracking levels of gas exploration and development. These include the number of exploration and production wells drilled in each play type, the proportion of the total number of wells to be drilled, the number and proportion of active cases, and the cleared area for seismic (Table C1).

Table C1. Field description for Oil and gas development indicator file.

Field	Description	Comment
CurrReplicate	replicate number	
Year	years from present	
nExpDrilled	cumulative number of exploration wells drilled for all play types	
nProdDrilled	cumulative number of production wells drilled for all play types	
PlayType	plains, foothills, central, CBG	A development scenario for CBG is not currently implemented
tExpDrilled	cumulative number of exploration wells drilled by play type	
nExpActive	cumulative number of exploration wells identified as successful (i.e., active cases)	
pExpDrilled	percent of the total number of exploration wells drilled for the replicate	
tProdDrilled	cumulative number of production wells drilled by play type	
pProdDrilled	percent of the total number of production wells drilled for the replicate	
nActiveCases#1 - 3	cumulative number of active cases in each case class (1: LOW, 2:MED, 3:HIGH) by play type	
tCases#1 - 3	total number of cases in each case class (1: LOW, 2:MED, 3:HIGH) by play type for the replicate	
AreaSeismic#1-2	cumulative area effected by seismic exploration (1:2D, 2:3D)	only 3D seismic is tracked

C.2 Forest Harvesting Indicators

A brief description of forest harvesting indicators are provided below. These files are useful for examining details on the state of the forest and harvesting activity over time.

C.2.1 Forest State Indicators

ageClass.txt

This file includes output of variables tracking the area of productive forest (ha) in 10 year age classes (up to 400 years), stratified by area inside the THLB (C#0 – C#10) and area outside of the THLB(NC#0 – NC#40). The first column (Simulation) indicates the replicate from which values are reported.

seralStage.txt

This file includes output of variables tracking the proportion of the landbase in young, immature, mature, and old seral stage classes defined according to table 12. Proportions are reported for the total landbase, contributing only (C), operable excluded only (OX), and inoperable landbase (I).

C.2.2 Forest Inventory Indicators

Growing Stock.txt

This file includes output of variables tracking the volume of live forest (m^3), area (ha) and mean age in various stratifications of the landbase.

LimitingConstraints.txt

This file includes output of variables tracking the area of the forest made unavailable for harvest according to various constraints. This is output as net and gross values, where the net value is the incremental area constrained after preceding constraints have been accounted for, and the gross value is the total amount that would be constrained independent of other constraints. The primary order of constraints applied is: 1) minimum harvest age, 2) road access (if enabled), 3) adjacency (if enabled), 4) forest cover constraints applied in order specified in input file.

C.2.3 Forest Harvest Indicators

harvestRecord.txt

This file includes output of variables tracking key aspects of the harvesting process (Table C2). All values are reported as means across the base time period (in this case 5 years).

Table C210. Field description for harvest report indicator file

Field	Description	Comment
CurrReplicate	replicate number	
Year	years from present	
vHarvTSA	volume harvested (m^3) with the TSA	
vHarvTFL	volume harvested (m^3) in TFL48	limited to scheduled harvest blocks identified within the PMT boundary
aHarvTSA	area harvested (ha) within the TSA	
aHarvTFL	area harvested (ha) within TFL 48	limited to scheduled harvest blocks identified within the PMT

		boundary
aAccessedTSA	area accessed (ha) within the TSA	
aAccessedTFL	area accessed (ha) within TFL 48	assumes area within scheduled cutblocks is 100% THLB
MnVPHtsa	mean volume per hectare harvested in the TSA	
MnVPHtfl	mean volume per hectare harvested in the TFL	
PercentOfTargetTSA	Percent of target volume harvested	harvest targets based on specified harvest levels
PercentOfTargetTFL	Percent of target volume harvested	harvest targets based on area within scheduled cutblocks
MnHarvAgeTSA	mean age of stands harvested in the TSA	
MnHarvAgeTFL	mean age of stands harvested in the TFL	
KmRoadsBuilt	kilometers of winter access roads built to access harvest blocks (includes spurs)	
vPrtn#1-4	volume harvested (m^3) in each partition of the AAC (1:Conifer, 2:Deciduous, 3:SmallPine, 4: TFL48)	
pAC	proportion volume harvested as Poplar and Black Cottonwood	
pAT	proportion volume harvested as Trembling Aspen	
pDR	proportion volume harvested as Red Alder	included in indicator, although not in contributing landbase
pE	proportion volume harvested as Birch	included in indicator, although not in contributing landbase
,pB	proportion volume harvested as Balsam	
pL	proportion volume harvested as Larch	included in indicator, although not in contributing landbase
pP	proportion volume harvested as Lodgepole Pine	
pS	proportion volume harvested as Spruce and Black Spruce	
NRLVol	Volume non-recoverable losses	
NRLArea	Area of non-recoverable losses	
pOld	proportion volume harvested classified as old stands	
pThrifty	proportion volume harvested classified as thrifty stands	
pManaged	proportion volume harvested classified as managed stands	
MeanPTHLB	area harvested / area accessed	
nSoftAdjViolations	number of soft adjacency violations	not enabled

C.2.4 Stratified Summary Outputs for Cumulative Impacts Analysis

In addition to the indicator files listed above, a series of indicator variables were measured for areas located within selected stratification zones. The file is formatted as a cross tabulation, where each row represents a unique strata combination. For each unique strata combination, a series of measured variables were reported. These files can be analyzed using pivot tables to summarize area and density measurements within zones of interest.

Stratified Indicator for Forest Harvesting (Forestry.txt)

This file reports measurements of area, growing stock and merchantable volume within a series of stratification zones for each replicate (Table C3). Stratified indicators are reported for each replicate once at the beginning of the simulation, and then every 10 years over the 50 year simulation time. Because of the number of unique categories within each strata, and the number of replicates run, the number of records reported for each time period is very large. The resulting text file is very large and cannot be opened in Excel, and should analyzed using MS Access, or other appropriate database software, in order to produce pivot table summary statistics.

Table C311. Description of stratified summary output file for forest harvesting

Field	Description	Comment
Year	years from present	currently reporting interval is set to 5 years.
Replicate	replicate number	
Strata		
PMT	PMT Boundary	0:out, 1:in
MU	Management Unit (TSA, TFL48)	
THLB	Timber harvesting landbase	0: <50% contributing 1: >=50% contributing
VQO	Visual Quality Objectives	1:IRM 2:VQOm 3:VQOp 4:VQOpr 5:VQOr
LU	Landscape Units	1:LowerMoberly 2:HudsonsHope 3:Boucher 4:Gething 5:UpperMoberly
AU	Analysis Units	see MoF 2002 for AU descriptions
Partition	Harvest Level Partition	deciduous conifer small pine
SeralStage	Seral Stage Class	see table 12 for seral stage class definitions.
Measured Variables		
Area	area (ha)	
Vol	volume of live trees (m^3)	
merchVol	volume of merchantable trees (m^3)	

Stratified Indicator for Gas Development (sGasDevelopment.txt)

This file reports measurements of area, area of seismic disturbances, number of wells, and lengths of pipeline and roads within a series of stratification zones for each replicate (Table C4). Stratified indicators are reported for each replicate once at the beginning of the simulation, and then every 10 years over the 50 year simulation time.

Table C4. Description of stratified summary output file for gas development

Field	Description	Comment
Year	years from present	currently reporting interval is set to 5 years.
Replicate	replicate number	
Strata		
PMT	PMT Boundary	0:out, 1:in
PlayType	Gas Playtype	Monias Plains Central
Measured Variables		
kmASrd	Kilometres of all season roads	nb: densities are computed by dividing by strata area
kmWrd	Kilometres of winter roads	
kmPipe	Kilometres of pipeline	
nWell	Number of wellpads	
aSeismic	Area cleared for 3d seismic (ha)	
Area	area (ha)	

Stratified Indicator for Cumulative Impacts Analysis (CumulativeImpacts.txt)

This file reports measurements of area, cleared area, length of linear features, road stream crossings within a series of stratification zones for each replicate (Table C5). Stratified indicators are reported for each replicate once at the beginning of the simulation, and then every 10 years over the 50 year simulation time.

Table C5. Description of stratified summary output file for cumulative impacts.

Field	Description	Comment
Year	years from present	reporting interval is currently set at 10 years.
Replicate	replicate simulation number	
Strata		
PMT	PMT Boundary	0:out, 1:in
PlayType	Gas Playtype	Monias Plains Central
Moose	Moose Habitat Capability	0:NoData 1:VHigh 2:High 3:Moderate

		4:Low 5:VLow 6:NonHab
CUA	Draft Management Areas	MA1: Management Area 1 MA2: Management Area 2 Pending: Under Discussion FNReserves: First Nations Reserves
Measured Variables		
Area	area (ha)	
clearedArea	Cleared Area (ha)	Cleared areas include wellpads, roads, pipelines, 3d seismic, and harvest blocks Cleared areas do not include camp locations, borrow pits or sumps. A cell is identified as cleared when the combined area cleared is >50% of the cell
kmLinear	Kilometres of linear developments	length of all season roads, winter roads and pipelines combined overlapping areas are counted only once densities are obtained by dividing by strata area
wS1S4	Winter road stream crossings for stream class s1 to s4 (fish bearing)	
wS5S6	Winter road stream crossings for stream class s5 to s6 (non-fish bearing)	
asS1S4	All season road stream crossings for stream class s1 to s4 (fish bearing)	
asS5S6	All season road stream crossings for stream class s5 to s6 (non-fish bearing)	
kmS1S4	Length of fish bearing streams (class s1 to s4)	
kmS5S6	Length of non-fish bearing streams (class s5 and s6)	