Cortex Consultants

# Fertilization Strategy and Tactical Plan: Quesnel Timber Supply Area

Version 1

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prepared for: **Quesnel TSA Strategic Forest Analysis Steering Committee**

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## Acknowledgements

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# 1 Introduction

The BC Forests for Tomorrow initiative is a provincial strategy to improve long-term timber supply through the re-establishment of forests that would otherwise remain non- or under-productive. The program includes the planning, development, and operations necessary to rehabilitate and reforest areas affected by: the Mountain Pine Beetle and wildfire; pre-existing areas classed as Not Satisfactorily Restocked; and, potentially, other areas that would otherwise not be re-forested (MoFR, 2005).

A potential method of improving timber supply is to enhance the growth of forest stands through fertilization. Forest fertilization has recently been approved in principle as a Mountain Pine Beetle (MPB) mitigation treatment.

The Quesnel Timber Supply Area (TSA) is a prime candidate area for mitigation since it is one of the areas most heavily impacted by the MPB. Significant short- to mid-term timber supply impacts have been forecast (MoF, 2004).

## 1.1 Project Objective

The objective of this project is to develop a tactical level fertilization strategy for the Quesnel TSA. The tactical strategy will provide the rationale for a five-year fertilization scheme and will spatially identify potential candidate stands. Candidate stands will require field reconnaissance in 2006 to confirm the proposed treatment. The field reconnaissance will be conducted under a separate operational-level project implementation led by West Fraser Mills Ltd. in Quesnel. It is expected that the TSA implementation will be coordinated with TFL and other proposed fertilization schemes to maximize efficiencies and minimize costs. The objectives of the fertilization strategy are:

- to mitigate short and mid-term timber supply impacts through strategically focused fertilization activities,
- to add merchantable volume to existing age class 1-4 stands to ensure that they can be operable sooner and mitigate mid-term timber supply impacts,
- to modify age class imbalances and help redistribute timber flow and availability,
- to help reduce the depth and duration of reduced timber supply,
- to help reduce the community and regional economic impacts due to the MPB infestation,
- to carry out investments in crown land to support both short and mid term employment, and
- to be an important complement to the FFT strategic investments which primarily focus on improving mid- to long-term impacts.

# 2 Methods

## 2.1 Developing an Initial Candidate Stand List

Fertilization candidate stands were selected from the resultant used for the Quesnel Type II silviculture analysis. Key selection criteria were the primary species, inventory site index, and inventory age class. Stands from the total productive forest were included in the selection set. In a second step, additional polygons were removed from the first selection set using refined criteria. Table 1 list the criteria used in the analysis.

**Table 1. Criteria for identifying candidate areas for fertilization.**

| Criteria # | Criteria | Criteria Notes |
|---|---|---|
| 1 | Leading species >80% F or S, wet belt or transition (submesic, and mesic) | |
| 1 | F or S mixed > 60%, wet belt or transition (submesic, subhygric and mesic) | |
| 2 | Site Index > 16 (current inventory based) | |
| 3 | Priority age class: 5 then 4 then 3 then 2 | Age class 5=81 to 100 yrs<br>Age class 4=61 to 80 yrs<br>Age class 3=41 to 60 yrs<br>Age class 2=21 to 40 yrs |
| 4 | Avoid rare ecosystems: SBSmw/00, MSxv/05, MSxv/02, SBSmw/03, SBSmk/02, SBSwk1/03 | |
| 5 | Avoid ungulate management areas | |
| 6 | Avoid high snow loading areas | |
| 7 | Avoid blocks with a high proportion of RMA, RRZ | Used only RRZ as selection criteria. |
| 8 | Avoid ESA's | |
| 9 | Avoid OGMA's | |
| n/a | Avoid proposed CLA's (Conservation Legacy Areas) | Final CLA's not available for the analysis. This selection criteria was not used. |
| 10 | < 100 km. to mills | 110 km was used to represent Quesnel city limits. |
| 11 | Target stands within 2 km. of existing roads | This was completing using orthophotos during visual selection process. |
| 12 | Slopes < 40% | All slopes in the final analysis area were < 40% slope. |

## 2.2 Establishing Stand Priorities with Orthophotos

Candidate stands were selected from the resultant using criteria 1-9. A coverage developed from this selection set was plotted on orthophotos, which were subsequently reviewed visually to select candidate stands using selection criteria 10, 11 and 12. Polygons were ranked as 1 (good candidate and requires immediate inspection), 2 (medium candidate and inspection can be completed in 2007 and beyond), and 3 (poor candidate not requiring inspection).

## 2.3 Estimating Yields for Interim Candidate Stand Types

Following photo assessment, batchTIPSY and TIPSY were used to update inventory volumes, predict harvest volume, and produce economic value estimates. Brockley (pers. com.) suggested that batchTIPSY may underestimate fertilization effectiveness and/or unduly increase compensation for competition, so yields were estimated with both systems.

### 2.3.1 batchTIPSY

Two yield tables per polygon were produced: no fertilization and fertilization. Fertilization age is inventory age.

For stands aged >40 years natural regeneration is assumed. All other assumptions are based on TSR 2 documentation.

Stands aged <= 40 are assumed planted and used all other TSR 2 assumptions.

For Douglas-fir polygons all BEC zone are assumed to be ICH. This assumption is applied because TIPSY does not show gains for all other interior BEC zones.

Table 2 lists the assumptions used for the batchTIPSY runs.

The harvest age is estimated by finding the minimum age when the polygon reaches 140 $m^3$/ha. Minimum harvest age is calculated as the age when polygon volume is >= 140 m3/ha. If the minimum harvest age is less than the fertilization age the minimum harvest age is fertilization age + 10. If the minimum harvest age is below the inventory age, then harvest age is inventory age + 10. Volume and revenue estimates are based on the volume harvested at the harvest age.

The total volume benefit from fertilization is calculated as the harvest volume from the fertilized yield table **minus** harvest volume from the non-fertilized yield table.

### 2.3.2 TIPSY

Fertilization analysis units are specified based on primary species, secondary species, BEC label, and inventory age. It was assumed that all secondary species for Douglas-fir are spruce (Brockly, pers. comm. and all secondary species in spruce polygons were ignored. The fertilization effectiveness was assumed to be 100% in consideration of the OAF1 and OAF2 values of 85% and 95% respectively. Table 3 lists the TIPSY assumptions.

Minimum harvest age is calculated as fertilization age + 10 or the age when polygon volume is >= 140 $m^3$/ha. If the minimum harvest age is less than the fertilization age the minimum harvest age is fertilization age + 10. If the minimum harvest age is below the inventory age, the harvest age is inventory age + 10. Volume and revenue estimates are based on the volume harvested at the harvest age.

The total volume benefit from fertilization is calculated as:harvest volume from the fertilized yield table **minus** harvest volume from the non-fertilized yield table.

**Table 2. batchTIPSY assumptions used in the fertilization analysis.**

| Primary Species | Inventory Age | Regen Method | Regen Delay | Expected Species | % Composition | Initial Density | BEC | Fert Age | OAF 1 | OAF 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fdi | > 40 | Natural | 2 | Inventory Species 1 and Species 2 | Inventory Species 1 % and Species 2 % | 2300 | ICH | Inventory Age | 15 | 5 |
| Fdi | <= 40 | Plant | 2 | Inventory Species 1 and Species 2 | Inventory Species 1 % and Species 2 % | 2300 | ICH | Inventory Age | 15 | 5 |
| S | > 40 | Natural | 2 | Inventory Species 1 and Species 2 | Inventory Species 1 % and Species 2 % | 3000 | Inventory BEC | Inventory Age | 15 | 5 |
| S | <= 40 | Plant | 2 | Inventory Species 1 and Species 2 | Inventory Species 1 % and Species 2 % | 3000 | Inventory BEC | Inventory Age | 15 | 5 |

**Table 3. TIPSY assumptions used in the fertilization analysis.**

| Fert Au | Species 1 | Species 2 | % Composition | Site Index Break | Inv. Age | Initial Density | BEC | Weighted Site Index | Regen Method | Fert Age | Area (ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | FD | | 100 | >=18.6 | > 40 | 2300 | ICH | 20.5 | Natural | 72 | 1,440 |
| 101 | FD | | 100 | 16-18.5 | > 40 | 2300 | ICH | 16.7 | Natural | 72 | 2,532 |
| 200 | FD | | 100 | >=18.6 | <= 40 | 2300 | ICH | 20.4 | Planted | 28 | 119 |
| 201 | FD | | 100 | 16-18.5 | <= 40 | 2300 | ICH | 16.9 | Planted | 31 | 1,286 |
| 300 | FD | S | 82/18 | >=18.6 | > 40 | 2300 | ICH | 21.8 | Natural | 75 | 255 |
| 301 | FD | S | 83/17 | 16-18.5 | > 40 | 2300 | ICH | 17.2 | Natural | 68 | 172 |
| 400 | FD | S | 80/20 | >=18.6 | <= 40 | 2300 | ICH | 20.9 | Planted | 32 | 84 |
| 401 | FD | S | 83/17 | 16-18.5 | <= 40 | 2300 | ICH | 17.0 | Planted | 29 | 553 |
| 500 | S | | 100 | >= 17.1 | > 40 | 3000 | IDF | 20.8 | Natural | 70 | 18 |
| 501 | S | | 100 | >= 17.1 | > 40 | 3000 | MS | 25.0 | Natural | 52 | 5 |
| 502 | S | | 100 | >= 17.1 | > 40 | 3000 | SBPS | 19.2 | Natural | 64 | 547 |
| 503 | S | | 100 | >= 17.1 | > 40 | 3000 | SBS | 20.7 | Natural | 78 | 402 |
| 511 | S | | 100 | 16-17 | > 40 | 3000 | MS | 16.0 | Natural | 50 | 10 |
| 512 | S | | 100 | 16-17 | > 40 | 3000 | SBPS | 16.4 | Natural | 64 | 799 |
| 513 | S | | 100 | 16-17 | > 40 | 3000 | SBS | 16.6 | Natural | 83 | 241 |
| 601 | S | | 100 | >= 17.1 | <= 40 | 3000 | MS | 19.0 | Planted | 22 | 2 |
| 602 | S | | 100 | >= 17.1 | <= 40 | 3000 | SBPS | 20.8 | Planted | 31 | 65 |
| 603 | S | | 100 | >= 17.1 | <= 40 | 3000 | SBS | 19.0 | Planted | 24 | 42 |
| 611 | S | | 100 | 16-17 | <= 40 | 3000 | MS | 16.0 | Planted | 38 | 89 |
| 612 | S | | 100 | 16-17 | <= 40 | 3000 | SBPS | 16.0 | Planted | 29 | 58 |
| 613 | S | | 100 | 16-17 | <= 40 | 3000 | SBS | 16.0 | Planted | 32 | 53 |

## 2.4 Determination of Return on Investment

Revenue estimates were derived for dimension lumber volumes outputs from the batchTIPSY and TIPSY runs. Three different price levels were used in the analysis: low, medium, and high. The price levels are based on assessment of data prices from the last 20 years and U.S.F.S. projections[1] (Winkle, pers. comm.). Also utilized are the default prices for TIPSY which are based on 2001 data.

Table 4 lists the dimensions used and the price assumptions for the analysis.

**Table 4. Dimensions and prices used in the fertilization analysis.**

| | | Lumber ($/MBF) | | | | Chips |
|---|---|---|---|---|---|---|
| **Value Cycle** | **Species** | **2x4** | **2x6** | **2x8** | **2x10** | **($/BDU)** |
| **Low** | | | | | | |
| | Interior Douglas-fir | 173 | 300 | 298 | 426 | 50 |
| | White spruce | 150 | 250 | 250 | 350 | 50 |
| **Medium** | | | | | | |
| | Interior Douglas-fir | 289 | 420 | 417 | 547 | 75 |
| | White spruce | 250 | 350 | 350 | 450 | 75 |
| **High** | | | | | | |
| | Interior Douglas-fir | 404 | 541 | 536 | 669 | 100 |
| | White spruce | 350 | 450 | 450 | 550 | 100 |
| **TIPSY Default** | | | | | | |
| | Interior Douglas-fir | 498 | 507 | 511 | 625 | 110 |
| | White spruce | 431 | 422 | 429 | 514 | 110 |

Fertilization costs are estimated at $350/ha, and includes the cost of purchase and application. Application costs are expected to average $180.00/ha.

Revenue gain from fertilization is calculated as harvest revenue from fertilized yield table minus harvest revenue from non-fertilized yield table.

Net revenue from fertilization is calculated as revenue gain from fertilization **minus** fertilization cost.

[1] From Section 5.2 Economics and Forest Products Outlook, Stand Density Management in the Cariboo: Recommendations for a Management by Objectives Approach. (P. Winkle, Jan. 2005)

Return on investment (ROI) from fertilization at medium cycle prices is calculated as:

((revGain / (disc_factor ^ harv_year)) - fert_cost) / fert_cost * 100

## 2.5 Selection and Prioritization of Candidate Stands

The final selection and prioritization is based on proximity of polygons, stand size, harvest year, and ROI grouping. The final selection further stratifies the candidate stands selected through the photo assessment.

## 2.6 Additional Database and GIS Query Definitions

Another set of selection queries was specified that select polygons based on species, age, site index, and proximity to Quesnel (Table 5). All selection criteria except proximity to Quesnel were completed aspatially. This selection set is then linked to a resultant and polygons were selected based on proximity criteria. A portable database has been created showing the results of the queries.

**Table 5. Additional database and GIS queries for the fertilization analysis.**

| Query | Species 1 | Species 2 | Age (yrs) | Site Index (m) | Dist* (km) |
|---|---|---|---|---|---|
| A1 | F | | 60 - 80 | 18+ | <100 |
| A2 | S | | 60 - 80 | 18+ | <100 |
| A3 | F | | 60 - 80 | 15 -18 | <100 |
| A4 | S | | 60 - 80 | 15- 18 | <100 |
| A5 | F | S | 60 - 80 | 18+ | <100 |
| A6 | S | F | 60 - 80 | 18+ | <100 |
| A7 | F | S | 60 - 80 | 15 -18 | <100 |
| A8 | S | F | 60 - 80 | 15- 18 | <100 |
| A9 | F | | 60 - 80 | 18+ | 100 - 200 |
| A10 | S | | 60 - 80 | 18+ | 100 - 200 |
| A11 | F | | 60 - 80 | 15 -18 | 100 - 200 |
| A12 | S | | 60 - 80 | 15- 18 | 100 - 200 |
| A13 | F | S | 60 - 80 | 18+ | 100 - 200 |
| A14 | S | F | 60 - 80 | 18+ | 100 - 200 |
| A15 | F | S | 60 - 80 | 15 -18 | 100 - 200 |
| A16 | S | F | 60 - 80 | 15- 18 | 100 - 200 |
| A17 | F | | 40 - 60 | 18+ | <100 |
| A18 | S | | 40 - 60 | 18+ | <100 |
| A19 | F | | 40 - 60 | 15 -18 | <100 |
| A20 | S | | 40 - 60 | 15- 18 | <100 |
| A21 | F | S | 40 - 60 | 18+ | <100 |

| Query | Species 1 | Species 2 | Age (yrs) | Site Index (m) | Dist* (km) |
|---|---|---|---|---|---|
| A22 | S | F | 40 - 60 | 18+ | <100 |
| A23 | F | S | 40 - 60 | 15 -18 | <100 |
| A24 | S | F | 40 - 60 | 15- 18 | <100 |
| A25 | F |  | 40 - 60 | 18+ | 100 - 200 |
| A26 | S |  | 40 - 60 | 18+ | 100 - 200 |
| A27 | F |  | 40 - 60 | 15 -18 | 100 - 200 |
| A28 | S |  | 40 - 60 | 15- 18 | 100 - 200 |
| A29 | F | S | 40 - 60 | 18+ | 100 - 200 |
| A30 | S | F | 40 - 60 | 18+ | 100 - 200 |
| A31 | F | S | 40 - 60 | 15 -18 | 100 - 200 |
| A32 | S | F | 40 - 60 | 15- 18 | 100 - 200 |
| A33 | F |  | 15 - 40 | 18+ | <100 |
| A34 | S |  | 15 - 40 | 18+ | <100 |
| A35 | F | S | 15 - 40 | 18+ | <100 |
| A36 | S | F | 15 - 40 | 18+ | <100 |
| A37 | F |  | 15 - 40 | 18+ | 100 - 200 |
| A38 | S |  | 15 - 40 | 18+ | 100 - 200 |
| A39 | F | S | 15 - 40 | 18+ | 100 - 200 |
| A40 | S | F | 15 - 40 | 18+ | 100 - 200 |
| B1 | F | Pl | 60 - 80 | 18+ | <100 |
| B2 | S | Pl | 60 - 80 | 18+ | <100 |
| B3 | F | Pl | 60 - 80 | 15 -18 | <100 |
| B4 | S | Pl | 60 - 80 | 15- 18 | <100 |
| B5 | F | Pl | 60 - 80 | 18+ | 100 - 200 |
| B6 | S | Pl | 60 - 80 | 18+ | 100 - 200 |
| B7 | F | Pl | 60 - 80 | 15 -18 | 100 - 200 |
| B8 | S | Pl | 60 - 80 | 15- 18 | 100 - 200 |
| B9 | F | Pl | 40 - 60 | 18+ | <100 |
| B10 | S | Pl | 40 - 60 | 18+ | <100 |
| B11 | F | Pl | 40 - 60 | 15 -18 | <100 |
| B12 | S | Pl | 40 - 60 | 15- 18 | <100 |
| B13 | F | Pl | 40 - 60 | 18+ | 100 - 200 |
| B14 | S | Pl | 40 - 60 | 18+ | 100 - 200 |
| B15 | F | Pl | 40 - 60 | 15 -18 | 100 - 200 |
| B16 | S | Pl | 40 - 60 | 15- 18 | 100 - 200 |
| B17 | F | Pl | 15 -40 | 18+ | <100 |
| B18 | S | Pl | 15 -40 | 18+ | <100 |
| B19 | F | Pl | 15 -40 | 18+ | 100 - 200 |
| B20 | S | Pl | 15 –40 | 18+ | 100 - 200 |

# 3 Results

## 3.1 Interim Candidates

The photo assessment identified 6,101 ha as candidate type 1 (good). Of this 6,101 ha, 641 ha are classified as Woodlot ownership, leaving a total area classified as interim candidates of 5,460 ha. Table 6 provides the area summary by candidate classification.

**Table 6. Area by fertilization candidate type.**

| Candidate # | Candidate Type | Land Base Classification | Area |
|---|---|---|---|
| 1 | Good | Productive – Crown | 5,460 |
| 1 | Good | Productive – Woodlot | 641 |
| | | **Total** | **6,101** |
| 2 | Medium | Productive – Crown | 1,787 |
| 2 | Medium | Productive – Woodlot | 135 |
| | | **Total** | **1,922** |
| 3 | Poor | Productive – Crown | 717 |
| 3 | Poor | Productive – Woodlot | 30 |
| | | **Total** | **747** |

The majority of good candidate stands are located south west of Quesnel. Figures 1-3 show the location of initial candidate stands.

**Figure 1. Initial candidate stands, NE Quesnel Forest District.**

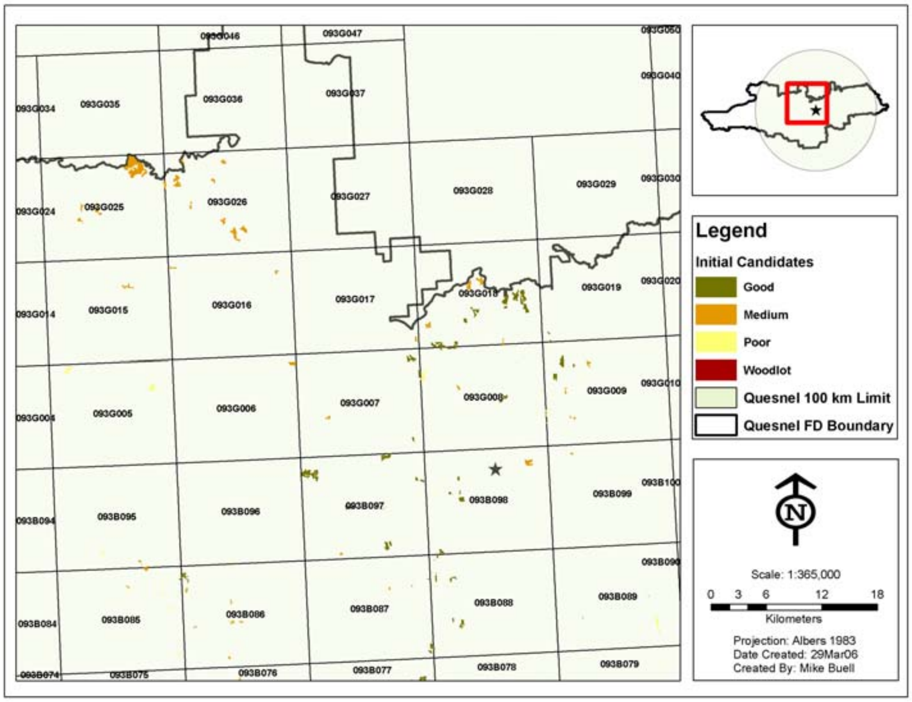



**Figure 2. Initial candidate stands, SE Quesnel Forest District.**

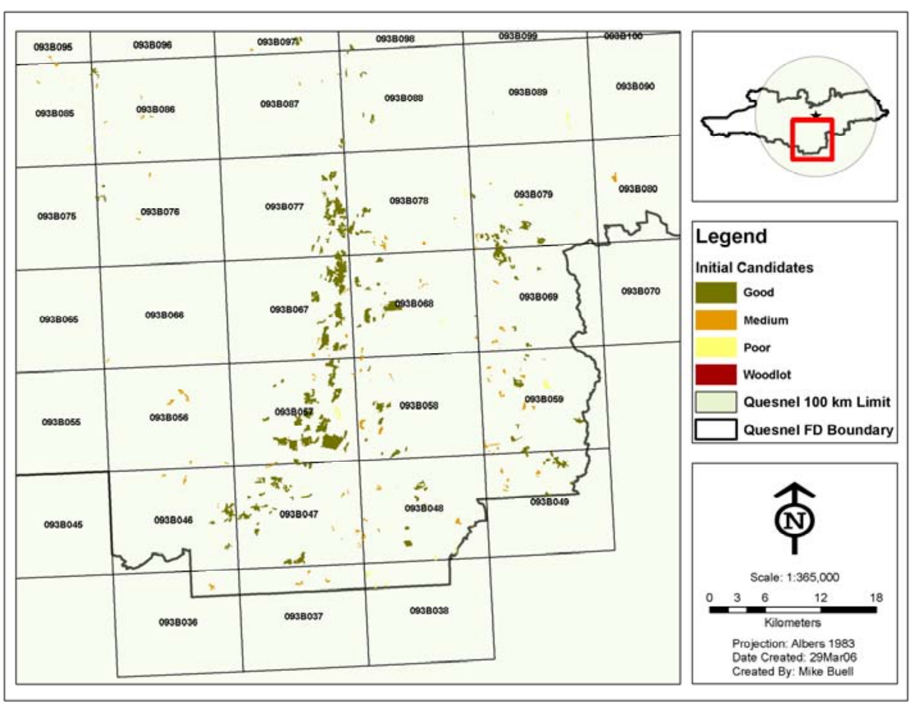
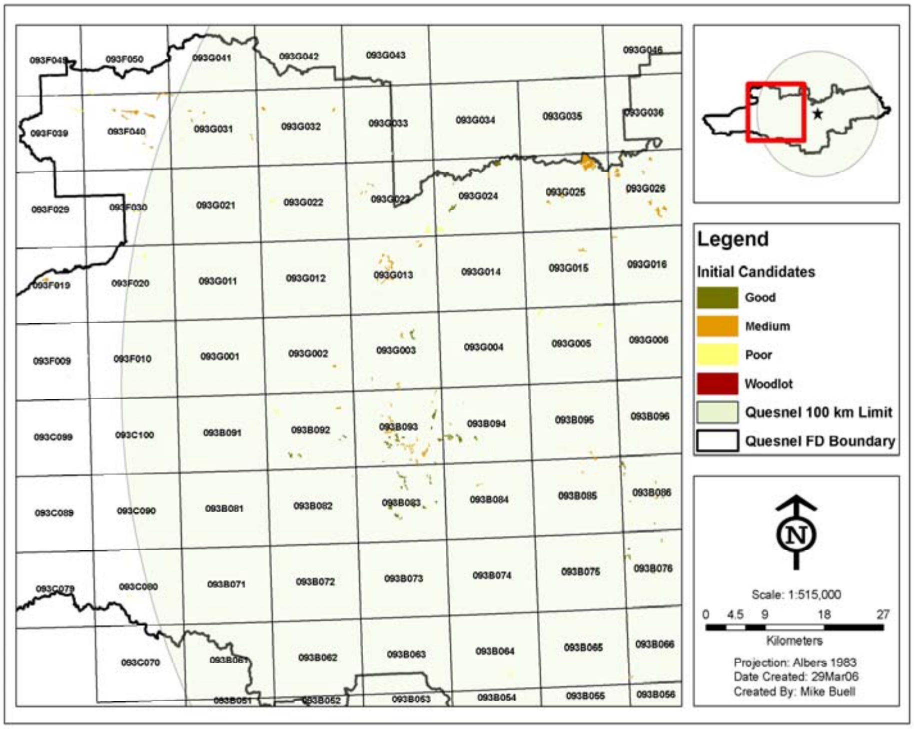


**Figure 3. Initial candidate stands, W Quesnel Forest District.**




## 2.1 Yield Estimates for Initial Candidates

After considering the yield tables obtained from the batchTIPSY and TIPSY analyses, it was decided that the data from the TIPSY run would be used as TIPSY allowed the control of fertilization effectiveness (set to 100%). Table 7 shows the average m3/ha and percent gain by fertilization analysis unit. Several analysis units were excluded since they were classified as medium or poor in the photo assessment or were classified as woodlots.

**Table 7. Average volume and percent gain for fertilization analysis.**

| Fert Au | Average Yield Gain ($m^3$/ha) | Average % Gain | Area (ha) |
|---|---|---|---|
| 100 | 10.0 | 3 | 1,194 |
| 101 | 10.7 | 6 | 1,570 |
| 200 | 14.0 | 9 | 95 |
| 201 | 12.0 | 8 | 1,068 |
| 300 | 8.0 | 2 | 208 |
| 301 | 12.9 | 8 | 94 |
| 400 | 14.0 | 9 | 78 |
| 401 | 13.0 | 8 | 253 |
| 502 | 15.4 | 5 | 130 |
| 503 | 8.5 | 2 | 245 |
| 512 | 15.6 | 9 | 390 |
| 513 | 16.0 | 5 | 121 |
| 613 | 12.0 | 7 | 13 |
| **Total** | | | **5,460** |

Note: Fert Au definitions are found in Table 3

Table 8 shows the expected year when the fertilization stand will be harvested. The table shows the expected harvest area and gain in harvest volume from fertilized stands.

**Table 8. Expected harvest area and volume gain from fertilized stands.**

| Year | Area Harvested (ha) | Harvest Volume Gain ($m^3$) |
|---|---|---|
| 2016 | 2,262 | 33,424 |
| 2021 | 188 | 1,334 |
| 2026 | 492 | 8,165 |
| 2031 | 62 | 650 |
| 2036 | 534 | 8,115 |
| 2041 | 398 | 4,112 |
| 2046 | 672 | 8,121 |
| 2051 | 580 | 6,427 |
| 2056 | 204 | 1,642 |
| 2061 | 66 | 912 |
| **Total** | **5,460** | **72,902** |

## 3.3 Cost Benefit Analysis for Initial Candidates

The cost benefit analysis shows expected returns from fertilization. The 2% ROI is achieved depending on cycle price and the default TIPSY prices. Table 9 shows the area by ROI class for all price cycles and TIPSY prices.

**Table 9. Area by ROI class.**

| ROI @2% Class (%) | VALUES | | | |
|---|---|---|---|---|
| | Low | Medium | High | TIPSY |
| >=300 | - | 5 | 474 | 459 |
| >=200 | - | 636 | 2,179 | 2,115 |
| >=100 | 1,018 | 2,148 | 1,625 | 1,633 |
| >2 | 3,843 | 2,671 | 1,182 | 1,252 |
| <=2 | 598 | - | - | - |
| **Total** | **5,460** | **5,460** | **5,460** | **5,460** |

## 3.4 Selection and Prioritization of Candidate Stands

The selection and prioritization of candidate stands is based on proximity, stand size, harvest year, and ROI grouping. Stands less than 2 ha in size are removed along with stands where the harvest year is greater than 2050. Prioritization is then based on harvest year and ROI grouping.

To fill in the fertilization candidates for years 2007 and 2009, initial candidates classified as 2 (medium) are included. These stands are coded as priority 3 and 4. A summary of the selected stands by priority group is provided in Tables 10, 11 and 12.

**Table 10. Selected stands, priority group 1.**

| PRIORITY GROUP | POLYGON GROUP # | ROI GROUP | ROI @ 2% | EARLIEST HARVEST YEAR | HA |
|---|---|---|---|---|---|
| 1 | 1 | 2 | >=200% | 2016 | 15 |
| 1 | 2 | 2 | >=200% | 2016 | 11 |
| 1 | 3 | 2 | >=200% | 2016 | 23 |
| 1 | 4 | 2 | >=200% | 2016 | 47 |
| 1 | 5 | 2 | >=200% | 2016 | 53 |
| 1 | 5 | 3 | >=100% | 2026 | 52 |
| 1 | 6 | 1 | >=300% | 2016 | 5 |
| 1 | 6 | 2 | >=200% | 2016 | 101 |
| 1 | 6 | 3 | >=100% | 2021 | 4 |
| 1 | 7 | 3 | >=100% | 2026 | 43 |
| 1 | 8 | 2 | >=200% | 2016 | 28 |
| 1 | 8 | 3 | >=100% | 2026 | 5 |
| 1 | 9 | 3 | >=100% | 2026 | 19 |

| | | | | | |
|---|---|---|---|---|---|
| 1 | 10 | 3 | >=100% | 2016 | 93 |
| 1 | 10 | 3 | >=100% | 2026 | 78 |
| 1 | 10 | 4 | >2% | 2016 | 23 |
| 1 | 11 | 3 | >=100% | 2016 | 109 |
| 1 | 12 | 2 | >=200% | 2016 | 22 |
| 1 | 12 | 3 | >=100% | 2016 | 47 |
| 1 | 12 | 4 | >2% | 2016 | 16 |
| 1 | 13 | 3 | >=100% | 2016 | 48 |
| 1 | 13 | 3 | >=100% | 2021 | 25 |
| 1 | 13 | 3 | >=100% | 2026 | 8 |
| 1 | 13 | 4 | >2% | 2016 | 6 |
| 1 | 14 | 2 | >=200% | 2016 | 18 |
| 1 | 14 | 3 | >=100% | 2016 | 559 |
| 1 | 14 | 3 | >=100% | 2026 | 33 |
| 1 | 15 | 2 | >=200% | 2016 | 100 |
| 1 | 15 | 3 | >=100% | 2016 | 264 |
| 1 | 15 | 3 | >=100% | 2026 | 77 |
| 1 | 16 | 2 | >=200% | 2016 | 19 |
| 1 | 16 | 3 | >=100% | 2016 | 61 |
| 1 | 16 | 3 | >=100% | 2026 | 6 |
| 1 | 16 | 4 | >2% | 2016 | 54 |
| 1 | 16 | 4 | >2% | 2021 | 53 |
| 1 | 17 | 3 | >=100% | 2016 | 163 |
| 1 | 17 | 3 | >=100% | 2026 | 6 |
| 1 | 17 | 4 | >2% | 2021 | 46 |
| 1 | 18 | 2 | >=200% | 2016 | 32 |
| 1 | 18 | 3 | >=100% | 2016 | 83 |
| 1 | 18 | 3 | >=100% | 2026 | 15 |
| 1 | 19 | 2 | >=200% | 2016 | 62 |
| 1 | 19 | 3 | >=100% | 2026 | 85 |
| 1 | 19 | 3 | >=100% | 2016 | 34 |
| 1 | 19 | 3 | >=100% | 2021 | 12 |
| 1 | 19 | 4 | >2% | 2016 | 35 |
| 1 | 20 | 3 | >=100% | 2026 | 41 |
| 1 | 20 | 3 | >=100% | 2021 | 31 |
| 1 | 21 | 2 | >=200% | 2016 | 74 |
| 1 | 21 | 3 | >=100% | 2026 | 25 |
| 1 | 21 | 3 | >=100% | 2021 | 14 |
| 1 | 21 | 4 | >2% | 2016 | 2 |
| 1 | 22 | 2 | >=200% | 2016 | 2 |
| 1 | 23 | 2 | >=200% | 2016 | 20 |
| 1 | 24 | 2 | >=200% | 2016 | 9 |
| 1 | 24 | 3 | >=100% | 2016 | 19 |
| 1 | 24 | 4 | >2% | 2016 | 4 |
| | | | | Total ha | 2,940 |

**Table 11. Selected stands, priority group 2**

| PRIORITY GROUP | POLYGON GROUP # | ROI GROUP | ROI @ 2% | EARLIEST HARVEST YEAR | HA |
|---|---|---|---|---|---|
| 2 | 4 | 3 | >=100% | 2036 | 15 |
| 2 | 5 | 3 | >=100% | 2036 | 9 |
| 2 | 14 | 4 | >2% | 2031 | 10 |
| 2 | 14 | 4 | >2% | 2046 | 7 |
| 2 | 15 | 3 | >=100% | 2036 | 19 |
| 2 | 15 | 4 | >2% | 2036 | 316 |
| 2 | 15 | 4 | >2% | 2046 | 57 |
| 2 | 15 | 4 | >2% | 2041 | 43 |
| 2 | 16 | 4 | >2% | 2046 | 72 |
| 2 | 16 | 4 | >2% | 2041 | 22 |
| 2 | 16 | 4 | >2% | 2031 | 8 |
| 2 | 17 | 3 | >=100% | 2036 | 2 |
| 2 | 17 | 4 | >2% | 2036 | 140 |
| 2 | 17 | 4 | >2% | 2046 | 29 |
| 2 | 17 | 4 | >2% | 2041 | 23 |
| 2 | 18 | 3 | >=100% | 2031 | 15 |
| 2 | 18 | 4 | >2% | 2046 | 442 |
| 2 | 18 | 4 | >2% | 2041 | 147 |
| 2 | 18 | 4 | >2% | 2036 | 6 |
| 2 | 19 | 4 | >2% | 2041 | 115 |
| 2 | 19 | 4 | >2% | 2031 | 3 |
| 2 | 20 | 3 | >=100% | 2031 | 21 |
| 2 | 20 | 4 | >2% | 2046 | 4 |
| 2 | 21 | 4 | >2% | 2046 | 52 |
| 2 | 21 | 4 | >2% | 2041 | 39 |
| 2 | 21 | 4 | >2% | 2031 | 6 |
| 2 | 21 | 4 | >2% | 2036 | 5 |
| 2 | 22 | 3 | >=100% | 2036 | 6 |
| 2 | 22 | 4 | >2% | 2036 | 13 |
| 2 | 22 | 4 | >2% | 2041 | 10 |
| 2 | 24 | 4 | >2% | 2046 | 9 |
| | | | | Total ha: | 1,663 |

**Table 12. Selected stands, priority group 3**

| PRIORITY GROUP | POLYGON GROUP # | ROI GROUP | ROI @ 2% | EARLIEST HARVEST YEAR | HA |
|---|---|---|---|---|---|
| 3 | 1 | 1 | >=300% | 2016 | 16 |
| 3 | 1 | 2 | >=200% | 2016 | 109 |
| 3 | 1 | 3 | >=100% | 2016 | 5 |
| 3 | 1 | 4 | >2% | 2016 | 8 |
| 3 | 2 | 2 | >=200% | 2016 | 24 |
| 3 | 3 | 1 | >=300% | 2016 | 8 |
| 3 | 3 | 2 | >=200% | 2016 | 61 |
| 3 | 4 | 2 | >=200% | 2016 | 12 |
| 3 | 4 | 3 | >=100% | 2016 | 9 |
| 3 | 5 | 2 | >=200% | 2016 | 84 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | 5 | 3 | >=100% | 2016 | 86 |
| 3 | 5 | 4 | >2% | 2016 | 12 |
| 3 | 6 | 2 | >=200% | 2016 | 22 |
| 3 | 7 | 2 | >=200% | 2016 | 3 |
| 3 | 7 | 4 | >2% | 2016 | 5 |
| 3 | 8 | 3 | >=100% | 2016 | 84 |
| 3 | 8 | 4 | >2% | 2016 | 5 |
| 3 | 9 | 2 | >=200% | 2016 | 6 |
| 3 | 9 | 3 | >=100% | 2016 | 9 |
| 3 | 9 | 4 | >2% | 2016 | 11 |
| 3 | 11 | 2 | >=200% | 2016 | 12 |
| 3 | 12 | 2 | >=200% | 2016 | 8 |
| 3 | 13 | 2 | >=200% | 2016 | 9 |
| 3 | 14 | 2 | >=200% | 2016 | 25 |
| 3 | 15 | 3 | >=100% | 2016 | 11 |
| 3 | 16 | 2 | >=200% | 2016 | 12 |
| 3 | 17 | 2 | >=200% | 2016 | 5 |
| 3 | 17 | 3 | >=100% | 2016 | 27 |
| 3 | 18 | 3 | >=100% | 2016 | 14 |
| 3 | 18 | 4 | >2% | 2016 | 12 |
| 3 | 19 | 2 | >=200% | 2016 | 11 |
| 3 | 19 | 3 | >=100% | 2016 | 5 |
| 3 | 19 | 4 | >2% | 2016 | 22 |
| 3 | 20 | 3 | >=100% | 2016 | 3 |
| 3 | 20 | 4 | >2% | 2016 | 8 |
| 3 | 21 | 3 | >=100% | 2016 | 29 |
| 3 | 24 | 2 | >=200% | 2016 | 10 |
| 3 | 25 | 1 | >=300% | 2016 | 2 |
| 3 | 25 | 2 | >=200% | 2016 | 121 |
| 3 | 28 | 2 | >=200% | 2016 | 12 |
| 3 | 28 | 3 | >=100% | 2016 | 28 |
| 3 | 29 | 2 | >=200% | 2016 | 32 |
| 3 | 29 | 3 | >=100% | 2016 | 13 |
| 3 | 30 | 2 | >=200% | 2016 | 30 |
| | | | | Total ha: | 1,043 |

**Table 13 Selected stands, priority group 4**

| PRIORITY GROUP | POLYGON GROUP # | ROI GROUP | ROI @ 2% | EARLIEST HARVEST YEAR | HA |
|---|---|---|---|---|---|
| 4 | 1 | 3 | >=100% | 2031 | 7 |
| 4 | 1 | 4 | >2% | 2031 | 3 |
| 4 | 2 | 3 | >=100% | 2036 | 9 |
| 4 | 3 | 3 | >=100% | 2026 | 19 |
| 4 | 7 | 4 | >2% | 2036 | 23 |
| 4 | 9 | 4 | >2% | 2031 | 33 |
| 4 | 10 | 4 | >2% | 2041 | 5 |
| 4 | 11 | 3 | >=100% | 2026 | 7 |
| 4 | 11 | 3 | >=100% | 2036 | 3 |
| 4 | 12 | 3 | >=100% | 2026 | 6 |

| | | | | | |
|---|---|---|---|---|---|
| 4 | 14 | 3 | >=100% | 2036 | 14 |
| 4 | 15 | 3 | >=100% | 2036 | 23 |
| 4 | 17 | 3 | >=100% | 2026 | 6 |
| 4 | 17 | 4 | >2% | 2036 | 28 |
| 4 | 17 | 4 | >2% | 2041 | 2 |
| 4 | 18 | 4 | >2% | 2036 | 4 |
| 4 | 18 | 4 | >2% | 2046 | 21 |
| 4 | 19 | 3 | >=100% | 2026 | 7 |
| 4 | 19 | 3 | >=100% | 2036 | 5 |
| 4 | 19 | 4 | >2% | 2021 | 6 |
| 4 | 19 | 4 | >2% | 2041 | 5 |
| 4 | 19 | 4 | >2% | 2046 | 25 |
| 4 | 20 | 3 | >=100% | 2021 | 4 |
| 4 | 20 | 4 | >2% | 2031 | 8 |
| 4 | 22 | 3 | >=100% | 2026 | 28 |
| 4 | 23 | 3 | >=100% | 2031 | 11 |
| 4 | 23 | 4 | >2% | 2036 | 10 |
| 4 | 24 | 3 | >=100% | 2036 | 13 |
| 4 | 25 | 4 | >2% | 2036 | 4 |
| 4 | 29 | 3 | >=100% | 2021 | 4 |
| 4 | 29 | 4 | >2% | 2041 | 6 |
| 4 | 30 | 4 | >2% | 2046 | 19 |
| 4 | 31 | 3 | >=100% | 2036 | 4 |
| | | | | | 372 |

Table 14 shows the final area by fertilization year and prioritization for the candidate stands.

**Table 14. Area by fertilization year and priority class.**

| Year | Priority Group | Area (ha) | Comments |
|---|---|---|---|
| 2006 | 1 | 2,940 | 1) Develop operational program for fall 2006 treatment<br>2) Initiate monitoring program |
| 2007 | 2 | 1,663 | 1) Develop operational program for fall 2007 treatment |
| 2008 | 3 & 4 | 1,415 | 1) Develop operational program for fall 2008 treatment |
| 2009 | | | 1) Assess monitoring response from 2006 S & F treatments.<br>2) Based on monitoring response results develop tactical recommendations for further F & S stand treatment |
| 2010 | | | 1) Develop operational F & S treatment program based on 2009 tactical recommendations.<br>2) Assess potential to apply second treatment to 2006 stands.<br>3) Consider starting a Pine fertilization program depending upon MPB and other forest health conditions. |
| | **Total** | **6,018** | |

Figures 4 to 6 shows the location of the prioritized candidates in relation to Quesnel.

**Figure 4. Prioritized candidate stands, NE Quesnel Forest District.**

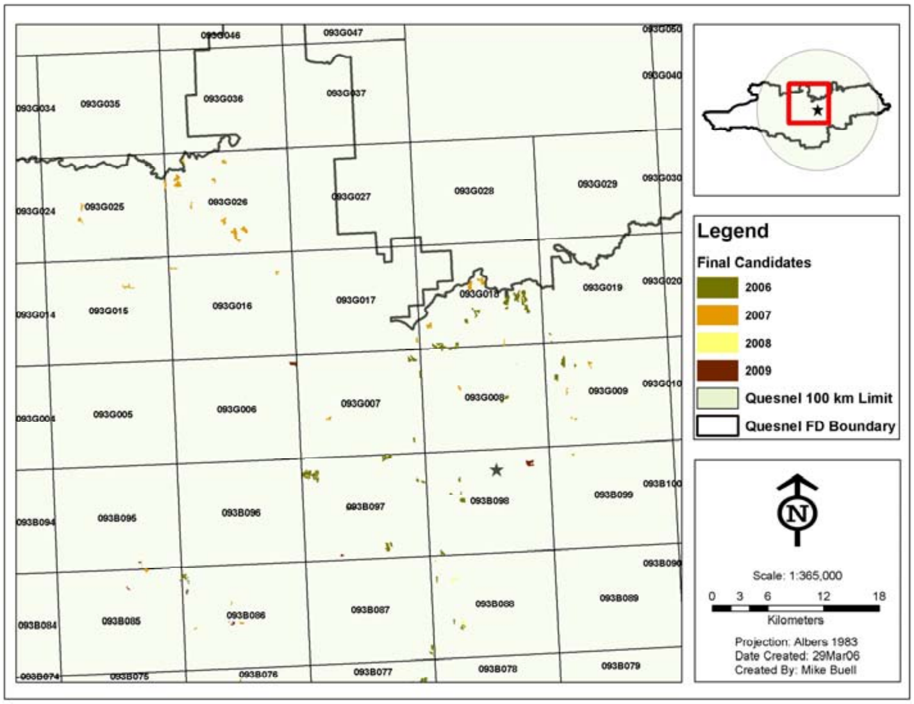



**Figure 5. Prioritized candidate stands, SE Quesnel Forest District.**

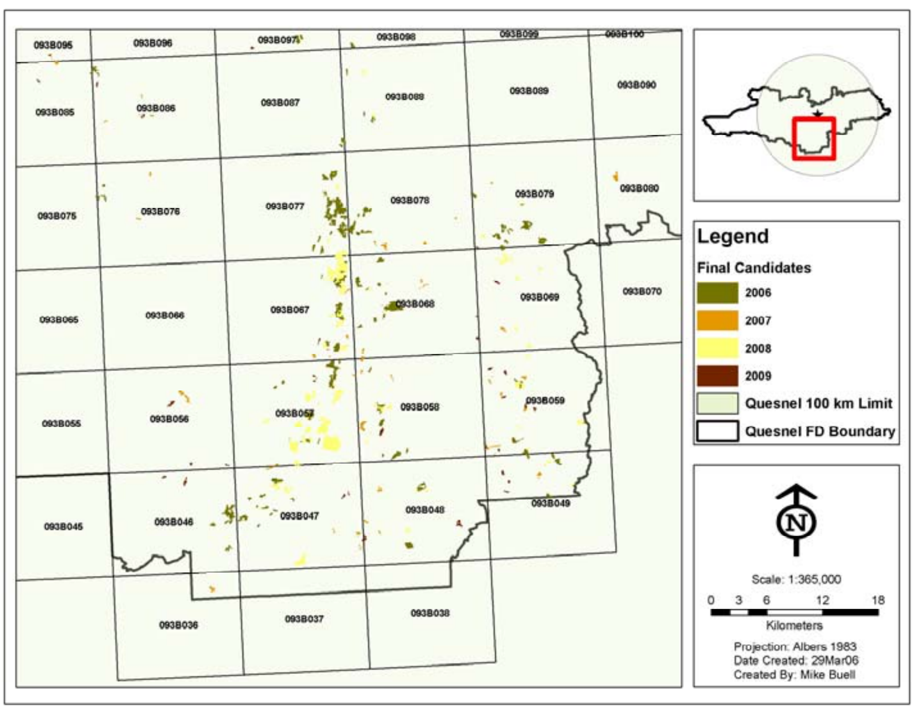
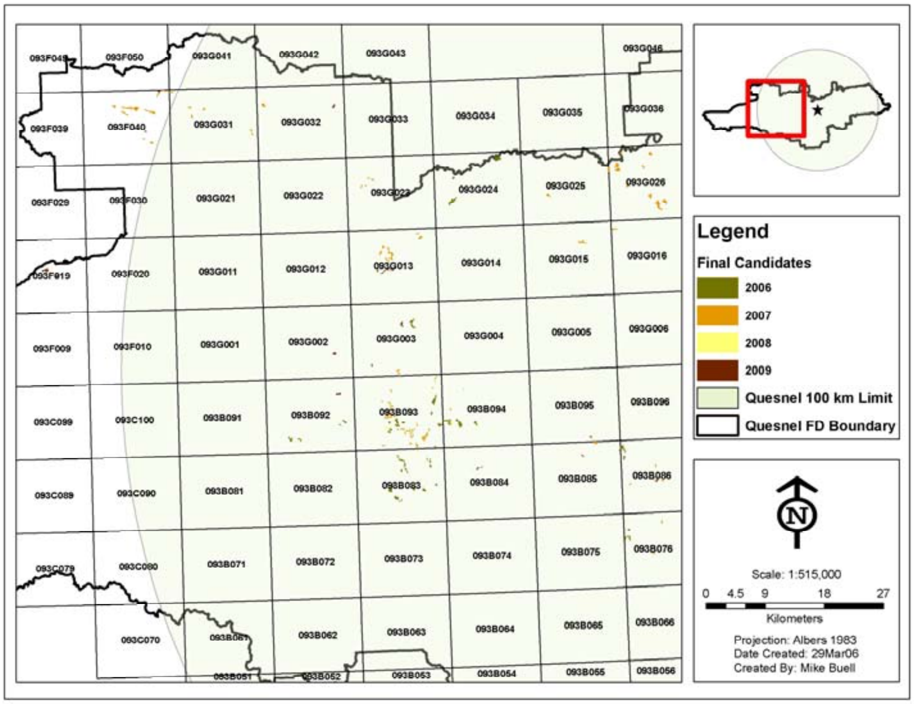


**Figure 6. Prioritized candidate stands, W Quesnel Forest District.**



# 4 Growth Monitoring

## 4.1 Growth Monitoring Scheme, Option 1

The growth monitoring scheme described in this section is drawn largely from Hawkins (2005).

Due to the large amount of area that can be fertilized and the full cost of application a growth monitoring program is required to evaluate the growth of treated stands. Control plots (untreated) will be established that have the same ecological attributes as the treated stands.

The monitoring approach is to install a small number of plots in each treated area and partner control area. Five randomly selected plots of 100 ha or less and at an intensity of five percent, to a maximum of 10 plots for stands greater than 100 ha will be installed. This protocol will be used in both treated and control areas, and assumes, as indicated in the guidelines, that the treated areas are relatively large.

The approach will be as follows:

1. select a point of commencement (POC) from stands in the final candidate resultant
2. grid with plots located every 100m is overlaid on the stand and is numbered sequentially
3. plot is selected if 100 m from any polygon border
4. random number list is generated for each stand – total random numbers = number of grid positions
5. if stand is < 100 ha first five sample points on random number list will be selected
6. if stand is >= 100 ha select plots if more than 100 m from a stand boundary
7. repeat process for the control area

The approach used in this analysis is the following:

1. overlay grid of 100m points onto the interim candidates
2. if stand does not have the minimum 5 plots then no plots are selected
3. for stands that will have minimum 5 plots use random number generator to find the number of plots needed – between minimum 5 and maximum 10
4. exclude points that are within 100m of stand boundary
5. randomly select points within stands using random number generator based on point id

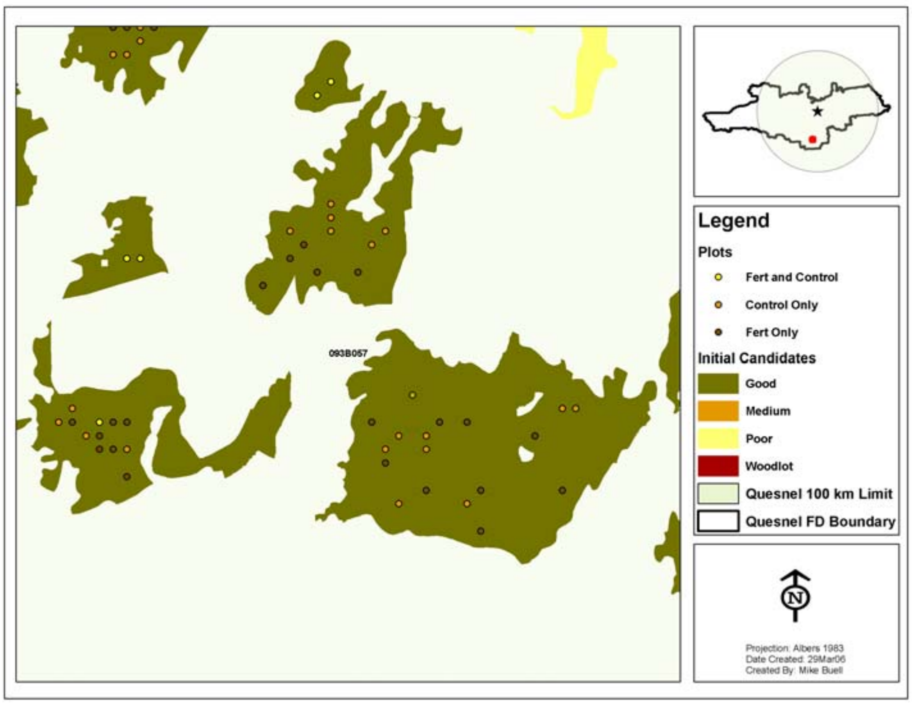
repeat process for control points

The results of the growth monitoring exercise show that 643 plots are required to support the fertilization program. Of the 643 plots, 168 had control and fertilization plots that overlap. Table 15 shows the number of control and fertilization plots required to support the program and Figure 7 provides a illustration of the results from the growth monitoring exercise.

**Table 15. Total plots required to support the Quesnel fertilization program.**

| Plot Type | Number of plots |
|---|---|
| Control only | 240 |
| Fertilization only | 235 |
| Control and fertilization combined | 168 |
| **Total** | **643** |

**Figure 7. Close-up of a selected plot, SE Quesnel Forest District.**




## 4.2 Growth Monitoring Scheme, Option 2

Quantification of expected responses to treatment is primarily based on TIPSY yield predictions. As there is an unknown measure of uncertainty inherent in all projections, an "effectiveness" monitoring program is required to know if growth and yield patterns over time are emerging as projected by the models. Therefore, an alternative approach to monitoring as defined in option 1, is to establish plots in the population of treated stands and re-measure the plots over time to verify the growth of the treated stands against TIPSY projections for similarly treated stands. If significant differences are noted between actual and predicted growth then further research would be required to determine the reason for the difference. Such an approach would require between 20 and 30 installations, preferably before treatment occurs.

# 5 Discussion

The tactical strategy is based on inventory estimates and TIPSY yield projections with an assessment using orthophotos. Therefore, due to potential inventory inaccuracies, stands will have to be ground and/or aerial truthed for fertilization suitability under the next level to develop an operational assessment plan. The tiered approach adopted for the tactical plan will make substitution of candidate stands in an operational assessment relatively straightforward.

Similarly, the operational treatment plan resulting from the operational assessment can easily be adjusted to allow for varying budget schedules.

Fertilizer treatment of the 6,000 hectares identified in this tactical plan will increase timber supply by 81,000 $m^3$ or more in the medium term – a time when a severe deficit in timber supply is forecast. The actual volume gain depends, in part, on when a stand is harvested and on the accuracy of TIPSY projections. Gains of this nature are needed to contribute to the future harvest portfolio in MPB devastated areas.

# 6 Recommendations

1. A five-year schedule of fertilization treatments is listed in Table 16.

**Table 16. Recommended fertilization treatment and activities by year and priority group.**

| Year | Priority Group | Area (ha) | Comments |
|---|---|---|---|
| 2006 | | | 1) Develop operational assessment and treatment programs for fall 2006 treatment |
| | 1 | 2,940 | 2) Design and initiate monitoring program |
| 2007 | 2 | 1,663 | 1) Develop operational program for fall 2007 treatment |
| 2008 | 3 & 4 | 1,415 | 1) Develop operational program for fall 2008 treatment |
| 2009 | | | 1) Assess monitoring response from 2006 S & F treatments.<br>2) Based on monitoring response results develop tactical recommendations for further F & S stand treatment |
| 2010 | | | 1) Develop operational F & S treatment program based on 2009 tactical recommendations.<br>2) Assess potential to apply second treatment to high response 2006 stands.<br>3) Consider initiating a Pine fertilization program depending upon MPB and other forest health conditions. |
| | **Total** | **6,018** | |

2. Conduct foliar analysis on select treated and untreated stands to determine potential formulation requirements (adjust for urea, ammonium nitrate and sulphur)

3. Select approximately 1,000 hectares, from the highest response older Fir and Spruce immature stands, for subsequent intensive repeated fertilizer applications and monitor

results to determine potential responses applicable to similar stand types in the Southern and Northern Interior Forest Regions

4. Select approximately 1,000 hectares from younger Fir and Spruce immature stands, for intensive repeated fertilizer application in conjunction with optimized pre-commercial thinning and monitor results to determine potential responses applicable to similar stand types in the Southern and Northern Interior Forest Regions
5. The operational plan must be verified with MOFR regional entomologists to assess the risk and value of the proposed fertilizer treatments in relation to any known or potential forest health issues
6. The operational plan must be verified with MOFR regional and local biologists to assess the potential for inclusion of treatment in any adjacent Ungulate Winter Ranges
7. ·A First Nations consultation process should be initiated as early as possible

# References

BC MoF. 2004. Quesnel Timber Supply Area Rationale for Allowable Annual Cut Determination.

BC MoFR. 2005. Forests for Tomorrow: Planning, Reforestation and Brushing Focused in Catastrophic Event-Impacted Management Units http://www.for.gov.bc.ca/hfp/fft/

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