

**PREDICTIVE ECOSYSTEM MAPPING
OF THE BOUNDARY TIMBER SUPPLY AREA 2002-2003
- FINAL REPORT**

Prepared for:

Pope & Talbot Ltd.
P.O. Box 70,
Midway, B.C.
V0H 1M0

Prepared by:

Timberline Forest Inventory Consultants Ltd.
1579 9th Avenue
Prince George, British Columbia
V2L 3R8

April 2003



EXECUTIVE SUMMARY

Ecological land classification is becoming an integral part of forest management in many jurisdictions given the current regulatory and policy environment. Timberline Forest Inventory Consultants Ltd. (Timberline) was selected By Pope & Talbot Ltd., Midway Operations, to undertake ecosystem mapping using a Predictive Ecosystem Mapping (PEM) approach for the entire landbase (approximately 580,100 hectares) of the Boundary Timber Supply Area. (TSA).

The PEM project involved a co-ordinated effort by a team of ecologists, GIS analysts, and database management specialists, working within a relatively short seven-month timeframe. The objective of the project was to produce a “site series PEM” map product for the entire project area, at a level of map accuracy that permitted its use in basecase timber supply analysis.

As a supporting layer of data information for PEM, the project generated a new soil moisture mapping inventory layer to enhance the accurate prediction of ecosystem units. Forest cover polygons, with some linework modification using selected ecological criteria, formed the base polygons for soil moisture regime classification.

Key input data layers used in the PEM included localised Biogeoclimatic unit mapping, soil moisture mapping, forest cover inventory, Granby/Kettle TEM classification, and slope/aspect information generated through the TRIM I Digital Elevation Model (DEM). All source layers were made seamless before GIS overlay and attribute extraction procedures were conducted. Cross product effect can be a major issue in PEM when overlaying map themes with complex map labels. To minimise this effect, soil moisture mapping polygons were used as the basic ecological boundary (i.e., final PEM polygons) and all other data information sources (FC1 etc.) were summarised thematically within each moisture-mapping polygon. Knowledge base attribute selection and weighting was also carefully performed in order to mitigate cross-product issues.

EcoNGen v1.0b was used as the PEM knowledge base software. The PEM knowledge base was developed using regional field guides, locally collected field data, and expert opinion. Field data from 400 plus field plots was used to calibrate and localize the knowledge base. The knowledge base was validated using map data that was tested against multiple sets of internal Quality Assurance/Accuracy Assessment (QA/AA) data. Overall knowledge base calibration accuracy (for all Biogeoclimatic units) was 87.4%. The final map accuracy, assessed internally by an independent accuracy data set of 65 polygons was 66.2% for Dominant Correct and 62.5% for Overlapping Correct, following the accuracy assessment protocol for ecosystem mapping documented in Meidinger (2000).

An official set of map accuracy data was collected concurrently with the PEM project by an independent, third party (Biome Ecological Services Ltd.). Data analysis for the assessment was conducted by J. S. Thrower & Associates Ltd. in April of 2003. % Dominant Correct and % Overlap Correct scores of 68% and 66% were attained in the official assessment, without any aggregation of site series.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ii

1.0 INTRODUCTION 1

1.1 Project Area 1

1.2 General PEM Approach..... 2

1.3 Project Deliverables..... 3

2.0 DESCRIPTION OF PEM INPUT DATA SOURCES..... 3

2.1 Large-Scale Biogeoclimatic Unit Mapping 4

2.2 Soil Moisture Mapping..... 4

2.3 Slope and Aspect 5

2.4 Ecosystem Field Data 6

2.5 Forest Cover Inventory 6

3.0 METHODS 7

3.1 Thematic Input Data Quality Assessments..... 7

3.1.1 Forest Cover Attributes 7

3.1.2 Soil Moisture Mapping Attributes..... 7

3.2 Spatial Input Data Quality Assessments..... 8

3.3 GIS Overlay and Attribute Extraction 8

3.4 Thematic Overlay of Data Information Layers 8

3.5 Input Database Preparation..... 8

3.6 Knowledge Base Development 10

3.7 Knowledge Base Calibration Using Field Data..... 10

3.8 Knowledge Base Validation 10

3.9 Final PEM Classification..... 11

3.9.1 Mapping Entities 11

3.9.2 Area Weighted Decile Derivation using ACCESS Conversion Tool 12

3.10 Structural Stage Modeling 12

3.11 Final Digital Mapping 13

3.11.1 Map Labels..... 13

4.0 RESULTS 13

4.1 Large-scale BGC Mapping..... 13

4.2 New Forested Ecosystem Unit in the PPdh1 14

4.3 PEM Knowledge Base Calibration..... 14

4.4 Preliminary PEM Prediction..... 15

4.5 Knowledge Base Validation 16

4.6 Internal Quality Assurance and Map Accuracy Assessment Data 17

4.7 Final PEM Prediction 18

4.8 Gross Area Distribution of Biogeoclimatic Units 18

5.0 DISCUSSION 21

5.1 Map Entity Area Summaries and Distribution 21

5.2 Internal Map Accuracy Assessment 22

5.3 Difficult Site Series for Prediction 22

5.4 Internal Quality Assurance 22

5.4.1 Field Data Collection 23

5.4.2 Soil Moisture Mapping Photo Interpretation..... 23
5.4.3 Internal Map Accuracy Assessment..... 23
5.5 Quality Assurance of Final PEM Deliverables..... 23
6.0 ACKNOWLEDGEMENTS 23
7.0 REFERENCES..... 24

LIST OF TABLES

Table 1 Slope Class Codes and Definitions 5
Table 2 Aspect Class Codes and Definitions 5
Table 3 Thematic Accuracy of Soil Moisture Mapping Attributes..... 7
Table 4 Knowledge Base Calibration Accuracy 15
Table 5 Accuracy Assessment Results of Preliminary PEM Predictions 16
Table 6 Knowledge Base Validation Results..... 16
Table 7 Site Series Area Summary of Validation Data..... 17
Table 8 Results for Internal Map Accuracy Assessment 18
Table 9 Biogeoclimatic Unit Area Summary for the Boundary TSA 19
Table 10 Biogeoclimatic Unit Area Summary for THLB portion of the Boundary TSA 19
Table 11 Total Areas by Forested, Non-forested, Water and Wetland Units by Biogeoclimatic Unit, in Hectares..... 20
Table 12 Gross Area of Forested Ecosystem Units by Biogeoclimatic Unit 21

LIST OF APPENDICES

Appendix I Table of Ecosystem Unit Distribution for 2001-2002 Project Area

1.0 INTRODUCTION

Pope and Talbot Ltd. (P&T Ltd.) has issued a Request For Proposal (RFP) to conduct ecosystem mapping of the Boundary Timber Supply Area (TSA) using a Predictive Ecosystem Mapping (PEM) method. Timberline Forest Inventory Consultants Ltd. (Timberline) was selected to undertake the mapping project. The objective of this project is to obtain high quality and spatially accurate ecosystem data to facilitate a variety of land and resource management interpretations.

Given the current regulatory and policy environment in B.C., ecological inventories have become an integral part of forest management and planning. Forest planners in the past have been faced with making decisions based on limited inventory information or inventories not suited to the issues being addressed. A clear need exists for ecological inventories to support accurate estimates of long-range sustained yields on managed stands, sustainable harvest levels, allowable annual cuts and many other land and resources management related activities (e.g., landscape and site level planning, indicator development, target setting, and monitoring etc.). Habitat supply modelling and identifying areas where silviculture treatments provide the best return on investment also require reliable inventories. With the on-going switch to a results-based Forest Practices Code, the forest industry requires detailed and high-resolution resource inventory data with which to make informed resource management decisions.

Geographic information systems (GIS), knowledge based systems, and enhanced data acquisition technologies are playing an increasingly important role in the integration of data, information, and knowledge. During the last ten years, significant advances have occurred in predictive modelling approaches to ecosystem mapping. Predictive Ecosystem Mapping (PEM) methods capitalize on the knowledge of expert ecologists and exploit digital information normally available to forest managers; including TRIM/DEM models and forest cover inventory data. PEM pilots and operational PEM projects in B.C. and elsewhere have demonstrated the value of this approach as a means of conducting large scale ecological land classification.

There are a number of PEM software products that have been operationally tested in B.C. and have been accepted as tools for the PEM process. *EcoNGen*[®], a software tool developed and tested by the B.C. Ministry of Forests (MoF), has been used for this project. *EcoNGen*[®] combines the capabilities of GIS and knowledge-based computing systems, along with the knowledge of expert ecologists to infer ecosystem units from a variety of data sources.

This report should be reviewed, and used in concert with the *Input Data Quality Assessment & Metadata Documentation Report 2002-2003* (Metadata Report, 2003).

1.1 Project Area

The Boundary Forest District, located in south-central British Columbia, covers approximately 658,500 hectares, and includes TFL 8, managed by P&T Ltd. in Midway, which occurs in two separate blocks covering a total of 77,500 hectares. The Boundary Timber Supply Area (TSA) consists of the remainder of the Forest District outside of TFL 8. The TSA is approximately 581,000 hectares in size. It measures approximately 100km long by 90km wide, and encompasses most of the Kettle and Granby River drainages. The Okanagan Highland Range of the Christina Range bound the project area on the west. The Canada-U.S.A border defines the southern boundary of the project area.

Three distinct Ecosections occur in the Boundary TSA. The Northern Okanagan Highland Ecosection occurs in the western portions of the TSA, which is drained by the Kettle River. This Ecosection consists

of a rolling highland with wide, deep, north-south valleys. In the east portion of the project area, drained by the Granby River, is the Selkirk Foothills Ecosection, which is characterized by mountainous terrain with wide, north-south valleys and trenches. The Southern Okanagan Highland Ecosection consists of a narrow band along the Canada-U.S.A. border. East-west valleys characterize this ecosection, with forested hillsides on north-facing slopes and open grasslands on south-facing slopes.

The TSA is a sparsely populated area with several small communities. The major population centre is the City of Grand Forks, where about one-third of the TSA’s population resides. Other communities include Christina Lake, Greenwood, Midway, Rock Greek, Bridesville and Beaverdell.

The following Biogeoclimatic (BGC) units best describe the climate and vegetation occurring in the TSA. There are a total of 14 BGC units present in the project area:

- PPdh1 Dry Hot Ponderosa Pine Kettle Variant
- IDFxh4 Very Dry Hot Interior Douglas-fir Boundary Variant
- IDFdm1 Dry Mild Interior Douglas-fir Kettle Variant
- MSdm1 Dry Mild Montane Spruce Okanagan Variant
- MSdm1a Dry Montane Spruce Okanagan Variant western redcedar Phase
- ICHdw1 Dry Warm Interior Cedar –Hemlock West Kootenay Variant
- ICHdw2 Dry Warm Interior Cedar –Hemlock Boundary Variant
- ICHmw2 Moist Warm Interior Cedar-Hemlock Columbia-Shuswap Variant
- ICHmk1 Moist Cool Interior Cedar-Hemlock Kootenay Variant
- ESSFdc1 Dry Cold Engelmann Spruce –Subalpine Fir Okanagan Variant
- ESSFdcu1 Dry Cold Engelmann Spruce-Subalpine Fir Upper Okanagan Variant
- ESSFwc1 Wet Cold Engelmann Spruce-Subalpine Fir Columbia Variant
- ESSFwc4 Wet Cold Engelmann Spruce –Subalpine Fir Selkirk Variant
- ESSFwcu4 Wet Cold Engelmann Spruce –Subalpine Fir Upper Selkirk Variant

1.2 General PEM Approach

A conventional approach to PEM in the province entails utilising available spatial data coverages such as forest cover or VRI, TRIM/DEM, and other existing data information combined through a straight GIS-based overlay process to generate resultant polygons. The thematic information associated with each resultant polygon is processed through a knowledge base, resulting in map entities being ascribed. Map entities may be a site series or grouping of two or more site series. While initial short-term cost and time saving may be attractive, the utility of the final product is highly dependent upon the type and quality of input data sources. The map entities for this project are individual site series, with no lumping or grouping of site series taking place.

Most of the existing landbase inventories do not have thematic map accuracy adequate enough to support PEM, particularly when a specified thematic accuracy of PEM map product is required. In this project a soil moisture mapping-focussed approach to PEM was developed and implemented. The key features of the method can be summarised as follows:

1. Creation of the PEM base polygons utilised existing ecologically oriented polygons from Biogeoclimatic (BGC) linework, Forest Cover (FC1), slope/aspect etc.). Polygon linework was modified based on selected ecological principles, with arcs added or removed based on changes in slope/aspect, slope breaks, riparian areas etc. The base polygons created at this stage formed final PEM polygons.
2. All data layers were thematically (not spatially) overlaid and summarised for each of the base

polygons. No cross-product polygons are created and the cross-product effects from overlaying multiple data layers are minimised through careful attribute and data layer selection.

3. The PEM process was a two-step process of Initial PEM classification and Final PEM classification. Initial classification entailed introducing data layers to the PEM Knowledge Base (KB) in a stepwise manner.
4. Soil moisture mapping, an alternative to bioterrain, was completed on all PEM base polygons within the timber harvesting landbase. Relative SMR, SNR and soil texture/depth was photo interpreted for all polygons.
5. Final PEM classification utilised the new input data created from soil moisture mapping, in addition to the best attributes or attribute combinations found during the initial PEM classification.
6. Multiple sets of internal QA/AA data was collected during field sampling and used for repeated validations and internal map accuracy assessment of PEM predictions. Independent third party accuracy data was collected concurrently with the PEM project, which enabled an official map accuracy assessment to be conducted during each stage of the PEM predictions.

1.3 Project Deliverables

The following were the project deliverables to be provided to P&T Ltd.:

1. An Input Data Quality Assessment report.
2. All data layers that were used for PEM input, cleaned and valued added (e.g., seamless soil moisture map with slope/aspect data added to each polygon; seamless FC1, and seamless terrain stability maps etc.).
3. A field sample plan.
4. Digital field plot data for GIF inspection points (VENUS 4.2) and hardcopy field plot cards.
5. Digital (ArcInfo[®]) ecosystem maps (at 1:20,000 scale on a TRIM planimetric background) and plot files for the entire project displaying Ecosystem, Biogeoclimatic units, ecosystem units, site modifiers, and a corresponding map legend defining all map units.
6. A seamless point coverage in ArcInfo[®] .e00 format for all ecosystem plots.
7. A set of hardcopy ecosystem maps at 1:20,000 scale.
8. A digital copy of the final knowledge base (.rtf).
9. A digital database that corresponds with above ecosystem map, including all core attributes required by the PEM Digital Standard and project specific attributes.
10. A final report that described mapping methodology and procedures, knowledge base accuracy, map accuracy etc.
11. A project metadata documentation report (per PEM standards) including input data assessment results and soil moisture mapping procedures and attributes report.
12. Structural stage rule base/knowledge base.
13. A structural stage spatial coverage, as a separate GIS layer.

2.0 DESCRIPTION OF PEM INPUT DATA SOURCES

Data sources used for the Boundary PEM project included:

- large scale Biogeoclimatic unit mapping (localised for this project);
- soil moisture mapping (new inventory developed to support the PEM project);
- slope and aspect (generated from TRIM I DEM);
- Granby/Kettle TEM mapping;
- Penticton Soils Mapping;

- existing forest cover inventory (updated by MoF to 1999);
- 450 ecosystem field plots and 900 brief field notes used in knowledge base development and calibration;
- 226 field verified random polygons for internal map accuracy assessment and repeated knowledge base validation; and
- 64 field verified polygons used in photo classifier calibration and knowledge base calibration.

The following sections provide detailed descriptions of the data sources listed.

2.1 Large-Scale Biogeoclimatic Unit Mapping

A reliable Biogeoclimatic (BGC) unit map at sufficiently large scale is of primary importance to the map user because many forest management decisions, strategies, and activities are based upon the Biogeoclimatic classifications (zone/subzone/variant). Localisation of the BGC unit boundaries from 1:250,000 scale (existing scale from MoF) to large scale (1:20,000 scale) was an integral part of this project. Tom Braumandl of Biome Ecological Services Ltd. (and former MoF Regional Ecologist, Nelson Forest Region) undertook large scale BGC mapping in the Boundary PEM project area during the period July-early December 2003. Dennis Lloyd (MoF Regional Ecologist, Kamloops Forest Region) and Marvin Eng (MoF, Research Branch) have reviewed and approved a final version of BGC maps. For more information regarding the Boundary TSA BGC localization work, please contact Tom Braumandl and/or Dennis Lloyd.

Timberline received a final version of localised BGC map in early December of 2003 from Marvin Eng of MoF. Following consultations with both P&T Ltd. and MoF personnel, Timberline GIS technicians smoothed the raster based BGC line work received from the MoF. This was done in order for the BGC linework to be compatible with PEM map line work (which was vector based).

2.2 Soil Moisture Mapping

This was a new inventory layer, generated specifically for the Boundary PEM. The timber harvesting landbase, covering approximately 476,700 ha, and excluding private land, upper elevation parkland/subalpine areas, and provincial parks, was stratified into ecologically oriented map units using a soil moisture focused approach. Large-scale BGC mapping was overlaid with FC1 mapping to produce a primary source of base polygons. The polygon linework was further refined digitally by selected ecological criteria such as major slope and aspect breaks, major changes in soil depth and texture, and riparian forests etc. Polygon line work modifications were completed prior to aerial photo interpretation of ecological attributes. The base polygons produced at this stage formed the finalized PEM polygons.

Each PEM base polygon within the timber harvesting landscape had the following ecological attributes classified by air photo interpretation:

- relative soil moisture regime;
- relative soil nutrient regime;
- soil depth and texture; and
- special sites that may not be defined by typical soil moisture/nutrient regimes such as anthropogenic units, wetland units not defined in regional field guides, etc.

Original cartographic FC1 photos (1:15000 scale, black and white) obtained from MoF Grand Forks District office were used for aerial photo interpretation work. Average polygon size was approximately 13.5 ha.

Polygons had up to a maximum of three edatope/soil texture-depth deciled components. To reduce the cross-product effect for polygons with complex labels (more than one decile), the soil texture/depth and special site attributes were directly tied to the appropriate edatope. An example of a polygon label is the following: 4/C-md⁴, 3/B-md³, 5/D-mf⁵. In this case the mf code (medium-textured fluvial) is linked to the 5/D edatope, not the 3/B edatope, although the decile value is the same. Refer to the Metadata Report (2003) attached to this document for a detailed description of the attributes list and definition for soil moisture mapping.

Prior to aerial photo interpretation, 64 field-verified polygons selected from several BGC units, and representing a variety of landforms were used to calibrate the photo interpreters selected to work on this phase of the PEM project.

2.3 Slope and Aspect

Slope and aspect class summaries for each finalized PEM base polygon were generated using the TRIM I Digital Elevation Model (DEM) function. The criteria used to define these classes are presented in Table 1.

Table 1 Slope Class Codes and Definitions

Slope Code	Description	Slope Range
LV	Level	0-10%
GE	Gentle	10.1-25%
MO	Moderate Slope	25.1-50%
MS	Moderately Steep	50.1-75%
VS	Very Steep	>75.1%

The criteria used to define aspect classes are presented in Table 2.

Table 2 Aspect Class Codes and Definitions

Aspect	Code	Criteria
Warm	w	135.1° - 285°
Cool	k	285.1° - 135°
Neutral	none	Slope < 10%

The percentage of the polygon area contained by each slope/aspect class was summarized in each of the PEM base polygon. Refer to the Metadata Report (2003) for detailed information about the derivation of slope and aspect data using DEM.

Dominant slope/aspect classes, up to three deciled components, were selected and normalized in each of the PEM base polygons. The normalized slope/aspect classes were used as primary input data during initial PEM classification (see Section 4.4).

2.4 Ecosystem Field Data

Field data collection involved several types of ecosystem data collection methods. Refer to “*Predictive Ecosystem Mapping For Boundary Timber Supply Area – Field Sample plan, 2002-2003*” and “*Boundary TSA PEM- Field sampling program report, October, 2002*” for a detailed review of the Boundary PEM field sampling program. The following provides a brief summary of ecosystem field data collected:

1. PEM knowledge base calibration field plots (450 point samples): the data were used for PEM knowledge base calibration and as data source information during soil moisture mapping.
2. Brief field mapping notes (approximately 900 points visited): the data were used for soil moisture mapping.
3. Photo interpretation calibration data (78 field plots or 64 polygons): the data were used in calibration of project photo interpreters (prior to soil moisture mapping) and in PEM knowledge base validation.
4. Knowledge base validation and internal map accuracy assessment polygons (field transect notes for 226 polygons from 70 polygon clusters throughout the THLB of the TSA).

2.5 Forest Cover Inventory

The forest cover inventory database, updated to 1999 by the Ministry of Forests (former Boundary Forest District) was used as an input data layer for the PEM. The FC1 database was flattened and made seamless prior to its use in PEM. Specific forest cover attributes extracted during the PEM process were:

- 1) Species Composition: each order of tree species (i.e., species 1 to species 5) was grouped by the following percent cover:
 - Abundant (a): greater than or equal to 90% (e.g., FDa);
 - Dominant (d): greater than 50% but less than 90% (e.g., FDd);
 - Significant (s) greater than or equal to 10% but less or equal than 50%; and
 - Presence (p): less than 10%.
- 2) Site class: site class (high, medium, and low) was derived using the FC1 inventory height field for leading species within each FC1 polygon relative to the average height for that tree species within the specific BGC unit.
- 3) Crown closure class: crown closure class (high, moderate, low, and open) was derived from the FC1 inventory crown closure field.
- 4) Non-vegetated, sparsely vegetated and anthropogenic units: non-vegetated, sparsely vegetated and anthropogenic units were derived from NPFORESTDSCRIPTOR of FC1 database.

Greater detail on FC1 attributes used in PEM is provided in the Metadata Report (2003).

2.6 Granby /Kettle TEM Mapping

This mapping project was conducted by Dave Clark, Larry Lacelle and Andy Stewart (MELP), starting in 1992. It was originally conceived as a Biophysical Habitat Mapping project. The mapping was completed in 1997, and was conducted at a 1:50,000 scale. Within the Boundary TSA the project area roughly comprises the northeast quarter of the TSA. Site series data from this TEM project was only extracted for portions of the PEM project area not subjected to soil moisture mapping.

2.7 Penticton Soils Mapping

Conducted in 1986, at a mapping scale of 1:100,000, limited information from this inventory was used in the PEM mapping project. This was in part due to uncertainty regarding positional accuracy of this data layer. Broad soil texture classes were derived using the data from this inventory. See the Metadata Report (2003) for further detail on the use of Penticton Soils Mapping.

3.0 METHODS

3.1 Thematic Input Data Quality Assessments

Digital files for all pertinent data sources (i.e., FC1, TRIM I/DEM, BGC mapping) were acquired from P&T Ltd. or the responsible government agency. Positional and thematic accuracy assessments were carried out wherever necessary and relevant. The following sections provide a brief summary of the results of the assessment. A subset of field collected PEM plots were used for the thematic assessment.

3.1.1 Forest Cover Attributes

Detailed tests were performed on a number of forest cover inventory attributes, and the results are presented in the Metadata Report (2003). The objective of the tests was to determine the reliability of these inventory attributes for use in PEM. However, forest cover polygons in the project area are often large, and the tree species present diverse. The single point observation of the species composition within any large forest cover polygon may produce misleading results of thematic accuracy of forest cover inventory. This was the case for this project in which forest cover data was collected in 444 ecosystem field observation points and the thematic assessment of the forest cover species composition produced undesirable results. The overall thematic map accuracy was 22.5% based on species type group assessed (see Section 2.1 of the Metadata Report (2003) for further details of the test result). It was concluded that the test for forest cover species composition of this PEM project is of little value to guide the use of species composition data for PEM.

3.1.2 Soil Moisture Mapping Attributes

The accuracy of photo interpreted soil moisture mapping data was assessed against 2002 field data collected for 226 polygons from the timber harvesting landscape of the project area. The test compared field verified polygon data against photo interpreted polygon data, rather than against point data, therefore providing an effective assessment of this data layer. Table 3 summarises the thematic accuracy of selected soil moisture mapping attributes.

Table 3 Thematic Accuracy of Soil Moisture Mapping Attributes

Soil Moisture Mapping Attribute	Soil Moisture Mapping Code	% Dominant Correct	% Overlap Correct
Soil Moisture Regime	SMR	61.2%	62.8%
Soil Nutrient Regime	SNR	66.4%	65.8%
Soil Texture/Depth		65.4%	63.4%

Refer to the Metadata Report (2003) for a detailed review of the assessment.

3.2 Spatial Input Data Quality Assessments

Detailed assessment of the spatial (positional) accuracy of the FC1 input layer was completed and documented, as per PEM Standards. It was determined that no spatial reconciliation was required for the FC1 layer. All other thematic input layers used in the PEM process in the THLB portion of the project area were determined to have acceptable spatial accuracy and are supported by the standard for use in PEM. Refer to the Metadata Report (2003) for detailed discussion of input data quality.

3.3 GIS Overlay and Attribute Extraction

In a seamless environment four input data layers (soil moisture mapping, FC1, Granby/Kettle TEM, and Penticton Soil Mapping) were overlaid using ArcInfo® to produce a “resultant polygon” coverage. BGC polygons had already been overlaid with soil moisture polygons in the generation of PEM base polygons. Map data from each contributing source layer was captured in each resultant polygon. The following is an abbreviated version of the overlay protocol to produce resultant polygons:

1. Soil moisture mapping polygon layer was overlaid with FC1 polygon layer to produce resultant polygon. Information contained in soil moisture polygons included soil moisture regime and related attributes, slope/aspect classes summary, and BGC related attributes.
2. All soil moisture polygon lines were hardlined (i.e. lines cannot be dissolved during later arc eliminations).
3. All polygons less than 0.5 hectares in size were dissolved producing a **Resultant 1** layer.
4. Resultant 1 layer polygons were hardlined. The Resultant 1 polygon layer was then overlaid with Granby/Kettle TEM (1:50,000 scale).
5. All polygons less than 2.0 hectares in size were dissolved producing a **Resultant 2** layer.
6. Resultant 2 layer polygons were hardlined and then overlaid with Penticton soil mapping layer (1:100,000 scale).
7. All polygons less than 2.0 hectares in size were dissolved producing a **Resultant 3** layer.
8. Thematic attributes from each contributing layer were extracted, captured in the resultant 3 layer polygons and used by the PEM knowledge base to predict site series.

3.4 Thematic Overlay of Data Information Layers

Cross-product effect, which results from the spatial overlay of complex labels from multiple data source layers, is a significant issue for PEM. Sources of cross product were identified and cross product effect minimised where possible for this project. A key means of attaining this objective involved the temporary overlay of other data information layers with PEM base polygons. PEM predictions were obtained for the Resultant 3 layer polygons as described above. The PEM predictions were then area weighted back into the PEM base polygons, using an *MS/Access* conversion tool developed by Timberline, and all the interim polygon layer were deleted. See Section 3.9.2 for a discussion of the functions of the conversion tool.

3.5 Input Database Preparation

PEM input database preparation involved collating the thematic information from the various data sources for each resultant polygon into a resultant database. Procedures included the grouping of selected existing attributes into attribute classes. A number of new attributes were derived from existing data sources. The following summarizes the procedures that took place:

1. Species composition, tree crown closure and site class data was extracted for FC1 polygons

where the inventory age of leading species was 40 years or greater. Tree species with inventory age ≥ 40 are considered semi-mature in this study area. However an exception was made for any polygons with inventory age less than 40 years that contained AC, PY, PW, CW or S. The presence of any of these indicator species was reflected in the PEM input database and considered by the PEM knowledge base.

2. **Site Class** was derived using the inventory height field from the FC1 inventory. The site class was derived using relative height of leading tree species, for a number of tree species on a BGC unit-specific basis. Site class was grouped into three classes: high (H) where relative height was greater than 1 standard deviation above the mean, low (L) where relative height was greater than 1 standard deviation below the mean, and medium (M) where relative height was within 1 standard deviation of the mean.
3. **Crown Closure** was grouped into 4 classes: high (crown closure $>60\%$), moderate (crown closure of 20.1-60%), low (crown closure of 10-20%), and open (crown closure $\leq 10\%$).
4. Slope and aspect data summary contained in PEM base polygons were re-compiled using two methods. The first method was to select the first 3 “slope+aspect” classes (by area) within each PEM base polygon. Their proportions were normalized (i.e., adjusted to total 100%). The normalized slope+aspect classes and their deciles were used as primary PEM input data during initial PEM predictions. The second method was based on “dominant” slope+aspect class, i.e., only polygons with a “dominant” slope/aspect class or “dominant” aspect class had this information used in the PEM knowledge base (see Metadata Report (2003) for definition of “dominant” slope/aspect class). This was the case in final PEM prediction where soil moisture data were used as a primary PEM input layer.

Elevation classes were derived from average polygon elevation values derived from DEM. Greater detail on this process is outlined in the Metadata Report (2003)

The input database was formatted to meet all the requirements of the PEM knowledge base software program (*EcoNGen*[®]). The following is a list of the attributes that were used during the PEM classification process.

- BGC unit: 14 units;
- Soil moisture: 8 classes (i.e., 0, 1, 2, 3, 4, 5, 6, 7);
- Soil nutrient: 5 classes (i.e., A, B, C, D, E);
- Soil texture/Depth: 10 classes;
- Elevation data: three classes for a given BGC unit (upper, middle, and lower);
- Slope/aspect: nine classes (LV+none, GE+k, GE+w, MO+w, etc.);
- Tree species composition: four classes: (abundant, dominant, significant, and present);
- Site class: three classes (high, medium, low);
- Crown closure: four classes (high, moderate, low, open);
- Special sites: non-vegetated and anthropogenic units, non-documented wetland etc.;
- Ecosystem unit and proportions from Granby/Kettle TEM project;
- Soil texture data from Penticton soil mapping project;
- Transitional ESSFdc1 areas (relatively drier and wetter areas were identified within the ESSFdc1 unit); and
- Riparian (TRIM I stream information derived for upper elevation ESSF units).

Granby/Kettle TEM and Penticton soil data were used only for the portions of landscape in which no soil moisture data were generated by this project (i.e., private land, parkland and provincial parks).

Refer to the “Attribute Definition Table” in the Metadata Report (2003) for greater detail and documentation of the PEM knowledge base attribute extraction and derivation process, and attribute class definitions.

3.6 Knowledge Base Development

Initial knowledge base development may be understood as transforming site series relationships, which are described in text format (i.e. descriptive sentences and paragraphs) into numerical belief values (ranks). The interpretation of these descriptions is highly dependent on the ecologist’s understanding of these relationships. An advantage of the PEM approach is that an ecologist’s interpretations of these relationships can be explicitly captured in knowledge base tables, and readily reviewed and modified, if required.

Initial knowledge base of the Boundary PEM was developed by Tom Braumandl of Biome Ecological Services Ltd. Mr Braumandl was the regional ecologist of the former Nelson Forest Region. His involvement in knowledge base development ensured his knowledge and understanding of ecological relationships in the TSA and region was translated into the knowledge base. The project benefited from his involvement in different stages of knowledge base work.

3.7 Knowledge Base Calibration Using Field Data

Knowledge base calibration refers to a process that applies an initially developed KB to project specific field data. Field sampling was conducted in 2002 for this project, with site, soil, vegetation, and site series information being collected. The KB calibration process used data from 451 PEM plots to further develop, refine and localise the PEM knowledge base. The field collected attributes formed the input database for the knowledge base calibration. The predicted map entities (site series, non-forested ecosystem units etc.) were compared against the field verified “known” map entities. The results were analysed, and the analysis focussed on correcting the error trends that existed.

The knowledge base was adjusted where consistent patterns of incorrect prediction were revealed. These error patterns usually reflected local variations in site series relationships. Knowledge base development and calibration was an iterative process, and many adjustments were required at this step, until the “perceived” maximum accuracy score ceiling was reached using field collected “true” data.

Refer to Section 4.4 of the Metadata Report (2003) for results for knowledge base calibration.

3.8 Knowledge Base Validation

Knowledge base validation involved applying the map input data to the calibrated knowledge base. This process was the most challenging step in the process of knowledge base development and PEM classification. Because map polygon data was derived from a number of input data layers (FC1, soil moisture mapping etc), there were errors and inconsistencies associated with each of these inventories and the resulting overlay. In addition, the inventory layers contributed in varying degrees to PEM ecosystem prediction. Knowledge base validation involved adjusting attribute belief values, individual attribute weightings and attribute combinations to achieve desired map accuracy for map entity predictions, using the map input data.

The knowledge base validation process was also an iterative one. The 226 validation polygons with field verification were subdivided into two sets, i.e., one set of 161 polygons used for knowledge base validation and quality assurance, and another set with 65 polygons used for final internal map accuracy

assessment and validation reporting. The 65 polygons were randomly selected from the pool of 226 polygons.

A former strategy called for the creation of multiple validation data sets. This permitted repeated knowledge base validation and internal map accuracy assessments to be conducted. This original strategy had to be modified because:

- there were an insufficient number of polygons to permit meaningful validation by BGC unit, if the data polygons were divided into multiple sets; and
- the short time frame restricted a repeated process of validation. Delays in project initiation meant the project did not get started until early September 2002, thus creating significant time constraints.

The first step in the knowledge base validation process was to apply the calibrated knowledge base to project input data. The validation set of 161 polygons data were used to assess map accuracy. Error sources and trends were analysed by BGC units and the knowledge base was adjusted to correct these through different attribute combinations and weighting, and PEM input data manipulation (e.g., if a classifier consistently classify soil moisture wetter than normal, an index associated with the classifier and the particular class of soil moisture was created).

After satisfactory results were achieved through the iterative validation process, the remaining 65 polygons (from the pool of 226 polygons) were used to report internal map accuracy.

3.9 Final PEM Classification

Final PEM classification involved applying the validated knowledge base to the final resultant database (PEM input data). The design and utility of the soil moisture mapping layer, with its focus on providing reliable soil moisture and soil nutrient regime values for each polygon, was given significantly greater weight in the PEM knowledge base for most of the BGC units during the final classification.

Once the PEM knowledge base had provided decided site series predictions for each *Resultant 3* polygon (formed by intersection of PEM base polygons with other data sources layer), it was necessary to re-compile this data back to the PEM base polygons (i.e., soil moisture mapping polygons). The various site series predictions were area-weighted and re-compiled using an *MS/Access* conversion tool developed by Timberline.

3.9.1 Mapping Entities

Site series per the Nelson Regional field guide (LMH #20), and other map entities per the mapcodes_jan2003.xls spreadsheet and Table 3.1 of the TEM Standards formed the map entities for this project.

A number of new BGC units were described and developed by Tom Braumandl and approved by Dennis Lloyd (MoF). These were the IDFxh4, ESSFdcu1, ESSFwcu4 and MSdm1a BGC units. In addition a new ecosystem unit was developed for the PPdh1. This was the FdPy – Snowberry – Pinegrass unit. The unit was submitted to Corey Erwin (MSRM) for generation of a provincial mapcode for this unit. See the Metadata Report (2003) for further detail on project map entities and new BGC units for the area.

No site series were aggregated/lumped for this project.

3.9.2 Area Weighted Decile Derivation using ACCESS Conversion Tool

After the final classification was completed, site series predictions were area weighted based on the original PEM base polygons (soil moisture mapping polygons). Resultant polygons formed by the data sources overlay (Resultant 3 polygons) were dissolved into the base PEM polygons. In other words, several other layers of data information contributed thematically to the PEM prediction but didn't produce final ecosystem polygons.

The following is a summary of the functions carried out by an *MS/Access* conversion tool that re-compiled all site series predictions to provide a maximum of three deciled site series components for each base PEM polygon:

1. The program takes predicted site series and decile output directly from *EcoNGen*[®], and performs a check to see that all required fields exist.
2. For tied site series predictions that occurred, the tool provided an average each of the tied predictions (e.g., ICHmk1 01 and 04 with equal final scores and both site series were accepted and given equal areas within the polygon).
3. The tool built a new *_FcPem* table and linked the forest cover polygons to the forest cover site series predictions.
4. The tool area-weighted the site series predictions based on resultant FC1/ PEM polygon areas.
5. The tool summed the scaled site series predictions for each PEM polygon.
6. If there were ties between two site series after they have been area-weighted, the tool added 0.00001 to the decile value of the lower-name polygons. This is required to determine an order.
7. If the rounded total of deciles 1-3 was less than 10 (i.e., there was a decile 4+ prediction) the difference between the total and 10 was weighted according to the unrounded decile 1-3 values and placed in the [adj1], [adj2], and [adj3] fields in the *_Pem* table.
8. These unrounded decile values were added to the [adjX] values, ranked placed in SSx and DEx fields in the *_Pem* table.

Two separate final databases were produced for this project. One database contained the base PEM polygons (soil moisture mapping polygons) with final site series predictions (43,012 polygons, a TEM-like database), site modifiers (modelled from slope/aspect information, soil texture and depth etc.) The second database was the PEM input database, which includes all resultant polygons and associated attributes used to make PEM predictions. This interim database was not normally required by PEM standards as a deliverable. All attributes included in both PEM databases were coded and documented according to the relevant digital standards (i.e., the PEM digital standard, the PEM standard, the TEM digital standard, and the VRI/forest cover digital standard).

3.10 Structural Stage Modeling

A knowledge base-driven model approach was used to produce a separate structural stage layer for the PEM project area. The final PEM database and the Boundary TSA Forest Cover Inventory data layers (updated to 2001) were used by the structural stage model. Ecological and stand attribute data were extracted from these layers for each resultant polygon and run through an *EcoNGen*[®]-based knowledge base to provide a structural stage classification for each polygon. Structural stage is delivered as a separate GIS layer, as per PEM standards. This layer can be displayed as a colour themed overlay on final PEM ecosystem maps. Documentation of structural stage model attributes, processing and the structural stage knowledge base are provided in Section 6.0 of the Metadata Report (2003).

3.11 Final Digital Mapping

Final digital mapping is based upon the final digital PEM database as described above. Digital and hard copy 1:20,000 scale ecosystem maps, complete with associated map legend were produced, with the map labelling and coding following the PEM standard. Map entities were presented using the two-digit number code where available, per the client’s request. Where appropriate the two-letter code was used in the absence of the two-number code. Site modifier generation followed PEM standards (slope and aspect modifiers).

3.11.1 Map Labels

The following are two examples map labels; a simple label, and a complex label:

- 03 k (100% 03 site series, cool aspect modifier); and
- 7 01 j
2 06 j
1 LU j (70% 01, 20% 05, 10% Low bench shrub floodplain, gentle slope modifier).

4.0 RESULTS

4.1 Large-scale BGC Mapping

Tom Braumandl of Biome Ecological Services Ltd. undertook large-scale BGC mapping for the Boundary TSA. As a result of the mapping, there were significant revisions made to BGC unit boundaries. In addition, there are several new BGC units named as follows:

- IDFxh4 (Very Dry Hot Interior Douglas-fir Boundary Variant): previously was described as IDFun (Interior Douglas-fir Undifferentiated). PEM mapping was completed using newly developed map entities for this unit;
- ICHdw1 (Dry Warm Interior Cedar–Hemlock West Kootenay Variant): previously was described as ICHdw. PEM mapping was completed using map entities per the ICHdw in the regional field guide;
- ICHdw2 (Dry Warm Interior Cedar–Hemlock Boundary Variant): previously was described as ICHdw. PEM mapping was completed using map entities per the ICHdw in the regional field guide. In comparison to ICHdw1, ICHdw2 had significantly higher presence of ponderosa pine, even on zonal sites (i.e., 01b site);
- ESSFdcu1 (Dry Cold Engelmann Spruce-Subalpine Fir Upper Elevation Okanagan Variant): previously described as AT (Alpine Tundra). PEM mapping was completed using newly developed map entities for this unit;
- ESSFwcu4 (Wet Cold Engelmann Spruce–Subalpine Fir Upper Elevation Selkirk Variant): previously described as AT (Alpine Tundra). PEM mapping was completed using newly developed map entities for this unit; and
- MSdm1a (Dry Mild Montane Spruce Okanagan Variant Western Redcedar Phase): previously described as ICHmk1. PEM mapping was completed using map entities per the ICHmk1 BGC unit in the regional field guide).

Site series classification and associated site and vegetation description of the new BGC units (i.e., IDFxh4, ESSFdcu1, and ESSFwcu4) are presented in Section 4.1 of the Metadata Report (2003).

4.2 New Forested Ecosystem Unit in the PPdh1

A new site series within the BGC unit PPdh1 was observed during the soil moisture mapping stage of the project. Since soil moisture mapping used cartographic photos from the forest cover inventory, numerous field data sources of forest cover attributes were documented on the photos. An ecosystem unit with Douglas-fir leading was found to occur extensively within a portion of PPdh1 landscape near the city of Grand Forks on steep cool aspect up to U.S. international border. Subsequent discussions with Dennis Lloyd, Regional Ecologist of Southern Interior Forest Region, confirmed the occurrence of the unit. Dennis Lloyd confirmed that the unit displays a similar plant association to the PPxh1 / 06 (SP ecosystem unit).

The following is a general description of the unit:

Unit name:	FdPy-Snowberry-Pinegrass
Forest canopy:	FD leading with PY and LW as minor components.
Soil moisture:	submesic to mesic.
Soil nutrient:	B, C, D.
Slope:	significant
Aspect:	cool
Soil texture:	medium
Parent materials:	Mb, Cb
Site series number:	00
Site series code:	SP

4.3 PEM Knowledge Base Calibration

Knowledge base calibration refers to a process that applies an initially developed knowledge base to project specific field data. Ecological relationships that have been captured elsewhere or translated from broad scale regional level may not be entirely applicable to the project area due to the influence of local climate (e.g., snow bowl or cold air drainage, shallow soils etc.), and local variations in hydrology, and geomorphological history. Adjustment of the knowledge base is required to achieve the desired knowledge base accuracy using localized field data.

The knowledge base calibration of this project used 470 field plots established by this project. An iterative process was performed to achieve an optimum knowledge base accuracy by using field collected input attributes. The assessment used a protocol of “exact match” receiving a score of 1.0. Where there were multiple predictions (one of which was correct), half marks were awarded (0.5). The scores are presented in Table 4.

Table 4 Knowledge Base Calibration Accuracy

Biogeoclimatic Unit	# Samples	Score (%)
ESSFdc1	48	81.3
ESSFdcu1	1	0.0
ESSFwc1	1	100.0
ESSFwc4	7	71.4
ESSFwcu4	n/a	n/a
ICHdw1	17	94.1
ICHdw2	59	96.6
ICHmk1	89	91.0
ICHmw2	76	84.2
IDFdm1	64	85.9
IDFxb4	11	81.8
MSdm1	71	87.3
MSdm1a	3	66.7
PPdh1	4	75.0
All Units	451	87.4%

¹ – Scored 1.0, ²– Scored 0.5

4.4 Preliminary PEM Prediction

The calibrated PEM knowledge bases were applied to project input data and a preliminary set of ecosystem unit predictions were obtained. Since the preliminary PEM occurred prior to soil moisture mapping, slope/aspect data were used as primary input to PEM with forest cover attributes as supplementary input data. The data of all 226 internal accuracy assessment polygons were used to assess the accuracy of PEM predictions. The assessment followed protocols as outlined in Meidinger (2000). Table 5 summarizes the assessment results from the preliminary PEM predictions.

Table 5 Accuracy Assessment Results of Preliminary PEM Predictions

Biogeoclimatic Unit	Predicted Site Series Map Accuracy		
	Number of Samples	Percent Dominant Correct (%)	Percent Overlap Correct (%)
MSdm1	43	39.5%	49.1%
MSdm1a	3	0.0%	20.0%
IDFxh4	21	42.9%	44.8%
IDFdm1	44	47.7%	46.4%
ICHdw1	2	50.0%	70.0%
ICHdw2	19	57.9%	65.3%
ICHmw2	28	35.7%	39.3%
ICHmk1	48	66.7%	54.2%
ESSFdc1	18	44.4%	51.1%
Total	226	48.2%	49.3%

4.5 Knowledge Base Validation

The internal quality assurance and map accuracy assessment data form the basis for knowledge base validation of this project. The data were used to assess map accuracy at polygon level (i.e., thematic map accuracy) as well as at landscape level (i.e., site series proportions). Accuracy results from application of map data for 161 of the 226 internal QA/AA polygons to the validated knowledge base are presented in Table 6.

Table 6 Knowledge Base Validation Results

Biogeoclimatic Unit	Number of Polygons	% Dominant Correct	% Overlap Correct
ESSFdc1	14	57.1%	58.6%
ICHdw1	1	100.0%	50.0%
ICHdw2	13	69.2%	79.2%
ICHmk1	35	57.1%	56.9%
ICHmw2	19	68.4%	60.5%
IDFdm1	30	83.3%	75.3%
IDFxh4	16	56.3%	62.5%
MSdm1	31	58.1%	63.2%
MSdm1a	2	100.0%	90.0%
Total	161	65.2%	64.8%

Actual versus predicted map entities for each of the polygons assessed in the knowledge validation process are presented in Appendix II of the Metadata Report (2003). It must be pointed out that no

ambiguous or transitional site series were documented for all internal QA/AA data. All the site series calls were best calls.

4.6 Internal Quality Assurance and Map Accuracy Assessment Data

Table 7 summarizes the area distribution of site series by BGC units for the validation data.

Table 7 Site Series Area Summary of Validation Data

Site Series	IDF _{xh4}	IDF _{dm1}	MS _{dm1}	ICH _{dw2}	ICH _{mw2}	ICH _{mk1}	ESS _{fdc1}
01	192.09	167.05	222.37		186.99	317.33	175.21
	38.44%	16.53%	26.43%		45.18%	40.13%	43.01%
01a				170.68			
				44.91%			
01b				121.30			
				31.92%			
02	60.65	220.47	80.25	64.18	7.09	59.79	18.17
	12.14%	21.82%	9.54%	16.89%	1.71%	7.56%	4.46%
03	61.81	146.60	31.82	23.13	113.45	93.28	51.35
	12.37%	14.51%	3.78%	6.09%	27.41%	11.79%	12.60%
04	146.75	441.15	443.69		58.32	201.74	138.75
	29.36%	43.65%	52.74%		14.09%	25.51%	34.06%
05	19.05	19.15			20.20	86.30	
	3.81%	1.89%			4.88%	10.91%	
06	3.34	11.27	54.53		16.20	26.91	15.47
	0.67%	1.11%	6.48%		3.91%	3.40%	3.80%
07		4.18	1.53		4.87	4.22	
		0.41%	0.18%		1.18%	0.53%	
08			3.16				
			0.38%				
09			1.75		1.93		
			0.38%		0.47%		
CF	16.06						
	3.21%						
FE		0.14					
		0.01%					
OW		0.57					
		0.06%					
RI					4.87		
					1.18%		
RO							3.86
							0.95%

Site Series	IDFxb4	IDFdm1	MSdm1	ICHdw2	ICHmw2	ICHmk1	ESSFdc1
TA			2.22	0.77		1.27	4.58
			0.26%	0.16%			1.12%
Total (ha)	499.74	1010.58	841.32	380.05	413.92	790.84	407.38
Total (%)	100%	100%	100%	100%	100%	100%	100%

4.7 Final PEM Prediction

Final PEM prediction used soil moisture data as primary input data. Data from the slope/aspect summaries, the selected forest cover attributes etc. were used as supplementary data in the PEM predictions. After an iterative process of PEM knowledge base validation, the validated knowledge base was applied to a final set of 65 QA/AA polygons to assess internal map accuracy. The assessment followed protocols as outlined in Meidinger (2000). The results of the internal map accuracy assessment are presented in Table 8.

Table 8 Results for Internal Map Accuracy Assessment

Biogeoclimatic Unit	Predicted Site Series Map Accuracy		
	Number of Samples	Percent Dominant Correct (%)	Percent Overlap Correct (%)
MSdm1	12	41.7%	50.8%
MSdm1a	1	0.0%	10.0%
IDFxb4	5	80.0%	66.0%
IDFdm1	14	71.4%	65.0%
ICHdw1	1	100.0%	80.0%
ICHdw2	6	83.3%	75.0%
ICHmw2	9	33.3%	51.1%
ICHmk1	13	69.2%	64.6%
ESSFdc1	4	75.0%	60.0%
Total	65	61.5%	60.5%

4.8 Gross Area Distribution of Biogeoclimatic Units

Table 9 summarizes the gross area of each BGC unit within the total project area.

Table 9 Biogeoclimatic Unit Area Summary for the Boundary TSA

Biogeoclimatic Unit	Total Area (ha)	% of Total TSA Area
ICHmk1	98,492.2	16.9
MSdm1	98,243.5	16.9
IDFdm1	82,449.2	14.2
ESSFdc1	78,901.2	13.6
ICHmw2	49,196.2	8.5
ICHdw2	44,271.2	7.6
IDFhx4	39,227.6	6.7
ESSFwc4	22,068.9	3.8
ICHdw1	18,372.7	3.2
ESSFdcu1	14,458.7	2.5
PPdh1	13,261.6	2.3
ESSFwc1	11,424.1	2.0
ESSFwcu4	9,463.8	1.6
MSdm1a	1,351.2	0.2
Totals	581,182.1	100.0%

However the area values in Table 9 include private lands and parks. The Timber Harvesting Landbase (THLB) areas, by BGC unit, are presented in Table 10.

Table 10 Biogeoclimatic Unit Area Summary for THLB portion of the Boundary TSA

Biogeoclimatic Unit	Total Area (ha)	% of Total TSA Area
ICHmk1	84,920.3	14.6
MSdm1	94,521.9	16.3
IDFdm1	59,293.7	10.2
ESSFdc1	63,658.9	11.0
ICHmw2	38,771.3	6.7
ICHdw2	40,748.2	7.0
IDFhx4	16,884.8	2.9
ESSFwc4	10,354.4	1.8
ICHdw1	8,403.2	1.4
ESSFdcu1	9,468.9	1.6
PPdh1	2,422.4	0.4
ESSFwc1	7,041.1	1.2
ESSFwcu4	3,267.7	0.6

Biogeoclimatic Unit	Total Area (ha)	% of Total TSA Area
MSdm1a	1,273.6	0.2
Totals	441,030.4	75.9%

The ESSFdcu1 and ESSFwcu4 upper elevation/parkland BGC units are considered part of the THLB, and so are presented in Table 10. However timber harvesting is limited to the lower elevations of these units. Soil moisture mapping was only conducted on portions of these parkland units.

Ecosystem units are comprised of forested and non-forested site series, wetland ecosystems, and non-vegetated, sparsely vegetated or anthropogenic site units. Table 11 summarizes the total areas in forested, non-forested, water and wetland units for each of the Biogeoclimatic units in the project area.

Table 11 Total Areas by Forested, Non-forested, Water and Wetland Units by Biogeoclimatic Unit, in Hectares

Biogeoclimatic Unit	Forested Units	Non-Forested Units	Water Features	Wetland units	Total Area
ESSFdc1	77,082.9	1,722.4	39.2	29.3	78,873.8
ESSFdcu1	12,848.3	1,431.2	8.3	160.9	14,448.7
ESSFwc1	11,316.0	92.1	5.6	5.7	11,419.4
ESSFwc4	21,907.7	143.2	12.2	0.0	22,063.1
ESSFwcu4	8,986.2	456.7	10.4	6.7	9,460.0
ICHdw1	15,584.7	209.8	1,320.2	7.2	17,121.9
ICHdw2	43,506.7	392.6	161.7	192.1	44,253.1
ICHmk1	97,380.1	708.8	290.9	71.2	98,451.0
ICHmw2	48,455.4	682.0	26.8	9.7	49,173.9
IDFdm1	74,409.6	7,159.9	621.9	220.5	82,411.9
IDFxh4	30,875.3	7,771.5	1,738.2	75.5	40,460.5
MSdm1	96,983.9	570.6	630.4	18.7	98,203.6
MSdm1a	1,346.0	5.2	5.3	0.1	1,356.6
PPdh1	7,353.2	5,491.4	359.0	54.8	13,258.4
Total	548,036.0	26,837.4	5,230.1	852.4	580,955.9

Table 12 summarizes the gross area and percentage distribution of forested ecosystem units (site series) by BGC unit.

Table 12 Gross Area of Forested Ecosystem Units by Biogeoclimatic Unit

Biogeoclimatic Unit	01	01a	01b	02	03	04	05	06	07	08	09	SP
ESSFdc1	32,592.0			6,030.6	28,451.6	9,033.6	38.0	790.4	146.7			
%	41.3%			7.6%	36.1%	11.5%	0.05%	1.0%	0.2%			
ESSFdcu1	3,625.4			3,343.9	3,997.1	84.9	139.9	1,657.0				
%	25.1%			23.1%	27.7%	0.6%	1.0%	11.5%				
ESSFwc1	6,415.4			3,329.5	1,453.7	29.2	88.2					
%	56.2%			29.2%	12.7%	0.3%	0.8%					
ESSFwc4	6,791.5			2,940.9	987.7	9,505.9	1,319.1	233.7	47.8	81.0		
%	30.8%			13.3%	4.5%	43.1%	6.0%	1.1%	0.2%	0.4%		
ESSFwcu4	3,717.2			1,208.1	2,337.0	246.0	395.1	1,082.7				
%	39.3%			12.8%	24.7%	2.6%	4.2%	11.4%				
ICHdw1		6,981.3	5,548.9	2,324.6	663.9	66.0						
%		40.8%	32.4%	13.6%	3.9%	0.4%						
ICHdw2		19,866.2	10,502.0	10,087.2	2,546.7	504.6						
%		44.9%	23.7%	22.8%	5.8%	1.1%						
ICHmk1	32,836.8			10,027.1	18,944.4	27,705.4	5,728.0	1,949.0	148.4	41.1		
%	33.4%			10.2%	19.2%	28.1%	5.8%	2.0%	0.2%	0.04%		
ICHmw2	18,635.1			3,174.6	14,186.7	9,236.1	2,161.2	989.2	30.1	1.3	41.2	
%	37.9%			6.5%	28.8%	18.8%	4.4%	2.0%	0.1%	0.0%	0.1%	
IDFdm1	21,483.9			6,155.1	10,620.4	30,574.7	3,747.8	1,710.4	117.3			
%	26.1%			7.5%	12.9%	37.1%	4.5%	2.1%	0.1%			
IDFhx4	10,181.8			2,787.6	7,679.6	8,054.1	1,598.5	573.7				
%	25.2%			6.9%	19.0%	19.9%	4.0%	1.4%				
MSdm1	27,892.4			6,513.1	15.5	56,922.0	62.3	4,319.5	55.0	376.6	827.5	
%	28.4%			6.6%	0.0%	58.0%	0.1%	4.4%	0.1%	0.4%	0.8%	
MSdm1a	286.2			197.6	27.5	682.9	77.5	61.8	0.9	11.6		
%	21.1%			14.6%	2.0%	50.3%	5.7%	4.6%	0.1%	0.9%		
PPdh1	516.4			1,855.0	2,731.1	607.2	92.4	101.8				1,449.4
%	3.9%			14.0%	20.6%	4.6%	0.7%	0.8%				10.9%

5.0 DISCUSSION

5.1 Map Entity Area Summaries and Distribution

Map entity areal representation, summarized from the internal QA/AA polygon dataset was used to guide final knowledge base manipulations. Site series proportions by BGC unit were reviewed. Review of the area distribution of final predicted site series in Table 12 illustrates some interesting trends. Submesic site series seem to predominate in the MSdm1 and IDFdm1 BGC units. However, internal field QA/AA data supports these site series area distributions (Table 7). During the field orientation with Tom Braumandl (former Regional Ecologist, Nelson Forest Region), difficulties were encountered finding good examples of zonal sites in the MSdm1 and IDFdm1 units. The prevalence of shallow, coarse-textured soils in these units makes the zonal site uncommon.

5.2 Internal Map Accuracy Assessment

Initial internal map accuracy assessment produced statistics of 66.2% for percent dominant and 62.5% for percent overlap correct. Corresponding initial external map accuracy assessment values of 65% and 62% supported this. Rather than lumping site series to produce a desired statistics (65% and 65%), Timberline decided to enhance PEM prediction accuracy by two means: enhance soil moisture mapping quality for certain portions of the project area, and enhance knowledge base based on error directions and sources, detected from the validation data set.

An interesting trend was observed during the iterative process of final PEM prediction improvement. Site series area distributions and proportions moved closer to the expected distribution, and external (independent) map accuracy values also improved. However, the internal map accuracy (using the 65 independent polygon set) decreased (i.e., from 66.2% and 62.5% to 61.5% and 60.5% respectively for percent dominant correct and percent overlapping correct statistics). Reasons for this trend remain unclear.

5.3 Difficult Site Series for Prediction

During the process of the PEM knowledge base validation and internal map accuracy assessment, great difficulties were encountered differentiating between the following ecosystem units for certain BGC units:

- ICHmw2/03 and ICHmw2/04;
- ICHmk1/03 and ICHmk1/04;
- MSdm1/05 and MSdm1/06; and
- ESSFdc1/04 and ESSFdc1/05.

A primary reason for the difficulties is that the ecosystem units occur in similar edatopic and site positions. Keys described in the regional field guides did not commonly coincide with field observations. For example the ICHmw2 / 03 and ICHmw2 / 04 occur in the soil moisture regime 2- 4 range. According to the regional field guide aspect is a key to separating the two units (i.e., 03 on warm aspects, 04 on cool aspects). However the field data did not reveal a predictable pattern based on change of aspect. The same issue arose with the ICHmk1 / 03 and 04 units.

The MSdm1 / 05 and ESSFdc1 / 05 are Trapper’s tea (*Ledum glandulosum*) dominated ecosystem units. They are locally common in certain parts of the landscape. Since there are no obvious photo interpretable keys developed to separate the units from those units also occurring in the similar edatopic positions, great difficulties were encountered in predicting these units. These units are not mappable at the current scale of mapping

Site series lumping of the above listed units was considered following the knowledge base validation process. However, the results of the initial external map accuracy assessment were quite positive (65% dominant correct and 62% overlapping correct). The decision was made to enhance the input data and knowledge base predictions rather than lump/group certain site series. However potential map users should be aware of this issue regarding unmappable site series when making interpretations regarding these units.

5.4 Internal Quality Assurance

Quality assurance was conducted on PEM procedures, and on PEM project final deliverables.

5.4.1 Field Data Collection

Quality assurance was conducted at every stage of the project to ensure a high quality PEM end product. The field data collection phase of the project commenced with a two-day field orientation session led by Tom Braumandl (Biome Ecological Services Ltd.). This session was attended by all members of Timberline field crew, and ensured consistency in site identification and interpretation by all field crew members (including the independent contractors responsible for collection of the independent accuracy assessment field data set).

5.4.2 Soil Moisture Mapping Photo Interpretation

During the field data collection phase of the project, the Senior Project Ecologist selected and field visited 64 polygons to determine polygon ecosystem composition. The polygons were selected from five BGC units that were extensive throughout the project area. Prior to soil moisture mapping, all potential photo interpreters undertook a rigid test of quality and consistency of their photo interpretation work. A number of potential photo interpreters were eliminated as a result of this test, primarily due to the concerns of quality issues. During the course of soil moisture mapping, the Senior Ecologist selected photos from each photo interpreter for the purposes of quality assurance and to ensure classification consistency. This QA procedure further enhanced the quality of soil moisture mapping.

5.4.3 Internal Map Accuracy Assessment

Ecosystem field data was collected for randomly selected polygons for use in testing internal map accuracy assessment. The procedures followed the level four protocol outlined in Meidinger (2000). This test is a valuable means of ensuring a high quality end product. As indicated in Table 7 of this document, results from Timberline’s internal map accuracy assessment were comparable to the results from the independent third party map accuracy assessment, further confirming the value of this assessment.

5.5 Quality Assurance of Final PEM Deliverables

Quality assurance of final deliverables is a mandatory requirement for all completed PEM projects. These QA procedures were formerly conducted by MELP/MSRM. Final products were checked with regard to correct spatial validity, attribute combinations and format, coding, metadata documentation and reporting.

A third party Quality Assurance group, hired by the client, can now perform these tasks. Preliminary QA standards have been introduced in 2003, and may be subject to revision. Timberline was advised by MSRM and P&T Ltd. to conduct a thorough QA on the Boundary PEM project deliverables. QA was conducted per the standards and procedures outlined in *Introduction to Quality Assurance Procedures – Ecosystem Inventory and Mapping Version 1.0* (MSRM, February 2003) and *Draft Quality Assurance Guidelines: Predictive Ecosystem Mapping Version 1.0* (MSRM, February 2003). QA deliverables were submitted to P&T Ltd. in April 2003.

6.0 ACKNOWLEDGEMENTS

Many individuals have contributed to the success and completion of this PEM project. In particular, Timberline would like to express its sincere appreciation to the following individuals:

Tom Braumandl (Biome Ecological Services Ltd.) has contributed significantly to several stages of the PEM project including field orientation and quality assurance, initial knowledge base development and subsequent advice on knowledge base refinement, new BGC unit and associated ecosystem units descriptions etc.

Randy Waterous (P&T Ltd.) was contract monitor and the key contact person for the project and, together with Geoff Bekker (P&T Ltd.), provided ongoing support and guidance for the project.

Del Meidinger, Dennis Lloyd (MoF), Dave Clark and Corey Erwin (MSRM) reviewed material or provided advice on the following components of the project: project methodology, PEM base polygon creation, field sample plan design, field data collection reporting, accuracy data collection and analysis.

The Ministry of Forests, Boundary Forest District, Grand Forks provided BCB Forest Cover cartographic air photos for use by this project in soil moisture mapping interpretations. The MoF also provided FC1 disturbance data for use in structural stage mapping.

7.0 REFERENCES

Braumandl T.F. and Curran, M.P. 1992. A Field Guide for Site Identification and Interpretation for the Nelson Forest Region. B.C. Ministry of Forests. Land Management Handbook Number 20.

Meidinger, D. 2000. Protocol for quality assurance and accuracy assessment of ecosystem maps. B.C. Ministry of Forests. Research Branch, Victoria, B.C. Internal Rep.

Resources Inventory Committee. 2000. Standard for Digital Terrestrial Ecosystem Mapping (TEM) Data Capture in British Columbia. Version 3. Terrestrial Ecosystems Task Force, Ecosystems Working Group. Victoria, BC.

Resources Inventory Committee. 1999. Standards for Predictive Ecosystem Mapping – Inventory Standard. Terrestrial Ecosystems Task Force. Victoria, BC.

Resources Inventory Committee. 1998. Standard for Terrestrial Ecosystem Mapping in British Columbia. Terrestrial Ecosystems Task Force, Ecosystems Working Group. Victoria, BC.

Standards For Predictive Ecosystem Mapping – Digital Data Capture In British Columbia. Version 1.0 (2000) RIC, Terrestrial Ecosystems Mapping Alternatives Task Force

Timberline Forest Inventory Consultants Ltd. 2002. Predictive Ecosystem Mapping For Boundary Timber Supply Area – Field Sample plan.

Timberline Forest Inventory Consultants Ltd. 2002. Boundary TSA PEM- Field Sampling Program Report.

Timberline Forest Inventory Consultants Ltd. 2003. Predictive Ecosystem Mapping of the Boundary Timber Supply Area 2002-2003 – Input Data Quality Assessment & Metadata Report.

Standard for Digital Predictive Ecosystem Mapping (PEM) Data Capture in British Columbia. Draft. 2000. Predictive Ecosystem Technical Standards & Database Manual.

Standard for Digital Terrestrial Ecosystem Mapping (TEM) Data Capture in British Columbia. 1998. Ecosystem Technical Standards and Database Manual. Version 2.0. Prepared by Ecosystem Data Committee, Ecosystems Working Group/Terrestrial Ecosystems Task Force For: Resources Inventory Committee (RIC).

Ministry of Sustainable Resources Management. 2003. Introduction to Quality Assurance Procedures – Ecosystem Inventory and Mapping, Wildlife Inventory, Wildlife Habitat Rating. Version 1.0.

Ministry of Sustainable Resources Management. 2003. Quality Assurance Guidelines: Predictive Ecosystem Mapping (PEM). Version 1.0. Draft.

APPENDICES

APPENDIX I

TABLE OF ECOSYSTEM UNIT DISTRIBUTION FOR 2002-2003 PROJECT AREA

PREDICTIVE ECOSYSTEM MAPPING – BOUNDARY TIMBER SUPPLY AREA

Ecosystem Unit	ICHdw1	ICHdw2	ICHmk1	ICHmw2	IDFdm1	IDFxb4	PPdh1	Total (ha)
01			32,836.8	18,635.1	21,483.9	10,181.8	516.4	83,653.9
01a	6,981.3	19,866.2						26,847.6
01b	5,548.9	10,502.0						16,050.9
02	2,324.6	10,087.2	10,027.1	3,174.6	6,155.1	2,787.6	1,855.0	36,411.1
03	663.9	2,546.7	18,944.4	14,186.7	10,620.4	7,679.6	2,731.1	57,372.9
04	66.0	504.6	27,705.4	9,236.1	30,574.7	8,054.1	607.2	76,748.1
05			5,728.0	2,161.2	3,747.8	1,598.5	92.4	13,327.9
06			1,949.0	989.2	1,710.4	573.7	101.8	5,324.1
07			148.4	30.1	117.3			295.8
08			41.1	1.3				42.3
09				41.2				41.2
AV				406.9				406.9
BE								0.0
CB			1.2		2,083.5			2,084.7
CF	37.4	182.9	160.7	4.3	4,193.5	6,195.2	3,900.8	14,674.8
CL			1.3	1.1				2.5
ES			0.6			4.0		4.6
FE	2.0	46.2			107.0	16.2		171.4
GB		51.0	16.7	2.2	129.8	54.3	16.6	270.6
GP			0.8	15.4	11.8	34.8		62.7
LA	1,317.4	3.6	190.0		31.0	1,271.9		2,813.9
LO		0.5	10.5				13.7	24.7
LU	4.6	45.8	0.2		57.2	36.2	3.4	147.4
MI		6.5	236.2		39.0	21.2		302.9
OF		2.2	8.5	0.6	2.9			14.3
OS	0.6	97.4	52.0	9.1	53.4	23.1	37.7	273.1
OW	2.3	31.5	14.3	9.9	34.3	1.9		94.2
PD		12.8	17.1	5.7	15.8	3.2		54.5
RI	0.5	113.8	69.5	11.2	540.8	461.2	359.0	1,555.9
RN		0.8						0.8
RO								0.0
RW		2.9	36.5		122.0	452.4	109.3	723.1
RZ	53.8	5.9	64.0	61.0	124.1	172.3	44.6	525.6
SP							1,449.4	1,449.4
TA	76.1	137.9	190.7	191.1	167.5	79.7	11.0	854.1
UR	42.6	4.7			288.9	757.6	1,409.1	2,502.9
Total (ha)	17,121.9	44,253.1	98,451.0	49,173.9	82,411.9	40,460.5	13,258.4	345,130.6

Forested Units have shading

PREDICTIVE ECOSYSTEM MAPPING – BOUNDARY TIMBER SUPPLY AREA

Ecosystem Unit	MSdm1	MSdm1a	ESSFdc1	ESSFdcu1	ESSFwc1	ESSFwc4	ESSFwcu4	Total (ha)
01	27,892.4	286.2	32,592.0	3,625.4	6,415.4	6,791.5	3,717.2	81,320.2
02	6,513.1	197.6	6,030.6	3,343.9	3,329.5	2,940.9	1,208.1	23,563.9
03	15.5	27.5	28,451.6	3,997.1	1,453.7	987.7	2,337.0	37,270.1
04	56,922.0	682.9	9,033.6	84.9	29.2	9,505.9	246.0	76,504.5
05	62.3	77.5	38.0	139.9	88.2	1,319.1	395.1	2,120.1
06	4,319.5	61.8	790.4	1,657.0		233.7	1,082.7	8,145.2
07	55.0	0.9	146.7			47.8		250.5
08	376.6	11.6				81.0		469.1
09	827.5							827.5
AV			55.6	647.6		6.3	47.8	757.2
BE	0.1							0.1
CF	236.0							236.0
CL			6.6				2.2	8.7
ES	1.4		3.2					4.6
FE				1.9			3.0	4.9
GP			4.3					4.3
LA	402.4	5.0	22.5	8.3			5.7	443.8
LU	18.7				3.4			22.1
OF			29.3	157.3			0.7	187.2
OS		0.1		1.7	2.3		3.0	7.1
OW	55.2	0.3	5.7			4.3		65.5
PD	72.3		11.0		5.6	7.9	4.7	101.5
RI	100.5							100.5
RN			2.4					2.4
RO			852.4		54.8	23.2		930.4
RW			11.6					11.6
RZ	31.0		5.3					36.3
TA	288.9	5.2	781.0	783.6	37.4	113.8	406.8	2,416.7
UR	13.1							13.1
Total (ha)	98,203.6	1,356.6	78,873.8	14,448.7	11,419.4	22,063.1	9,460.0	235,825.2

Forested Units have shading

APPENDIX II