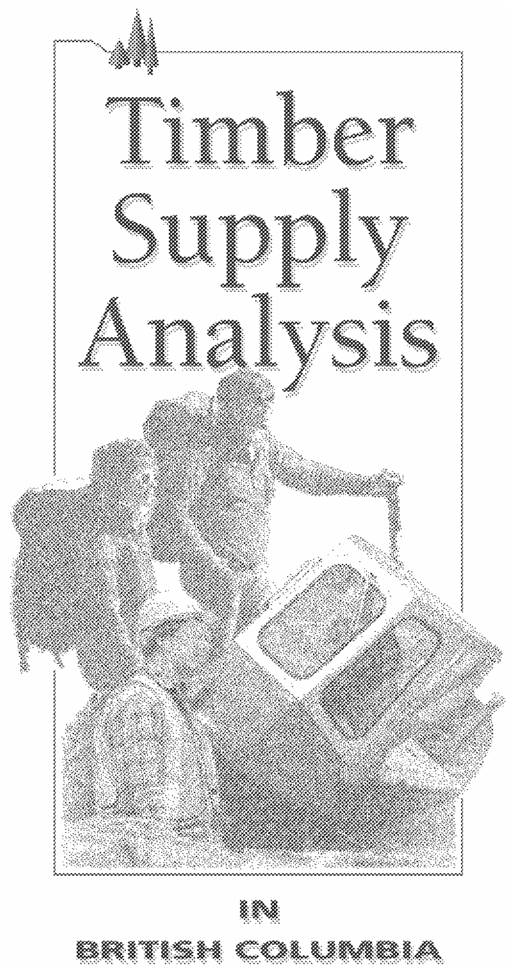


# Timber Supply Analysis for DFAM Licensees: Assignment Handouts

**February 2004**

Cortex Consultants

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# Section 1.0
# Timber Supply Concepts

**Time: 30 minutes**

## Learning Objectives

Participants will learn to estimate timber supply using methods other than a timber supply model. Long-term supply will be estimated as LRSY (MAI x area). Short-term supply will be estimated as a function of standing mature operable inventory. Discussion will focus on both the serious shortcomings of these approaches, and their appropriate applications.

## Key Concepts

- short-, mid-, and long-term timber supply
- LRSY, LTHL
- anything that affects either MAI or area also affects the estimate of LRSY.

## Exercise 1.1

Estimating LRSY—"sharp-pencil" approach

## Exercise 1.1:
## Estimating LRSY—sharp-pencil approach

### Method

Participants will calculate long-run sustained yield (LRSY) using a simple paper-and-pencil approach, for the *Petrified Forest* (Tables 2.1-3 and 2.1-4).

### Discussion

Not every problem requires a computer model. For some problems, careful thought, and working with pencil, paper, and calculator will produce as good an estimate of timber supply, as will working with a sophisticated model. Some decisions or problems are so fraught with uncertainty about data and assumptions that the best one can do is to make a general estimate of timber supply (e.g., trying to estimate the impact of implementing a management guideline that will affect harvesting practices, without knowing details about how and where it will be applied). Sometimes one needs to make a rough estimate of LRSY as a starting point for simulation runs.

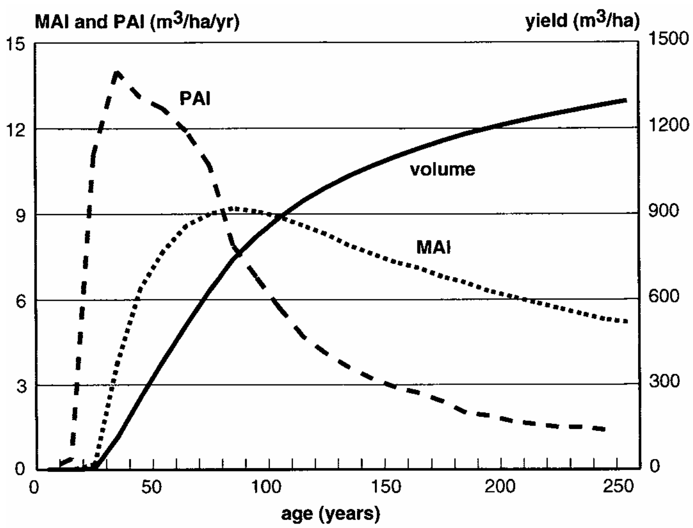
In this exercise, we will explore approaches to making such initial estimates of LRSY in relatively simple ways. We differentiate here between LRSY (which is calculated by multiplying mean annual increment times area), and the maximum sustainable long-term harvest level (LTHL), found through simulation.

Figure 1.1-1 shows a typical stand yield curve. Average volume production over the life of the stand is shown as mean annual increment (MAI), and is highest when it equals periodic annual increment (PAI).

MAI, the average growth of the stand, can be used to estimate:

- the yield from one hectare (multiply stand age by MAI at that age)
- the average annual growth of the stand (multiply stand area by MAI)
- the stand yield (multiply stand area by yield/ha).

**Figure 1.1-1 Typical changes over time in stand yield ($m^3$/ha), periodic annual increment, and mean annual increment ($m^3$/ha/yr).**




The highest, or culmination MAI (CMAI) in the figure is 9.2 $m^3$/ha/yr, which occurs at about 80 years. If a 75 ha stand is managed on a rotation of 80 years, the annual growth of the stand will be about (9.2 $m^3$/ha/yr * 75 ha =) 690 $m^3$/yr. The yield at harvest will be (9.2 $m^3$/ha/yr * 80 yr =) 736 $m^3$/ha, and (690 $m^3$/yr * 80 yr =) 55,200 $m^3$ for the stand.

LRSY is calculated by multiplying the area of each stand type by its maximum average annual rate of growth (CMAI). Expressed in mathematical notation,

$$\text{Estimated LRSY} = \sum_{\text{for all } i} (CMAI_i * AREA_i)$$

To calculate LRSY for each analysis unit, choose a yield curve that represents the outcome of applying the expected management regime. Find the MAI at the expected timber rotation age, and multiply it by the area of the analysis unit. Table 1.1-1 shows an example LRSY calculation for a forest of 11,900 ha. The CMAI and area are identified for each of the seven analysis units. The sum of their products is LRSY for the forest.

**Table 1.1-1 An example LRSY calculation for a forest of 11,900 ha**

| Analysis Unit | CMAI ($m^3$/ha/yr) | Area (ha) | LRSY ($m^3$/yr) |
|---|---|---|---|
| Fd G | 8.2 | 707 | 5797 |
| Fd M | 4.7 | 1190 | 5593 |
| Fd P | 2.8 | 922 | 2582 |
| Cw G,M | 3.7 | 1245 | 4607 |
| Cw P | 2.4 | 6730 | 16,152 |
| B G,M | 2.4 | 751 | 1802 |
| B P | 2.0 | 355 | 710 |
| Totals | | 11,900 | 37,243 |

In practice, most stands are not cut at the CMAI. This is one of the reasons that the LTHL is always less than the theoretical maximum LRSY.

## Exercise 1.1 Assignment

Calculate LRSY for the example *Petrified Forest*. The area and volume tables for each analysis unit are shown in the attached Tables 1.1-2 and 1.1-3.

**Table 1.1-2 Area summary for *Petrified Forest***

| Analysis Unit | Area (ha) |
|---|---|
| Interior Douglas-fir G | 20,500 |
| Spruce/balsam fir | 85,000 |
| Lodgepole pine | 90,000 |
| | 195,500 |

**Table 1.1-3 Volume tables for *Petrified Forest***

| Age | Fd G, existing stands | S/B G, existing stands | Pl M, existing stands | Fd G, managed stands | S/B G, managed stands | Pl M, managed stands |
|---|---|---|---|---|---|---|
| **20** | 0 | 0 | 0 | 0 | 0 | 0 |
| **30** | .6 | 0 | 3 | 2 | 0 | 0 |
| **40** | 8 | 3 | 11 | 11 | 3 | 14 |
| **50** | 29 | 12 | 30 | 32 | 15 | 43 |
| **60** | 54 | 27 | 59 | 70 | 31 | 75 |
| **70** | 78 | 50 | 86 | 114 | 56 | 110 |
| **80** | 102 | 74 | 111 | 159 | 86 | 136 |
| **90** | 124 | 99 | 134 | 201 | 115 | 159 |
| **100** | 144 | 123 | 156 | 237 | 146 | 179 |
| **110** | 164 | 146 | 176 | 267 | 170 | 199 |
| **120** | 181 | 167 | 195 | 294 | 190 | 219 |
| **130** | 198 | 187 | 213 | 318 | 201 | 237 |
| **140** | 213 | 205 | 226 | 339 | 206 | 251 |
| **150** | 226 | 222 | 237 | 356 | 210 | 262 |

# Exercise 1.2:
# Compare the LRSYs of three forests

## Assignment

To many people, the short-term harvest level, which is strongly related to the current condition of the forest, is the most important facet of timber supply. Can the sharp-pencil estimate of LRSY provide any insights into short-term supply?

Estimate the LRSY using the (MAI x area) approach for three forests—each with the same composition as the *Petrified Forest* (Exercise 2.1), but with different age-class distributions (Figures 1.2-1a,b,c). How significant is LRSY?

**Figure 1.2-1a.  Balanced forest.**

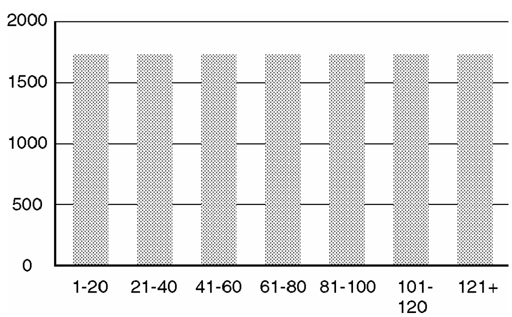



**Figure 1.2-1b.  Young forest.**

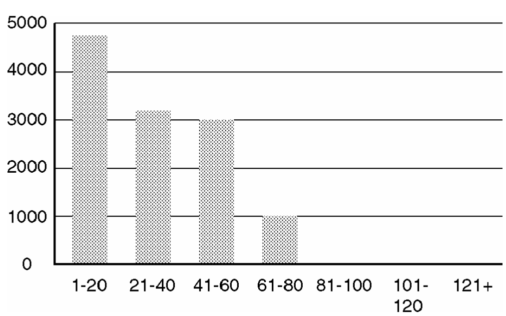
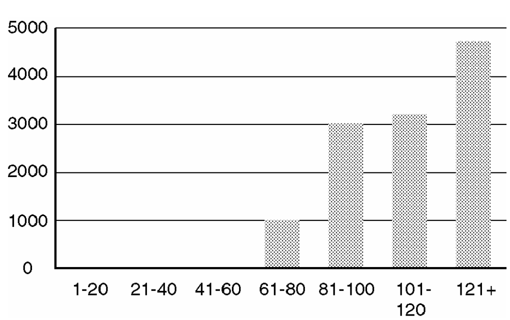



**Figure 1.2-1c.  Old forest.**



# Section 2.0
# Introduction to Timber Supply Modeling

**Time: 2.5 hours**

## Learning Objectives

Participants will understand:

- how simulation models are used in forest level analysis
- how the elements of forest-level analysis are represented in a model (yield tables, inventory, management and other assumptions)
- the mechanics of a simulation model (growth, cutting, treatment)

## Key Concepts

- simulation model
- forest-level perspective
- even-aged management
- modeling approach should fit the problem.

## Exercises

Exercise 2.1: Introduction to forest-level simulation using *EVEN*

# Exercise 2.1: Introduction to Forest Level Simulation using *Even*[1]

## The Model *Even*

This lab demonstration uses a simulation model called *Even* to investigate harvest scheduling in even-aged forests. The model can be used to:

1. describe the evolution of the forest over time when it is managed according to a variant of area control
2. predict the effects of changing the allowable cut on the value of the forest.

The *Even* model is based on the following assumptions:

- the state of the forest at a specific point in time is described by the area in each age class
- the silvicultural system consists of clearcutting followed by immediate artificial regeneration
- the volume of timber in a particular age class is strictly a function of the age of the stand
- the management policy is a variant of area control—specifically, the manager fixes the area to be cut during each time interval
- oldest stands are always cut first; this implies a rotation that is equal to the total area of the forest divided by the average area cut every year.

The code, written in BASIC, is listed in Figure 2.1-1. *Even* consists of one main program and six subroutines, described in the following sections. The variables used in the program are defined in Table 2.1-1.

### *MainProgram*

The program *MainProgram* directs the flow of information between subroutines and updates the simulation clock. *MainProgram* first reads the initial condition of the forest and the management data. Then, for each decade, it displays the current status of the forest, and the predicted growth of the remaining forest during the next decade. The program then increases the time by 10 years. This cycle is repeated to the end of the specified simulation period.

---

[1] This material was adapted from Buongiorno, J. and K. Gilless, 1986, Forest management and economics, Macmillan. Pages 203-214. Changes have been made to the computer program (Even), some of the text, and the problems.

### Subroutine *InitializeSimulation*

Subroutine *InitializeSimulation* sets the initial time and the initial present value of the harvests to zero. It then reads the initial area in each of the 10 age classes. The ages of trees within an age class span a decade. For example, in Figure 2.1-1 there are 250 ha in age class 1, 150 ha in age class 2, and so on, up to 120 ha in age class 10. The total area of the forest is 2280 ha. Any stand older than 100 years is included in the oldest age class. The number of age classes remains the same throughout the projection period, although the area in each age class changes as area is cut and ages over time.

Subroutine *InitializeSimulation* then reads the volume of timber as a function of age, in cubic metres per hectare. For example, in Figure 2.1-1, stands of timber 50 years old carry some 289 $m^3$/ha (data are for lodgepole pine in the BC Interior, site index 25).

### Subroutine *ManagementInformation*

Subroutine *ManagementInformation* reads the management data, beginning with the desired length of the simulation—set at 150 years (Figure 2.1-1). The subroutine then reads the maximum allowable cut (380 ha). This is the area that would be cut every decade if the forest (2280 ha) was regulated at a rotation age of 60 years (2280/60 x 10 = 380 ha/decade).

### Subroutine *ShowGrowingStock*

Subroutine *ShowGrowingStock* displays on the computer screen the current year and, under it, the area in each age class at the beginning of that year (screen output shown in Figure 2.1-2).

### Subroutine *Cutting*

Subroutine *Cutting* first initializes the total area and the total volume cut in the next 10 years to zero. Then it cuts the allowed area in the following steps, starting with the oldest age class:

1. The area to be cut in the current age class is set equal to the allowable cut minus the total area already cut in the current decade.
2. If the area to be cut is greater than the area that is available in the current age class, then the cut can only be equal to the area available.
3. The area left in the current age class after the cut is determined.
4. The total area and the total volume that have been cut in the current decade are computed.

These steps are repeated for younger and younger age classes, until the total area cut in the decade equals the allowable cut.

### Subroutine *ShowCut*

Subroutine *ShowCut* displays the area cut in each age class during the coming decade, as well as the volume cut and the cumulative net present value of the returns up to and including those generated during the coming decade (output shown in Figure 2.1-2).

### Subroutine *Growth*

Subroutine *Growth* simulates the growth of the part of the forest that will not be cut during the coming decade. The area cut during the coming decade will constitute age class 1 at the end of the decade. Simultaneously, the areas in age class 1 to 8 grow into age classes 2 to 9. The new age class 10 at the end of the decade consists of what is left of the old age class 10 after the cut, plus what was in age class 9 at the beginning of the decade.

**Figure 2.1-1 EVEN: Simulation of even-aged forest management under area control** (Source: Buongiorno, J. and K. Gilless 1986. Forest management and economics. Macmillan p. 203-214.)

```
'_____________________________________________
' MainProgram: Directs flow of information to subroutines
'_____________________________________________
mainProgram:
  CLS
  GOSUB initializeSimulation                 'initiate forest
  GOSUB managementInformation                'define management
  WHILE year <= endingYear                   'until max time is reached
    GOSUB showGrowingStock                   'display current growing stock
    GOSUB cutting                            'cut forest
    GOSUB showCut                            'display cut data
    GOSUB growth                             'predict growth
    PRINT
    INPUT "Hit Enter to continue with next iteration", CR
    year = year + 10                         'increase time
  WEND                                       'go back to WHILE statement
END                                          'end of main program

'_____________________________________________
' InitializeSimulation: Read initial forest condition
'_____________________________________________
initializeSimulation:
  year = 0                                   'initial time
  presentValue = 0                           'initial present value
  FOR ageClass = 1 TO 10
    READ areaBeginning(ageClass)             'initial area (hectares)
  NEXT ageClass
  DATA 250,150,320,400,0,100,300,110,530,120
  FOR ageClass = 1 TO 10
    READ VolumePerHectare(ageClass)          '(m3/ha)
  NEXT ageClass
  DATA 0.0,2.0,87,192,289,364,421,466,470,470
RETURN                                       'return to MainProgram
```

```
'_______________________________________________
' ManagementInformation:  Define management regime
'_______________________________________________
managementInformation:
  READ endingYear                           ' max simulated time (years)
  DATA 150
  READ aacArea                              ' (hectares/decade)
  DATA 380
RETURN                                      ' return to MainProgram

'_______________________________________________
' ShowGrowingStock:  Display current growing stock
'_______________________________________________
showGrowingStock:
  PRINT "year"; year
  PRINT " stock(ha)";
  FOR ageClass = 1 TO 10
    PRINT USING "####."; areaBeginning(ageClass);
  NEXT ageClass
  PRINT
RETURN                                      ' return to MainProgram

'_______________________________________________
' Cutting:  Cut forest
'_______________________________________________
cutting:
  totalAreaCut = 0                          ' total area cut during decade
  totalVolumeCut = 0                        ' total volume cut during decade
  FOR ageClass = 1 TO 10
    areaCut(ageClass) = 0                   ' area cut in age class during decade
  NEXT ageClass
  ageClass = 10                             ' start with oldest age class
  WHILE totalAreaCut < aacArea
    areaCut(ageClass) = aacArea - totalAreaCut
    IF areaCut(ageClass) > areaBeginning(ageClass) THEN
        areaCut(ageClass) = areaBeginning(ageClass)
    areaBeginning(ageClass) = areaBeginning(ageClass)-
      areaCut(ageClass)                     ' area left after cut
    totalAreaCut = totalAreaCut + areaCut(ageClass)
    totalVolumeCut = totalVolumeCut +
      areaCut(ageClass) * volumePerHectare(ageClass)
    ageClass = ageClass-1
  WEND
RETURN                                      ' return to MainProgram

'_______________________________________________
' Showcut:  Display area, volume of cut and net present value
'_______________________________________________
showCut:
  PRINT
  PRINT " cut (ha) ";
  FOR ageClass = 1 TO 10
    PRINT USING "####."; areaCut(ageClass);
  NEXT ageClass
  PRINT
  PRINT USING " Volume cut ######,_cu.m.; totalVolumeCut;
RETURN                                      ' return to MainProgram
```

```
'————————————————————————————————————————————
' Growth:  Predict growth of forest during next decade
'————————————————————————————————————————————
growth:
  areaEnding(1) = totalAreaCut              'area reforested
  FOR ageClass = 2 TO 9
    areaEnding(ageClass) = areaBeginning(ageClass-1)
                                            'moves up one age class
  NEXT ageClass
  areaEnding(10) = areaBeginning(10) + areaBeginning(9)
                                            'area in oldest age class

'————————————————————————————————————————————
'Area at beginning of next decade is equal to area at end of current decade
'————————————————————————————————————————————
  FOR ageClass = 1 TO 10
    areaBeginning(ageClass) = areaEnding(ageClass)
  NEXT ageClass
RETURN                                      'return to MainProgram
```

**Table 2.1-1 Definition of variables in program *Even***

| Variable | Definition |
|---|---|
| *ageClass* | Age-class index, varies from 1 to 10. Class width is 10 years. |
| *aacArea* | Area to be cut per decade (ha) |
| *areaBeginning (ageClass)* | Area in an age class at the beginning of a decade (ha) |
| *areaCut (ageClass)* | Area cut in an age class during a decade (ha) |
| *areaEnding (ageClass)* | Area in an age class at the end of a decade (ha) |
| *endingYear* | Maximum simulated time (years) |
| *totalAreaCut* | Total area cut in a decade (ha) |
| *totalVolumeCut* | Total volume cut in a decade ($m^3$) |
| *volumePerHectare* | Volume per hectare ($m^3$) |
| *year* | Simulation time, increased by 10-year intervals |

## Output and Applications of *Even*

### Forest Dynamics

Part of the results of a simulation run with *Even* appear in Figure 2.1-2. The input data are those from subroutines *InitializeSimulation* and *ManagementInformation* (Figure 2.1-1). Every decade, 380 ha are cut from the forest, as required by the area-control strategy. This corresponds to a rotation of 60 years. The oldest age class is always cut first, and the number of age classes decreases over time to six. The presence of old timber on the initial forest results in more volume being cut during the first decades than later on. Sixty years after the beginning of the simulation, the forest is regulated. Thereafter, it remains in a steady state, producing always the same timber volume and retaining the same growing stock.

**Figure 2.1-2 Output of program *Even*** (volumes are in $m^3$; stock and cut are in ha)

```
year 0
  stock (ha)250. 150. 320. 400.   0. 100. 300. 110. 530. 120.
  cut (ha)    0.   0.   0.   0.   0.   0.   0.   0. 260. 120.
  Volume cut 178,600 cu.m.

Hit Enter to continue with the next iteration

year 10
  stock (ha)380. 250. 150. 320. 400.   0. 100. 300. 110. 270.
  cut (ha)    0.   0.   0.   0.   0.   0.   0.   0. 110. 270.
  Volume cut 178,600 cu.m.

Hit Enter to continue with the next iteration

year 20
  stock (ha)380. 380. 250. 150. 320. 400.   0. 100. 300.   0.
  cut (ha)    0.   0.   0.   0.   0.   0.   0.  80. 300.   0.
  Volume cut 178,280 cu.m.

                                ...

Hit Enter to continue with the next iteration
year 60
  stock (ha)380. 380. 380. 380. 380. 380.   0.   0.   0.   0.
  cut (ha)    0.   0.   0.   0.   0. 380.   0.   0.   0.   0.
  Volume cut 138,320 cu.m.

Hit Enter to continue with the next iteration

year 70
  stock (ha)380. 380. 380. 380. 380. 380.   0.   0.   0.   0.
  cut (ha)    0.   0.   0.   0.   0. 380.   0.   0.   0.   0.
  Volume cut 138,320 cu.m.
```

## Conclusions

The simulation model *Even* offers a straightforward approach to evaluating some management strategies for even-aged forest management. The examples shown here illustrate the importance of context and perspective in choosing management parameters like rotation age.

Although this model deals only with area-control management, it is not hard to see how it could be adapted to volume control by simply changing the allowable cut from a specified area to a volume. Other features could also be added to the model. While there is a natural tendency to want to add refinements to make a model as realistic as possible, it should be resisted. Increasing the realism of a model does not necessarily improve it—added features may make a model more difficult to understand and more prone to errors. The model should be designed at a level of abstraction and simplicity that helps one focus on the key characteristics of the problem.

# Section 3.0
# Introduction to FSSIM

**Time: 2 hours**

### Learning Objectives

Participants will understand:

- how the forest and the elements of forest-level analysis are represented in FSSIM (yield tables, inventory, management, assumptions)
- how non-timber values are represented using zones, groups, and management requirements
- how FSSIM is used to do an analysis
- what is considered in recommending an AAC and preparing information to support the recommendation.

### Key Concepts

- FSSIM
- classes, analysis units, zones, and groups
- management requirements (constraints)
- using indicators to evaluate a run
- sensitivity analysis.

### Exercises

Exercise 3.1: Determining the base case

### Method

Participants will use FSSIM to undertake part of a timber supply analysis with a prepared data set for the Awesome Creek Management Unit.

### Materials

- FSSIM for Windows
- FSSIM data model provided.

## The Awesome Creek Management Unit Data Model

This exercise uses an FSSIM data model of an area called the Awesome Creek Management Unit, located in the Dawson Creek TSA. Awesome Creek, almost 49,000 ha, comprises two landscape units: the Flatbed and Redwillow LUs. The elements of the data model (landbase, growth and yield, management) are described in the following sections.

The topography in this management unit features gently rolling prairie broken by rivers. The climate is severe, with long, cold winters and a short growing season. Most of the area lies in the Boreal White and Black Spruce (BWBS) biogeoclimatic ecosystem classification zone (for this exercise, we've ignored the fact that portions of the management unit are in the Engelmann Spruce–Subalpine Fir (ESSF) and Sub-Boreal Spruce (SBS) zones). White spruce and lodgepole pine are the major commercial tree species. Trembling aspen and cottonwood are not currently utilized commercially.

The towns of Bumblebee Ridge (3800 residents) and Awesome Creek (11,600 residents) are the largest towns in the area.

The current Allowable Annual Cut for this management unit is 103,000 $m^3$/yr.

### Landbase Definition

The database consists of four mapsheets:

| | | | |
|---|---|---|---|
| 093I087 | 093I088 | 093I097 | 093I098 |

A total of 48,910 ha of productive forest land was identified in the management unit (Table 3-1). This table is roughly equivalent to Table 1 of the TSR timber supply analysis reports, which shows the timber harvesting landbase—both harvestable and non-harvestable—and the areas outside the THLB (e.g., non-commercial and roads). Most of the area that formerly would have been removed from the timber harvesting landbase is classed as "non-harvestable (Class Type I)" (Course Notes, section 6.2.1).

**Table 3-1 Forest landbase classification (hectares)**

| Category | Criteria | Non-commercial | Non-harvestable (Class type "I") | Harvestable (Class type "O") |
|---|---|---|---|---|
| Non-commercial | Type ID = 5 | 721 | | - |
| Inoperable | Operable class = I | | 1,279 | |
| Roads | 10 metre road width allowance | 267 | | - |
| Streams | 30 metre buffer | | 1,803 | - |
| ESA1 | ESA1 = P (sensitive soils) | | 93 | - |
| Problem types | site index below Poor equivalent | | 14, 461 | - |
| Deciduous | Inventory type group>34 | | 6,172 | - |
| Net Operable | not previously excluded | | | 24,114 |
| Total | | 988 | 23, 808 | 24,114 |

## Analysis Unit Definition and Yield Table Development

Twelve analysis units have been defined for this forest, representing natural and managed stands with leading species of pine and spruce–balsam on good, medium, and poor sites. In addition, analysis unit 999 is used for hectares with no volume, and is a catch-all for unclassified hectares. The criteria used to define analysis units are summarized in Table 3-2.

**Table 3-2 Analysis unit definitions**

| Analysis unit # | | Analysis unit name (leading species - site class) | Inventory type groups | Site index range | Minimum harvestable age | |
|---|---|---|---|---|---|---|
| natural stands | managed stands | | | | natural | managed |
| 1 | 101 | Pine - good | 27-34 | 14.00+ | 100 | 80 |
| 2 | 102 | Pine - medium | | 12.00 - 13.99 | 110 | 100 |
| 3 | 103 | Pine - poor | | < 12.00 | 120 | 110 |
| 4 | 104 | Spruce/balsam - good | 18-26 | 12.00+ | 100 | 100 |
| 5 | 105 | Spruce/balsam - medium | | 9.50 - 11.99 | 120 | 120 |
| 6 | 106 | Spruce/balsam - poor | | < 9.50 | 150 | 150 |
| 999 | 999 | all other | all other | all | n/a | n/a |
| ROAD | | future roads | all | all | - | - |

Yield tables were developed with VDYP for natural stands and with TIPSY for managed stands. Managed stands include all existing stands younger than age 5, some existing stands younger than age 15, and all future regeneration. The parameters used to develop the yield tables are shown in Table 3-3. See file *vols.dat*.

**Table 3-3 Yield table parameters for natural and managed stands**

| Natural stands | | Managed stands | |
|---|---|---|---|
| *Stand model* | VDYP | *Stand model* | TIPSY |
| *FIZ* | L | *regeneration* | planted |
| *PSYU* | 0192 | *density* | 1500 trees/ha |
| *Utilization* | 17.5 cm (spruce) | *Utilization* | 12.5 cm (all species) |
| | 12.5 cm (pine) | *Regeneration delay* | 4 years (to be modeled as regen delay in FSSIM) |

## Zonation and Grouping

The landbase in this FSSIM data set has been organized using FSSIM *zones* as the basic land unit. Zones are mutually exclusive (non-overlapping) geographic units. Every class in the forest inventory is in only one zone (see file *class.dat*).

FSSIM *groups* are collections of zones, analysis units, age classes, and class types. Each group is created by defining (in file *group.dat*) the combinations of these attributes that are included in it (e.g., all analysis units in the partial retention zone in the Flatbed landscape unit). Zones may be identified individually as *groups*, or combined to make other groups.

The Awesome Creek landbase is subdivided into two landscape units (Flatbed and Redwillow), represented in the model as groups. Within each landscape unit (group), specific visual quality objective (VQO) zones have been established (Table 3-4), and VQO green-up objectives specified (Table 3-5). In addition, biodiversity requirements have been specified for each landscape unit in the form of seral stage requirements (Table 3-6). The numbering scheme used for groups and zones is designed to facilitate interpretation later in the analysis—all Flatbed zones are 70 series, all Redwillow zones are 80 series.

**Table 3-4 Zoning/grouping scheme, showing harvestable and non-harvestable area by VQO zone**

| Geographic Unit | Zone # | Group Name | Non-harvestable area (Class type " I ") (ha) | Harvestable area (ClassType " O ") (ha) |
|---|---|---|---|---|
| **Flatbed Landscape Unit** | - | Flatbed | | |
| • Partial Retention VQO zone | 72 | Flat-PR | 395 | 787 |
| • Modification VQO zone | 73 | Flat-MOD | 450 | 739 |
| • no VQO (IRM) zone | 74 | Flat-IRM | 9,509 | 10,229 |
| **Redwillow Landscape Unit** | - | Redwillow | | |
| • Partial Retention VQO zone | 82 | Red-PR | 989 | 809 |
| • Modification VQO zone | 83 | Red-MOD | 1,183 | 729 |
| • no VQO (IRM) zone | 84 | Red-IRM | 11,282 | 10,821 |
| **Total Area** | | | 23,808 | 24,114 |

## Forest Cover Requirements

*Green-up requirements* for each VQO zone are based on the zone's visual quality objectives. Only the harvestable (Class Type O) component of the landbase contributes to meeting green-up requirements (Table 3-5). See file *axs.dat*.

**Table 3-5 Green-up requirements for each VQO zone**

| | Flatbed Landscape Unit | | Redwillow Landscape Unit | |
|---|---|---|---|---|
| **Visual quality objective** | Green-up age | Green-up % | Green-up age | Green-up % |
| Partial retention | 28 | 15 | 28 | 10 |
| Modification | 28 | 25 | 28 | 20 |
| IRM | 20 | 33 | 20 | 33 |

*Biodiversity requirements* for each landscape unit (group) are based on the BWBS biogeoclimatic unit (Natural disturbance type 3). Both harvestable (Class type O) and non-harvestable (Class type I) components of the landbase contribute to meeting biodiversity requirements (Table 8-6). See file *axs.dat*.

**Table 3-6 Biodiversity (seral stage) requirements for each landscape unit**

| Landscape unit | Biodiversity emphasis | Early seral stage | | Mature+old seral stage | | Old seral stage | |
|---|---|---|---|---|---|---|---|
| | | Age | Max % | Age | Min % | Age | Min % |
| Flatbed | intermediate | < 40 | 54 | >= 101 | 23 | >= 141 | 11 |
| Redwillow | high | < 40 | 40 | >= 101 | 34 | >= 141 | 16 |

Note: in FSSIM, constraints must be stated as either, “<”, or “>=” (not,”<=”, or “>”).

### Age Class Assignment

Stands were grouped into 10-year age classes (e.g., 1-10, 11-20, 21–30, ….). Existing NSR areas were assigned age -5 yr, based on the assumption that NSR will be restocked in five years. Using a negative age delays the time when the stand begins developing according to the yield curve for the analysis unit. See file *class.dat*.

### Future Road Allowances

For analysis purposes, it was assumed that all stands less than age 31 at the start of the simulation have already been roaded. During the simulation remaining areas are reduced to account for future road allowances by assigning 5% of their area to a “ROAD” analysis unit following the first harvest. The ROAD analysis unit is defined as follows:

- there is zero volume in the volume tables (file *vols.dat*),
- age after harvest is set at –1000 years to ensure that roaded area remains in an early seral state throughout the planning horizon (file *road.dat*)
- minimum harvestable age is set at 1000 years so that roaded area never becomes eligible for harvesting during the planning horizon.

### Forest Class Assignment

Forest stands were aggregated into the same *class* if they have the same:

- analysis unit
- zone
- age class
- class type (operability).

### Regeneration

All classes currently assigned to natural stand analysis units (1–6) are converted to the corresponding managed stand analysis units (101–106) after harvesting.

Classes in managed stand analysis units revert to the same analysis unit following harvest. A four-year regeneration delay is assumed in all cases. See file *regen.dat*.

### Landbase and Yield Reductions

No further reductions in the landbase or yields have been included (i.e., landbase and yield table OAFs were set to 1.0).[2] See files *landOAF.dat* and *oaf.dat*.

### Harvest Priorities

Harvest priorities, the rules for ranking stands for harvesting, were established by zone. Lowest priority (3) was assigned to zones with no visual quality objectives. Modification VQOs were assigned a higher priority (2), and partial retention VQOs were given the highest priority (1). Within each zone, classes will be ranked for harvest by age, using harvest rule 2, *relative oldest first* (Table 3-7). See file *priority.dat* and *config.dat*.

**Table 3-7 Harvest Rules Used in FSSIM**

| Number | Rule |
|---|---|
| 1 | Absolute oldest first |
| 2 | Relative oldest first |
| 3 | Absolute youngest first |
| 4 | Random |

### Harvest Volume Target

A sample target harvest schedule (starting at 35,000 $m^3$/yr) has been specified in the data set (file *targets.dat*). This harvest level has no significance—it is provided simply to show you the format for specifying harvest level targets. You should set your own schedule of harvest targets.

[2] FSSIM has two operational adjustment factors (OAFs): the LandOAF can be applied to reduce the landbase (in the *landoaf.dat* file), and the yield OAF reduces yield table values (in the *oaf.dat* file). These FSSIM OAFs are separate from the OAFs that are used in WinTIPSY to produce the yield curves for each analysis unit.

## Exercise 3.1 Assignment (FSSIM)

You have about two hours to complete the following activities:

- familiarize yourself with the study area forest (0.5 hour)
- establish your base case (1.5 hours).

These activities are described in the sections below.

A complete data model of the Awesome Creek Management Unit is provided– analysis units have been defined, yield tables prepared, and management requirements specified.

Table 3-10 lists the FSSIM input files for your reference. See the Course Notes Section 7.0 for other reference material on FSSIM.

Before beginning your analysis, read the extracts from the Chief Forester's "Rationale for Allowable Annual Cut (AAC) Determination":

- Guiding Principles for AAC Determinations
- The Role of the Base Case in AAC Determinations
- Section 8 of the *Forest Act*
- Economic and Social Objectives of the Crown.

You should also read the text of the chief forester's UBC Jubilee Lecture.

### 1. Familiarize yourself with the study area forest (0.5 hour)

It is essential that you become familiar with the forest being modeled before beginning your analysis. Examine the description of the data model on the preceding pages.

You may find it useful to prepare summaries of the forest structure (e.g., age-class distribution). You can use FSSIM to display graphs of the initial age-class distribution and growing stock inventory.

### 2. Establish two alternative base case harvest forecasts (1.5 hours)

The base case is the best harvest forecast you can produce, based on current management practices. It should ensure the long-term productivity of forest lands, while avoiding excessive changes from decade to decade and future shortfalls. The base case provides a basis for comparison when assessing uncertainty about, or changes to, data and assumptions (you can read more about this in any Rationale for Allowable Annual Cut Determination).

As you will see when you begin to develop your base case forecast, this particular management unit presents challenges which make the choice of base case forecast less than unobvious. In such situations the analyst will sometimes present the chief forester with more than one possible base case for his consideration. For this exercise, you should develop two distinctly different base case forecasts – one with an initial harvest level equal to the current AAC (103,000 $m^3$/yr), and another with a much lower initial harvest level.

Establishing the base case forecast involves finding the maximum LTHL, setting the initial harvest level, and defining the transitional harvest level.

**Table 3-8 Area and CMAI by analysis unit, Awesome Creek Management Unit**

| | Area (ha) | | | CMAI | LRSY |
|---|---|---|---|---|---|
| AU | Inoperable | Operable | Total | ($m^3$/ha/yr) | ($m^3$/yr) |
| 1 | 166.22 | 3,519.69 | 3,685.91 | 2.07 | |
| 2 | 391.25 | 5,726.36 | 6,117.61 | 1.54 | |
| 3 | 9,147.60 | 4,035.53 | 13,183.13 | 1.27 | |
| 4 | 209.05 | 2,309.15 | 2,518.20 | 2.04 | |
| 5 | 289.73 | 2,805.63 | 3,095.36 | 1.59 | |
| 6 | 6,795.05 | 3,924.17 | 10,719.22 | 1.30 | |
| 101 | 0.23 | 602.29 | 602.52 | 2.95 | 12159.84 |
| 102 | 0 | 910.60 | 910.60 | 1.98 | 13141.18 |
| 103 | 17.46 | 193.04 | 210.50 | 1.53 | 6469.71 |
| 104 | | | | 3.28 | 7574.01 |
| 105 | 0 | 87.47 | 87.47 | 2.26 | 6538.41 |
| 106 | | | | 1.79 | 7024.26 |
| 999 | 6,791.90 | 0 | 6,791.90 | 0 | |
| Total | **23,808.49** | **24,113.93** | **47,922.42** | | **52907.41** |

(i) *Find the maximum LTHL*: The LTHL is the maximum harvest level that can be supported by an entirely second-growth forest. A simple and quick approach to finding LTHL is to use LRSY as a first estimate. The LRSY for this forest is 52,907 $m^3$/yr (Table 3-8).

(ii) *Set the initial harvest level*: Find an initial harvest level that is the maximum that can be cut without causing the harvest in later periods to drop much below the LTHL. If possible, the initial harvest level should be close to the current AAC (103,000 $m^3$/yr for the Awesome Creek Management Unit).

(iii) *Define the transitional harvest level*: Find an acceptable transitional flow from initial harvest level to LTHL. There are many possible combinations of initial and transitional harvest levels, so you should decide early on what "acceptable" means. **Write it down**. For example, you might choose to maximize the first-decade harvest, subject to subsequent harvests never declining by more than 5% per decade .

Your definition of an acceptable transitional flow defines the harvest flow policy for your analysis. Keep in mind that your choice of flow policy may require changing the initial harvest level.

Target harvest levels are set in the file called *targets.dat*.

Run FSSIM. Use FSSIM's graphs and reports to evaluate the run. Then adjust your harvest levels, and repeat the process. Continue with this cycle of simulate-evaluate-adjust targets until you feel that you have found an appropriate or acceptable base case harvest forecast.

Changing harvest levels is straightforward—you simply change the values in *targets.dat*—but evaluating a run (measuring the change in forest performance) can be difficult, as discussed in the following section.

### Measuring forest performance

Measuring forest performance is difficult to do with timber supply models because the goodness of the outcome of a run is subjectively evaluated. For example, in a particular planning situation one person might prefer a forecast in which harvests are high in the first two decades and decline sharply in later decades (the "me first" scenario), while another person might insist on a non-declining scenario (the "save it for our children" scenario). The measures of forest performance must capture not only the volume to be cut, but the schedule of those cuts, preferences about the volumes and schedule, and measures of other forest attributes as well. These measures are used to evaluate each run.

FSSIM provides a number of indicators of the state of the forest in each period, many of which can be used as measures of forest performance: growing stock inventory; age class distribution in each period; mean harvest age; harvest-age distribution; mean volume per hectare harvested; and area harvested. Before beginning the analysis it is important to choose criteria that will be used to evaluate indicators. For example, one might choose to maximize the first-decade harvest, subject to the following requirements:

- the drop in harvest level between periods must not exceed 10%
- the target harvest level must be met in every period
- growing stock inventory must not be declining at the end of the planning horizon
- growing stock inventory must never be less than 6 million $m^3$.

After changing the value of a parameter (e.g., initial harvest level, minimum harvestable age) and completing a run with FSSIM, you then evaluate the results (forest performance). In the example shown above, you could measure forest performance in terms of the first-decade harvest volume, given no violation of the other criteria. If, for instance, growing stock inventory was declining towards the end of the planning horizon, the run would be unacceptable according to the third criterion listed above. The harvest target would have to be reduced, and another run done. If the growing stock inventory was increasing at the end of the planning horizon, you might increase LTHL slightly.

## Sensitivity analysis

In general, sensitivity analysis involves changing the value of a model parameter (e.g., minimum harvestable age), and then measuring the effect of that change on forest performance (e.g., maximum sustainable harvest). It is done to determine the significance of uncertainty about (i.e., sensitivity of forest performance to changes in) the value of a parameter. The changes are always relative to the base case value, and therefore can only be done after the base case has been established.

Three kinds of sensitivity analysis are used with simulation models such as FSSIM:

- *Exploratory* sensitivity analysis, in which the analyst brackets a base case parameter value by increasing and decreasing the parameter value by some arbitrary amount. For example, if it is contended that yield curves are inaccurate, all yields could be increased by 5% and decreased by 5% to determine if, and by how much, such changes would affect forest performance.
- *Focused* sensitivity analysis, in which a parameter value is changed to reflect an expected or probable change. For example, if yields from a specific cover type are suspected to be underestimated, the yield tables for only that cover type could be increased by 5%, 10%, and 15%.
- *Threshold* sensitivity analysis, in which a parameter value is changed incrementally until a significant effect is detected. For example, yields for a particular cover type are increased incrementally until a significant change in the forecast is detected. The value of the parameter at this point of significant effect is the parametric *threshold*. The threshold identifies for decision-makers how much the value of the parameter could change (i.e., how much uncertainty would be acceptable) before their decision outcome would be affected (i.e., before their decision would change).

Here are a few additional hints to get you started with your analysis:

**Think about what you are doing** before you do it, while you're doing it, and after you do it. Don't start blindly making model runs.

Organize your analysis by planning the steps you will follow. Carefully record the inputs for and results of each run in Table 3-11.

When adjusting model parameters (e.g., harvest level) between runs, change only one parameter at a time. If you change the value of more than one parameter (e.g., harvest level and minimum harvestable age), you won't be able to tell which change caused the change in model results.

Remember, you can't hurt the computer, so don't be afraid to experiment. On the other hand, you have a limited amount of time, so use it carefully.

**Table 3-10 FSSIM data files**

| | |
|---|---|
| *axs.dat* | green-up and old-growth constraint parameters |
| *class.dat* | forest class zone, analysis unit, age, area, class type |
| *config.dat* | harvest rule (and some other model parameters) |
| *group.dat* | defines group membership by, zone, AU, age range, class type |
| *landoaf.dat* | land area reduction by zone or AU |
| *oaf.dat* | minimum harvestable age and volume OAF, by AU |
| *param.dat* | planning horizon and period length |
| *priority.dat* | harvest eligibility ranking by zone, AU, and group |
| *regen.dat* | AU regeneration path and regen delay |
| *reports.dat* | reports to be generated, by group |
| *road.dat* | % landbase reduction, age boundary, and road AU, by AU and zone |
| *targets.dat* | harvest volume targets, by zone |
| *vols.dat* | volume tables |