A Forest Estate Plan For The Invermere Enhanced Forest Management Pilot Area

by:

Mark Messmer
and Dave E. White

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Introduction

The Invermere Forest District in Southeastern British Columbia was chosen as one of three areas in the province for the location of an “Enhanced Forest Management Pilot Project” (EFMPP). The purpose of the project is to explore through various analyses the biological effectiveness and economic efficiency of forest management activities across a forest estate defined as the Invermere EFMPP area[1]. To this end, a number of different projects have been undertaken. This paper presents the results of one of these projects.

Enhanced forest management in the context of silviculture, can involve a number of activities. These activities include juvenile spacing, fertilization, pruning, planting, commercial thinning and various types of partial harvesting. Each activity, either by themselves or in combination with each other, have the potential to enhance the expected volume and/or value of current and expected future harvests. However, these activities are not free, and expenditures on them have real opportunity costs. Also, when assessing opportunities for silviculture activities across a forest estate, one must consider the possibility that there may be interactions between various objectives applied to the forest estate, in addition to the objective of an expected level of harvest. It is in this context that the potential for silviculture activities to have a positive biological and/or economic impact must be considered. This point will be elaborated upon further in this report.

The objectives of this analysis are as follows:

1. To define, on a five year period basis the amounts and kinds of silviculture activities that should be undertaken in order to achieve a given projected harvest level.

2. To define, on a five year period basis the cost of silviculture activities mentioned in the previous point number one.

3. To conduct sensitivity analyses with input data defining the biological impact of silvicultural activities and the level of various constraints.

4. To define the interactions between various constraints designed to achieve non-timber objectives, and opportunities for conducting silviculture activities.

5. To define the interactions between various constraints designed to achieve projected harvest flow objectives, and opportunities for conducting silviculture

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[1] Enhanced Forest Management Pilot Project - Joint Steering Committee/Technical Advisory Committee/Pilot Area Meeting Summary Notes - MoF File:400-20/FMS, March 18, 1996

activities.

6. To present caveats, shortcomings and assumptions made in this analysis, and provide recommendations for improvements to any future endeavors of this nature.

Silviculture activities chosen for the pilot area were not subjected to stand level economic analysis. It was decided to initially ignore their relative economic contributions at the stand level, and focus on their potential contribution to a timber supply objective and non-timber value constraints. Subsequent to this, expected present values of silviculture costs and revenues from harvesting can be compared using different budget constraints and timber flow constraints.

Another important factor that is also not considered is who pays for expenditures on silviculture activities. The approach presented assumes that the driving force for any silviculture expenditure is its contribution to the a maximum flow of harvest from the pilot area over a predefined future time period, subject to a host of objectives. These objectives may or may not be timber production related. The corollary to the timber production objective is that whatever maximum flow of timber is projected, this supply of timber will be demanded at a price the market will always be willing to pay.

Methods

This analysis addresses the problem of determining the relationship between expenditures on silviculture activity, and the flow of harvest. For this reason, it was deemed ideally suited to be solved as a constrained linear optimization problem. Constrained linear optimization analyses are common in forest estate analyses, and have been used to address questions around appropriate levels of silviculture spending (see Reyner et al., 1996, and Davis et al., 1992).

The problem stated as a constrained linear optimization is as follows:

Maximize the flow of harvestable timber over a long time period (100 years in this case), subject to one or more of the following:

- Harvest flow constraints
- Silviculture activity budgets
- Spatial approximation rules for cutblock adjacency/location
- Spatial approximation rules for wildlife habitat
- Spatial approximation rules for biodiversity objectives
- Spatial approximation rules for old-growth forest objectives

- Spatial approximation rules for other non-timber objectives

Although there are other constraints or assumptions that may act to constrain the value of the objective function, the above lists those that were explicitly identified in the LP problem.

Harvest Flow Constraints

A harvest flow constraint, is defined in this analysis as some exogenously determined limit on the amount of harvest in a given period. Such constraints are determined by policy in British Columbia, and have been applied in one of two ways - as a limit on how much different the harvest level can be between successive periods, or as a floor and/or a ceiling on a given periods' harvest level that must not be violated. Flow constraints may consist of any combination of floor, ceiling, upper bound, and lower bound, and may be applied to all or only parts of the planning horizon.

Harvest flow constraints are applied in harvest flow scheduling problems to mimic policies attempting to address sustainability concerns. Typically in British Columbia, they have been applied across areas of land that constitute "sustainable units". The units of sustainability in British Columbia are the Timber Supply Area (TSA) and the Tree Farm License (TFL) area. Although there is much variation in their relative size, current age class distributions, harvest histories and capacities to produce flows of harvestable timber, their use as sustainable units is ostensibly a policy choice[2]. The Invermere EFMPP area is only a portion of the Invermere TSA, therefore, in such a policy context, there is no apparent reason to apply harvest flow constraints. However, to the extent that flow constraints are known for the entire Invermere TSA, it may be possible to apply TSA-level flow constraints on a *pro- rata* basis. This would also imply that the contribution to a TSA-level projected flow of harvest is known for the EFMPP area (which presently, is not well known).

Silviculture Activity Budgets

A silviculture activity budget exists for all possible "incremental" silviculture activities in the model. Incremental silviculture activities are defined as those

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[2] Harvest flow constraints in a timber supply modeling context were first applied in the early 1970's in B.C. when it appeared that future harvest levels from "managed" forests would be unable to support present day harvest levels from the existing stock of old forest. Since that time, it is also apparent that uncertainty exists in all of the measures used to portray this result, and other measures which would impact it have been ignored entirely. Therefore the impacts of harvest flow constraints applied to the *de facto* "unit of sustainability" , the TSA or TFL have yet to be completely assessed in light of policies they were designed to address.

that are not required to meet the legislated requirements for reforesting a harvested area. Incremental activities include planting backlog NSR, juvenile spacing, pruning, and fertilization and various combinations of them. Activities such as planting, and natural regeneration are not considered costless, and are accounted for in the analysis.

Spatial Approximation Rules

One of the purposes of spatial approximation rules was not only to ensure that a sufficient area of forest of a given age existed over time to contribute to some non-timber objective, but also to ensure the spatial feasibility of a projected harvest schedule. For example, if it takes a clear cut area 17 years from harvest on average to reach an average stand height deemed sufficiently tall to allow for the harvest of the adjacent stand, and the average harvest age is 80 years, and if the entire area is available for harvest, then no more than 21.25% of the area (17 years divided by 80 years) should be less than 17 years of age at any given time. Abiding by this rule, all else being equal, should help to ensure that no two cut-over areas will be required to be adjacent to each other before the other one is at least 17 years old. This “rule of thumb” is based on map coloring theory and is explained in detail in Nelson and Errico, 1993, and Daust and Nelson, 1993.

Spatial approximation rules can be used to account for continued existence of non-timber resources, but their utility in this regard is not well understood. In the linear programming problem a constraint is defined as a limitation or restriction on some portion of the age class distribution in a given time period and over a given portion of the forest estate. For example, to meet habitat objectives for woodland caribou winter range, at least 40% of the area that contributes to woodland caribou habitat must be greater than a minimum age of 140 years in perpetuity (or for the entire length of the model run which is 125 years). All spatial approximation rules for this analysis are constructed in this fashion.

Defining Silviculture Activities

Silviculture activities were defined as proposed series of treatments applied to the land base. Each proposed series of treatments for each differentiated stand type constitutes a silviculture regime. A total of 59 potential regimes were proposed. Stand type is defined by species composition and productivity. Merchantable volume by log diameter class over 5-year age class was projected for each regime with TASS[3], a growth and yield model. TASS is capable of projecting managed stand volumes that include the impacts of juvenile spacing, commercial thinning, pruning, and planting. The biological impact of fertilization on merchantable volume was determined exogenously.

Table 1 presents a summary of the variables defining each silviculture regime.

Table 1: A Summary of the Silviculture Regimes for the Invermere EFMPP

Regime	Site Index	Regen	%	Delay	1st sp.	OAF1	OAF2	2nd sp.	OAF1	OAF2
1 F L PY G all slopes	19.1 (21)	plant	33	5	F 70	15	10.8	Pl 30	15	10.8
2 F L PY G all slopes	19.1 (21)	nat	33	5	F 70	20	10.8	Pl 30	15	10.8
3 F L PY G all slopes	19.1 (21)	nat	34	5	F 70	20	10.8	Pl 30	15	10.8
4 F L PY G <25% slope	19.1 (21)	plant	33	5	F 70	15	10.8	Pl 30	15	10.8
5 F L PY G <25% slope	19.1 (21)	nat	33	5	F 70	20	10.8	Pl 30	15	10.8
6 F L PY G <25% slope	19.1 (21)	nat	34	5	F 70	20	10.8	Pl 30	15	10.8
7 F L PY M all slopes	16.4 (18)	plant	33	5	F 60	15	10.8	Pl 40	15	10.8
8 F L PY M all slopes	16.4 (18)	nat	33	5	F 60	20	10.8	Pl 40	15	10.8
9 F L PY M all slopes	16.4 (18)	nat	34	5	F 60	20	10.8	Pl 40	15	10.8
10 F L PY M <25% slope	16.4 (18)	plant	33	5	F 60	15	10.8	Pl 40	15	10.8
11 F L PY M <25% slope	16.4 (18)	nat	33	5	F 60	20	10.8	Pl 40	15	10.8
12 F L PY M <25% slope	16.4 (18)	nat	34	5	F 60	20	10.8	Pl 40	15	10.8
13 F L PY P	13	plant	25	5	F 60	15	8.1	Pl 40	15	8.1
14 F L PY P	13	nat	50	5	F 60	20	8.1	Pl 40	15	8.1
15 F L PY P	13	nat	25	5	F 60	20	8.1	Pl 40	15	8.1
16 F L PY L	8.3	plant	10	5	F 60	15	8.3	Pl 40	15	8.3
17 F L PY L	8.3	nat	60	5	F 60	20	8.3	Pl 40	15	8.3
18 F L PY L	8.3	nat	30	5	F 60	20	8.3	Pl 40	15	8.3
19 S B G	19.8	plant	70	5	S 70	15	5	Pl 30	15	5
20 S B G	19.8	nat	15	5	S 70	15	5	Pl 30	15	5
21 S B G	19.8	nat	15	5	S 70	15	5	Pl 30	15	5
22 S B M	15	plant	50	5	S 60	15	5	Pl 30	15	5
23 S B M	15	nat	25	5	S 60	15	5	Pl 30	15	5
24 S B M	15	nat	25	5	S 70	15	5	Pl 30	15	5
25 S B P,L	10.5	plant	50	5	S 70	15	5	Pl 30	15	5
26 S B P,L	10.5	nat	25	5	S 70	15	5	Pl 30	15	5
27 S B P,L	10.5	nat	25	5	S 70	15	5	Pl 30	15	5
28 C H GMPL	15.5	plant	60	5	S 50	15	5	Pl 50	15	5
29 C H GMPL	15.5	nat	20	5	S 50	15	5	Pl 50	15	5
30 C H GMPL	15.5	nat	20	5	S 70	15	5	Pl 50	15	5
31 Pl Pw G	21(23)	plant	25	5	Pl 80	15	8.7	F 20	15	8.7
32 Pl Pw G	21(23)	nat	45	5	Pl 80	20	8.7	F 20	15	8.7
33 Pl Pw G	21(23)	nat	30	5	Pl 80	20	8.7	F 20	15	8.7
34 Pl Pw G <25% slope	21(23)	plant	25	5	Pl 80	15	8.7	F 20	15	8.7
35 Pl Pw G <25% slope	21(23)	nat	45	5	Pl 80	20	8.7	F 20	15	8.7
36 Pl Pw G <25% slope	21(23)	nat	30	5	Pl 80	20	8.7	F 20	15	8.7
37 Pl Pw G <25% slope	21(23)	plant	25	5	Pl 80	15	8.7	F 20	15	8.7
38 Pl Pw G <25% slope	21(23)	nat	45	5	Pl 80	20	8.7	F 20	15	8.7
39 Pl Pw G	21(23)	plant	25	5	Pl 80	15	8.7	F 20	15	8.7
40 Pl Pw G	21(23)	nat	45	5	Pl 80	20	8.7	F 20	15	8.7
41 Pl Pw M	18(20)	plant	25	5	Pl 90	15	8.7	F 10	15	8.7
42 Pl Pw M	18(20)	nat	45	5	Pl 90	20	8.7	F 10	15	8.7
43 Pl Pw M	18(20)	nat	30	5	Pl 90	20	8.7	F10	15	8.7
44 Pl Pw M <25% slope	18(20)	plant	25	5	Pl 90	15	8.7	F 10	15	8.7
45 Pl Pw M <25% slope	18(20)	nat	45	5	Pl 90	20	8.7	F 10	15	8.7
46 Pl Pw M <25% slope	18(20)	nat	30	5	Pl 90	20	8.7	F10	15	8.7
50 Pl Pw M <25% slope	18(20)	plant	25	5	Pl 90	15	8.7	F 10	15	8.7
51 Pl Pw M <25% slope	18(20)	nat	45	5	Pl 90	20	8.7	F 10	15	8.7
52 Pl Pw M	18(20)	plant	25	5	Pl 90	15	8.7	F 10	15	8.7
53 Pl Pw M	18(20)	nat	45	5	Pl 90	20	8.7	F 10	15	8.7
54 Pl Pw P	12.3	plant	25	5	Pl 70	15	8.7	F 30	15	8.7
55 Pl Pw P	12.3	nat	45	5	Pl 70	20	8.7	F 30	15	8.7
56 Pl Pw P	12.3	nat	30	5	Pl 70	20	8.7	F 30	15	8.7

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[3] TASS is an acronym for Tree And Stand Simulator. It is one of a number of growth and yield models and associated databases developed by the B.C. Ministry of Forests Research Branch

Table 1 Continued...

Regime	Initial Density	Spaced@age	1st lift prune	2nd lift prune	fertilize	comm. thin	js cost	f cost	pr.cost
1 F L PY G all slopes	1400	no			yes	no		200	
2 F L PY G all slopes	5000	1400@15			yes	no	550	200	
3 F L PY G all slopes	3000	no			yes	no		200	
4 F L PY G <25% slope	1400	no				@65-35%vol			
5 F L PY G <25% slope	5000	1400@15				@65-35%vol	550		
6 F L PY G <25% slope	3000	no				@65-35%vol			
7 F L PY M all slopes	3000	no			yes			200	
8 F L PY M all slopes	3000	1400@15			yes		550	200	
9 F L PY M all slopes	3000	no			yes			200	
10 F L PY M <25% slope	3000	no				@65-35%vol			
11 F L PY M <25% slope	3000	1400@15				@65-35%vol	550		
12 F L PY M <25% slope	3000	no				@65-35%vol			
13 F L PY P	1400	no							
14 F L PY P	5000	1400@15					550		
15 F L PY P	3000	no							
16 F L PY L	1400	no							
17 F L PY L	5000	1400@15					550		
18 F L PY L	3000	no							
19 S B G	1400	no							
20 S B G	5000	1400@15					650		
21 S B G	3000	no							
22 S B M	1400	no							
23 S B M	5000	1400@15					650		
24 S B M	3000	no							
25 S B P,L	1400	no							
26 S B P,L	5000	1400@15					650		
27 S B P,L	3000	no							
28 C H GMPL	1400	no							
29 C H GMPL	5000	1400@15					650		
30 C H GMPL	3000	no							
31 Pl Pw G	1400	no							
32 Pl Pw G	5000	1400@15					400		
33 Pl Pw G	3000	no							
34 Pl Pw G <25% slope	1400	no				CT@40 35% >20cm			
35 Pl Pw G <25% slope	5000	1400@15				CT@40 35% >20cm	400		
36 Pl Pw G <25% slope	3000	no				CT@40 35% >20cm			
37 Pl Pw G <25% slope	1400	no			yes[4]			200	
38 Pl Pw G <25% slope	5000	1400@15			yes		400	200	
39 Pl Pw G	1400	no	3m@15 700sph	6m@25 700sph		CT unpruned @ age 50			700/ha/lift
40 Pl Pw G	5000	1400@15	3m@15 700sph	6m@25 700sph		CT unpruned @age 50	400		700/ha/lift
41 Pl Pw M	1400	no							
42 Pl Pw M	5000	1400@15					400		
43 Pl Pw M	3000	no							
44 Pl Pw M <25% slope	1400	no				CT@50 35% >20cm			
45 Pl Pw M <25% slope	5000	1400@15				CT@50 35% >20cm	400		
46 Pl Pw M <25% slope	3000	no				CT@50 35% >20cm			
50 Pl Pw M <25% slope	1400	no			yes			200	
51 Pl Pw M <25% slope	5000	1400@15			yes		400	200	
52 Pl Pw M	1400	no	3m@15 700sph	6m@25 700sph		CT unpruned @ age 50			700/ha/lift
53 Pl Pw M	5000	1400@15	3m@15 700sph	6m@25 700sph		CT unpruned @ age 50	400		700/ha/lift
54 Pl Pw P	1400	no							
55 Pl Pw P	5000	1400@15					400		
56 Pl Pw P	3000	no							

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[4] Fertilize planted or natural 1400 sph stands of Pli maximum 4 times per rotation beginning at age 20, add 12m3/ha immediately for each fertilization treatment

Linear Programming Model Structure and Inputs

The proprietary software package, Woodstock™, was used to generate the LP matrix, and produce output files and reports. Woodstock™ is a high-level programming language that has a number of default and built-in functions essential for constructing a harvest level projection model, yet most of the model's structure is defined by the user.

Several types of information were required as input to the model:

- forest areas (resultant areas) by age and various descriptive attributes
- projected merchantable volume by five year age class for each silviculture regime
- average cost per hectare of each silviculture regime/activity
- spatial approximation rules for each management zone/objective, and each old-growth/mature seral stage requirement

Forest areas were obtained from the "class.dat" format file created by district staff for a separate timber supply projection exercise[5]. This file was derived from the forest inventory planning files from the district, and prepared using guidelines from the "Invermere District Data Package Document" (May 02,1997).

Merchantable volume over age projections were simulated with TASS, as previously described.

Average cost per hectare by silviculture activity is listed in the previous Table 1, and are based on estimates made by district staff.

Spatial approximation rules were obtained from Table 14 of the "Invermere District Data Package Document" (May 02,1997).

Woodstock Input and Output Files

A copy of the input files for the first run (run 1) appears in the appendix. The primary input file contains the linear program objective function and constraints, variable definitions for all the attributes used to define the forest, and a list of all other input files that are called from the primary file. Yield curves, as well as the unit costs of silviculture activities are in a separate file. There are 10,094 analysis areas also in a separate file. Each analysis area is defined by the following attributes:

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[5] This exercise utilizes the B.C. Ministry of Forests "Forest Service Simulator Model" (FSSIM). This model is used for timber supply analyses for the Ministry's Timber Supply Review Process.

- Landscape Unit - The Invermere EFMPP is divided into 7 landscape units. Each is a geographically contiguous area.

- Analysis Unit - Analysis Units are not geographically contiguous. There are 18 analysis units. They are essentially timber type/site class combinations, although 4 analysis units are also defined by management considerations. Three of the four are for partial harvesting only, and one is for areas designated for Christmas tree production.

- Biogeoclimatic Zone and Natural Disturbance Type - both of these attributes are geographically contiguous in the EFMPP. There are 9 unique combinations of BEC/NDT. The BEC/NDT theme is used in the creation of mature and old seral stage forest cover constraints (spatial approximation rules).

- Management Zone - Unlike what the name would imply, management zones are actually management objectives. They are somewhat geographically contiguous, but not necessarily. There are seven zones, namely, forest ecosystem networks, full retention visual quality objectives, partial retention visual quality objectives, important watersheds, ungulate winter range, Rocky Mountain Trench, and integrated resource management zone. All area in the EFMPP is defined by one of these management objectives(zones). Each management zone is defined by a green-up height and age, and the maximum percent areas that may be less than the green-up age/height. In the case of the ungulate winter range zone, there is also a minimum area that can be less that 140 years of age to satisfy ungulate winter range requirements.

- Operability - There are four states of operability. The first is “operable”, this means that an area is available for harvest. The second is “indefinitely deferred” areas are never available for harvesting, but contribute to the achievement of management zone and mature/old seral stage objectives. Third, are areas deferred from harvesting for the next forty years, and these coincide with area defined as contributing to the forest ecosystem network objective. In forty years time they will be available for partial harvesting. Lastly are inoperable areas. These areas are never available for harvesting, and they also do not contribute to meeting management zone and mature/old seral stage objectives. In addition to this theme, operability for harvesting is also defined by a minimum harvest age. Minimum harvest ages are defined by timber type, site class, silviculture regime, and in some cases mature/old seral stage requirements, and ungulate winter range requirements.

- Slope - slope is required to defined operability for commercial thinning. Commercial thinning is assumed to be inoperable on areas with slope greater than 25%.

- Silviculture Regime Status- There are sixteen states of silviculture, although not all of them refer to silviculture activity, namely, road and landing reductions, regenerated deciduous stands, not sufficiently restocked stands, and height repressed young pine stands. The remainder are various combinations of planting, natural regeneration, juvenile spacing, commercial thinning, pruning, and fertilization.

Results

The Scenarios

Six variations of the model were produced. Two variables were modified, namely the silviculture budget constraint, and the harvest flow constraint. Table 2 lists the magnitudes of these variables for each of the six runs.

Table 2: The Six Scenarios

Run Number	Silviculture Budget[6] $ per five year period	Flow Constraint Ceiling - m^3/year	Flow Constraint Floor - m^3/year
1	<= $50,000,000. (unlimited)	<= 250,000	>= 100,000
2	<= $10,000. (severely constrained)	<= 250,000	none
3	<= $50,000,000. (unlimited)	none	none
4	<= $50,000. (severely constrained)	none	none
5	<= $2,500,000.	<= 250,000	>= 100,000
6	<= $1,000,000.	<= 250,000	>= 100,000

The floor and ceiling values of the flow constraints were chosen based on recommendations from district staff. These levels were derived from analysis conducted with a forest estate timber supply simulation model of the EFMPP

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[6] The silviculture budget applies only to incremental silviculture activities, not basic or legally required activity. Spending on basic silviculture is unconstrained.

area by Invermere district staff. They represent approximations of the proportion of projected timber flow expected from the pilot area based on previous timber supply projections of the entire Invermere TSA.

It was not possible to constrain run 2 with a “floor” flow constraint and generate a feasible solution. In the virtual absence of an incremental silviculture budget with run 2, it was not possible to maintain a harvest level above 100,000 m^3 per year in every five year period.

It was intended that silviculture budget constraints for run 2 and run 4 be equivalent, however it was not possible to generate a feasible solution with run 4 and only a <= $10,000. per period budget constraint. For this reason, the budget constraint was increased to $50,000. per period. Arguably both levels are significantly small numbers in terms of the level of silviculture activity that could be accomplished with such funding.

The $50 million dollar per period budget constraint was chosen as a level well in excess of what could possibly be spent each period. With this level of funding available, the amount of silviculture activity that is undertaken, and the actual amount of money spent is only related to the activity’s contribution to the objective function of maximizing the sum of timber harvested from the EFMPP area over the next 100 years.

Budget constraint levels for runs 5 and 6 were chosen based on advice from district staff. These levels ($500,000 per year for run 5 and $200,000 per year for run 6) were considered to be ballpark estimates of potential funding levels available for incremental silviculture.

In addition to these constraints, 17 additional constraints were defined for management zone, and mature/old seral stage requirements. Subsequent to defining these constraints to levels documented in the data package (table 14), it was discovered that portions of the EFMPP area were insufficient to meet prescribed levels. For example, the maximum percent area allowed less than the green-up age in the full retention VQO zone is 5%. The current inventory contains 15%, which is 10% above this level. The forest ecosystem network zone is allowed to have no more than 5% of the area less than the green-up age, and presently there is 11%. If constraints in the LP are set below what actually exists in the forest, the problem will be rendered infeasible, and no solution output can be generated. To avoid this trap, it was necessary to increase the minimum values allowed in constraints for the first few periods, where actual values were above constraint levels specified in the data package. In order to allow the projected inventory to “grow” as quickly as possible, harvesting activity was deferred for the first few periods in these areas.

The linear programming matrices generated were sufficiently large that each run took several hours to complete.[7] Graphical output of some of these results is presented and discussed on the following pages.

The Relationship Between Expected Harvests and Budget Constraints With the Maximization of Volume Objective.

Figure 1: Expected total harvest flow - runs 1 and 2

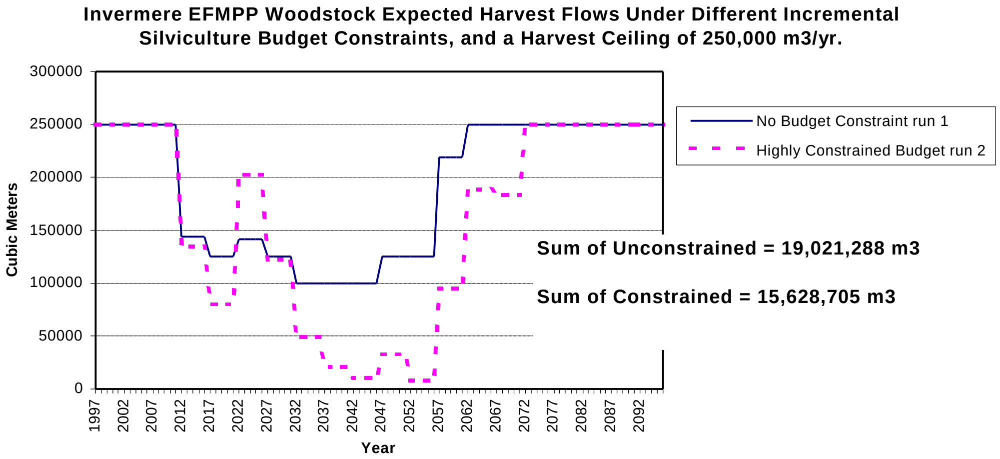

Figure 1 displays total expected harvest flows from the Invermere Pilot Area over the next 100 years, both in the absence of an incremental silviculture budget (run2), and with no constraints on incremental silviculture spending (run1). These two runs also include absolute limits on the maximum amount of periodic harvest, and in the case of run 1, a minimum floor on harvest of 100,000 m3 per year. No constraints were imposed limiting the amount of variation between successive five year periods.

Clearly, silviculture spending has had an impact on the expected flow of future harvest, but a number of important questions remain:

Do the expected benefits from the additional expected harvest outweigh the costs, in terms of timber?

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[7] Run 1 had an MPS-format LP matrix with 49,441 constraint rows, 166,809 columns, and 2,831,977 non-zero elements, for a total size of 110,665,023 bytes. On a pentium-75Mhz PC with 72 MB RAM, it took 1 hour and 37 minutes to generate the MPS file, and took 2 hours and 14 minutes to produce an optimal solution. These times were halved on a pentium-pro 200Mhz with 128MB RAM.

Are there any benefits in terms of lessening the impacts of non-timber constraints that can be attributed to silviculture spending?

Are the differences between expected harvest flows affected by the presence or absence of harvest flow constraints, and if so, in what way?

Subsequent results will hopefully shed some light on these questions.

Figure 2 shows expected levels of expenditure on incremental silviculture activity for the harvest flows in Figure 1. There is extreme variation between periods of actual expenditures. It is unknown if such a flow of expenditure would be consistent with the available levels of capital and labour in the silviculture contracting sector, at least not without having impacts on the prices available for such services.

Figure 2: Expected flow of incremental silviculture expenditures - runs 1 and 2

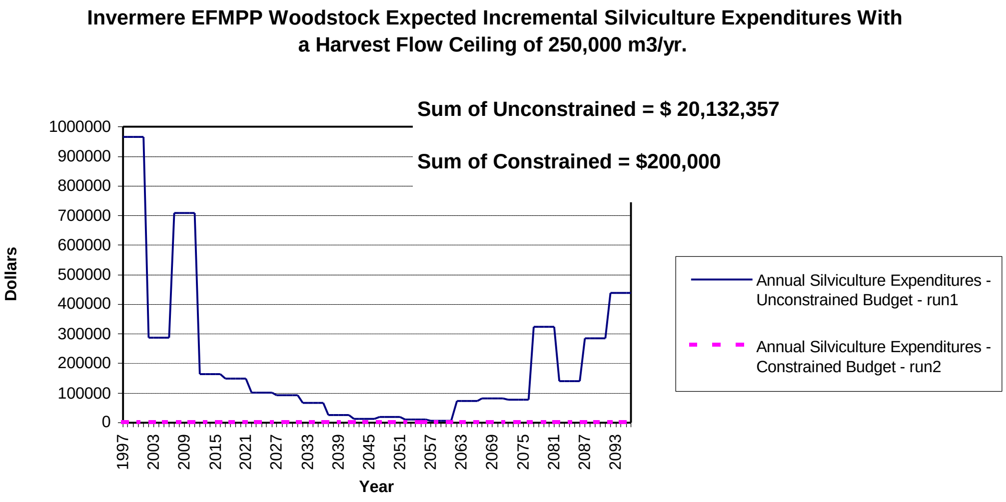
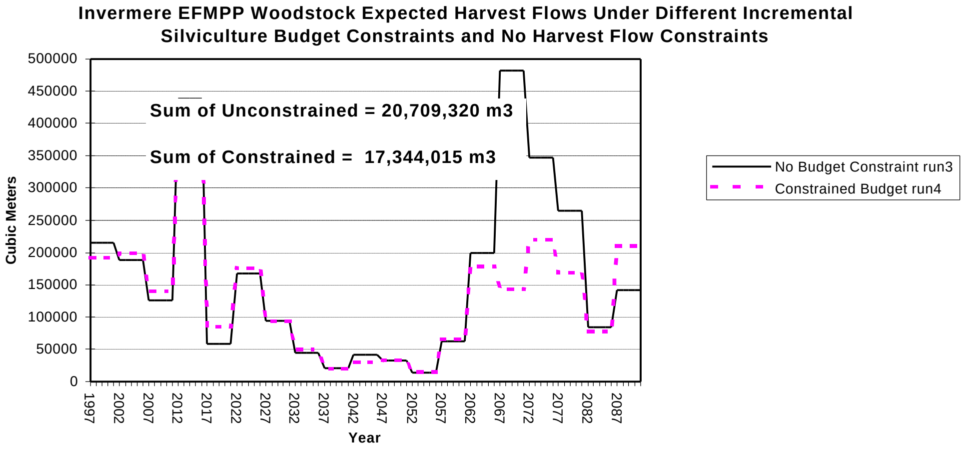


Figure 3 shows expected harvest levels given the same budgets constraints as in runs 1 and 2 in Figures 1 and 2, however the constraints on harvest flow are absent.

Figure 3: Expected total harvest flow - runs 3 and 4



It is important to note that the expected harvest flow in figure 3 is five years less than that for runs 1,2,5 and 6 (Figures 1 and 5). Without harvest flow constraints, or ending inventory constraints, the last period's harvest is perhaps unreasonably large, since there are no future periods to consider, therefore it was excluded from the chart. However even if it were included, it did not seen to affect the results, as the difference in total harvest flow between run 3 and 4 with the last period included was 16.2% and excluded was 17%.

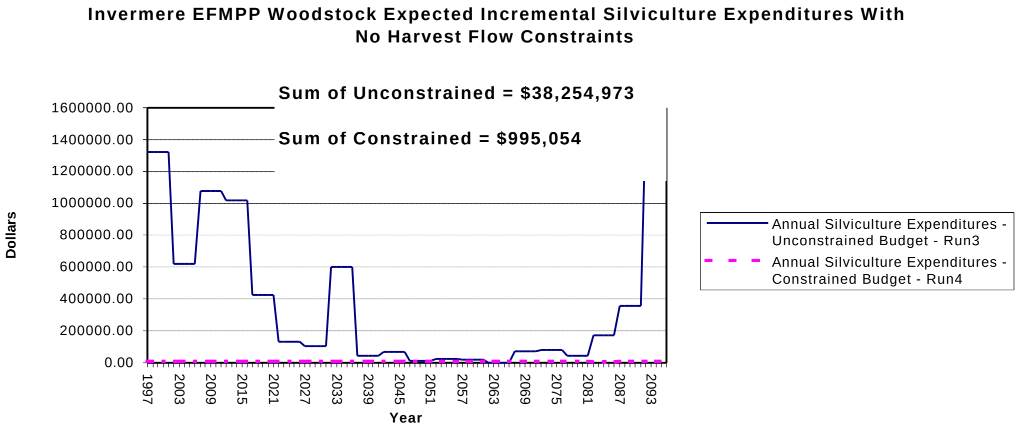
Without harvest flow constraints, annual harvest varies from about 14,000 m3 to over 1.1 million m3. The sum of unconstrained harvest over the 100 year planning horizon is about 1.68 million m3 different (runs 1 and 3) when incremental silviculture is unconstrained, versus a difference of 0.5 million m3 between the constrained runs (2 and 4). This suggests flow constraints have a negative impact on the ability to enhance expected harvest flows with incremental silviculture. If it is necessary to harvest stands (or delay harvest) to a particular age in the schedule that maximizes harvest flow, and this age of harvest is not the same as the age which optimizes the biological (or economic) impact of silviculture expenditures, then one would expect this result.

Flow constraints may make sense insofar as the objective is to provide a relatively constant supply of timber to one or more mills from the "unit of sustainability" (the TSA or TFL). It is not at all obvious that their application at the TSA and TFL level is consistent with providing a constant flow of timber *at reasonable cost* to mills, or with attempting to capture the greatest biological and/or economic benefit from the timber. In this analysis, flow constraints applied to an area which is a subset of the TSA, may tend to amplify these effects.

The policy objectives of flow constraints may attempt to address the issue of providing for a sustainable flow of harvest over time to meet a certain level of industrial capacity, but it is foolhardy at best to expect that this notion of sustainability has anything to do with resource supply. Common sense suggests strongly that the sustainability of resource use has everything to do with the demand side, the movement of prices, and the changing distribution of the cost to extract the resource and get it to market. It can be argued that the nature of flow constraints inherent in policy are closely tied to the fact that the issuance of most forms of tenure in B.C. require tenure holders to own wood processing capital. The economic implications of such policies are ripe fruit for discussion in another paper.

Planning for stands to be harvested at either their biologically or economically optimal rotation age may make sense in the mythical world of forest estates with equal amounts of growing stock across all ages. The reality in B.C. (with some notable exceptions) of uneven age class distributions, and non timber objectives (constraints), appears to dampen the desirability of harvesting at an optimum biological or economic rotation age, and thus the ability to capture benefits from incremental silviculture activities. This is especially true for the Invermere EFMPP in the presence of harvest flow constraints.

Figure 4: Expected flow of incremental silviculture expenditures - runs 3 and 4



Harvest flows and annual expenditures for runs 5 and 6 are shown in figures 5 and 6.

Figure 5: Expected total harvest flow - runs 5 and 6

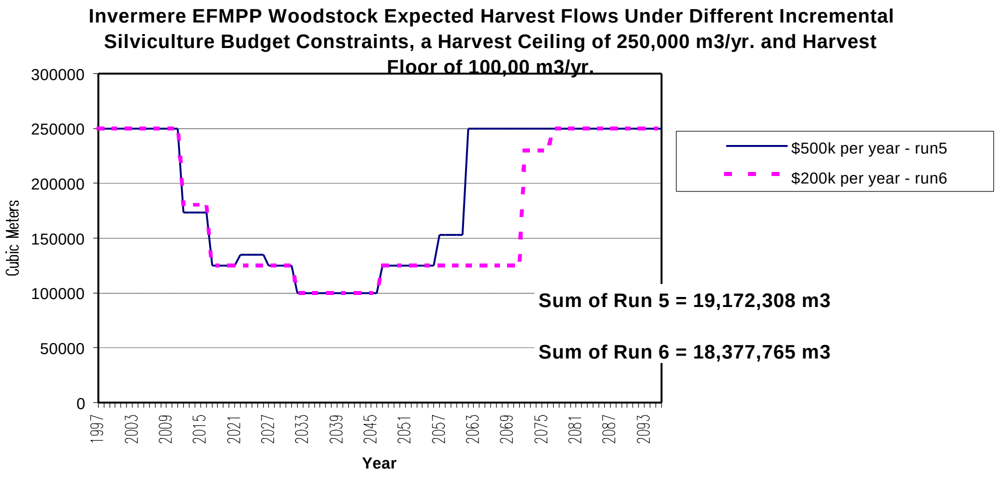
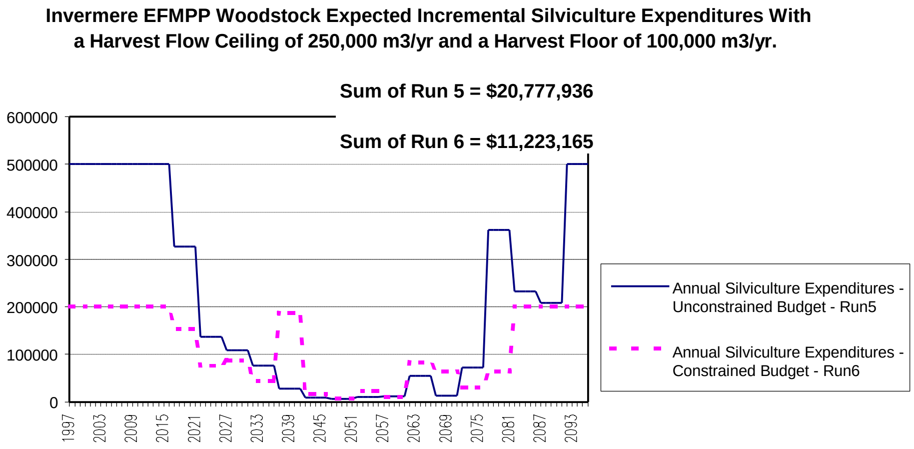


Figure 6: Expected flow of incremental silviculture expenditures - runs 5 and 6



The majority of difference in these expected harvest flows is not expected to occur for about 60 years, yet the difference in expenditures is almost double for run 6 and the majority of these occur in the first thirty years. The extra $300,000 per year budgeted in run 5 clearly has minimal impact especially given the long time frame and associated uncertainties around it. Comparing the unconstrained budget expected harvest flow in run 1 with runs 5 and 6, it is apparent that the upper limit on what can be spent is no more that $500,000 per year, and over half of that budget has minimal impact on the expected flow of harvest.

It must be remembered that this optimization analysis provides the maximum value for the sum of harvest over the planning horizon, and in doing so two important considerations are evident. The first is that a cubic meter of harvest today (the first period) has the same “value” as a cubic meter of harvest in any other period. The second, is that when silviculture expenditures are unconstrained (there is more than enough dollars to spend in a given period on all feasible activities), and when spending a dollar results in an increase of even 0.01 cubic meters of harvest in some distant period, the dollar will be spent. These two considerations are non-trivial in an economic context, as clearly, the value of a cubic meter of (expected) harvest 50 years from now is not the same as a cubic meter of (actual) harvest today. There are different opportunity costs associated with a dollar of silviculture expenditure that allowed for 10 additional cubic meters of expected harvest and one that adds only 0.01 cubic meter.

Silviculture expenditures do not appear to have an impact on changing the relationship between the objective function (maximize harvest) and all of the non-timber constraints. Evidence of this can be seen in the shadow prices associated with each constraint in each period. Shadow prices[8] for the majority of constraints, in the majority of periods are zero, in all of the six runs, and where they are not zero, their magnitude and occurrence does not appear to be affected by either harvest flow constraints, or an incremental silviculture budget constraint. The presence of a zero shadow price for a given constraint in a given period simply means that there is more than enough of the condition (e.g. maximum area allowed under green-up age) present to satisfy the constraint. Applying more money for silviculture activity, does not affect this for the EFMPP area.

Shadow prices are calculated for each unique area defined in the existing inventory. These are by far the most constraining, given their relative magnitudes, which in general far exceed those for harvest flow constraints, non-timber constraints, and budget constraints. What does this mean? Ideally the “best forest” to have in the present period is one in which there is sufficient area across all age classes to maintain a maximum harvest flow across all periods of the planning horizon. The actual age class distribution of the forest is such that there are enormous “costs” in having too little area in certain age classes. This starting condition represents far more of a constraint than any other constraints (non-timber constraints) that are applied to the land base in subsequent periods.

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[8] Shadow prices are produced as an output from the LP solution and provide some indication of the relationship between the level of the constraint, and the value of the objective function. These files are fairly large, and output is somewhat cryptic. A sample of shadow prices from run 1 is presented in the appendix.

The Impact of Juvenile Spacing Activity on Expected Harvest Flows

Juvenile spacing is generally thought to have at least one of the following impacts, to shift the distribution of harvest volume into larger diameter classes, to allow for a commercial thinning, or to allow for a final harvest at an earlier age of entry. Assuming that one or more of these impacts exist (this can, in most cases, be supported by biological evidence), questions remain as to the extent and significance of these impacts in the context of an expected schedule of harvest.

Figures 7, 8 and 21 to 24 show the percent distribution of expected harvest by average diameter class for each of the six runs. The expected harvest flow from run 1 in figure 7 incorporates the maximum amount of juvenile spacing activity over time given no budget constraint. Figure 8 from run 2 presents the opposite extreme, where there is no incremental silviculture budget and therefore no juvenile spacing activity.

The biological impact of juvenile spacing is included in the analysis in two ways. The first is the use of a yield projection that accounts for the spacing activity, and the second (and more contentious) is the assumption of an earlier age of entry for juvenile spaced areas. It was assumed areas that had received spacing could be harvested 1 to 2 periods (5 to 10 years) earlier, depending on timber type, than their non-spaced counterparts. This assumption is intended to capture the notion that a spaced stand may have greater merchantable volume above a minimum diameter at a younger age, but only with a significant sacrifice in total merchantable volume, had the stand been allowed to grow longer, in a non-spaced condition, and with a higher minimum harvest age. This is contentious, as it may very well be possible that a non-spaced stand may also be harvested at a slightly earlier age, and also provide less merchantable volume, and the somewhat smaller diameter timber may be quite adequate. This is a question that requires further research, especially with respect to the economic implications.

Figure 7: Expected harvest by diameter class - run 1

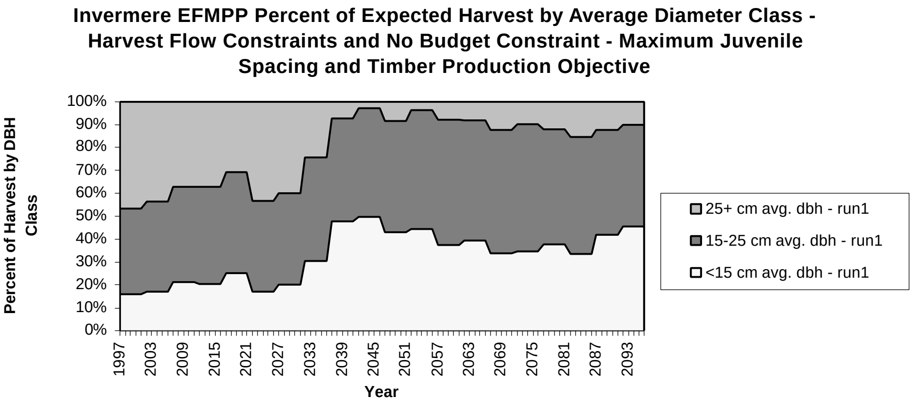
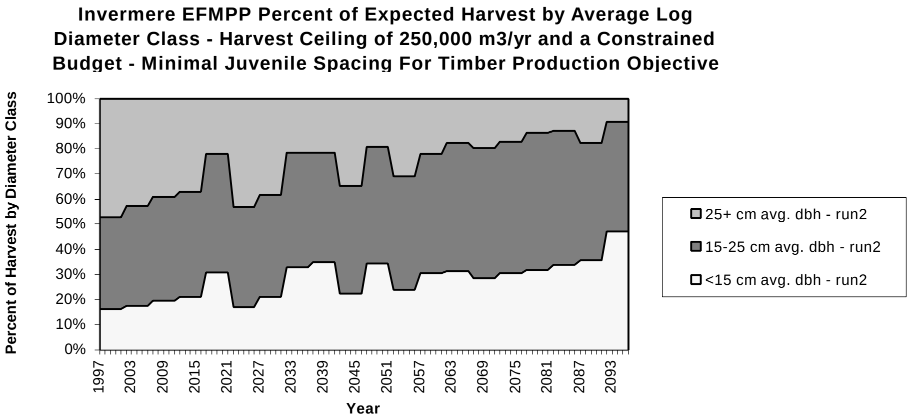


Figure 8: Expected harvest by diameter class - run 2



There are two inferences that can be drawn from the outcomes depicted in Figures 7 and 8. The first is that juvenile spacing had no appreciable impact on shifting the distribution of harvest volume into larger diameter classes. If anything, the reverse is true, as allowing for harvest at younger ages actually increases the proportions of harvest from the 12.5cm to 15cm diameter class, especially during the period beginning 30 years hence. The second is that without the assumption of a lower minimum harvest age for juvenile spaced stands, it is unlikely spacing would have been chosen as an activity, as merchantable volumes are lower across all ages (see Figure 31 in the Appendix).

The impacts of juvenile spacing at the stand level are generally assessed at two ages, the age that maximizes net present value, and the age that maximizes production of expected merchantable volume. This is fundamental in assessing the potential contribution from any silvicultural treatment. However, the probability that a given stand of forest will be scheduled for harvest at either of these ages is likely remote, given the initial constraints implicit in the starting point of an uneven age class distribution, and the possibility of conflict with the achievement of non-timber objectives.

Figures 21 and 22 show the impact of ***not*** imposing harvest flow constraints on the distribution of diameter class from the expected harvest. Comparing Figure 21, for run 3, where the budget constraint for juvenile spacing is unlimited, to Figure 22 where there is no juvenile spacing, shows that there is no appreciable difference between the diameter class distributions of the expected harvest flows. All that has been “bought” from the investment of juvenile spacing, is the opportunity to harvest some stands a bit earlier.

Extremely dense (>10,000 sph) lodgepole pine stands are identified separately from other spacing opportunities, and where no budget is allowed for spacing, it is assumed that these stands will not attain merchantable volumes before the end of the 100 year projection period.

Levels of Silviculture Activity in Each of the Six Runs

Figures 9 through 20 show levels of silviculture activity for each of the six runs. These activities are aggregated by regime into levels of juvenile spacing (conventional and repressed pine types), fertilization, planting (conventional and NSR), natural regeneration, and pruning. More detailed output showing levels of activity by regime type are available in the form of a large database file produced as output from each run. The database shows the amount of each activity by development type by period, including the three harvesting activities (conventional, partial, and commercial thinning). Each development type is referenced by each of the seven landscape themes, so it is possible to know each period how much activity is expected to occur in hectares, and for silviculture, the associated expected costs (in nominal dollars). These nominal dollars can be converted to real dollars (and/or present values) either within Woodstock, or calculated from existing output.

When budgets are constrained (runs 2,4,5 and 6) fertilization, spacing of repressed pine, and NSR planting are all favored activities, and roughly in that order of priority. This is especially evident in runs 5 and 6 (figures 13, 14, 19, 20), where budget levels are constrained but sufficient budgets are available to pay for large quantities of activity.

Figure 9: Projection of silviculture activities - run 1

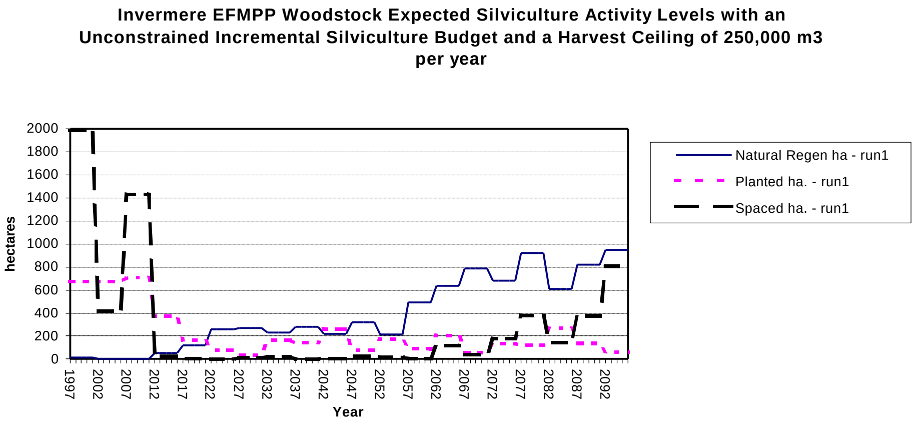


Figure 10: Projection of silviculture activities - run 2

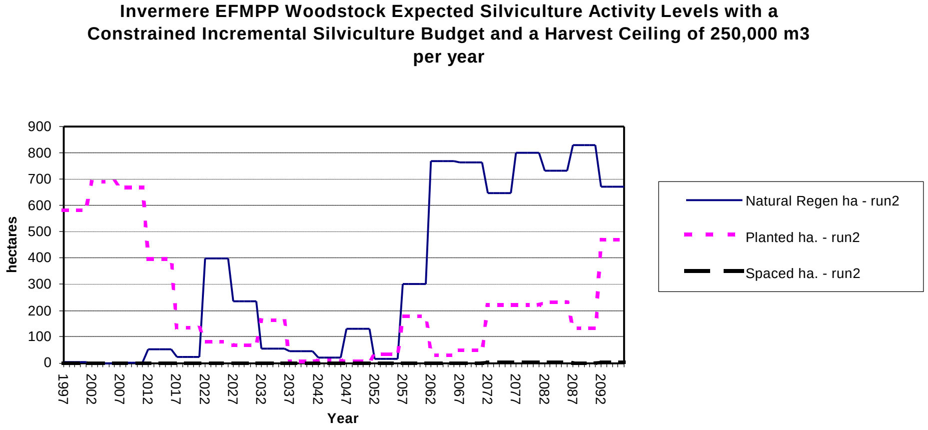


Figure 11: Projection of silviculture activities - run 3

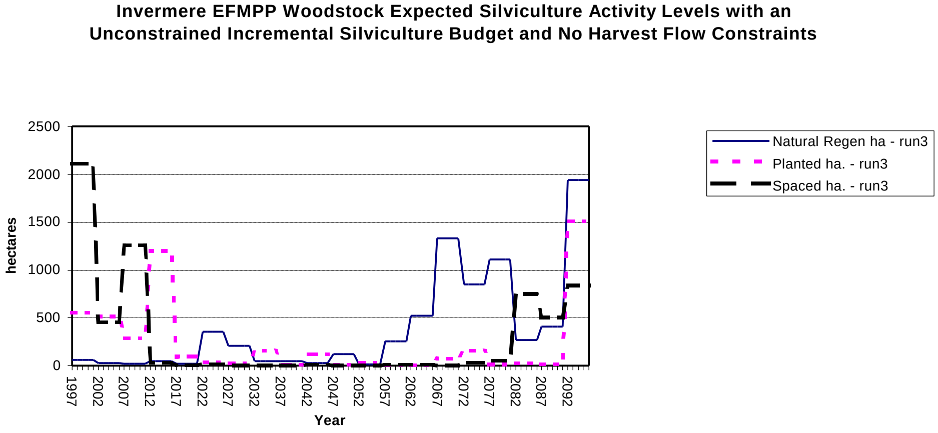
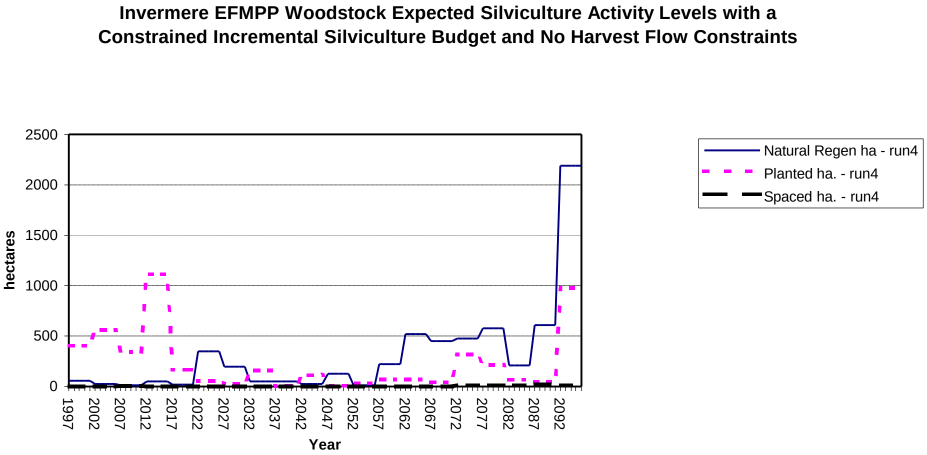
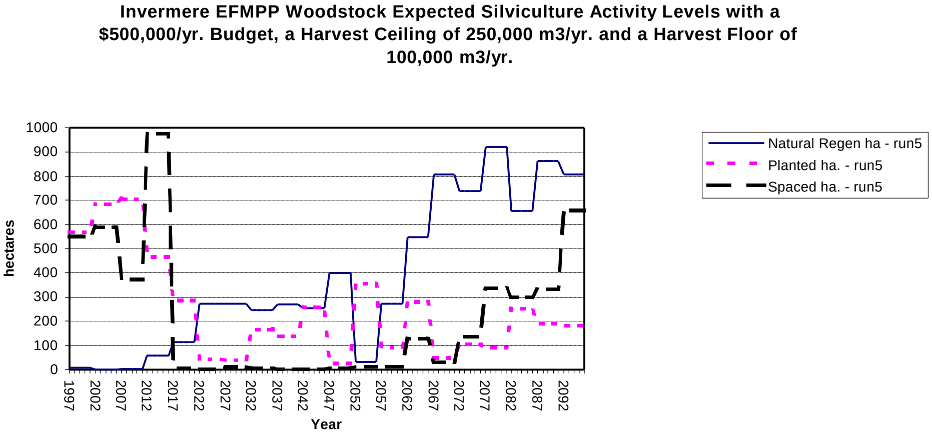


Figure 12: Projection of silviculture activities - run 4



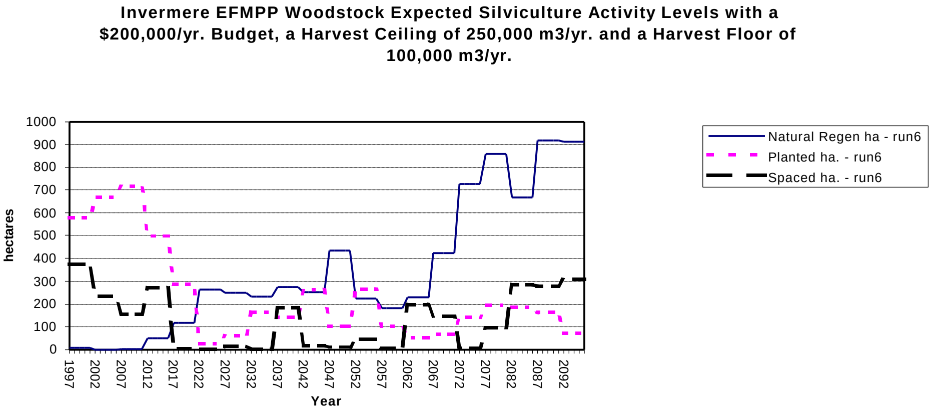
Invermere EFMPP Woodstock Expected Silviculture Activity Levels with a Constrained Incremental Silviculture Budget and No Harvest Flow Constraints

Figure 13: Projection of silviculture activities - run 5



Invermere EFMPP Woodstock Expected Silviculture Activity Levels with a $500,000/yr. Budget, a Harvest Ceiling of 250,000 m3/yr. and a Harvest Floor of 100,000 m3/yr.

Figure 14: Projection of silviculture activities - run 6



Invermere EFMPP Woodstock Expected Silviculture Activity Levels with a $200,000/yr. Budget, a Harvest Ceiling of 250,000 m3/yr. and a Harvest Floor of 100,000 m3/yr.

Figure 15: Projection of silviculture activities - run 1

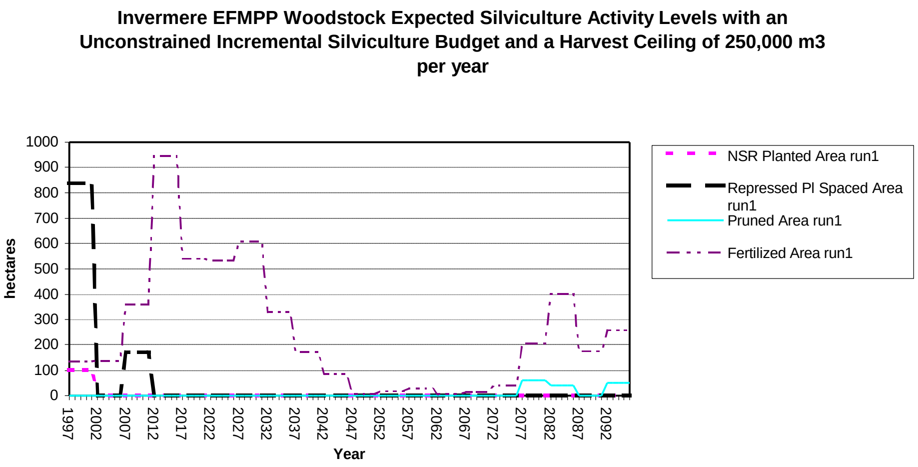

Invermere EFMPP Woodstock Expected Silviculture Activity Levels with an Unconstrained Incremental Silviculture Budget and a Harvest Ceiling of 250,000 m3 per year

Figure 16: Projection of silviculture activities - run 2

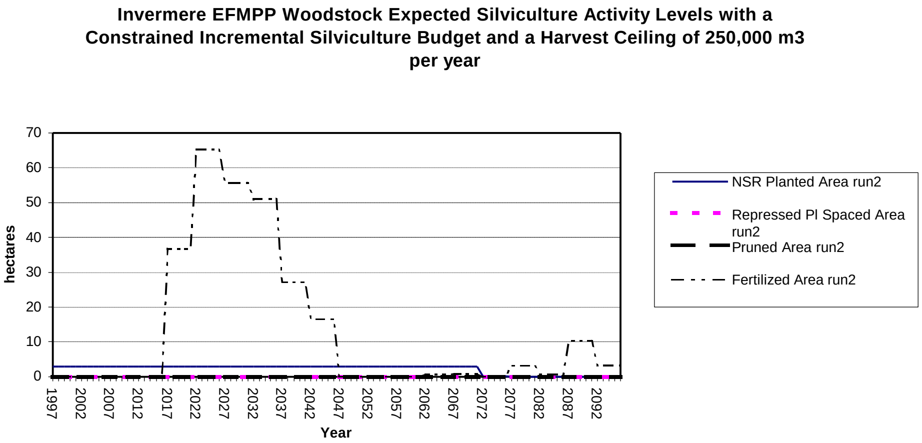

Invermere EFMPP Woodstock Expected Silviculture Activity Levels with a Constrained Incremental Silviculture Budget and a Harvest Ceiling of 250,000 m3 per year

Figure 17: Projection of silviculture activities - run 3

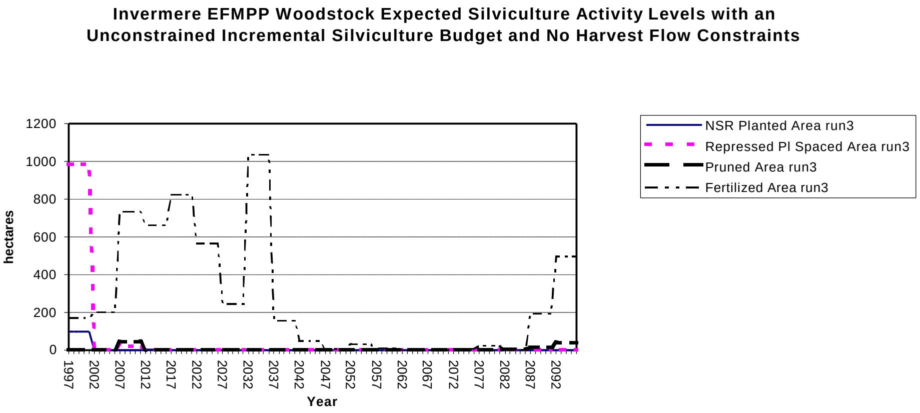

Invermere EFMPP Woodstock Expected Silviculture Activity Levels with an Unconstrained Incremental Silviculture Budget and No Harvest Flow Constraints

Figure 18: Projection of silviculture activities - run 4

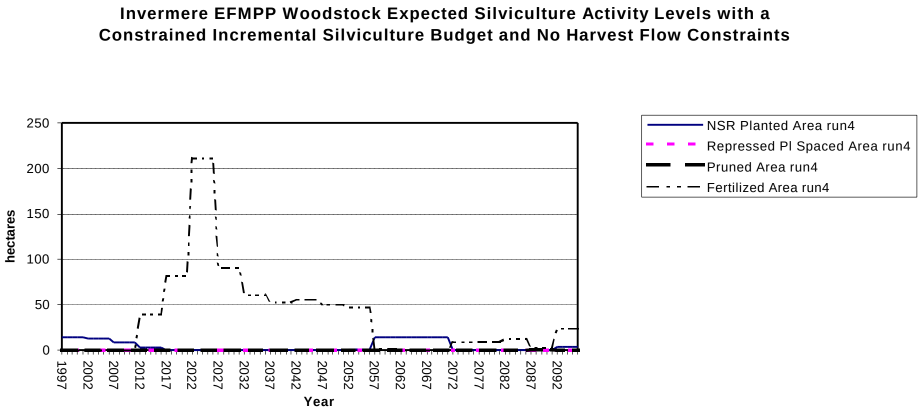


Figure 19: Projection of silviculture activities - run 5

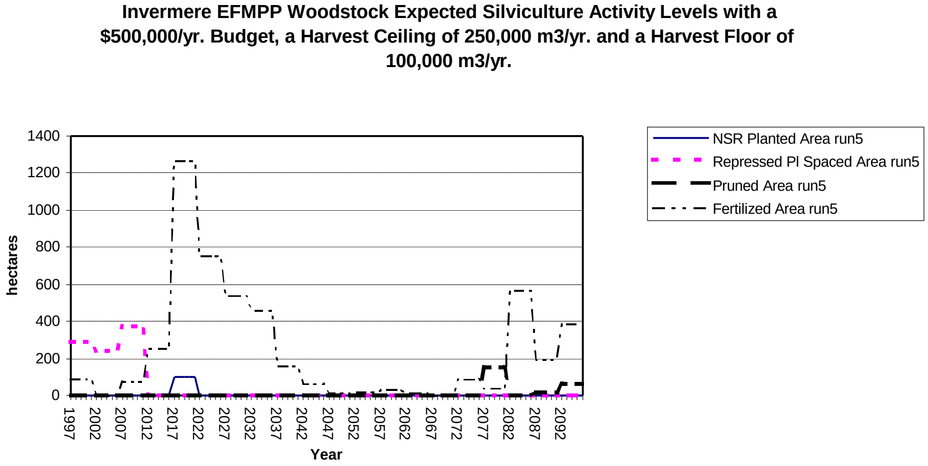


Figure 20: Projection of silviculture activities - run 6

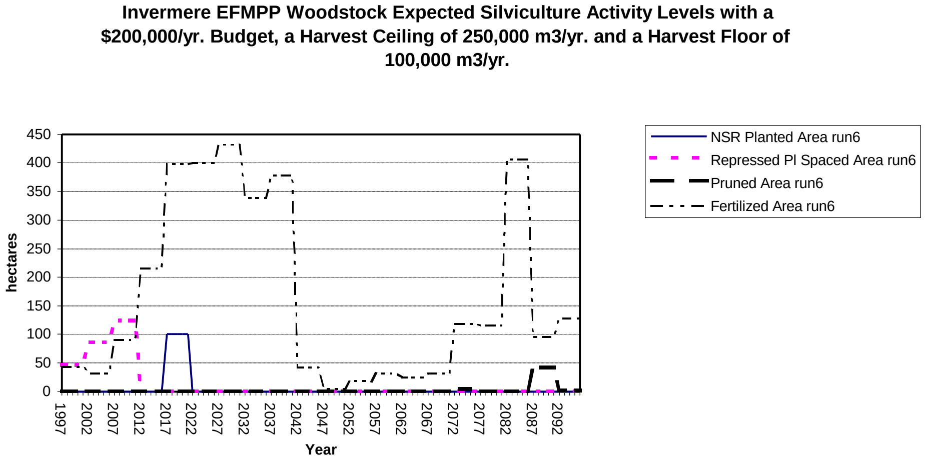


Figure 21: Expected harvest by diameter class - run 3

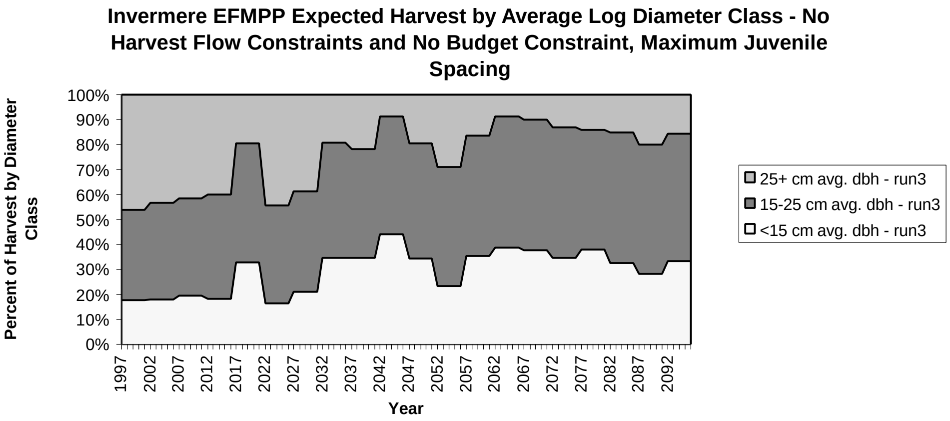


Figure 22: Expected harvest by diameter class - run 4

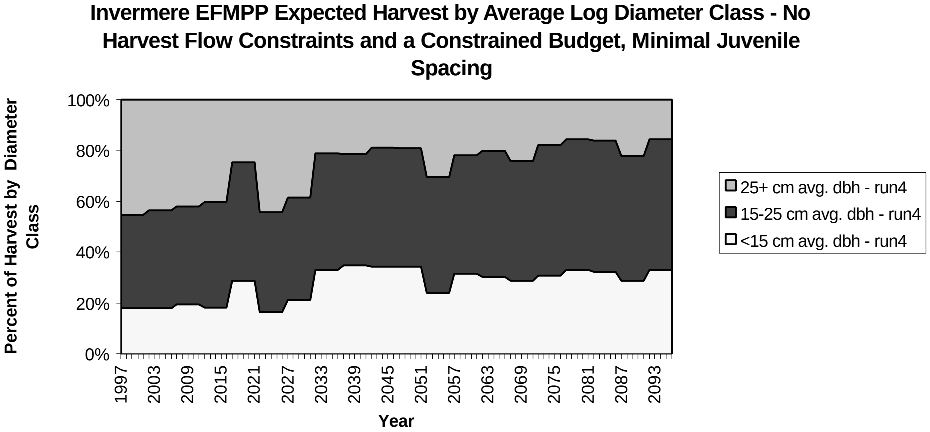


Figure 23: Expected harvest by diameter class - run 5

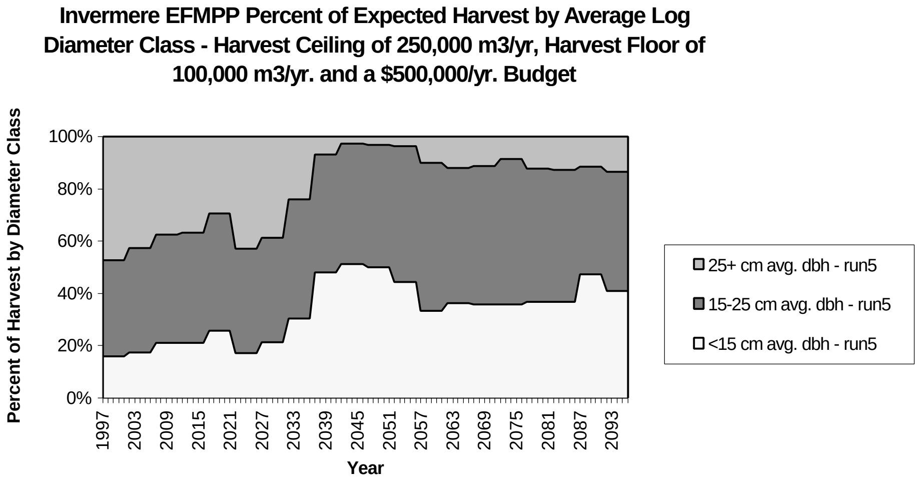
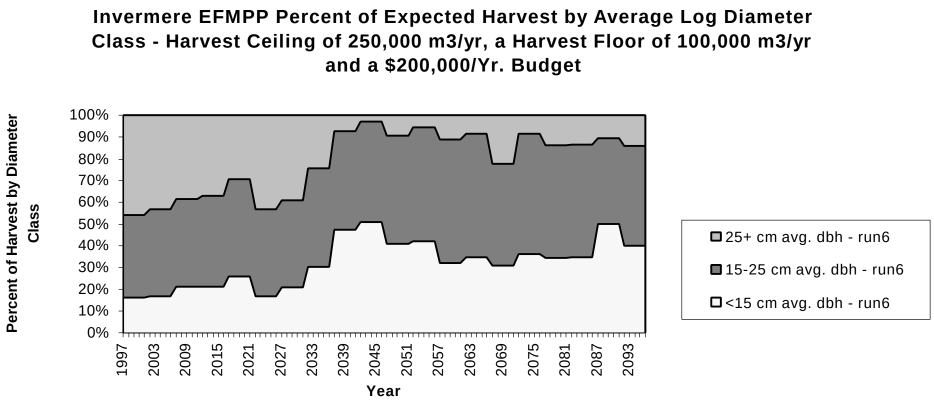


Figure 24: Expected harvest by diameter class - run 6

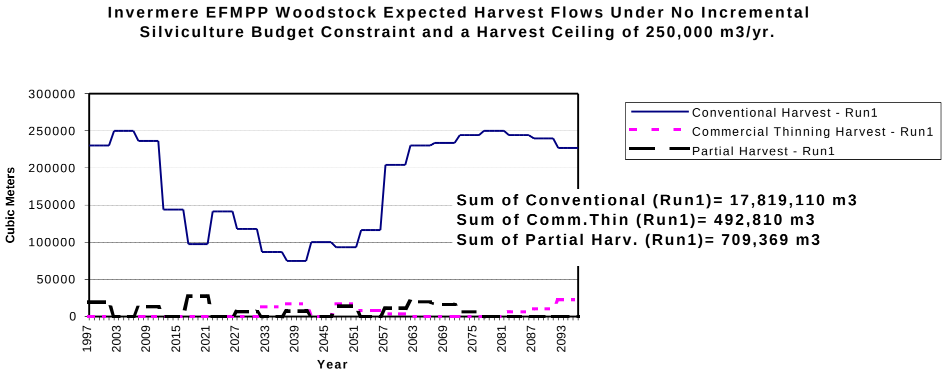


Figures 25 to 30 project harvest levels by three general types of harvest - conventional (clear cutting), partial harvest, and commercial thinning. In all cases, both commercial thinning and partial harvesting were not considered part of a budget constraint, even though in some sense they may be considered silvicultural activities. However, commercial thinning is often done in conjunction with spacing, pruning, and fertilization, and if these activities do not occur, then operable commercial thinning types will not be created.

Partial harvesting is only operable in three analysis units that have visual quality objectives. This rather limiting definition of operability was used as a function of the limited means to define partial harvesting in FSSIM (the simulation model used in a separate analysis of harvest level projection for the EFMPP). Had the option been available to create a data set for the Woodstock analysis independent of FSSIM requirements, partial harvesting activities would be defined in a more precise manner, and not necessarily as just a function of the visual quality objective. Economic operability, and stand conditions generally dictate the desirability of partial harvest activities.

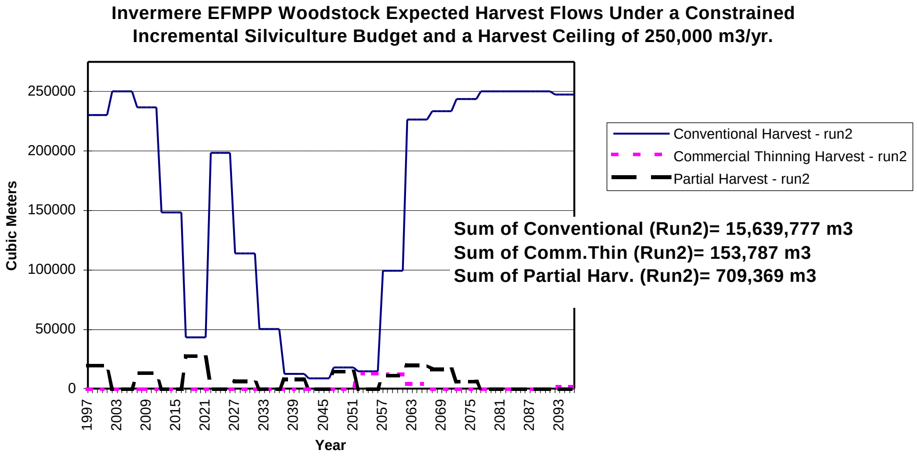
As partial harvesting is operable only in areas with visual quality objectives, the maximum amount of harvest is scheduled subject to the visual quality constraint. However, it in not known in reality the extent to which this activity is economically feasible, as economic attributes were not considered in defining the operability of the activity. Even though the maximum amount of partial harvest was scheduled in each of the six runs, the expected volumes from this activities is insufficient to augment the expected decline in harvest in future periods. This observation applies to commercial thinning, with the exception that commercial thinning operability is limited by budget constraints on incremental activities associated with it.

Figure 25: Expected harvest with an unlimited budget and flow constraints by harvest type


Invermere EFMPP Woodstock Expected Harvest Flows Under No Incremental Silviculture Budget Constraint and a Harvest Ceiling of 250,000 m3/yr.

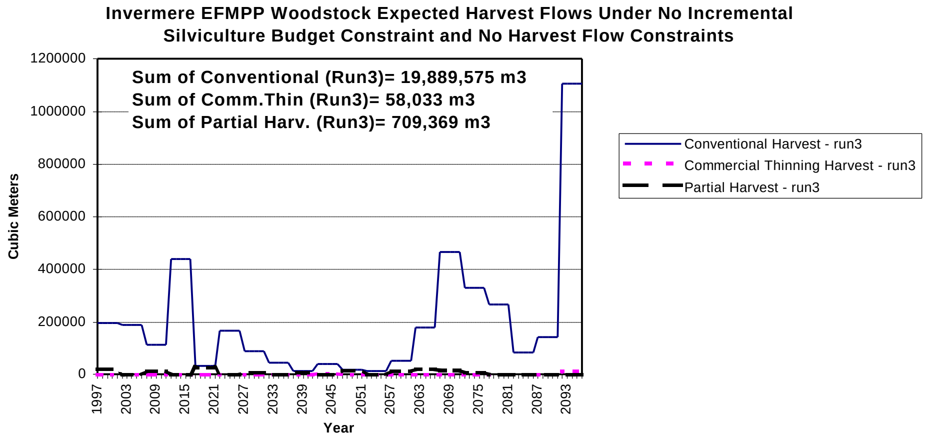
Sum of Conventional (Run1)= 17,819,110 m3
Sum of Comm.Thin (Run1)= 492,810 m3
Sum of Partial Harv. (Run1)= 709,369 m3

Figure 26: Expected harvest with no budget and flow constraints by harvest type


Invermere EFMPP Woodstock Expected Harvest Flows Under a Constrained Incremental Silviculture Budget and a Harvest Ceiling of 250,000 m3/yr.

Sum of Conventional (Run2)= 15,639,777 m3
Sum of Comm.Thin (Run2)= 153,787 m3
Sum of Partial Harv. (Run2)= 709,369 m3

Figure 27: Expected harvest with an unlimited budget and no flow constraints by harvest type


Invermere EFMPP Woodstock Expected Harvest Flows Under No Incremental Silviculture Budget Constraint and No Harvest Flow Constraints

Sum of Conventional (Run3)= 19,889,575 m3
Sum of Comm.Thin (Run3)= 58,033 m3
Sum of Partial Harv. (Run3)= 709,369 m3

Figure 28: Expected harvest with no budget and no flow constraints by harvest type

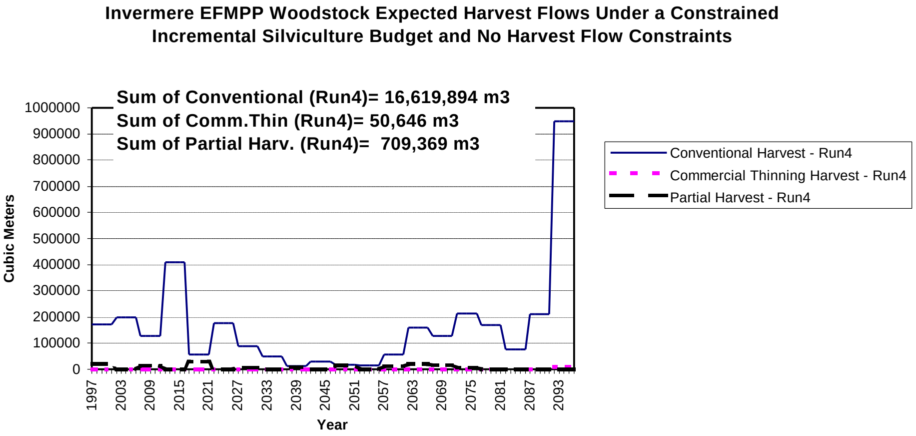


Figure 29: Expected harvest with a $500k/yr budget and flow constraints by harvest type

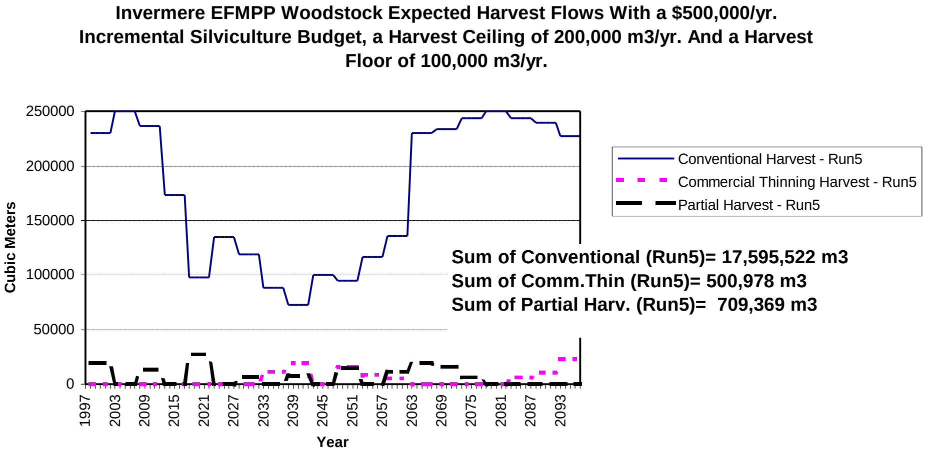
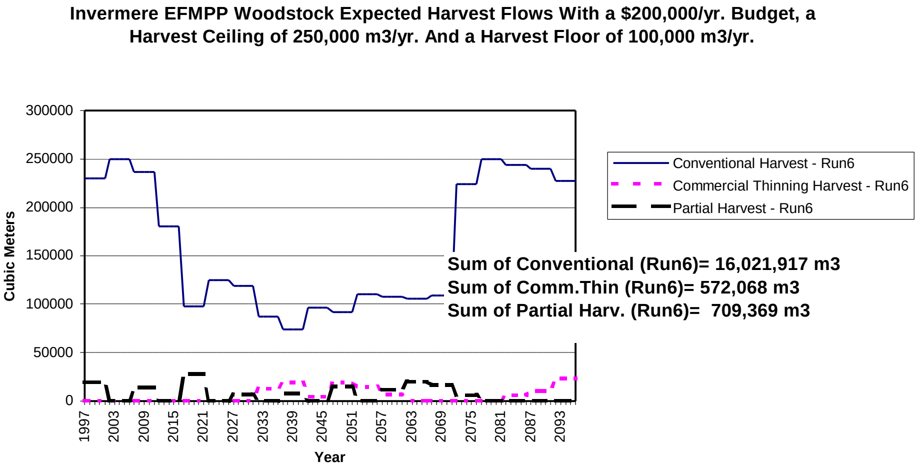


Figure 30: Expected harvest with a $200k/yr budget and flow constraints by harvest type



Conclusions

This analysis has demonstrated both the utility and efficiency of a constrained linear optimization method for the timber harvest scheduling and silviculture budget allocation problem. Results generated can be used for both operational and strategic planning purposes, and can be used as input to one of a number of spatial planning tools to further increase the output's relevance to operational planning.

In answering questions related to the relationships between harvest level objectives, and the variety of constraints (harvest flow, silviculture budget, non-timber resource values) it is apparent that the most constraining input or condition in this problem was the initial age distribution of the EFMPP area. As most of the non-timber constraints for wildlife, green-up, community watersheds, and visual quality were slack constraints in most periods, it was relatively easy to find feasible solutions. However, in certain periods, especially during the first twenty to thirty years, some of these constraints, if applied in the most rigorous fashion, would have generated infeasible solutions. This is simply due to the fact that current inventory conditions are insufficient to meet levels of constraints defined for the current period.

The role of incremental silviculture is such that there are clearly marginal diminishing returns to each successive dollar spent. There is absolutely nothing in terms of the maximize harvest objective to be gained from a budget in excess of $200,000 per year, and in future periods this level is well in excess of what is required, assuming harvest flow constraints are set "correctly". Even in this context, an eventual drop in expected harvest flow is likely to occur in future periods, simply as a function of the current age class distribution. Economic, technological, demand side conditions, and improved analytical ability in future will dictate the extent to which this expected drop becomes reality. Harvest flow constraints in this context serve only to redistribute expected harvest across successive periods, and thus result in opportunity costs. A more rational approach would be to consider the expected flow of economic rent from harvest relative to alternative sources of fibre, given current and expected industry demands.

With the advent of high-end desktop computers and software capable of accessing large amounts of run-time memory and disk space, it is now relatively easy to make strategic forest estate plans. These plans can be developed in sufficient detail so as to have considerable operational relevance as well.

Harvest level projections for the Invermere EFMPP area will respond to some level of silviculture input, but the appropriateness of this level is affected by inputs defining the response of treatment regimes, and the nature of harvest flow objectives, non-timber objectives, and the current age class distribution of the forest. It is evident that these objectives require more explicit definition. This will not be accomplished in isolation of the relative contributions of fibre from surrounding forest areas to local mills. Appropriate levels of silviculture activity will also be affected by changes in future utilization and operability of harvesting activities, and the market driven nature of these variable is difficult to predict. The inherent uncertainty in these variables should be an important factor in assessing the risks associated with incremental silviculture spending, and for driving the nature of sensitivity analysis.

The impacts of projected silviculture expenditures on harvest levels are not necessarily what one would expect when assessing their impact at the stand level. Achieving a maximum flow of harvest requires stands to be harvested in time periods which may not be optimal from the point of view of obtaining expected maximum biological and/or economic impact from treatment.

As with most analytical undertakings in forestry, at least as many questions are generated as are answered. This leads to suggestions for future work for analysis of these problems.

1. The objective function used maximizes expected harvest volume, and could be changed to maximize expected harvest value. This would acknowledge the fact that a cubic meter of harvest today is more valuable than a cubic meter of expected harvest in some future period. Sensitivity analyses would include various projections of price, and discount rate variables. Discounted costs of silviculture expenditure can be compared to expected discount revenues and costs from harvest.

2. The inventory file could be modified to include variables that capture actual delivered wood costs. These would have to be estimated for stands less than the age of physical operability, and development and transportation costs would have to be pro-rated and linked to each resultant area. This would allow for more explicit recognition of the harvesting cost structure of the forest, and how it may affect the achievement of the expected harvest value objective function.

3. The sequence file generated from the LP solution could be further assessed as to its spatial feasibility. A digitized representation of areas in the inventory file is required for this in order to use a spatial harvesting scheduling tool. These areas are initially transformed into representations of blocks of activity, and the activities are scheduled on them to achieve levels from the LP solution. Constraints such as block size, adjacency, operability and other landscape features are included in the digital representation of areas. Such an analysis would determine the amount of activity that could be blocked on the landscape over time and lend further operational credibility to the results.

References

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Davis, R.G. and D.L. Martell 1992. A decision support system that links short-term silviculture operating plans with long-term forest-level strategic plans. Can. J. For Res. 23: 1078-1095.

Nelson, J.D. and D. Errico. 1993. Multiple-pass harvesting and spatial constraints: an old technique applied to a new problem. For. Sci. Vol 39, No. 1 137-151.

Reyner, K.M., W.A. Leuschner, and J. Sullivan. 1996. A silviculture investment model for industrial forests. Forest Prod. J. 46(1):25-30.

Appendix

Invermere Woodstock Input Data Files

```
{Invermere District, EFMPP Model RUN1
File Name:  INV2.PRI - this is the primary file Woodstock Invermere
EFMPP model - This first run is for 100 years, or 20 5-year periods.
There is an
unlimited budget for incremental silviculture, basic silviculture is
accounted for, but excluded from the budget. Spatial approximation rules
from the EFMPP data package are included as constraints as per the FSSIM
modeling exercise.

This run includes a number of changes as per discussions with Dave White
up to January 6th,1998:
- include "new" yield curves with revised site indexes
- lower minimum harvest ages for managed stands
- Dfi types now available for fertilization
- pine medium from '85 burns (about 5000 ha) regenerates as repressed
  thus requiring spacing to generate merch yields
- New flow constraints a ceiling of 250,000 m3/yr a floor of 125,000 m3/yr, except
  for periods 8-10, which must be 100,000 m3 to generate a feasible solution
- no adjacency constraint in IRM zone for pine types
- about 500 ha of backlog NSR in mostly pine types}

CONSTANTS
SL 20     {the number of periods into the future the simulation
          will run - a period is equal to 5 years}
CONTROL
*LENGTH          #SL
*OPTIMIZE        OFF
*SCHEDULE          ON
*REPORTS          ON
*QUEUE          OFF
*IMAGE          ON
*BUILD          ON
*WARNINGS        OFF
*GRAPHICS        ON
*STATUS          OFF
*BOUNDS          ON

OPTIMIZE
*OBJECTIVE
 _MAX HARVEST2 1.._LENGTH
*CONSTRAINTS
 HARVEST2 >=  625000             1..7
 HARVEST2 >=  500000             8..10
 HARVEST2 >=  625000            11.._LENGTH
 HARVEST2 <= 1250000             1.._LENGTH
 BUDGET  <= 50000000             1.._LENGTH
 GVQOR - 0.15 * TVQOPR <= 0      1..5
 GVQOR - 0.05 * TVQOPR <= 0      6.._LENGTH
 GVQOPR - 0.15 * TVQOPR <= 0     1.._LENGTH
 GFEN - 0.05 * TFEN <= 0         3.._LENGTH
 G1UNGU - 0.3 * TUNGU <= 0       1.._LENGTH
```

```
 G2UNGU - 0.4 * TUNGU >= 0       1.._LENGTH
 GTREN - 0.25 * TTREN <= 0       1.._LENGTH
 GIRM - 0.25 * TIRM <= 0         1.._LENGTH
 GWSHED - 0.25 * TWSHED <= 0     4.._LENGTH
 MESSF35 - 0.14 * TMESSF35 >= 0  1.._LENGTH
 MESSF36 - 0.14 * TMESSF36 >= 0  1.._LENGTH
 MESSF37 - 0.14 * TMESSF37 >= 0  1.._LENGTH
 MESSF38 - 0.14 * TMESSF38 >= 0  1.._LENGTH
 MESSF39 - 0.14 * TMESSF39 >= 0  1.._LENGTH
 MESSF310 - 0.14 * TMESSF310 >= 0 1.._LENGTH
 MIDF44 - 0.17 * TMIDF44 >= 0 1.._LENGTH
 MIDF45 - 0.17 * TMIDF45 >= 0 1.._LENGTH
 MIDF49 - 0.17 * TMIDF49 >= 0 1.._LENGTH
 MIDF410 - 0.17 * TMIDF410 >= 0 1.._LENGTH
 MICH310 - 0.05 * TMICH310 >= 0 1..3
 MICH310 - 0.07 * TMICH310 >= 0 4..9
 MICH310 - 0.14 * TMICH310 >= 0 10.._LENGTH
 MMS34 - 0.14 * TMMS34 >= 0 1.._LENGTH
 MMS35 - 0.11 * TMMS35 >= 0 1.._LENGTH
 MMS36 - 0.14 * TMMS36 >= 0 1.._LENGTH
 MMS37 - 0.14 * TMMS37 >= 0 1.._LENGTH
 MMS38 - 0.11 * TMMS38 >= 0 1.._LENGTH
 MMS39 - 0.14 * TMMS39 >= 0 1.._LENGTH
 MMS310 - 0.14 * TMMS310 >= 0 1.._LENGTH
 MPP44 - 0.14 * TMPP44 >= 0 1.._LENGTH
 *FORMAT MPS

SCHEDULE [C:\messmer\invermer\RUN1\inv2.seq]

LANDSCAPE
{1}*THEME Landscape Unit
  LU4
  LU5
  LU6
  LU7
  LU8
  LU9
  LU10

{2}*THEME Analysis Unit
  AU01    fir/py/larch G
  AU02    fir/py/larch M
  AU03    fir/py/larch P/L
  AU04    larch G
  AU05    larch M
  AU06    larch P/L
  AU07    spruce/balsam G
  AU08    spruce/balsam M
  AU09    spruce/balsam P/L
  AU10    cedar/hemlock GMPL
  AU11    pl/pw G
  AU12    pl/pw M
  AU13    pl/pw P/L
  AU14    decid
  AU19    fir/larch/py G partial harvest
  AU20    fir/larch/py M partial harvest
  AU21    fir/larch/py P partial harvest
  AU33    Christmas tree area
*AGGREGATE NOPINE
 AU01 AU02 AU03 AU04 AU05 AU06 AU07 AU08 AU09 AU10 AU14 AU19 AU20 AU21 AU33
```

```
{3}*THEME BECNDT
  ATNDT2
  ATNDT5
  ESSFNDT2
  ESSFNDT3
  ESSFNDT5
  ICHNDT3
  IDFNDT4
  MSNDT3
  PPNDT4

{4}*THEME MANAGMENT ZONE
  VQOR      visual quality objectives - retention zone
  VQOPR     visual quality objectives - partial retention zone
  WSHED     community watershed objectives
  FEN       forest ecosystem network objectives
  UNGU      ungulate habitat objectives
  TRENCH    rocky mountain trench objectives
  IRM       integrated resource management objectives

*AGGREGATE HARV
  TRENCH IRM FEN VQOR VQOPR WSHED UNGU

{5}*THEME Operable
  DEF1   Indefinite deferral
  DEF2   FEN areas deferred for forty years
  INOP   Inoperable
  OP     Operable

*AGGREGATE CONAREA
  DEF1 OP

{6}*THEME Slope
  None   Slope Unknown
  Flat   Slope class < 5

{7}*THEME Regime
  Natural   natural regeneration
  Planted   planting
  Spaced    juvenile spacing
  Cthin     commercial thinning
  PLCthin   planting and commercial thinning
  SPCthin   juvenile spacing and commercial thinning
  PRCthin   pruning and commercial thinning
  SPRCthin  juvenile spacing and pruning and commercial thinning
  NSFert    natural regen and juvenile spacing and fertilization
  PFert     planting and fertilizing
  PPrune    planting and pruning
  SPrune    spacing and pruning
  Road      area reduction for roads, landings, etc.
  REGEN     regenerated deciduous
  NSR       not sufficiently restocked
  REPRES    height repressed young pine

*AGGREGATE Stocked
  Natural Planted Cthin PLCthin Pprune
  PRCthin NSFert Pfert REGEN
*AGGREGATE SPALL
  Spaced SPCthin SPrune SPRCthin
LIFESPAN
 ? ? ? ? ? ? ? (100+#SL)   {maximum age before death}
```

OUTPUTS [C:\messmer\invermer\RUN1\inv2.out]
{the file identifies all of the outputs to be generated}

REPORTS [C:\messmer\invermer\RUN1\inv2.rpt]
{file lists all of the outputs to be reported}

YIELDS [C:\messmer\invermer\RUN1\inv2.yld]
{yield curves for the development types}

AREAS [C:\messmer\invermer\RUN1\inv2.aas]
{contains all of the age and area attributes}

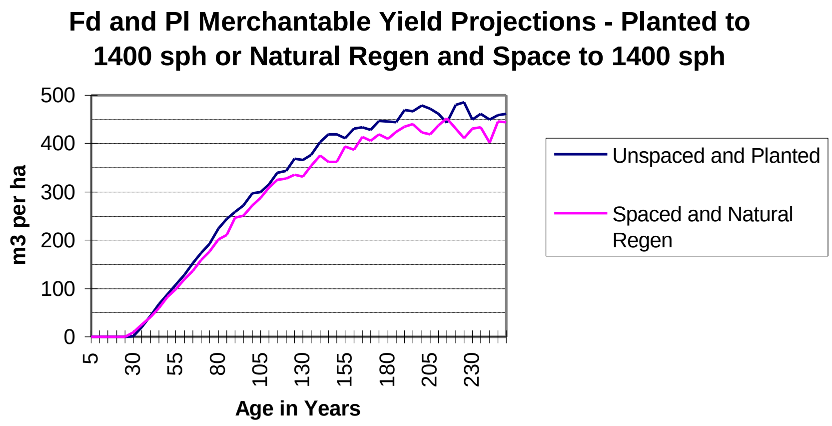
ACTIONS [C:\messmer\invermer\RUN1\inv2.act]
{file contains all of the actions which are to take place, an action is any silvicultural treatment, harvest, administrative activity or naturally occurring event}

TRANSITIONS [C:\messmer\invermer\RUN1\inv2.trn]
{the file outlines what will happen to the actioned areas; the transitions specifiy the outcomes of actions, each action must have a transition}

QUEUE [C:\messmer\invermer\RUN1\inv2.que]
{the file outlines the timing and magnitude of the actions which occur during the simulation, it is turned off during LP}

GRAPHICS [C:\messmer\invermer\RUN1\inv2.gra]

Figure 31: Comparing Merchantable Yield Projections for a Spaced and an Unspaced Stand



Shadow Prices for Run 1 for Each Constraint

The following is a list of each constraint in each five year period for Run 1. Variable definitions in each constraint are listed in the previous Woodstock Input file for Run 1. The list of starting inventory constraints is over 10,000 lines long, and is truncated to include only the first 20. These begin on page 45.

C1R1	HARVEST201 >= 625000	0.0
C1R2	HARVEST202 >= 625000	0.0
C1R3	HARVEST203 >= 625000	0.0
C1R4	HARVEST204 >= 625000	0.0
C1R5	HARVEST205 >= 625000	0.0
C1R6	HARVEST206 >= 625000	0.0
C1R7	HARVEST207 >= 625000	0.0
C2R1	HARVEST208 >= 500000	1.7558
C2R2	HARVEST209 >= 500000	1.5773
C2R3	HARVEST210 >= 500000	0.4318
C3R1	HARVEST211 >= 625000	0.2501
C3R2	HARVEST212 >= 625000	0.0915
C3R3	HARVEST213 >= 625000	0.0
C3R4	HARVEST214 >= 625000	0.0
C3R5	HARVEST215 >= 625000	0.0
C3R6	HARVEST216 >= 625000	0.0
C3R7	HARVEST217 >= 625000	0.0
C3R8	HARVEST218 >= 625000	0.0
C3R9	HARVEST219 >= 625000	0.0
C3R10	HARVEST220 >= 625000	0.0
C4R1	HARVEST201 <= 1250000	-0.1030
C4R2	HARVEST202 <= 1250000	-0.0561
C4R3	HARVEST203 <= 1250000	-0.0125
C4R4	HARVEST204 <= 1250000	0.0
C4R5	HARVEST205 <= 1250000	0.0
C4R6	HARVEST206 <= 1250000	0.0
C4R7	HARVEST207 <= 1250000	0.0
C4R8	HARVEST208 <= 1250000	0.0
C4R9	HARVEST209 <= 1250000	0.0
C4R10	HARVEST210 <= 1250000	0.0
C4R11	HARVEST211 <= 1250000	0.0
C4R12	HARVEST212 <= 1250000	0.0
C4R13	HARVEST213 <= 1250000	0.0
C4R14	HARVEST214 <= 1250000	-0.0748
C4R15	HARVEST215 <= 1250000	-0.1299
C4R16	HARVEST216 <= 1250000	-0.1859
C4R17	HARVEST217 <= 1250000	-0.2383
C4R18	HARVEST218 <= 1250000	-0.2875
C4R19	HARVEST219 <= 1250000	-0.3379
C4R20	HARVEST220 <= 1250000	-0.4180
C5R1	BUDGET01 <= 50000000	0.0
C5R2	BUDGET02 <= 50000000	0.0
C5R3	BUDGET03 <= 50000000	0.0
C5R4	BUDGET04 <= 50000000	0.0
C5R5	BUDGET05 <= 50000000	0.0
C5R6	BUDGET06 <= 50000000	0.0
C5R7	BUDGET07 <= 50000000	0.0
C5R8	BUDGET08 <= 50000000	0.0
C5R9	BUDGET09 <= 50000000	0.0
C5R10	BUDGET10 <= 50000000	0.0
C5R11	BUDGET11 <= 50000000	0.0
C5R12	BUDGET12 <= 50000000	0.0
C5R13	BUDGET13 <= 50000000	0.0
C5R14	BUDGET14 <= 50000000	0.0
C5R15	BUDGET15 <= 50000000	0.0
C5R16	BUDGET16 <= 50000000	0.0
C5R17	BUDGET17 <= 50000000	0.0
C5R18	BUDGET18 <= 50000000	0.0
C5R19	BUDGET19 <= 50000000	0.0
C5R20	BUDGET20 <= 50000000	0.0
C6R1	GVQOR01 - 0.15 * TVQOPR01 <= 0	0.0
C6R2	GVQOR02 - 0.15 * TVQOPR02 <= 0	0.0
C6R3	GVQOR03 - 0.15 * TVQOPR03 <= 0	0.0

```
C6R4    GVQOR04 - 0.15 * TVQOPR04 <= 0                      -204.0542
C6R5    GVQOR05 - 0.15 * TVQOPR05 <= 0                      0.0
C7R1    GVQOR06 - 0.05 * TVQOPR06 <= 0                      0.0
C7R2    GVQOR07 - 0.05 * TVQOPR07 <= 0                      0.0
C7R3    GVQOR08 - 0.05 * TVQOPR08 <= 0                      -10.9482
C7R4    GVQOR09 - 0.05 * TVQOPR09 <= 0                      -220.7342
C7R5    GVQOR10 - 0.05 * TVQOPR10 <= 0                      -11.1000
C7R6    GVQOR11 - 0.05 * TVQOPR11 <= 0                      -185.6831
C7R7    GVQOR12 - 0.05 * TVQOPR12 <= 0                      -13.7632
C7R8    GVQOR13 - 0.05 * TVQOPR13 <= 0                      -9.5586
C7R9    GVQOR14 - 0.05 * TVQOPR14 <= 0                      -15.0475
C7R10   GVQOR15 - 0.05 * TVQOPR15 <= 0                      -18.5051
C7R11   GVQOR16 - 0.05 * TVQOPR16 <= 0                      -249.2849
C7R12   GVQOR17 - 0.05 * TVQOPR17 <= 0                      -3.7788
C7R13   GVQOR18 - 0.05 * TVQOPR18 <= 0                      -1.8297
C7R14   GVQOR19 - 0.05 * TVQOPR19 <= 0                      -15.0475
C7R15   GVQOR20 - 0.05 * TVQOPR20 <= 0                      -193.7440
C8R1    GVQOPR01 - 0.15 * TVQOPR01 <= 0                     0.0
C8R2    GVQOPR02 - 0.15 * TVQOPR02 <= 0                     0.0
C8R3    GVQOPR03 - 0.15 * TVQOPR03 <= 0                     0.0
C8R4    GVQOPR04 - 0.15 * TVQOPR04 <= 0                     0.0
C8R5    GVQOPR05 - 0.15 * TVQOPR05 <= 0                     0.0
C8R6    GVQOPR06 - 0.15 * TVQOPR06 <= 0                     0.0
C8R7    GVQOPR07 - 0.15 * TVQOPR07 <= 0                     0.0
C8R8    GVQOPR08 - 0.15 * TVQOPR08 <= 0                     0.0
C8R9    GVQOPR09 - 0.15 * TVQOPR09 <= 0                     0.0
C8R10   GVQOPR10 - 0.15 * TVQOPR10 <= 0                     0.0
C8R11   GVQOPR11 - 0.15 * TVQOPR11 <= 0                     0.0
C8R12   GVQOPR12 - 0.15 * TVQOPR12 <= 0                     0.0
C8R13   GVQOPR13 - 0.15 * TVQOPR13 <= 0                     0.0
C8R14   GVQOPR14 - 0.15 * TVQOPR14 <= 0                     0.0
C8R15   GVQOPR15 - 0.15 * TVQOPR15 <= 0                     0.0
C8R16   GVQOPR16 - 0.15 * TVQOPR16 <= 0                     0.0
C8R17   GVQOPR17 - 0.15 * TVQOPR17 <= 0                     0.0
C8R18   GVQOPR18 - 0.15 * TVQOPR18 <= 0                     0.0
C8R19   GVQOPR19 - 0.15 * TVQOPR19 <= 0                     0.0
C8R20   GVQOPR20 - 0.15 * TVQOPR20 <= 0                     0.0
C9R1    GFEN03 - 0.05 * TFEN03 <= 0                     0.0
C9R2    GFEN04 - 0.05 * TFEN04 <= 0                     0.0
C9R3    GFEN05 - 0.05 * TFEN05 <= 0                     0.0
C9R4    GFEN06 - 0.05 * TFEN06 <= 0                     0.0
C9R5    GFEN07 - 0.05 * TFEN07 <= 0                     0.0
C9R6    GFEN08 - 0.05 * TFEN08 <= 0                     0.0
C9R7    GFEN09 - 0.05 * TFEN09 <= 0                     0.0
C9R8    GFEN10 - 0.05 * TFEN10 <= 0                     0.0
C9R9    GFEN11 - 0.05 * TFEN11 <= 0                     0.0
C9R10   GFEN12 - 0.05 * TFEN12 <= 0                     0.0
C9R11   GFEN13 - 0.05 * TFEN13 <= 0                     0.0
C9R12   GFEN14 - 0.05 * TFEN14 <= 0                     0.0
C9R13   GFEN15 - 0.05 * TFEN15 <= 0                     0.0
C9R14   GFEN16 - 0.05 * TFEN16 <= 0                     0.0
C9R15   GFEN17 - 0.05 * TFEN17 <= 0                     0.0
C9R16   GFEN18 - 0.05 * TFEN18 <= 0                     0.0
C9R17   GFEN19 - 0.05 * TFEN19 <= 0                     0.0
C9R18   GFEN20 - 0.05 * TFEN20 <= 0                     0.0
C10R1   G1UNGU01 - 0.3 * TUNGU01 <= 0                       0.0
C10R2   G1UNGU02 - 0.3 * TUNGU02 <= 0                       0.0
C10R3   G1UNGU03 - 0.3 * TUNGU03 <= 0                       0.0
C10R4   G1UNGU04 - 0.3 * TUNGU04 <= 0                       0.0
C10R5   G1UNGU05 - 0.3 * TUNGU05 <= 0                       0.0
C10R6   G1UNGU06 - 0.3 * TUNGU06 <= 0                       0.0
C10R7   G1UNGU07 - 0.3 * TUNGU07 <= 0                       0.0
C10R8   G1UNGU08 - 0.3 * TUNGU08 <= 0                       0.0
C10R9   G1UNGU09 - 0.3 * TUNGU09 <= 0                       0.0
C10R10  G1UNGU10 - 0.3 * TUNGU10 <= 0                       0.0
C10R11  G1UNGU11 - 0.3 * TUNGU11 <= 0                       0.0
C10R12  G1UNGU12 - 0.3 * TUNGU12 <= 0                       0.0
C10R13  G1UNGU13 - 0.3 * TUNGU13 <= 0                       0.0
C10R14  G1UNGU14 - 0.3 * TUNGU14 <= 0                       0.0
C10R15  G1UNGU15 - 0.3 * TUNGU15 <= 0                       0.0
C10R16  G1UNGU16 - 0.3 * TUNGU16 <= 0                       0.0
```

```
C10R17  G1UNGU17 - 0.3 * TUNGU17 <= 0                0.0
C10R18  G1UNGU18 - 0.3 * TUNGU18 <= 0                0.0
C10R19  G1UNGU19 - 0.3 * TUNGU19 <= 0                0.0
C10R20  G1UNGU20 - 0.3 * TUNGU20 <= 0                0.0
C11R1   G2UNGU01 - 0.4 * TUNGU01 >= 0               1.3772
C11R2   G2UNGU02 - 0.4 * TUNGU02 >= 0               0.0
C11R3   G2UNGU03 - 0.4 * TUNGU03 >= 0               5.0957
C11R4   G2UNGU04 - 0.4 * TUNGU04 >= 0               0.0
C11R5   G2UNGU05 - 0.4 * TUNGU05 >= 0               5.6377
C11R6   G2UNGU06 - 0.4 * TUNGU06 >= 0               0.0
C11R7   G2UNGU07 - 0.4 * TUNGU07 >= 0               340.5742
C11R8   G2UNGU08 - 0.4 * TUNGU08 >= 0               0.0
C11R9   G2UNGU09 - 0.4 * TUNGU09 >= 0               0.0
C11R10  G2UNGU10 - 0.4 * TUNGU10 >= 0                0.0
C11R11  G2UNGU11 - 0.4 * TUNGU11 >= 0                0.0
C11R12  G2UNGU12 - 0.4 * TUNGU12 >= 0                0.0
C11R13  G2UNGU13 - 0.4 * TUNGU13 >= 0                0.0
C11R14  G2UNGU14 - 0.4 * TUNGU14 >= 0                0.0
C11R15  G2UNGU15 - 0.4 * TUNGU15 >= 0                0.0
C11R16  G2UNGU16 - 0.4 * TUNGU16 >= 0                0.0
C11R17  G2UNGU17 - 0.4 * TUNGU17 >= 0                0.0
C11R18  G2UNGU18 - 0.4 * TUNGU18 >= 0                0.0
C11R19  G2UNGU19 - 0.4 * TUNGU19 >= 0                0.0
C11R20  G2UNGU20 - 0.4 * TUNGU20 >= 0                0.0
C12R1   GTREN01 - 0.25 * TTREN01 <= 0              0.0
C12R2   GTREN02 - 0.25 * TTREN02 <= 0              0.0
C12R3   GTREN03 - 0.25 * TTREN03 <= 0              0.0
C12R4   GTREN04 - 0.25 * TTREN04 <= 0              0.0
C12R5   GTREN05 - 0.25 * TTREN05 <= 0              0.0
C12R6   GTREN06 - 0.25 * TTREN06 <= 0              0.0
C12R7   GTREN07 - 0.25 * TTREN07 <= 0              0.0
C12R8   GTREN08 - 0.25 * TTREN08 <= 0              0.0
C12R9   GTREN09 - 0.25 * TTREN09 <= 0              0.0
C12R10  GTREN10 - 0.25 * TTREN10 <= 0               0.0
C12R11  GTREN11 - 0.25 * TTREN11 <= 0               0.0
C12R12  GTREN12 - 0.25 * TTREN12 <= 0               0.0
C12R13  GTREN13 - 0.25 * TTREN13 <= 0               0.0
C12R14  GTREN14 - 0.25 * TTREN14 <= 0               0.0
C12R15  GTREN15 - 0.25 * TTREN15 <= 0               0.0
C12R16  GTREN16 - 0.25 * TTREN16 <= 0               0.0
C12R17  GTREN17 - 0.25 * TTREN17 <= 0               0.0
C12R18  GTREN18 - 0.25 * TTREN18 <= 0               0.0
C12R19  GTREN19 - 0.25 * TTREN19 <= 0               0.0
C12R20  GTREN20 - 0.25 * TTREN20 <= 0               0.0
C13R1   GIRM01 - 0.25 * TIRM01 <= 0             0.0
C13R2   GIRM02 - 0.25 * TIRM02 <= 0             0.0
C13R3   GIRM03 - 0.25 * TIRM03 <= 0             0.0
C13R4   GIRM04 - 0.25 * TIRM04 <= 0             0.0
C13R5   GIRM05 - 0.25 * TIRM05 <= 0             0.0
C13R6   GIRM06 - 0.25 * TIRM06 <= 0             0.0
C13R7   GIRM07 - 0.25 * TIRM07 <= 0             0.0
C13R8   GIRM08 - 0.25 * TIRM08 <= 0             0.0
C13R9   GIRM09 - 0.25 * TIRM09 <= 0             0.0
C13R10  GIRM10 - 0.25 * TIRM10 <= 0              0.0
C13R11  GIRM11 - 0.25 * TIRM11 <= 0              0.0
C13R12  GIRM12 - 0.25 * TIRM12 <= 0              0.0
C13R13  GIRM13 - 0.25 * TIRM13 <= 0              0.0
C13R14  GIRM14 - 0.25 * TIRM14 <= 0              0.0
C13R15  GIRM15 - 0.25 * TIRM15 <= 0              0.0
C13R16  GIRM16 - 0.25 * TIRM16 <= 0              0.0
C13R17  GIRM17 - 0.25 * TIRM17 <= 0              0.0
C13R18  GIRM18 - 0.25 * TIRM18 <= 0              0.0
C13R19  GIRM19 - 0.25 * TIRM19 <= 0              -3.2544
C13R20  GIRM20 - 0.25 * TIRM20 <= 0              -8.9504
C14R1   GWSHED04 - 0.25 * TWSHED04 <= 0               0.0
C14R2   GWSHED05 - 0.25 * TWSHED05 <= 0               0.0
C14R3   GWSHED06 - 0.25 * TWSHED06 <= 0               0.0
C14R4   GWSHED07 - 0.25 * TWSHED07 <= 0               -91.4384
C14R5   GWSHED08 - 0.25 * TWSHED08 <= 0               -37.5203
C14R6   GWSHED09 - 0.25 * TWSHED09 <= 0               -39.1413
C14R7   GWSHED10 - 0.25 * TWSHED10 <= 0               0.0
```

```
C14R8   GWSHED11 - 0.25 * TWSHED11 <= 0                          0.0
C14R9   GWSHED12 - 0.25 * TWSHED12 <= 0                          0.0
C14R10  GWSHED13 - 0.25 * TWSHED13 <= 0                          0.0
C14R11  GWSHED14 - 0.25 * TWSHED14 <= 0                          0.0
C14R12  GWSHED15 - 0.25 * TWSHED15 <= 0                          0.0
C14R13  GWSHED16 - 0.25 * TWSHED16 <= 0                          0.0
C14R14  GWSHED17 - 0.25 * TWSHED17 <= 0                          0.0
C14R15  GWSHED18 - 0.25 * TWSHED18 <= 0                          0.0
C14R16  GWSHED19 - 0.25 * TWSHED19 <= 0                          -29.0943
C14R17  GWSHED20 - 0.25 * TWSHED20 <= 0                          -190.5573
C15R1   MESSF3501 - 0.14 * TMESSF3501 >= 0                      0.0
C15R2   MESSF3502 - 0.14 * TMESSF3502 >= 0                      0.0
C15R3   MESSF3503 - 0.14 * TMESSF3503 >= 0                      0.0
C15R4   MESSF3504 - 0.14 * TMESSF3504 >= 0                      0.0
C15R5   MESSF3505 - 0.14 * TMESSF3505 >= 0                      0.0
C15R6   MESSF3506 - 0.14 * TMESSF3506 >= 0                      0.0
C15R7   MESSF3507 - 0.14 * TMESSF3507 >= 0                      299.7166
C15R8   MESSF3508 - 0.14 * TMESSF3508 >= 0                      0.0
C15R9   MESSF3509 - 0.14 * TMESSF3509 >= 0                      0.0
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C15R12  MESSF3512 - 0.14 * TMESSF3512 >= 0                      0.0
C15R13  MESSF3513 - 0.14 * TMESSF3513 >= 0                      0.0
C15R14  MESSF3514 - 0.14 * TMESSF3514 >= 0                      0.0
C15R15  MESSF3515 - 0.14 * TMESSF3515 >= 0                      0.0
C15R16  MESSF3516 - 0.14 * TMESSF3516 >= 0                      0.0
C15R17  MESSF3517 - 0.14 * TMESSF3517 >= 0                      0.0
C15R18  MESSF3518 - 0.14 * TMESSF3518 >= 0                      0.0
C15R19  MESSF3519 - 0.14 * TMESSF3519 >= 0                      0.0
C15R20  MESSF3520 - 0.14 * TMESSF3520 >= 0                      0.0
C16R1   MESSF3601 - 0.14 * TMESSF3601 >= 0                      0.0
C16R2   MESSF3602 - 0.14 * TMESSF3602 >= 0                      0.0
C16R3   MESSF3603 - 0.14 * TMESSF3603 >= 0                      0.0
C16R4   MESSF3604 - 0.14 * TMESSF3604 >= 0                      0.0
C16R5   MESSF3605 - 0.14 * TMESSF3605 >= 0                      0.0
C16R6   MESSF3606 - 0.14 * TMESSF3606 >= 0                      0.0
C16R7   MESSF3607 - 0.14 * TMESSF3607 >= 0                      0.0
C16R8   MESSF3608 - 0.14 * TMESSF3608 >= 0                      0.0
C16R9   MESSF3609 - 0.14 * TMESSF3609 >= 0                      0.0
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C16R11  MESSF3611 - 0.14 * TMESSF3611 >= 0                      0.0
C16R12  MESSF3612 - 0.14 * TMESSF3612 >= 0                      0.0
C16R13  MESSF3613 - 0.14 * TMESSF3613 >= 0                      0.0
C16R14  MESSF3614 - 0.14 * TMESSF3614 >= 0                      0.0
C16R15  MESSF3615 - 0.14 * TMESSF3615 >= 0                      0.0
C16R16  MESSF3616 - 0.14 * TMESSF3616 >= 0                      0.0
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C16R18  MESSF3618 - 0.14 * TMESSF3618 >= 0                      0.0
C16R19  MESSF3619 - 0.14 * TMESSF3619 >= 0                      0.0
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C17R2   MESSF3702 - 0.14 * TMESSF3702 >= 0                      0.0
C17R3   MESSF3703 - 0.14 * TMESSF3703 >= 0                      0.0
C17R4   MESSF3704 - 0.14 * TMESSF3704 >= 0                      0.0
C17R5   MESSF3705 - 0.14 * TMESSF3705 >= 0                      0.0
C17R6   MESSF3706 - 0.14 * TMESSF3706 >= 0                      0.0
C17R7   MESSF3707 - 0.14 * TMESSF3707 >= 0                      0.0
C17R8   MESSF3708 - 0.14 * TMESSF3708 >= 0                      0.0
C17R9   MESSF3709 - 0.14 * TMESSF3709 >= 0                      0.0
C17R10  MESSF3710 - 0.14 * TMESSF3710 >= 0                      0.0
C17R11  MESSF3711 - 0.14 * TMESSF3711 >= 0                      0.0
C17R12  MESSF3712 - 0.14 * TMESSF3712 >= 0                      0.0
C17R13  MESSF3713 - 0.14 * TMESSF3713 >= 0                      0.0
C17R14  MESSF3714 - 0.14 * TMESSF3714 >= 0                      0.0
C17R15  MESSF3715 - 0.14 * TMESSF3715 >= 0                      0.0
C17R16  MESSF3716 - 0.14 * TMESSF3716 >= 0                      0.0
C17R17  MESSF3717 - 0.14 * TMESSF3717 >= 0                      0.0
C17R18  MESSF3718 - 0.14 * TMESSF3718 >= 0                      0.0
C17R19  MESSF3719 - 0.14 * TMESSF3719 >= 0                      0.0
C17R20  MESSF3720 - 0.14 * TMESSF3720 >= 0                      0.0
C18R1   MESSF3801 - 0.14 * TMESSF3801 >= 0                      0.0
```

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C18R2   MESSF3802 - 0.14 * TMESSF3802 >= 0                   0.0
C18R3   MESSF3803 - 0.14 * TMESSF3803 >= 0                   0.0
C18R4   MESSF3804 - 0.14 * TMESSF3804 >= 0                   0.0
C18R5   MESSF3805 - 0.14 * TMESSF3805 >= 0                   0.0
C18R6   MESSF3806 - 0.14 * TMESSF3806 >= 0                   0.0
C18R7   MESSF3807 - 0.14 * TMESSF3807 >= 0                   260.9078
C18R8   MESSF3808 - 0.14 * TMESSF3808 >= 0                   0.0
C18R9   MESSF3809 - 0.14 * TMESSF3809 >= 0                   0.0
C18R10  MESSF3810 - 0.14 * TMESSF3810 >= 0                   0.0
C18R11  MESSF3811 - 0.14 * TMESSF3811 >= 0                   0.0
C18R12  MESSF3812 - 0.14 * TMESSF3812 >= 0                   0.0
C18R13  MESSF3813 - 0.14 * TMESSF3813 >= 0                   0.0
C18R14  MESSF3814 - 0.14 * TMESSF3814 >= 0                   0.0
C18R15  MESSF3815 - 0.14 * TMESSF3815 >= 0                   0.0
C18R16  MESSF3816 - 0.14 * TMESSF3816 >= 0                   0.0
C18R17  MESSF3817 - 0.14 * TMESSF3817 >= 0                   0.0
C18R18  MESSF3818 - 0.14 * TMESSF3818 >= 0                   0.0
C18R19  MESSF3819 - 0.14 * TMESSF3819 >= 0                   0.0
C18R20  MESSF3820 - 0.14 * TMESSF3820 >= 0                   0.0
C19R1   MESSF3901 - 0.14 * TMESSF3901 >= 0                   0.0
C19R2   MESSF3902 - 0.14 * TMESSF3902 >= 0                   0.0
C19R3   MESSF3903 - 0.14 * TMESSF3903 >= 0                   0.0
C19R4   MESSF3904 - 0.14 * TMESSF3904 >= 0                   0.0
C19R5   MESSF3905 - 0.14 * TMESSF3905 >= 0                   0.0
C19R6   MESSF3906 - 0.14 * TMESSF3906 >= 0                   0.0
C19R7   MESSF3907 - 0.14 * TMESSF3907 >= 0                   0.0
C19R8   MESSF3908 - 0.14 * TMESSF3908 >= 0                   0.0
C19R9   MESSF3909 - 0.14 * TMESSF3909 >= 0                   0.0
C19R10  MESSF3910 - 0.14 * TMESSF3910 >= 0                   0.0
C19R11  MESSF3911 - 0.14 * TMESSF3911 >= 0                   0.0
C19R12  MESSF3912 - 0.14 * TMESSF3912 >= 0                   0.0
C19R13  MESSF3913 - 0.14 * TMESSF3913 >= 0                   0.0
C19R14  MESSF3914 - 0.14 * TMESSF3914 >= 0                   0.0
C19R15  MESSF3915 - 0.14 * TMESSF3915 >= 0                   0.0
C19R16  MESSF3916 - 0.14 * TMESSF3916 >= 0                   0.0
C19R17  MESSF3917 - 0.14 * TMESSF3917 >= 0                   0.0
C19R18  MESSF3918 - 0.14 * TMESSF3918 >= 0                   0.0
C19R19  MESSF3919 - 0.14 * TMESSF3919 >= 0                   0.0
C19R20  MESSF3920 - 0.14 * TMESSF3920 >= 0                   0.0
C20R1   MESSF31001 - 0.14 * TMESSF31001 >= 0                 0.0
C20R2   MESSF31002 - 0.14 * TMESSF31002 >= 0                 0.0
C20R3   MESSF31003 - 0.14 * TMESSF31003 >= 0                 0.0
C20R4   MESSF31004 - 0.14 * TMESSF31004 >= 0                 0.0
C20R5   MESSF31005 - 0.14 * TMESSF31005 >= 0                 0.0
C20R6   MESSF31006 - 0.14 * TMESSF31006 >= 0                 0.0
C20R7   MESSF31007 - 0.14 * TMESSF31007 >= 0                 0.0
C20R8   MESSF31008 - 0.14 * TMESSF31008 >= 0                 0.0
C20R9   MESSF31009 - 0.14 * TMESSF31009 >= 0                 0.0
C20R10  MESSF31010 - 0.14 * TMESSF31010 >= 0                 0.0
C20R11  MESSF31011 - 0.14 * TMESSF31011 >= 0                 0.0
C20R12  MESSF31012 - 0.14 * TMESSF31012 >= 0                 0.0
C20R13  MESSF31013 - 0.14 * TMESSF31013 >= 0                 0.0
C20R14  MESSF31014 - 0.14 * TMESSF31014 >= 0                 0.0
C20R15  MESSF31015 - 0.14 * TMESSF31015 >= 0                 0.0
C20R16  MESSF31016 - 0.14 * TMESSF31016 >= 0                 0.0
C20R17  MESSF31017 - 0.14 * TMESSF31017 >= 0                 0.0
C20R18  MESSF31018 - 0.14 * TMESSF31018 >= 0                 0.0
C20R19  MESSF31019 - 0.14 * TMESSF31019 >= 0                 0.0
C20R20  MESSF31020 - 0.14 * TMESSF31020 >= 0                 0.0
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C21R2   MIDF4402 - 0.17 * TMIDF4402 >= 0                     0.0
C21R3   MIDF4403 - 0.17 * TMIDF4403 >= 0                     0.0
C21R4   MIDF4404 - 0.17 * TMIDF4404 >= 0                     0.0
C21R5   MIDF4405 - 0.17 * TMIDF4405 >= 0                     0.0
C21R6   MIDF4406 - 0.17 * TMIDF4406 >= 0                     0.0
C21R7   MIDF4407 - 0.17 * TMIDF4407 >= 0                     0.0
C21R8   MIDF4408 - 0.17 * TMIDF4408 >= 0                     0.0
C21R9   MIDF4409 - 0.17 * TMIDF4409 >= 0                     0.0
C21R10  MIDF4410 - 0.17 * TMIDF4410 >= 0                     0.0
C21R11  MIDF4411 - 0.17 * TMIDF4411 >= 0                     0.0
C21R12  MIDF4412 - 0.17 * TMIDF4412 >= 0                     0.0
```

```
C21R13  MIDF4413 - 0.17 * TMIDF4413 >= 0                          0.0
C21R14  MIDF4414 - 0.17 * TMIDF4414 >= 0                          0.0
C21R15  MIDF4415 - 0.17 * TMIDF4415 >= 0                          0.0
C21R16  MIDF4416 - 0.17 * TMIDF4416 >= 0                          0.0
C21R17  MIDF4417 - 0.17 * TMIDF4417 >= 0                          0.0
C21R18  MIDF4418 - 0.17 * TMIDF4418 >= 0                          0.0
C21R19  MIDF4419 - 0.17 * TMIDF4419 >= 0                          0.0
C21R20  MIDF4420 - 0.17 * TMIDF4420 >= 0                          0.0
C22R1   MIDF4501 - 0.17 * TMIDF4501 >= 0                         0.0
C22R2   MIDF4502 - 0.17 * TMIDF4502 >= 0                         0.0
C22R3   MIDF4503 - 0.17 * TMIDF4503 >= 0                         0.0
C22R4   MIDF4504 - 0.17 * TMIDF4504 >= 0                         0.0
C22R5   MIDF4505 - 0.17 * TMIDF4505 >= 0                         0.0
C22R6   MIDF4506 - 0.17 * TMIDF4506 >= 0                         0.0
C22R7   MIDF4507 - 0.17 * TMIDF4507 >= 0                         0.0
C22R8   MIDF4508 - 0.17 * TMIDF4508 >= 0                         0.0
C22R9   MIDF4509 - 0.17 * TMIDF4509 >= 0                         0.0
C22R10  MIDF4510 - 0.17 * TMIDF4510 >= 0                          0.0
C22R11  MIDF4511 - 0.17 * TMIDF4511 >= 0                          0.0
C22R12  MIDF4512 - 0.17 * TMIDF4512 >= 0                          0.0
C22R13  MIDF4513 - 0.17 * TMIDF4513 >= 0                          0.0
C22R14  MIDF4514 - 0.17 * TMIDF4514 >= 0                          0.0
C22R15  MIDF4515 - 0.17 * TMIDF4515 >= 0                          0.0
C22R16  MIDF4516 - 0.17 * TMIDF4516 >= 0                          0.0
C22R17  MIDF4517 - 0.17 * TMIDF4517 >= 0                          0.0
C22R18  MIDF4518 - 0.17 * TMIDF4518 >= 0                          0.0
C22R19  MIDF4519 - 0.17 * TMIDF4519 >= 0                          0.0
C22R20  MIDF4520 - 0.17 * TMIDF4520 >= 0                          0.0
C23R1   MIDF4901 - 0.17 * TMIDF4901 >= 0                         2.1076
C23R2   MIDF4902 - 0.17 * TMIDF4902 >= 0                         10.7656
C23R3   MIDF4903 - 0.17 * TMIDF4903 >= 0                         17.1926
C23R4   MIDF4904 - 0.17 * TMIDF4904 >= 0                         0.0
C23R5   MIDF4905 - 0.17 * TMIDF4905 >= 0                         0.0
C23R6   MIDF4906 - 0.17 * TMIDF4906 >= 0                         0.0
C23R7   MIDF4907 - 0.17 * TMIDF4907 >= 0                         0.0
C23R8   MIDF4908 - 0.17 * TMIDF4908 >= 0                         0.0
C23R9   MIDF4909 - 0.17 * TMIDF4909 >= 0                         0.0
C23R10  MIDF4910 - 0.17 * TMIDF4910 >= 0                          0.0
C23R11  MIDF4911 - 0.17 * TMIDF4911 >= 0                          0.0
C23R12  MIDF4912 - 0.17 * TMIDF4912 >= 0                          0.0
C23R13  MIDF4913 - 0.17 * TMIDF4913 >= 0                          0.0
C23R14  MIDF4914 - 0.17 * TMIDF4914 >= 0                          0.0
C23R15  MIDF4915 - 0.17 * TMIDF4915 >= 0                          0.0
C23R16  MIDF4916 - 0.17 * TMIDF4916 >= 0                          0.0
C23R17  MIDF4917 - 0.17 * TMIDF4917 >= 0                          0.0
C23R18  MIDF4918 - 0.17 * TMIDF4918 >= 0                          0.0
C23R19  MIDF4919 - 0.17 * TMIDF4919 >= 0                          0.0
C23R20  MIDF4920 - 0.17 * TMIDF4920 >= 0                          0.0
C24R1   MIDF41001 - 0.17 * TMIDF41001 >= 0                         0.0
C24R2   MIDF41002 - 0.17 * TMIDF41002 >= 0                         0.0
C24R3   MIDF41003 - 0.17 * TMIDF41003 >= 0                         0.0
C24R4   MIDF41004 - 0.17 * TMIDF41004 >= 0                         0.0
C24R5   MIDF41005 - 0.17 * TMIDF41005 >= 0                         0.0
C24R6   MIDF41006 - 0.17 * TMIDF41006 >= 0                         0.0
C24R7   MIDF41007 - 0.17 * TMIDF41007 >= 0                         0.0
C24R8   MIDF41008 - 0.17 * TMIDF41008 >= 0                         0.0
C24R9   MIDF41009 - 0.17 * TMIDF41009 >= 0                         0.0
C24R10  MIDF41010 - 0.17 * TMIDF41010 >= 0                          0.0
C24R11  MIDF41011 - 0.17 * TMIDF41011 >= 0                          0.0
C24R12  MIDF41012 - 0.17 * TMIDF41012 >= 0                          0.0
C24R13  MIDF41013 - 0.17 * TMIDF41013 >= 0                          0.0
C24R14  MIDF41014 - 0.17 * TMIDF41014 >= 0                          0.0
C24R15  MIDF41015 - 0.17 * TMIDF41015 >= 0                          0.0
C24R16  MIDF41016 - 0.17 * TMIDF41016 >= 0                          0.0
C24R17  MIDF41017 - 0.17 * TMIDF41017 >= 0                          0.0
C24R18  MIDF41018 - 0.17 * TMIDF41018 >= 0                          0.0
C24R19  MIDF41019 - 0.17 * TMIDF41019 >= 0                          0.0
C24R20  MIDF41020 - 0.17 * TMIDF41020 >= 0                          0.0
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C25R2   MICH31002 - 0.05 * TMICH31002 >= 0                          0.0
C25R3   MICH31003 - 0.05 * TMICH31003 >= 0                          0.0
```

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C26R1   MICH31004 - 0.07 * TMICH31004 >= 0                    0.0
C26R2   MICH31005 - 0.07 * TMICH31005 >= 0                    0.0
C26R3   MICH31006 - 0.07 * TMICH31006 >= 0                    0.0
C26R4   MICH31007 - 0.07 * TMICH31007 >= 0                    0.0
C26R5   MICH31008 - 0.07 * TMICH31008 >= 0                    0.0
C26R6   MICH31009 - 0.07 * TMICH31009 >= 0                    0.0
C27R1   MICH31010 - 0.14 * TMICH31010 >= 0                    0.0
C27R2   MICH31011 - 0.14 * TMICH31011 >= 0                    0.0
C27R3   MICH31012 - 0.14 * TMICH31012 >= 0                    0.0
C27R4   MICH31013 - 0.14 * TMICH31013 >= 0                    0.0
C27R5   MICH31014 - 0.14 * TMICH31014 >= 0                    0.0
C27R6   MICH31015 - 0.14 * TMICH31015 >= 0                    0.0
C27R7   MICH31016 - 0.14 * TMICH31016 >= 0                    0.0
C27R8   MICH31017 - 0.14 * TMICH31017 >= 0                    0.0
C27R9   MICH31018 - 0.14 * TMICH31018 >= 0                    0.0
C27R10  MICH31019 - 0.14 * TMICH31019 >= 0                    0.0
C27R11  MICH31020 - 0.14 * TMICH31020 >= 0                    81.8161
C28R1   MMS3401 - 0.14 * TMMS3401 >= 0                    0.0
C28R2   MMS3402 - 0.14 * TMMS3402 >= 0                    0.0
C28R3   MMS3403 - 0.14 * TMMS3403 >= 0                    0.0
C28R4   MMS3404 - 0.14 * TMMS3404 >= 0                    0.0
C28R5   MMS3405 - 0.14 * TMMS3405 >= 0                    0.0
C28R6   MMS3406 - 0.14 * TMMS3406 >= 0                    0.0
C28R7   MMS3407 - 0.14 * TMMS3407 >= 0                    0.0
C28R8   MMS3408 - 0.14 * TMMS3408 >= 0                    0.0
C28R9   MMS3409 - 0.14 * TMMS3409 >= 0                    0.0
C28R10  MMS3410 - 0.14 * TMMS3410 >= 0                    0.0
C28R11  MMS3411 - 0.14 * TMMS3411 >= 0                    0.0
C28R12  MMS3412 - 0.14 * TMMS3412 >= 0                    0.0
C28R13  MMS3413 - 0.14 * TMMS3413 >= 0                    0.0
C28R14  MMS3414 - 0.14 * TMMS3414 >= 0                    0.0
C28R15  MMS3415 - 0.14 * TMMS3415 >= 0                    0.0
C28R16  MMS3416 - 0.14 * TMMS3416 >= 0                    0.0
C28R17  MMS3417 - 0.14 * TMMS3417 >= 0                    0.0
C28R18  MMS3418 - 0.14 * TMMS3418 >= 0                    0.0
C28R19  MMS3419 - 0.14 * TMMS3419 >= 0                    0.0
C28R20  MMS3420 - 0.14 * TMMS3420 >= 0                    0.0
C29R1   MMS3501 - 0.11 * TMMS3501 >= 0                    0.0
C29R2   MMS3502 - 0.11 * TMMS3502 >= 0                    0.0
C29R3   MMS3503 - 0.11 * TMMS3503 >= 0                    0.0
C29R4   MMS3504 - 0.11 * TMMS3504 >= 0                    0.0
C29R5   MMS3505 - 0.11 * TMMS3505 >= 0                    0.0
C29R6   MMS3506 - 0.11 * TMMS3506 >= 0                    0.0
C29R7   MMS3507 - 0.11 * TMMS3507 >= 0                    0.0
C29R8   MMS3508 - 0.11 * TMMS3508 >= 0                    0.0
C29R9   MMS3509 - 0.11 * TMMS3509 >= 0                    0.0
C29R10  MMS3510 - 0.11 * TMMS3510 >= 0                    0.0
C29R11  MMS3511 - 0.11 * TMMS3511 >= 0                    0.0
C29R12  MMS3512 - 0.11 * TMMS3512 >= 0                    0.0
C29R13  MMS3513 - 0.11 * TMMS3513 >= 0                    0.0
C29R14  MMS3514 - 0.11 * TMMS3514 >= 0                    0.0
C29R15  MMS3515 - 0.11 * TMMS3515 >= 0                    0.0
C29R16  MMS3516 - 0.11 * TMMS3516 >= 0                    0.0
C29R17  MMS3517 - 0.11 * TMMS3517 >= 0                    0.0
C29R18  MMS3518 - 0.11 * TMMS3518 >= 0                    0.0
C29R19  MMS3519 - 0.11 * TMMS3519 >= 0                    0.0
C29R20  MMS3520 - 0.11 * TMMS3520 >= 0                    0.0
C30R1   MMS3601 - 0.14 * TMMS3601 >= 0                    0.0
C30R2   MMS3602 - 0.14 * TMMS3602 >= 0                    0.0
C30R3   MMS3603 - 0.14 * TMMS3603 >= 0                    0.0
C30R4   MMS3604 - 0.14 * TMMS3604 >= 0                    0.0
C30R5   MMS3605 - 0.14 * TMMS3605 >= 0                    0.0
C30R6   MMS3606 - 0.14 * TMMS3606 >= 0                    0.0
C30R7   MMS3607 - 0.14 * TMMS3607 >= 0                    0.0
C30R8   MMS3608 - 0.14 * TMMS3608 >= 0                    0.0
C30R9   MMS3609 - 0.14 * TMMS3609 >= 0                    0.0
C30R10  MMS3610 - 0.14 * TMMS3610 >= 0                    0.0
C30R11  MMS3611 - 0.14 * TMMS3611 >= 0                    0.0
C30R12  MMS3612 - 0.14 * TMMS3612 >= 0                    0.0
C30R13  MMS3613 - 0.14 * TMMS3613 >= 0                    0.0
C30R14  MMS3614 - 0.14 * TMMS3614 >= 0                    0.0
```

```
C30R15  MMS3615 - 0.14 * TMMS3615 >= 0                          0.0
C30R16  MMS3616 - 0.14 * TMMS3616 >= 0                          0.0
C30R17  MMS3617 - 0.14 * TMMS3617 >= 0                          0.0
C30R18  MMS3618 - 0.14 * TMMS3618 >= 0                          0.0
C30R19  MMS3619 - 0.14 * TMMS3619 >= 0                          0.0
C30R20  MMS3620 - 0.14 * TMMS3620 >= 0                          0.0
C31R1   MMS3701 - 0.14 * TMMS3701 >= 0                         0.0
C31R2   MMS3702 - 0.14 * TMMS3702 >= 0                         0.0
C31R3   MMS3703 - 0.14 * TMMS3703 >= 0                         0.0
C31R4   MMS3704 - 0.14 * TMMS3704 >= 0                         0.0
C31R5   MMS3705 - 0.14 * TMMS3705 >= 0                         0.0
C31R6   MMS3706 - 0.14 * TMMS3706 >= 0                         0.0
C31R7   MMS3707 - 0.14 * TMMS3707 >= 0                         0.0
C31R8   MMS3708 - 0.14 * TMMS3708 >= 0                         0.0
C31R9   MMS3709 - 0.14 * TMMS3709 >= 0                         0.0
C31R10  MMS3710 - 0.14 * TMMS3710 >= 0                          0.0
C31R11  MMS3711 - 0.14 * TMMS3711 >= 0                          0.0
C31R12  MMS3712 - 0.14 * TMMS3712 >= 0                          0.0
C31R13  MMS3713 - 0.14 * TMMS3713 >= 0                          0.0
C31R14  MMS3714 - 0.14 * TMMS3714 >= 0                          0.0
C31R15  MMS3715 - 0.14 * TMMS3715 >= 0                          0.0
C31R16  MMS3716 - 0.14 * TMMS3716 >= 0                          0.0
C31R17  MMS3717 - 0.14 * TMMS3717 >= 0                          0.0
C31R18  MMS3718 - 0.14 * TMMS3718 >= 0                          0.0
C31R19  MMS3719 - 0.14 * TMMS3719 >= 0                          0.0
C31R20  MMS3720 - 0.14 * TMMS3720 >= 0                          0.0
C32R1   MMS3801 - 0.11 * TMMS3801 >= 0                         0.0
C32R2   MMS3802 - 0.11 * TMMS3802 >= 0                         0.0
C32R3   MMS3803 - 0.11 * TMMS3803 >= 0                         4.0115
C32R4   MMS3804 - 0.11 * TMMS3804 >= 0                         0.0
C32R5   MMS3805 - 0.11 * TMMS3805 >= 0                         0.0
C32R6   MMS3806 - 0.11 * TMMS3806 >= 0                         0.0
C32R7   MMS3807 - 0.11 * TMMS3807 >= 0                         0.0
C32R8   MMS3808 - 0.11 * TMMS3808 >= 0                         0.0
C32R9   MMS3809 - 0.11 * TMMS3809 >= 0                         0.0
C32R10  MMS3810 - 0.11 * TMMS3810 >= 0                          0.0
C32R11  MMS3811 - 0.11 * TMMS3811 >= 0                          0.0
C32R12  MMS3812 - 0.11 * TMMS3812 >= 0                          0.0
C32R13  MMS3813 - 0.11 * TMMS3813 >= 0                          0.0
C32R14  MMS3814 - 0.11 * TMMS3814 >= 0                          0.0
C32R15  MMS3815 - 0.11 * TMMS3815 >= 0                          0.0
C32R16  MMS3816 - 0.11 * TMMS3816 >= 0                          0.0
C32R17  MMS3817 - 0.11 * TMMS3817 >= 0                          0.0
C32R18  MMS3818 - 0.11 * TMMS3818 >= 0                          0.0
C32R19  MMS3819 - 0.11 * TMMS3819 >= 0                          0.0
C32R20  MMS3820 - 0.11 * TMMS3820 >= 0                          0.0
C33R1   MMS3901 - 0.14 * TMMS3901 >= 0                         0.0
C33R2   MMS3902 - 0.14 * TMMS3902 >= 0                         0.0
C33R3   MMS3903 - 0.14 * TMMS3903 >= 0                         0.0
C33R4   MMS3904 - 0.14 * TMMS3904 >= 0                         0.0
C33R5   MMS3905 - 0.14 * TMMS3905 >= 0                         0.0
C33R6   MMS3906 - 0.14 * TMMS3906 >= 0                         0.0
C33R7   MMS3907 - 0.14 * TMMS3907 >= 0                         0.0
C33R8   MMS3908 - 0.14 * TMMS3908 >= 0                         0.0
C33R9   MMS3909 - 0.14 * TMMS3909 >= 0                         0.0
C33R10  MMS3910 - 0.14 * TMMS3910 >= 0                          0.0
C33R11  MMS3911 - 0.14 * TMMS3911 >= 0                          0.0
C33R12  MMS3912 - 0.14 * TMMS3912 >= 0                          0.0
C33R13  MMS3913 - 0.14 * TMMS3913 >= 0                          0.0
C33R14  MMS3914 - 0.14 * TMMS3914 >= 0                          0.0
C33R15  MMS3915 - 0.14 * TMMS3915 >= 0                          0.0
C33R16  MMS3916 - 0.14 * TMMS3916 >= 0                          0.0
C33R17  MMS3917 - 0.14 * TMMS3917 >= 0                          0.0
C33R18  MMS3918 - 0.14 * TMMS3918 >= 0                          0.0
C33R19  MMS3919 - 0.14 * TMMS3919 >= 0                          0.0
C33R20  MMS3920 - 0.14 * TMMS3920 >= 0                          0.0
C34R1   MMS31001 - 0.14 * TMMS31001 >= 0                         0.0
C34R2   MMS31002 - 0.14 * TMMS31002 >= 0                         0.0
C34R3   MMS31003 - 0.14 * TMMS31003 >= 0                         0.0
C34R4   MMS31004 - 0.14 * TMMS31004 >= 0                         0.0
C34R5   MMS31005 - 0.14 * TMMS31005 >= 0                         0.0
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C34R6   MMS31006 - 0.14 * TMMS31006 >= 0                       0.0
C34R7   MMS31007 - 0.14 * TMMS31007 >= 0                       0.0
C34R8   MMS31008 - 0.14 * TMMS31008 >= 0                       0.0
C34R9   MMS31009 - 0.14 * TMMS31009 >= 0                       0.0
C34R10  MMS31010 - 0.14 * TMMS31010 >= 0                       0.0
C34R11  MMS31011 - 0.14 * TMMS31011 >= 0                       0.0
C34R12  MMS31012 - 0.14 * TMMS31012 >= 0                       0.0
C34R13  MMS31013 - 0.14 * TMMS31013 >= 0                       0.0
C34R14  MMS31014 - 0.14 * TMMS31014 >= 0                       0.0
C34R15  MMS31015 - 0.14 * TMMS31015 >= 0                       0.0
C34R16  MMS31016 - 0.14 * TMMS31016 >= 0                       0.0
C34R17  MMS31017 - 0.14 * TMMS31017 >= 0                       0.0
C34R18  MMS31018 - 0.14 * TMMS31018 >= 0                       0.0
C34R19  MMS31019 - 0.14 * TMMS31019 >= 0                       0.0
C34R20  MMS31020 - 0.14 * TMMS31020 >= 0                       0.0
C35R1   MPP4401 - 0.14 * TMPP4401 >= 0                     0.0
C35R2   MPP4402 - 0.14 * TMPP4402 >= 0                     0.0
C35R3   MPP4403 - 0.14 * TMPP4403 >= 0                     0.0
C35R4   MPP4404 - 0.14 * TMPP4404 >= 0                     0.0
C35R5   MPP4405 - 0.14 * TMPP4405 >= 0                     0.0
C35R6   MPP4406 - 0.14 * TMPP4406 >= 0                     0.0
C35R7   MPP4407 - 0.14 * TMPP4407 >= 0                     0.0
C35R8   MPP4408 - 0.14 * TMPP4408 >= 0                     0.0
C35R9   MPP4409 - 0.14 * TMPP4409 >= 0                     0.0
C35R10  MPP4410 - 0.14 * TMPP4410 >= 0                     0.0
C35R11  MPP4411 - 0.14 * TMPP4411 >= 0                     0.0
C35R12  MPP4412 - 0.14 * TMPP4412 >= 0                     0.0
C35R13  MPP4413 - 0.14 * TMPP4413 >= 0                     0.0
C35R14  MPP4414 - 0.14 * TMPP4414 >= 0                     0.0
C35R15  MPP4415 - 0.14 * TMPP4415 >= 0                     0.0
C35R16  MPP4416 - 0.14 * TMPP4416 >= 0                     0.0
C35R17  MPP4417 - 0.14 * TMPP4417 >= 0                     0.0
C35R18  MPP4418 - 0.14 * TMPP4418 >= 0                     0.0
C35R19  MPP4419 - 0.14 * TMPP4419 >= 0                     0.0
C35R20  MPP4420 - 0.14 * TMPP4420 >= 0                     0.0
C36     LU10 AU01 ESSFNDT3 IRM DEF1 NONE NATURAL          @ 2.0 = 0.71     -184.0301
C37     LU10 AU01 ESSFNDT3 IRM OP NONE NATURAL            @ 2.0 = 6.01     -206.3189
C38     LU10 AU01 ESSFNDT3 IRM OP NONE NATURAL            @ 42.0 = 6.83    -642.3383
C39     LU10 AU01 ICHNDT3 FEN DEF1 NONE NATURAL           @ 3.0 = 5.95     -165.0501
C40     LU10 AU01 ICHNDT3 FEN DEF2 NONE NATURAL           @ 3.0 = 7.39     -188.5558
C41     LU10 AU01 ICHNDT3 FEN DEF2 NONE NATURAL           @ 4.0 = 2.27     -200.5012
C42     LU10 AU01 ICHNDT3 FEN DEF2 NONE NATURAL           @ 20.0 = 2.83    -172.5759
C43     LU10 AU01 ICHNDT3 IRM OP NONE NATURAL             @ 3.0 = 4.96     -212.3357
C44     LU10 AU01 ICHNDT3 IRM OP NONE NATURAL             @ 4.0 = 1.22     -227.5310
C45     LU10 AU01 ICHNDT3 IRM OP NONE NATURAL             @ 6.0 = 2.25     -395.5830
C46     LU10 AU01 ICHNDT3 IRM OP NONE NATURAL             @ 30.0 = 1.03    -590.8080
C47     LU10 AU01 ICHNDT3 IRM OP NONE NATURAL             @ 48.0 = 1.47    -642.4088
C48     LU10 AU01 ICHNDT3 UNGU OP NONE NATURAL            @ 1.0 = 10.01    -40.6556
C49     LU10 AU01 IDFNDT4 FEN DEF2 NONE NATURAL           @ 1.0 = 1.67     -165.0501
C50     LU10 AU01 IDFNDT4 FEN DEF2 NONE NATURAL           @ 6.0 = 3.96     -403.9860
C51     LU10 AU01 IDFNDT4 TRENCH OP NONE NATURAL          @ 1.0 = 3.42     -193.1838
C52     LU10 AU01 IDFNDT4 TRENCH OP NONE NATURAL          @ 2.0 = 2.04     -206.5221
C53     LU10 AU01 IDFNDT4 UNGU OP NONE NATURAL            @ 1.0 = 5.24     -52.1098
C54     LU10 AU01 MSNDT3 FEN DEF1 NONE NATURAL            @ 30.0 = 1.28    -165.0501
C55     LU10 AU01 MSNDT3 FEN DEF2 NONE NATURAL            @ 2.0 = 1.05     -176.4119
```