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CHAPTER 1

1. INTRODUCTION

1.1 Objectives

This report was prepared for the Washington State Department of Natural Resources (DNR) by the University of Washington senior Forest Engineering class during the Spring of 1993. It contains a proposed comprehensive harvest and transportation plan for the Elochoman B Planning area (Township 9N Range 5W) in Wahkiakum County just outside of Cathlamet, Washington.

The "Elochoman Drainage" of DNR managed land contains approximately 3,700 acres. This section is also refered to as "sub-block B". It is bounded by the Elochoman River to the west, by Beaver Creek to the south, by the Bradley Truck Trail to the east, and the 7000 road to the north. The Elochoman Drainage contains approximately two-thirds second growth Western Hemlock with some scattered Douglas Fir and Red Alder. The remaining third has been clearcut and roaded within the last 25 years, and is now Douglas-Fir regeneration.

The DNR's objectives for the Elochoman Drainage are to design a workable Transportation and Harvest Plan which complies with all current requirements of the Forest Practices Act. The plan must also adhere to environmental and economical concerns. These concerns must be feasible within the following parameters:

(1) Protect wildlife habitat.
(2) Maintain high water quality.
(3) Minimize visual impacts.
(4) Provide even timber flow.
(5) Develop an inventory and transportation map which shows the location of, and access to timber inventory.
(6) Determine the removal schedule and road network which optimizes revenue.
(7) Determine the effects of management decisions on present net worth.

1.2 DNR Planning Guidlines

The DNR's Southwest Regional Management specified the following criteria to be used in the Elochoman Drainage:

Planning requirements:

Sale Unit Layout:

- -Maximum unit clearcut size not exceeding 100 acres with settings optimal between 20 and 70 acres.
- -Unit boundaries should follow natural breaks and be placed away from streams.
- -Use 5 year green up period between adjacent units.
- -Units shall be considered adjacent unless separated by at least 400'.
- -Target removal of 2 MMBF/year (even flow)
- -Target removel of 10 MMBF/period (5 yr. even flow)
- -Precommercial thin usually at age 15 years.
- -Commercial thin at 30-40 years.
- -Final cut at 55-65 years.
- -Planning period (timeperiod) is 5 years which is their action plan time frame.

Activities:

- -There currently is one sale, named "Alder Panacea". It is located in the SW 1/4 of the SW 1/4 of section 28 and the SE 1/4 of the SE 1/4 of section 29.
- -Some blowdown removals are scheduled in the block.

Roads:

- -Rock situation is very poor for ballast. Usually need 65 cyd/station for crushed rock and 85-95 cyd/station for pit-run rock. The costs for pit-run rock are $6-7/cyd, and $8-10/cyd for crushed in-place.
- -Try to minimize road milage constructed.
- -Utilize all exsisting "old" truck roads and railroad grades, when practical.
- -Design to use larger yarding systems such as shylines, slacklines, etc..., on the steeper, unstable soils(60%+), or during the wet season, where compaction is severe.
- -Road Grades: Mainlines and secondary haul roads should have maximun adverse grades between 8-12%, spur roads could go up to 15-18% if needed.

Stream Protection:

- -Minimize stream crossings.
- -Keep parrallel roads more than 200 ft away.
- -Yard away from stream type 1,2,3,4, and 5 whenever feasible.
- -RMZ boundary lines (width) will vary from a minimum of 25' (each side of stream) on floodplains to the topographic breaks on steeper grounds.

Recreation:

-Motorcycle trail runs through a section of the planning area. Trailhead is at intersection of the B1000 road and the M2000 road (see figure 4.1 for map of road numbers). Trail follows Bradley Truck Trail north, then up an old railroad grade and over to another before coming back to the Bradley Truck Trail. See figure 1.1 for a map of motorcycle trail.

Figure 1.1 - Motorcycle Trail

General issues:

- -Accommodate commercial thinning, pre-logging, partial harvest activities on grounds less than 30% and along existing or new roads when feasible.
- -Consider low compaction machinery vs. cable yarding systems.
- -Green tree retention consisting of 3 green standing trees, 3 dead standing trees and 2 down pieces of wood shall be considered on 60% of the stands.
- -Gene pools and seral stage stands shall be taken into account in the management activities.
- -If feasible, use Equal Annual Increments in the Economic Analysis as well as Present Net Worth.

The UW's objective is to provide students with the opportunity to apply classroom knowledge and skills to a real world project while providing the DNR with a harvest and transportation plan that will fulfill their management objectives. The specific project goals were to develop the proposed setting boundaries, harvest schedule, and transportation systems that maximize revenues under the given constraints (maximum unit size, adjacency and green up considerations, resource protection and volume flow objectives).

1.3 PHYSICAL RESOURCES

1.3.1 Access:

The planning area can be accessed initially via SR 407 from the west, Mill Creek Road from the south, Abernathy Creek Road to the northeast, then from either Beaver Creek County Road to the south, the 3000 road to the western central portion, or the 7000 road to the north (see the Vicinity Map, Figure 1.2). Most timber from this area is hauled to Longview Fiber, in the Longview area for processing or export. Distances from the study area to Longview are shown below.

Table 1.1 Distances from the study area to Longview mills.

Distance (Miles)	Via this route
30	Hwy 407 to Cathlamet route
21	Beaver Creek road route
24	Abernathy Creek road route
23	Mill Creek road route

Figure 1.2 - Vicinity Map

1.3.2 General

The planning area contains approximately 3700 acres of DNR managed forest lands located in sections 11, 12, 14, 15, 21, 22, 23, 27, 28 and small pieces of sections 1, 2, 10, and 16 of Township 9 North, Range 5 West. Planning efforts as reported in this document concentrate on harvesting practices and roading. Because the western portion has been recently cut, management efforts there concentrate more immediately on thinning. Harvest planning will encompass all sections in the planning area to prepare for their future harvest period, except those units that are already sold.

1.3.3 Topography

The planning area varys in elevation from 300' to 1200' above sea level. The relief is rarely extreme. The ground is somewhat level at the top, easterly boundary, then drops off west toward the Elochoman River. To the west side of the planning area, all streams drain to the Elochoman River. The east portion drains into Beaver Creek, which then drains into the Elochoman. Streams reaching the Elochoman are generally class four (4) and five (5) streams. Two class three (3) streams enter the Elochoman river near the Elochoman Salmon Hatchery. The rest of the area is drained by the Beaver Creek drainage. Again this eventually enters the Elochoman at the Beaver Creek Steelehead Hatchery. Water quality concerns will be addressed later in the report.

Ground slopes vary from zero to extremes over 70 percent, the average slope being 23 percent. Four slope classes were established for the purpose of analyzing the feasibility of different yarding systems and road locations.

<30% : for determining those areas that may be suitable for ground skidding activity and are best for road locations.

31-50%: for determining those areas that are still suitable for road construction with balanced cut and fills, and potentially suitable for highlead systems.

51-70%: for determining those areas that require full bench and sidecast road construction, and best suited for skyline systems.

>71% : for determining those areas that require full bench and end-haul road construction and should be avoided when possible.

The breakdown of slope classes by area and percentage of total area are in table 1.2.

Table 1.2 : Slope class by area in planning block.

Slope Class	Acres	Percentage of Total
<30%	2353.11	63.47
31-50%	1114.00	30.05
51-70%	198.29	5.35
>71%	21.15	.57
Totals	3707.71	99.6

1.3.4 Soils

Most of the Elochoman Drainage planning area soils consist of silty loams over basaltic bedrock. These are well-drained, deep soils, averaging 5 feet deep. The parent material is Columbia River Basalt for Raught-Germany soils, and Sandstone for Cathlamet soils.

The following soil types are found within the planning area:

Table 1.3 : Soil types and their representation in the planning area.

Soil Name	Percent of Planning Area	USCS classification	Site Index (Age 50)
Cathlamet	66.48	ML-MH	DF=131, WH=115
Germany	23.89	ML-MH	DF=125, WH=116
Grehalem	0.12	CL	DF=140
Montesa	0.31	ML	RA=102
Rock Pit	0.05	rock	rock
Raught	7.61	GP	DF=131, WH=115
Stimson	1.53	CL-ML	RA=95

Two soil types, Cathlamet and Germany, cover more than 90% of the planning area. The majority of the proposed road locations are on these two soil types. These soils are very deep, well drained soil on shoulders and uplands. See chapter 5.3 for more soil information and management interpretations for the soils.

1.3.5 Water Resources

The planning area is divided into two major drainage areas. Both contain class 1, 2, 3 and numerous type 4 and 5 streams (See figure 1.4). The Elochoman drainage, which encompasses most of the western side of the planning area, collects mostly class 4 and class 5 streams. There are three class 3 streams in the vicinity of the Elochoman Salmon hatchery. The Elochoman river drains into the Columbia River. The Elochoman drainage area exhibits mostly a series of low class streams draining parallel downslope to the Elochoman River. This extends along the western length of the planning area. The Beaver Creek drainage exhibits more of a fanned system of mostly class 4 and class 5 streams which join together collectively in Beaver Creek. Beaver Creek then drains into the Elochoman and farther to the Columbia River.

1.3.6 Climate

The climate is relatively mild, with most precipitation occurring during the winter and early spring months. Mean annual precipitation in this area ranges between 70 and 100 inches a year. The storm winds blow up the Colombia River from the Pacific Ocean, then northward up the Elochoman River valley. This leaves southern aspects most exposed to windthrow. The average temperature is around 50 degrees Fahrenheit.

1.3.7 Timber Resources

The Elochoman B planning area is approximately 3687 acres, including riparian buffer areas. About 1650 acres is plantation with an average age of 20. The remaining 2037 acres, average of 60 years old, was naturally grown after railroad logging (Table 1.4).

Table 1.4: Age classes and areas for the two major age classes in the planning area

STAND AGE DISTRIBUTION		
Age classes	Acres	
Plantation		
0 - 25 years	1650	
Mature		TOTAL 3687
25+ years	2037	

The primary species in the mature timber area is western hemlock. Secondary species includes Douglas-fir, red cedar, and red alder. Douglas-fir stands reside on the west side of the planning area, western hemlock is east and centrally located, and alder stands are mixed between. The average site index for western hemlock is 118 and for Douglas-fir is 125. Refer to the Timber Type Map (Figure 1.3).

Timber information came from the DNR's GIS data base. Current inventory data, as of June 2, 1993 is reflected on the following table and also on the Stand MBF/ACRE map (Figure 1.4). Insufficient volume information was filled in using empirical yield tables from the Washington State Department of Natural Resources.

Table 1.5: Volume classes in mbf/acre and acres in each class.

STAND VOLUMES			ACRES
Plantation	0 - 20	MBF/ACRE	1650
Mature	20 - 40	MBF/ACRE	576
	40 - 60	MBF/ACRE	794
	60+	MBF/ACRE	897

There are five major stand types within the mature timber age class. These were delineated from the Ortho photos and cross-checking with the GIS stand attribute tables of timber information.

Table 1.6: Stand type separations using the polygon fiu_id number as the stand number.

TIMBER STAND TYPES				
OPEN	THICK	ALDER	MIX	RIPARIAN
1558	1568	1613	1498	1553
1542	1560	1500	1537	1552
1563	1556	1598	1509	1592
1577	1529			1492
1510	1536			1602
1581	1540			1578
1573	1506			1572
1552	1514			
1594	1539			
1554	1523			

Over half of the planning area is mature timber and all of it is basically the same age class. Clearcut size restrictions, and green-up constraints prevent some of this timber from being harvested for 30 or more years. The next obvious question to be answered in this situation is if thinning some stands now would produce an increase in volume over a 20 or 30 year period. If an increase in volume is not produced, could the value of the stands be increased by thinning.

Chapter 7 has detailed information on this spring quarter's work, and an analysis of the thinning question.

CHAPTER 2

2. PLANNING GUIDELINES AND CONSTRAINTS

2.1 DNR PLANNING GUIDELINES

Before we started the harvest plan for Elochman area "B", the class had to become familiar with existing and upcoming plans for the area. We met with DNR managers to find out what would be needed for compliance with economic and environmental factors.

2.2 YARDING CONSIDERATIONS

2.2.1 Turn Weight and Payload Analysis

Setting analysis is depended, among other things, on log weight. Logweight were estimated by defferent methods. The first method was based on a log count per truck, assuming a 50,000 lbs per load. And also assuming 4500 bdft and 12 logs per truck load. The weight per turn using 3 chokers would be 12500 lbs. (3 logs each weighting 4166 lbs).

THe second method is based on the individual log weight , from average DBH and Hight. In this planning area, an average DBH of 18" ranging from 15" to 20". The following figure shows the turn weight for different length logs. The volume in bdft was figured from the following equation:

bf = ((16^2-3*16)/10*.5*(log length in ft))/3

The volume in cft was found by multiplying by a conversion factor of 4.46 and the log weight was finding by multiplying the cft vol. and 53.2. Finaly Turn weight was computed by multiplying the log weight and 3.

Table 2.1.1 Based on 18 inches diameters log for different length. (Conversion Factors for the PNW, Collerge of Forest Resources)

Log Length	Vol. (BF)	Vol. (CFT)	Log Weight (lbs.)	Turn Weight (lbs.)
30	104.00	54.8	2915	8745
32	110.93	58.3	3102	9306
34	117.87	61.9	3293	9879
36	124.80	65.4	3479	10467
38	131.73	68.9	3665	10995
40	138.67	72.5	3857	11571

* Conversion factor is 53 lbs / CFT based on 90 % Moisture content
Volume Weight and tree weights for an 18 inches log and various length
(% O.D. wt. basis)

Table 2.1.2 shows log volume for different length and diameter. Log volume range from a low of 43 cft (16" X 30 ') to 89 cft (20" X 40'), or 2300 to 4700 lbs per log based on a green weight of 53 lbs / cft.

Table 2-1-2 Cubic foot log volume , including trim for various log lenght and diameter.

Avg. dim. (Inches)	30	32	Log 34	Length 36	(feet) 38	40
16	43.3	36.1	48.9	51.7	54.5	57.2
18	54.8	58.3	61.9	65.4	68.9	72.5
20	67.6	72	76.4	80.7	85.1	89.4

2.2.2 Machine Specification

The machines used will depend on the ground topography, average and external yarding distance, and payloads. These constraints will allow choices to be made between the three most used systems in the Pacific Northwest. Those three systems are running skyline (with yarding distances between 1000 ft and 1300 ft), the shotgun system (with yarding distances between 1300 ft and 1800 ft on at least 50 percent slopes), and the highlead system (yarding distances up to 1400 ft and it mainly uses down hill yarding).

The highlead system can be broken up into 2 different systems. For shorter yarding distances, up to 600 ft, 40 ft or 50 ft tower is used. For longer spans a 90 ft tower is used. Both operate on slopes not higher than 50 percent, but not less than 30 percent where a tractive logging would be used.

Table 2-2 Yarder type and system used

Yarder type	# of drums	Yarding system	Yarding direction
TMY 90	3	Live Skyline	U / D
YARDER		High lead Longspan	U
		Running Skyline	U / D
		Standing Skyline	U / D
TMY 70	3	Live Skyline	U / D
YARDER		High lead Longspan	U
		Running Skyline	U / D
TMY 50	3	High lead Shortspan	U
YARDER		Live Skyline	U
		Running Skyline	U / D
TMY 40	3	High lead shortspan	U
YARDER		Live Skyline	U / D

U : Uphill D : Down Hill

The skidding equipment chosen was the CAT 518 Cable Skidder, CAT D5H Custom Skidder, CAT 235C Log Loader, and the CAT 227 Feller-buncher. Moreover, the other ground-based logging equipment chosen were Timberjack 1010 Forwarder, Timberjack 1270 Single Grip Harvester, Timberjack 933C Clam bunk Skidder, Timberjack 2618 / 2628 Level Swing Feller Buncher.

The specifications of ground-based equipment are in table 2.3.1, 2.3.2, 2.3.3, 2.3.4.

The ground-based logging system has a combination of using equipment. The Timberjack 1010 Forwarder is operated with Timberjack 1270 Single Grip Harvester. The Timberjack 933C Clam bunk Skidder is operated with Timberjack 2618 / 2618 Level Swing Feller Buncher. Timberjack 1270 can fell and bunch the logs, but Timberjack 2618 / 2628 only fell the tree; therefore, this combination is required to harvest.

Table 2.3.1: Specifications for 4 yarders

Thunderbird TMY-40 Mobile yarder
Tower height : 40 ft
Carriage weight : 400 lbs
175 hp with 4 speed transmission
Flexible system

	Skyline	Mainline	Haul back	Guy line
Diameter (in)	7/16"	1/2"	3/4"	1/2"
Weight (lb./ft)	0.35	0.46	1.04	0.46
Safe Loading load (kip)	6.8	8.9	19.6	8.9
length (ft)	4200	2000	2000	135
Max. line pull (lbs)	22320	23260	22320	----
Max. line speed (ft/min.)	2265	2130	2210	----

Thunderbird TMY-50 Mobile yarder
Tower height : 50 ft
Carriage weight : 1,600 lbs
350 hp with 5 speed transmission
Flexible system

	Skyline	Mainline	Haul back	Guy line
Diameter (in)	1" (1-1/8")	3/4"	3/4"	1 1/8"
Weight (lb./ft)	1.85 (2.34)	1.04	1.04	2.34
Safe Loading load (kip)	34.5 (43.3)	19.6	19.6	43.3
length (ft)	500 (2000)	2000	4400	200
Max. line pull (lbs)	108900	1820	101800	16200
Max. line speed (ft/min.)	3270	3680	3800	3800

Thunderbird TMY-70 Mobile yarder
Tower height : 70 ft
Carriage weight : 1,600 lbs.
430 hp with 5 speed transmission
Flexible system

	Skyline	Mainline	Haul back	Guy line	Slackpuller
Diameter (in)	1" (1-1/8")	7/8"(3/4")	3/4"	1 1/8"	7/8"

Weight (lb./ft)	1.85 (2.34)	1.42(1.04)	1.04	2.34	1.42
Safe Loading load (kip)	34.5 (43.3)	26.5(19.6)	19.6	43.3	26.5
length (ft)	2500(2000)	2100(2700)	4400	220	3100
Max. line pull (lbs)	119500	111800	105200	16200	55040
Max. line speed (ft/min.)	3650	4120	4300	-----	5020

Thunderbird TMY-90 Mobile yarder

Tower height : 90 ft — Carriage weight : 3,000 lbs.

450 hp with 6 speed transmission — Compromise between DNR and ROSS

Flexible system — Corp. specs. for a feasible

	Skyline	Mainline	Haul back
Diameter (in)	1-1/4" (1-3/8)	7/8"	3/4"
Weight (lb/ft)	2.89 (3.5)	1.42	1.04
Safe Loading load (kip)	53.3 (64.0)	26.5	19.6
length (ft)	2500(2000)	3100	6100
Max. line pull (lbs)	108900	101820	101800
Max. line speed (ft/min.)	171500	154200	52300

Table 2.3.2 Machine specifications for representative ground-based logging equipment (2)

CAT 518 CABLE SKIDDER

CAT 3304 turbocharged diesel engine
Flywheel power at 2200 RPM -- 130 hp
Operating weight -- 26,500 lb.
Shipping weight -- 24,810 lb.
Speeds with 23.1x26 tires:

Gear	Forward	Reverse
1st	3.8 mph	4.6 mph
2nd	7.6 mph	9.2 mph
3rd	14.5 mph	17.6 mph

Line pull (max. at stall) -- 26,363 lb.
Line speed (bare drum) at rated RPM -- 302 ft/min. at 9,334 lb.
Drum capacity -- 251 ft of 5/8" wire rope
Fuel tank capacity -- 50.9 gallons
Crankcase capacity -- 5 gallons

CAT 235C LOG LOADER

CAT 3306 turbo-charged and after-cooled diesel engine
Flywheel power at 2000 RPM -- 250 hp
Maximum drawbar pull -- 69,200 lb.
Operating weight:
- With Young Y-42B Log Loader & 62" grapple -- 109,885 lb.
- With Young YUL46 Log Loader & 63" grapple -- 111,320 lb.

Horizontal reach:
- Young Y-42B -- 42 ft.
- Young YUL46 -- 46 ft.

Fuel tank capacity -- 130 gallons
Crankcase capacity -- 7.25 gallons

CAT 227 FELLER-BUNCHER

CAT 3208 diesel engine
Flywheel power at 2000 TPM -- 135 hp
Maximum drawbar pull -- 52,773 lb.
Operating weight -- 69,892 lb.
Shear capacity -- equipped with CAT felling head (two spherical shaped blades cut 20" softwood, 14" hardwood -- standard side-tilt tilts 12.3 degrees right, 14.1 degrees left).
Horizontal reach -- 27 ft.
Fuel tank capacity -- 105 gallons
Crankcase capacity -- 3.5 gallons

Table 2.3.3 Machine specifications for representative ground - based logging equipment (3)

TIMBERJACK 1010 FORWARDER	
Engine :	GM-Perkins 1004 turbo 6 cylinder
Maximum hp	110 hp @ 2400 rpm
Fuel Tank Capacity	36.9 gal
Operating Weight	25,733 lbs
Loader :	FMG 60 telescopic outer boom
- Reach	22.3ft
- Gross Lifting Moment	53,107 lb.ft
- Grapple Model	N25
Opening	51 in
Area	2.7 sq ft
TIMBERJACK 1270 SINGLE GRIP HARVESTER	
Engine :	GM-Perkins 1006-6T turbo 6 cylinder
Maximum hp	152 hp @2200 rpm
Fuel Tank Capacity	132 gal
Operating Weight	32,958 lbs
Crane :	FMG L 190 parallel crane
- Horizontal Reach	27 ft
- Gross Lifting Moment	108,427 lb.ft
- Crane Tilt	10 degrees back, 22 degrees front
- Swing Angle	236 degree
Harvester Head :	FMG 762 B
- Max. felling dia.	20 in
- Max. delimbing dia.	16.9 in
- Feed speed max.	13 ft/sec.
- Weight with Rorater	2,600 lbs
TIMBERJACK 933C CLAM BUNK	
Engine:	Volvo TD 71A 6 cylinder turbo diesel
Maximum hp	209 hp
Fuel Tank Capacity	68.7gal
Operating Weight	61,731 lbs
Loder :	FMG 130 L fixed outer boom
- Horizontal Reach	24.3 ft
- Gross Lifting Moment	113,590 lb.ft
- Grapple Model	T-355
Opening	82.8 in
Area	3.76 sq ft
Clam Back	32 sq ft
- Opening	150 in
- Load Capacity	40,000 lbs
- Rotation	160 degrees
- Tilt Capacity	+13degrees, -17degrees

Table 2-3-4 Machine specifications for representative ground - based logging equipment (4)

TIMBERJACK 2618 LEVEL SWING FELLER BUNCHER	
Engine :	Cummins 6CT
Maximum hp	202 hp @ 2,000 rpm
Operating Weight	52,300 lbs
Fuel Tank Capacity	195 gal
Max. Operation Angle	45 degrees (100%)
Max. Boom Reach	24' 4"
Lift Capacity	3,000 lbs @ 24'9"
	15,600lbs @ 11'9"
Harvester Head	Koehring 20"
Weight	4,350 lbs
TIMBERJACK 2628 LEVEL SWING FELLER BUNCHER	
Engine :	Cummins 6CTA
Maximum hp	230 hp @ 2,000 rpm
Operating Weight	57,600 lbs
Fuel Tank Capacity	195 gal
Max. Operation Angle	45 degrees (100%)
Max. Boom Reach	25'5"
Lifting Capacity	2,870lbs @ 24'9"
	16,800 lbs @ 11' 9"
Harvester Head	Koehring 20"
Weight	5,100 lbs

2.2.3 Stump Anchor and Tail Tree Installation

This section is the same as *Siouxon, Cougar Planning area F Harvest and Transportation Plan,* logging Engineering, University of Washington spring 1992.

The Nakamura holding capacity equation:

$$F = 0.285 * D^{1.65}$$

is used to find the minimum stump diameter for a given line size. F is the maximum holding force of the stump in kips and D is the stump diameter in inches. The equation came from *Skyline Anchors and Multiple Stump Anchors* by Luke A. F. Merry, College of Forest Resources, University of Washington, March 1985. The cable breaking strength in table 2.4 is from *Heckle Creek Harvest and Transportation Plan*, Logging Engineering, University of Washington, January 1986, and it shows the minimum stump diameters for different line sizes calculated from the equation above.

Table 2.4 Minimum stump diameters for a given line size

Line Size (inch)	Breaking Strength (kips)	Stump Diameter (inch)
3/8	15.1	11.1
1/2	26.6	15.6
3/4	58.8	25.3
7/8	79.6	30.4
1	103.4	35.6
1 1/8	130.0	40.9
1 1/4	159.8	46.3
1 3/8	192.0	51.8

Two approaches were used to calculate the holding power for two stumps for a given line size. One approach used the method outlined in the (Setting Design For Cable Systems, Forest Engineering Inc., November 1, 1985). Table 2.5 shows minimum stump diameters for various line sizes using two stumps. These values were calculated using a holding factor approach for each diameter (Setting Design For Cable Systems, Forest Engineering Inc., November 1, 1985). See appendix 2 for calculations.

Table 2-5 Required stump diameters for a given line size with 2 stumps, using Nakamura's holding capacity equation.

Line Size (inch)	Breaking Strength (kips)	Stump Diameter (inch)
1	103.4	26
1 1/8	130.0	29
1 1/4	159.8	33
1 3/8	192.0	37

Another approach is to use the Nakamura's equation along with a static analysis. Because the anchor stumps receive large dynamic forces, a factor of safety must be included to account for this force. The values from these two methods do not differ much. Table 2.6 shows the stump sizes for different line sizes. See appendix 2 for calculations.

Table 2.6 Required stump diameter for a given line size with 2 stumps (using Nakamura holding capacity equation with static analysis).

Line Size (inch)	Breaking Strength (kips)	Stump Diameter (inch)
1	103.4	26
1 1/8	130.0	30
1 1/4	159.8	34
1 3/8	192.0	38

Table 2.7 shows the minimum stump diameters for various line sizes using 3 stumps. These values were calculated using the Nakamura holding capacity equation approach with static analysis. See appendix 2 for calculations.

Table 2.7 Minimum stump diameter required for a given line size with 3 stumps (Using Nakamura holding capacity equation with static analysis).

Line Size (inch)	Breaking Strength (kips)	Required Diameter (inch)	Required Diameter (inch)
1	103.4	25	15
1/8	130.0	29	17
1 1/4	159.8	32	20
1 3/8	192.0	36	22

Tail trees are another area of concern. With smaller lines and often marginal profiles, tail trees allow improved payloads. One needs to understand the limits and diameters that reasonable can be used. An analysis was done to determine the tree diameters that might be required for tailtrees to provide feasible yarding corridors.

Tail trees are pulled over, or buckled, by the same forces that cause towers to overturn or buckle. To prevent this problem and to improve payload, knowledge of required tree sizes are required in order to determine that indeed such tail trees can be found in the stands at hand.

The allowable buckling force on a wooden column used for a tailtree in logging is a function of the modules of elasticity. The formula used for this analysis is the Euler Buckling Formula (Setting Design For Cable Systems, Forest Engineering Inc., November, 1985).

P = (0.12ED^2)/L^2 = Allowable Buckling Load

where; E = Modules of elasticity (lb/sqin)
L = Height to block (in)
D = Diameter (inside bark) at 2/3 height to the block (in)

When being used for tailtrees, Douglas fir (coast) has a modules of elasticity of 1,500,000 psi and Hemlock has 1,200,000 psi. The average length of cable line from tail tree block to stump is assumed to be 50 ft. A T-Bird TMY 40 Mobile Yarder, a T-Bird TMY 50 Mobile Yarder, a T-Bird TMY 70 Mobile Yarder, and a T-Bird TY 90 Slackline Yarder will be used for harvest operations. Tail tree height analyzed are 10 ft, 15 ft, 20ft, 25 ft, and 30 ft. Skyline tension (SWL) for a T-Bird TMY 70 Mobile Yarder is 34,400 lbs and 43,000 lb and 53,300 lb for T-Bird TY 90 Slackline Yarder. See appendix 2 for required diameter calculation of tailtrees.

The above equation is valid for wooden spars. For field evaluations one needs to include the bark thickness to arrive at an overall diameter. Table 2-8 shows rigging heights and skyline tensions. (See appendix 2 for bark thickness calculations).

Table 2.8 Required tail tree diameters for a given skyline tension and various rigging heights.

Skyline Tension (kips)	Tailtree Height (feet)	Tailtree DBH Douglas-fir (inch)	Tailtree DBH Hemlock (inch)
34.5	15	12.9	13.0
	20	14.2	15.2
	30	17.7	18.7
43	15	13.9	13.9
	20	15.2	16.2
	30	17.7	18.7
53.5	15	13.9	14.9
	20	15.2	16.2
	30	19.7	20.7

Table 2.9 Guy line size in relation with equipment weight.

Equipment Weight	Skyline or Guyline Size
30,000 lb. or D6 Class	up to and including 7/8"
40,000 lb. or D7 Class	up to and including 1"
65,000 lb. or D8 Class	up to and including 1 3/8"

Table 2.10 Guide lines for mobil anchor application (from Logging Systems Guide).

Mobile anchors (crawler tractors) may be used for anchoring guy lines or skylines under the following conditions:

1. Guyline or skyline angle shall not exceed 40 degrees.

2. The tractor must be equipped with a blade. The dozer blade must be dug in so that at least one half the depth of the blade is below natural ground or 2 feet, whichever is greater (see Appendix 3).

3. The skyline or guyline must be attached to the machine at the drawbar, belly hook, or both trunnions and pass over the blade.

4. The slope of the tracks shall not exceed 25% (see Appendix 3) in the direction of pull.

2.3 EQUIPMENT COSTS

Purchase and rigging price of equipment evaluated was obtained from two companies:

NC Machinery, Seattle WA
Ross Corporation, Eugene OR

These prices and productivity are shown in table 2.10. Owning and operating costs are covered in section 2.4.

Table 2.11 Machine Purchase Prices and estimated productivitis in thinnings and Clear Cut for Machines Evaluated.

	Purchase Price	Productivity Thinning (logs)	Productivity C.C. (logs)
CAT 235 Log Loader	$160,000		
CAT 518 Grapple Skidder	$345,000	2.7 mbf/hr	3.6 mbf/hr
CAT 227 Feller-buncher	$275,000		
Thunderbird TMY40 Yarder	$435,000	1.51mbf/hr	3.89 mbf/hr
Rigging for TMY40 Yarder	$8,250		
Thunderbird TMY50 Yarder	$465,000	1.84 mbf/hr	4.76 mbf/hr
Rigging for TMY50 Yarder	$18,700		
Thunderbird TMY70 Yarder	$560,000	1.88mbf/hr	4.86 mbf/hr
Rigging for TMY70 Yarder	$18,700		
Thunderbird TMY90 Yarder	$235,500	* ----	5.46 mbf/hr
Rigging for TMY90 yarder	$35,200		
TimberJack 1010 Forwarder	$44,500	1.8 - 2.8 mbf/hr	2.23 mbf/hr
TimberJack 1270 Harvester	$411,835		
TimberJack 933C Clam Bunk	$318,500	*(7.5mbf/hr)	8.75 mbf/hr
TimberJack 2618 Feller Buncher	$349,860		
Timberjack 2628 Feller Buncher	$475,000		

* Thunderbird TMY 90 yarder and Timberjack 933C Clam Bunk Skidder is too large to operate thinning operation.

2.4 PRODUCTION AND MACHINE RATES

Estimating the production costs are not only invariably the most important but also the most difficult task when evaluation yarding systems. The Forest Service has developed a detailed appraisal system. Production costs eventually reflect the stumpage price based on current market condition as shown in the current mill prices. The production cost will determine the stumpage mill price and production rates. Production costs together with equipment costs are usually beyond the control of the landowner. Production rates and costs are, however, affected by volume and timber size as well as average yarding distance. Therefore, we can estimate production cost and rate which are developed from the Average Yarding Distance (AYD) and DBH by using Forest Service regression equation. The figures showing cost vs. AYD (figures 2-3 to 2-5) used date of Forest Service regression equation.

2.4.1 Optimum Average Yarding Distance (AYD) and Road spacing for Yarder.

Optimum AYD is the AYD with the lowest total cost which is the sum of the road construction cost and yarding cost is at a minimum. The objective of planning is to address the lowest cost by selecting the proper road spacing which results on the optimum average yarding distance. The production rate and costs are depended on volume and timber size, as well as average yarding distance. Costs for felling, yarding and loading (stump to truck costs) were calculated using regression equations developed from the Forest Service appraisal data and computer simulation studies. (Chris B. LeDoux 1986; *Western Journal of Applied Forestry* (April, 1986; pp 19-22). The regression equations are suitable for this type of preliminary analyses because they only require DBH and AYD as variables, which are easily obtained from cruies data. If one needs more detailed equation, they are used by private logging companies for individual situation. These base number is based on the "WASHINGTON 078 YARDER".

The equations are:

A: Felling, Limbing, and Bucking cost

($/MCF)=-17.4+876/DBH

MCF = thousand cu ft
DBH = Arithmetic mean DBH in inch
Percent delay = 18.33-3.33(VOAC)
When VOAC exceeds 4.3, delay is 4 %
VOAC=Volume removed per acre in MCF
Variable Limit:
DBH = 6~24 in
VOAC = 0.4~4.3 MFC

B: Yarding costs

($/MCF)=737.4-61.09(DBH)+1.2926(DBH)^2+0.1497(SYD)+52.7/VOAC

SYD = average slope distance feet
Variable Limit:
SYD =100~1200ft
VOAC = 0.4~15MFC
DBH = 6~24 inch
Percent delay = 22.9 - 2.61(VOAC)
When VOAC exceeds 5.4, delay is 9 %

C: Loading costs

($/MFC)=-9.8+545/(DBH)

Percent delay = -4+104/(DBH)
When DBH exceeds 13.0, delay is 4 %
Variable Limit:
DBH = 6~13 in

D: Conversion factor for BF to CF is :

BF/CF = 1.5236 + 0.2291 (DBH) - 0.00284 (DBH)^2

First of all, we look at a previous year's data using this equation and this years base cost to find a ideal road spacing. An average road construction cost is $800.00~1000.00 / Station. Now there are two assumptions that landing was to the center and center top of the square unit of side.

- Equation of the square unit side:

Method 'A': The landing is located at the center of the setting:

$$S = 2 * (AYD/0.7652)$$

Method 'B': The landing is located at the center top of the setting:

$$S = AYD/0.629$$

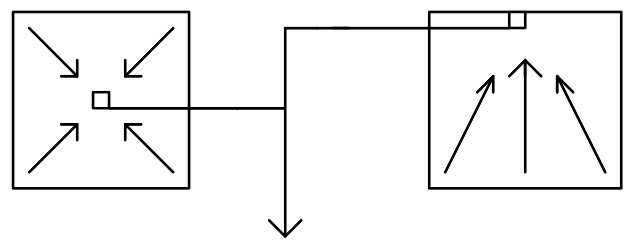

Figure 2.1 Relative landing location

The equation a: is based on Handbook on timber appraisal's table 415.36b <u>AVERAGE SKIDDING DISTANCE FACTORS 1/</u> Figure 1 (E/e = 1.0). The other equation is based on the sample calculation of the Engineering Program "TLPS" which is deveroped by Frank Greulich at University of Washington. The side distance of "S" is actually theoretical road spacing for the given AYD.

The optimum AYD is 350 ft ~ 450 ft in the method "A" and 550 ft ~ 650 ft in the method "B". We have other information about total cost of the highlead, tractor, and Shovel yarding which is come from ITT Rainier flat rate, and Forest Survice flat rate. The USFS flat rate is based on the MBF/ac which is not the same base as our information, so we should derive the same bases from the our basic information. We estimate that thinning is 10.5 inches DBH, 30 MBF/ac, 4 track load/ day and clear cut is 18.5 inches DBH, 40 MBF/ac, 8 track load/day. Comparing cable yarding total cost, ITT Rainier is $200 /MBF (Tinning, Berger Swing Yarder), USFS is $78.50/MBF, and our method "A", and "B" are $144.48/MBF and $71.17/MBF.

Method "A" is close to the ITT Rainier flat rate, and Method "B" is almost the same as the USFS flat rate. In general, most of settings has the similar to the method "B" setting. Therefore, we should use method "B" to establish the total cost.

Road cost ($/MBF) of the road is determined by the theoretical road spacing "S" dicided by the feld volume .

The equation is as follows;

Rd = (5280 / S) x 52.8 (sta/section)

Then the cost/MBF is calculated by the Rd and volume we will cut. The equation is as follows;

R(AYD) = [Rd] x [road const. cost/sta] x [1 / 640] x [1 / cut volume (MBF/AC)]

This is the theoretical road spacing, therefore; we should adjusted to actual conditions. This is caused of roads separate, switch backs, and similar situations. This adjustment factor was calculated from the data from past field studies such as "Harvesting and transportation plan for the Beaver Creek Drainage, 1984" and Heckle Creek. For Example, East side harvest plan of the Beaver Creek report, 1984, shows an average AYD = 444 ft and road length per station = 290.5 sta/sec. An optimal road density = a:) 298.55 sta/sec. Therefore, the adjustment = 444 / 290.5 = 0.973. For the result of the adjustment values are on the table 2.10.

Moreover, we can find the road efficient factor from the AYD and road density, which indicates general road terrain. The following is the equation of finding the "Road Efficiency Factor".

$$a = S\ (\text{Km}) \times RD\ (\text{m/ha})$$

a : Road efficient factor.
S : Average Yarding Distance (km/ft = 0.0003048)
RD : Road Density ((m/ha) / (sta/sec) = 0.1177)

Road efficiency factor (a) ;
4 - 5 : Flat Terrain
5 - 7 : Hilly Terrain
7 - 9 : Steep Terrain
> 9 : Very steep, Irregular terrain.

2.4.2 The optimum Road Spacing & AYD of the ground based System.

Ground - based system cam employ standard skidders or forwarders. One is the Skidder and the other is Forwarder. Forwarder will discuss later. Skidding system is the most common ground yarding system in the PNW region. It is cheep machine cost, and has very high reliability. On the other hand, it damage the soil easily, such as compacting, and dusting the soil.

The way of the calculation the yarding cost, road density, road construction cost, and total cost is followed.

1) To find average log weight and turn weight.
2) To find travel time by using general speed of hauling and inhaling.

3) To find the cycle time, then production per hour.
4) To convert production per hour. ("Logs/hr." to "MBF/hr.")
5) To find the machine cost per hour.
6) To calculate yarding cost from production per hour and machine cost per hour.

To find the road spacing 'S' is used different equation from the cable yarding system. Theoretically, road spacing is four times as much as average yarding distance. (Fig 2.2)

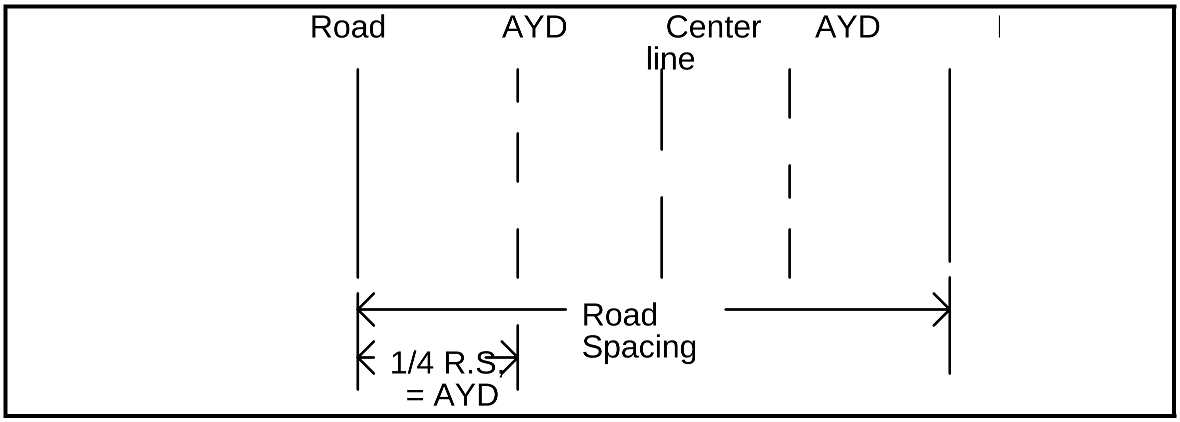

Figure 2.2 Road spacing for continuous landing for ground based system.

Therefore, the equation is;

$$S = 4 \times AYD$$

To find the road density and Road cost is the same as the cable yarding system. The result of the optimum AYD is about 450 ft and optimum total cost is \$45.52/MBF. This is much cheaper than cable yarding system. The result of this consideration is in table 2-12

Table 2-12 Yarding and Road Construction Cost in relation to AYD / road spacing for ground based system

AYD	100	200	300	400	500	600	700	800	900
YC (\$/mbf)	34.3	35.7	37.1	38.6	40.0	41.4	42.8	44.2	45.6
R (AYD)(\$/mbf)	28.16	14.08	9.39	7.04	5.63	4.69	4.02	3.52	3.13
Tot al Cost	62.45	49.79	46.52	45.60	45.61	46.09	46.85	47.77	48.80
Rd.Sp. S	400	800	1200	1600	2000	2400	2800	3200	3600
Rd(sta./sec.)	697	348	232	174	139	116	99	87	77

(The machine rate is \$150.00 / hr)
YC : Yarding Cost
R(AYD) : Rosd construction cost
Rd. Sp.S : : Road spacing
Rd : Rosd density

2.4.3 The optimum Yarding cost, road spacing and AYD for the Forwarder.

We use the "Forwarder PC" to evaluate the forwarder and to find the optimum road spacing. Our option of the forwarder is Tinberjack 1010 which is just made recently ; therefore, we do not have enough information for regression equation. The reason of using "Forwarder PC" is that point. The typical condition , which we are faced on, is listed as follows.

For 9 Tons payload Forwarder:
The conditions of forwarder:
Tire specification:
Front : - Standard 23.1 - 26/10 ply
Rear : - Standard 600/55 -26/16 ply
(use 20 % as an upper limit)
Cone Index
- Fine 120
- Coarse 190
- Ave. 150
Type of earth
- A mixture of Clay & Sand.
Log load weight
- 18000 lbs (9 tons)

** Road spacing analysis data: **
- Effective reach of harvester
24 feet.
- Cost of running forwarder per degree
Uphill = $90.00 / hr / degree
Downhill = $75.00 / hr / degree
- Road construction cost per mile
$ 41600 .00 / mile
- Cut volume / Ac
8 MBF ~ 15 MBF (10 MBF)

- % slope to be forwarded:
Uphill 0 ~ 15 % (5%)
Downhill 0 ~ 15 % (5%)
- Weigh of log load on forwarder:
18000 lbs
- Volume of Log Load
1.77 MBF
- Total # Log load
45

- Average distance move between log plies
20 ~ 40 ft
(30 ft)
- # of logs / grapple during off loading
6 logs

The result is optimum road spacing is 4464 ft to 4128 ft and Average machine cost is the rage of $ 8.39/MBF ~ $ 12.59/MBF. Therefore, AYD should be around 1116 ft to 1032 ft, and road spacing is 65.45sta./sec. to 67.53sta./sec.. This is much less road required to clear cut or thinning compare to the skidding and cable yarding. And also Forwarder make less impact for the soil. Unfortunately, forwarder is more cost on the machine rate; therefore, the total cost would increase. For example, the optimum total cost of the skidding is about $45/MBF, for the forwarder, it is about $51/MBF. Moreover, workers need more time to get used to use the Forwarder.

2.4.4 The Yarding cost of the Shovel and Highlead yarding system.

The yarding cost of the shovel and highlead yarding system is determined by the USFS flat rate method. The cost purposes, a production of 12 loads per day was assumed. Daily production equals 54 MBF , based on 4.5 MBF per truck load

Table 2-13-a , -b shows the USFS flat rate.

Table 2.13-a Cost and Production rate for Shovel yarding (from USFS flat rate method)

Production mbf/day	F&B $/mbf	Yarding&Load $/mbf	Gen. Expen. $/mbf	Equip. Dep. $/mbf	Total Cost $/mbf
<18	11.30				
18-26	9.55	38.65	18.70	22.90	89.80
27-37	8.75	27.45	13.00	15.75	64.95
38-48	8.75	20.35	10.10	11.55	50.75
49-59	**8.75**	**15.85**	**7.90**	**9.40**	**41.90**
60-70	8.75	13.15	6.65	7.85	36.40

Table 2.13-b Cost and Production rate for Highlead yarding (from USFS flat rate method)

Production mbf/day	F&B $/mbf	Yarding&Load $/mbf	Gen. Expen. $/mbf	Equip. Dep. $/mbf	Total Cost $/mbf
<25	9.55				
25 - 34	8.75	48.95	14.15	13.25	85.10
35-44	8.75	43.75	13.85	12.15	78.50
45-55	**8.75**	**41.15**	**13.30**	**11.55**	**74.75**
56-69	8.75	39.45	12.90	10.75	71.85
70-80	8.75	36.15	12.40	10.05	67.35

2.4.5 comparison of previous study.

We look at previous study of the harvest and transportation plan, to study them. Table 2.14 is the summary of the previous study.

Table 2.14 Comparison of current planning area characteristics with previous planning areas.

Planning Area Name.	BC 83 East	BC 83 South	HC 85	SC 88	SC 92	Eloch 93 mature	Eloch 93 re-gen	**** Eloch 93 total
Total Area Harvest (ac)	624	1029	2985	2850	1531	*1867.6	1507.7	3370.4
Total Volume Harvest (MMBF)	14.7	25.7	103.9	110	49.8	**92037	0	
Ave. Volume / Acre (MBF/Ac)	24	23.6	34.8	38.6	32.5	53.34	0	
Number of Setting landings	18	52	103	65	76	***94	84	
Ave. Setting Size (ac)	35	19	30	41	20.1	19.87	17.9	
Ave. Slope AYD (ft)	444	356	531	612	600	537.23	270	
Total Road Length (sta.)	282	333.9	826.2	1061	539	945.75	------	1425
Road density (sta./sec.)	290.5	208.7	177	240	225.5	290	------	271
Ideal Road density.								
Method 'A' (sta./sec.)	240	300	201	174	177	199	395	
Method 'B' (sta./sec.)	395	493	330	287	293	326	649	
Ratio of Real/Ideal								
Method 'A'	1.21	0.70	0.88	1.38	1.27	1.46	------	1.36
Method 'B'	0.74	0.42	0.54	0.84	0.77	0.89	------	0.83

BC : BEAVER CREEK (Elbe Hills)
HE : HECKLE CREEK
SC : SIOUXON COUGAR Mt.

*   Only fully matured setting
**   Only volume which on the setting
***   Total number of selected settings
**** The blank is the same as the mature stand

PS. The total length of the road is in the planning area. The border line's road is counted by half of its length. "Eloch 93 mature" only counted "use road" length. "Eloch 93 total" counted all existing road and use proposal road length.

Looking at this table, we know that center top yarder setting was more road required to connect the landings. Optimum AYD is about 350 ft with only a gradual increase in total cost up to about 550 ft. For the planning purposes the following guideline were adapted:

2.4.6 Machine cost evaluation

Machine Rate is depended upon both owning cost and operation cost. The equipment owning cost has several valuables such as Initial cost, Tax & license cost, and interest expense. The equipment performance such as fuel ,oil and lubrication, and crew wage are the operation cost. Moreover this dose not count any delay, therefore, Machine Rate will be increased by delay factor.

To find the machine rate with delays is determined by following equation.

Real machine rate = Ideal machine rate x machine availability.

The possible delays are listed by percent in the Table 2.15 harvest system & mechanical availability.

Table 2.15 Harvest system & mechanical availabilities

	System of use	% of delay	Machine Availability %
CAT Skidder System.	skid	10 - 15	90 - 85
	winch	17	77
Cable Yarding System	Running Skyline	31	69
	Live Skyline	14	86
	Highlead	14	86
Ground Based system		15 - 25	85 - 75

2.4.7 Planning Guideline for Settion Analysis

1) The overall average optimum AYD should be with in the 350 ~ 650 ft to satisfy the lowest total cost criterion. This would require an average road spacing of 914.8 ~ 1699 ft (304.8 ~ 164.1 sta/sec.), which is center setting method, or 556.4 ~1033 ft (501 ~ 269.8 sta/sec.), which is center top setting method.

2) When AYD become less than 275 ft, the road construction cost become increasing, therefore, if the setting less than 275 ft AYD, we should consider the alternative yarding system such as grand based skidding system.

3) When the ground condition required to use ground based system, the optimum AYD will be 1116 ft which is longer than the skidding system, therefore; If the ground-based system is allowed to use, we should consider using this system instead of using skidder system.

2.5 ROAD CONSTRUCTION AND HAUL COSTS

The road construction cost is depended on the side slpe, soil type, and management standard. More rock includes, more many required to construct roads. The cost is come from Bob Hoffman who is engneer of the Department of Natural Resources.

Table 2.16 Total construction costs per station of road for each slope class and construction type.

Cost / Station.

Side slope	Management std	common soil	Rip Rock	Shoot rock
<30%	optional	$931	$989	$1,317
30%-50%	optional	$1,111	$1,234	$1,886
>50%	optional	$1,344	$1,560	$3,043
<30%	required	$1,231	$1,371	$2,002
30%-50%	required	$1,553	$1,823	$3,103
>50%	required	$1,989	$2,443	$5,386

Variable road costs or haul rates were calculated from DNR road maintenance rates and timber hauling rates set by the Washington Sate Utility and Transportation Commission, 1987. The DNR flat rate for road maintenance of an existing road is now $1.00/mi/mbf.

The UTC rates are shown in table 2.12 for road classes A through E. Listed for each class are values for $/mi/1000 lb. and $/mi/mbf for the UTC rate. The last column includes the DNR's maintenance rate of $1.00/mi/mbf.

Table 2.17 Tariff rates (UTC) for different road classes.

Road Class	$/mile/1000 lb. UTC rate	$/mile/MBF UTC rate	$/mile/MBF (ARF of $1.00)
A	0.045	0.50	1.50
B	0.064	0.71	1.71
C	0.0.81	0.90	1.90
D	0.129	1.43	2.43
E	0.183	2.03	3.03

UTC rates are set for different classes. For example, Class B roads, having an unpaved surface (fine gravel surface, free of chuck holes) or grades >6% and <12%, have a charge of $0.064 per mile per 1000 pounds. Class C roads, having unpaved surface of grade >12% and <18%, have a charge of $0.81 per mile per 1000 pounds. It was estimated that a logging truck could carry 4.5 mbf of timber, equivalent to a payload of 50,000 pounds, Thus, a ratio of 0.09 mbf/1000 lbs was established.

Not included in the rate structure shown in the table above is the Base Rate per trip. However, since all trips are treated in the same fashion, this error is not significant.

LOGGING SPECS

TYPE OF MACHINES	90' tower slacline SKL and mainline highlead. Thunderbird 50-70' tower AYD1200' 1 ton carriage.
OUTPUT	8-10,000 lb. payload.
CABLE SIZE	plow steel 1 1/8 extra strength mainline, 7/8 haulback.
TAILHOLD HEIGHT	3' use North Bend to pull rig side ways.
BUCKING SPECS	use 40' logs.
TURN SIZES	3 logs
THINNING USAGE	20-25' spacing, dia depends on type of stand.
DOWN HILL YARDING	OK
LANDING SIZE	about 10 acres per landing, keep as small as possible, at least 2/3 of log on landing.

clearcut Hemlock stands.
fly across type 4 streams.
40-45,000 bdft to the acre, old growth up to 90,000 bdft.
4500 bdft per truck load, 12 logs per load, 18 to 20" DBH.
about 20 trucks per day.
ave production is 17-18 loads per day.

CHAPTER 3

3. THE PLANNING PROCESS

3.1 Programs Used in the Planning Process

Prior to our field investigation, and throughout the planning process we made extensive use of computerized planning tools and commercial software. Some of these programs include PC ARC/INFO, PLANS, SCHEDULER, NETWORK, and WINDOWS.

Preliminary Logging Analysis System (PLANS) is a program developed by the Cooperative for Forest-Systems Engineering (a partnership of the Forest Sevice and the University of Washington). PLANS is used in initail design to analyze cable harvest settings using specified yarding equipment.

PC ARC\INFO is a GIS system being used by the University of Washington Forest Engineering group for the second time in this project. (1990 & 91) It was developed by Environmental System Research Institute. It was used throughout the planning process to store, analyze and present cartographic data. The database files created by ARC\INFO can be exported directly into EXCEL or PARADOX .This allowed for easy exporting and importing of data for calculation outside of ARC\INFO. Once a database file has been exported to EXCEL or PARADOX do not put it back into ARC\INFO.

SCHEDULER, a program developed at the University of Washington. This program was used to develop a feasible harvest schedule based on adjacency, two period green-up requirement , and area and volume constraints. The resulting files were then exported to NETWORK.

The PC version of the program NETWORK was used for network analysis of possible log hauling routes.

Word processing and spreadsheet calculations were done using WINDOWS based products from Microsoft : WORD for word processing and EXCEL for a spreadsheet.

We used six computer stations. The Skagit (386, 33MHz)was mainly used for Arc/Info computations and plotting. The Snake (386, 20Mhz)was utilized primarily for digitizing information into PLANS and Arc/Info. The Snoqualmie (386, 20MHz) was mostly used for running LISA, as well as for word processing and spreadsheet calculations. The Snail (286 12MH) was used for plotting ARC/INFO plot files to keep Skagit free. The Chumstick (386, 16MHz), with its limited disk space, was used primarily for word processing and printing. The

SUSHI (486, 33 MHz) was the the work horse for the SCHEDULER and NETWORK runs.

3.1.1 PLANNING PROCESS FLOW

A flow chart showing the path of the project has been provided in Figure 3.1.1. The flow chart provides the computer program path and file path taken through the planning procedure.

3.2 The Planning Process - Resource Identification

3.2.1. Physical Resources

This category includes topography, water, climate, and slope. Topography has a profound effect on yarding systems and road costs. Climate affects yarding times and haul times as well as road construction practices and standards. These were all obtained from Arc/Info.

The following maps or information were either used or derived:

Contour map 1" = 400'. It formed the basis of the harvest unit and road layout work. This was plotted from ARC/INFO. The DEM was developed by scanning the originals.

Soil type map Scale of 1" = 400'. Generated from DNR's GIS data using ArcI/Info.

Stream type map Scale of 1" = 400'. The HYDRO layer from DNR's data was used for the planning process. This layer did not match the topography which was provided in ELOTOPO. Several field checks were made to verify this point. We found that the differences were severe enough that the cover could not be used to develope reliable stream slope data.

Existing road map Scale of 1" = 400'. This was derived from a Road's Cover provided by DNR from their Arc/Info system. The Bradley Mt. bike trail was digitized into ARC/INFO as best as possible based on a photocopy of a map from the DNR and added to the transportation cover.

Slope class map Scale of 1" = 1000'. This was plotted from ARC/INFO using the PCLASS2 cover. This map composition was then used divided into slope classes of 0 - 30%, 31 - 50% and 50% or greater. This became the basis for our yarding type selection, being ground based, highlead, and skyline yarding respectively.

3.2.2. Biological Resources

This category considered the timber resource, site index, and general vegetation pattern. Fish, wildlife concerns were also considered here. Proper timber resource assessment as it relates to species, volume/area tree size (volume/tree, diameter) and tree count (stem/area) are of crucial importance. Some of this information was recently added from a timber cruise this year. Yarding system selection, production and cost calculations are directly influenced by the reliability of the timber resource assessment.

> **Timber type map** Scale of 1" = 400'. Generated from DNR GIS POCAL data. The FIU's were checked against the photo coverage and the boundries matched up well. A new set of inventory data was received the first week of April. This information was added to the POCAL data base. 15 of 70 FIU,s were updated with this new information. The remaining FIU,s inventory data was obtained using the DNR,s yield tables westside.

3.2.3 Technical/Equipment Resources

This category considered equipment specifications, capabilities, costs and availability. To some degree the physical and biological resources would determine the type of equipment required. For example, on steep ground and/or critical soils that could suffer severe compaction and erosion, a cable system would be required. Based on technical information, numerous possible cable yarders were evaluated. Typically, a generic yarding system would be developed using information about locally used equipment as well as best available technology.

Information used and/or generated were:

- Equipment manufacturer's specification
  (refer to section 2.2.2)
- Production and cost estimation based on empirical/regression equations
  (refer to section 2.4)

The timber resource provided information for derivations of possible payloads for a given system. That in turn led to production and cost derivation for different equipment. The above "preparatory work" resulted in a:

1. Issues map which included slope class/danger zone map indicating areas of varying risks for locating either roads or landings.

2. Payload and yarding configuration to be used with the PLANS software. As part of PLANS the following tower specifications were used .

They are typical of towers used in S.W. Washington.

Yarding Tower: (TY90 - Live skyline)

Tower height	= 90 feet
Maximum slope rigging dist.	= 2500 feet
Desired payload	= 9000 lbs
Carriage weight	=1200 lbs
Minimum required ground clearance	= 15 feet
Carriage height (flying clear)	= 55 feet
Tailhold height	= 3 feet
Allowable skyline tension	= 53,300 lbs
Skyline weight	= 2.89 lbs\ft
Mainline weight	=1.43 lbs\ft

3.3. THE COMPUTER PLANNING PROCESS

3.3.1 DNR GIS DATA LAYERS

The planning area data set was received from the D.N.R. in february 1993. The data included the POCAL, TRANS, HYDRO, ELOTOPO,and SOILS G.I.S. data layers. Also received was a Digital Elevation Model (DEM). The geographic extent of the data was Township 9 North , Range 5 West and Township 8 North, Range 5 West W.M.

POCAL is the timber inventory and growth data combined with the D.N.R. Trust Boundries. TRANS is the transportation net showing all existing roads, HYDRO contains all the water information, ELOTOPO is the topography, and SOILS contains the soil information. The DEM is a three-dimensional representation of the planning area .

Each of the G.I.S covers contain multiple database files which are related to the parent coverage by system ID's within each database file. All related databases within each layer were joined together, based on the related item, using the JOINITEM command under the STARTERKIT module. This gave us one database for each G.I.S layer. The database files contained numerous items which were not attributed, these items were either dropped from the database or information was provided.

A master planning boundary was digitized using the ARCEDIT module. This boundary was the planning area known as Elochoman 'B'. CLP_COV included the planning boundry only. We then used CLP_COV as a "cookie cutter" to clip out the planning area from the D.N.R. data layers. Running ARC\INFO on PC introduces constraints on available memory and processing capabilities. By clipping only the information needed for the plan we were able to minimize processing time and conserve memory. By limiting the data to the planning area we were able to concentrate on relevant data and achieve a great amount of detail. This process gave us Hydro_clp, Trans_clp, and Soils_clp.

CLIPPER was another cover, created to clip an area larger than the planning boundry. This cover was used to clip the data layer ELOTOPO, which was then used to create the DEM for the planning area. CLIPPER was also used to clip data layers for data outside the planning area. This was useful when considering the transportation net, streams, and topography outside the planning area.

The data created using CLP_COV and CLIPPER was then backed up for later reference if needed. The harvest and transportation plan is based on this set of data.

The next step in the planning process was to combine the SETTINGS cover , provided from PLANS, with the RMZ cover and attribute the new SET_RMZ cover with volume by setting.

The SET_COV was overlayed with the RMZ_CLP using the UPDATE command in the ARC\INFO OVERLAY module to create SET_RMZ. If done properly this command performs a real clean "cut and paste." SET_RMZ was then overlayed with TIMBER using the INTERSECT command in the ARC\INFO OVERLAY module. This process created the TIM_DAT cover which had a very large number of polygons containing attributes from both databases. Befor the IDENTITY command is used the database items needed from TIMBER need to be multiplied by their respective acreage's, and be given a unique item name. The IDENTITY command in the ARC\INFO OVERLAY module was then used to calculate the geometrcic intersection of the two coverages. The FREQUNCY command was then used to sum the setting volume, DBH, and acres by setting number. The result of the FREQUENCY is a database file (PAT.DBF) attributed with setting volume, acres, AYD, and number. The JOIN command was then used from the ARC\INFO TABLES module to join SET_RMZ\ PAT.DBF with the new (PAT.DBF). SET_RMZ\PAT.DBF was then passed to EXCEL so the harvest could be calculated for SCHEDULER.

3.3.2 ARC\INFO covers (created for use with PLANS)

PCLASS2

OBJECTIVE: To create a data layer of the planning area that would give the slope class by 5% increments of any area within the planning boundry.

PROCEDURE: ELOTOPO was exported to a DNR workstation and was made into a TIN. The TIN was then made into a polygon coverage by using the LATTICE command to select slope information. This created polygons with a 100 ft. by 100 ft. resolution.Each polygon record contains the average side slope for a 1000 ft^2 polygon. This procedure needed to be done on a workstation due to the size of the files created and the processing time.

DEM (ARC\INFO, PLANS)

OBJECTIVE: To create a Digital Elevation Model of the planning area for use in PLANS.

PROCEDURE: This procedure also needed to be done on the DNR workstation. The TIN was made into a DTM using the LATTICE command by selecting on elevation information. The DTM created by ARC\INFO was then exported to PLANS using the IMPORT DEM Program. This program changes the file from ASCII to Binary code.

SYS5_COV

OBJECTIVE: To create a map cover to delineate slope classes 0 - 30%, 30 - 50%, and 50% or greater and assign a logging system capable of yarding within a specific slope class.

PROCEDURE: A slope map at 1:12,000 was plotted with the slope class breakdown shaded in different colors by the slope classes previously given. 0 - 30% was designated as tractive yarding, 31 - 50% as highlead yarding, and 51% and above as skyline yarding. We then outlined these classes on an overlay to divide the planning area into yarding systems by slope class. This overlay was then digitized using ARCEDIT. Sys5_cov overlayed with a topography map and timber age map became the basis for our settings design.

ISSUES_MAP

OBJECTIVE: To create a map which would show areas within the planning area which were of concern throughout the planning process.

PROCEDURE: The Issues map is a composition of five different covers which were plotted using the ARCPLOT module. Sens_cov delineates areas of steep slopes adjacent to water courses. It was created by overlaying the slope map with the hydro cover and digitizing the selected areas. Rmz_cov which shows the RMZ boundries within the planning area. Trans cover which shows the transportation routes by road class. Rec_cov which delineates a hiking trail,and Hydro which shows the water courses by stream type. All these covers were overlayed into one map composition.

3.4 The Planning Process

3.4.1 Landing Location and Setting Boundary Delineation

The PLANS program was used primarily for unit design at the beginning of this process.

First, using an imported DTM file from Arc/Info, we analyzed various single profiles that we could specify along with a yarder and payload parameter. These profiles were placed in areas where the ground is steep and uneven. Landings and tailholds were then placed on the profiles by PLANS. These were used to get a general idea about the locations of possible landings and unit boundaries.

Second, using a Thunderbird 90 yarder, we digitized potential landing locations and their corresponding unit boundary throughout our area. We chose landings that cover the most area and at the same time overlaps with other unit boundaries. Furthermore, we tried to cover as many areas as possible with the landings available.

We used the digitizer to locate and analyze the landings and the units they serve. We preferred the digitizer over the keyboard because we can go through the process more efficiently. This process was observed on the computer screen so draws, blind leads, ridges, etc. could be reached or avoided..

We could select the number of corridors to be analyzed for a given landing. We used 18 corridors for the SKYTOWER module and 10 corridors for the HIGHLEAD module.

Once we felt that a particular landing was sufficient and serves a desirable area, we copied the landing location and the external yarding boundary of the corresponding unit to a mylar sheet superimposed over our planning area. We numbered our landings from 001, 002, 003, and up as we digitized more landings. In this way, we were able to keep track of landing and unit locations. We also saved the landing and unit design to a file for future references. We used the filename conventions of #01_##. The first letter correspond to the type of logging system, the next two digits were incremented by one for each new landing.The last two digits represented the tower height.

Although our model yarder is a Thunderbird 90 with a 3 foot tailhold, we kept our options open for tailholds from a 3-foot up to a 20-foot to reach difficult terrain and to cover more area with the landings available. Our desired payload was 9000 lbs.

We then used the overlays and contour maps, both in 1" = 400', to peg in roads linking as many of our landings as possible. Sometimes we had to go back to plans to re digitize a landing that could not be reached by a road. We tried to move the landing to an area that could be reached with a road and still cover adequate area. We also looked at the possibility of downhill yarding to make our landings accessible. If a landing could not be reached the landing was droppped and its adjacent landings were adjusted to encompass the new area. After all road linkage possibilities were considered, we removed the overlap between settings by aligning the boundries along natural topography features, water courses, RMZ's, etc. The setting boundries and landings were then digitized using ARC/INFO.

The planning area included two distinct age classes. Plantation, age 2 - 20 years, and mature, age > 40 years. Care was taken that a particular setting or skyline corridor did not cross into a distinctly different age class.

Good landing locations typically are on ridges, along slope breaks and other areas that allow good deflection as well as adequate landing space. Downhill yarding was only acceptable if the landing was on a gentle slope or if it allowed enough area to land the turns.

The settings are summarized in Tables 3.1. - 3.3 Setting size ranges from 8.24 to 48.31 acres. The setting numbers are divided into three groups. The 100 series are ground systems, the 200 series are Highlead systems, and the 300 series are Skyline systems.

3.4.2.   PLANS RESULTS

Presented below is each setting within the re-gen timber and their related database items.

.Table 3.3.1 Setting

Legend: System 1 = Tractive yarding ground
System 2 = Highlied yarding ground
System 3 = Skyline yarding ground

SET_NO	SYS	ACRES	SET_VOL	vol/ac	AYD	UNIT_NO
4002	1	7.4	0	0	250.00	5001
4003	3	13.6	0	0	550.00	5001
4006	3	24.7	0	0	600.00	5001
4166	1	11.2	0	0	550.00	5001
4004	3	10.1	0	0	550.00	5002
4005	3	18.9	2	0	600.00	5002
4008	3	10.5	0	0	550.00	5002
4165	3	7.7	5	1	550.00	5002
4007	3	20.7	0	0	600.00	5003
4010	3	36.7	0	0	600.00	5003
4015	3	12.8	5	0	550.00	5003

4009	1	6.2	0	0	250.00	5004
4013	2	34.6	0	0	600.00	5004
4019	2	18.5	0	0	550.00	5004
4016	3	26.0	406	16	250.00	5008
4020	3	19.6	47	2	550.00	5008
4027	3	14.5	15	1	600.00	5008
4030	3	12.5	0	0	550.00	5008
4049	3	7.3	55	8	250.00	5011
4050	3	7.5	0	0	550.00	5011
4052	3	5.6	0	0	550.00	5011
4174	3	17.5	0	0	600.00	5011
4175	2	34.0	0	0	250.00	5011
4037	3	7.2	0	0	550.00	5012
4042	1	7.5	0	0	250.00	5012
4044	3	15.0	0	0	250.00	5012
4047	3	28.9	0	0	600.00	5012
4170	1	14.8	0	0	250.00	5012
4029	3	24.1	0	0	600.00	5013
4031	3	2.8	0	0	250.00	5013
4038	3	16.9	0	0	250.00	5013
4045	1	3.2	3	1	250.00	5013
4167	1	18.7	0	0	550.00	5016
4168	1	28.5	0	0	250.00	5016
4171	3	3.7	0	0	550.00	5016
4051	1	18.2	0	0	250.00	5017
4054	1	1.8	0	0	250.00	5017
4055	1	22.6	0	0	600.00	5017
4058	2	11.9	0	0	600.00	5017
4169	3	12.0	0	0	250.00	5017
4056	2	31.8	0	0	900.00	5018
4172	3	12.4	0	0	250.00	5018
4173	3	19.6	0	0	600.00	5018
4059	3	11.2	0	0	550.00	5019
4063	2	11.9	0	0	900.00	5019
4065	3	16.0	5	0	550.00	5019
4071	2	12.1	23	2	900.00	5019
4077	2	3.6	11	3	600.00	5019
4079	2	2.6	155	60	550.00	5019
4062	2	22.7	0	0	600.00	5029
4064	2	8.7	0	0	600.00	5029
4067	2	10.0	0	0	550.00	5029
4072	2	11.2	0	0	250.00	5029
4075	1	36.5	29	1	550.00	5029
4094	2	27.0	0	0	250.00	5031
4102	2	22.8	0	0	600.00	5031
4110	1	21.2	17	1	600.00	5031

4133	3	8.7	0	0	600.00	5042
4136	3	11.6	0	0	250.00	5042
4141	3	12.9	325	25	550.00	5042
4143	1	12.8	655	51	550.00	5043
4144	1	10.0	287	29	550.00	5043
4152	3	33.7	1112	33	600.00	5043
4176	3	26.6	420	16	600.00	5045
4177	3	43.6	201	5	550.00	5045
4155	3	19.2	530	28	600.00	5046
4160	2	20.9	105	5	600.00	5046
4154	2	16.6	545	33	250.00	5047
4156	2	27.5	30	1	600.00	5047
4130	1	39.8	187	5	550.00	5048
4137	2	20.4	188	9	600.00	5048
4147	1	11.6	12	1	250.00	5048
4151	2	8.1	0	0	550.00	5048
4135	1	43.6	1356	31	600.00	5049
4139	2	26.8	0	0	550.00	5049
4126	2	40.8	2558	63	600.00	5050
4128	1	17.3	1220	71	600.00	5050
4146	2	56.0	0	0	550.00	5051
4153	2	30.4	106	3	250.00	5051
4158	1	18.0	83	5	550.00	5052
4161	2	9.9	244	25	900.00	5052
4163	2	24.3	484	20	600.00	5052
4164	2	19.4	501	26	550.00	5052

total	1507.7	22650.00
average	17.9	270

Number of setting = 84

Number of units 24

Presented below is each setting within the mature timber and its related database
items.

Table:3.3.2 setting data
Legend:

System 1 = Tractive yarding ground
System 2 = Highlied yarding ground
System 3 = Skyline yarding ground

SET_NO	UNIT_NO	SYS	ACRES	VOL/AC	SET_VOL	AYD	HARV_CO
4011	5007	1	26.6	83.8	2229	550	70.85
4012	5006	3	30.7	60.7	1864	600	84.14
4014	5006	1	15.6	52.8	824	550	111.14
4017	5005	3	14.3	59.3	848	600	97.37
4018	5014	1	7.5	102.7	770	250	43.27
4021	5005	3	18.9	55.3	1045	550	95.52
4022	5007	1	13.4	80.0	1072	550	60.13
4023	5014	3	19.3	87.9	1697	550	53.45
4024	5007	3	12.6	45.9	578	550	129.89
4025	5005	3	26.7	47.0	1255	600	131.97
4026	5014	3	12.4	73.3	909	550	53.62
4028	5009	3	12.8	45.6	584	550	152.19
4032	5015	3	1.7	105.9	180	600	42.60
4033	5009	1	34.1	55.1	1879	900	109.09
4034	5015	3	8.4	38.2	321	250	38.06
4035	5015	3	5.5	35.3	194	250	52.24
4036	5009	3	8.5	49.2	418	900	144.62
4039	5009	1	16.6	55.4	920	250	83.90
4040	5015	1	1.3	40.8	53	550	42.14
4041	5015	1	6.9	39.9	275	550	41.75
4043	5009	3	5.3	55.1	292	250	83.90
4046	5010	3	23.5	53.3	1253	600	113.15
4048	5009	3	3.1	56.8	176	600	97.43
4053	5010	3	19.8	50.7	1004	550	129.74
4057	5010	3	16.0	55.6	890	600	113.09
4060	5020	2	38.3	57.1	2187	550	95.48
4061	5020	2	32.5	53.1	1726	550	111.13
4066	5021	1	12.7	59.8	760	250	71.14
4068	5030	2	8.0	122.6	981	550	134.68
4069	5022	1	5.7	66.7	380	550	61.67
4070	5030	1	32.4	30.0	972	550	112.19
4073	5025	3	26.2	56.3	1475	600	113.08
4074	5021	1	42.0	50.5	2121	550	95.65
4076	5025	1	11.0	59.7	657	600	97.36

4078	5022	1	9.2	69.5	639	600	55.35
4080	5027	1	13.4	58.8	788	250	83.82
4081	5028	2	18.1	60.4	1093	250	83.92
4082	5026	1	31.4	54.3	1705	250	83.92
4083	5025	1	5.7	58.9	336	550	82.32
4084	5025	1	34.4	49.7	1710	550	82.55
4085	5022	1	13.3	69.7	927	600	55.34
4086	5021	1	20.2	49.9	1008	250	71.38
4087	5028	2	19.4	43.4	842	600	181.74
4088	5026	1	9.8	48.9	479	550	95.70
4089	5022	1	18.3	69.7	1276	600	48.60
4090	5028	2	19.6	57.6	1129	550	111.03
4091	5027	1	7.2	57.9	417	250	83.84
4092	5026	1	15.8	49.4	781	550	82.56
4093	5026	1	29.4	49.6	1458	550	71.45
4095	5027	1	31.8	47.8	1520	550	82.61
4096	5024	1	5.9	70.5	416	900	58.36
4097	5022	1	14.8	55.1	816	600	55.62
4098	5028	2	17.6	47.5	836	600	154.36
4099	5024	1	40.0	55.8	2232	250	43.86
4100	5032	1	21.4	49.6	1061	550	82.55
4101	5033	1	34.2	49.9	1707	550	71.44
4103	5039	2	44.7	58.2	2602	600	48.80
4104	5023	1	17.7	93.7	1659	600	63.52
4105	5033	3	20.7	47.9	992	600	73.29
4106	5032	1	7.2	56.4	406	900	125.21
4107	5024	2	16.2	49.2	797	600	63.79
4108	5023	1	11.4	61.3	699	600	63.49
4109	5032	1	37.8	49.8	1882	250	60.68
4111	5038	1	17.7	54.1	958	550	82.43
4112	5039	1	12.6	59.4	748	900	58.55
4113	5033	1	2.6	49.2	128	600	84.42
4114	5023	1	21.9	55.5	1215	550	111.07
4115	5040	2	33.0	54.8	1808	550	95.54
4116	5023	1	23.2	60.0	1392	250	83.80
4117	5034	2	19.4	46.9	910	600	84.50
4118	5040	2	16.2	60.1	974	600	55.51
4119	5038	1	10.3	53.0	546	600	73.15
4120	5038	1	10.8	50.7	548	600	63.74
4121	5041	1	15.3	53.2	814	550	53.99
4122	5035	2	28.4	55.8	1585	550	111.07
4123	5037	2	25.2	28.9	728	550	130.18
4124	5038	3	21.10	32.6	688	550	255.94
4125	5034	1	58.2	46.6	2712	600	97.71
4127	5041	1	15.3	62.0	949	600	43.09
4129	5054	3	9.3	39.1	364	600	73.63

4131	5041	1	12.8	33.1	424	550	130.50
4132	5037	2	32.1	19.5	626	550	214.98
4134	5035	2	41.8	40.5	1693	550	213.10
4138	5041	1	15.0	60.0	900	600	55.51
4140	5054	3	14.2	19.1	271	600	217.56
4142	5037	1	14.1	39.9	563	600	64.13
4145	5054	3	17.0	34.9	593	550	83.17
4148	5037	1	9.4	40.7	383	600	64.09
4149	5036	1	25.2	38.7	975	600	150.00
4150	5041	1	7.6	60.5	460	550	47.13
4157	5036	1	44.3	38.7	1714	600	150.00
4159	5044	2	30.3	16.0	485	600	100.00
4162	5053	1	99.7	7.4	738	0	287.44
4178	5044	2	6.7	21.3	143	600	200.00
Total			1867.60	5014.4	92037.0	5050	8924.66
Average			19.86	53.34	979.1	537.2	94.94

# of settings = 94

# of unit = 31

3.4.3 ROAD SYSTEMS DEVELOPMENT

Once the total planning area was accessed by landings and overlapping unit boundaries the process of route development and unit boundary assignment began.

Paper road locations were typically "pegged" in by hand with a pair of dividers. If possible more than one road link was established to a landing. The objective of this road location process was to establish as many road links as possible including access on difficult slopes. The selection of the optimal road network was then carried out in a separate process through the network analysis.

In the road location process, landings were identified by Point feature. Nodes were then assigned at road intersections and changes from one slope category to another (e.g., 30-50% to 50-70%). Longview was the only mill location or destination for the network system.

The Arc/Info program was then used to find the road construction and road haul costs. The roads were broken up into different cost segments by nodes, then each arc was attributed a grade, side slope class and a culvert cost (where needed). The haul cost was a given UTC rate depending on the type of road (see chapter 2). Once the roads were attributed, ARC/INFO calculated the distance between nodes so that the haul cost and construction costs could be found for each road segment. These values were then used as input for NETWORK analysis.

General road design specifications were as follows:

Adverse: 12% max.
16 for short distances with good alignment
6% for steep draws, before bridges, etc

Favorable: 12% max.
18 % for short distances with good alignment
8% for steep draws, before bridges, etc.

Roads into/out of landings: 5% for 100 to 150 feet.

3.4.4 Arc/Info

The next step in the process was digitizing features Settings and roads into Arc/Info. We created a cover for our settings and used polygons to define the boundaries of each setting. Label points were then assigned to each polygon and attributes were added to these labels. Another cover was created for roads.

The new roads were digitized from the pegged routes. A node defines the beginning and ending of an arc. Nodes were also placed on intersections and junctions as well as to points where values will change for a certain feature like, say, construction costs for a certain arc changing because of change in sideslopes and grades. These covers were then cleaned up and built to smooth out the lines and polygons. This allowed us to run queries and highlight possible harvest schedules and extract pertinent information such as volume and acreage per harvest period.

3.5 HARVEST SCHEDULING AND NETWORK ANALYSIS

3.5.1. The SCHEDULER Program

The SCHEDULER program generates a long range harvest schedule through a random search algorithm. Several harvest schedules are generated and the information can be entered into ARC\INFO through the program command UPDATE.Several harvest schedules can be created by running the program with different random number seeds for the desired number of solutions. Sensitivity analysis can be done to determine the best harvest schedule which gives the best return.

The program requires two data files for determining the harvest schedule and creates a data file for input into NETWORK.

Data file #1 contains information for individual settings . Each data line contains.

File # 1

Setting ID	Area of Setting	Harvest Cost $/MBF	Timber Volume (MBF)
4165	7.70	21.60	153

The file format requires the **setting ID** and the **timber volume** to be **intergers** while the **harvest cost** and **acres** to be **real numbers with two decimal places**.

Data file #2 can be divided into four sections:

- -Section one contains the number of units included in that sale
- -Section two the sale ID number, number of settings in the sale and setting ID number
- -Section three contains information about sales adjacent and adjacency requirements.

-Section four contains information regarding restricting a sale or sales to a specific period.
-Section four was not used since we did not restrict a sale to a specific period.

The specific scheduling constraints used for the planning area are as follows:

No single or contiguous harvest units were allowed to exceed 100 acres in total size. An adjacency of two periods was required. In effect it meant that adjacent units to a current clearcut could not be harvested in the same or following period. A period is defined as three years based on the assumptions that the planning area had to be treated within a thirty-year period (the SCHEDULER is currently restricted to 10 time periods). The net effect of a one-period adjacency is that within a period a sale can effectively be scheduled for harvest in any one of the three years. The minimal adjacency would therefore be three years, the maximum adjacency could be seven years with a mid point range of five years. Six sets of seed numbers were run for ten time periods for sixty possible solutions. The best solution is the one with the best present net value. This file now becomes the sales file for NETWORK.

3.6 The NETWORK Program

This NETWORK program allows possible road combinations and harvest schedules to be analyzed in terms of present value costs. In large area harvest planning, this program is an aid in selecting the most cost efficient road network based on a given harvest schedule (developed under the SCHEDULER).

Once the sale boundaries and possible road segments were determined, the Network software package was used to help determine the most cost efficient road system using all exsisting and proposed roads.
Road data is entered in the form of individual road segments or "links". Network considers fixed and variable costs of each road link when analyzing a possible road network combination. Variable cost is the haul cost and is expressed in terms of dollars per unit volume of timber passing over the road link. This cost will primarily be a road maintenance cost, and will generally be a function of the link's length, and average grade. Fixed costs are the road construction costs and generally vary with respect to such factors as side slope, slope stability, soil type, drainage, borrow and end-haul quantities. The fixed cost is input in terms of dollars for each link. This file is the road network file form ARC\INFO, it's format is as follows.

File # 1 (Road Link File)

Link Round Trip Construction

Identifier (from)	(to)	Haul Cost ($ / Truck / Link)	Cost ($ / Link)

The sales file from SCHEDULER is file #2 for input into NETWORK. It contains the volume harvested by setting and unit for each period together with its destination. The sales file format is as follows.

File # 2 (Scheduler Sales File)

Settings #	Destination #	Harvest Volume (MBF)	Year
4178	10000	6200	0

The output from NETWORK output file contains volume per road link and has the following format.

File # 1 (Volume summary by road link)

Link Identifier (From)	(To)	Accumulated Volume Over Link (MBF)
1	2	848

3.6.1 Automating the use of Scheduler and Network with ARC/INFO

As has been previously mentioned, PC ARC/INFO was employed as the geographic information data base, passing information from graphic to digital form (through digitizing) and from digital to graphic through map production. The abilities provided by the programs SML (Simple Macro Language) utility alow the user to go beyond simply manipulating spacial data internally and begin to pass data, in digital format, to and from external programs thus utilizing the GIS program as a data "toolbox". An example of this process is the methods used to perform the Harvest Schedule analysis for planning area. The basic function of both the SCHEDULE and NETWORK programs has been described previously, but the procedure for producing input files for and output maps from these programs has been, or can be automated through the use of ARC/INFO SML's. A copy of the SML used to produce maps from NETWORK Report files is included in appendix 6 and a discussion of the data provided is in chapter 6.

Chapter 4

4. Road Reconnaissance

4.1 Introduction

The following reconnaissance reports are based on field data collected during road layout in Kelso. Included are roads recommended as feasible as well as any alternative routes, and routes which were attempted and deemed a failure.

Before the field work was done, field recon maps were prepared in the office The proposed road location, proposed grade, and the proposed station length for the different grades were printed on each map. The final roads that are proposed on the following pages tie in with roads on the field recon maps. The enclosed road descriptions represent exact final loccation of those roads.

As a rule, the following data was recorded during road recons: distance and stationing by pacing or string chain, clinometer readings for grade/grade lines, direction using hand compass, and side slopes taken every station to the left and right of grade line

The above information was recorded in the field and then entered back in the office/hotel into ARC/INFO ROADRECON layers.

The standard practice for flagging included ribbons every 50 feet, or so you can see one or two ahead. If a road location was picked for final location, it was blazed and painted, and labeled every station with aluminium tags stating road number, grade, distance and date.

With great excitement we jumped into the field. It might be noted that we now have a better feel for the planning area then the unit foresters. Almost all road systems within the area were either visited by foot, tire or tire+chain.

Table 4.1.1 showing Road Type lengths

Road Type	Total Length(mi)
Existing	47.7
proposed/paper plan	17.5
Recon/filed verified	10.2

We planned 17.5 miles of road, and field verified 10.2 miles of that total. These included critical mainline roads and areas of stability concern. Spurs and small obviously straight forward road segments were visually or office checked.

Road Name: 7300 Take-Off **Tagged by:** Peter and Karen

Road #: 7300 **Stations :** 16+10

Takes off from: Existing landing at end of 7300 road

Terminates: At station 16 + 10, a potential landing location

Other Junctions: None

Settings Accessed: 4012 and 4014

Status: Blazed

Soils: Cathlamet (24, 25, 26)*

Side Slopes:

left 0 - 35%
right 0 - 30%

Grades:

0 + 00	to	2 + 50	0 - 3%
2 + 50	to	3 + 75	3 - 10%
3 + 75	to	8 + 50	10%
8 + 50	to	16 + 10	5%

Stream Crossings:

First creek crossing is at station 4 + 00, need 10 ft fill. Second creek crossing is between station 7 + 00 and 8 + 00. To the east of station 5 + 50 at 70 degrees and 75 ft is a wet area we avoided for road location.

Switchbacks: None

Comments:

The original paper plan for this road tied into the 3000 road to the west. This original tie-in was deleted. The area west of the now blazed road was questionable because of steep sideslopes (60+), generally wet, moist soils, and deep (4+ ft deep).

When trying to connect from the 3000 road to the 7300 road, a knife ridge between two creeks prevented the road connection. The 3000 road ends in split spurs. A landing located on one of these splits could be used to reach the area between the two road ends.

*United States Department of Agriculture and Soil Conservation Service, 1986. Soil Survey of Grays Harbor County Area, Pacific County, and Wahkiakum County, Washington.

Road Name: Bridge B **Tagged by:** Karen, Rick, and Toshi

Road #: 1010 **Stations :** 20+30

Takes off from: Switchback center ties into road #1000 that Peter, Scott, and Andreas put in the same day

Terminates: Station 20 + 30 connects to station 5 + 10 of notes we lost. (! they may be in the couches of Room 243 at the Best Western in Longview) This road terminates at a spur off the 2000 road (

Other Junctions: Road #1011 Yahoo Pink Spur to left at station 9 + 15.

Settings Accessed: 4145 and 4140. (From spur 1011 off the 1010, settings 4148 and 4142).

Status: Blazed

Soils: Germany (40,41,42).*

Side Slopes:

left	0 + 00 to 7 + 15	30 - 65%
	7 + 15 to 11 + 25	0 - 5%
	11 + 25 to 20 + 30	30 - 50%
right	0 + 00 to 7 + 15	30 - 55%
	7 + 15 to 12 + 25	5 - 20%
	12 + 25 to 20 + 30	30 - 45

Grades:

0 + 00 to 8 + 40	-12%
8 + 40 to 20 + 30	-13%

Stream Crossings:

Station 12 + 00, needs culvert

Switchbacks: At the end of the road segment is a switchback - ties into the 1000 road.

Comments:

The GIS maps shows the end of the existing spur road crossing a creek (NW 1/4, SE 1/4 Section 27). It actually doesn't so the road layout is for a bridge or large culvert to cross the creek. This section "terminates" at a switchback where it ties into the road Peter, Scott and Andreas put in. This is also near the proposed location for a new **rock pit**.

This section of road could serve as a connector between the 1000 and the 2000 depending on what settings to access and which haul route is desired.

Road Name: Karen Road **Tagged by:** Rick, Scott, and Karen

Road #: 3200 **Staions :** 33+00

Takes off from: Spur right off road #2100 and ties into the 3200 road.

Terminates: Station 29 + 80 ties into the 3200 road.

Other Junctions: Spur left, #3201 (Screamer!)

Settings Accessed: 4115 and 4140. (From road 3201 setting 4103)

Status: Blazed

Soils: Cathlamet (24, 25, 26).*

Side Slopes:

left	0 - 30%	
right	0 + 00 to 7 + 75	30 - 55%
	7 + 75 to 29 + 80	0 - 30%

Grades:
This road begins off the 2100 road going north

0 + 00 to 4 + 80	8%	
4 + 80 to 8 + 90	-12%	
8 + 90 to 10 + 50	4%	
10 + 50 to 11 + 35	-8%	ties into Toshi and Peter's road notes coming from the opposite direction (south).

This road begins off the landing on the 3200 road (NE 1/4, SE 1/4 Section 21)

0 + 00 to 6 + 75	-8%	
6 + 75 to 12 + 80	2%	
12 + 80 to 15 + 00	-2%	
15 + 00 to 21 + 60	8%	ties into station 11 + 35 of 'Karen' road

Stream Crossings: None
Switchbacks: None

Comments:

Between stations 0 + 00 and 6 + 95 are small bowls below the road location that looked like it had slide potential. We purposely located the road out of these bowls because of that potential. At station 8 + 40 is a 16th corner marker that says: T9N R5W E16 SEC 28. It is approximately 35 ft AZ 150 degrees from the station to the corner marker. From the corner to station 7 + 75 is AZ 232 degrees.

This road is a connector between the 3200 and the 2000. The middle portion may not be needed depending on which settings you want to access.

Road Name: Cinco Road **Tagged by:** Karen, Toshi, Andreas and Peter

Road #: 3250 **Stations :** 27+08

Takes off from: The 3200 road (NE 1/4, SE 1/4 Section 15)

Terminates: At the 5000 road (SE 1/4, SE 1/4 Section 15)

Other Junctions: At station 18 + 09 road #3251 takes off to tie into spur road #3252
At station 27 + 08 this road ties into the railroad grade road #5000.

Settings Accessed: 4073

Status: Blazed

Soils: Cathlamet (24, 25, 26) and Germany (40, 41, 42).*

Side Slopes:
left 0 - 30%
right 0 - 30%

Grades:

0 + 00	to	9 + 61	15%
9 + 61	to	13 + 34	10%
13 + 34	to	15 + 33	-4%
15 + 33	to	24 + 42	6% average
24 + 42	to	27 + 08	-6% average

Stream Crossings: None

Switchbacks:
At station 16 + 76 is the beginning, station19 + 76 is end of the switchback.

Comments:

Depending on the access route to get to setting 4073, the first 1800 feet of the 3250 may not need to be constructed. The landing for setting 4073 could be accessed fromthe 5000 road, either with 3250 or 3251 (w/o switchback), again depending on the exit route of the trucks.

The separation of the 3250 from the 3200 was difficult and needed a 15% grade to get away.

This road is also a connector between the 3200 an the 5000. This gives a faster haul route out to Elochoman River rather than going all the way around on the 5000 road.

Road Name: Alternate Route **Tagged by:** Peter, Toshi and Karen

Road #: 3251 **Stations :** 9+55

Takes off from: The 3252 road heading north then east.

Terminates: At the 3250 road connecting into the switchback at station 18 + 09

Other Junctions: None.

Settings Accessed: 4083

Status: Blazed

Soils: Cathlamet (24, 25, 26) and Germany (40, 41, 42).*

Side Slopes:

left	0 + 00 to 1 + 69	0 - 15%
	1 + 69 to 3 + 34	30 - 45%
	3 + 34 to 9 + 55	0 - 30%
right	0 + 00 to 8 + 32	0 - 30%
	8 + 32 to 9 + 55	45%

Grades:

0 + 00 to 0 + 79	0 to 10%
0 + 79 to 1 + 69	0%
1 + 69 to 3 + 70	-10%
3 + 70 to 4 + 69	0%
4 + 69 to 9 + 55	-5% average

Stream Crossings: None

Switchbacks: None.

Comments:

An alternate route for this road to tie into the 5000 road is the 3250. Construction of one or the other road will depend on the exit route of the trucks.

Road Name: Knot-head **Tagged by:** Karen and Scott

Road #: 3221 **Stations :** 10+95

Takes off from: Near the end of the 3210 road.

Terminates: At station 3 + 06 of the 3273 road.

Other Junctions: At station 5 + 70 of 3221, the Bummer road begins, heading north.

Settings Accessed: 4028. (From 3222 spur, setting 4021).

Status: Blazed

Soils: Cathlamet (24, 25, 26).*

Side Slopes:

left	0 + 00 to 5 + 70	0 - 30%
	5 + 70 to 9 + 70	30 - 50%
	9 + 70 to 10 + 95	0 - 30%
right	0 + 00 to 5 + 70	0 - 30%
	5 + 70 to 9 + 70	30 - 60%
	9 + 70 to 10 + 95	0 - 30%

Grades:

0 + 00 to 6 + 70	8% average
6 + 70 to 10 + 95	15%

Stream Crossings: Creek crossings at station 7 + 35 and 9 + 85

Switchbacks: None.

Comments:

At station 6 + 20, a bench is noted 50 - 100 feet downslope. A switchback cannot be located at the connection with the Knot-head because side-slopes are too steep and is also a wet area. Excavation would be major to put a turn there. A shoe-fly was also considered, but there wasn't enough room and also would have been located in the wet soil.

This serves as a connector between the 3210 and 7300. Depending on the settings to access or which haul route desired, determines if this road section will be built.

Road Name: Yahoo Pink Spur **Tagged by:** Rick and Karen

Road #: 1011 **Stations :** 5+65

Takes off from: At station 9 + 15 of the 1010 road this spur takes off NE.

Terminates: At landing location station 5 + 65.

Other Junctions: None.

Settings Accessed: 4148 and 4142

Status: Blazed to end of traverse.

Soils: Germany (40, 41, 42).*

Side Slopes:
left 0 - 30%
right 0 - 30%

Grades:
0 + 00 to 5 + 65 -2%

Stream Crossings:
Creek at station 1 + 60: 20 ft wide, wet and mushy. Needs culvert.

Switchbacks: None.

Comments:
Another landing location is possible due east about 600 ft. There is a large wet area between the now proposed landing location and the other possible location. Depending on the buffer requirements desired, one or the other landing location is possible.

Road Name: Bradley Spur One **Tagged by:** Rick, Karen and Scott

Road #: 1050 **Stations :** 28+40

Takes off from: The Bradley Truck Trail in the NW 1/4 of Section 23.

Terminates: At landing location station 28 + 40.

Other Junctions: None.

Settings Accessed: 4089, 4096, 4099, and 4107

Status: Proposed road flagged. Old rail road grade

Soils: Runs along a soil line between Raught (122, 123, 124) and Germany (40, 41, 42).*

Side Slopes:
Side-slopes were not recorded because the ridge the spur was located on was wide enough to make side-slope insignificant.

Grades:
0 + 00 to 28 + 40 ranging from -11% to 5% running along the ridge.

Stream Crossings: None
Switchbacks: None.

Comments:
Followed an old railroad spur to station 4 + 85 where it ended. Continued past it along the same ridge line. Discovered another RR grade around station 12 + 95 that we may have been parallelling, but did not use. It wasn't located along the north edge of the ridge were we wanted the road to be. It would be just as expensive to rebuild the old RR grade as it will be to reconsruct the new location. The new location is in better side-slope ground (flat vs steeper).

Road Name: Bradley Spur Two **Tagged by:** Rick, Karen and Scott

Road #: 1060 **Stations :** 20+75

Takes off from: The Bradley Truck Trail in the NW 1/4 of Section 23.

Terminates: At landing location station 20 + 75.

Other Junctions: None.

Settings Accessed: 4104, 4097, 4108, and 4099

Status: Proposed road flagged.

Soils: Begins in Germany (40, 41, 42) soils, goes through a bit of Raught (122, 123, 124) and terminates in Stimson (138).*

Side Slopes:
At beginning of spur at station 2 + 40 ss left is -50% and ss right is 0%. From then on is basically a free alignment along the ridge with insignificant side-slopes.

Grades:
0 + 00 to 20 + 75 ranging from -10% to 10% running along the ridge.

Stream Crossings: None
Switchbacks: None.

Comments:
At station 18 + 85 a couple metal tag type signs were grown into a few trees. The tags had PL engrossed on them, probably from Crown Z land exchange (old property line location).

Road Name: **Tagged by:** Karen and Peter

Road #: 7010 **Stations :** 6+45

Takes off from: .The 7000 road.

Terminates: .At existing landing

Other Junctions: None.

Settings Accessed: 4165 and 4166

Status: Drivable Existing Road.

Soils: Cathlamet (24, 25, 26).

Side Slopes: None recorded, the road is already drivable.

Grades:

0 + 00 to 4 + 60	15%
4 + 60 to 6 + 45	-8%

Stream Crossings: None
Switchbacks: None.

Comments:

The grade coming out of the landing is severe at 15% (adverse).

Road Name: **Tagged by:** Karen and Peter

Road #: 7015 **Stations :** 4+50

Takes off from: .The 7000 road.

Terminates: .At what used to be a landing.

Other Junctions: None.

Settings Accessed: 4003

Status: Existing Road **-** put to bed. Needs to be brushed or sprayed **NOW** before the alder gets too established in the road bed. The alder are about 25 feet tall. The road is rocked with basalt.

Soils: Cathlamet (24, 25, 26).

Side Slopes: None recorded.

Grades:

0 + 00	to	2 + 00	15%
2 + 00	to	4 + 50	3%

Stream Crossings: None
Switchbacks: None.

Comments:

The alder needs to be cut very soon!

Road Name: Cool **Tagged by:** Scott and Rick

Road #: 3270 **Stations :** 38+78

Takes off from: E7050.

Terminates: At station 38 + 78 at an optional landing

Other Junctions: Spur 3273 and spur 3275 at station 16 + 93
Spur 3271 at station 3 + 35

Settings Accessed: 4025, 4028, 4036, and 4043

Status: Blazed to station 21 + 38. Flagged from station 21 + 38 to 38 + 78.

Soils: Cathlamet (24, 25, 26).

Side Slopes: 0 to 45%

Grades:

0 + 00 to	14 + 28	-10 to 10%	
14 + 28 to	16 + 93	-10%	(rolls near slope break)
16 + 93 to	38 + 78	5%	(rolls near slope break)

Stream Crossings: Station 17 + 28. five feet wide channel, 10 ft cut, 48" culvert.
Station 19 + 00
Station 22 + 30 24" culvert
Station 26 + 93
Station 33 + 43

Switchbacks: None.

Comments:

The original plan was to tie down to 3240, but where we planned to tie in, the 3240 road didn't exist (it existed on paper, but not on the ground). Other attempts to tie in further west failed because of steep slopes above the 3240, and the grade would have to drop at 16%+ to tie in.

Road Name: Cedar and Pinner **Tagged by:** Scott and Rick

Road #: 3273 **Stations :** 23+80

Takes off from: The 7040.

Terminates: At station 16 + 93 of the 3270

Other Junctions: At station 10 + 95 of the 3221 (Knot-head) to the 3 + 06 of the Cedar.

Settings Accessed: 4019 and 4021

Status: .Blazed

Soils: Cathlamet (24, 25, 26).

Side Slopes:

left	0 - 45%
right	0 - 45%

Grades:

Cedar:			
0 + 00	to	2 + 76	0%
2 + 76	to	8 + 44	8 - 12%
Pinner			
0 + 00	to	4 + 00	5%
4 + 00	to	8 + 00	0%
8 + 00	to	11 + 00	-5%
11+ 00	to	15 + 36	5%

Stream Crossings: Station 4 + 51 (of the Cedar)
Station 10 + 00 (of the Pinner)

Switchbacks: At station 2 + 16 of the Cedar and station 0 + 00 of the Pinner (this is the same location on the ground) the switchback goes with the Pinner.

Comments:

Road is used mostly as a connector between 3270 and 7040. On the following page is a sketch to help clarify which road name and stations go with which road segment.

Road Name: Spur 3271 **Tagged by:** Scott and Rick

Road #: 3271 **Stations :** 3+35

Takes off from: Proposed landing location for setting 4028.

Terminates: At station 22 + 13 of 3270 (22 + 13 of 3270 = 3 + 35 of 3271)

Other Junctions: None.

Settings Accessed: 4028 and 4036

Status: Flagged

Soils: Cathlamet (24, 25, 26).

Side Slopes:
left 0 - 35%
right 0 - 35%

Grades:
0 + 00 to 3 + 35 12%

Stream Crossings: None

Switchbacks: None

Comments:
Short spur. Flagged to exit trucks south, will need a switchback to exit trucks north.

Road Name: Prayer **Tagged by:** Scott and Rick

Road #: 3275 **Stations :** 20+62

Takes off from: Station 19 + 18 of 3270

Terminates: At the Bradley Truck Trail

Other Junctions: None.

Settings Accessed: 4033

Status: Flagged

Soils: Cathlamet (24, 25, 26).

Side Slopes:

left	0 + 85 recorded 10 %		16 + 12 recorded 55%
right	" "	-10%	

No more side-slopes were recorded

Grades: 12%

Stream Crossings: None

Switchbacks: None

Comments:

As the name implies! This road was an attempt to tie 3270 to the Bradley Truck Trail since the original plan failed (to tie into the 3240). One 60' shot at 34% to get up on the bench where the road needed to be, then 2 stations of run-out before starting to climb sidehill.

Road Name: Bradley - Abernathy Tie **Tagged by:** Scott and Rick

Road #: 3399 **Stations :** 9+80

Takes off from: Bradley Truck Trail

Terminates: At the end of the 7400 road.

Other Junctions: None

Settings Accessed: Possibly 4025 if slightly relocated.

Status: Flagged, pink and blue.

Soils: Cathlamet (24, 25, 26).

Side Slopes:
left 0 - 25%
right 0 - 25%

Grades: 0 + 00 to 3 + 90 8%
3 + 90 to 9 + 80 -10%

Stream Crossings: None

Switchbacks: None

Comments:
This road ties the Bradley Truck Trail to 7400, which feeds out to Abernathy Road. Road should be pushed out more to slope break to access setting 4025.

Road Name: Bummer **Tagged by:** Scott and Rick

Road #: 3222 **Stations :** 11+45

Takes off from: Station 5 + 70 of 3221 (Knot-head)

Terminates: At the proposed landing for setting 4017 at station 11 + 45.

Other Junctions: None

Settings Accessed: 4017 and 4021.

Status: Blazed.

Soils: Cathlamet (24, 25, 26).

Side Slopes:

0 + 00 to 4 + 20 6 + 30 to 8 + 30	-0 to -30%
4 + 20 to 6 + 30 8 + 30 to 11 + 45	30 to 50%

Grades:

0 + 00 to 10 + 60	-10%
10 + 60 to 11 + 45	-2%

Stream Crossings: Station 5 + 30 needs a culvert.
Station 8 + 30 needs a culvert.
Big headwall between station 4 + 20 and 5 + 70 (150 ft across) with the creek at 5 + 30. Also small headwall at station 8 + 30.

Switchbacks: None.

Comments:
Spur road. Should be put to bed after use.

Road Name: Trunk A, RR1, and Trunk B **Tagged by:** Toshio and Andreas

Road #: 5000 **Stations :** 105+95

Takes off from: Bradley Truck Trail (SW 1/4 of Section 14)

Terminates: At the end of 2120 road.

Other Junctions: Station 28 + 70 ties in with 3250.
Station 44 + 70 ties in with 3252

Settings Accessed: 4074, 4088, 4092, 4091, 4095, 4100, 4109, 4111, 4110
Spurs off from trunk access: 4086, 4084, 4093, 4082, 4080, 4081

Status: Trunk A - flagged
RR1 flagged
Trunk B blazed

Soils: Germany (40, 41, 42).

Side Slopes:
left 0 - 30% Trunk A, RR1 and Trunk B are all along old RR grades
right 0 - 30%
Station 54 + 50 has 40% ss of Trunk A
Station 2 + 00 to 5 + 00 and 25 + 00 has 50% ss of RR1

Grades: Grades are all less than 5%.

Stream Crossings: Station 3 + 00 of RR1

Switchbacks: None.

Comments:
Railroad grade. Needs some reconstruction: dig out old culverts, drainage along wet areas, etc. Last portion into 2120 is new construction (No Rail Road grade)

Road Name: Spur 3252 **Tagged by:** Toshio and Peter

Road #: 3252 **Stations :** 3+50

Takes off from: Trunk A at station 44 + 70

Terminates: At end of RR grade station 3 + 50

Other Junctions: None

Settings Accessed: 4083

Status: Flagged Old rail road grade.

Soils: Germany (40, 41, 42).

Side Slopes: 0%

Grades: <2%

Stream Crossings: None

Switchbacks: None

Comments:

Used for tie in to road 3251. End of spur 3252 at 3 + 00 = 0 + 00 of 3251 road.

Road Name: Shore **Tagged by:** Toshio and Andreas

Road #: 9000 **Stations :** 15+00

Takes off from: NW 1/4 of Section 28

Terminates: SW 1/4 of Section 20

Other Junctions: None

Settings Accessed: None

Status: Flagged

Soils: Cathlamet (24, 25, 26).

Side Slopes: 0- 45%

Grades:

Stream Crossings: Station 0 + 50
Station 5 + 20
Station 11 + 90

Switchbacks: None

Comments:

NOT recommended for use. It is too wet, too steep, and curves needed to connect in are too tight.

Road Name: Sunny **Tagged by:** Toshio and Andreas

Road #: 9110 **Stations :** 11+50

Takes off from: A spur off the 2100 road. NE 1/4 of Section 28.

Terminates: At proposed landing, station 11 + 50.

Other Junctions: None

Settings Accessed: Setting 1454

Status: Flagged

Soils: Germany (40, 41, 42).

Side Slopes: Mostly 0 - 30%
Station 6 + 75 left is -40%

Grades: <5%

Stream Crossings:

Switchbacks: None

Comments:
In plantation, 10 - 15 yrs old. First 250 feet is at edge of a break. After is on the middle to the foot of the slope.

Road Name: Fire **Tagged by:** Toshio and Andreas

Road #: 9120 **Stations :** 18+50

Takes off from: The proposed landing location.

Terminates: The 2100 road. (NW 1/4 of Section 27) at station 18 + 50.

Other Junctions: None

Settings Accessed: Settings 4133, 4144, 4155.

Status: Flagged

Soils: Spur begins in Germany (40, 41, 42) and ends in Raught (122, 123, 124).

Side Slopes: Most side-slopes are between 0 - 30% except at the landing location 0 + 00 the side-slope is -50%

Grades: <3%

Stream Crossings: Wet area noted around station 8 + 25.

Switchbacks: None

Comments:

The notes mention that the connection of the spur to the existing road could be better - seems the curve was a little too tight.

Road Name: Straight Shot **Tagged by:** Toshio and Andreas

Road #: 9130 **Stations :** 9+70

Takes off from: The proposed landing location, station 9 + 70.

Terminates: The 2120 (SE 1/4 Section 21).

Other Junctions: None

Settings Accessed: Setting 4112

Status: Flagged

Soils: Spur begins in Germany (40, 41, 42) and ends in Cathlamet (24, 25, 26).

Side Slopes: Most side-slopes are between 0 - 30% except at stations 2 + 90 to 3 + 70, the side-slope is 45 - 55%

Grades: <10%

Stream Crossings: None.

Switchbacks: None

Comments: None

Road Name: The Easy Road **Tagged by:** Peter, Andreas, and Scott

Road #: B 1001 **Stations :** 20+65

Takes off from: The Bradley Truck Trail

Terminates: At the landing location, station 20 + 65.

Other Junctions: road 1000 connects in at station 13 +65 of 1001 road.

Settings Accessed: Setting 4125.

Status: Flagged

Soils: Germany (40, 41, 42).

Side Slopes: none recorded

Grades: <6%

Stream Crossings: None.

Switchbacks: None

Comments:

Station 13 + 65 has a trail sign for truck trail. Old rail road grade. The road talen off the Bradley track road. Follows an old RR grade. Leaves RR grade at station 13+65 and terminates at station 20+65 at landing

Road Name: B1000 **Tagged by:** Peter, Andreas, and Scott

Road #: B 1000 **Stations :** 44+40

Takes off from: The B1001 road at station 13 + 65

Terminates: At a landing location NW of the rock pit at station 0 + 00.
These notes connect into the switchback at the rock pit location.

Other Junctions: The 1010 road (Yahoo Bridge road) at the rock-pit-switchback

Settings Accessed: Settings 4116, 4117, 4123, 4132, 4129.

Status: Blazed

Soils: Germany (40, 41, 42).

Side Slopes: mostly 0 - 40% except station 1 + 15 to 2 + 05 (of the tie between the rock-pit-switchback and the #3 landing) has side slope of 55 - 65%

Grades: <10%

Stream Crossings: None.

Switchbacks: At station 10+00 with 80 feet radious.

Comments:

A map explaining where each road segment is and stationing to refer to notes is following. The notes refer to a tie-in to Andreas' notes which we cannot find! They also may be in the couch cushions at the Best Western in Longview.

Road Name: Screamer **Tagged by:** Peter, Rick, and Scott

Road #: 3201 **Stations:** 13 + 30

Takes off from: At a landing location

Terminates: 3200 road ("Karen" road) at station 6 + 50 of Peter and Toshi's notes for the Karen road.

Other Junctions: None.

Settings Accessed: Setting 4103

Status: Blazed

Soils: Cathlamet (24, 25, 26).

Side Slopes: Are between 0 - 30% except stations 5 + 00 and 11 + 90

Grades:

0 + 00	to	5 + 50	10%
5 + 50	to	11 + 50	15%
11 + 50	to	13 + 30	5%

Stream Crossings: None.

Switchbacks: At intersection of 3201 to 3200

Comments:

Spur to access setting 4103

Chapter 5

5. Stability Problems

5.1 Slope Stability Analysis:

There is always a potential for debris flows and mass movement when slopes are steep, or soils are unstable. An analysis was performed to help estimate the effects of road construction and timber harvest on slope stability. Data for the stability analysis was compiled from the State Soil Survey, base topographic maps, aerial photos, and field reconnaissance. The following tools/methods were used in the analysis:

1. "A Method for Assessing Landslide Potential as an Aid in Forest Road Placement" developed by Stan Duncan of Weyerhaeuser Company.
2. The Level I Stability Analysis (LISA) program developed by the USDA Forest Service Intermountain Research Station.

Each of these methods and our results are outlined below.

5.1.1 "A Method for Assessing Landslide Potential as an Aid in Forest Road Placement" (DUNCAN)

This method, developed by Duncan, Ward, and Anderson (1987) was designed by Weyerhaeuser to aid their engineers in road reconnaissance. They took samples from various failure sites west of the Cascade Range and used the factors that caused those failures to come up with a simple aid to calculate the stability of other places. They did this by assigning a stability value for each of the nine variables used in a Duncan evaluation. The variables are:

- -slope angle
- -slope position,
- -slope form,
- -soil depth and texture,
- -bedrock type,
- -groundwater information,
- -elevation,
- -road placement and
- -stand age.

The whole reason Duncan was developed so that you didn't have to be a soil scientist or geologist to know which slopes are unstable. The input is very straight forward, and applies for all of western Washington and Oregon. During a field recon, a Duncan plot can be done at any station where there might be a concern for slope stability. Figure 5.1 lists the stability value to use for each variable at a station of concern.

Duncan was used as a tool in the field to indicate relative stability of a given station of road. Our class performed Duncan plots whenever the need arose, such as on slopes over 50%, in draws or headwalls, or near creek crossings. Field data results are summarized in Table 5.1 below:

Table 5.1: Duncan stability index results from field reconnaissance.

Location	Slope Class	Slope Position	Stability Index
Road 3270 Station 6+84	30-50%	Upper 1/3	12
Road 3275 Station 9+66	30-50%	Lower 1/3	22
Road 3275 Station 12+50	50-70%	Upper 1/3	20
Road 3200 Station 7+50	30-50%	Above slump	17
Road 3200 Station 7+50	50-70%	Middle of slump	27
Road 3200 Station 7+50	30-50%	Bottom of slump	30

A good example of Duncan results are on the proposed road #3200 (See figure 4.1 for road numbers and locations). There, the road location was moved up from the paper location to avoid a series of hollows and old slumps. The proposed road was located near the slope break above these slumps. To get a feel for Duncan, the class did a Duncan plot assuming the road was placed 1) above the slump, 2) through the middle of the slump, and 3) at the bottom of the slump. The slump was approximately 40 feet wide, 20 feet deep, and 100 feet long. It also looked like it was very old, before the railroad logging of the 1930's. The Duncan results at these places indicate that the road placement above the slump is all right, but if the road were placed lower in the slump, there would be an increasing probability of failure.

Duncan is a tool that indicates which stations of road are located on potentially unstable soils and may warrant further investigation by a qualified person.

5.1.2 Level I Stability Analysis

The Level I Stability Analysis (LISA) computer program is a tool that was used to evaluate the relative stability of natural slopes and the effects of timber harvest on slope stability. Many studies have shown that clearcutting increases the frequency of landslides, particularly debris avalanches on steep slopes with shallow soils. This is because the root start to rot once the trees are cut. About ten years after a clearcut, root cohesion is the lowest. If an area is selectively cut, more root cohesion will remain. Or if the area is left in its natural state, root cohesion is the highest. LISA can be run to evaluate slope stability under both natural and cut conditions and the output will tell us which areas are most likely to fail under specified conditions. Data variable required by LISA are:

-soil depth (ft)
-ground slope (%)
-tree surcharge (psf)
-root cohesion (psf)
-friction angle (°)
-soil cohesion, (psf)
-dry unit weight (pcf)
-moisture content (%)
-groundwater (Dw/D ratio)
-specific gravity

Values for these variables for the worst case run were determined as below:

Soil depth: This is the depth of material above the layer of bedrock, assumed to be 5' from DNR GIS database.

Ground slope: This is the critical variable, so LISA was used to evaluate slope stability at different slope classes. This was done to determine the critical slope class, so we could focus our attention on those sensitive slopes.

Tree surcharge: Surcharge is the pressure of the trees on the soil and is calculated by dividing the weight of the trees by the area they act on, and changes from a natural to a clearcut state. However, LISA output is fairly insensitive to tree surcharge, so I chose the lowest value I found in the LISA manual so we could evaluate the worst case scenario.

Root cohesion: Values for root cohesion were obtained from the LISA manual assuming the failure plane to be below the zone of root penetration. This means a value of about 20 psf for the clearcut state and 40 psf for natural state. Since LISA was run under worst case scenario, a value of 20 psf was used.

Groundwater ratio: The amount of groundwater present is usually the triggering mechanism for slope failure, and is one of the most sensitive variables in the LISA program. This value changes from a natural state to a clearcut state, so for the worst case analysis, I made two runs, one using groundwater ratio as 1.0 assuming fully saturated conditions at a convergence area, and another with values between 0.5 and 0.7 for most areas.

Soil friction angle: This value is based on the soil type, and from the DNR GIS database, most of the soils are silty loams with similar characteristics. For the worst case runs, I used the lowest value reported in the LISA manual for our soil type, which was 32 degrees. A field test of friction angle yielded a value of 30 degrees.

Soil cohesion: This value is also based on the soil type. For the worst case scenario runs, I assumed this to be 100 psf reported in the LISA manual. A field test yielded a cohesion of 1300 psf, which seems unreasonable high for a silt and is probably unlikely. Therefore, I assumed a cohesion of 100 psf was more reasonable for the soil types there.

Soil dry unit weight: This value is also based on the soil type. For the worst case runs, I assumed a value of 80 pcf reported from the LISA manual.

Soil moisture content: LISA is fairly insensitive to moisture content, so I assumed a value of 30%, which corresponds to an almost fully saturated soil.

LISA uses the Infinite Slope Equation, a standard stability analysis method, to compute the factor of safety of a given slope. The factor of safety (FS) is the ratio of the forces resisting a slope failure to the forces driving the failure. A slope with an FS greater than 1.0 indicates stable conditions, whereas an FS less than 1.0 indicates unstable conditions. However, an FS of less than 1.0 does not mean the slope will immanently fail. The actual probability of failure is between 0.4 and 0.6, even though there are more forces driving failure than there are resisting failure.

$$FS = \frac{\text{forces resisting failure}}{\text{forces driving failure}}$$

To account for the variability of *in situ* conditions on any given slope or landform, and the many uncertainties in estimating input values for the variables, LISA performs a probabilistic analysis. A Monte Carlo simulation is used to estimate the probability of slope failure (Pf) rather than a single FS value. The program randomly selects a value for each input variable from a range and distribution of possible values specified by the user (listed above). The infinite slope equation is then used to calculate the corresponding value of the FS - this is one Monte Carlo pass. The program automatically calculates the FS for 1000 such combinations for each run. The end result is a histogram of the calculated factors of safety and the probability of failure. LISA calculates the probability of failure by dividing the number of unstable combinations by the total number of passes.

$$P_f = \frac{\text{\# combinations with FS <1.0 (unstable)}}{\text{1000 randomly selected combinations}}$$

For the purpose of risk assessment, the probability of failure may be interpreted as the percent land area in, or potentially in, a failed state. It should be noted, that LISA evaluates the probabilities of slope failures and delineates areas which merit further investigation, but it does not evaluate the impact (the results) of a slope failure. Nor can LISA predict exact locations or type of failure.

5.1.3 LISA results

Assuming common values of groundwater ratio between 0.5 and 0.7, the worst case runs showed that slopes less than 65% only have a probability of FS<=1 of 0.05, meaning they should be stable. Slopes over 70% have a probability of about 0.30, which means these slopes should be analyzed more precisely if a clearcut is planned on them. See appendix ##, page for data and graph of P[FS<=1] versus slope.

Assuming fully saturated soil conditions of the saturated run, slopes of less than 50% have a probability of FS<=1 of only 0.10. Slopes over 50% have a probability of 0.25 and increases up to 0.99 for slopes of 80%. This means we should be concerned with slopes over 50% if the soil if fully saturated, for instance by culverts discharging into draws or hollows. See appendix ##, page for data and graph of P[FS<=1] versus slope.

After a field test of soil shear strength, we had different numbers to plug into LISA. A soil friction angle of 30 degrees was used and a soil cohesion of 1300 psf was used. These numbers yielded a LISA result showing slopes up to 200% were stable. This result doesn't compare with what we saw in the field, because the steepest slopes in the planning area were not over 80%.

A graph of LISA results versus slope class for each case (worst case, fully saturated, and field checked runs) is given in figure 5.3.

From this information, we used the worst case run to delineate areas of slope stability concerns as those slope greater than 50-60%. This agreed with what we saw in the field. We used this information as a tool to plan our paper road locations, avoiding steep slopes wherever feasible. As a tool in the field, the 50-60% slope cutoff seemed to be a pretty good indicator of slope concerns. See section 5.3.5 for more information on slope stability and road recon.

5.2 Field evidence of past failures and field reconnaissance

In the Elochoman sub-block 'B', there are two existing road failures. One failure is along the 3220 road, which separated this road system. The other existing road failure is on the spur right 3/4 of a mile up the 2110 road. This failure isolates the rest of that road system. These failures are on roads built around 20 years ago to log the areas once owned by Crown Z. The previous road placement and design at these failures was over the edge of the slope break, and the cut bank undercut the natural terrain. It was these cut banks that originally failed, then the weight over the fill started it moving.

In the case of the major failure on road 3220, there was no bench below to catch the fill. Instead, there was an 80%+ slope for 200 feet or more slope distance. Originally, the cut bank gave way and fell onto the road bed. When the fill gave way under the added weight, there was nothing below to catch the material as it slid, so it gathered more material as it traveled down hill. What caused the major failure of the 3220 road was poor road placement, over the edge of the slope break.

The other road failure along the 2110 road is similar to the one on the 3220 road. The slope initially let go above the road, then the fill was forced downhill. It slid 5 feet in elevation to isolate the rest of the road system from the 2110 road. Also, further along the 2110 road, it too is starting to give way because it right on the slope break. This road should be put to bed and re-graded since it is not needed for many years, to reduce the risk of failure. This section has the same problems as the 3220 road failure.

Originally, a gradeline was flagged in to connect this isolated road system to a few proposed landings, then back out to the 2100. It crossed side slopes in excess of 55%. After discovering the existing road failures, this road location was rejected, and the landings move so the 2110 spurs would not need to be used (see Road Recon 9110 road). The entire length of the 2110 road follows along this slope break and exhibits early signs of failure, such as tension cracks. It may eventually have the same fate as road 3220.

Harvesting in the block does not seem to cause slides. Air photos showed no evidence of failures from the recent wave of harvesting in the area. We found no evidence of recent slides from the railroad logging of old-growth. Most slides in the area seemed to be more than 100 years old, which means logging had no impact on them. This would lead us to believe harvesting operations should not start slope failures. The main concern for harvesting in the area is compaction from wheeled equipment during wet months.

5.3 Slope stability and soil concerns

Most of sub-block 'B' consists of Cathlamet soils, which are silty loams. These are deep, well drained soils, formed from weathered sandstone. Permeability is moderate, and the hazard of water erosion is moderate. These soils support mainly conifers with a 50 year site index of 131 for Douglas-fir and 115 for western hemlock. There is a big concern for the effects of harvesting activities on these soils. Steep slopes limit the use of tractive equipment, but cable systems disturb the soils less. Rock ballast must be placed deep enough to support the loads traveling over them. This, and the fact that there is little usable rock, makes the cost for ballast high. Cathlamet soils are also poor for road fill, as they have little strength. Cut banks and fills should be seeded to provide cover and stability. Unused roads should be put to bed and water barred to reduce the impacts of soil erosion.

Table 5.2 - Soil type and engineering properties.

Soil Name	USCS classification	Fiction Angle	Soil Cohesion
Cathlamet	ML-MH		
Germany	ML-MH		
Grehalem	CL		
Montesa	ML		
Raught	GP		
Stimsom	CL-ML		

As seen on the stability concern map of figure 5.4, there seems to be a band around the area where slides appear most likely. This band is around 600' - 800' elevation. This zone starts near the north fork of Beaver Creek, and wraps around the ridge to head northward through the 3200 road area and the 3220 failure, and all the way up through the north end of the block. All old slides are in this elevation zone, which means to take extra precaution when locating a road through this zone.

The 3270 road is a good example of the use LISA, Duncan, and other evidence of stability concerns. In an attempt to connect the 3270 to another road system, our paper plan called for the 3270 to run from the end of existing road 7050 to the 3240 (see figure 4.1 for road numbers and locations). Our first attempt to tie the 3270 down to the 3240 failed when the first day we found that part of the road on the GIS was not really there. The next day we tried to tie the 3270 to the 3240 further south, but encountered steep side slopes and an old slide. Had we looked at the slope stability map, we would have seen that LISA had designated this area as having sensitive slopes, and was probably not a good place for a road. Also, it was near the 600' - 800' elevation zone of stability concern. This was verified when we first encountered an old slide. Then we found side slopes in excess of 60% for the next 10 stations. So we gave up this attempt and tried the 3275. This road we called the "Prayer" road because we knew there was only a small chance this road location would work. The 3275 was flagged in a last ditch effort going up the hill on constant 55% side slopes to tie to the Bradley Truck Trail. This would require full bench and end haul, and would probably create the problem we saw on the existing road failures. Duncan plots along the way gave a value between 20 and 22, which says to use standard construction. However, since most of our Duncan plots were below 20, we took this to imply relatively unstable conditions. Fortunately, this road was not used in any of our Network runs, so it should not be built, even though Duncan results say it is all right to build using standard engineering practices.

We only saw two old road failures, on the 3220 and just off the 2110. This would lead us to believe that road stability should not be a problem if the road is placed back from the slope break and the cut bank does not undercut the existing terrain. For our road location in the field, we placed most roads on a bench near the slope break, not over it, wherever possible. If it was necessary to place a road on steep side slopes for a few stations, we tried to do so where there was a bench not far below to catch the material if it did fail. This was of great concern because of the fish hatcheries near by. If sediments did move down hill, they would hopefully be trapped by a bench before entering a stream channel. Looking at the slope stability concern map, most of our proposed roads avoid the areas of sensitive slopes, and are not placed right on the slope break. Therefore, our proposed road system should not have as many problems as the existing roads do.

Chapter 6

6. Proposed Harvest Unit and Tranceportation Plan for the Elochoman

6.1 Harvest Scheduling introduction

Prior to developing a harvest schedule, information regarding the resource and it's capabilities had to be joined with information regarding the physical limitations of harvesting and transporting timber from the planning area.

As a result of analysis both in the field and through the use of PLANS on Digital Terrain Models a number of feasible harvest setting polygons were developed. The settings were developed to overlap each other so that flexibility in choosing final setting boundaries was possible. These settings were subject to riparian buffer limitations and land capability based on harvest system and timber type boundaries. Once the boundaries for these settings were determined they were overlain with the timber map using ARC/INFO (Identity and Frequency commands). This overlay resulted in a setting by setting collection of timber volume data stored along with type of harvest system to be employed and the cost of harvesting the setting with that system (determined through production calculation methods described in chapter 2).

Another source of information was the road network, which was developed by hand (pegging) on maps and then field modified / verified before being digitized as an ARC/INFO cover. This cover included information determined from field reconnaissance and Engineering calculation regarding construction cost, length and haul cost for each section of road (Arc).

The ultimate goal handed down from the DNR governing this project is to produce a Harvest and Transportation plan for the Elochoman B sub-block. The process of Scheduling and Nerworking culminates this goal. Timber data is assembled in Scheduler to produce a harvest schedule following DNR project constraints. Network then combines this harvest schedule with the developed road network to produce a constraint driven transportation plan supporting the harvest schedule.

This represents the finite solution to this project's goal.

6.2 The Harvest Schedule Process

Once the information mentioned above was collected the harvest settings were amalgamated into harvest Units. This was done by hand choosing settings that were geographically related, by similar road systems, and to minimize distance of harvest system movement between landing points. This amalgamation reduced the planning area to groupings of two(2) to five(5) settings per unit (see Table 3.3.2). Each one of these 'Units' was then evaluated by Scheduler for time of harvest. Scheduler groups these Units farther into 'sales' by period. Each period then represents a sale made up of two or more units. The process at this point became largely one of file management

The SCHEDULER program requires two input files. The first (designated as 'good1.skd') contains a list of I.D. numbers, area , harvest cost and timber volume for each setting. This file was assembled in EXCEL from data output from ARC/INFO and then output as an ASCII file. The other input file (designated as 'good2.skd') contains three sections. The first is simply the number of sale units in the file. The next section describes which settings make up each sale unit. the final section is where adjacency requirements are established by identifying which sales are next to one another and how many periods must pass between harvest of adjacent units. This file, previously assembled by hand, was assembled according to adjacency constraints using an ARC/INFO SML called "sched.sml" and then "sched.awk".

With the necessary files assembled, they can be imputed into Scheduler. The data entering Scheduler at this point is the same. The data is now examined and manipulated by Scheduler according to imputed contraints. By varying these constraints, we were able to produce several different harvest schedules. Each one represents specific constraint trends. In total we developed four(4) different harvest schedules. We ran the program with a standard set of parameters to ensure comparable output, the parameters used are listed bellow:

Planning Horizon : 30
Number of periods : 10
Sale price per MBF : 600.00
Discount rate : 5.00 percent

The "Number of Periods" refers to the time in the future Scheduler will plan ahead. In all our runs, one period equals three(3) years. Thus, Scheduler will look 30 years into the future at the mature timber.Growth factors were calculated from Stand Projection System simulation runs. The same growth factors were used for each of the schedule variations.

Growth factors are :
Period : 1 - 1.00
Period : 2 - 1..08
Period : 3 - 1.16
Period : 4 - 1.24
Period : 5 - 1.29
Period : 6 - 1.35
Period : 7 - 1.39
Period : 8 - 1.43
Period : 9 - 1.48
Period : 10 - 1.51

Two constraints, volume and area, were varied to produce four(4) different harvest schedules. The first, 'YO55', represented the strictest computer generated and constrained model. 'RELAX', represented a less constrained computer generated version of 'YO55'. 'OPEN' represented an even more relaxed computer generated version of 'RELAX', and 'HAND' represented a model generated by hand with only adjacency as the driving constraint. Below is a table showing the range and increment of volume constraint and the range of area constraint for each variation.

Table 6.1: Showing volume constraints with increments entered into Scheduler for harvest schedules. Only the minimum (= period 1) and the maximum (= period 10) volume constraints are shown. The "by..." indicates the increment by which volume increases from one period to the next.

Harvest Schedule	Vol. Constraints (Mbf)
YO	5400 >>= VOL =<< 6600 by 100 by 200 6300 >>= VOL =<< 8400
RELAX	5000>>=VOL=<<7000 by 200 by 500 6800>>=VOL=<<11500
OPEN	6000 >>= VOL =<< 8600 by 200 by 600 7800 >>= VOL =<<13800
HAND	N/A

Table 6.2: Showing area constraint entered into Scheduler for the four harvest schedules. Scheduler reads this as the total number of acres it can cut per period.

	YO	RELAX	OPEN	HAND
Area	80>>=A=<<250	80>>=A=<<300	80>>=A=<<360	N/A

For the YO, RELAX, and OPEN schedule variations, the appropriate constraint specifications were made upon imputing into Scheduler and the runs made. For each run, Scheduler generated 100 solutions. From these 100 solutions it chooses the optimum Scheduler output solution. It does this through an iterative process of comparing each of the 100 solutions for the best one, and deleting the others.

The HAND variation was not run through Scheduler for obvious reasons. HAND's objective was to generate a harvest schedule by hand, not computer.

Table 6.3: Shows a comparison of total area(acres) cut and total area(acres) left by each of the harvest variations.

	Mature Timber cut (acres)	**Mature Timber left (acres)**
YO	**1097.1**	**770.5**
RELAX	**1297.9**	**569.7**
OPEN	**1459.3**	**408.3**
HAND	**1867.6**	**0**

The completed Scheduler runs now represent in an output file containing l harvest schedules. These output files were fed through "GO" to change them into sales file (xxx.SLS) format. The HAND sales file was built by hand in EXCEL.

At this time, the Link file (zzz.LNK) file for each variation was also built in EXCEL. This file represents the a description of roads in the planning area for NETWORK.

Once the Sales File and Link File for each variation was built, it can be entered as imput into NETWORK II. NETWORK then builds a transportation plan for each variation (YO, RELAX, OPEN, HAND).

These NETWORK outputs break the road system down into "links" and evaluates economically the use of each link in relation to the unit it harvests for the entire planning area. It then produces a hardcopy output showing which road links need to be constructed and/or used to service the appropriate units by period. By adding, deleting, or changing stategic links in the Link File, we were able to more closely represent the actual conditions in the field or route traffic in desired directions. For instance, if a certain portion of road can only accomodate outhaul, that segment can be specifically modified in the Link File so that NETWORK will evaluate it as an outhaul route. We were also able to use this technique to optimize the NETWORK generated transportation plan to include bridge or excessive construction costs. If for instance a road includes a bridge crossing, that specific link can be attributed with varying bridge costs. NETWORK then considers that link in relation to all other links associated with it and develops a plan including the new variation.

Each variation (i.e. link modification made in the Link File) represents a new NETWORK solution. We specified that NETWORK do at least 50 iterations on each solution to find the optimal solution for that set of 'new rules'.

Thus, for each of the four schedule plans (YO, RELAX, OPEN, HAND) we generated between three and five possible NETWORK analyses. From these choices, we picked an 'optimal NETWORK solution' for each of the four harvest schedules. The optimal NETWORK solution represents an optimization of total variable and fixed costs. In NETWORK this means the largest negative value.

For each of the four harvest schedules, there now exists a sale harvest schedule and a road network servicing those sales over a ten period (30 years) time span.

6.2.2 Harvest Exit Combinations to Longview Fiber

The following figure shows the haul route exit points with their link node numbers. Starting from the left side and moving counter-clockwise; Node number 71 represents exit to the Elochoman road (SR 407). Node number 288 represents haul route along the elochoman road to Cathlamet. Node number 290 represents exit via the Beaver Creek County road. Node number 291 represents exit via the B1000 road. Node number 276 represents haul routes voer the B2000 road. Node number 82 represents exit via the Bradley to the M1000 road. Node number 33 represents exit out the Abernathy road.

These exit node numbers relate directly to map 6.xx.xx and all NETWORK outputs in the appendices.

Following figure shows the relationship of various exit points to Longview.

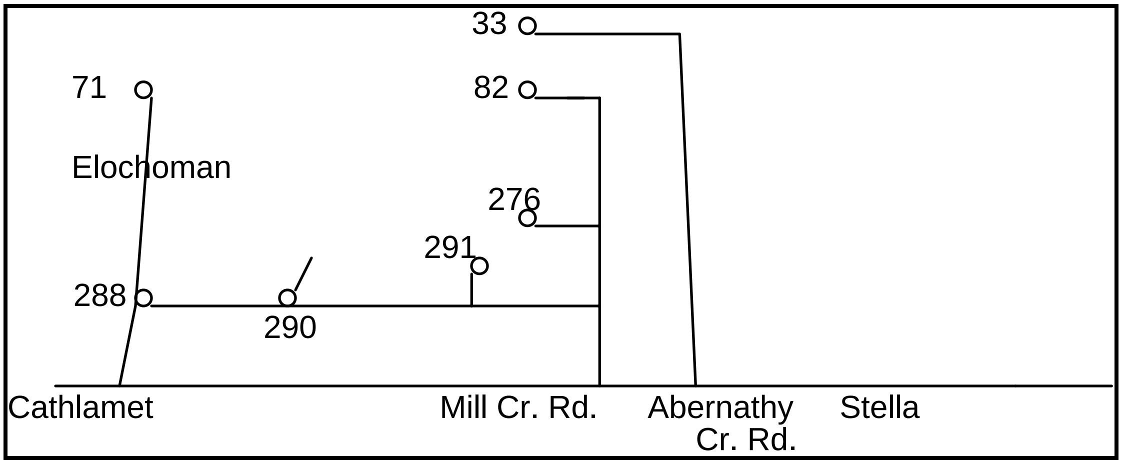

Figure 6.2 Exit Point to Longview saw mill

Directly associated with the haul route are the distances and UTC haul cost along those routes. NETWORK looks at the haul cost in the road link file as a factor in determining the most economical haul route.

Table 6.4 Distance and Haul cost from various exit points to Longview via Stella

Exit Node	to Stella Type C miles	Stella Type A miles	Stella Longview Type A miles	UTC Haul Cost $
33	3.3	8.7	11.68	36.84
82	1.1	10.65	11.68	35.59
276	3.3	6.56	11.68	33.64
288		18.62	11.68	45.46
290		10.71	11.68	33.86
291	1.1	9.08	11.68	33.24

6.3 COMPARISON OF HARVEST SCHEDULING AND NETWORKING

As mentioned in the previous section, the final harvest and transportation plan for each of the four variations (YO, RELAX, OPEN, HAND) differ in link combinations. This results in varying characteristics of harvest flow for each plan.

6.3.1 Constraint Harvest Schedule YO55 Summary

General Description:

YO55 represents the tightest contrained of the four models. Road 2100 and 2000 take approximately 44% (30857 MBF) of harvested volume along it's route. This represents a large portion of the volume in this model. The entire section of the Trunk Line is never completely built. This can be explained by the fact that not all of the available mature acres were taken.

The Rock Pit is accessed in period 5. This makes available the Rock Pit as a resource for the following 5 periods. Only after period 5 does substantial construction continue.

This NETWORK analysis does not utilize a bridge on the 1010 road. Instead, traffic is routed past the Rock Pit along the 1000 series to intersect with the B1000. YO55 moves approx. 48471 MBF (69.2%) via the Beaver County Road, and approx. 21619 MBF (30.8%) via the B2000 exit.

The 2110 and southern 2100 road networks in section 28 and the middle portion of the 1000 road in section 14 are not used by NETWORK at all. These road systems are recomended for "put to bed" status.

Total acres cut	=	1097.1	=	58.7%
Total acres left	=	770.5	=	41.3%
Total volume cut(MBF)	=	70090		
Present Net Worth($)	=	16142661.00		
Present Net Worth($/Mbf)	=	229.34		
Road cost ($/Mbf)	=	5.13		
Ave. Volume constraint	=	6000 acres		
Vol. constraint range	=	1200		
.LNK File	=	R15_COST		
.SLS File	=	YO55		

Refer to figure 6.1 for exact location of links. The following 'links cut' numbers represent the link end node numbers. The direction of haul is indicated by the order of link node numbers. For example, 23-33 indicates that the haul direction is from node number 23 to node number 33.

Links cut: 23-33, 33-23, 35-32, 32-35, 194-203, 203-194, 278-275, 285-282, 9-23.

'Links Changed' indicates the link was altered and not entirely removed from the link file.

Links changed: 4069-125 to 4069-155.

This link was changed because NETWORK decided that haul from node number 125 would travel an entirely different route than from 155. The origin setting number (4069) is part of a unit along the 1000 road. NETWORK desided that the haul route 4069-125 would travel north, even though the neighboring setting in the same unit hauled south. The northern haul route cost 35.44 $/Mbf and the southern haul route cost 2.09 $/Mbf to haul over for this setting. Cost of hauling was the direct reson for changing this link.

6.3.2 Constraint Harvest Scheduler RELAX Summary

General Description:

RELAX represents a lower constraint level than YO55. RELAX builds the Rock Pit in period 3. The entire 1000 series to the B1000 is constructed at this time. This portion is not used again until period 6 when the rest of that block is selected. Construction on the Trunk line begins in period 4. Although the entire Trunk is not completed, more is consturcted then in RELAX.

The bridge option at the 1010/2000 road junction is not used.

Again, there is high timber volume flow over the 2100 and 2000 segments common in YO55. Approximately 38585 MBF (44.4%) flows over this segment. Approximately 40088 MBF (46.2%) is hauled out over the Beaver county road. Approximately 22724 MBF (26.2%) travels out the B2000. Approximately 8123 MBF(9.4%) is hauled over the Abernathy road and 4618 MBF (5.3%) over the Bradley exit.

The 2110 and southern 2100 road networks in section 28 and the middle portion of the 1000 road in section 14 are not used by NETWORK at all. These road systems are recomended for "put to bed" status.

Total acres cut	=	1298	=	69.5%
Total acres left	=	569.7	=	30.5%
Total volume cut(MBF)	=	86750		
Present Net Worth($)	=	19371378.00		
Present Net Worth($/Mbf)	=	222.53		

Road cost ($/Mbf)	=	4.77
Ave. Volume constraint	=	6000 acres
Vol. constraint range	=	2000
.LNK File	=	RELAX6.R7C
.SLS File	=	RELAX6.SLS

Refer to map 6.xx.xx for exact location of links. The following 'links cut' numbers represent the link end node numbers. The direction of haul is indicated by the order of link node numbers. For example, 23-33 indicates that the haul direction is from node number 23 to node number 33.

Links cut: 9991-282, 133-127, 282-278, 54-57, 267-9991.

Links changed: 4069-125 to 4069-155.

This link was changed because NETWORK decided that haul from node number 125 would travel an entirely different route than from 155. The origin setting number (4069) is part of a unit along the 1000 road. NETWORK desided that the haul route 4069-125 would travel north, even though the neighboring setting in the same unit hauled south. The northern haul route cost 35.44 $/Mbf and the southern haul route cost 2.09 $/Mbf to haul over for this setting. Cost of hauling was the direct reson for changing this link.

6.3.3 Constraint Harvest Scheduler OPEN Summary

General Description:

OPEN represents an even more relaxed version of RELAX. Open begins construction on the Trunk road in the first period from the 2100 side, and from the 1000 road in the second period. The entire Trunk is not constructed though.

The bridge option is also cut out in this version. All traffic is routed up the 1000 series early in period two. This opens the Rock Pit for all later construction early in period two.

Again, the 2100/2000 portiion near the south east exit draws heavy volume. Approximately 47919 MBF (48.9%) travels over this section.

Approximately 48809 MBF (49.8%) is hauled out over the Beaver county road. Approximately 21098 MBF (21.5%) is hauled over the B2000 exit route.Approximately 15533 MBF (15.9%) goes out via the Bradley route and about 4152 MBF (4.2%) makes it's way over the Abernathy road.

The 2110 and southern 2100 road networks in section 28 and the middle portion of the 1000 road in section 14 are not used by NETWORK at all. These road systems are recomended for "put to bed" status.

Total acres cut	=	1459	=	78.2%
Total acres left	=	408.3	=	21.8%
Total volume cut(MBF)	=	97939		
Present Net Worth($)	=	22661101.00		
Present Net Worth($/Mbf)	=	230.49		
Road cost ($/Mbf)	=	4.79		
Ave. Volume constraint	=	7300 acres		
Vol. constraint range	=	2600		
.				
LNK File	=	R7C_COST		
.SLS File	=	OPEN2.SLS		

Refer to map 6.xx.xx for exact location of links. The following 'links cut' numbers represent the link end node numbers. The direction of haul is indicated by the order of link node numbers. For example, 23-33 indicates that the haul direction is from node number 23 to node number 33.

Links cut: 269-9991

Links changed: N/A

6.3.4 Constraint Harvest Scheduler HAND Summary

General Description:

HAND represented the hand scheduled scheduling process.

The constraints are "loose" in that they only address adjacency relationships. HAND was not a viable choice for us as a usable harvest schedule. Instead we used HAND as a comparison tool, in essence a 'control' to measure the varying constraint levels in the computer generated models.

Most notable about HAND, it uses the bridge option at the 2000/1010 junction.

HAND also uses the 2000/2100 road segment extensively. Approximately 42163 MBF (37.3%) crosses the portion. HAND moves approx. 27643 MBF (24.5%) through the B2000 exit, 59515 MBF (52.6%) over the Beaver county road exit, 16510 MBF (14.6%) via the Bradkey road, and 9410 mbf (8.3%) via the Abernathy road.

The 2110 and southern 2100 road networks in section 28 and the middle portion of the 1000 road in section 14 are not used by NETWORK at all. These road systems are recomended for "put to bed" status.

Total acres cut	=	1868	=	100%
Total acres left	=	0	=	0%

Total volume cut(MBF)	=	113078
Present Net Worth($)	=	26212081.00
Present Net Worth($/Mbf)	=	231.81
Road cost ($/Mbf)	=	4.53
Ave. Volume constraint	=	N/A
Vol. constraint range	=	N/A
.LNK File	=	RO_COST
.SLS File	=	HAND1.SLS

Links cut: N/A

Links changed: N/A

6.4 Comparing YO, RELAX, OPEN, in HAND SCHEDULER and NETWORK

The four NETWORK output solutions YO, RELAX, OPEN, and HAND represent four possible harvest and transportation plans viable for the Elochoman B planning area. Each has varying constraint levels and exhibit corresponding characteristics. A specific recommendation to use only one of these solutions is not condusive to the longterm goals of this project. In fact, it is for the DNR to decide which of the four solutions will best suit their policies. The possiblity that one or more of the solutions should be used at any point in time is also still open. This decision will be governed by political, environmental and practical influences.

Initially the most obvious contrast between the four solutions is the number of total harvested acres taken. It should be reemphasized that only the mature timber between the ages of 25 and 65 years is considered for the next 30 years. The 'regen' (everything under 25 years) is not included in the scheduling or networking process.

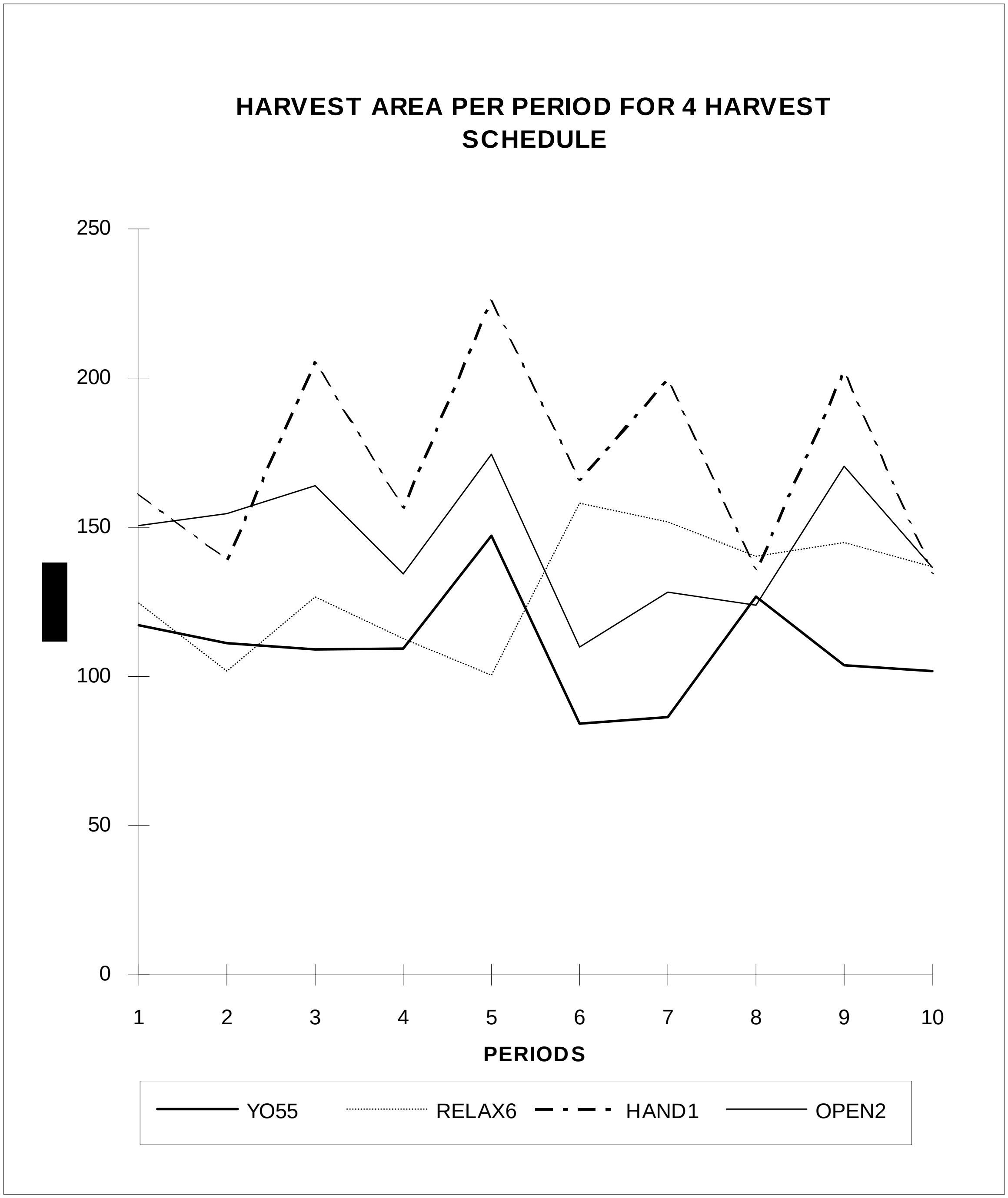

Figure 6.7 This figure shows the harvested area for each period and for each of the four harvest schedules.

From Figure 6.7 we see that only the HAND solution actually cut all harvestable mature timber in the 30 year planning window. Notice the range of minimum amd maximum values for each model.

Table 6.5 The area picked in each period for harvest fluctuates drastically over the full 30 years.

	YO	RELAX	OPEN	HAND
minimum harvest area value (acres)	80	100	110	130
maximum harvest area value (acres)	150	150	165	220

The first reasoning for this is that HAND does not consider volume constraints. YO, RELAX, and OPEN also fluctuate but not to the same extent. These fluctuations are better explained by the variation in stocking present in the planning area. As the stocking varies more from one extreme to the other, more or less area must be taken to accommodate the volume constraint. As the volume constraint range becomes tighter on each model, the harvest area curve flattens out. This is most evident by comparing YO (very tight volume constraint) and HAND (no volume constraint). The YO harvest area curve maintains a much tighter range than HAND because it is restricted in how much timber volume is available for cutting. With this in mind, one can assume that not all the available mature timber acres were choosen for harvest by YO. In fact, we can say that the tighter the volume constaints, the more timber gets left in this planning window.

		YO	RELAX	OPEN	HAND
Mature Timber left in first 30 year	%	41.3	30.5	21.9	0
planning window	acres	770.5	569.7	408.3	0

This presents new problems. With the HAND solution, 0% of timber is remaining for the second 30 year planning window. This means that all timber will be cut at the optimum age (in this case between 55 and 65 years). The other extreme is YO. In this solution, 41.3 % of mature timber is left hanging somewhere in the second planning period. This timber could conceivably be 80 to 90 years old at the beginning of the second period. This surplus timber needs to either be considered early in the next planning window for harvest, or applied to new forestry issues. For instance introducing greater stand diversity, maintaining wildlife habitats, or isolating leave areas for visibility or political motives.

As mentioned in section 6.xx.xx, the volume constraints are tightest on YO and non-existant in HAND. The DNR supplied a starting volume level of 2MMbf harvested volume per year. This works out to 6MMbf per period. By looking at Figure 6.xx.xx it verifies that tighter volume constraints produce a more constant volume flow.

Table 6.6 Minimum and maximum voulme constraints

	YO	RELAX	OPEN	HAND
maximum harvest volume (Mbf)	6600	5000	6000	N/A
minimum harvest volume (Mbf)	5400	7000	8600	N/A
ave. volume constraint value (Mbf)	6000	6000	7300	N/A
range of vol. constraint	1200	2000	2600	N/A

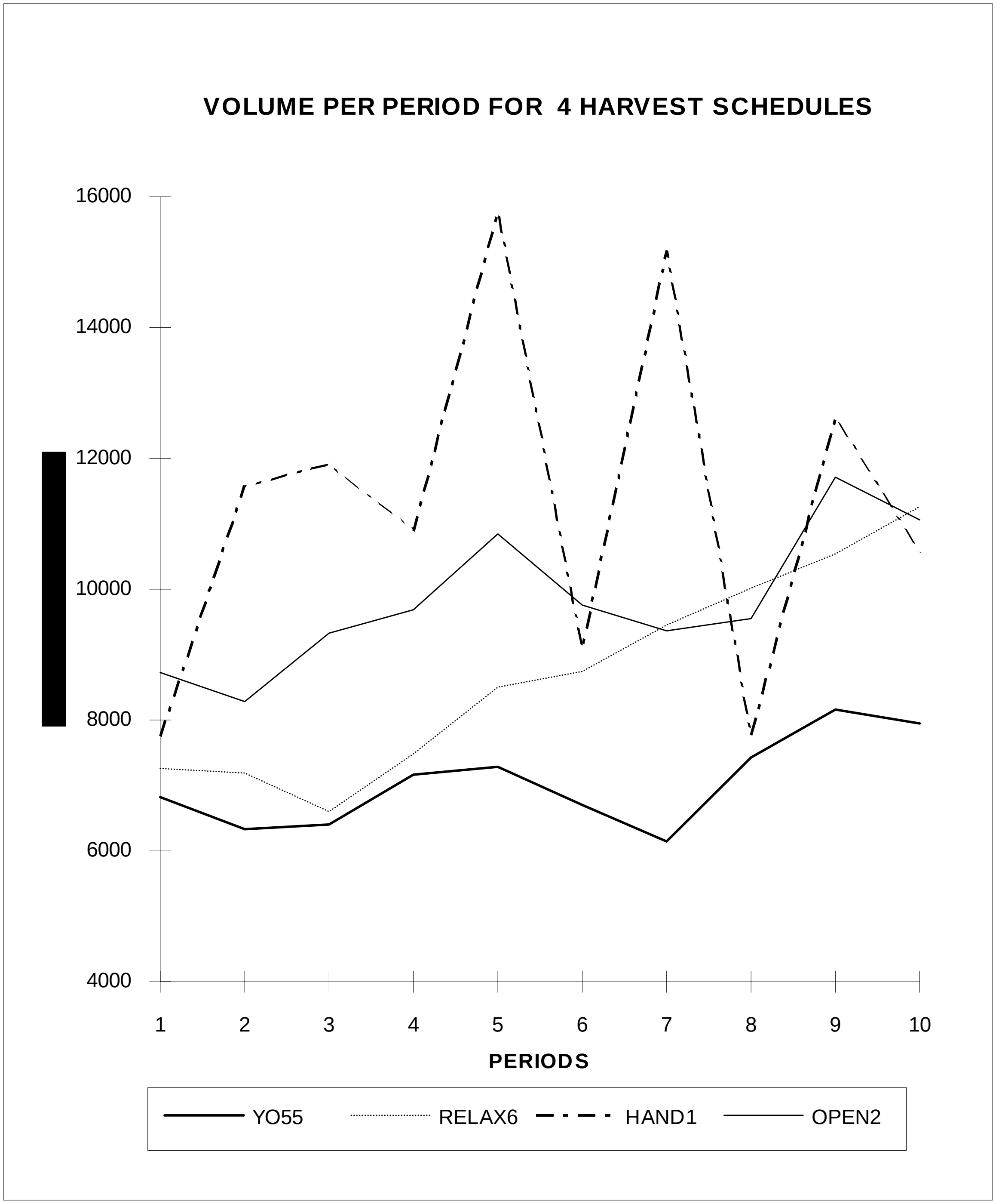

Figure 6.8 Shows relationship of volume cut per period for YO, RELAX, OPEN, and HAND.

The 6MMbf volume maximum per period is not set in stone. This means the volume harvested by HAND which peaks around 16MMbf in period 5 is still a viable solution. Again it should be noted that HAND harvested all timber in the first 30 years. This combined with no volume constraints explains the large variation in HAND's volume curve. The aspect of total revenue parrallels volume harvest levels.

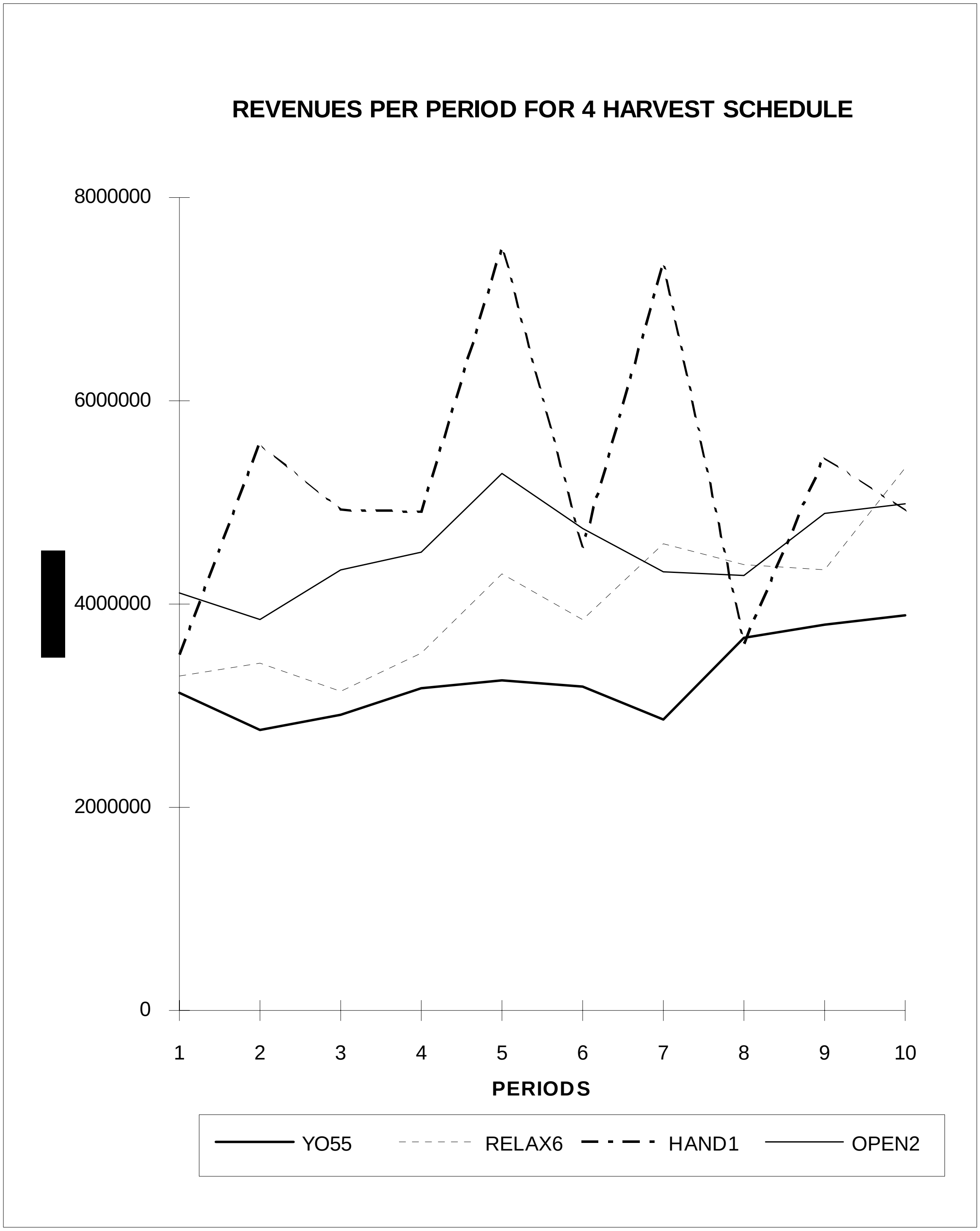

Figure 6.9 Revenues per period for YO,RELAX, OPEN, and HAND.
It follows that the more timber cut, the more revenue.

This is apparent in Figure 6.9. HAND was able to harvest the largest volume of timber and consequently gained the largest revenue. If YO were extended to harvest all available timber, it would comparable revenue results. Again we see how more constrained harvest scheduling results in a more constant revenue flow. The question of increased roading due to more volume cut is answered by comparing the Volume and Road construction cost charts.

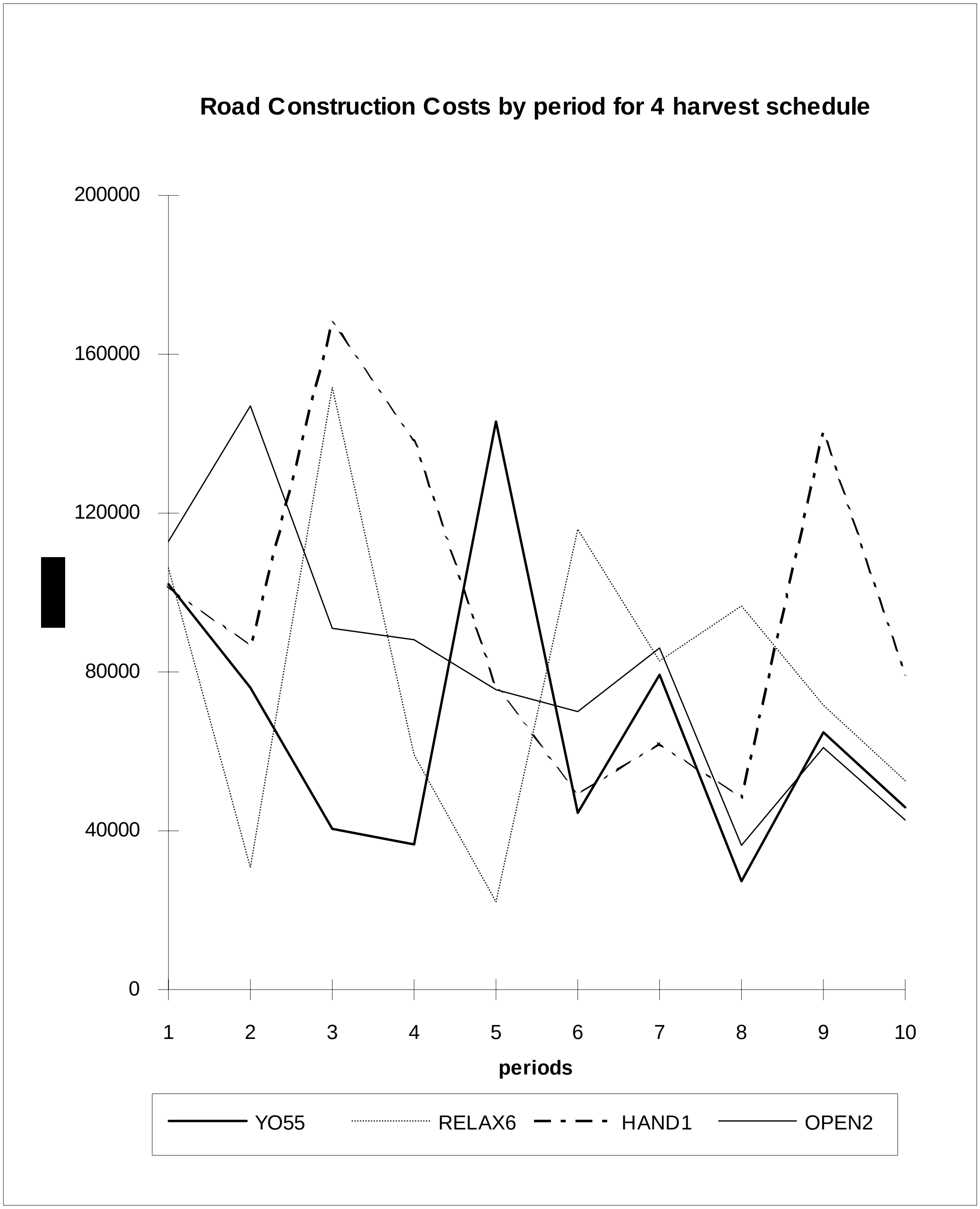

Figure 6.10 shows Road Construction costs by period for YO, RELAX, OPEN, and HAND.

By period 10, YO has constructed approximately 670 stations. Comparatively, HAND has constucted approximately 960 stations of road. At first glace this may imply that the increaseed volume cut in HAND results in more road activity. But one must remember that YO did not cut as much volume. If the road construction curve for HAND were pulled back to equal YO's volume level (somewhere around the middle of period 6) it becomes obvious that Mbf for Mbf, the same amount of road construction occurs. By looking at all the graphs, it is also apparent that both road constuction costs and total stations constucted is not a function necessarily of volume, but of terrain, previous harvest activities, and sale location.

From the NETWORK Summarys we can also see that HAND produced the lowest road construction cost, 4.53 $/Mbf. Open equaled 4.79 $/Mbf, RELAX equaled 4.77 $/Mbf and YO equaled 5.13 $/Mbf. HAND's low construction cost results from spreading roading cost over larger revenues.

6.5 A comparison of Hand Scheduling to using SCHEDULER

In addition to the computer generated schedules we decided to create a schedule by hand. The comparison between methods revealed several advantages of using the computerized method and only a few disadvantages. The primary disadvantage of SCHEDULER is having to construct the input file 2. The potential for human error during file construction is high and editing mistakes can be tedious and time consuming (to obtain a single schedule from the SCHEDULER program took longer than obtaining the first hand schedule), however we believe that much of this problem could be alleviated by writing an ARC/INFO SML program that would automate the file construction process (much as construction of file 1 is reasonably automated and direct). The time required to produce a single hand schedule in our project required; - approximately 2 hours to group settings into sales (required for both hand and SCHEDULER methods), - 8 hours minimum to produce the schedule. However the production of additional schedules actually took longer than the first since certain options were now unavailable (avoiding repetition). The results of the one hand schedule are presented in the previous "HAND SUMMARY".

The advantages to using the SCEDULER program became more evident as multiple feasible solutions were required for NETWORK analysis. A complete run of SCHEDULE and NETWORK analysis of the output would take approximately 20 minutes, and much of this procedure can be batched and run without operator attention being required.

On a project of this size it is feasible to produce hand schedules that meet most constraints required by planners but as the area or number of units increases and as constraints become more complex the computerized tool becomes essential.

CHAPTER 7

TIMBER RESOURCES

7.1 DATA SOURCES

Information on timber resources came from the Department of Natural Resources (DNR) Geographic Information System's (GIS) data base. During winter quarter the class began learning to use GIS with this data base. The timber resource layer had complete information for all the polygons within the Elochoman B planning area our class was assigned. The first week of spring quarter, recent inventory data was recieved and the map plotted out along with its polygon attribute table. A comparison was made between the two sets of information and maps. The recent inventory filled 15 of 70 polygons and the rest were blank. To complicate matters further, this polygon layer had different shapes than the previous one, so information couldn't be transferred directly over from the old map to fill the empty polygons of the new map.

Larry O'Brien, a research assisstant for the College of Forest Resources, was also our part time GIS ARC/INFO consultant. He used ARC/INFO to help solve the problem between the two timber layers. We used the command "identity" to merge all the information from both layers into one file. In 'tables' of the created layer, 'additem' put in the attributes desired on the final layer. Then "frequency" tells the computer to add up all the times those attributes appear (gets a weighted average). "Joinitem" then put those weighted averages into the final layer, filling the empty polygons with numbers.

A comparison was made between the volumes produced by the computer and the volumes from the recent inventory. The computer generated volumes from weighted averages of previous data were generally half of what the inventory gave (these values were comparing the mature timber volumes, the plantation values were not as important at this time). The computer generated information didn't seem to work real well. There were 38 total polygon shapes of mature timber with 15 of recent inventory. To fill the plantation polygons, the computer generated information was used. To fill the 23 mature polygons with volume information, DNR empirical yield tables for west side timber was used (Tables A, B, C). The computer generated numbers for diameter and ages were used for these polygons. Now the timber polygon information was complete for use in the scheduler program and AYD and harvest costing.

On June 2 of 1993, the last week of the quarter, a disk was sent with more recent inventory data. A comparison of the estimated volumes obtained from the empirical yield tables to the new inventory revealed about a 15% deviation from the estimated to the actual sampled volumes.(Table 7.1.4).

Table 7.1.4: Comparison of actual volumes to estimated volumes by stand number.

STAND NO	ACTUAL	ESTIMATE
1492	29789	
1498	61174	59775
1501	42072	101422
1506	65102	55098
1509	38215	
1510	48755	70540
1514	55058	55098
1523	59958	59775
1529	50985	59775
1535	32965	59775
1536	62708	49467
1537	31072	
1539	61516	59775
1540	69994	
1542	49951	49467
1552	44572	
1553	14101	55098
1554	67655	46236
1556	59759	
1558	62859	
1560	59398	
1563	53850	59775
1565	43192	
1568		38050
1569	59991	55098
1572		39658
1573	29728	70540
1577	53266	59775
1578	39920	
1581	63254	70540
1584		70540
1592		55098
1594	38725	
1598	35345	
1602	15959	
1607	23560	
1613	21306	
1769	25761	21597

7.2 EXISTING TIMBER CONDITIONS

The Elochoman B planning area is approximately 3687 acres, including riparian buffer areas. About 1650 acres is plantation with an average age of 20. The remaining 2037 acres, average of 60 years old, was naturally grown after railroad logging (Table 7.2.1).

Table 7.2.1 Age classes and areas for the two major age classes in the planning area

Age classes	Acres	
Plantation		
0 - 25 years	1650	
Mature		TOTAL 3687
25+ years	2037	

The primary species in the mature timber area is western hemlock. Secondary species includes Douglas-fir, red cedar, and red alder. Douglas-fir stands reside on the west side of the planning area, western hemlock is east and centrally located, and alder stands are mixed between. The average site index for western hemlock is 118 and for Douglas-fir is 125. Refer to the Timber Type Map (Figure 1.3.7.1).

Timber information came from the DNR's GIS data base. Current inventory data, as of June 2, 1993 is reflected on the following table(Table F and Table H) and also on the Stand MBF/ACRE map (Figure 1.3.7.2). Insufficient volume information was filled in using empirical yield tables from the Washington State Department of Natural Resources.

STAND VOLUMES			ACRES
Plantation	0 - 20	MBF/ACRE	1650
Mature	20 - 40	MBF/ACRE	576
	40 - 60	MBF/ACRE	794
	60+	MBF/ACRE	897

Five major stand types were delineated within the mature timber age class. These were delineated from the Ortho photos and cross-checked with the GIS stand attribute tables of timber information (Table 7.2.7). The open stands were heavily textured on the Ortho photo and generally had low stocking density (100 - 150 TPA). Thick stands had uniform texture and generally had more trees per acre (200). These stand delineations were to aggregate and thus reduce the number of stands to deal with in the analysis.

Table 7.2.7: Stand type separations using the polygon fiu_id number as the stand number.

TIMBER STAND TYPES				
OPEN	THICK	ALDER	MIX	RIPARIAN
1558	1568	1613	1498	1553
1542	1560	1500	1537	1552
1563	1556	1598	1509	1592
1577	1529			1492
1510	1536			1602
1581	1540			1578
1573	1506			1572
1552	1514			
1594	1539			
1554	1523			

20 YEARS OLD		<10 YEARS OLD	SALE IN PROGRESS
1548	1757	1495	1769
1562	1759	1768	1607
1766	1758	1599	
1770	1504	1589	
1767	1513	1590	ROCK PIT
1600	1407	1579	1583
1585	1600	1582	
1562	1767	1597	
1502	1770	1593	
1503			

7.3 STAND PROJECTION SYSTEM

The stand growth simulation program used for analysis of these stands is the Stand Projection System (SPS) by James D. Arney, Ph.D. For a copy of the program the contact address and phone is Applied Biometrics, P.O. Box 28838, Spokane, WA 99228, (509) 467 - 6164). This simulation program was used to generate possible future stand conditions, for analysis in thinning, and for growth factors used in the Scheduler program.

For possible future stand conditions the "open" stands and the "thick" stands were simulated. For both of these simulations, an average of the stand numbers in each stand type were calculated using actual inventory data recieved at the beginning of the quarter. For the open stands, stand numbers 1594 and 1565 were used (Table I or Appendix X) and for the thick stands, stand numbers 1540, 1556, and 1560 (Table J or Appendix X).

Growth factors for the Scheduler program were generated using an average from both the open and thick stand simulations. The growth factors are calculated by dividing the next years volume by the previous years volume. The factors were then cumulated, always refering back to year one for the Scheduler program input (Table 7.3.1).

Table 7.3.1: A list of the growth factors generated by SPS and the cumulated growth factors used for Scheduler program input.

Growth Factors from SPS	Cumulative Growth Factors
1.05	1.05
1.03	1.08
1.08	1.16
1.06	1.24
1.05	1.29
1.06	1.35
1.04	1.39
1.04	1.43
1.05	1.48
1.03	1.51

The simulation program, SPS, was used to simulation plantation age stands. It did not seem to work. The future outputs would not come close to either volumes of existing stands that age or to volumes checked against empirical yield tables. The program seemed to work quite well to simulate existing stands into the future. Doug Maguire, associate professor at the University of Washington specializing in mensuration was contacted to answer questions about this program's reliability for simulation. He felt that the program was good for the existing, older stands, but that it did not perform very well for younger stands. At the beginning of the planning process, SPS was available and I had gained some familiarity with it the previous quarter. The DNR provided another simulation program, DNR/IMPS, but after starting with one simulation program, I did not feel that data produced by two simulations could be used for proper analysis.

One should not switch simulation program packages in the middle of a planning/analysis process because the resulting data would not have any meaning.

When using the simulation program for analysis, the outputs of these programs should not be looked at as what actually will be out in the stands. This is just a tool to estimate stand charactaristics. The outputs do not take into consideration the defect that may be present and/or any natural disasters that may occur over time. These programs are just tools to estimate stand charactaristics. If another program were used for this planning process, outputs could produce different results and thus different conclusions. I tried to cross-check the values SPS gave to give the outputs some credibility. Empirical yield tables and the recent inventory data recieved at the beginning of the quarter were referenced for reality checks on simulation outputs.

7.4 THIINNING

The stand types (Table 7.2.7) were placed on a Density Management Diagram for Douglas-fir (Figure 7.4.1) using trees per acre and average diameter (I am not aware of a density diagram for western hemlock). The 'thick' stand type placed on this diagram was in the B zone, which is the "lower limit of zone of imminent competition mortality". This, translated, means the trees are in heavy competition, some are dying and the stand may benefit from a thinning (in silvicultural terms its called a release). The relative density index for this stand is above 0.6. The open stand did not meet the criteria for thinning analysis. It's trees per acre were too low.

To analyse the thick stands for thinning, an average of three stands (1540, 1556, 1560) were used. The stands were simulated into the future for three different prescription alternatives.

1) to thin now and final harvest in 20 or 30 years.
2) to final harvest in 20 or 30 years without thinning
3) clearcut harvesting now.

The results of the three alternatives were graphed to visually review them all together (Figures 7.4.2, 7.4.3, 7.4.4, 7.4.5, 7.4.6, 7.4.7).

As the volume graphs show, none of the stands increased in volume over a 30 year period after thinning. But the diameter graphs show a larger diameter at the end of the 30 year period. The next question to be answered now, is what does this larger diameter mean in economic terms? Will the larger average tree size translate into a higher value at the end of the rotation period (average 2 saw logs vs 3 saw)?

I talked with different people to get an idea of what kind of economic returns were needed to decide if the stand should be thinned. People gave input from ITT, the Silviculture lab at the UW, Weyerhaeuser, Longview Fiber, and Chad Oliver from the UW (silvicultural specialist). Generally felt the desired return between prescription 1 over 2 should be greater than 10%. This return would take into consideration any windthrow, disease,and machine damage which creates future rot. Weyerhaeuser uses 15% as their decision criteria to thin.

The log price input used in the economic analysis for this area came from LOG LINES Log Price Reporting Service for the Pacific Northwest located at Arbor-Pacific Forestry Services, Inc., P.O. Box 1234, Mount Vernon, WA 98273, phone (206) 336 - 6850 (Table 7.4.1). Export and domestice log prices for Douglas-fir and western hemlock were averaged to get one price for each specie (Table 7.4.2).

Table 7.4.2: Prices used to obtain the average log price per specie ($/MBF).

	DF	WH
Export prices	1000	721
	850	660
Domestic	711	549
	584	487
Average price used in analysis	**785**	**605**

The cost used in the economic analysis for this area came from USFS Flat Rate Method, Westside for TRACTOR harvesting (Table 7.4.3). Assumptions used for clearcut harvesting were 4.5 mbf/load * 12 loads/day = mbf/day. This value was looked up in Table N to get $/mbf. The value used in this analysis was $57/mbf. For thinning harvest methods, 2 mbf/load * 3 loads/day was assumed. The value used for thinning was $87/mbf.

All revenue and costs were projected 20 or 30 years at 5%.

Detailed computations of the economic comparisons of the three prescription alternatives are in Appedix 7. Below is a summary of the results for each prescription (Table O, P, and Q).

Table 7.4.4: Results comparing the alternatives by thinning from below to 150 TPA.

CUT NOW	NO THIN	THIN NOW HARVEST IN 20 YEARS	30YEARS
$ 88,684	136,002	133,276	
144,458	249,969		247,924
%RETURN		**-2%**	**-0.08%**

Table 7.4.5: Results comparing the alternatives by thinning from below to 120 TPA.

CUT NOW	NO THIN	THIN NOW HARVEST IN 20 YEARS	30YEARS
$ 88,684	136,002	130,454	
144,458	249,969		240,618
%RETURN		**-4%**	**-3.7%**

Table 7.4.6: Results comparing the alternatives by thinning from above to 150 TPA

CUT NOW	NO THIN	THIN NOW HARVEST IN 20 YEARS	30YEARS
$ 88,684	136,002	101,168	
144,458	249,969		183,317
%RETURN		**-25%**	**-26%**

The conclusion derived from this analysis is that thinning these stands is not a economical method of harvesting. Political reasons such as spotted owl habitat management or visual constraints may be why thinning would be the desirable method of harvest. If thinning were done at all, it would mean an economical loss to the timber manager. The values given in this analysis were derived using numbers and simulations. This method does not substitute for a field check of the area. When actually observing these stands, there is a bit of defect seen. Defect inclues wolfy trees, forked tops, crooks, and small scattered pockets of mistletoe. This conclusion was derived using SPS, one of many growth simulators which does not account for defect. Including the defect in the analysis would make thinning an even less desirable method of harvest for this particular area.