Road Alignment and Haul Time Computations for Surfacing Design

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Forest Engineering

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Executive Summary

In Brief

The following conclusions have been reached after analysis of Surface Design and Road Alignment options for the major haul route used by the DNR and Weyco in the S toessel Creek drainage. The haul route will be used for a 20 year span. The total volume to be hauled over the road during its lifetime is 2 13 MMBF.

1. For the average road parameters (CBR of subgrade is 30, CBR of aggregate is 35 at 90 % and 95% compaction at 80 psi) the present value of the 20 yr. plan was $308 748 at 90% compaction and $175 732 at 95% compaction. The present value for the 5 yr. plan with reconstruction every five yrs (3 reconstructions) was $369 440. The 20 yr. plan needed to extrapolate the rut depth equation past the allowable ESAL's, while the 5 yr. plan was within the allowable parameters for ESAL's. At 90% compaction, the options are very similar in cost. The 5 yr. plan would be the best choice for design as it is within the parameters of the equation which was essential to the analysis. It also allows for flexibility and options within the design every five years.

   NOTE:

   The comparison is only valid for a 12 ft. road surface width between the 20yr. plan and the 5 yr. plan because a 5 yr. plan must use a 12 ft. road surface width.

   The average subgrade parameter of 30 for the CBR was calculated by assuming that the soil would compact after the first five years to raise the CBR value. We took the mean value for our standard GP-GM soil and the mean value for the higher grade GP soil and averaged these two values to produce a CBR for the subgrade of 30.

2. The 18 ft. running surface design was justifiable for the 20 yr. plan at 50 psi corresponding to 90% and 95% compaction, and also for the 20 yr. plan at 80 psi corresponding to 95% compaction. The 20 yr. plan at 80 psi corresponding to 90% compaction must have a 12ft running surface design. These justifications are based upon economic analysis. We compared the savings due to shortened haul time for widening the road to the cost for additional ballast and construction (please see the section labeled Findings for the detailed economic discussion).

3. The additional ESAL’s from the required dump trucks had no effect on the ballast thickness.

4. The cost to realign the road between stations 34+00 and 50+00 was greater than the benefit of the time savings due to high excavation costs. The analysis rejected the possibility of realignment.

Introduction

Nomenclature

The seniors of the Forest Engineering program of the University of Washington were approached by Peter Schiess (professor of FE 444 Forest Engineering Design) with the following problem description:

> The Stoessel Road is one of the major haul routes in Marckworth Forest. The two major landowners include the Department of Natural Resources (DNR) and Weyco. The seniors from the class of 1985 developed an overall harvest and transportation plan for the Marckworth Forest. As part of the planning the Stoessel Road is becoming a major haul route.
>
> The total volume of timber to be hauled over the road is 2 13 MMBF over a 20 year period. There is additional volume from Weyco, estimated to be 50 MMBF. The timber is all second growth fir and hemlock, typically 50 to 70 years old.
>
> Given:
> 1. Proceeding information
> 2. The survey notes from the 1985 road crew
> 3. DNR is considering leaving the road at 12 ft. running width with only improving the ballast.
>
> Required:
> 1. Determine the effect of the additional ESAL's of the dump trucks used for ballast haul on the ballast depth in light of the normal traffic situation.
> 2. Determine if an 18ft. running surface is more appropriate by using an economic analysis of cost in additional ballast vs. savings due to shorter haul times for a twenty year plan and for a five year plan requiring additional reconstruction at the end of each of the five years proceeding to twenty years.
> 3. For the average road parameters, determine which of the plan (five year or twenty year) is more economically sound.
> 4. Determine if the reverse curve between stations 34+00 and 50+00 should be realigned to reduce haul time in order to be more cost effective than the present design.
> 5. Present a Report including findings recommendations and justification (both technical and economical) for the Stoessel Greek

Model

Aggregate Thickness:	We chose to use the procedure outlined in example 5.3.2 (pg. 87) of the *Earth and Aggregate Surfacing Design Guide for Low Volume Roads.* This design example provided a ballast depth for Multiple Season Design. It incorporated the use of the "STP" computer program for computing ballast depth given required parameters. Please note the limitations to the use of the equation used to compute rut depth for this example. The limitations are listed on pg. 15 of the SDG manual.
Haul times:	We chose to use the procedure outlined in the U.S *Agriculture Department Agriculture Handbook No. 183*. (pg. 17).
Realignment:	We chose to use Roadeng. to compute volumes of cut and fill to be excavated for a cost analysis vs. realigned savings due to shortened haul times.

Findings

Additional ESAL's from the required Dump Trucks

The procedural analysis will show that the ballast thickness was calculated for the design vehicles without the input of the dump truck in regards to ESAL's. From this volume of ballast, the dump truck ESAL's could be estimated. The ESAL's were then added to the total ESAL's. The analysis was run on the more extreme ballast thickness for 80 psi for both the five year plan and the twenty year plan. The percentage of ESAL's from the dump trucks was not enough to increase the thickness of ballast. Please see Tables 1 and 2 below. Therefore, they were ignored in the analysis as the same ballast depths occur with them or without them. Since we computed the ballast volumes without them, we could rely on the those calculations for ballast depths. It is important to mention however, that all of the ESAL's for the Dump Trucks would be realized within the first year of construction. Hence, the wear imposed by the dump truck ESAL's would not be spread over the design life as is all the other design vehicle ESAL's.

Table 1. ESAL's at reliability factor of 2.32 @ 80 psi for five year plan with Dump Trucks

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	3.17	10520	77368	72.6262
Empty Log Truck	0.76	10520	18549	17.4122
Pickup Truck	0.09	2630	549	0.51535
Washington 208	16.87	26	1024	0.96124
Dump Truck Loaded	2.01	1265	5899	5.53746
Dump Truck Unloaded	1.07	1265	3140	2.94755
		Total ESAL's	106529	100

Table 2. ESAL's at reliability factor of 2.32 @ 80 psi for twenty year plan with Dump Trucks

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	3.17	52600	386841	77.2549
Empty Log-Truck	0.76	52600	92744	18.5216
Pickup Truck	0.09	2630	5491	1.09659
Washington 208	16.87	132	5197	1.03788
Dump Truck Loaded	2.01	1464	6826	1.3632
Dump Truck Unloaded	1.07	1464	3634	0.72574
		Total ESAL's	500733	100

ESAL's for the five year plan

At a reliability factor of 2.32 (corresponds to the 90% chance of success of the road within the design life) and at 50 psi for the five year plan, the ESAL's for the input vehicles were 34 766. The heaviest percentage of ESAL's were due to the logging trucks, please see Table 3 below.

Table 3. ESAL's at reliability factor of 2.32 @ 50 psi for five year plan

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	1.07	10520	26115	75.1165
Empty Log Truck	0.29	10520	7078	20.359
Pickup Truck	0.09	2630	549	1.57913
Washington 208	16.97	26	1024	2.94541
		Total ESAL's	34766	100

At a reliability factor of 2.32 and at 80 psi for the five year plan, the ESAL's for the input vehicles were 97 490. The heaviest percentage of ESAL's were due to the logging trucks, please see Table 4 below.

Table 4. ESAL's at reliability factor of 2.32 @ 80 psi for five year plan

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	3.17	10520	77368	79.3599
Empty Log Truck	0.76	10520	18549	19.0266
Pickup Truck	0.09	2630	549	0.56313
Washington 208	16.87	26	1024	1.05036
		Total ESAL's	97490	100

Ballast Volumes, and cost comparisons for 12 ft and 18 ft road widths for the five year plan

The study was performed at two differing compactions. In all cases the ballast depth was less at the higher level of compaction. The cost savings in ballast was much lower than the added $0.30 to $0.40 for extra compaction. Tables 5 and 6 show that the ballast volumes for the 18 ft running surface were more than the ballast depths for the 12 ft running surface at 50 psi and 80 psi respectively. Later findings (Tables 14) will show that the cost for the added ballast (including the construction costs for the additional road width) was greater than the revenue realized in time savings, for any of the five year options (note the "u" after the cost difference at the bottom of table signifies that the plan is unfavorable for 18 ft road widths).

Table 5. Ballast depth @ 50 psi and two inch allowable rut for five year plan

	Compaction at 90%	Compaction at 95%
Subgrade CBR	11	24.2
Aggregate CBR	22.4	29.2
Ballast Depth (in)	11	7
12 ft running surface		
cubic yards of agg.	11814.8	7709.2
Ballast cost ($12/cyd)	141778	92510.5
18 ft running surface		
cubic yards of agg.	15323.6	9910.6
Ballast cost ($12/cyd)	183883	118927.2
Ballast + Construct.	229854	148659.0
Cost Difference	88076.4 u	56148.5 u

Table 6. Ballast depth @ 80 psi and two inch allowable rut for five year plan

	Compaction at 90%	Compaction at 95%
Subgrade CBR	11	24.2
Aggregate CBR	22.4	29.2
Ballast Depth (in)	16	9
12 ft running surface		
cubic yards of agg.	16387	9797
Ballast cost ($1 2/cyd)	196644	117564
18 ft running surface		
cubic yards of agg.	21461	12652
Ballast cost ($12/cyd)	257532	151824
Ballast + Construct.	321915	189780
Cost Difference	125271 u	72216 u

ESAL's for the twenty year plan

At a reliability factor of 2.32 (corresponds to the 90% chance of success of the road within the design life) and at 50 psi for the twenty year plan, the ESAL's for the input vehicles were 176 65 1. The heaviest percentage of ESAL's were due to the logging trucks, please see Table 7 below.

Table 7. ESAL's at reliability factor of 2.32 @ 50 psi for twenty year plan

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	1.07	52600	130574	73.9164
Empty Log Truck	0.29	52600	35389	20.0333
Pickup Truck	0.09	26300	5491	3.10839
Washington 208	16.97	132,	5197	2.94196
		Total ESAL's	176651	100

At a reliability factor of 2.32 and at 80 psi for the twenty year plan, the ESAL's for the input vehicles were 490 273. The heaviest percentage of ESAL's were due to the logging trucks, please see Table 8 below.

Table 8. ESAL's at reliability factor of 2.32 @ 80 psi for twenty year plan

Vehicle type	Factor	# Passes	18 Kip ESAL	%of Total ESAL's
Loaded Log Truck	3.17	52600	386841	78.9032
Empty Log Truck	0.76	52600	92744	18.9168
Pickup Truck	0.09	26300	5491	1.11999
Washington 208	16.87	132	5197	1.06002
		Total ESAL's	490273	100

Ballast Volumes, and cost comparisons for 12 ft and 18 ft road widths for the twenty year plan

Tables 9 and 10 show that the ballast volumes for the 18 ft running surface were more than the ballast depths for the 12 ft running surface at.50 psi and 80 psi respectively. Later findings (Table 14) will show that the cost for the added ballast was greater than the revenue realized in time savings, for the 80 psi option at 90% compaction (note the "u" after the cost difference at the bottom of table signifies that the plan is unfavorable for 18 ft road widths). The other options, 50 psi at both compactions and 80 psi at 95% compaction show favorable "f' revenue realized for haul time savings versus added cost of ballast for the 18 ft road width.

Table 9. Ballast depth @ 50 psi and two inch allowable rut for twenty year plan

	Compaction at 90%	Compaction at 95%
Subgrade CBR	11	24.2
Aggregate CBR	22.4	29.2
Ballast Depth (in)	19	11
12 ft running surface		
cubic yards of agg.	18994	11815
Ballast cost ($12/cyd)	227928	141780
18ft running surface		
cubic yards of agg.	24996.2	15323.6
Ballast cost ($12/cyd)	299954	183883.2
Ballast + Construct.	374943	229854
Cost Difference	147015 f	88074 f

Table 10. Ballast depth @ 80 psi and two inch allowable rut for twenty year plan

	Compaction at 90%	Compaction at 95%
Subgrade CBR	11	24.2
Aggregate CBR	22.4	29.2
Ballast Depth (in)	28	14
12 ft running surface		
cubic yards of agg.	25729	14644.4
Ballast cost ($12/cyd)	308748	175732.8
18 ft running surface		
cubic yards of agg.	34639	19116.4
Ballast cost ($12/cyd)	415668	229396.8
Ballast + Construct.	519585	286746
Cost Difference	210837 u	111013.2 f

Logging truck haul time for 12 ft running surface

Table 11 shows the time per mile as controlled by grade and as controlled by alignment. In all cases, loaded or unloaded, haul time is controlled by alignment.

Table 11. Time per mile for a 12ft running surface (min)

section	As controlled by grade Loaded	Unloaded	As controlled by alignment Loaded	Unloaded
1	1.3	1.2	3.0	2.5
2	1.7	1.2	3.6	3.3
3	2.0	1.4	2.9	2.8
4	1.4	1.2	2.0	1.8

Table 12 reveals that the total cost per round trip is $16.25. This figure is based on the estimate obtained for the cost per hour to operate, $57.50. It was possible to establish the costs for the total number of trips for the logging trucks for the 12 ft running surface. For 52 600 trips (20 yr. plan) the cost is $854 622. For 10 520 trips (5 yr. plan) the cost is $170 924. We will later establish the costs for the 18 ft surface for the twenty year and five year plan (Tables 13 and 14). The comparison will show us the total revenue realized for savings in haul times.

Note: The Governing unloaded time is multiplied by a 1.5% delay for our chosen turnout spacing.

Table 12. Round trip Time for a 12 ft running surface

Section	Governing unloaded time*1.015 (minutes)	Total time per round trip mile (minutes)	Distance (miles)	Time per section (minutes)	Cost per section (dollars)
1	2.54	5.54	0.68	3.77	3.6
2	3.35	6.95	0.25	1.71	1.6
3	2.84	5.74	0.23	1.31	1.2
4	2.44	4.84	2.10	10.17	9.
		Total	3.26	16.95	16.2
20 yr. plan : $16.25 per round trip times 52600 round trips is					854622
5 yr. plan: $16.25 per round trip times 10520 round trips is					170924

Logging truck haul time for 18 ft running surface

Table 13 shows the time per mile as controlled by grade and as controlled by alignment. In all cases, loaded or unloaded, haul time is controlled by alignment.

Table 13. Time per mile for an 18ft running surface (min)

section	As controlled by grade Loaded	Unloaded	As controlled by alignment Loaded	Unloaded
1	1.3	1.2	2.8	2.4
2	1.7	1.2	3.3	3.2
3	2.0	1.4	2.6	2.5
4	1.4	1.2	1.8	1.6

Table 14 reveals that the total cost per round trip is $13.17. It was possible to establish the costs for the total number of trips for the logging trucks for the 18 ft running surface. For 52 600 trips (20 yr. plan) the cost is $692 963. For 10 520 trips (5 yr. plan) the cost is $161 659. The cost savings for the 18ft running surface was calculated by subtracting the costs realized for haul times for the 18 ft running surface (20 yr. and 5 yr. plan respectively) from the costs realized for haul times with the 12 ft running surface. After we know the revenue savings, we can compare these savings against the cost for the additional ballast and construction from Tables 5, 6, 9, and 10.

Table 14. Round trip Time for an 18ft running surface and cost estimate (based on truck rate of $57.5/hr

section	Governing unloaded time*1.015 (minutes)	Total time per round trip mile (minutes)	Distance (miles)	Time per section (minutes)	Cost per section (dollars)
1	2.44	5.24	0.68	3.57	3.42
2	3.20	6.50	0.25	1.60	1.53
3	2.54	5.14	0.23	1.17	1.12
4	1.73	3.53	2.10	7.41	7.10
		Total	3.26	13.75	13.17

$13.17 dollars per round trip times 52600 (20 yr) round trips is 692963.36
Cost Savings for 18ft running surface is 161659.53

$13.17 dollars per round trip times 10520 (5 yr) round trips is 138592.7
Cost Savings for 18ft running surface is 32331.91

Recommendations

We recommend the use of the use of the five year plan. For the average road parameters (CBR of subgrade is 70, CBR of aggregate is 29.2 at 90 % and 95% compaction at 80 psi) the present value of the 20 yr. plan was $308 748 at 90% compaction and $175 732 at 95% compaction. The present value for the 5 yr. plan with reconstruction every five yrs (3 reconstructions) was $328 350. The 20 yr. plan needed to extrapolate the rut depth equation past the allowable ESAL's, while the 5 yr. plan was within the allowable parameters for ESAL's. At 90% compaction, the options are very similar in cost. The 5 yr. plan would be the best choice for design as it is within the parameters of the equation which was essential to the analysis. The five year plan is the best choice, it provides time windows for planning flexibility which is worth some of the additional cost. Economically, it is comparable.

For the five year plan we deduced that the costs for using an 18ft wide running surface is not a viable option. The cost for the added ballast was greater than the revenue realized in time savings, for any of the five year options, see Tables 5 and 6 for ballast volume and construction costs, and also table 14 for time haul revenue from time savings.

Finally we recommend that the road alignment should remain as is. The costs for excavation exceeded the savings realized by shortened time of haul. From Procedural analysis, Section IV. Steps 5 and 6, the present worth savings over 20 years is $4,536.75. Analysis (using Roadeng) of the amount cubic yards of cut that will need to be made to realign the road, along with the minimal time saved by increasing the radius of the 2 curves reveals that realignment is obviously not economically feasible. At an excavation cost of $1 per cubic yard, it would take about 5000 cubic yards to pass the present worth of $4,536.75 realized in revenue from time of haul savings. The cubic yard values revealed from Roadeng analysis are much larger than 5000 cubic yards.

Appendix 1.
Procedure for Analysis

I. Ballast Thickness

Follow section 5.3 Aggregate Surface New Construction Multiple Season Design Algorithm (pg. 87 of Earth and Aggregate Surfacing Design Guide for Low Volume Roads).

Step 1: Traffic

a. Using a 20 yr. Design life for aggregate surface, determine the number of trips of each vehicle type:
   - No. of log trucks: for an average haul of 5MBF (52 600 **loaded, 52 600 unloaded)**
   - **No.** of rec. vehicles in and out (.25 of log trucks, pg. 17) (13 **150 in, 13 150 out)**
   - **No.** of yarders in and out (66 **in,** 66 **out)**

b. Determine the ESAL's for each Vehicle
   - Log trucks loaded @ 50 psi = 1.07, @ 80 psi = 3.17
   - Log trucks empty @ 50 psi = 0.29, @ 80 psi = 0.76
   - Unloaded pickups = 0.09
   - Washington 208 w/tower @ 80 psi = 16.97 (pg 92 of manual)

c. Determine the total ESAL's for all the expected traffic

d. Determine the reliability factor (2.32 for 90% reliability).

e. Design ESAL's = ESAL's * reliability factor.

Step 2. Materials

a. Determine the number of seasons with similar soil conditions (section 3.4.1) (we **will use one season, as the soil parameter that takes into account the differences in soil strength does not vary in the case of the sight in question, the number is the same in the wet season or the dry season).**

b. CBR of the subgrade and aggregate

	@ 90% compaction	@95% compaction
1. Subgrade	11	24.2

2. Aggregate @90% compaction 22.4 | @95% compaction 29.2

Step 3. Get results using the computer program "STP," aggregate new construction design the program will give aggregate structural thickness, for a given max. rut depth (book states 2" or no greater than ½ ballast thickness).

a. Realize that given 90% and 95% compaction choices, along with 50 psi and 80 psi options for a 5yr and a twenty year plan will give eight different ballast depths.

Step 4. Estimate Ballast Volume for 12 ft. wide running surface.

Step 5. Repeat steps 1-6 for same vehicles and CBR values but for a five year plan given the following new number of passes.

- No. of log trucks: (10520 loaded, **10520unloaded**)
- No. of unloaded pickups (.25 of log trucks, pg. 17) (2630)
- No. of yarders in and out (26)

a. Realize that given 90% and 95% compaction choices, along with 50 psi and 80 psi options for a 5yr and a twenty year plan will give eight different ballast depths.

Step 6. Obtain ballast depth and correlate the ballast depth to a volume of cubic yards of material.

1. Use Roadeng. to get a ballast volume inputting a depth in inches.

a. Hand calculate the cubic yard volumes for turnouts.
   1. 172 stations/ 500 ft per turnout= 34.4 turnouts
   2. Dimensions for turnout = 34 400 sq. ft.
   3. Turn 34 400 into cubic yrds. and multiply times the ballast depth (cyd) to get a volume for turnouts.
   4. Calculate the number of ESAL's required by dividing the volume of ballast by 10 cubic yards of material per truck for each ballast depth.
   5. Recompute the ballast depth with the new ESAL's for the Dump truck load (note the difference, in our case there was no difference).

II. Determination of haul times

Step 1. Get road data

a. Determine curve radii

- use 1" = 200ft. Plan view of the road.
- only curves with a A > 30° considered.

b. Break road up into sections

- Determine sections taking into account grade and horizontal alignment.

c. Determine number of curves/ mile for each section

- Simply count # of curves/ section, and then divide by the section distance.

Step 2. Determine b factor for design vehicle

a. Design vehicle = standard log truck

b. Assume average truck horsepower = 400 hp

- Determined by inquiring with multiple sources with knowledge of this data

c. Assume e = .72

- Because entire road is under 1,000 ft. Elevation (.72 = value at 1,000 ft elevation, and .74 value for 0 elevation. So used the conservative amount)

d. Assume gross vehicle weight = 80,000 lb.

- standard estimate of loaded log truck weight.

e. Results

- b(loaded) = 3.6 (graphs only go to 3.5, so 3.5 was used)
- b(unloaded) = 11.0 (graphs only go to 10.0, so 10.0 was used)

Step 3. Compute time per mile for loaded and unloaded

a. As controlled by grade

- using the graphs from the 183 handbook and the b values from above.

b. As controlled by alignment

- using the graphs from the 183 handbook and the b values from above.

c. Longer time for loaded and unloaded governs which time will be used for haul time calculations

d. Assume minimum time/ mile = 2.4 min/mile (25 mph avg.)

Step 4. Compute total round trip travel time

a. Determine delay factor due to turnouts and traffic volumes on unloaded travel time

- assume turnout spacing is 100ft.
- vehicles passing over road per hour = 2
- 65,750 total vehicles over road life * 20 year road life = 3,287.5 vehicles/ year * 200 work days/ year = 16.4375 vehicles/ day * 10 hour work day = 1.64 vehicles/ hour. Round off to 2 vehicles/ hour.
- result is increase in unloaded travel time of 1.5%

b. Compute round trip time/ mile for each section

- = (governing unloaded time/ mile* delay (1 .O 15)) + governing loaded time/ mile

c. Compute round trip time/ section

- = time per round trip mile * section distance

d. Compute total haul time/ round trip

- add round trip time/ section together for all sections

Step 5. Repeat same process for 18 ft running surface (1 ½ lanes)

a. Assume min travel time 1.7 min/ mile (35 mph avg.)

b. Note needs to be made that some excavation will need to be made to accommodate the wider road, but the cost of this excavation will be much less than the cost of the ballast material.

III. Compare savings in haul time vs. Expense in added ballast for wider road

IV. Analyze 3 1+00 to 34+00 to determine if new location will reduce haul times

Step 1. Design parameters

a. Savings due to reduced haul times must offset the cost of road reconstruction

Step 2. Determine appropriate design radius for double curves

a. Design radius = 250'

- Balance point between radius of curve that will allow our desired speed and a practical curve radius
- References
  - Optimum curve radius book peter showed to us on 2/12/97, and the graph out of the 183 handbook on speeds vs. Curve radius.

Step 3. Realign road using Roadeng

a. Use horizontal offset method to achieve desired curve radii

Step 4. Recalculate haul times for the section that contains the realigned portion of the road

a. Section 2 after realignment
- governing unloaded time * 1 .O 15 = 3.045
- total time per round trip mile = 6.445
- distance = .2347
- time/ section = 1.513
- total distance after realignment = 3.2454 mi.
- total time per round trip = 13.66 min
- time savings/ round trip = .09 min (5.4 sec.)

Step 5. Determine savings over 20 years

a. Savings = $4,536.75
- .09 min * 52,600 trips = 4734 min = 78.9 hours * 57.5 $/ truck hr. = $4,536.75.

Step 6. Determine feasibility of realigning road

a. Compare savings in haul times to cost of realignment, looking at the amount of cuts that will need to be made to realign the road, along with the minimal time saved by increasing the radius of the 2 curves, common sense tells us that this obviously is not feasible.

V. Compare Savings in Haul time vs. Expense in added ballast to road dimensions.

Step 1. Follow Step 6 in Section I. to compute ballast volumes for 18ft running surf.

Step 2 Add in cost for constructing an 18 ft surface (25% of ballast cost) to get a total cost for the 18 ft. road surface.

Step 3. Compare with Haul time savings.

Step 4. Accept or reject 18 ft option.

Step 5. From Volumes obtain a cost for cubic yards of ballast for 20 yr. and 5 yr. plans.

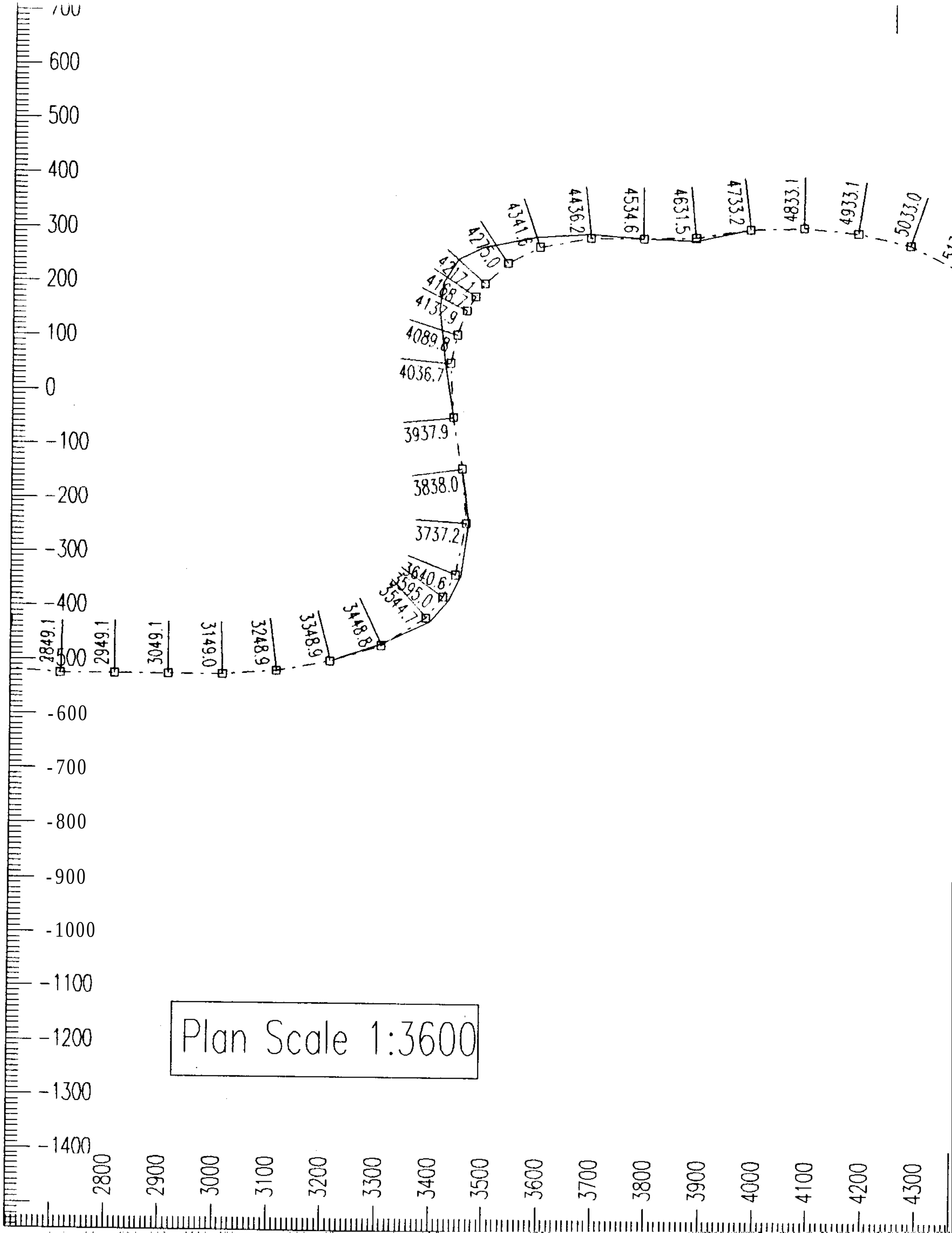
1. Use an estimate of $12 per cubic yard for good grade F 3” inch minus ballast.

2. Realize that the 20 yr. plan is an immediate cost, whereas the 5 yr. plan must take into account future costs of reconstruction.

3. The new CBR value for greater natural compaction of subgrade for traffic through years 0-5 is 30. This value is to be used to calculate new volumes for the average situation which we took to be the 80 psi @ 95% compaction for both the 20 yr. and 5 yr. options (follow steps 5&6 from section I. for new volumes) for years 5-10 and 10- 15 and 15-20.

4. Compare present value of road costs to determine which procedure is most economically sound.

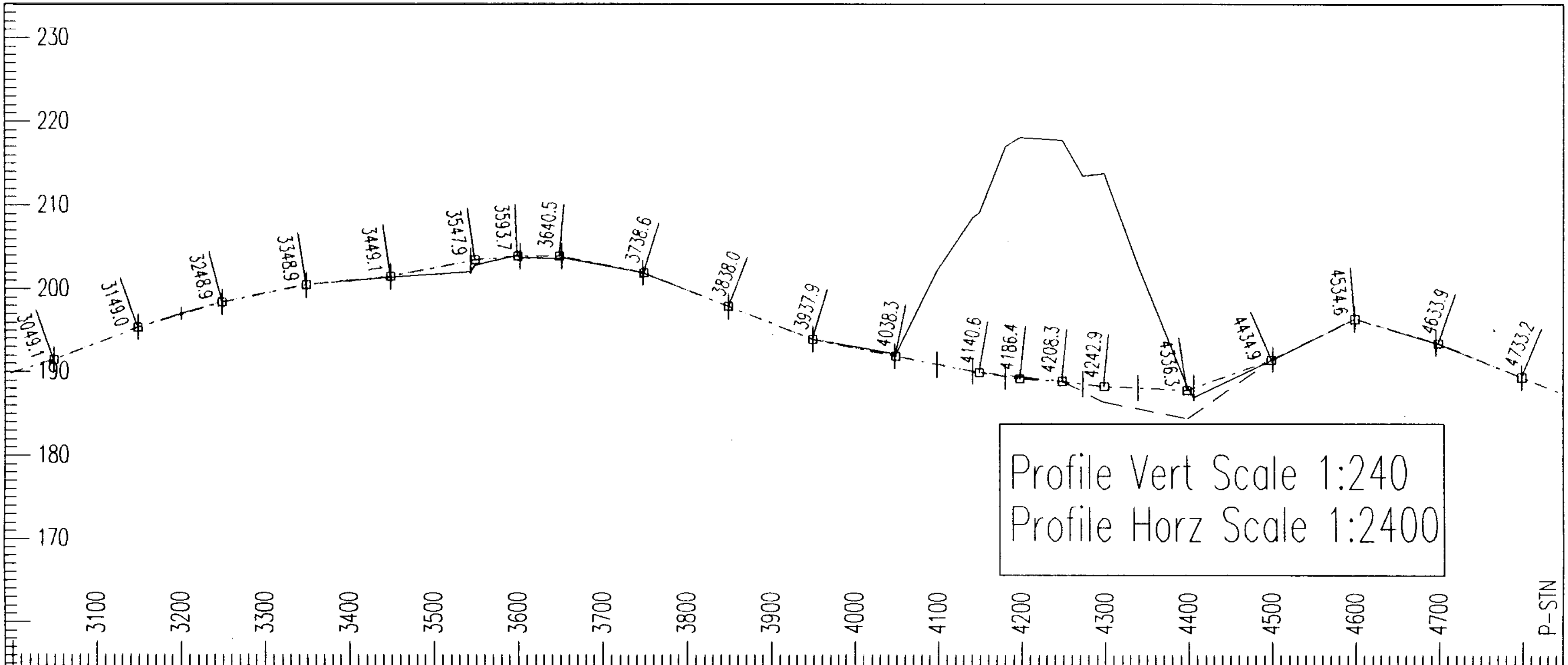
Average inflation is 2%, IRR is 5%

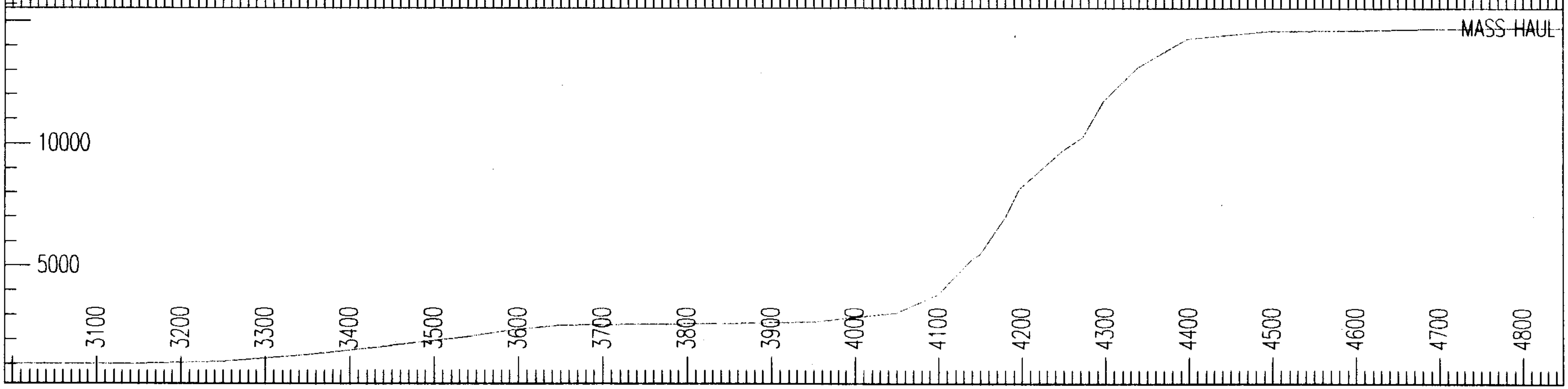


3348.9	3348.9	0.0	0.0	2.0	275.6
3448.9	3449.1	-0.1	2.7	1.0	363.2
3548.9	3547.9	-0.6	-12.1	2.0	421.6
3598.9	3593.7	0.0	-13.4	1.1	283.7
3648.9	3640.5	-0.3	-10.3	0.0	154.5
3748.9	3738.6	-0.0	-3.9	-2.0	39.4
3848.8	3838.0	0.0	0.0	-4.0	55.8
3948.7	3937.9	0.0	0.0	-4.0	57.9
4048.7	4038.3	0.2	11.2	-2.0	364.0
4148.7	4140.6	19.2	50.9	-2.0	2349.8
4197.6	4186.4	29.0	65.2	-1.5	2764.0
4248.0	4208.3	28.8	65.9	-1.2	1533.5
4298.0	4242.9	25.5	55.4	-1.9	2027.1
4397.7	4336.3	0.5	20.3	-0.5	2571.5
4498.5	4434.9	-0.1	7.1	3.6	386.2
4598.4	4534.6	0.0	0.0	5.0	40.3
4698.4	4633.9	-0.1	-6.4	-3.0	43.9
				-4.0	43.5

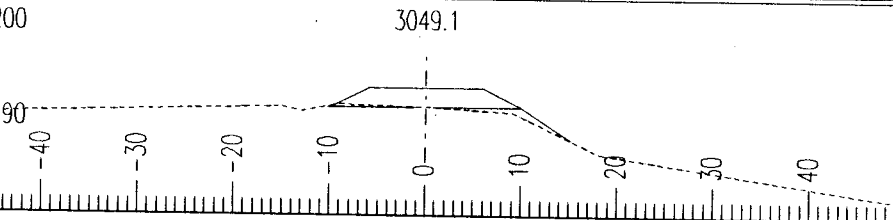
97/02/12

Stoessel Creek **Road** Alignment Project
University of Washington Forest Engineering
Jason Brulotte, **Jason** Mettler, **Charles Frank**

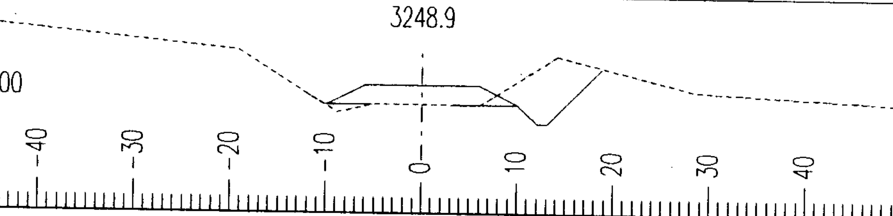




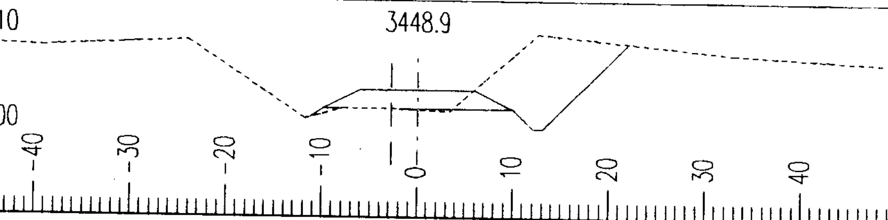
P-Stn ft.	L-Stn ft.	Cut Dp. ft.	H.Off ft.	Grade %	Cut V. cu.yd.
3049.1	3049.1	0.0	0.0	4.0	25.5
3149.0	3149.0	0.0	0.0	3.0	122.0



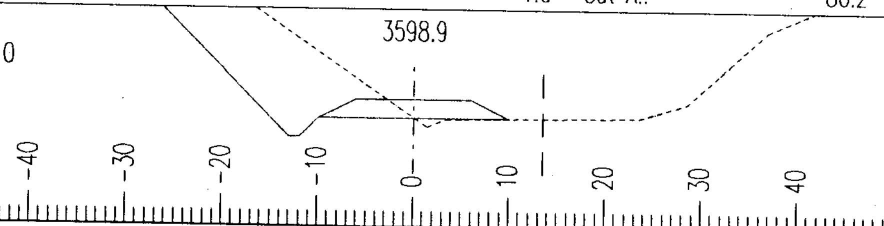
tn:	3049.1	Grd.Nxt %:	4.0	Cut Dp:	0.0
ine V. Off:	0.0	Grd.Lst %:	3.0	Cut A.:	1.4



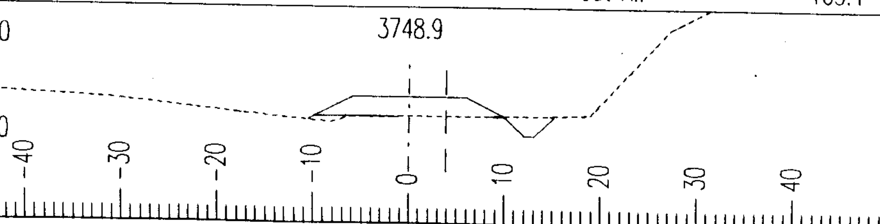
tn:	3248.9	Grd.Nxt %:	2.0	Cut Dp:	0.0
ine V. Off:	0.0	Grd.Lst %:	3.0	Cut A.:	40.0



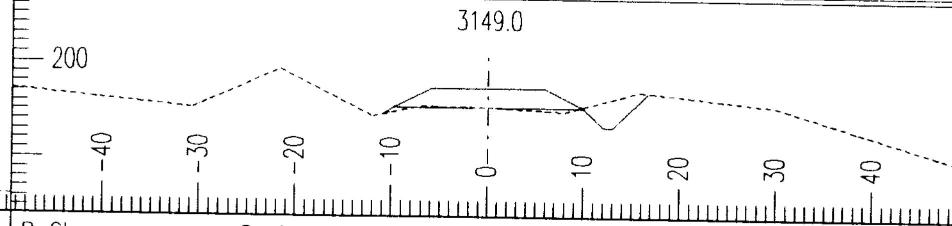
n:	3448.9	Grd.Nxt %:	2.0	Cut Dp:	-0.1
ine V. Off:	0.0	Grd.Lst %:	1.0	Cut A.:	86.2



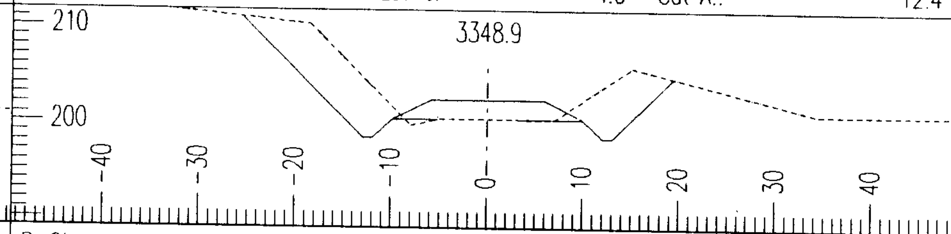
n:	3598.9	Grd.Nxt %:	0.0	Cut Dp:	0.0
ne V. Off:	0.0	Grd.Lst %:	1.1	Cut A.:	165.4



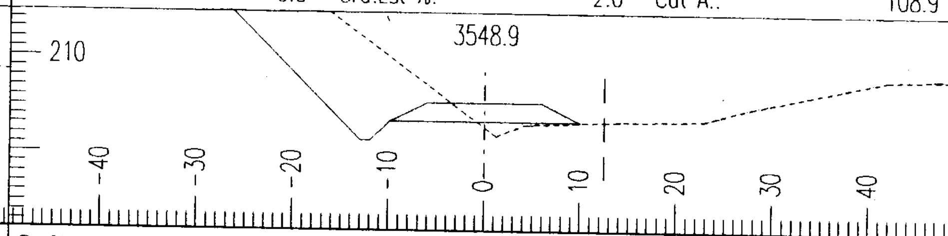
n:	3748.9	Grd.Nxt %:	-4.0	Cut Dp:	-0.0
e V. Off:	0.0	Grd.Lst %:	-2.0	Cut A.:	6.6



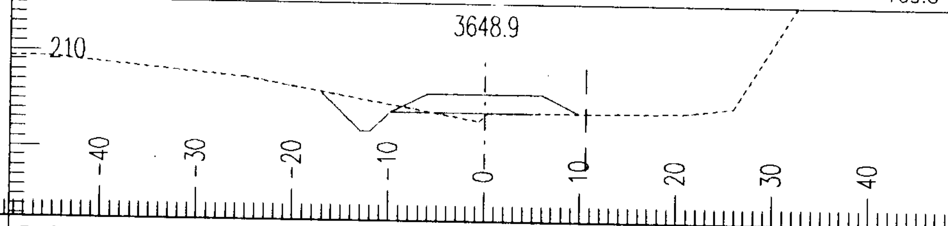
P-Stn:	3149.0	Grd.Nxt %:	3.0	Cut Dp:	0.0
P-Line V. Off:	0.0	Grd.Lst %:	4.0	Cut A.:	12.4



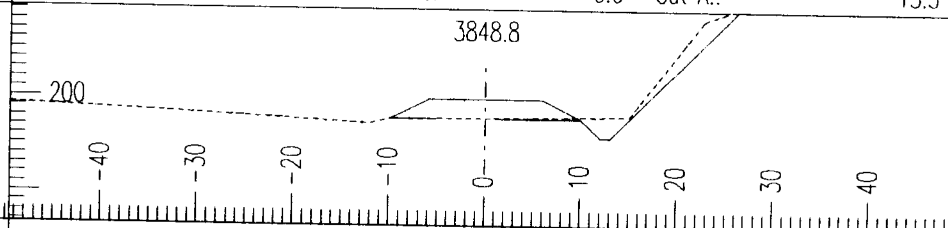
P-Stn:	3348.9	Grd.Nxt %:	1.0	Cut Dp:	0.0
P-Line V. Off:	0.0	Grd.Lst %:	2.0	Cut A.:	108.9



P-Stn:	3548.9	Grd.Nxt %:	1.1	Cut Dp:	-0.6
P-Line V. Off:	0.0	Grd.Lst %:	2.0	Cut A.:	169.5



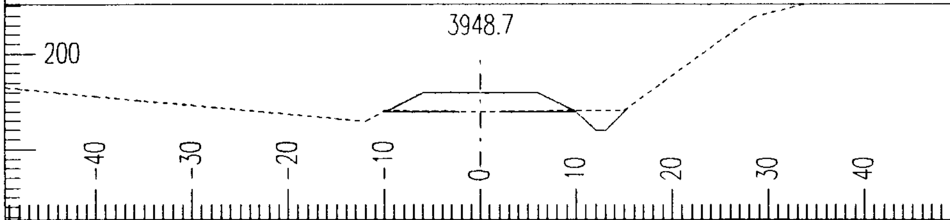
P-Stn:	3648.9	Grd.Nxt %:	-2.0	Cut Dp:	-0.3
P-Line V. Off:	0.0	Grd.Lst %:	0.0	Cut A.:	15.5



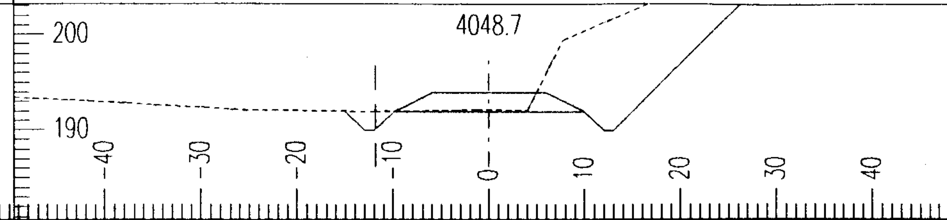
P-Stn:	3848.8	Grd.Nxt %:	-4.0	Cut Dp:	0.0
P-Line V. Off:	0.0	Grd.Lst %:	-4.0	Cut A.:	23.6

P-Line V. Off:	0.0	Grd.Lst %:	-2.0	Cut A.:	6.6

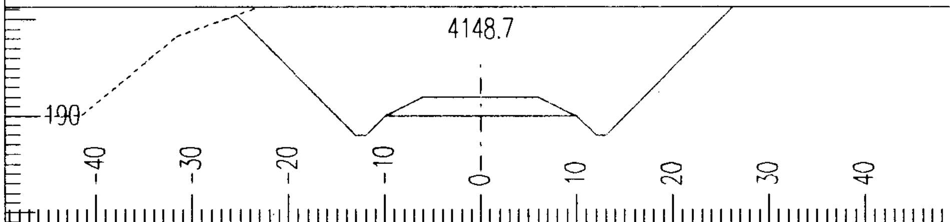
P-Line V. Off:	0.0	Grd.Lst %:	-4.0	Cut A.:	25.6



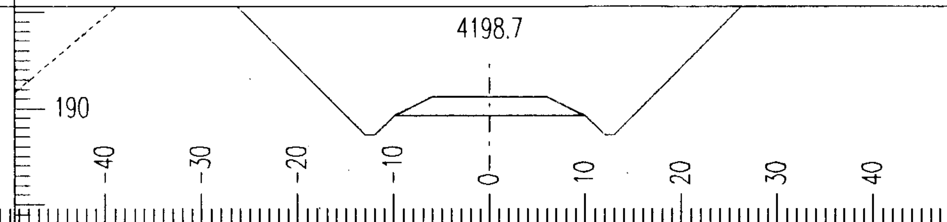
P-Stn:	3948.7	Grd.Nxt %:	-2.0	Cut Dp:	0.0
P-Line V. Off:	0.0	Grd.Lst %:	-4.0	Cut A.:	7.7



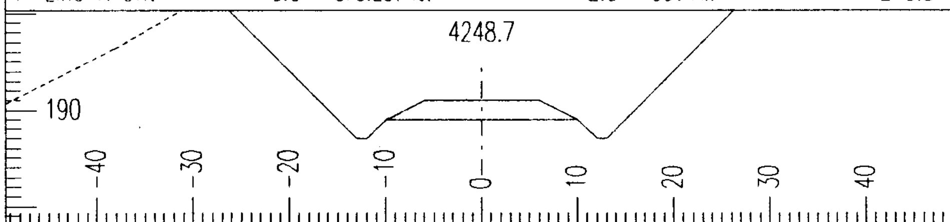
P-Stn:	4048.7	Grd.Nxt %:	-2.0	Cut Dp:	0.2
P-Line V. Off:	0.0	Grd.Lst %:	-2.0	Cut A.:	188.2



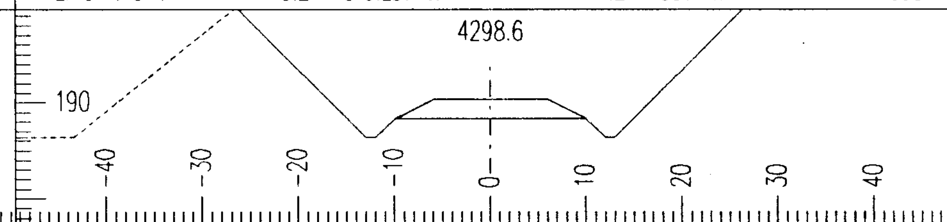
P-Stn:	4148.7	Grd.Nxt %:	-1.5	Cut Dp:	19.2
P-Line V. Off:	0.0	Grd.Lst %:	-2.0	Cut A.:	1213.5



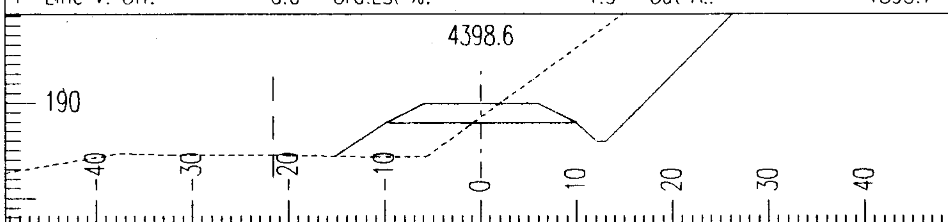
P-Stn:	4198.7	Grd.Nxt %:	-1.2	Cut Dp:	29.1
P-Line V. Off:	0.2	Grd.Lst %:	-1.2	Cut A.:	1895.1



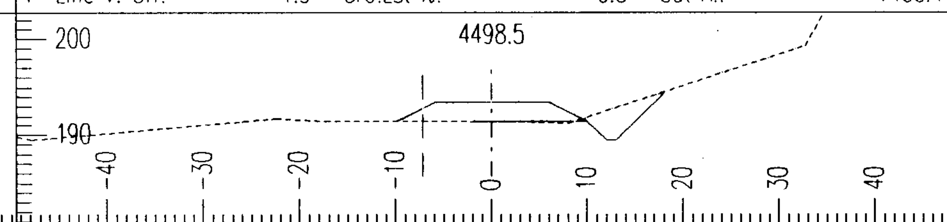
P-Stn:	4248.7	Grd.Nxt %:	-1.9	Cut Dp:	28.9
P-Line V. Off:	-0.0	Grd.Lst %:	-1.9	Cut A.:	1893.7



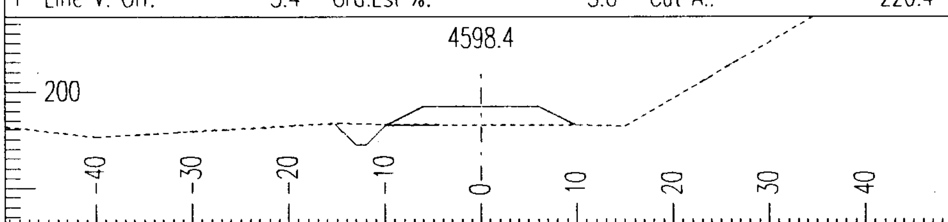
P-Stn:	4298.6	Grd.Nxt %:	-0.5	Cut Dp:	25.5
P-Line V. Off:	-1.9	Grd.Lst %:	-0.5	Cut A.:	1466.4



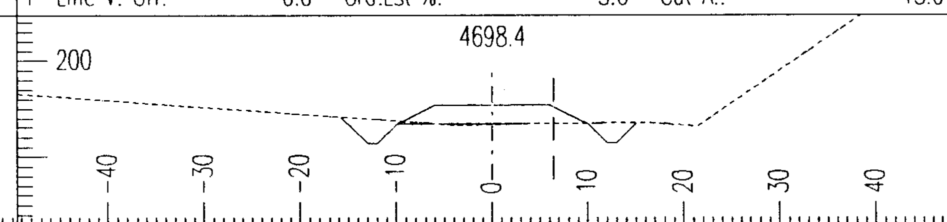
P-Stn:	4398.6	Grd.Nxt %:	3.6	Cut Dp:	0.5
P-Line V. Off:	-3.4	Grd.Lst %:	3.6	Cut A.:	220.4



P-Stn:	4498.5	Grd.Nxt %:	5.0	Cut Dp:	-0.1
P-Line V. Off:	0.0	Grd.Lst %:	3.6	Cut A.:	15.0



P-Stn:	4598.4	Grd.Nxt %:	-3.0	Cut Dp:	0.0
P-Line V. Off:	0.0	Grd.Lst %:	5.0	Cut A.:	7.5



P-Stn:	4698.4	Grd.Nxt %:	-4.0	Cut Dp:	-0.1
P-Line V. Off:	0.0	Grd.Lst %:	-3.0	Cut A.:	16.5