# Paper Location of a Road through St. Edward's Park

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FE 345 ▪ Design of Low Volume Roads ▪ University of Washington

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# Summary

A road is needed from a point of interest to one of two roads A or B, as shown in the slope class map in Appendix A. This road must meet the following criteria:

- maximum grade = 10% adverse, 15% favorable
- minimum curve radius = 60'
- switchback on < 35% sideslopes only
- 12' running surface
- total length of road, which runs parallel to a creek within 150 ft, cannot exceed 500 ft.
- stay within the Park boundary

Two potential routes were laid out, as shown on the map in Appendix D. These routes were found to be made up of the following 100 ft stations in each slope class:

| | 0-30 % | 30-50 % | 50+ % | Total |
|---|---|---|---|---|
| **To Road A** | 20.00 | 23.50 | 0.00 | 43.50 |
| **To Road B** | 7.50 | 8.50 | 9.00 | 25.00 |

An economic analysis of the two routes based on cross sectional area data in Appendix E (and the subsequent volume calculations) and the cost data in Appendix F yielded the following total costs and cost per station for each route:

| | Total Cost | Cost Per Station |
|---|---|---|
| **To Road A** | $78,331.32 | $1,800.72 |
| **To Road B** | $31,116.63 | $1,244.67 |

Based on total cost, length, location, and stream proximity, the route to Road B was found be preferable to the other route. Appendix G lists the necessary information (grades, distances, and bearings) to lay this route in the field.

# Slope Class Map

The slope class map can be found attached in Appendix A. Below is described the method used to create the slope class map.

## *Scale Determination*

The slope class map was constructed over a topographic map of St. Edward's Park. The scale of the map was determined to be 1:3491 by measuring the map scale and canceling units. The calculation can be found in Appendix B.

## *Slope Calculation*

Based on this map's contour interval of ten feet, the horizontal distance between contour lines on slopes of thirty and fifty percent were determined to be:

30%: .3437" = 5/16" = 9 mm
50%: .0687" = 1/16" = 2 mm

A sample calculation of the method used to reach the numbers above can be found attached in Appendix C.

## *Slope Classification*

Slopes were classified on the map by the following scale:

| % Slope | Map Color |
|---|---|
| 0 – 30 | Green |
| 30 – 50 | Yellow |
| 50 + | Red |

The slope on the map between contour lines was found by setting a pair of dividers to widths of 9mm and 2mm to correspond with 30% and 50% slopes respectively. Contours that were greater than 9mm in apart had a slope of less than 30% so were shaded green. Those that were less than 2mm apart had a slope of more than 50% so were shaded red. Everything else in-between was shaded yellow.

# Road Location

Two roads were drawn on the contour map of St. Edward's Park and an economic analysis will determine which of the two is the less expensive. The road location map can be found attached in Appendix D. Below is described the method used to locate the roads.

## *Requirements*

The following is the list of criteria that the road must meet:

- maximum grade = 10% adverse, 15% favorable
- minimum curve radius = 60'
- switchback on < 35% sideslopes only
- 12' running surface
- total length of road, which runs parallel to a creek within 150 ft, cannot exceed 500 ft.
- stay within the Park boundary

## *Pegging the Road*

The road was "pegged" by "walking" a set of dividers from one contour line to another from the point of interest to each of the roads A and B. However, the position of the road had to meet the requirements listed above.

### Grade

To meet the maximum grade requirement a set of dividers was set at a width equivalent to a 10% grade of 5/16." See Appendix C to view a set of sample calculations based on the method used to determine this value.

With the dividers set at 5/16" they were "walked" from the point of interest to each of the roads A and B, with each "step" placed no more than one contour line away from the last "step." In this way it was insured that no road was laid with a slope greater than 10%.

### Length Parallel to a Creek

To insure that the length of any road running parallel to a creek within 150 ft does not exceed 500 ft in length, an overlay was created with a perimeter drawn 150 ft from each creek. Any portion of the road that fell within the 150 ft perimeter was measured with a set of dividers was moved or the road was abandoned if it could not be moved.

### Curves and Switchbacks

No switchbacks were included and any curves were checked with the dividers set to an appropriate width to insure that ample space would be present for a curve of a minimum 60' radius. Any road curves that could not meet this requirement were moved or abandoned.

## Road Cost Estimation

The total cost and cost per station of each of the two potential roads is listed in Table 1, below.

**Table 1: Cost of each potential road**

| | Total Cost | Cost Per Station |
|---|---|---|
| **To Road A** | $78,331.32 | $1,800.72 |
| **To Road B** | $31,116.63 | $1,244.67 |

There were three parts to calculating these values:

1. Determination of the cross sectional areas of each road cross section within each slope class.
2. Determination of the total volumes of excavation, and ballast.
3. Determination of cost based on the number of culverts needed for stream crossings, volumes of excavation and ballast, and estimates of clearing and grubbing.

### *Cross Sectional Area*

For each slope class the following average side slopes were used for calculations:

**Table 2: Average slope value used for calculations, based on the slope range**

| Roads on slopes in the range of: | Average slope value used: |
|---|---|
| 0 – 30 % | 20 % |
| 30 – 50 % | 40 % |
| > 50 % | 60 % |

For each slope class it was assumed that 2/3 of the road bed is in the hill slope and 1/3 is on the fill portion. The required excavation volume was calculated based on the following standard cross section dimensions:

**Table 3: Required road cross section dimensions**

| | |
|---|---|
| Traveled width | 12 ft |
| Ballast depth | 12 in |
| Shoulder slope | 2:1 |
| Ditch width and depth | 3 ft, 1ft |
| Cut slope ratio | 1:1 |
| Fill slope ratio | 1.5:1 |

A profile of the roads in each slope class and the calculations used to determine the dimensions of each profile can be found in Appendix E.

## *Total Volumes*

To determine the cost of both roads individually the total length of each road in each slope class was determined:

**Table 4: Number of 100 ft stations in each slope class along potential routes to Roads A and B in St. Edward's Park**

| | 0-30 % | 30-50 % | 50+ % | Total |
|---|---|---|---|---|
| **To Road A** | 20.00 | 23.50 | 0.00 | 43.50 |
| **To Road B** | 7.50 | 8.50 | 9.00 | 25.00 |

Tables 5 and 6 below list the dimensions of the potential roads.

**Table 5: Dimensions of the potential road to Road A**

| Slope Class | Length | Width | Cross Section Area | Surface Area | Cut Volume | Ballast Volume |
|---|---|---|---|---|---|---|
| 0-30% | 2000 ft | 44 1/12 ft | 20.1 ft² | 2.0 ac | 1488.9 yd³ | 1037.0 yd³ |
| 30-50% | 2350 ft | 56 11/12 ft | 53.5 ft² | 3.1 ac | 4656.5 yd³ | 1218.5 yd³ |
| >50% | 0 ft | 67 6/12 ft | 270.8 ft² | 0.0 ac | 0.0 yd³ | 0.0 yd³ |
| | 4350 ft | | | 5.1 ac | 6145.4 yd³ | 2255.6 yd³ |

**Table 6: Dimensions of the potential road to Road B**

| Slope Class | Length | Width | Cross Section Area | Surface Area | Cut Volume | Ballast Volume |
|---|---|---|---|---|---|---|
| 0-30% | 750 ft | 44 1/12 ft | 20.1 ft² | 0.8 ac | 558.3 yd³ | 388.9 yd³ |
| 30-50% | 850 ft | 56 11/12 ft | 53.5 ft² | 1.1 ac | 1684.3 yd³ | 440.7 yd³ |
| >50% | 900 ft | 67 6/12 ft | 270.8 ft² | 1.4 ac | 9026.7 yd³ | 466.7 yd³ |
| | 2500 ft | | | 3.3 ac | 11269.3 yd³ | 1296.3 yd³ |

## *Economic Analysis*

Based on the values included in Appendix F and the total volumes found above, the costs listed in Tables 7 and 8 below were calculated based on an assumption of common soil material.

**Table 7: Economic analysis of potential route to Road A**

| Slope Class | Clearing and Grubbing | Excavation | Ballast | Cross Drain Culverts | Stream Culverts |
|---|---|---|---|---|---|
| 0-30% | $ 1,214.42 | $ 1,340.00 | $10,370.37 | $ 2,000.00 | |
| 30-50% | $ 1,842.34 | $ 5,029.00 | $12,185.19 | $ 2,350.00 | |
| >50% | $ - | $ - | $ - | $ - | |
| | $ 3,056.76 | $ 6,369.00 | $22,555.56 | $ 4,350.00 | $42,000.00 |

**Table 8: Economic analysis of potential route to Road B**

| Slope Class | Clearing and Grubbing | Excavation | Ballast | Cross Drain Culverts | Stream Culverts |
|---|---|---|---|---|---|
| 0-30% | $ 455.41 | $ 502.50 | $ 3,888.89 | $ 750.00 | |
| 30-50% | $ 666.38 | $ 1,819.00 | $ 4,407.41 | $ 850.00 | |
| >50% | $ 836.78 | $11,373.60 | $ 4,666.67 | $ 900.00 | |
| | $ 1,958.56 | $13,695.10 | $12,962.96 | $ 2,500.00 | $ - |

## Conclusion and Discussion

The route to Road B is the best of the two alternatives.

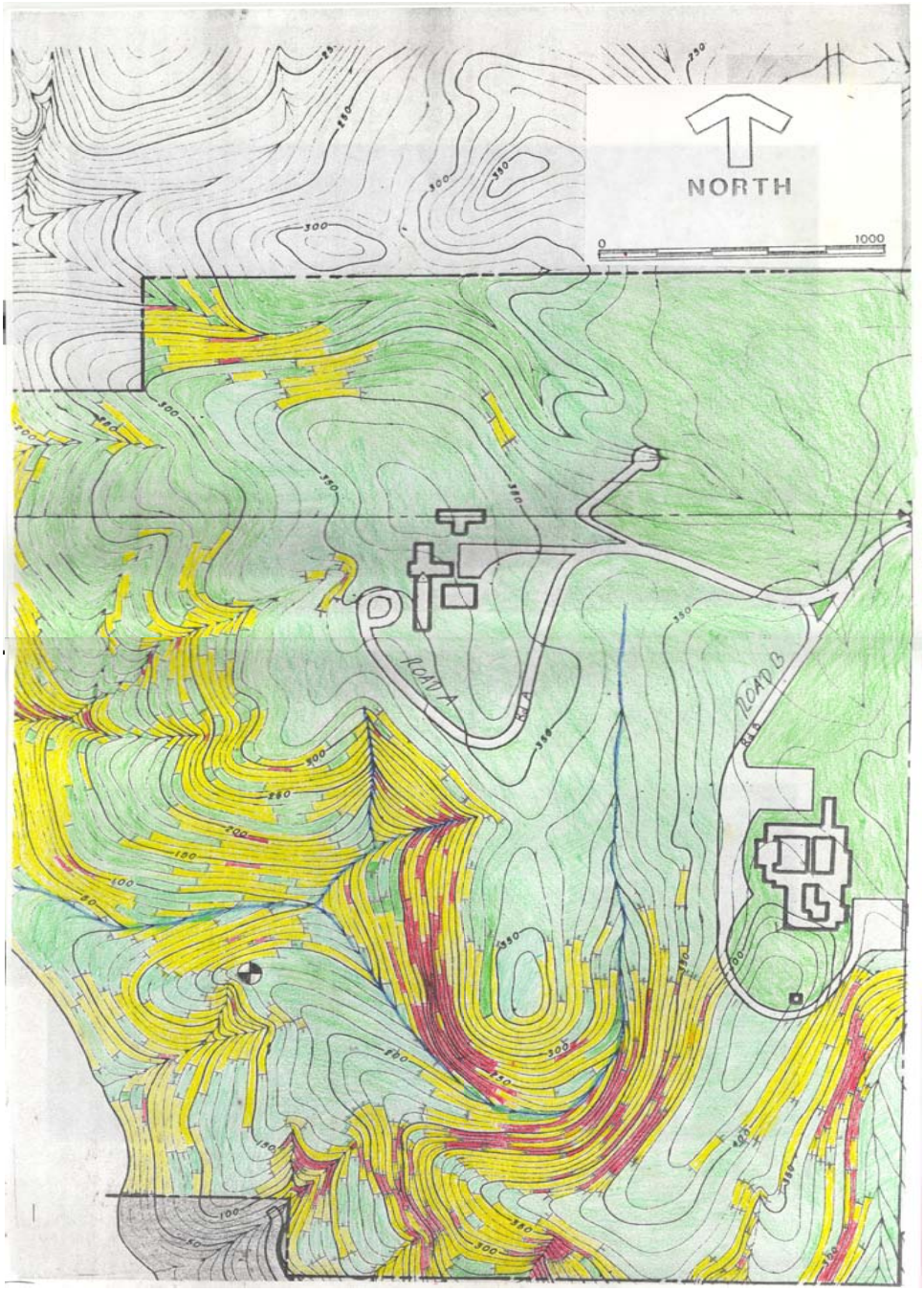
This route has the smallest total cost and the smallest cost per station. While this road remains closer to a stream longer than the other route, it never exceeds the design parameters. This disadvantage is balanced by the fact that this road is the shorter of the two and requires no stream crossings.

Appendix G lists the necessary information (grades, distances, and bearings) to lay this route in the field.

# Appendix

## *A. Slope Class Map of St. Edward's Park*

Slope Class Key: **0 – 30 %**, **30 – 50 %**, **50 + %**
Contour interval: 10 ft
Please note that the map below has been rescaled from the original and the scale is **not** 1:3491.



## B. Scale Determination

1000 ft (ground) = 3 7/16 in (map) * 1 ft / 12 in

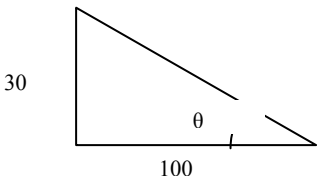
1000 ft / 1000 ft = .2865 ft / 1000 ft

1:3491

## C. Slope Calculation

A thirty percent slope has a rise of thirty feet for every 100 feet laterally. To find the slope in degrees:

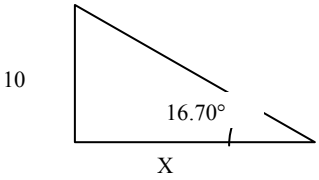
$\theta = \tan^{-1} (30/100) = 16.70°$




The map contour interval is ten feet. There is more than on method to solve for the distance X on the ground for a 30% slope over a vertical change of 10 ft:

A. Trigonometry:
   $X = 10 / \tan (16.70°) = 33.33$ ft

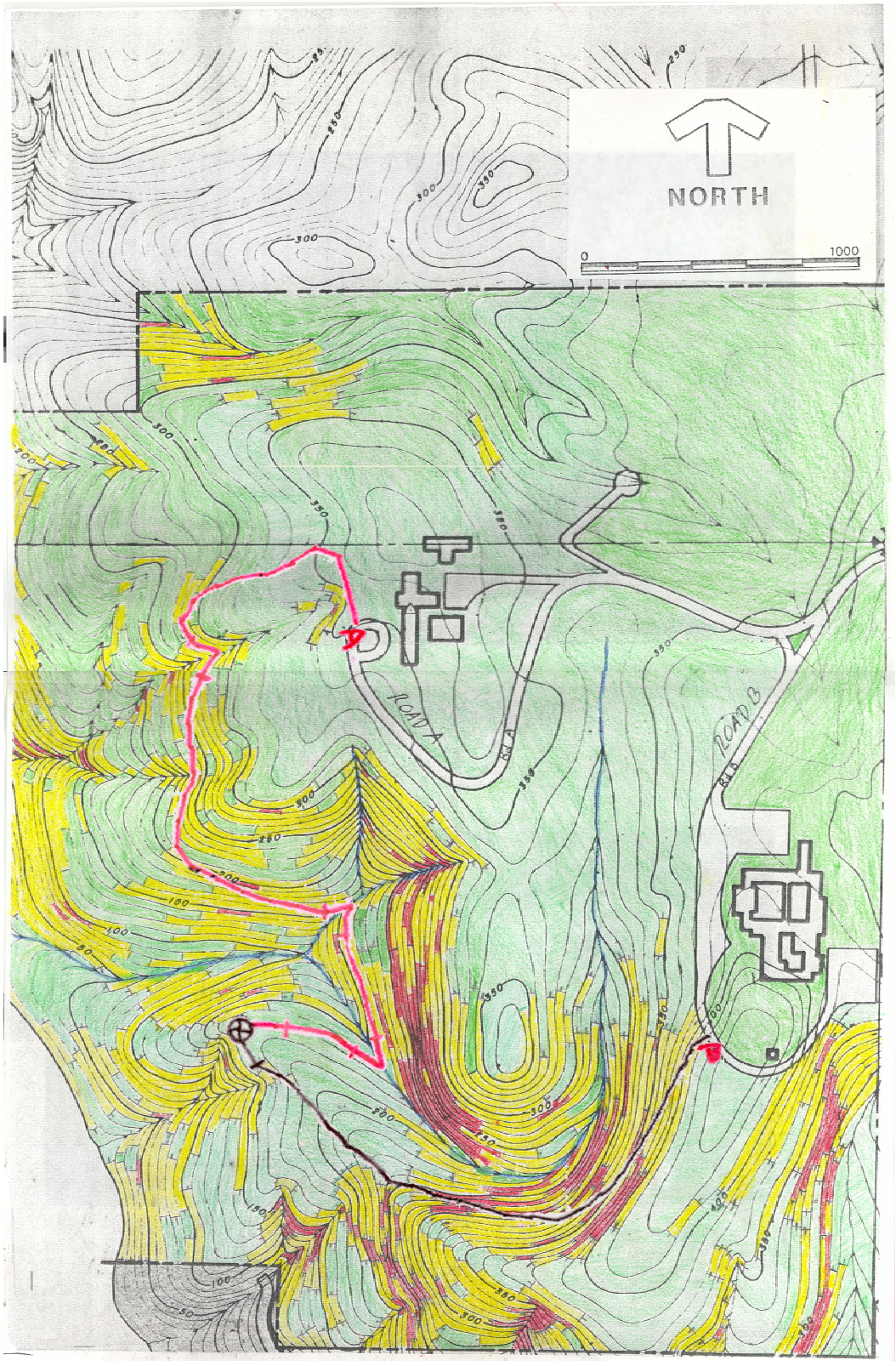
B. Ratio:
   $30/100 = 10/X \rightarrow X = 10 * 100/30 = 33.33$ ft



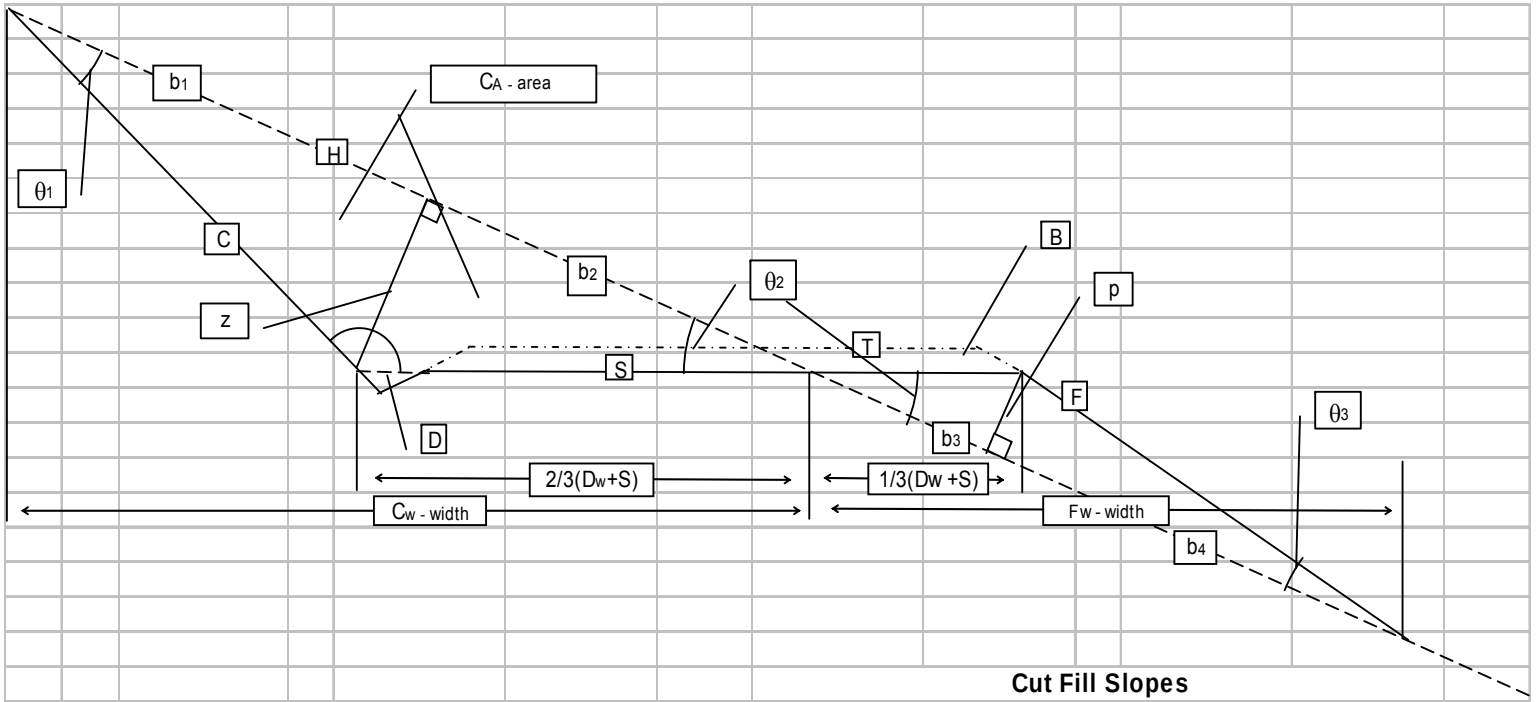

Finally, the horizontal distance on the ground was converted to fractions of an inch on the map:

33.33 ft (ground) * 1 (map) / 3491 (ground) * 12 in / 1 ft
= .1144" = 2/16" = 3 mm

## *D. Potential Road Locations in St. Edward's Park*



## *E. Road Cross Section Profile*

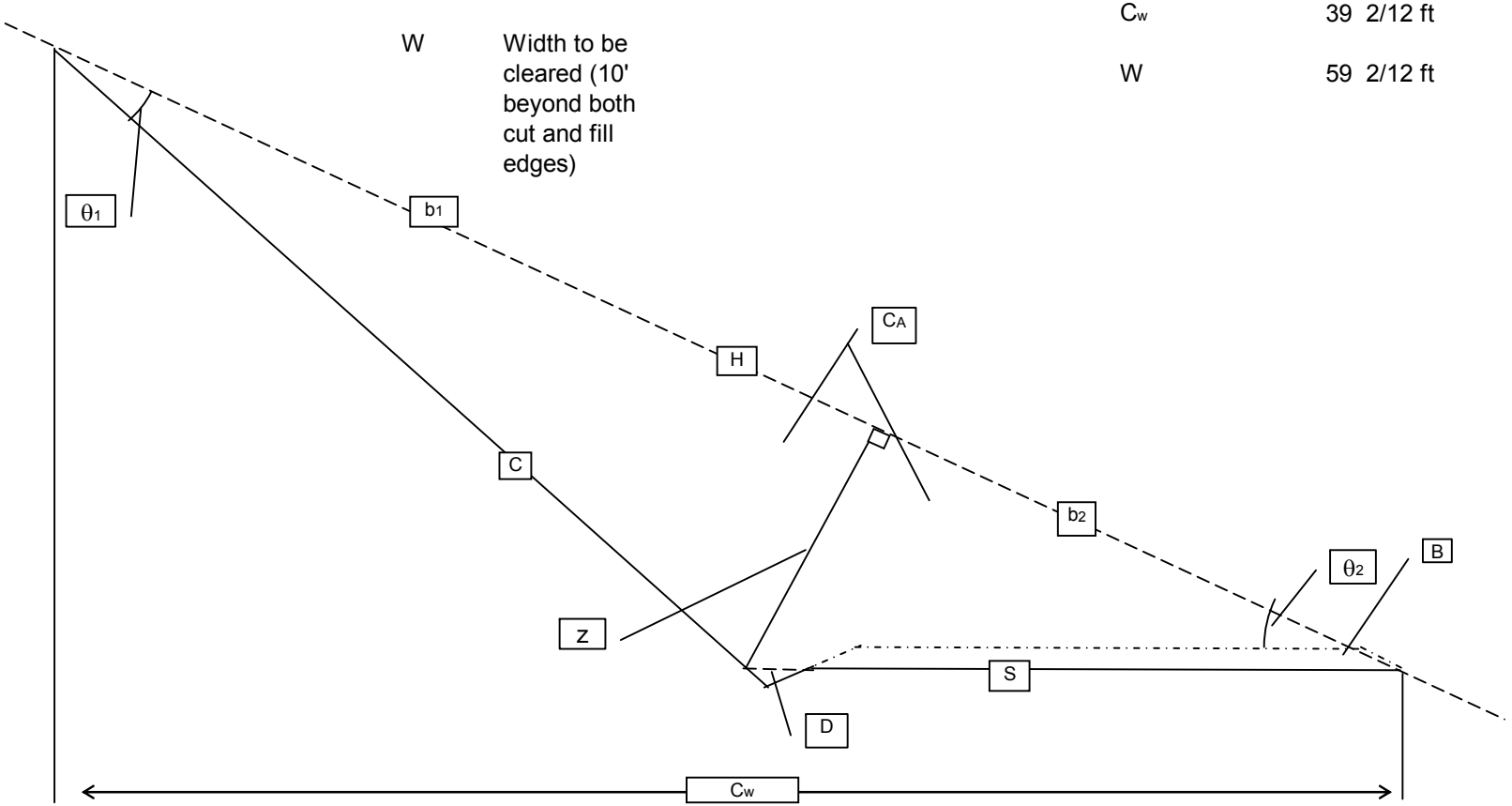



| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Cut Fill Slopes** | | | |
| | H | Hill Slope | T width | 12.0 ft | Hill Slope % | 20% | Hill Slope % | 40% | | |
| | C | Cut Slope | B depth | 1.0 ft | $\theta_1$ | 33° 41/60 | $\theta_1$ | 23° 12/60 | | |
| | D | Ditch | S width | 16.0 ft | $\theta_2$ | 11° 19/60 | $\theta_2$ | 21° 48/60 | | |
| | S | Subgrade | D depth | 1.0 ft | z | 2 6/12 ft | z | 4 8/12 ft | | |
| | T | Travelled Way | D width | 3.0 ft | $b_2$ | 12 5/12 ft | $b_2$ | 11 9/12 ft | | |
| | F | Fill Slope | 2/3($D_w$+S) | 12 8/12 ft | $b_1$ | 3 9/12 ft | $b_1$ | 11 0/12 ft | | |
| | B | Ballast | 1/3($D_w$+S) | 6 4/12 ft | $C_A$ | 20.1 ft² | $C_A$ | 53.5 ft² | | |
| | | | | | $C_w$ | 15 10/12 ft | $C_w$ | 21 1/12 ft | | |
| | W | Width to be | | | $\theta_3$ | 22° 23/60 | $\theta_3$ | 11° 53/60 | | |
| | | cleared (10' | | | p | 1 3/12 ft | p | 2 4/12 ft | | |
| | | beyond both | | | $b_3$ | 6 3/12 ft | $b_3$ | 5 11/12 ft | | |
| | | cut and fill | | | $b_4$ | 3 0/12 ft | $b_4$ | 11 2/12 ft | | |
| | | edges) | | | $F_w$ | 9 1/12 ft | $F_w$ | 15 10/12 ft | | |
| | | | | | W | 44 11/12 ft | W | 56 11/12 ft | | |

| | | | | | |
|---|---|---|---|---|---|
| H | Hill Slope | T width | 12.0 ft | | |
| C | Cut Slope | B depth | 1.0 ft | | |
| D | Ditch | S width | 16.0 ft | | |
| S | Subgrade | D depth | 1.0 ft | | |
| T | Travelled Way | D width | 3.0 ft | | |
| F | Fill Slope | | | | |
| B | Ballast | | | | |
| W | Width to be cleared (10' beyond both cut and fill edges) | | | | |

**Full Bench (>50%)**

| | |
|---|---|
| Hill Slope % | 60% |
| $\theta_1$ | 14º 2/60 |
| $\theta_2$ | 30º 58/60 |
| z | 8 1/12 ft |
| $b_2$ | 13 5/12 ft |
| $b_1$ | 32 3/12 ft |
| $C_A$ | 184.1 ft² |
| $C_w$ | 39 2/12 ft |
| W | 59 2/12 ft |



## *F. Economic Analysis*

The following is taken from http://courses.washington.edu/fe346/lectures/2-week/assignments/Pegging_Project/04_Paper%20location.htm

**Road construction costs consist of**

**-Clearing & grubbing**
**clearing** is the process of removing (felling) timber from the right of way
**grubbing** is the process of removing stumps/rootwads from the construction area.
Typically a common cost value used for clearing & grubbing is $ 600.-/acre

**-Excavation;** use table values below

U.S.F.S. unit rate for excavation.*

| Type of Material | Base Unit DOLLARS/CYD |
|---|---|
| Common | $0.90 |
| Rippable | $1.80 |
| Solid | $3.60 |

Slope Adjustment Factor adjust base rate with factor below, based on material

0-30% : 1.0
30-50% : 1.2
Over 50% : 1.4

**-Rock (Road ballast);** @ $ 10.-/cubic yard in-place

**-Cross drain culverts** @ 100.-/station
stream culverts separate, if any

Report the costs as total $ values and also in $/station.
Provide the relative ratios (percent) of each cost component in the total (e.g. clearing/grubbing, ballast, excavation, drainage/culverts)

## *G. Plan for Laying a Route to Road B (grades, distances, and bearings)*

| Azimuth | Bearing | Map Distance (in) | Ground Distance (ft) | Grade |
|---|---|---|---|---|
| 150° | S 30° E | 5/16 | 100 | 0% |
| 113° | S 67° E | 5/16 | 100 | 10% |
| 128° | S 52° E | 5/16 | 100 | 10% |
| 134° | S 46° E | 5/16 | 100 | 10% |
| 143° | S 37° E | 5/16 | 100 | 10% |
| 130° | S 50° E | 5/16 | 100 | 10% |
| 122° | S 58° E | 5/16 | 100 | 10% |
| 133° | S 47° E | 5/16 | 100 | 10% |
| 100° | S 80° E | 5/16 | 100 | 10% |
| 119° | S 61° E | 5/16 | 100 | 10% |
| 117° | S 63° E | 5/16 | 100 | 10% |
| 103° | S 77° E | 5/16 | 100 | 10% |
| 102° | S 78° E | 5/16 | 100 | 10% |
| 98° | S 82° E | 5/16 | 100 | 10% |
| 89° | N 89° E | 5/16 | 100 | 10% |
| 69° | N 69° E | 5/16 | 100 | 10% |
| 50° | N 50° E | 5/16 | 100 | 10% |
| 48° | N 48° E | 5/16 | 100 | 10% |
| 38° | N 38° E | 5/16 | 100 | 10% |
| 41° | N 41° E | 5/16 | 100 | 10% |
| 43° | N 43° E | 5/16 | 100 | 10% |
| 29° | N 29° E | 5/16 | 100 | 10% |
| 28° | N 28° E | 5/16 | 100 | 10% |
| 23° | N 23° E | 5/16 | 100 | 10% |
| 52° | N 52° E | 5/16 | 100 | 10% |