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Use of the Abney Level in
Highway Location

Thesis for the degree of C.E.

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Civil engineering - Surveying

Use of the Abney Level in
Highway Location

A Thesis Submitted to
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by

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THESIS

FOREWORD

Since this thesis is a study of the highway location methods of the United States Forest Service in Region Five, it might be well to consider part of the specifications under which these roads are constructed.

Tests performed with loaded pick-up trucks ($\frac{1}{2}$ ton) on gravel surfaced roads pointed out that the maximum grades which could be economically climbed in various gears were: 1st gear, 15%; 2nd gear, 10%; and high gear, 5%. Grades between these values, as a 7% grade, are to be avoided for a long duration for they present too much pull to be made in high gear and in 2nd gear the motor is not working at full capacity. This is an important detail, for in location work a balance of yardage must not be made by altering the grade. The grade must remain the same and the location must be changed to produce a difference in the involved yardage. In other words, the grade remains at the ruling specified grade for all parts of the road except on curves of 80 feet in radius or less. This, of course,

pertains to highways designed to overcome elevation, as a road from a canyon bottom to the top of a ridge. Roads in which distance is to be overcome at no great change in elevation the conventional undulating grade location is used.

Two types of grade compensation are used. A grade compensation for curvature is used so that loaded trucks may maintain a uniform speed on any part of the grade. Also improvement and reconstruction of an uncompensated curve always results in a curve of steeper grade than the ruling grade which is highly undesirable. On the other hand a compensated curve from 3 to 5% lower than the ruling grade can be reconstructed at a larger radius and the resulting grade will still remain at or below the ruling grade.

A compensation for elevation is also employed. As the grade climbs in elevation above the 3,000 foot level a decrease in grade of 1% is made on the ruling grade for every 1,500 feet additional rise. Thus a 10% ruling grade becomes a 9% at 4,500 feet, 8% at 6,000 feet, 7% at 7,500 feet, etc. This is based on the fact that as the motor climbs into the higher altitudes the efficiency is reduced. The above compensations are designed to allow a uniform speed on any part of the grade regardless of alignment or elevation.

INTRODUCTION

Within the past ten years the western Regions of the United States Forest Service have embarked upon an extensive road building program. The steadily increasing western travel, bringing crowds into the almost vacant National Forests, created a need for roads and parks. But greater than this public utility need was the need of roads for fire protection. Along with these strangers to the mountains came the ever increasing fire hazard. Carelessly tossed cigarettes and forgotten campfires commenced to turn huge areas of valuable brush country and timber lands into burns. As the frequency of these fires increased it became apparent that an extensive road building program must be developed to facilitate placing men into a fire region in a minimum of time.

As the program began, fire surveys were made on all of the National Forests in the west and roads planned which would put men from fire suppression camps located throughout the forest into a fire zone within forty-five minutes after detection. To one who knows of the few roads in the almost virgin mountains this was an extremely ambitious program. In roughing out the specifications for these roads, two things became at once apparent. First, since

the roads would be used most for official business, the actual car-miles of travel would be much lower than on county and state highways. Hence there was no economical justification for a high cost per mile. Secondly, if lower cost per mile were to be realized, entirely new methods of construction and surveying must be developed.

It might be well at this point to mention the type of construction equipment used in the construction of these roads, for the survey must be made with a thorough knowledge of what is to be expected and what is possible with the equipment at hand. The bulldozer was decided upon as the major piece to be used for excavation. This piece of equipment is a heavy model tractor with a cast steel blade mounted in front on a heavy A-frame. Along the cutting edge is bolted a tough mole board, which with the aid of two cutting points at the ends, carries the brunt of the excavation work. This blade is equipped with a quick acting oil pressure pump which activates the blade for vertical movement. It has the advantage of carrying a down pressure on the blade so that the entire weight of the tractor may be brought to bear on the blade. The bulldozer proved very efficient on mountain slopes as high as forty-five degrees on the cross section slope. In normal excavating with average slopes it is capable of excavating and placing 700 yards during

an eight hour shift. On the writer's location of Oak Opening Road, where an estimated 30,000 cu. yds. were involved in $5\frac{1}{2}$ miles of road, and where approximately 30% of the volume was rock and decomposed granite, the bulldozer averaged nearly 200 cu. yds. excavated and placed in an eight hour shift.

The choice of the bulldozer was due to its ease in handling in rough terrain. It has the advantage of being able to excavate from the uphill side of the section and side-cast the material immediately to make the fill on the down hill side. One of the advantages of grade location is based on this advantage. The efficient end-haul was rather limited being about 75 to 100 feet. However, this made possible the economical construction of a 200 foot through cut or fill by working the yardage from the center of the cut or fill mass. This short end-haul limit did not interfere materially with the location for rarely was it necessary to locate a through cut or fill longer than 200 feet.

In the field of location and surveying, Mr. C.L. Young, Chief Surveyor of Region Five, California, developed the Abney level method of location. It was apparent from previous experience that the cost of transit surveys was out of all proportion to the cost of construction. Cost being the important item to reduce it became necessary to depart

widely from previous surveying methods in the development of a system that would prove itself efficient.

Primary in the development was the principle that office work was to be eliminated so far as possible. This in itself would be a major saving but it meant that some method for working out problems of grade, alignment, and yardage, must be perfected for field use. With grades it meant that the engineer must learn to fit the grade to the ground and not to an office profile. It meant that alignment and yardage must be worked out coincidentally with the grades. If computations of yardage were to be made in the field it meant that the end-area and mass diagram method must be replaced.

All of this was to be accomplished under extremely difficult conditions. The types of roads on which this method was to be used were, by virtue of their need, always in rough country. These roads must cut through heavy brush country, rocky ridges, and canyons, to reach points of fire advantage. In most cases the mountain slopes are from 25 to 40 degrees and some go as high as 50 degrees. Below these mountain slopes are the fertile valleys of California. Too many times have the effects of heavy rains falling on burned over areas resulted in damaging floods in the valleys below. So it is that

the best location for fire protection is the worst possible from an engineering standpoint.

To meet the required speed in this rough country the Abney level method of road location was developed. The writer's position in this work was that of Junior Civil Engineer whose duty it was to carry on the complete work of location, surveying, and engineering details necessary to the construction of the roads.

In the presentation of this method acknowledgement is hereby made to Mr. C.L. Young for cost figures and to the United States Forest Service for tables.

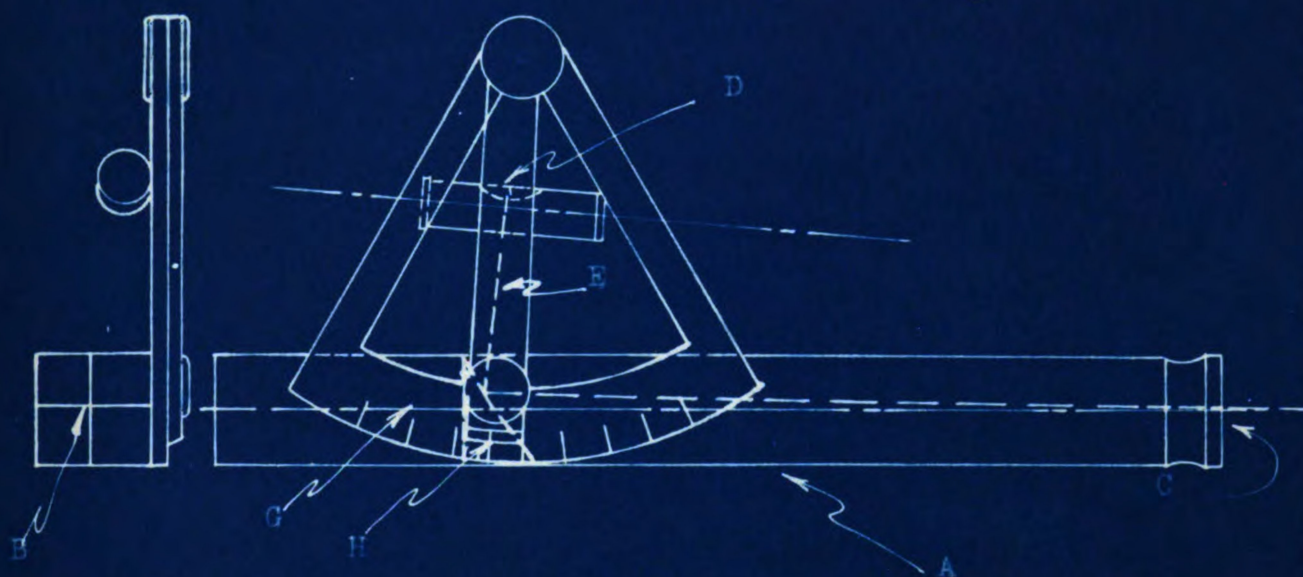
THE ABNEY LEVEL

The Forest Service type Abney level is in many respects similar to the hand level. Its major parts are: (See Plate No. 1, page 7) the barrel, "A", which has a horizontal crosshair, "B"; eyepiece, "C", which telescopes for focusing purposes; level bubble "D", which has a single cross mark etched at the level position and is attached to movable arm "E". This arm swinging from a pivot slides over scale "G" which is graduated in percent of grade plus and minus. Directly below the bubble is a prism mirror "H" which allows the level bubble to be visible coincidently with the cross hair in the end of the barrel.

When the arm is set at zero on the scale the instrument is handled as the ordinary hand level. If the sliding scale is set at -10% and the instrument placed to the eye and the level bubble brought to the level position, the line of sight through the barrel will be on a -10% grade.

If it is desired to run a given grade, irrespective of elevations, distance between stations, and alignment, the following is the procedure: The instrumentman first determines his personal H.I. as with a hand level. Then to set any other point on a given grade no matter what the distance to that point

Plate No. 1
The Abney Level



Approximately full scale
9-11-36 GDL

may be, he has but to set that grade on the Abney level scale and locate the rodman until his personal H.I. is read on the rod as the level bubble shows level. The point under the rod is then at the given grade from the point on which the instrumentman was standing. In this manner the grade is actually run out on the ground, each point being on grade and not having a cut or fill to reach grade.

The decided advantage in running a highway grade with the Abney level in this manner is that the sight distance is not limited as when computing grades at even stations. If the sight distance is 40 feet, well enough, but if it be 250 feet, so much the better. Since no measurement need be taken to determine the distance to the rodman the flexibility of the system is easily seen. The disadvantage of using this method for running a grade line is that alignment resulting is sinuous in nature.

GRADE STAKING

Grade staking in this thesis shall be defined as: Setting a stake on the grade of the road which is irrespective of the centerline of the road; that is with neither cut nor fill at that point.

Tangent shall be defined as: Any part of a location wherein the radius of curvature is more than 80 feet.

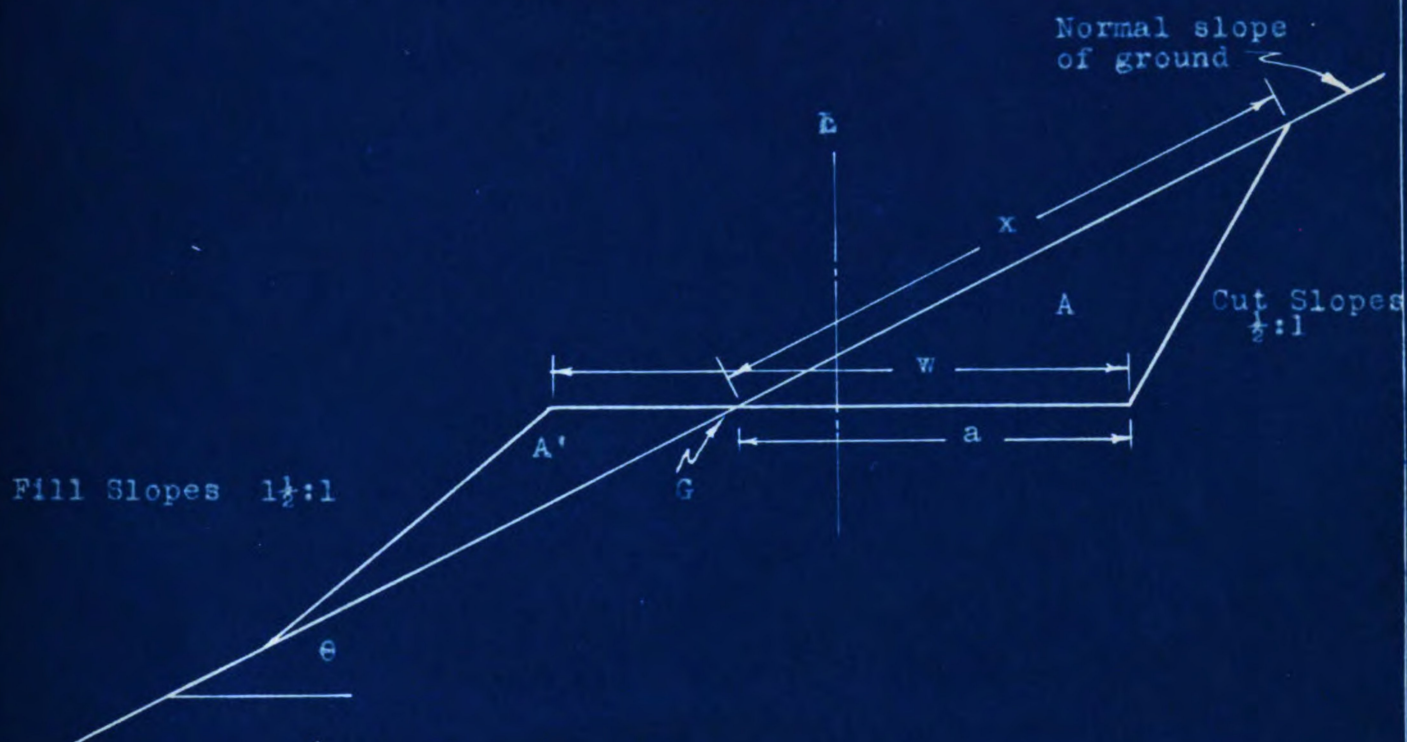
A curve shall be defined as: Any part of a location wherein the radius of curvature is 80 feet or less.

The usual meaning of tangent as referring to long straight lines between successive P.T's. and P.C's. does not apply in Abney level surveys since tangent as defined applies to all curves over 80 feet in radius.

Referring to Plate No. 2, page 10, it will be noted that most roads constructed in mountainous country will be of this Balanced Section type. It will also be noted that it is possible to set a stake on the grade of the road irrespective of the centerline of the section. This is at point "G". It is this stake which is referred to when the term "grade staking" or "staking the location on grade" is used.

If the cut bank has a slope of $\frac{1}{2}:1$, the fill slope is $1\frac{1}{2}:1$, and the angle θ is known, it is possible to set up equations for the end areas of cut

Plate No. 2
BALANCED SECTION



- θ Angle of slope of ground in degrees
 x Slope distance measured on slope of ground
 w Width of roadbed
 a Width of roadbed in the solid
 A Area in Cut
 A' Area in Fill
 V Volume

$$A = \frac{a^2}{2 \cot S - 1}$$

$$A' = \frac{W - a}{2 \cot S - 3}$$

$$V = 1.352A$$

$$x = \frac{2A}{a \sin S}$$

and fill. Viz:

$$A = \frac{a^2}{2 \cot \theta - 1} \quad \text{and} \quad A' = \frac{w-a}{2 \cot \theta - 3}$$

By solving these formulae for various values of θ by approximating a value for a ; and if A is equated to A' (Balanced section, cut equals fill) then:

$$A = A' \text{ and } V = 1.852A \text{ and the slope distance } x = \frac{2A}{a \sin \theta}$$

Therefore with tables computed for various values of road width and cross section slope it becomes quite simple to locate a stake on grade and tape the distance up the slope to locate the cut stake.

The end areas used in the developement of the formulae do not take into account a shrinkage factor. This detail is left to the judgement of the locating engineer for the soil conditions change so rapidly as the survey progresses that any constant shrinkage factor introduced into the formulae would not be consistent with operating conditions.

Plate No. 3, page 12, shows a section of a table developed from the above formulae. The cross section angle θ is measured at the station by means of a slope rule or inclinometer reading in degrees. Under "a" is found the distance from the grade stake to the heel of the cut. A use for this will be shown later. "x" gives the distance measured along the slope of the ground from the grade stake to the cut stake or the toe of the cut. Under "V" is the

PLATE NO. 3

Slope Stakes and Volumes

Width of Road 16' Cut Slope $\frac{1}{2}:1$ Fill Slope $1\frac{1}{2}:1$

Balanced Excavation Table

θ	x	V	a
10	9.4	12.9	8.4
11	9.6	14.6	8.4
12	9.8	16.3	8.5
13	9.9	18.2	8.6
14	10.2	20.2	8.7
15	10.5	22.2	8.7
16	10.7	24.1	8.8
17	11.0	26.4	8.9
18	11.3	28.9	9.0
19	11.6	31.7	9.1
20	11.9	34.6	9.2
21	12.3	37.9	9.3
22	12.7	41.4	9.4
23	13.1	45.3	9.5
24	13.6	49.6	9.7
25	14.2	54.5	9.8
26	14.7	60.0	10.0
27	15.4	66.4	10.2
28	16.2	73.8	10.5

θ is the cross section
slope angle in degrees

a is the width of the
road bed in the solid

V is the volume in cu.
yds. per 50' section

x is the distance meas-
ured up the slope from
grade stake to the
cut stake.

volume of a 50' section. Since this table was computed by equating the cut and fill end areas it follows that all of the cut is required to make the fill in the section, making due allowance for shrinkage. Other tables for various values of road widths and cut bank slopes are at the engineer's hand when different soil conditions are encountered. It was found that if the slope angle was taken intelligently (usually averaged over the section) splendid results were obtained in the balancing of yardage when grade and proper road width were obtained.

In Plate No. 4, page 14, is shown a stake line location which has been set on a plus 5% grade contour. That is to say, each stake has been set at 50 foot stations on a plus 5% grade. As noted in the field notes, ground elevations and grade elevations are identical. This method of location was used wherever alignment of the grade contour was in good keeping with proper location and curves of radius less than 80 feet did not result. In other words, grade location was used on tangents. Plate No. 5, page , 15 shows the location after excavation.

The grade contour curves which result are parabolic in nature and have good driving easement. Photographic evidence of grade location may be seen



Plate No. 4

10-7-76 SDL

Grade Excavation



in the Appendix, page 1, Figs. 1 and 2.

A study of the limits of grade location will be discussed. There are three cases when location by the grade point must be abandoned: First, where a through cut is necessary to provide fill or to materially better alignment; second, where a through fill will materially better the alignment; and lastly where the grade alignment results in a curve of less than 80 feet in radius.

Since the grade method produces a road sinuous in nature it would be expected that in some cases short through cuts and through fills would straighten out a location through country cut up by many sharp ridges and gulches. In this case an economical balance must be drawn by the engineer between better driving ease and cost of additional excavation.

In like manner when the location approaches a gulch the grade contour will produce a hair-pin curve. This may be seen in the plan view of a minus grade contour shown in Plate No. 6, page 17. The stations are at 25 foot intervals and the grade is minus 4%, scale being 50 feet to the inch. It is obvious that the grade contour curve is useless in this case. Superimposed over this grade contour curve is a circular curve which is located on center-line in the conventional method. The cut from the canyon walls furnishes the fill over the drainage

Plate No. 6

Plan View of Grade
and
Circular Curves

-----Grade Contour
-----Circular Curve
Scale 1"= 50'

10-4-36 SDL

channel. When sufficient cut has been obtained to make the fill the location returns to grade again.

In concluding the discussion on grade location it may be said that in gently sloping country (cross section slopes up to 33 degrees, the natural angle of repose) which is not cut up by short sharp ridges and gulches, grade location produces excellent results from the standpoint of costs, alignment, and construction ease. When the cross section slope is greater than 33 degrees the grade point cannot be staked for the entire section must be of the bench type, all of which is in cut. When the terrain becomes of such a nature that the location is a series of curves of less than 80 feet in radius the survey must be run on the conventional centerline.

CENTERLINE LOCATION

As pointed out in the previous chapter grade location cannot be used in all cases. For use with centerline location, tables similar to those described under the Balanced Section have been prepared. One may enter these tables with a cut on centerline and the cross section slope in degrees and find the yardage involved for excavation and for fill (if the section is not a through cut); or the yardage involved if the section is in cut. Similar tables give the fill yardage for sections part in cut and part in fill as well as for sections all in fill. A separate table gives the distance to the cut stake and the cut at that point. It was the writer's practice when dealing with through cuts and fills to slope stake them in the conventional manner. For in most cases considerable yardage was involved and a good balance desired.

In this problem of centerline location the case of tangent through cuts and fills will be first taken up. See Appendix, page 2, Fig. 3. As in all discussion it will be assumed that a preliminary survey line has been established. In which case the through cut or fill may have been roughed out with preliminary stakes. In any case in approaching a

problem of this type it must first be determined where the location is to leave grade and enter upon centerline. Plate No. 7, page 21, gives a graphic representation of grade contour replaced by a centerline location to give a tangent with through cuts and fills. Here the location has been progressing on grade from the righthand side and has been ended at Sta. A, the point which has been chosen as one suitable for entering upon centerline location. At Sta. A must be determined the true centerline of the section. Referring to Plate No. 2, page 10, it may be seen that the centerline may be established by measuring from "G" a distance equal to $(a - w/2)$. The distance "a" may be found in the tables, page 12, for any slope and roadwidth. From this is subtracted one-half of the width and the result is the distance from the grade point to the centerline of the section. This is the distance "y" on Plate No. 7 and Sta. A' is then on the centerline of the section.

When the engineer has in mind the point at which the location is to return to grade, the centerline location is carried to that point in the conventional method. The station stakes are set in line and elevations run with the Abney set at the level position. At the final station the reverse operation is done to locate the grade point, or it may be done by merely setting the rod on grade by reading the com-

Plate No. 7



$$y = a - w/2$$

Refer to Plate No. 3 for
values of a

puted grade rod.

The next step is the determination of yardages which is done by taking cross section slopes and entering the tables. Since in most cases the grade is predetermined and should not be changed, any discrepancy in yardage balance should be adjusted by a change in location rather than in a change in grade. As in all other cases, where care and judgment were employed in the selection of the proper slope for the section (average slope) an excellent balance in yardage was obtained when grade and road width were obtained. 10% over fill yardage was a common figure but was varied as the geological formations differed.

CENTERLINE LOCATION

Curves

When a location progressing on grade resulted in curves of less than 80 feet in radius the method of surveying was of the centerline type and accurate circular curves were staked. As pointed out previously sight distance was generally limited and this necessitated curve location by the middle ordinate method.

Tables for various radii and chords were computed from the formula middle ordinate = $\frac{1}{2}C^2/R$. See table on Plate No. 8, page 24. In locating a circular curve the points A and B must be located on the centerline of the section and not on the grade point. If for example an 80 foot radius curve is to be staked, the points A and B are determined by consulting the tables under the proper cross section slope and road width. The curve tables give the ordinate for an 80 foot curve with 25 foot chords as 3.9'. This is the full ordinate to be used on the circular curve. Since in locating the first point on the curve only half the distance from A to C is on the curve, only half the ordinate or 1.95' is used and is set off at point B. The line of sight established along AB' and point C is located. At C the full ordinate is set off and a line of sight established to

Plate No. 8

Table of Middle
Ordinates

R in Feet	Chord Length (BC) in feet						
	20	25	30	35	40	45	50
	Middle Ordinate CO' in feet						
60	3.3	5.2	7.5	10.2	13.3	16.8	20.9
70	2.9	4.5	6.4	8.7	11.5	14.5	17.9
80	2.5	3.6	5.6	7.7	10.0	12.6	15.7
90	2.2	3.5	5.0	6.8	8.9	11.2	13.6
100	2.0	3.1	4.5	6.1	8.0	10.1	12.5

D. When the curve approaches tangency again the half value of the ordinate is again used. The middle ordinate method is not out of the ordinary and consequently no more time will be devoted to it. However, the location as it pertains to the Abney level will be discussed in some detail.

Curve location is quite naturally the backbone of driving ease on mountain roads. Major points to be considered in the design of curves are: Driving ease, cost of construction, drainage, and cost of the survey. Curves of the type shown in Appendix, pages 2 and 3, Figs. 4 and 5, show how the grade runs from cut on the canyon walls to fill over the natural drainage channel and back to cut on the far side of the canyon. Good location calls for well designed approach tangents, a curve which will fit into the natural terrain, and a good balance of yardage. Since in most cases the survey is run on grade at each end of the curve it follows that the cut from the canyon sides must make the necessary fill in the center over the channel. Borrow pits are never used.

The engineer experienced in Abney level surveys approaches the curve problem in the following manner: First he must visualize the grade points on each tangent. Then he must be able to picture the proposed curve in place between the two grade points

and the approximate yardage involved. When the location is set to the best of knowledge it is staked as described by the ordinate method. When this has been accomplished with good alignment the ground elevations are run between the grade points in conventional method. Grades and cuts are computed for 25 foot stations and the yardage determined from the tables. If a balance is obtained the curve as staked becomes final. If there is a discrepancy in the cut and fill yardage the curve must be relocated for it must be borne in mind that in most cases the grade is fixed and can not be changed to accommodate a change in yardage. If there is an excess of cut the curve may be pulled down the canyon to decrease the cut and increase the fill. Possibly a change in radius will give the desired results. Various problems occur and in most cases each is different and the solution of them depends on the topography. No rule can be fixed for their solution. Skill and past experience in Abney level surveys will give the engineer uncanny judgment which results in good fast locations. As in all other branches of the Abney level method the ability to picture the constructed grade in the rough terrain is the key to good surveys.

It was the writer's experience that after a few months of this type of surveying it was possible

to locate a well designed curve on the first attempt
in most cases.

CONCLUSION

In the writer's opinion the Abney level method of surveys has solved the problem of highway location on secondary mountain roads. It has extremely flexible characteristics. When starting a new job it was the writer's practice to obtain a U.S.G.S. map of the district and plot in the proposed grade by means of dividers set to the proper scale. This proved very helpful in determining whether the road could be designed as a 5% or a 10% ruling grade. It also brought out whether the grade could be carried directly to the proper termini without the use of switchbacks. With this knowledge in mind and the U.S.G.S. map in hand one day or two in the field would generally suffice for a good reconnaissance survey. During this survey the primary control points were fixed. Secondary control points, that is, possible switchback locations, saddles through which the grade must pass, and crossings over bad canyons were also fixed. An altimeter proved very helpful in this survey. A two-man party working in average country could cover about five miles of reconnaissance in two days.

The preliminary survey was carried on with a five-man party. This survey was usually run without setting station stakes. With the ruling grade

having been picked this grade was carried out by tying red flagging at every Abney station regardless of distance. At points of grade changes, and at points where the location changed from center-line to grade and vice versa, double flagging was placed. Since most cases of circular curves and through cuts and fills were roughed in on the preliminary survey this method proved ample when the final location was made. In average country where brush conditions were not too bad a five-man party could do a mile of preliminary survey a day. In this connection it might be said that a good reconnaissance and a good preliminary survey are invaluable to the engineer when he sets about staking the final location. This method gives ample opportunity to make alternate preliminary surveys in an endeavor to pick the route, for as might be expected in mountainous country a great many alternate routes are generally available. A preliminary roughed in by flagging can quickly and inexpensively determine which is the proper location.

Final location work varies widely with the type of country. In heavy brush country which has not been cleared after the preliminary makes location work slow. But in cases where the brush has been cleared it progresses with marked rapidity.

To take a complete example of the flexibility of the system the case of the writer's location survey of the Oak Opening Road in the Sequoia National Forest will be used.

The completed length of this road was 5.5 miles, with the lower terminus at elevation 2,500 feet and the upper at elevation 4,500 feet. The general route of the road was along a ridge and its purpose was for fire protection in a country of high fire hazard. It was a segment of the Ponderosa Way, a road which will ultimately traverse the entire length of the Sierra Mountains.

The reconnaissance survey was completed in two days with a two man party. During this survey the primary and secondary controls were established. This survey together with an hour or two of office work with a U.S.G.S. map showed that the road could be constructed with proper grades between the major control points. On the morning of the third day the construction equipment and brush crew were waiting at the lower major control point. The preliminary survey was worked out to the first saddle, a distance of about 1,000 feet, in several hours. By noon of the same day grade and slope stakes were in and the ground cleared of brush and timber. By night the grade had been roughed out and was ready for blading. Under no other method of surveying is such speed attainable.

When the grade is staked the bulldozer operator can plainly see the grade point and on shallow cuts can start the blade digging at grade. On steeper cuts the blade is started digging at the upper cut stake and works down until grade is reached.

Costs of these surveys, as prepared by Mr. C. L. Young, Chief Surveyor of Region Five, show some interesting savings.

Open timber, slopes uniform and not more than 30 degrees (easy country)	\$75 per mile
Average heavy timber, heavy slopes.	\$150 per mile
Dense brush, heavy slopes.....	\$275 per mile

On the northern forests the costs average around \$150 per mile while on the southern forests the cost per mile is about average at \$250. These costs include traversing the road after completion but do not include office work. This may be explained in the system where days of bad weather and other work are charged off as office work. In this connection it may be stated that the only office work required in this method is the preparation of monthly reports, profiles for use by the construction foreman, and making traverse maps. In this connection a man-day per mile of road would seem a fitting figure to charge against office work.

With present day trends toward longer radius curves, more through cutting ridges and filling gulches

the balanced section will be used less and less in rough cut up country. However, it will never be entirely replaced. It has had a great part in highway location by developing a type of location wherein the road grade is literally fitted to the surrounding terrain. Curves are laid into natural gulches and canyons. But perhaps most of all it has sought to develop the engineer to a skillful designer. He has been forced to picture both plan and profile in his mind at once. He has been forced into making quick and accurate estimates of yardage involved in cuts in steep country. It was the writer's experience that after eight months of this type of surveying uncanny judgment was developed. In rough country centerline location could be staked for a distance of 1,000 feet at a time and have the yardage on all cuts and fills balance when the ruling grade was applied to the ground elevations. Which, of course, is the outcome of working with the grade on the ground instead of an office profile.

The system, as to be expected, has its disadvantages. Men going into this work must be trained to the new surveying standards. Yardage computations, though giving excellent balancing, would not suffice for contract purposes according to eastern practices. However, after seeing it in operation, seeing the results, and using it for some time, there

is no question but what there is valuable food for thought for the engineer. There are doubtlessly numerous places where this type of surveying might be employed to great advantage.

APPENDIX

Photographs in the appendix are by the writer and depict roads constructed on the writer's Abney level surveys.



Fig 1

The sinuous nature of a grade location is well shown here with the resulting long graceful parabolic curves. Oak Opening Road in the Sequoia National Forest.



Fig 2

A portion of the Oak Opening Road in Sequoia Forest showing a typical stretch of grade location using the balanced section.



This center line thru cut and fill eliminated a bad double reverse curve had the location been surveyed on grade. San Jacinto Ridge Rd, San Bernardino National Forest.

Fig 3



Fig 4

A typical long radius curve located on centerline across a gulch. Grade location used on approach tangents. Oak Opening Road, Sequoia National Forest.



Fig 5

A center line location of a switchback followed by series of reverse curves. Note open-top culvert and spillway. Kramer Gulch Road, Sequoia Forest.



Fig 6

"... these types of roads, by virtue of their need, were always in perplexing terrain."



Fig 7

A culvert being set to proper grade with the abney level. Grade stakes can be set for long culvert installations quickly when the abney is set at the proper grade. San Jacinto Ridge Road, San Bernardino National Forest.



Fig 8

A switchback graded over the above culverts by center line method.

TYPICAL FIELD NOTES

Sta	± Rod	Gr. El	Grade El.	Gr'd	S	^E C or F	Yardage Cut	Fill
74+50		3117.0	3117.0	+5%	21	θ	37.9	
75+00		3119.5	3119.5	+5%	17	θ	26.4	
50		3122.0	3122.0	+5%	24	θ	49.6	
76+00		3124.5	3124.5	+5%	24	θ	49.6	
50	+5.7	3130.2	3127.0	+5%	22	C 3.2	120.0	
77+00	+6.4	3136.6	3129.5	+5%	25	C 7.1	210.0	
PC 25	-1.4	3135.2	3130.3	+3%	20	C 5.2	96.0	
50	-2.3	3132.9	3131.0	+3%	20	C 1.9	37.0	2.5
75	-1.3	3131.6	3131.8	+3%	17	F 0.2	8.5	21.0
78+00	-3.2	3128.4	3132.5	+3%	17	F 4.1		120.0
25	-3.4	3125.0	3133.3	+3%	15	F 8.3		268.0
50	+3.9	3128.9	3134.0	+3%	16	F 5.1		141.0
75	+4.8	3133.7	3134.8	+3%	19	F 1.1	5.0	46.0
79+00	+3.9	3137.6	3135.5	+3%	22	C 2.1	41.0	5.0
25	+3.7	3141.3	3136.3	+3%	22	C 5.0	93.0	
PT 50	-1.3	3140.0	3137.0	+3%	20	C 3.0	54.0	
75	-1.7	3138.3	3138.3	+5%	25	θ	27.3	
80+00		3139.5	3139.5	+5%	28	θ	56.0	
50		3142.0	3142.0	+5%	28	θ	74.0	

Note: θ refers to "grade".

The field notes on the preceding page were taken from a section of road progressing on grade, through a curve section on centerline, and back to grade again. From Sta 74+50 to Sta 76+00 the location is on grade with ground and grade elevations identical and no cut or fill at the grade stake. The cross section slope appears under "S" and the cut yardage to balance the section is entered in the yardage column.

From Sta 76+50 a short tangent on centerline was run to Sta 77+25, the P.C. The column under the plus and minus Rod are the elevation differences between the stations.

From the P.C. the curve runs to Sta 79+50, the P.T. on centerline. The location returns to grade at the next station.

The yardages involved on the curve, that is between Sta 76+50 and Station 79+50, are:

Cut 664.5 and Fill 603.5

which with a 10% allowance for fill will give a good balance of the yardage. The yardages were computed from tables similar to those shown on page 12 and tables of similar nature for sections in excavation and embankment.

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