ROAD DESIGN METHODOLOGY

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It is difficult to describe the road location and design method used by Forest Engineers in the United States. In the first place we do not have one method, but many, depending on the engineer, type of road, topography, money and time available, etc. In order to put this subject in some type of prospective, I have made an attempt to classify these methods into five groups. Keep in mind this is just my idea, and there is certainly nothing official about the classification. I will call them Methods I through V for the sake of simplicity. A rough description follows.

I. Full Paper Location Method

This is our most accurate method, and at the time of railroad logging, our only method. It is sometimes referred to as the Engineering Method or the C.E. method. It is still the principal method for locating and designing our highways and railroads. It has lost favor with Forest Engineers since the demise of railroad logging because it is too costly and slow. In addition, most Forest Engineers feel that it is not necessary to spend all the extra time, energy and money on the average logging road. We do use it occasionally, however, and for that reason, most Forest Engineers, especially those who are registered, understand it and use it at such times when an expensive bridge, culvert or paved high speed mainline is encountered. Steps and equipment necessary to use this method are basically as follows:

Field

1. Extensive planning and office preparation
2. Extensive field reconnaissance
3. A thorough examination of several alternative routes.
4. Office and field work on control point selection.
5. Tag or grade line run with abney or clino

6. Preliminary "P" line, run with transit or theodolite, chaining with steel chain or E.D.M. devices
7. Levels and B.M.'s run with Self Leveling or Dumpy Level.
8. Topog off "P" line run in such a manner that contours can be calculated and drawn in the field or office.

Office Design

1. Plot of "P" line, RP's, BM's, ties contours etc. is made.
2. "P" line profile is drawn
3. Preliminary "L" is drawn as tangents with curves fitted at each P.I. Complete "L" tested and changes made until designer is satisfied.
4. Preliminary earthwork calculated and cost estimates made.
5. Tangent and curve notes are made up for field staking of "L" line.
6. Extensive use of the computer.

Field

1. "L" line with 50 stations, PC's, PT's and sometimes PI's staked.
2. Levels run

Office

1. Final "L" profile made complete with grades, vertical curves, culvert locations, etc.
2. Preliminary Mass Diagram made with haul schedule and costs.
3. Cuts and fills calculated.

Field

1. Slope stakes, RP's for some slope stakes, BM set.

Office ,

1. Final mass diagram, costs and haul schedule drawn and calculated.

II. Offset-Location Method

As seen from the description of the Full Paper Location method, a tremendous amount of time and money is spent. Most logging roads do not require this accuracy and costly effort, so a less complicated method was developed. The USFS was the leader in this development, but many of the private companies used similar techniques. The method was introduced soon after World War II and is very famous today.

The main differences between the Full Paper (I.) and the "Offset" (II.) method are as follows:

1. A staff compass is used instead of a transit or theodolite.
2. A hand level is substituted for the larger tripod supported levels.
3. Topog is expressed as cross sections instead of contours.
4. The "L" line is not actually run in the field, it is offset from the "P" line. New stations are calculated for the offset "L" stake.
5. The office design is a "one shot" affair and produces all offset notes, mass diagram, "L" profile, cut and fill notes, haul schedule and costs.
6. The stakes are not evenly spaced. They will average approximately seventy feet apart however.
7. PC's, PT's and PI's are not set.

III. Rapid Survey Design Method

(Not necessarily the U.S.F.S. version)

The R.S.D. method is an offshoot of the Bowman method described under IV. The R.S.D. adaptation is more accurate, slower, more expensive, but it gives better alignment and grade. It also gives the designer engineer more latitude in making improvements in design.

Reconnaissance, grade line, "P" line and topog are taken in the same manner as the Bowman's method. The "P" line is then plotted in the office, and a profile of the "P" line drawn. A grade or grades with vertical curves are placed on the profile and cuts and fills are calculated. The advantage of the system is that programs are written for the hand held computer that allow the designer to place the "L" line in any position in relation to the "P" line to improve alignment.

It is necessary for the crew to make an additional trip to the field to set slope stakes. Five programs are needed in the hand held computer when using this method, and they are:

Regular Section - Cut end area not equal to fill end area

Balanced Section - Cut end area equal to fill end area. Shrinkage or swell considered

Through Cut - 100% cut section

Through Fill - 100% fill section

Full Bench - 100% cut section, cut at outside edge is 0.

IV. Bowman's Method

John Bowman, a Forest Service Engineer produced a method that shows great promise and is used extensively in the U.S.F.S. Actually several private companies were using similar methods at this time but without the help of the hand held computer. I will describe a method that is a mixture of Bowman and a couple of the more popular company methods. This approach is based on the assumption that the "Full Paper Location" and the "Offset'" location are too expensive and slow for some of the lower class roads used by the industry and public agencies. Lower class road is usually described as one where the trucks travel at speeds under twenty five miles per hour, grades run up to twenty percent, and radii down to sixty feet.

The main features of this method are:

1. The road is tag lined, designed "L" line staked, and all slope stakes and reference stakes are in with one pass. Obviously, the reconnaissance "run" has to preceed the tag line etc.

2. The tag line is assumed to be grade,and the hand held computer dictates the location of the center line and all slope stakes.
3. The computer is programmed to accept the following inputs: ground slope, road bed and ditch width, backslope cut and fill slopes. Outputs also include cut and fill end areas, and center line cut or fills.
4. Bearings are obtained with staff or hand compass. Distances are obtained with cloth tape, steel tape, or stadia.
5. A special program was developed by Bowman that will balance the cut and fill end areas with the desired shrinkage or swell percentages inputed. This will not automatically balance the volumes but can be fairly close if the ground is consistent.
6. Since the "L" is not run in or off-set, the alignment is irregular. The result will not give you tangents and simple curves but a line similar to a grade contour. The finished "L" line approximates a series of spirals. Actually it gives a pleasing effect since it fits into the natural topography so well.
7. The computer program mentioned in #5 above has to be abandoned in cases of through cuts and fills and sections where a full bench is necessary. It is also abandoned where the center line position is dictated by other constraints.

V. Grade Line Method

Some engineers refer to this method as the "Eye Ball" method. Being on the bottom of the list and a name like that might give the impression that this is an unacceptable way to go. This is not always true, however. A good engineer and an experienced "cat" skinner can do a good job using this method. Obviously, you wouldn't expect this technique to be used on a two lane mainline that you expect to pave. A short lower class spur is a possible candidate. The process usually follows these steps.

1. A tag line is run by an abney or clino between two control points. Sometimes the line is chained, and the stakes, which are on grade, are marked.
2. The clearing stakes are usually set, sometimes with the aid of tables.
3. The "cat" then proceeds to build the road between the upper and lower clearing stakes using the grade stake as a guide.

Figure 1. Characteristics of the Various Location and Design Methods

Method of Location and Design	Instruments Used	Party Chief's Education and/or Experience Required
I Full Paper Location	-Theodolite or transit -Steel tape or E.D.M. -Staff compass -Self leveling level or hand level	-Thorough knowledge of simple, spiral curves and earthwork -Trigonometry -Knowledge and experience in operating theodolites, transits, high order levels, and E.D.M.'s
II Offset Location	-Staff compass -Steel tape -Hand level	-Knowledge of simple curves and earthwork -Trigonometry -Knowledge and experience in operating staff compass, tape, and hand level
III R.S.D. (Rapid Survey and Design)	-Staff or hand compass -Steel or cloth tape -Abney or clinometer, hand level	Same as "Offset Location"
IV Bowman's	-Hand compass -Abney or clinometer -Cloth tape	-Knowledge and experience in operating abney or "clino" and tape
V "Eye Ball" or "Grade Line"	-Abney or clinometer	-Knowledge and experience in operating abney and "clino"

Figure 2. Characteristics of the Various Location and Design Methods.

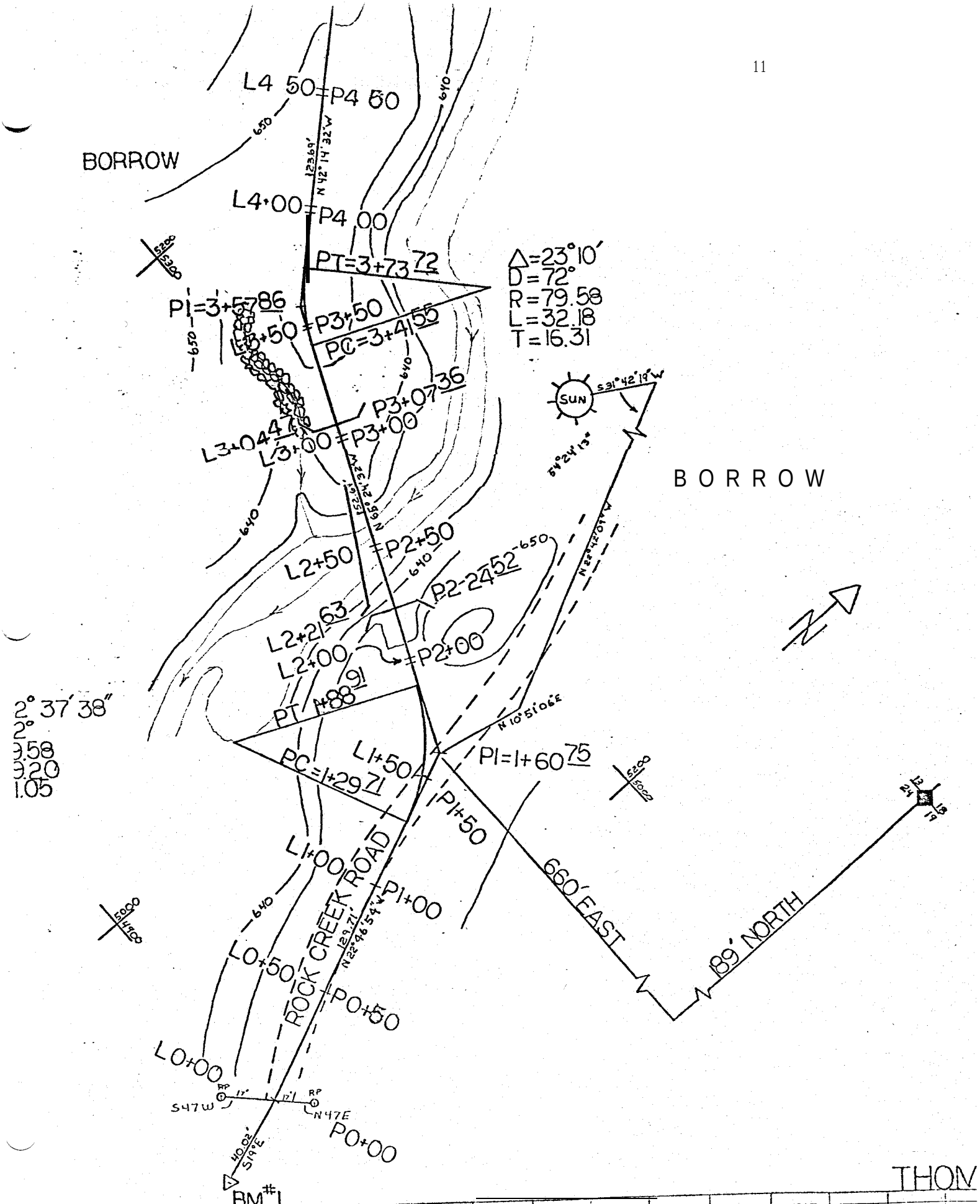
Method of Location and Design	Reconnaissance	Tag or Grade Line	Levels
I Full Paper	-Aerial photos -Topo maps -Picking control points on photos, maps, and on the ground -Walking area and sometimes flying it	-Running abney or clino between control points and flagging grade -Picking turning points	-Self leveling Dumpy
II Offset	-Similar to II, but on a lower scale	-Running abney or clino between control points and flagging grade	-Hand level, abney
III R.S.D.	Same as II	Same as II	-Hand level, abney or clino
IV Bowman's	Same as II	Same as II	-Hand level, abney or clino
V Grade Line	-Usually concerned with running grade between two control points -A "walk through" is made to check area and to pick a trial grade	-Tag line run in normal manner, but field offsets are made to get improved line and grade	-None

Figure 3. Characteristics of the Various Location and Design Methods.

Method of Location and Design	Topography	Design	"L" Line Layout
I Full Paper	-Contours -Hand level, rod and cloth tape -C.I. from 2' to 10'	-Full design, usually with the help of a table top computer or larger -Plat, profile, M. diagram, etc. -Curves and tangents -Mainline high speed road	-Run in all curves and tangents, staked every 50'
II Offset	-Cross sectioning at every stake -Abney, clino, or hand compass, and cloth tape	-Similar only cross sections are used instead of contours -Computer used extensively -High grade spurs	-Offset from "P" line to "L" line station
III R.S.D.	Same as II	-Cross sections usually not drawn -Data is manipulated in computer to give required results -Plat profile and sometimes mass diagram drawn -"L" line position calculated by computer and offset made	-Combination of II and IV
IV Bowman's	-Same as II, but data goes into a hand held computer in field -Results used to set slope stakes in field	-Design completed in field by common sense and computer	-Hand held computer determines location of "L" line from grade line stake in the field -"L" stake is 'offset from "P" stake
V Grade Line	None	None	-Grade stake is the "L" stake -No offsets necessary

Figure 4. Characteristics of the Various Location and Design Method.

Method of Location and Design	Advantages and Disadvantages	Approximate Cost Per Mile
Full Paper Location	Highest accuracy and cost, most time consuming method. Design will include mass diagrams, haul schedule, and costs. Slope stakes, reference points, clearing stakes and other construction stakes are set. PC, PT, PI, and POC's of each curve are set. Every 50' stake is set. Control of grade and line is excellent.	$10,000 to $22,000
Offset Location	Fairly high accuracy and cost, moderate time consuming method. Design can include mass diagram; haul schedule, and costs. Slope stakes, R.P.'s, clearing stakes set. PC, PT, and PI of each curve are not set; POC's are. Grade control and line control are fair.	$5,000 to $7,000
R.S.D. (Rapid Survey and Design)	Moderate accuracy and cost, low time consuming method. Modified mass diagram used. Slope stakes, RP's clearing stakes set. Curves are not identified as such. Grade control is fair.	$3,500
Bowman's	Moderate accuracy and low cost, fast process. Slope stakes, R.P.'s and clearing stakes can be set. Curves not identified as such. Grade control fair. Method is very dependent on experience and skill of chief of party.	$2,500
"Eye Ball" or Grade Line	Lowest cost, least accuracy and fastest process. Usually center line or grade line is only line set in field. Right-of-way flagging sometimes set.	$1,000 to $1,500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BORROW
L4+00=P4 00
PT=3+73 72
Δ=23°10'
D=72°
R=79.58
L=32.18
T=16.31
PI=3+57 86
L3+50=P3+50
PC=3+41 55
P3+07 36
L3+44 76
L3+00=P3+00
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S 31°42'19" W
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BORROW
L2+50=P2+50
P2-24 52
L2+21 63
L2+00=P2+00
PT 1+88 91
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1.05
PC=1+29 71
L1+50
PI=1+60 75
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ROCK CREEK ROAD
660' EAST
189' NORTH
L0+50
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THON

Δ=30°45'
D=72°
R=79.6'
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Δ=100°
D=68°
R=84.3'
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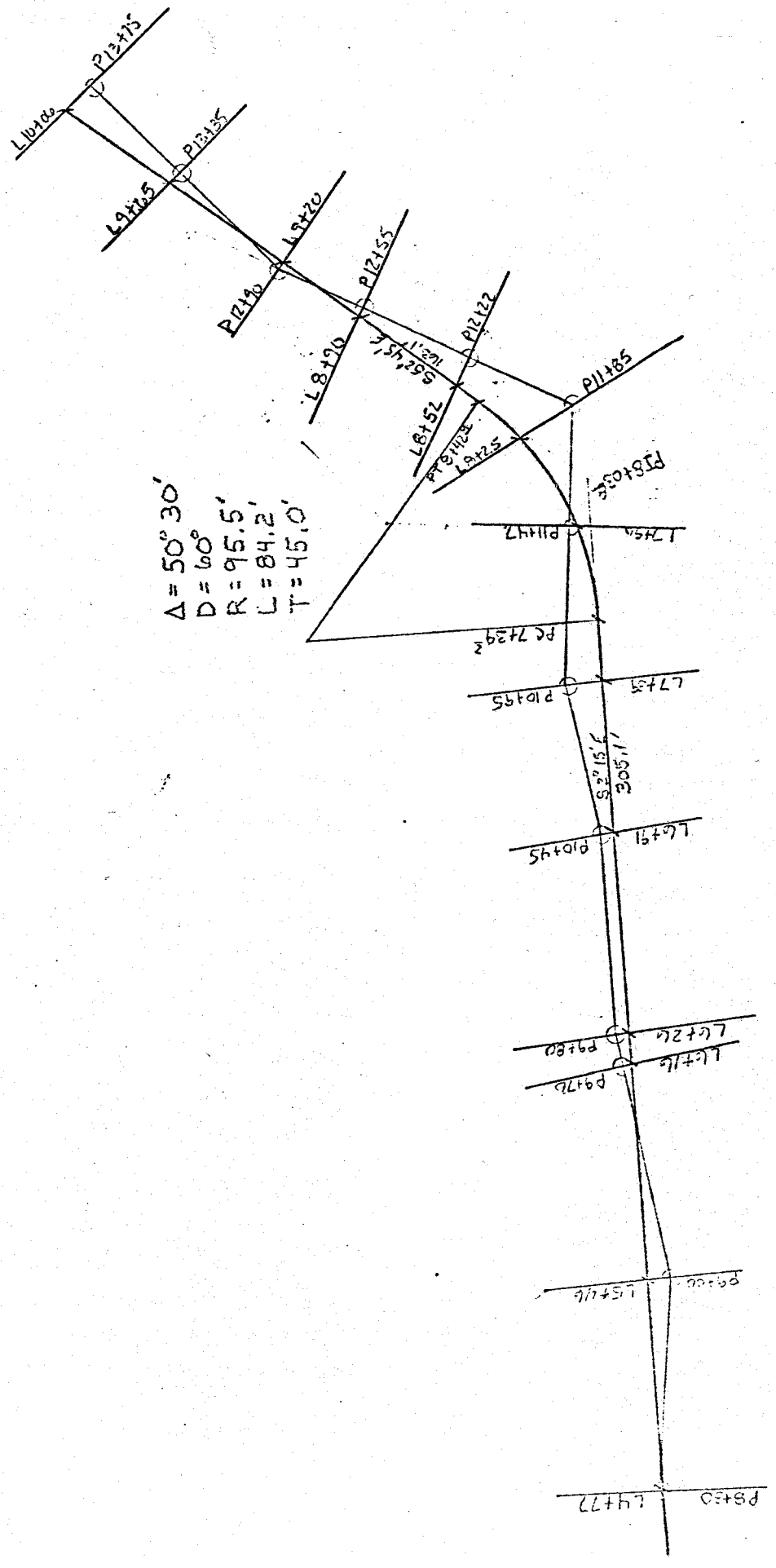
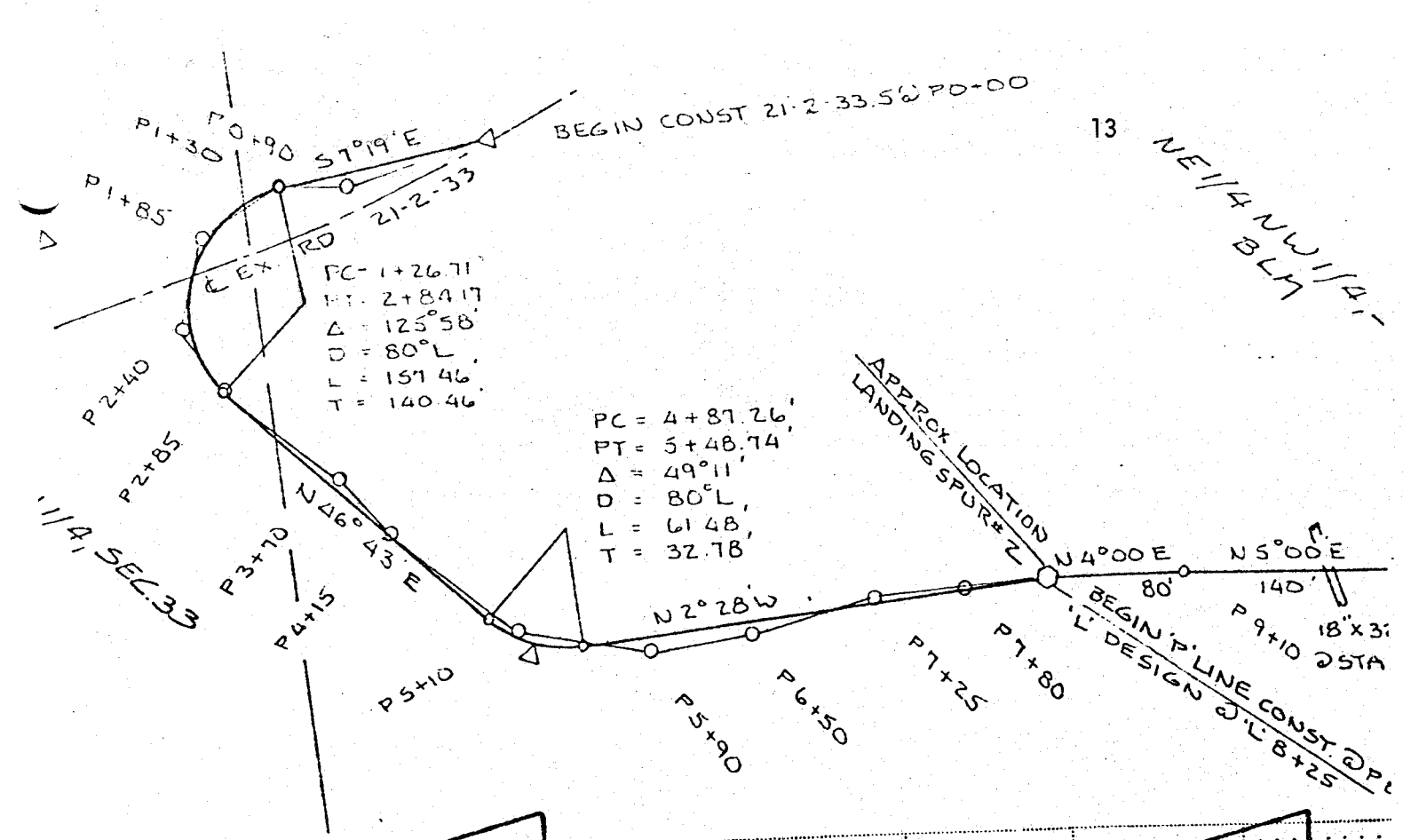
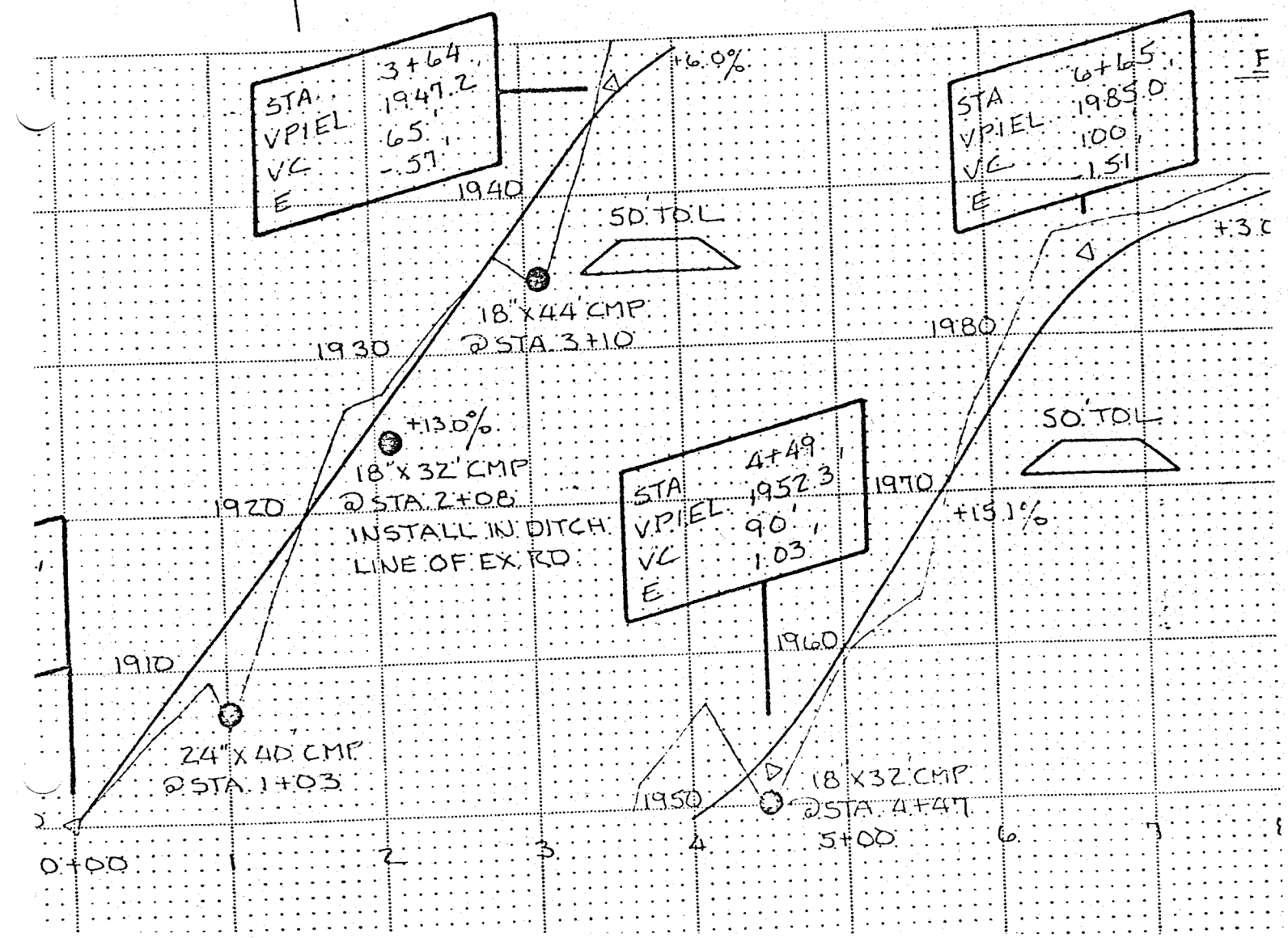
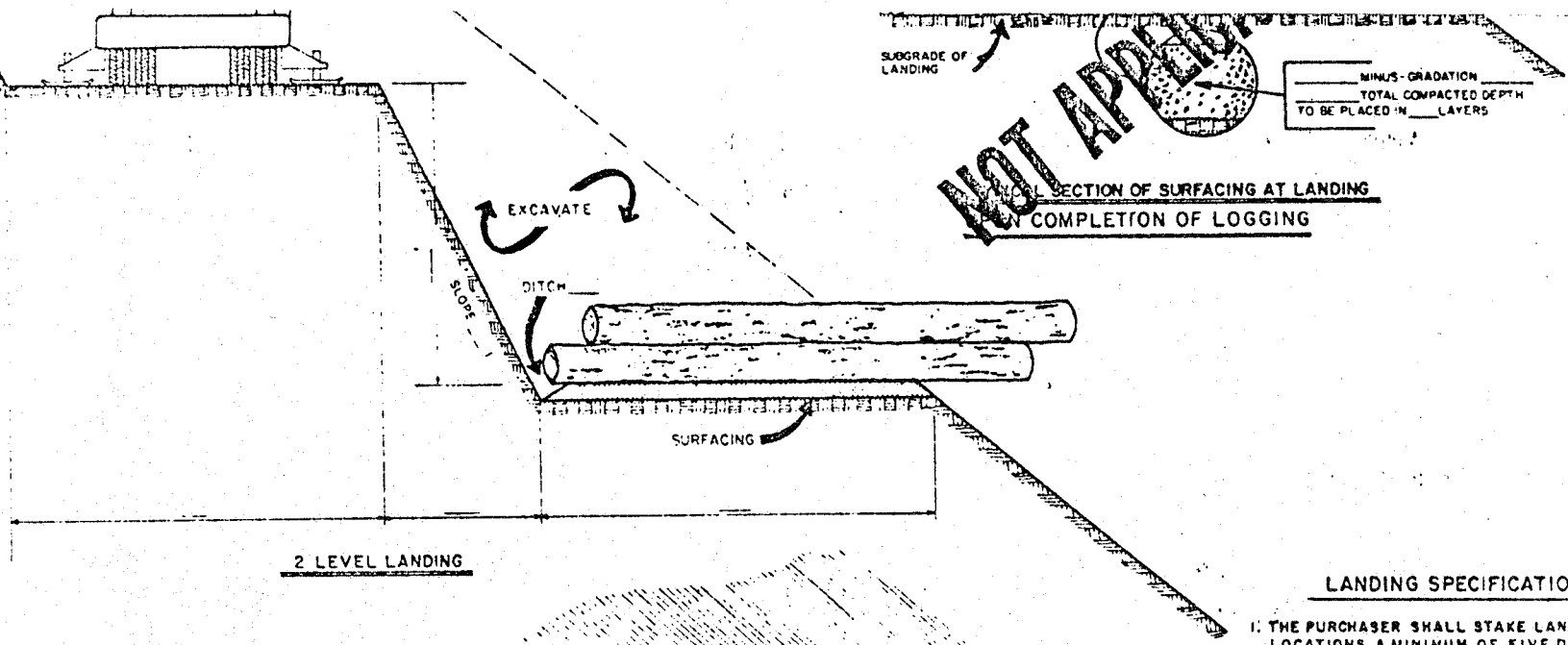

Δ = 50° 30'
D = 60°
R = 95.5'
L = 84.2'
T = 45.0'
P13+75
P13+55
L9+25
L9+20
P12+90
P12+55
P12+32
L8+90
S62°45'E
100.1'
L8+52
P11+85
P11+72
P10+95
S2°15'E
305.1'
P9+80
P9+76
P8+50
L4+72


BEGIN CONST 21-2-33.5 & P0-00
P0+90
S7°19'E
P1+30
P1+85
21-2-33
℄ EX. RD
PC = 1+26.71
PT = 2+84.17
Δ = 125°58'
D = 80° L
L = 157.46'
T = 140.46'
P2+40
P2+85
N46°43'E
P3+70
P4+15
1/4 SEC. 33
PC = 4+87.26'
PT = 5+48.74'
Δ = 49°11'
D = 80° L
L = 61.48'
T = 32.78'
N2°28'W
P5+10
P5+90
P6+50
P7+25
P7+80
APPROX LOCATION LANDING SPUR #2
N4°00E
80'
N5°00E
140'
P9+10
18"x3
BEGIN 'P' LINE CONST @ P
'L' DESIGN @ L 8+25
NE1/4 NW1/4
BLM

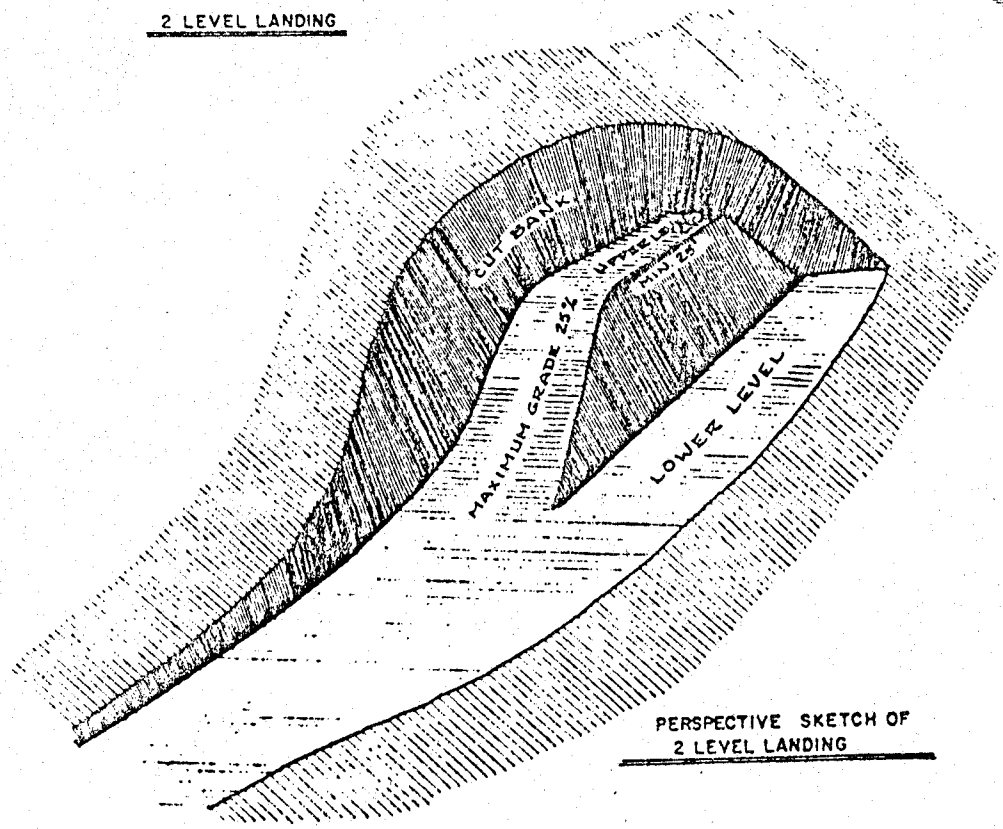

STA 3+64
VPIEL 1947.2
VC 65'
E -.57'
1940
+6.0%
50' TOL
18"x44' CMP
@STA 3+10
1930
+13.0%
18"x32' CMP
@STA 2+08
INSTALL IN DITCH
LINE OF EX. RD
1920
STA 4+49
VPIEL 1952.3
VC 90'
E 1.03
1910
24"x40' CMP
@STA 1+03
0+00
1
2
3
4
1950
18"x32' CMP
@STA 4+47
5+00
6
7
1960
STA 6+65
VPIEL 1985.0
VC 100'
E 1.51
1980
50' TOL
+15.1%
1970



NOT APPROVED

TYPICAL SECTION OF SURFACING AT LANDING
ON COMPLETION OF LOGGING

2 LEVEL LANDING



PERSPECTIVE SKETCH OF
2 LEVEL LANDING

LANDING SPECIFICATIONS

1. THE PURCHASER SHALL STAKE LANDING LOCATIONS A MINIMUM OF FIVE DAYS IN ADVANCE OF CONSTRUCTION. LOCATIONS SHALL BE APPROVED BY THE AUTHORIZED OFFICER PRIOR TO CONSTRUCTION.

2. ALL EXCAVATED MATERIAL SHALL BE END-HAULED TO DISPOSAL AREAS AS SHOWN ON EXHIBIT 'C' OR SPECIFIED BY THE AUTHORIZED OFFICER.

3. AT THE COMPLETION OF LOGGING OPERATION, TEMPORARY LANDINGS SHALL BE SCARIFIED ITS FULL WIDTH TO A DEPTH OF ____ INCHES, TO ELIMINATE COMPACTION.

IN ACCORDANCE
ON 3061.21

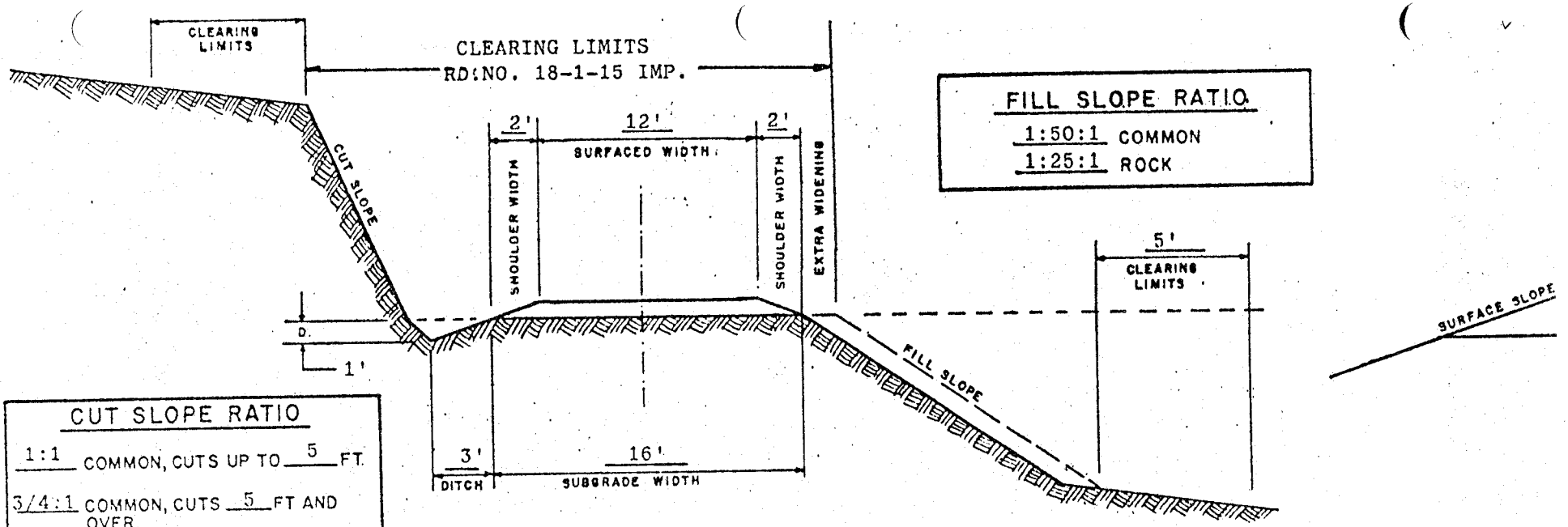
U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

TYPICAL LANDING DETAILS

21-2-33.5 & LANDING SPUR 1 & 2

DESIGNED SAN.	RECOMM. _____ AREA ENGINEER
DRAWN W.F.P.	
CHECKED _____	APPROVED _____ AREA MANAGER
SCALE	
DATE 2/27/81	SHEET 15 OF 17
DRAWING NO.	

14



FILL SLOPE RATIO

1:50:1 COMMON
1:25:1 ROCK

CUT SLOPE RATIO

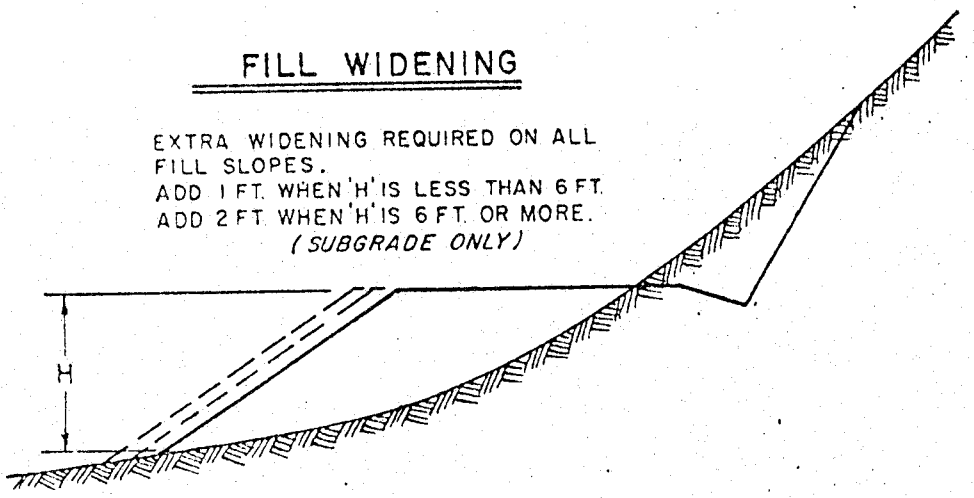
1:1 COMMON, CUTS UP TO 5 FT.
3/4:1 COMMON, CUTS 5 FT AND OVER.
1/4:1 SOLID ROCK
1/2:1 SOFT ROCK OR HARDPAN

TYPICAL SECTION SUBGRADE

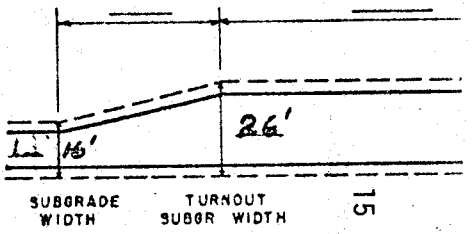
DITCH IS REQUIRED AT APPROPRIATE DISTANCES ON BOTH SIDES OF ROAD IN ALL THROUGH CUTS AND IN AREAS WHERE SIDESLOPE(S) ON LOWER SIDE(S) OF ROAD IS LESS THAN 10 PERCENT.

FILL WIDENING

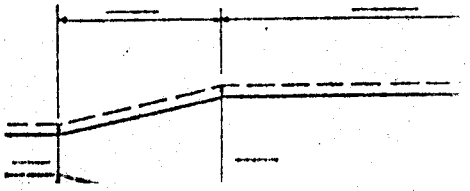
EXTRA WIDENING REQUIRED ON ALL FILL SLOPES.
ADD 1 FT. WHEN 'H' IS LESS THAN 6 FT.
ADD 2 FT. WHEN 'H' IS 6 FT. OR MORE.
(SUBGRADE ONLY)

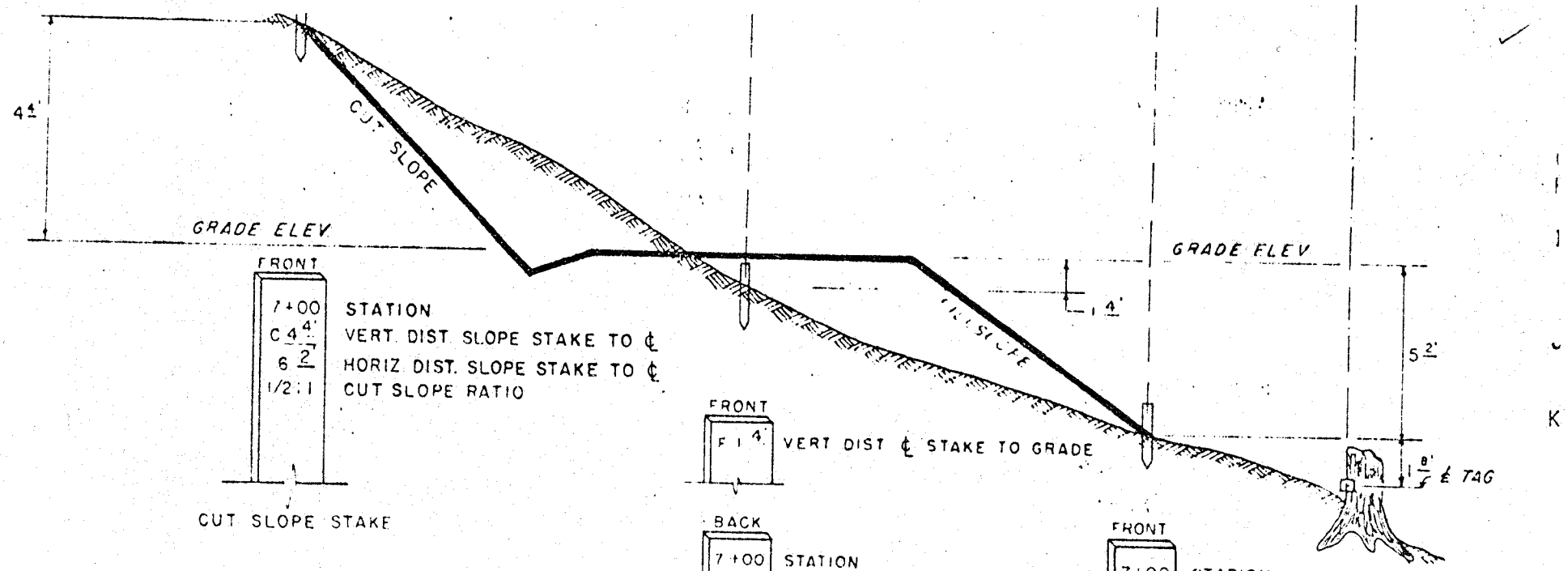


TURNOUT LENGTHS VARY (SI



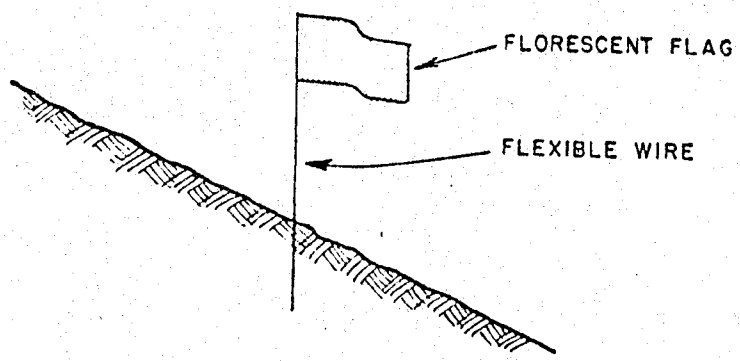
TURNOUTS RIGHT



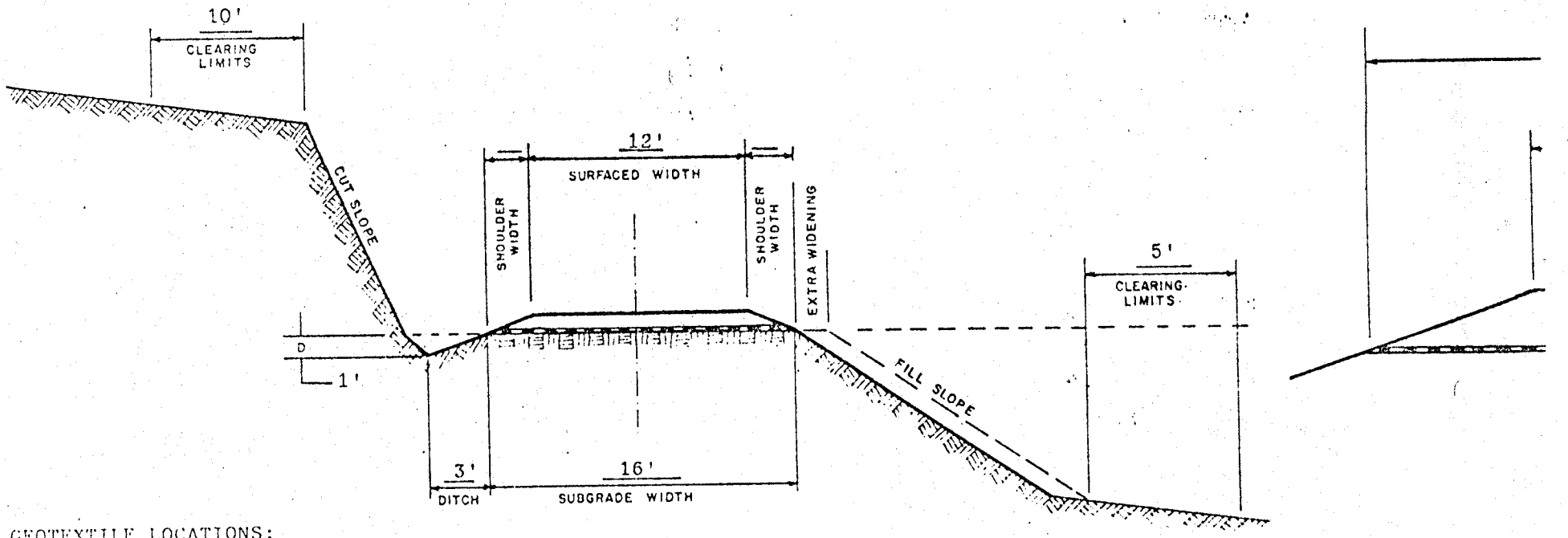


NOTE: ALL STAKES SHALL BE 1 3/4" x 1/4" x 36" S4S CEDAR, TIPPED WITH RED OR ORANGE LUMINOUS PAINT.

SLOPE STAKING DIAGRAM



① SLOPE STAKE MARKER (TEMPORARY)



TYPICAL SECTION
SUBGRADE

GEOTEXTILE LOCATIONS:

RD. NO. 18-1-13.1

* STATION	TO STATION
0+00	3+00
6+00	9+00
12+50	13+20
15+00	16+60
19+00	22+00
23+50	26+00
36+50	38+60
43+50	45+00
52+40	54+00
60+00	63+00
66+50	67+50
69+00	71+00
74+30	76+00
77+60	79+30
80+70	84+10

RD. NO. 18-1-13.3

2+50	6+80

LANDING SPUR

0+00	2+00

NOTE:

* INCLUDES TURNOUTS

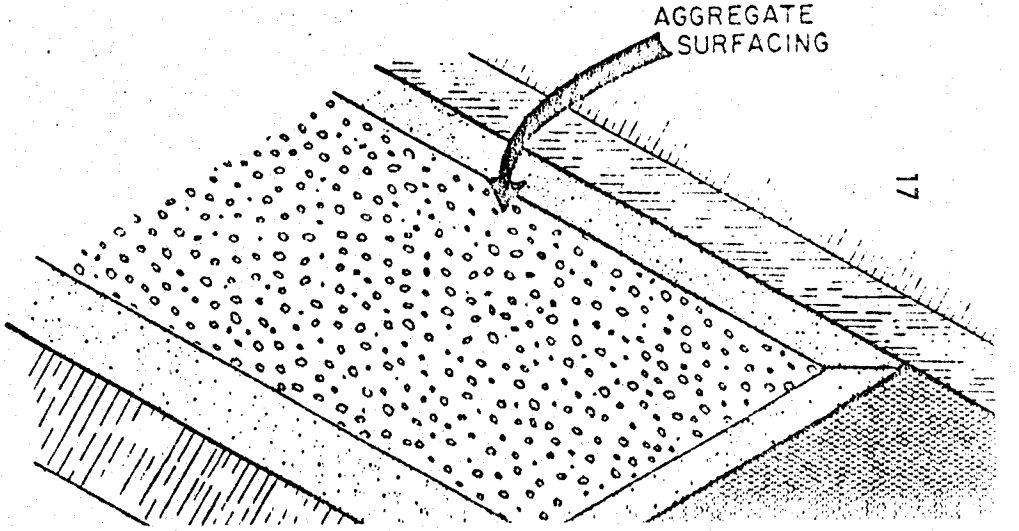
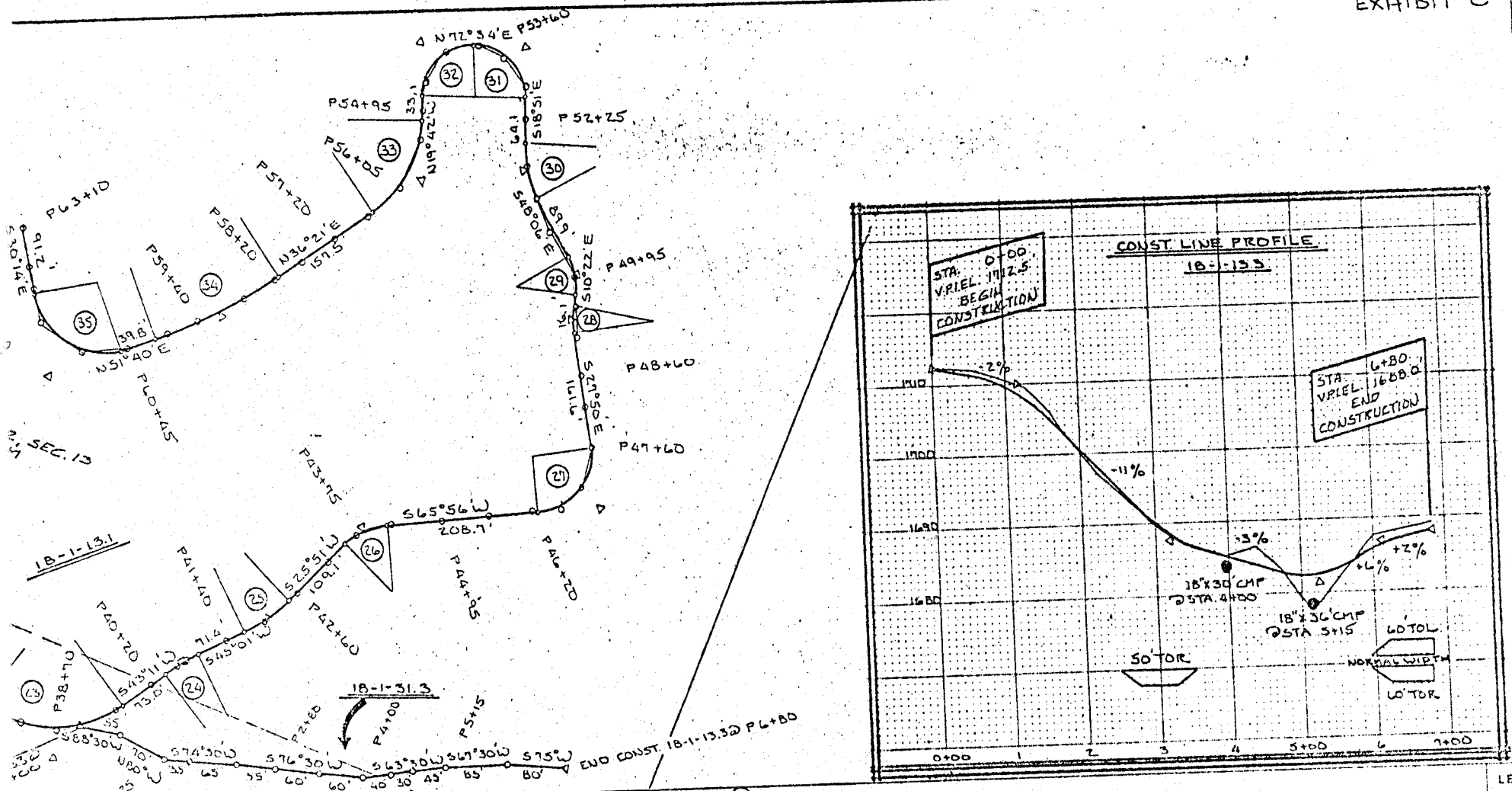
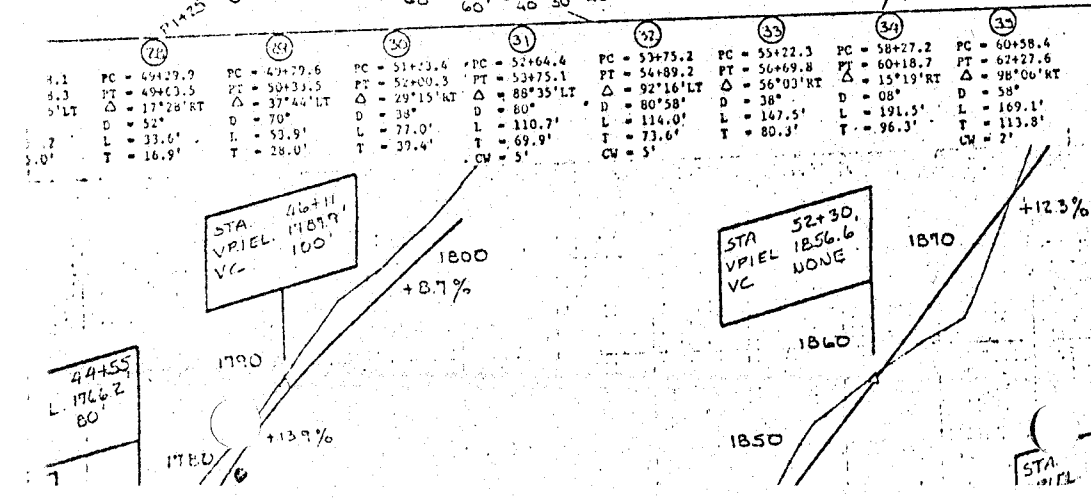
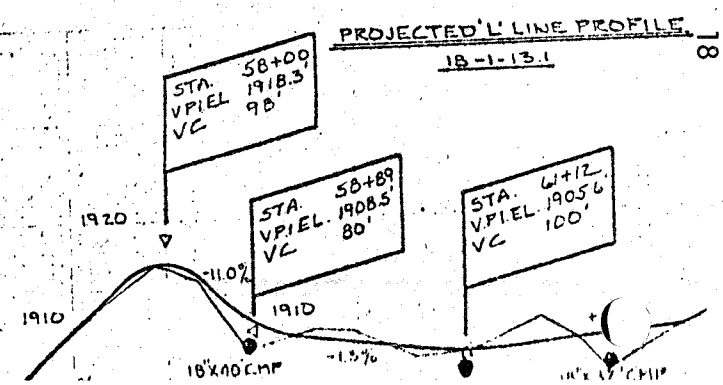


EXHIBIT 'C'



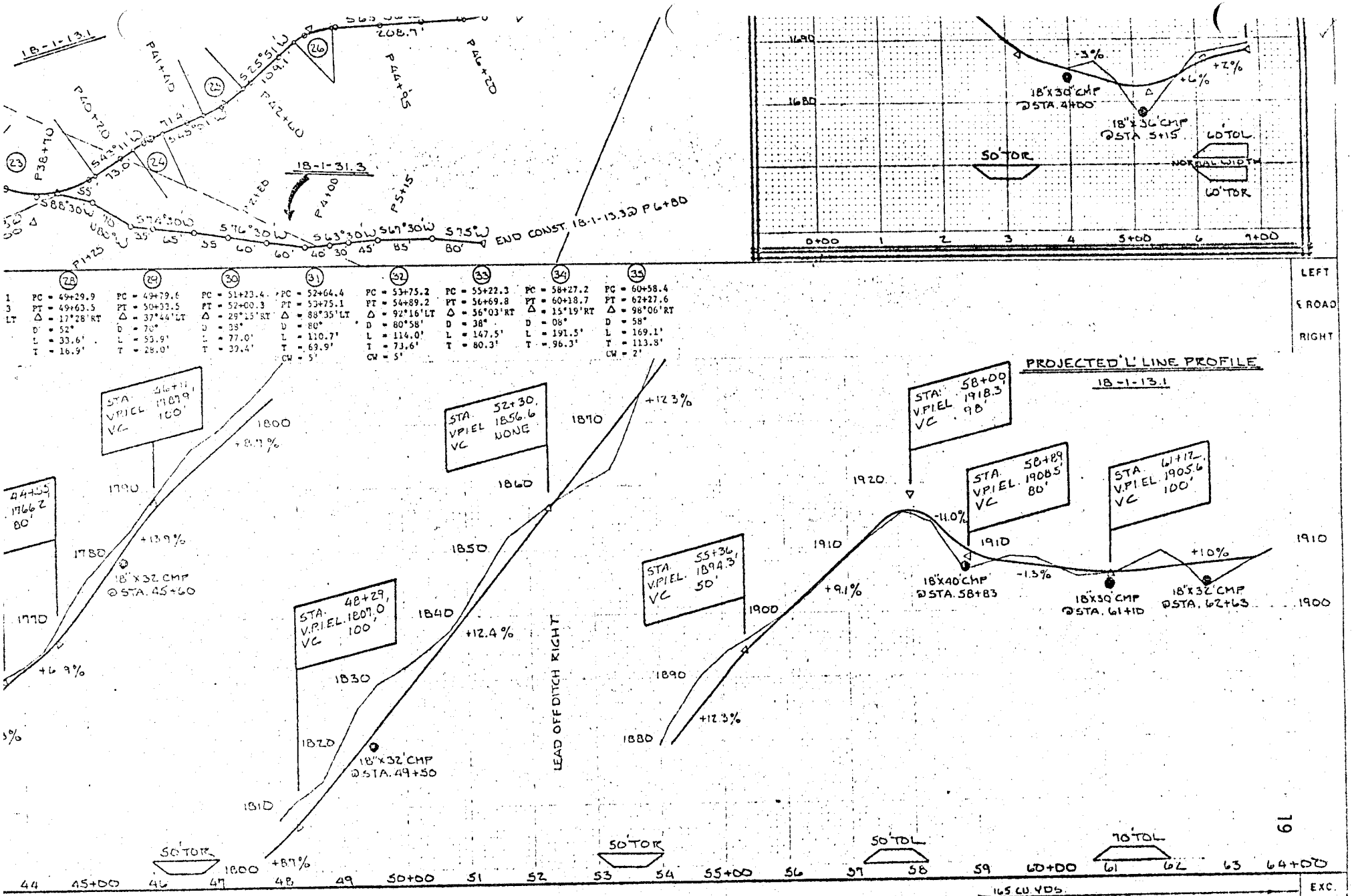
	28	29	30	31	32	33	34	35
	PC = 49+29.9	PC = 49+29.6	PC = 51+33.4	PC = 52+64.4	PC = 53+75.2	PC = 55+22.3	PC = 58+27.2	PC = 60+58.4
	PT = 49+63.5	PT = 50+33.5	PT = 52+00.3	PT = 53+75.1	PT = 54+89.2	PT = 56+69.8	PT = 60+18.7	PT = 62+27.6
	Δ = 17°28'RT	Δ = 37°44'LT	Δ = 29°15'RT	Δ = 88°35'LT	Δ = 92°16'LT	Δ = 56°03'RT	Δ = 15°19'RT	Δ = 98°06'RT
	D = 52°	D = 70°	D = 38°	D = 80°	D = 80°58'	D = 38°	D = 08°	D = 58°
	L = 33.6'	L = 53.9'	L = 77.0'	L = 110.7'	L = 114.0'	L = 147.5'	L = 191.5'	L = 169.1'
	T = 16.9'	T = 28.0'	T = 39.4'	T = 69.9'	T = 73.6'	T = 80.3'	T = 96.3'	T = 113.8'
				CW = 5'	CW = 5'			CW = 2'





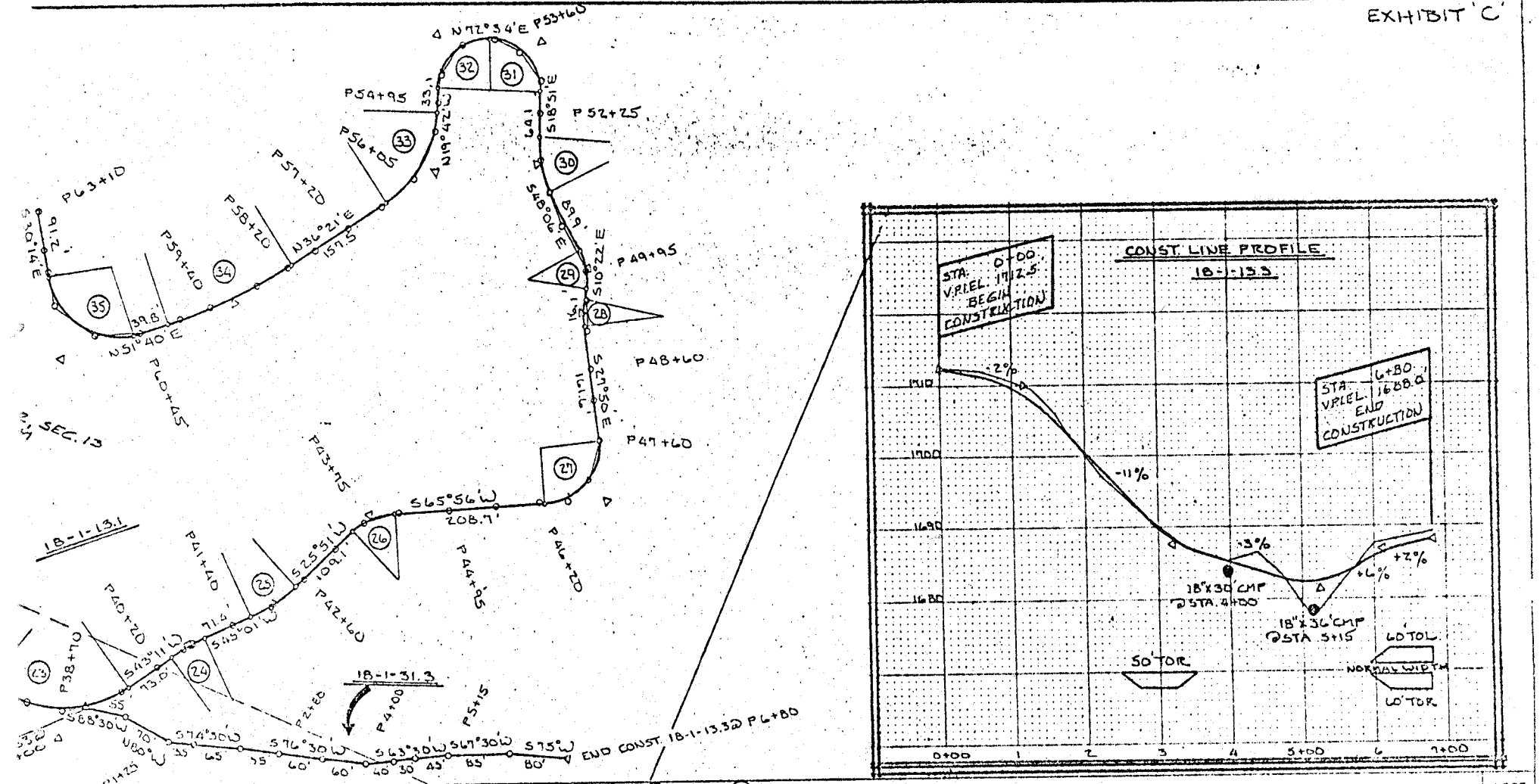
LEFT
& ROAD
RIGHT

8



S HEREON ISTMENT	U.S. DEPARTMENT OF INTERIOR BUREAU OF LAND MANAGEMENT	0' 100' 200' 300' PLAN SCALE IN FEET	PROFILE SCALE · REDUCED VERTICAL 1"=20' 1"=10' HORIZONTAL 1"=100' REDUCED 1"=200'	STATE	DISTRICT	PROJECT NUMBER	SHEET NUMBER	TOTAL SHEETS
				OREGON	EUGENE	18-1-13.1 18-1-13.3 LANDING SPUR	26	29

EXHIBIT 'C'



28	29	30	31	32	33	34	35		
PC = 49+29.9	PC = 47+29.6	PC = 51+33.4	PC = 52+64.4	PC = 53+75.2	PC = 55+22.3	PC = 58+27.2	PC = 60+58.4		
PT = 49+63.5	PT = 50+33.5	PT = 52+00.3	PT = 53+75.1	PT = 54+89.2	PT = 56+69.8	PT = 60+18.7	PT = 62+27.6		
Δ = 17°28'RT	Δ = 37°44'LT	Δ = 29°15'LT	Δ = 88°35'LT	Δ = 92°16'LT	Δ = 56°03'RT	Δ = 15°19'RT	Δ = 98°00'RT		
D = 52°	D = 70°	D = 38°	D = 80°	D = 80°58'	D = 38°	D = 08°	D = 58°		
L = 33.6'	L = 53.9'	L = 77.0'	L = 110.7'	L = 114.0'	L = 147.5'	L = 191.5'	L = 169.1'		
T = 16.9'	T = 28.0'	T = 39.4'	T = 69.9'	T = 73.6'	T = 80.3'	T = 96.3'	T = 113.8'		
			CW = 5'	CW = 5'			CW = 2'		

LEFT
ROAD
RIGHT