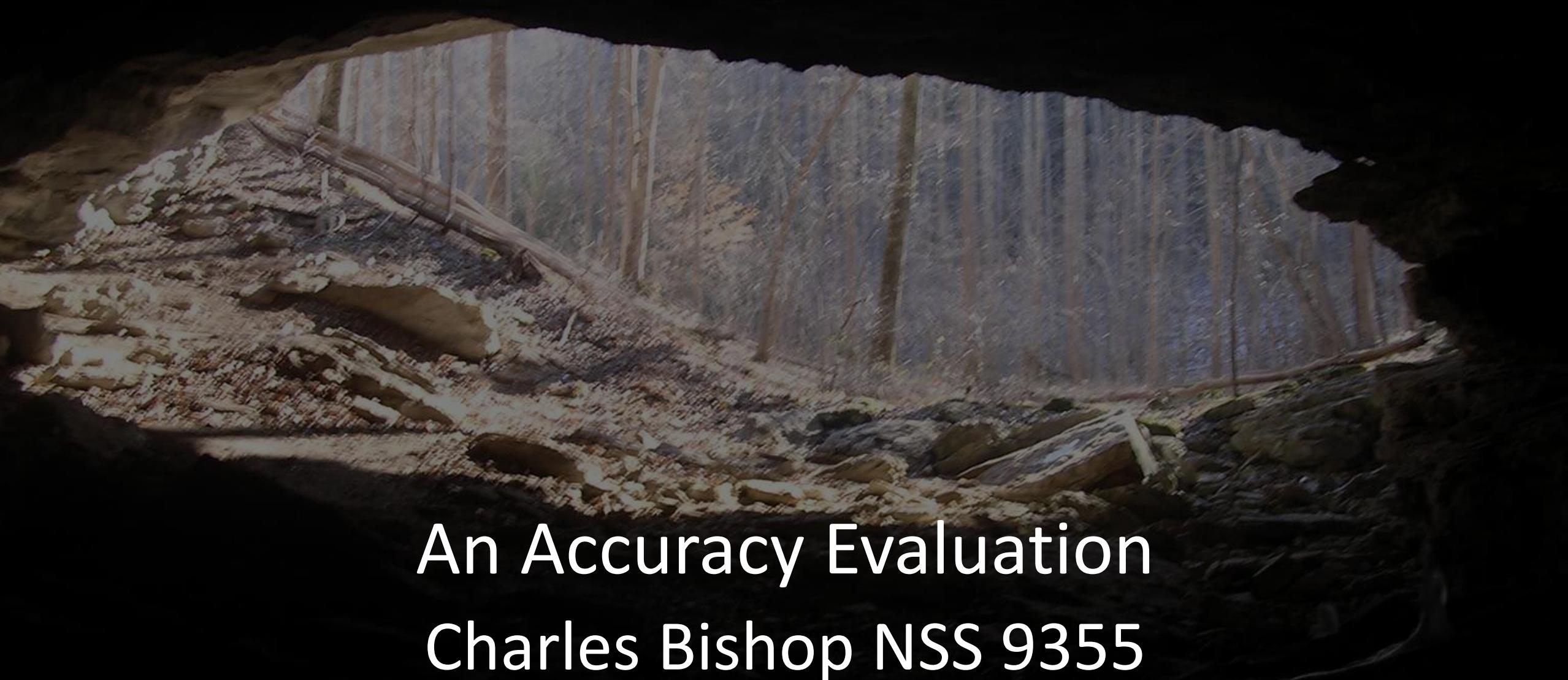
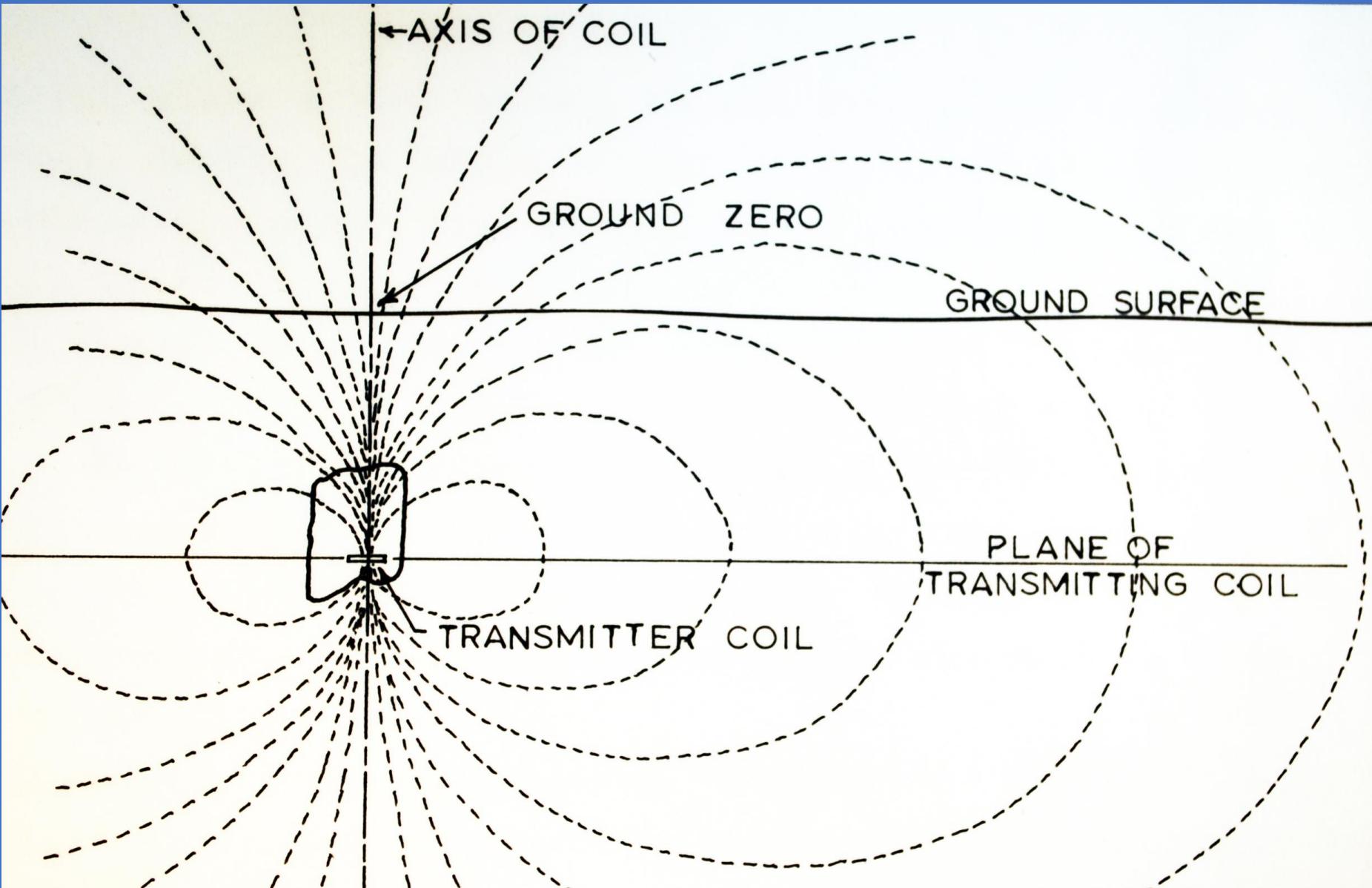


# Cave Radio Electromagnetic Locating

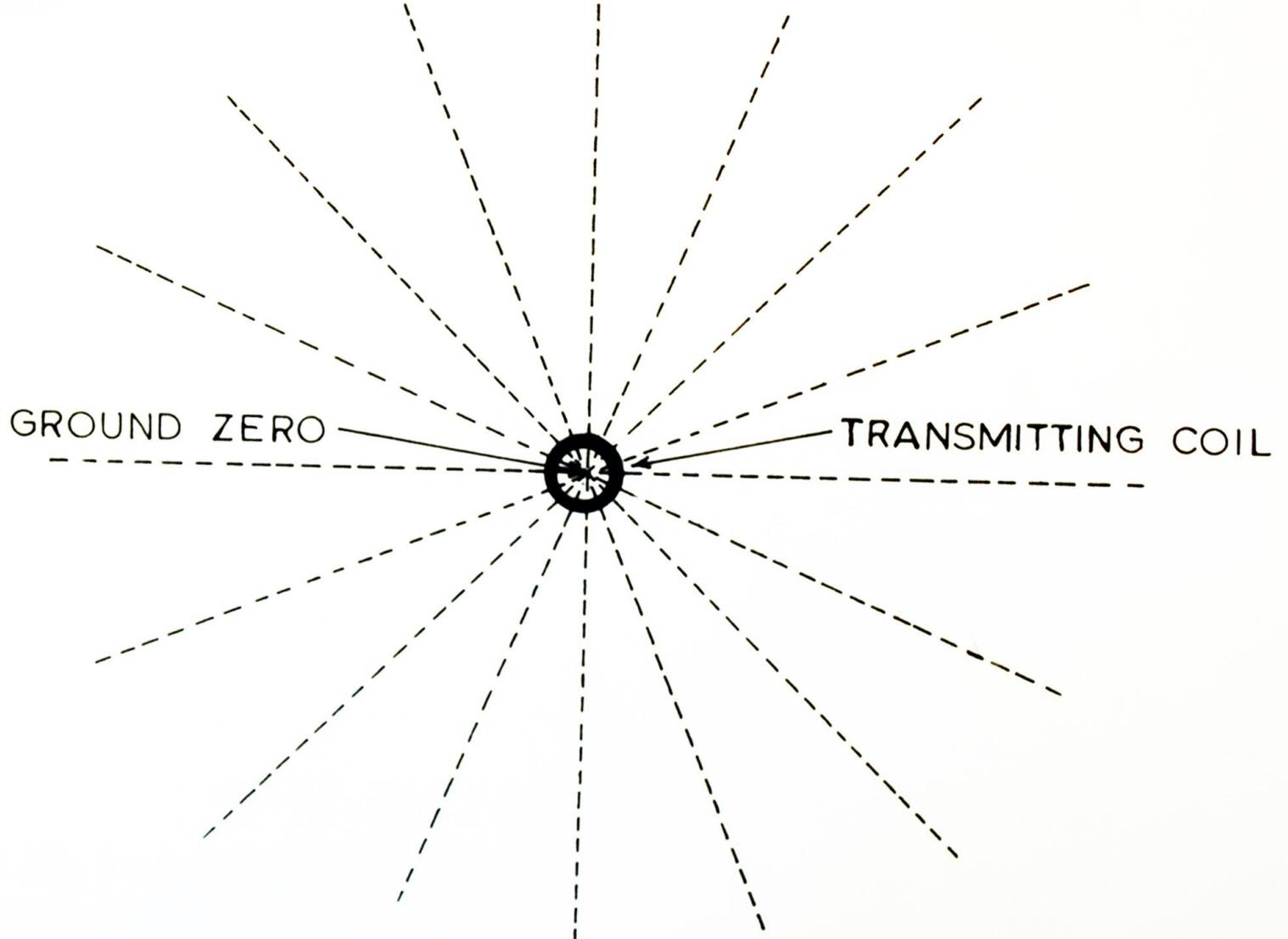


An Accuracy Evaluation  
Charles Bishop NSS 9355



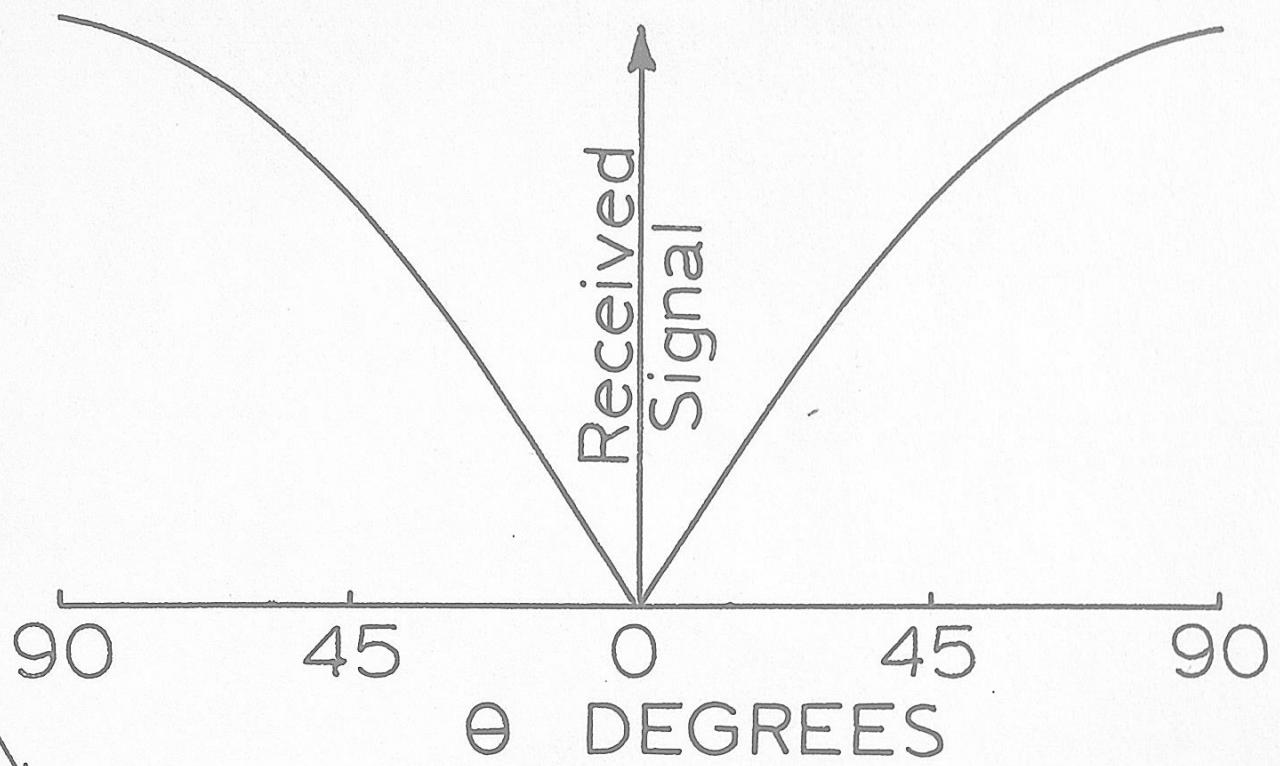
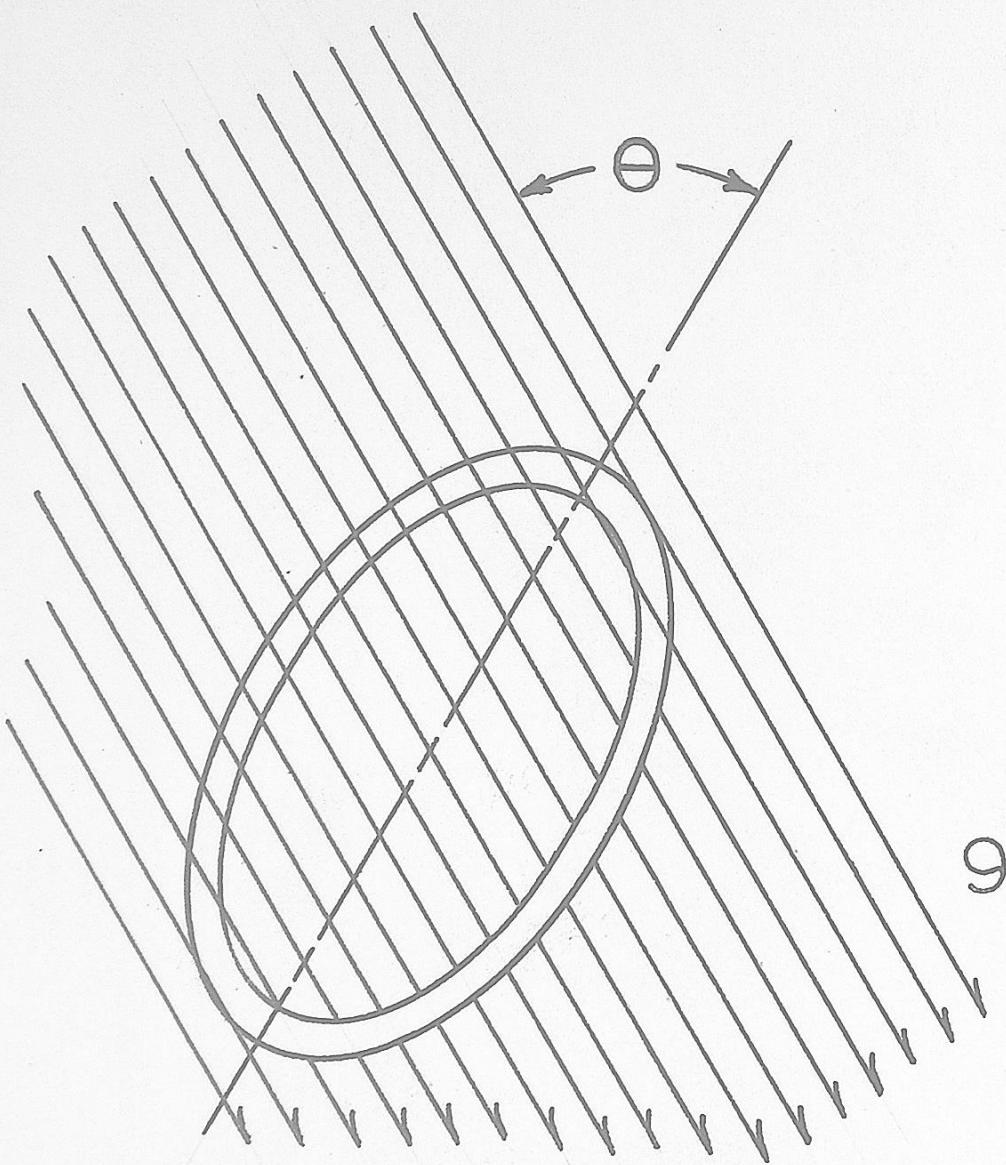


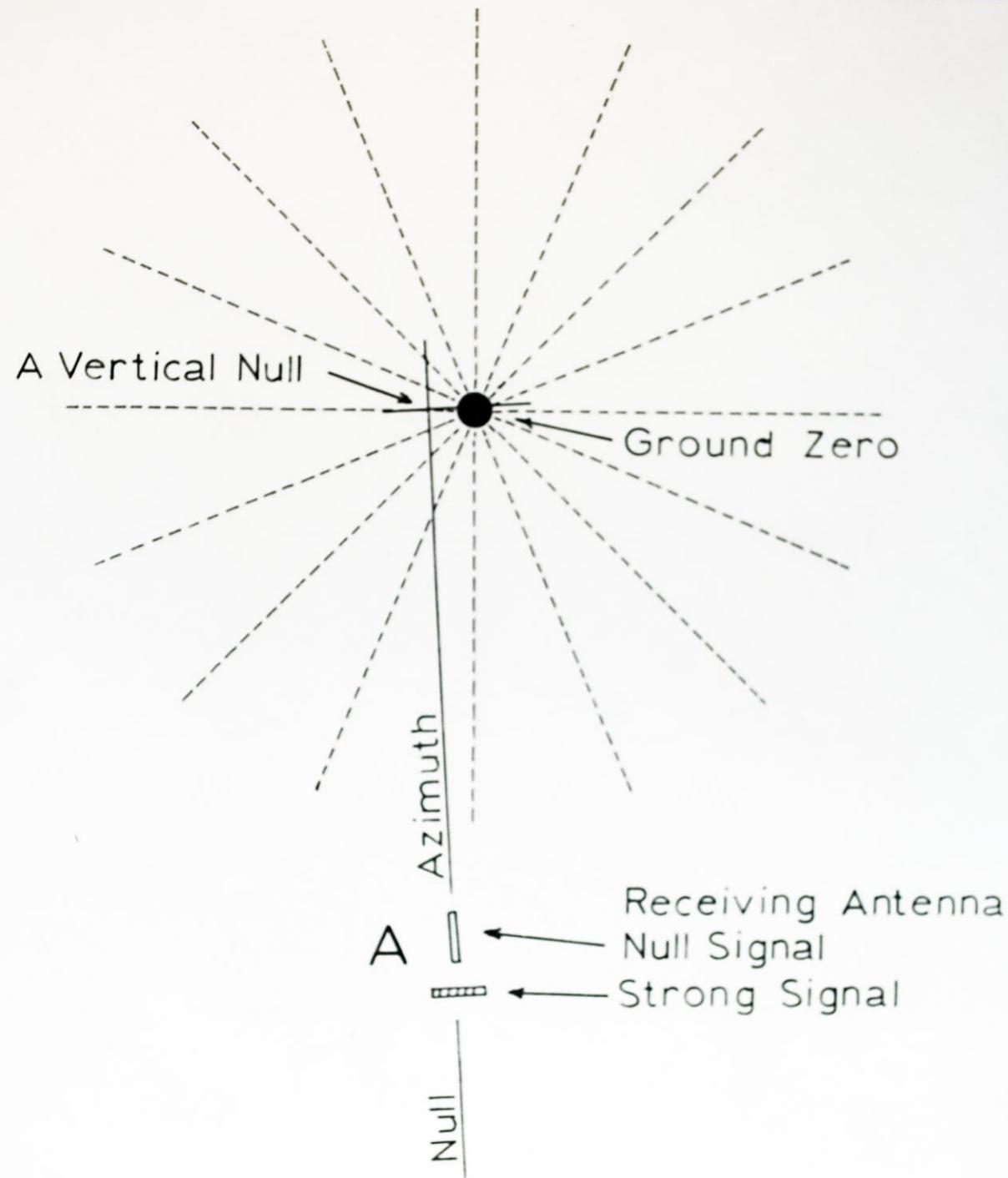
PROFILE VIEW



PLANE VIEW

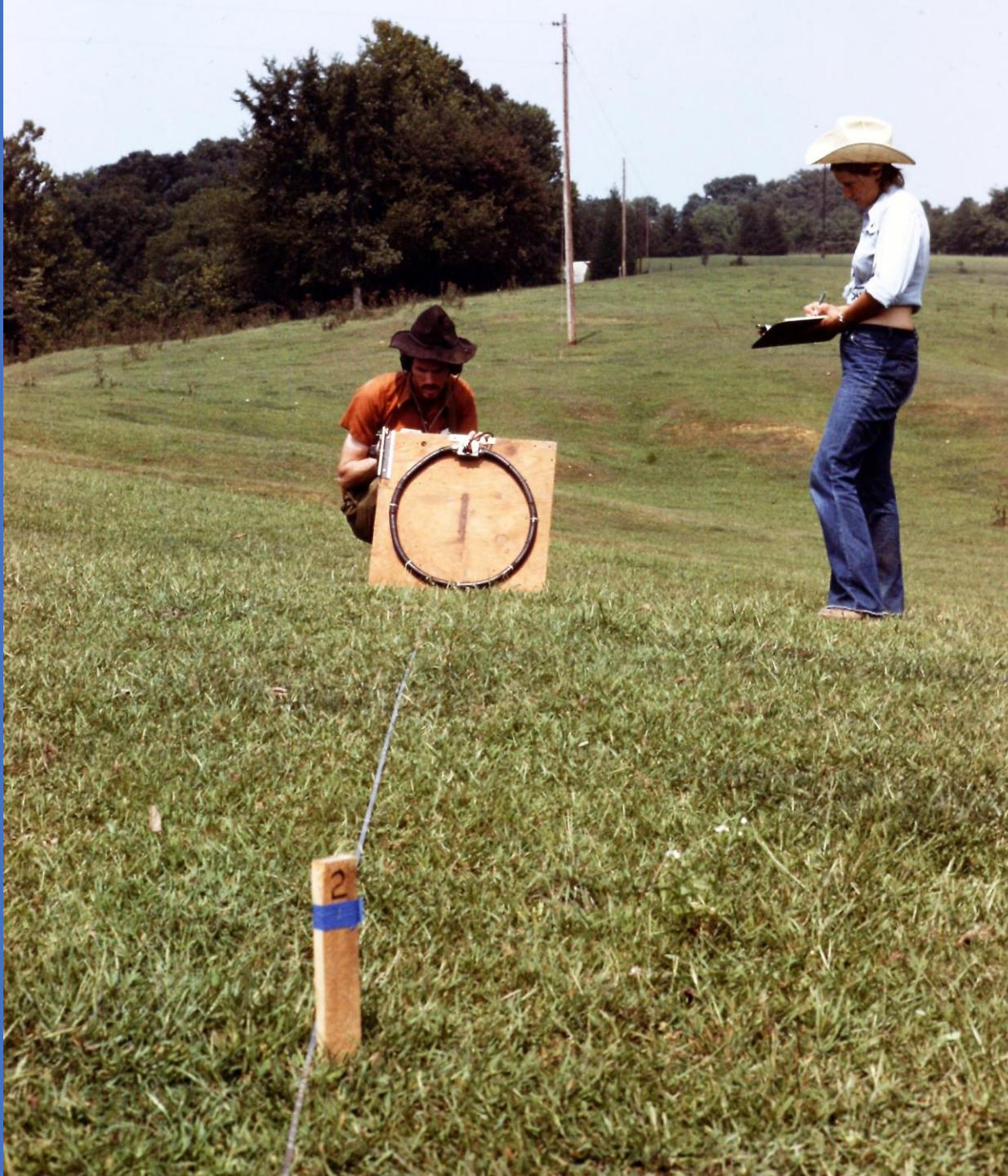










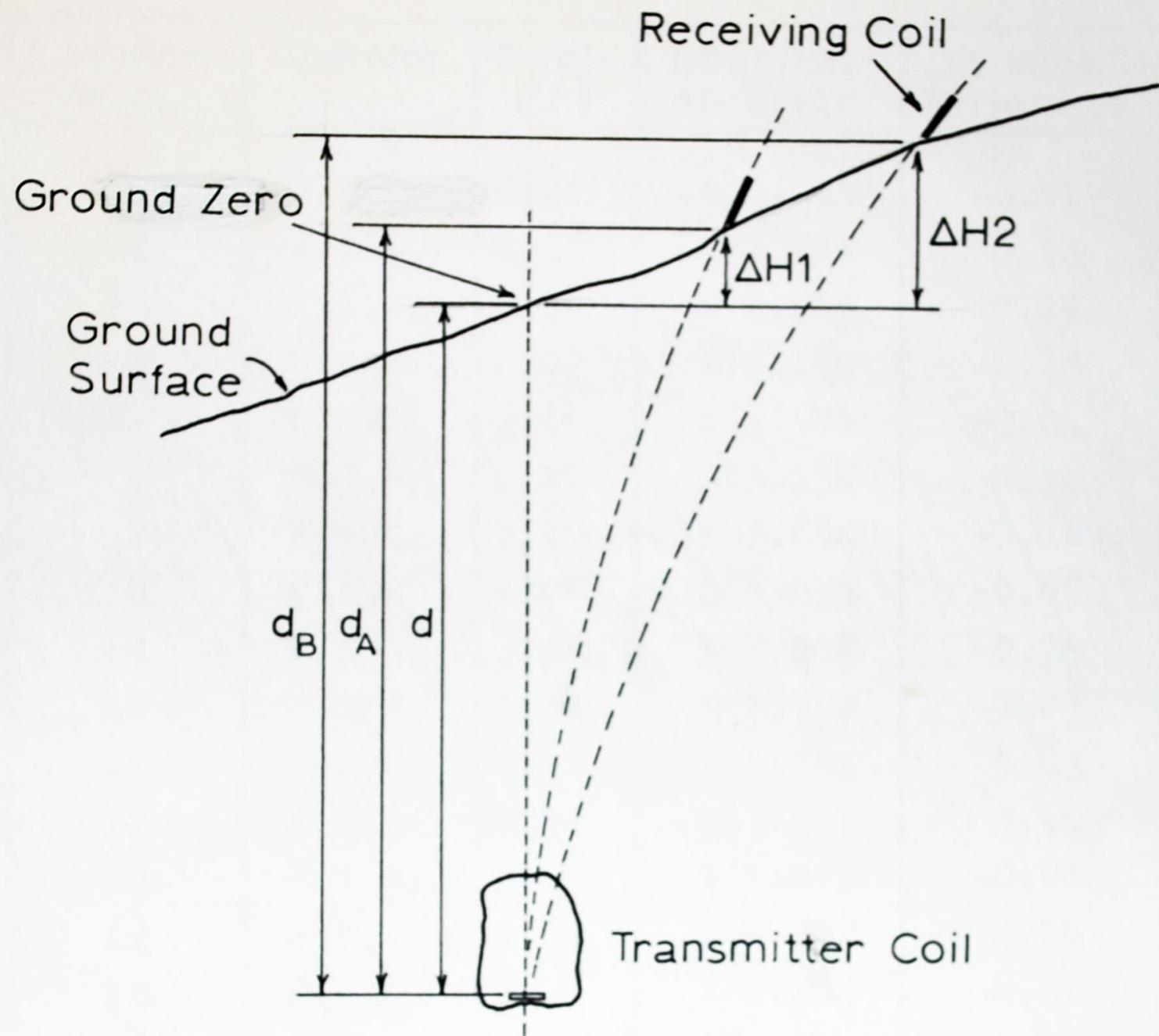






PROJECT TITLE RLAE  
 UNDERGROUND LOCATION #20 Silliman Avenue  
 SURFACE LOCATION #20 Stake #4  
 UNDERGROUND PARTY MEMBERS:  
D. Kelley M  
K. Hoskins A  
D. Pollock I  
 SURFACE PARTY MEMBERS:  
 OPERATOR F. Reich  
 NOTES C.S. Bishop  
N. Edson  
Rod H. Bishop  
 TRANSMITTING SCHEDULE 50 minutes, Atmos. Noise has not  
 increased since sundown  
 RECEIVING CONDITIONS Very Weak  
 TIME OF SIGNAL ACQUISITION 8:33 PM INITIAL DISTANCE FROM GROUND ZERO  
 ACQUISITION RADIUS 900 ANGLE UNITS 2X = Grads DISTANCE UNITS

L	θ	D	Δh	D - Δh
0	—	—	5.92 0.00	
50	8.8	268.99	5.23 0.69	268.30 0M15
55	9.0	289.20	5.16 0.76	288.94
60	9.6	295.41	5.17 0.75	294.66
65	10.5	292.01	5.15 0.77	291.24
70	11.8	278.93	4.95 0.97	277.96
75	12.1	291.21	4.88 1.04	290.17
80	13.1	286.12	4.86 1.06	285.06
85	13.1	304.00	4.73 1.19	302.81
90	13.8	304.91	4.58 1.34	303.57
95	15.15	291.90	4.51 1.41	290.49
100	15.5	299.97	3.97 1.95	298.02
105	16.2	300.61	4.12 1.80	298.81
110	16.2	314.93	4.27 1.65	313.28
115	17.3	307.04	4.10 1.82	305.22
120	18.1	305.26	3.82 2.10	303.16
125	18.7	303.51	3.81 2.11	301.40
130	19.7	301.78	3.75 2.17	299.61
135	20.4	301.68	3.63 2.29	299.39
140	20.8	306.27	3.37 2.55	303.72
145	21.7	302.74	3.31 2.61	300.13
150	20.9	326.42	3.25 2.67	323.75 0M15
			$\bar{x} = 297.22$	
			S = 8.31	
			SHEET <u>1</u> OF <u>1</u>	



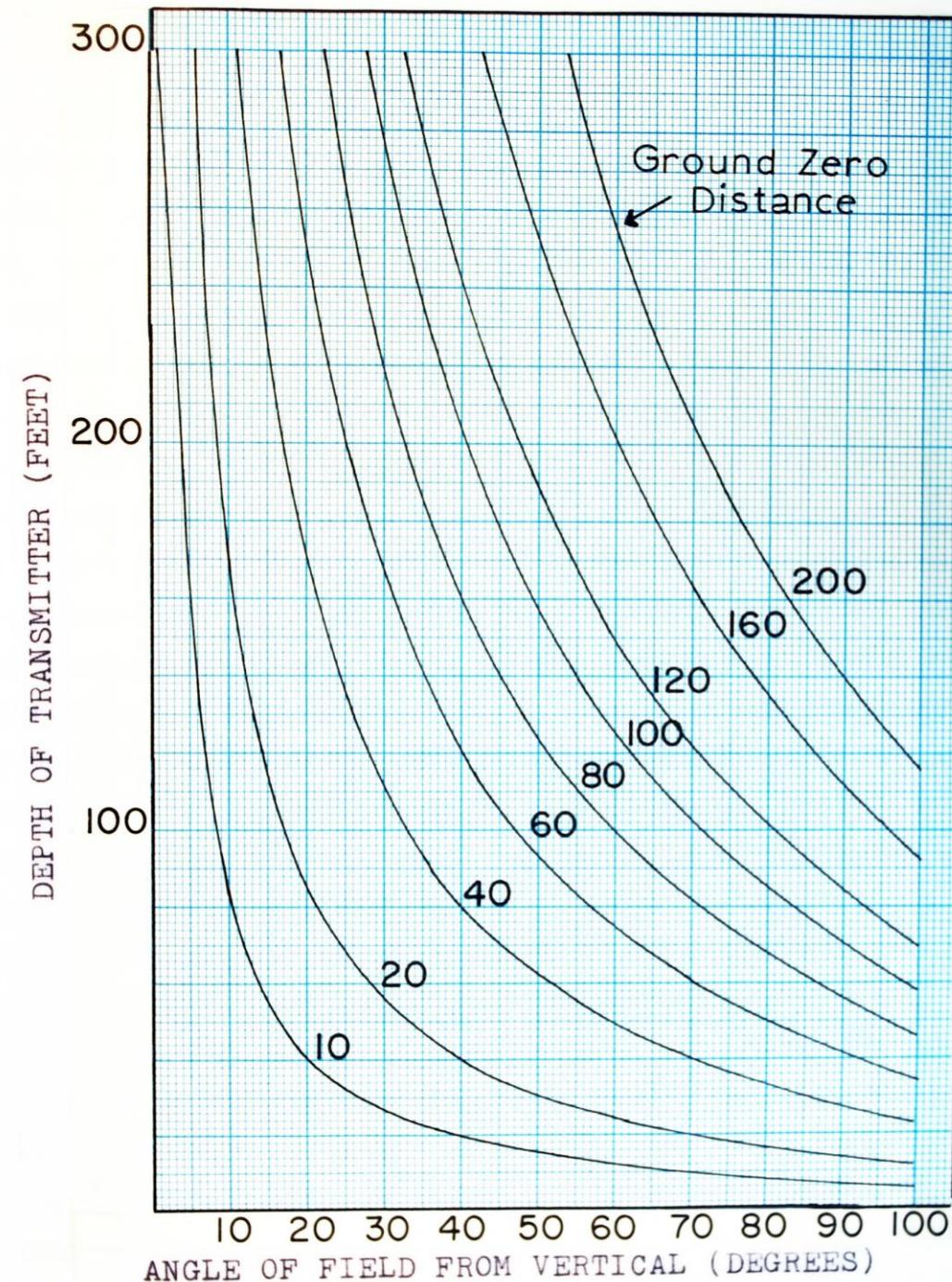
# Depth Calculation

$$D = \frac{L(3 + \sqrt{9 + 8 \tan^2 \theta})}{4 \tan \theta}$$

D = depth

L = distance from ground zero

$\theta$  = angle of magnetic field



# Evaluation Locations

Bluespring Caverns, Indiana

Mammoth Cave National Park

# Bluespring Caverns Horizontal Control Survey

Third Order Traverse Accuracy

Wild T-2 One Second Theodolite

Two Positions Each Instrument Setup

Wild DI-10 Electronic Distance Meter

100 Foot Steel Tape, 20 lb. Pull Tension

780 Foot Traverse, Closure Error = 0.10 Foot

Closure Ratio= 1:8,650

# Mammoth Cave National Park

## Horizontal Control Surveys

H.D. Walker Surveys, 1935 & 1936

Third Order Traverses, 34 Benchmarks Set In The Cave

TT5W Wright's Rotunda, 22,560' Foot Traverse  
1.55' Foot Closure, Closure Ratio 1:14,500

TT14W Silliman Avenue, 33,913' Foot Traverse

Assumed Closure Ratio 1:5,000, Assumed Closure **6.78'** Feet

TT21W & TT8W Rocky Mountain, Less Than 1000' Traverse  
Assumed Closure Ratio 1:5,000, Assumed Closure **0.20'** Feet

# **Vertical Control**

## **H. D. Walker Survey MCNP**

Closed Loop, Dumpy Level, Philadelphia or Sawed-Off New York Rods

Third Order, Class II?, Specification +/- 0.023 ft/ mile, Single Shot +/- 0.003'

For the 22,560' Loop The Allowable Closure Is = +/- 0.08 Foot

## **Bluespring Caverns and Surface/In-Cave Control**

Closed Loop Three Wire Level Survey With Wild Automatic Level

Surface/In Cave Loop Closure Error =/-0.01 Foot















# Horizontal Position Determinations

# Bluespring Caverns, Depth 74 Feet

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	0.41	S87.03E	-0.01
2	F.S.R.	0.32	S37.57W	0.13
3	F.S.R.	0.18	N 8.46W	-0.12
4	F.S.R.	0.02	N18.15W	-0.12
5	F.S.R.	0.16	S62.50W	-0.04
6	F.S.R.	0.24	S83.13W	0.14
7	F.S.R.	0.19	N57.80E	-0.10
8	F.S.R.	0.08	S58.95E	-0.05
9	F.S.R.	1.18	N68.00E	-0.76
10	C.S.B.	0.32	N67.99E	-0.03
11	C.S.B.	0.30	N69.58E	-0.03
12	F.S.R.	0.47	S63.49E	0.15
13	F.S.R.	0.38	N18.09E	-0.08
14	C.S.B.	0.58	N68.00E	0.08
15	C.S.B.	0.48	N88.20E	0.00
16	F.S.R.	0.52	S83.11W	-0.44
17	F.S.R.	0.33	S65.39E	-0.10
18	F.S.R.	0.28	S15.37W	-0.28
19	F.S.R.	0.09	S41.40E	-0.07
20	C.H.B.	0.17	S43.29E	0.04

# Mammoth Cave, Wright's Rotunda, Depth 198 Feet

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	7.58	N86.12E	1.37
2	F.S.R.	8.69	N82.72E	0.56
3	F.S.R.	29.27	S89.50E	18.86
4	F.S.R.	9.23	N73.26E	1.22
5	C.S.B.	9.13	N80.58E	0.53
6	F.S.R.	9.61	N84.86E	0.53
7	C.S.B.	8.91	N82.31E	0.17
8	C.S.B.	8.33	N79.92E	-0.42

# Mammoth Cave, Rocky Mountain, Depth 212 Feet

Location Point	Operator	Error (ft.)	Direction of Error	Distance Difference
1	F.S.R.	4.76	N32.30W	-2.17
2	F.S.R.	8.30	N78.17W	-0.22
3	F.S.R.	0.49	N47.90E	6.55
4	F.S.R.	2.01	N 4.62E	5.48
5	F.S.R.	7.63	S84.45W	-1.09
6	F.S.R.	5.30	N40.33W	-1.70
7	C.S.B.	13.77	N43.44W	-1.27
8	F.S.R.	86.15	N43.77W	-31.90
9	F.S.R.	40.88	S77.48E	-0.52
10	C.S.B.	6.21	N50.56W	-1.16
11	C.S.B.	8.38	N79.83W	-0.35
12	F.S.R.	11.54	N63.75W	1.75

# Silliman Avenue, Depth 298 Feet

## Horizontal Position

<u>Location</u>	<u>No. Locations</u>	<u>Range (feet)</u>	<u>Average Error (feet)</u>
Valley Wayside Cut	9	12.8' to 26.1'	19.8'
Silliman Avenue	12	36.0' to 51.3'	45.3'

## Distance Difference

<u>Location</u>	<u>Range (feet)</u>	<u>Average (feet)</u>
Valley Wayside Cut	-0.34' to 6.65'	2.72'
Silliman Avenue	-5.91' to 5.92'	-0.07'

**NOTE:** The location points in Silliman Avenue were located approximately 100 feet horizontally from the locations in Valley Wayside Cut.

# Depth Determinations

# Bluespring Caverns, Depth 74 Feet

Location Point	Operator	Elevation Difference	EMLD		EMLD Depth %
			Depth	$\sigma$ Std	$\Delta$ Elevation
1	F.S.R.	74.43	--	--	--
2	F.S.R.	74.18	72.49	0.94	97.7%
3	F.S.R.	74.24	72.78	1.22	98.0%
4	F.S.R.	74.33	73.00	1.51	98.2%
5	F.S.R.	74.06	73.49	2.40	99.2%
6	F.S.R.	74.03	72.42	1.94	97.8%
7	F.S.R.	73.58	70.71	1.49	96.1%
8	F.S.R.	73.72	65.08	3.99	88.3%
9	F.S.R.	73.60	70.48	1.26	95.8%
10	C.S.B.	73.15	70.24	1.31	96.0%
11	C.S.B.	74.06	72.21	1.51	97.5%
12	F.S.R.	74.03	72.37	1.35	97.8%
13	F.S.R.	74.10	71.86	1.38	97.0%
14	C.S.B.	73.86	72.02	1.44	97.5%
15	C.S.B.	74.18	73.73	1.38	99.4%
16	F.S.R.	73.79	73.68	2.03	99.9%
17	F.S.R.	73.02	72.00	1.52	98.6%
18	F.S.R.	73.87	71.60	1.83	96.9%
19	F.S.R.	73.84	71.42	1.07	96.7%
20	C.H.B.	73.08	71.00	0.84	97.2%

# Wright's Rotunda, Depth 198 Feet

Location Point	Operator	Elevation Difference	EMLD Depth	$\sigma$ Std	EMLD Depth % $\Delta$ Elevation %
1	F.S.R.	198.58	188.17	4.19	94.8%
2	F.S.R.	198.71	193.24	7.00	97.2%
3	F.S.R.	193.53	193.98	4.36	100.2%
4	F.S.R.	198.22	188.97	3.73	95.3%
5	C.S.B.	197.93	187.96	3.96	95.0%
6	F.S.R.	197.86	187.42	4.04	94.7%
7	C.S.B.	197.99	187.51	7.02	94.7%
8	C.S.B.	196.44	184.05	6.28	93.7%

# Rocky Mountain, Depth 212 Feet

Location Point	Operator	Elevation Difference	EMLD		EMLD Depth % $\Delta$ Elevation %
			Depth	$\sigma$ Std	
1	F.S.R.	217.05	199.29	5.46	91.8%
2	F.S.R.	212.27	206.14	4.21	97.1%
3	F.S.R.	212.13	201.97	3.87	95.2%
4	F.S.R.	201.78	194.31	4.97	96.3%
5	F.S.R.	212.86	203.81	3.63	95.7%
6	F.S.R.	216.58	204.19	3.12	94.3%
7	C.S.B.	211.07	199.43	3.49	94.5%
8	F.S.R.	201.84	194.93	3.30	96.6%
9	F.S.R.	219.21	245.00	7.03	111.8%
10	C.S.B.	216.17	203.82	5.67	94.3%
11	C.S.B.	212.49	200.39	5.60	94.3%
12	F.S.R.	212.74	197.26	3.83	92.7%

# Silliman Avenue, Depth 298 Feet

Location Point	Operator	Elevation Difference	EMLD		EMLD Depth %
			Depth	$\sigma$ Std	
1	C.S.B.	304.01	299.36	143.35	98.5%
2	C.S.B.	304.03	397.76	39.70	130.8%
3	C.S.B.	304.26	353.59	39.78	116.2%
4	C.H.B.	304.87	269.46	49.57	88.4%
5	C.S.B.	304.20	278.27	30.87	91.5%
6	C.H.B.	290.36	259.05	14.00	89.2%
7	C.S.B.	290.31	263.62	17.75	90.8%
8	C.S.B.	291.29	257.94	26.70	88.6%
9	C.H.B.	289.47	243.98	18.25	84.3%
10	C.S.B.	303.76	280.77	14.77	92.4%
11	F.S.R.	304.39	288.40	18.76	94.7%
12	F.S.R.	304.34	295.63	17.43	97.1%
13	C.S.B.	304.26	305.67	18.74	100.5%
14	F.S.R.	304.20	299.58	11.65	98.5%
15	F.S.R.	303.66	233.94	17.59	77.0%
16	C.S.B.	290.37	259.18	12.76	89.3%
17	C.S.B.	290.58	276.07	11.53	95.0%
18	F.S.R.	290.52	289.03	11.01	99.5%
19	C.S.B.	292.55	271.60	14.71	92.8%
21	F.S.R.	303.43	297.22	8.31	98.0%

# Summary of Results

<u>Depth (feet)</u>	<u>Horizontal Position</u>		<u>Depth Determination</u>	
	<u>Average Error (feet)</u>	<u>Pattern(feet)</u>	<u>Average %</u>	<u>Std. Deviation %</u>
74	0.29	-0.05	97.6	+/- 2.42
198	8.78	0.57	95.1	+/- 2.07
212	6.84	0.58	94.8	+/- 1.61
291 VWC	19.8	2.72	91.1	+/- 4.60
304 SA	45.3	-0.07	93.7	+/- 6.97

NOTE: Pattern in the table is the average of the distance differences.

# Acknowledgements

Bluespring Caverns, Indiana

Mammoth Cave National Park

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D.E. Kelley      J.D. Pollock

J.F. Quinlan      H.S. Schillereff

N.S. Eidson      R. Richers

# Thank You For Listening



Is There Anyone Who Wants To Take This Deeper?