

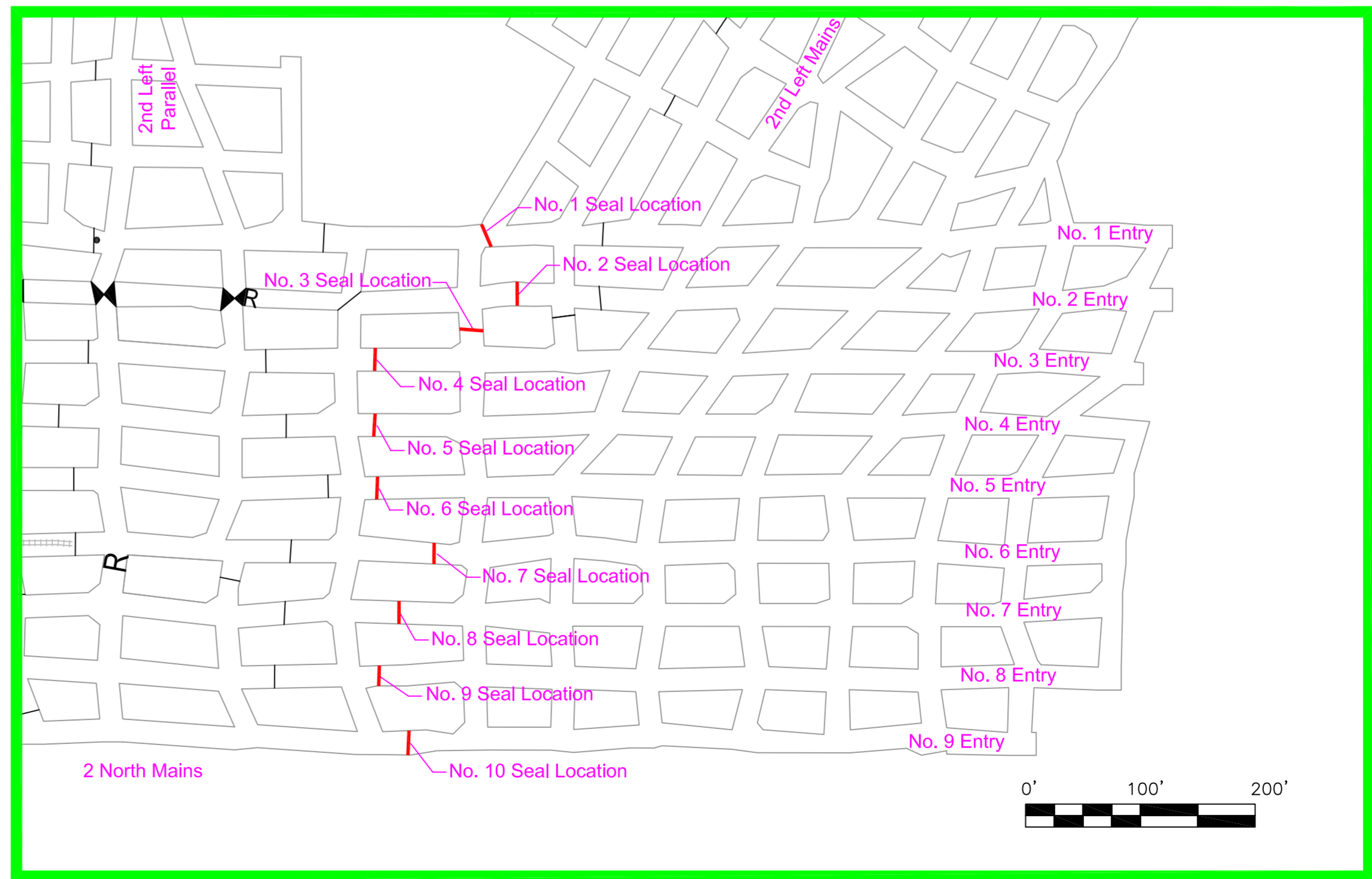
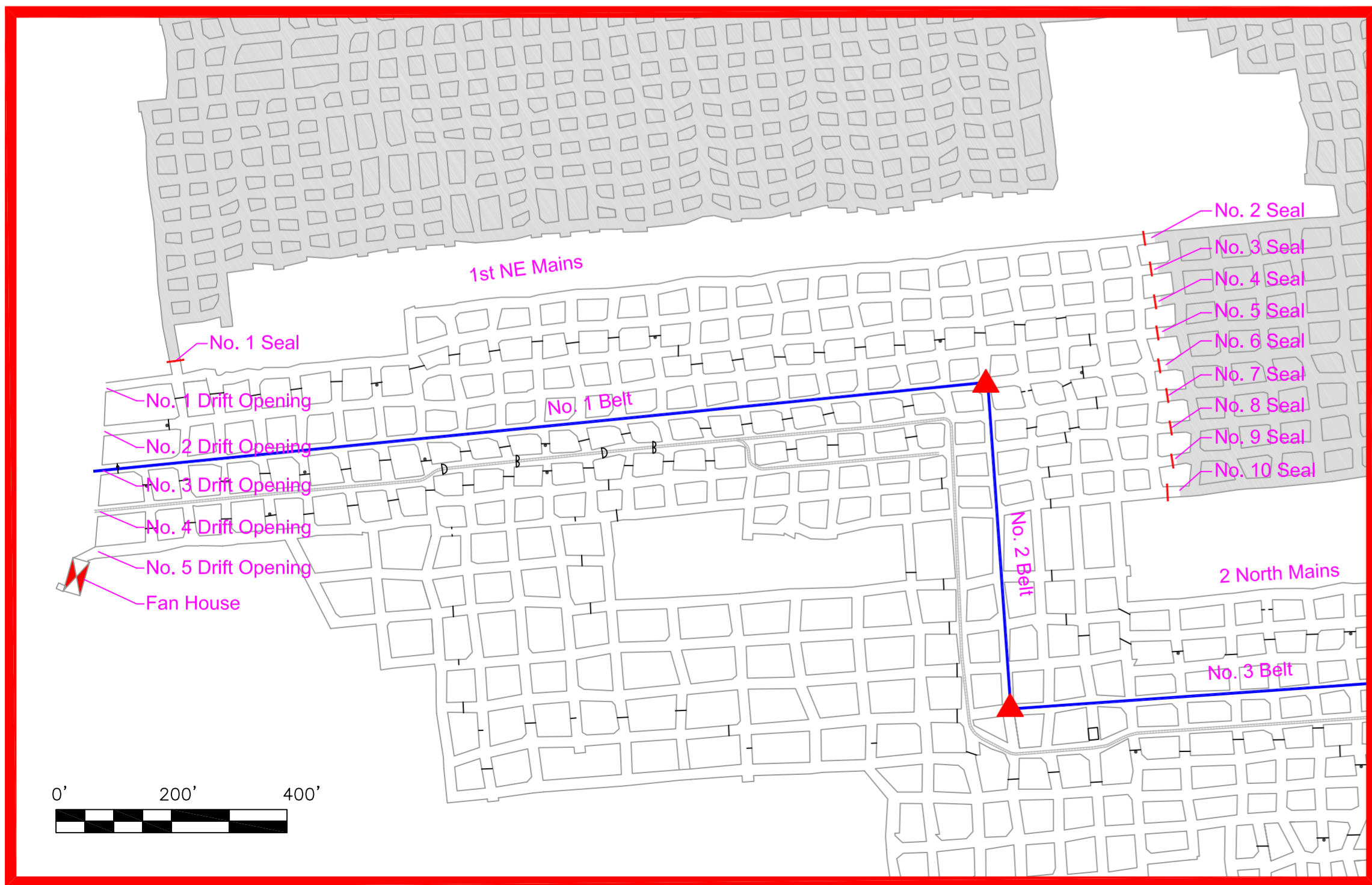
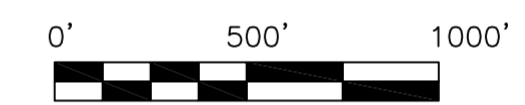
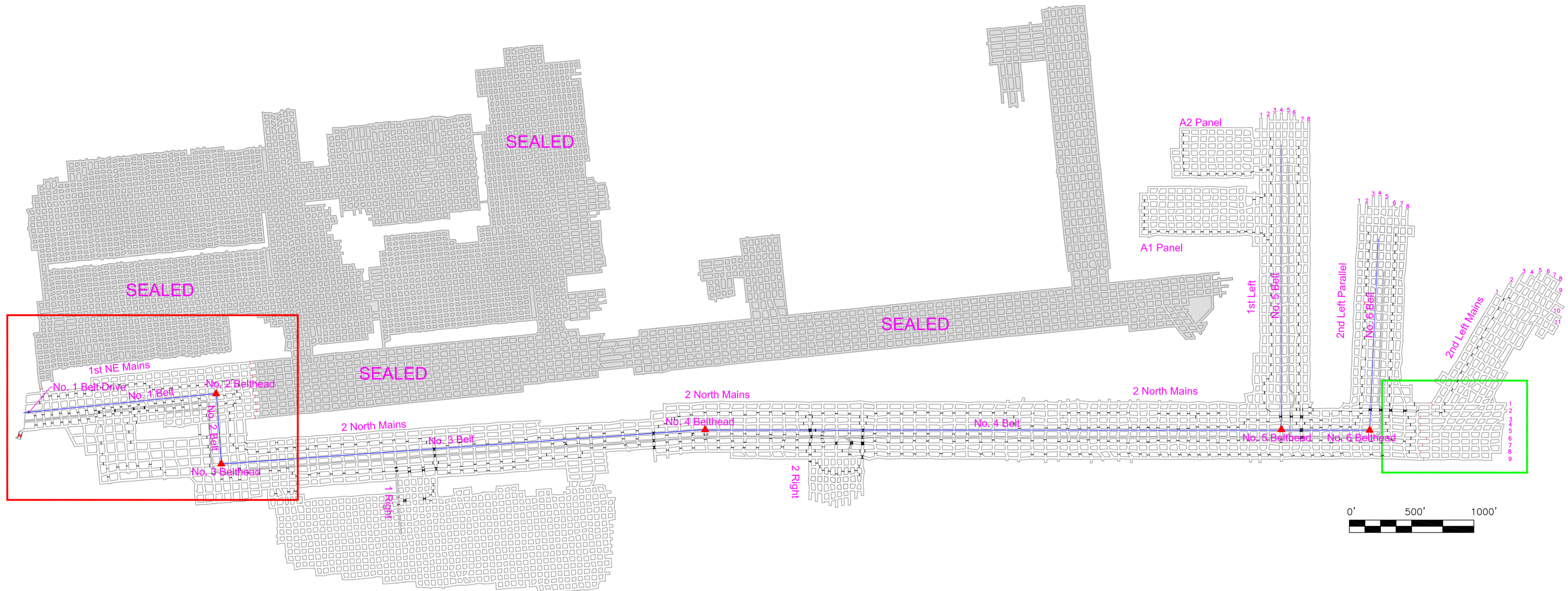
Appendix A - List of Deceased and Injured Miners

Deceased Miners

<u>Name</u>	<u>Occupation</u>
Thomas P. Anderson	2nd Left Parallel Shuttle Car Operator
Alva M. Bennett	2nd Left Parallel Mining Machine Operator
James Bennett	2nd Left Parallel Shuttle Car Operator
Jerry L. Groves	2nd Left Parallel Roof Bolter Operator
George J. Hamner	2nd Left Parallel Shuttle Car Operator
Terry Helms	Mine Examiner
Jesse L. Jones	2nd Left Parallel Roof Bolter Operator
David W. Lewis	2nd Left Parallel Roof Bolter Operator
Martin Toler Jr.	2nd Left Parallel Section Foreman
Fred G. Ware	2nd Left Parallel Mining Machine Operator
Jackie L. Weaver	2nd Left Parallel Electrician
Marshall Winans	2nd Left Parallel Scoop Operator

Injured Miner

<u>Name</u>	<u>Occupation</u>	<u>Injury</u>
Randal McCloy Jr.	2nd Left Parallel Roof Bolter Operator	Carbon Monoxide Poisoning



Appendix C - Mine Rescue Personnel and Teams Responding

Consol Energy Corporation

Mine Rescue Personnel

Spike Bane
Elizabeth Chamberlain

Rick Marlow
Kevin Whetzel

Blacksville No. 2

James Ponceroff
Richard Tolka
Lonny Meyers

David Rush
Robert Wade
Tony Casini

McElroy Mine Rescue

Danny Beyser
Dennis Crow
James Klug
Kelvin Jolly
Robert Rohoe

Michael Clark
James Smith
Randy Clark
Jack Price
William Blackwell

Shoemaker Mine Rescue

Cliff Ward
Charles Fisher
Ted Hunt
Silas Stavischek
Glenn McWhorten

Jim Jack
Okey Rine
Robert Hines
Shan Michener

Robinson Run Mine Rescue

Alfred Bell
Craig Carpenter
Sherman Goodwin
Phillip Morgan
Larry Tenney

Jerry Bienkoski
Gary Given
Mark Koor
William Reed

Loveridge Mine Rescue

Leslie R. Cosner
Nick A. Tippi
Donald A. Jack
Robert Hovatter

James Clendenen
Richard Shockley
Charles P. Layman
Gary Hayhurst

Appendix C - Mine Rescue Personnel and Teams Responding (cont' d)

Eighty-Four Mine Rescue

Don Klek
Dale Tiberie
Richard Gindlesperger
Kenneth Clark
Robert Volpe

Adrian Gordon
John Stowinsky
Dan Puckey
Brad DeBush
Mickey Miskiewiez

Bailey Mine Rescue

Dennis Vicinelly
Mike Spears
Dave Cass
Gene Menozzi
Larry Cuddy

George Joseph
Kevin Williamson
Steve Edgehouse
Bob Calhoun

Barbour County Mine Rescue

Mark W. Chewning
Fred Radabaugh
Brian Curtis
Roger Hedrick
Teddy Hickman
Ryan Jeran

Clyde M. Tenney
Doug Andrews
Paul Maxson
Jeff Byard
John Cottrill
James Paugh

Viper Mine Rescue

Brad Kaufman
Ty Hunt
Paul Perrine
Brandon Sanson

Clifford Bryant Jr.
Allen Setzer
Bret Bushong

Tri-State

Christopher C. Lilly
Mike Grimm
Kerry Lilly
Mark Thorn
Dan Bismark

Andrew Lilly
Ben Wilson
Don Firn
Chris Sisler
Gary Bolyand

Appendix C - Mine Rescue Personnel and Teams Responding (cont' d)

State Mine Rescue

Region 1

Barry Fletcher
Jeffery Bennett

John Scott
John Hall

Region 4

Clarence Dishman
Mike Rutledge
Eugene White

William Tucker
Randy Smith

Region 3

James Hodges

MSHA Mine Emergency Unit

Virgil Brown
Jerry Cook
Charles Pogue
Mike Hicks
Ronald Hixson
Greg Ison
James Langley
Jan Lyall

Scott Mandeville
Fred Martin
Frank Thomas
Stanley Sampsel
Clayton Sparks
Mike Shumate
Tony Sturgill

Pittsburgh Safety and Health Technology Center

John Urosek
William Francart
Gary Shemon
Mike Valoski

Richard Stoltz
George Aul
George Durkt
Tony Argirakis

Appendix D - Barbour County Mine Rescue Team Air Quality Measurements

Date	Time	Drift Opening No. 1			Drift Opening No. 2			Drift Opening No. 3			Drift Opening No. 4		
		CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)
1/2/2006	1:25 PM	1372	0	20.6									
1/2/2006	1:27 PM				77	0	20.9						
1/2/2006	1:29 PM							24	0	20.7			
1/2/2006	1:30 PM										14	0	20.5
1/2/2006	1:46 PM	1860	0										
1/2/2006	1:47 PM				155	0	20.7						
1/2/2006	1:48 PM							54	0	20.7			
1/2/2006	1:50 PM										32	0	20.6
1/2/2006	2:04 PM	2430	0.6	19.7									
1/2/2006	2:04 PM	2700	0.5	19.6									
1/2/2006	2:06 PM				417	0	20.6						
1/2/2006	2:06 PM				544	0	20.5						
1/2/2006	2:08 PM							178	0	20.6			
1/2/2006	2:08 PM							179	0	20.4			
1/2/2006	2:09 PM										135	0	20.7
1/2/2006	2:09 PM										105	0	20.5
1/2/2006	2:27 PM	1880	.0.6	19.7									
1/2/2006	2:27 PM	2280	.0.5	19.6									
1/2/2006	2:33 PM				292	0	20.7						
1/2/2006	2:33 PM				212	0	20.5						
1/2/2006	2:38 PM							127	0	20.6			
1/2/2006	2:38 PM							92	0	20.5			
1/2/2006	2:42 PM										72	0	20.5
1/2/2006	2:42 PM										69	0	20.4
1/2/2006	3:14 PM	1800	0.5	19.5									
1/2/2006	3:16 PM				507	0	20.3						

Appendix D - Barbour County Mine Rescue Team Air Quality Measurements

Date	Time	Drift Opening No. 1			Drift Opening No. 2			Drift Opening No. 3			Drift Opening No. 4		
		CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)
1/2/2006	3:35 PM	2136	0.4	19.6									
1/2/2006	3:37 PM				280	0	20.4						
1/2/2006	3:52 PM	1985	0.4	19.9									
1/2/2006	4:02 PM	2251	0.4	20.2									
1/2/2006	4:04 PM				410	0	20.9						
1/2/2006	4:07 PM							120	0	20.9			
1/2/2006	4:09 PM										82	0	20.9
1/2/2006	4:35 PM	2064	0.5	20.1									
1/2/2006	5:19 PM	1626	0.3	19.9									
1/2/2006	5:21 PM				369	0	20.4						
1/2/2006	5:40 PM	1375	0.3	20.2									
1/2/2006	5:42 PM				255	0	20.4						
1/2/2006	5:55 PM	1358	0.3	19.9									
1/2/2006	6:30 PM	1198	0.3	19.9									
1/2/2006	6:35 PM				275	0	20.4						
1/2/2006	7:45 PM				16	0	20.7						
1/2/2006	8:15 PM				17	0	20.5						
1/2/2006	8:50 PM				0	0	20.7						
1/2/2006	9:37 PM				0	0	20.9						
1/2/2006	10:17 PM				0	0	20.9						
1/2/2006	10:58 PM				0	0	20.0						
1/2/2006	11:55 PM				0.6	0	20.9						
1/3/2006	12:30 AM				0	0	20.9						
1/3/2006	1:00 AM				0	0	20.9						
1/3/2006	1:30 AM				0	0	20.9						
1/3/2006	2:00 AM				0	0	21.1						

Appendix D - Barbour County Mine Rescue Team Air Quality Measurements

Date	Time	Drift Opening No. 1			Drift Opening No. 2			Drift Opening No. 3			Drift Opening No. 4		
		CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)	CO (ppm)	Methane (%)	Oxygen (%)
1/3/2006	2:30 AM				0	0	20.9						
1/3/2006	3:00 AM				0	0	20.9						
1/3/2006	3:30 AM				0	0	20.9						
1/3/2006	4:00 AM				0	0	20.9						
1/3/2006	4:26 AM				0	0	20.9						
1/3/2006	4:55 AM				0	0	20.9						
1/3/2006	6:26 AM				0	0	20.9						
1/3/2006	6:55 AM				0	0	20.9						
1/3/2006	7:25 AM				0	0	20.9						
1/3/2006	7:55 AM				0	0	20.9						
1/3/2006	8:25 AM				0	0	20.9						
1/3/2006	8:55 AM				0	0	20.9						
1/3/2006	9:25 AM				0	0	21.1						
1/3/2006	9:55 AM				0	0	20.9						
1/3/2006	10:00 AM	322	0.2	20.7									
1/3/2006	10:32 AM				0	0	20.9						
1/3/2006	10:35 AM	311	0.2	20.6									
1/3/2006	10:54 AM				0	0	20.9						
1/3/2006	10:55 AM										0	0	20.9

Note: Team continued to take handheld measurements throughout rescue effort.

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/2/2006 14:45		19.26		0.29	2600	0.28			0	
1/2/2006 15:00		19.71		0.27	2570	0.27			0	
1/2/2006 15:10		20.26		0.27	2340	0.29			0	
1/2/2006 15:30		19.68		0.25	2130	0.24			0	
1/2/2006 15:45		19.91		0.24	1970	0.23			0	
1/2/2006 16:00		19.15		0.22	1870	0.23			0	
1/2/2006 16:30		20.41		0.22	1750	0.22			0	
1/2/2006 17:15		19.84		0.22	1740	0.22			10	
1/2/2006 17:45		20.46		0.20	1510	0.20			10	
1/2/2006 17:55		20.43		0.19	1420	0.18			10	
1/2/2006 18:30		20.46		0.18	1290	0.17			10	
1/2/2006 19:20		20.26		0.18	1130	0.16			10	
1/2/2006 19:20	755	20.44	78.15	0.14	1101	0.15	12	0	6	0.93
1/2/2006 19:55		20.12		0.18	1060	0.15			10	
1/2/2006 20:00	890	20.48	78.10	0.14	1025	0.15	21	32	6	0.93
1/2/2006 20:30		20.06		0.17	1000	0.14			10	
1/2/2006 21:00	893	20.49	78.10	0.14	940	0.14	22	31	11	0.93
1/2/2006 21:00		20.46		0.17	960	0.14			10	
1/2/2006 21:30		20.52		0.18	950	0.13			10	
1/2/2006 22:00	567	20.51	78.09	0.17	893	0.15	26	28	28	0.93
1/2/2006 22:00		20.36		0.17	920	0.13			10	
1/2/2006 22:30		20.42		0.17	900	0.13			10	
1/2/2006 23:00	792	20.52	78.10	0.15	845	0.13	19	30	16	0.93
1/2/2006 23:30	752	20.54	78.10	0.14	806	0.13	6	21	4	0.93
1/3/2006 0:00	671	20.60	78.06	0.14	779	0.12	8	25	0	0.93
1/3/2006 0:30	599	20.55	78.12	0.14	751	0.12	15	19	0	0.93
1/3/2006 1:00	657	20.57	78.11	0.13	725	0.12	5	14	0	0.93
1/3/2006 1:30	726	20.57	78.10	0.13	699	0.12	10	21	0	0.93
1/3/2006 2:00	639	20.56	78.13	0.13	654	0.11	10	21	0	0.93

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/3/2006 2:30	632	20.64	78.06	0.13	635	0.11	8	16	4	0.93
1/3/2006 3:00	632	20.61	78.10	0.13	604	0.11	4	18	0	0.93
1/3/2006 3:30	359	20.61	78.14	0.12	570	0.10	0	0	0	0.93
1/3/2006 4:00	491	20.60	78.14	0.12	550	0.09	4	0	0	0.93
1/3/2006 4:30	435	20.61	78.14	0.12	531	0.10	0	0	0	0.93
1/3/2006 5:00	543	20.65	78.10	0.12	507	0.10	0	0	0	0.93
1/3/2006 5:30	410	20.65	78.13	0.12	478	0.09	0	0	0	0.93
1/3/2006 6:00	374	20.67	78.12	0.11	445	0.09	0	0	0	0.93
1/3/2006 6:30	379	20.71	78.08	0.11	432	0.08	0	0	0	0.93
1/3/2006 7:00	358	20.68	78.11	0.11	414	0.09	0	11	0	0.93
1/3/2006 7:30	404	20.68	78.11	0.11	389	0.08	0	0	0	0.93
1/3/2006 8:00	301	20.71	78.18	0.11	375	0.08	9	10	0	0.93
1/3/2006 8:30	363	20.71	78.10	0.11	355	0.08	0	0	0	0.93
1/3/2006 9:00	267	20.71	78.11	0.11	340	0.08	0	0	0	0.93
1/3/2006 9:30	250	20.71	78.11	0.11	334	0.08	7	0	0	0.93
1/3/2006 10:00	230	20.70	78.13	0.11	314	0.08	0	8	0	0.93
1/3/2006 10:30	207	20.73	78.11	0.10	295	0.07	6	8	5	0.93
1/3/2006 11:00	205	20.72	78.11	0.10	282	0.07	0	0	0	0.93
1/3/2006 11:30	184	20.78	78.06	0.11	271	0.07	0	8	0	0.93
1/3/2006 12:00	170	20.80	78.13	0.10	216	0.07	0	0	0	0.93
1/3/2006 12:30	190	20.79	78.07	0.10	213	0.07	0	0	0	0.93
1/3/2006 13:00	188	20.79	78.06	0.11	263	0.07	0	0	0	0.93
1/3/2006 13:30	164	20.81	78.12	0.10	212	0.07	0	0	0	0.93
1/3/2006 14:30	115	20.82	78.07	0.09	167	0.06	0	4	0	0.93
1/3/2006 15:00	99	20.81	78.06	0.09	170	0.06	4	5	0	0.93
1/3/2006 15:30	83	20.83	78.07	0.09	164	0.06	0	0	0	0.93
1/3/2006 16:30	70	20.84	78.06	0.09	148	0.06	0	0	0	0.93
1/3/2006 17:00	61	20.83	78.07	0.09	141	0.06	0	0	0	0.93
1/3/2006 17:30	56	20.85	78.06	0.09	136	0.06	0	0	0	0.93
1/3/2006 18:30	55	20.85	78.06	0.09	119	0.05	0	0	0	0.93
1/3/2006 19:00	52	20.86	78.06	0.08	119	0.06	0	0	0	0.93
1/3/2006 19:30	50	20.88	78.03	0.09	118	0.05	0	0	0	0.93
1/3/2006 20:00	50	20.86	78.06	0.08	107	0.05	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/3/2006 20:30	45	20.86	78.06	0.08	102	0.05	0	0	0	0.93
1/3/2006 21:00	42	20.86	78.06	0.08	128	0.05	0	0	0	0.93
1/3/2006 21:30	40	20.87	78.06	0.08	120	0.05	0	0	0	0.93
1/3/2006 22:00	41	20.86	78.05	0.08	109	0.06	0	0	0	0.93
1/3/2006 23:00	33	20.87	78.06	0.08	97	0.05	0	0	0	0.93
1/3/2006 23:30	31	20.87	78.06	0.08	95	0.05	0	0	0	0.93
1/4/2006 0:01	30	20.87	78.06	0.08	95	0.05	0	0	0	0.93
1/4/2006 1:15	29	20.86	78.07	0.08	80	0.05	0	0	0	0.93
1/4/2006 1:30	27	20.87	78.06	0.08	76	0.05	0	0	0	0.93
1/4/2006 2:00	26	20.86	78.07	0.08	72	0.05	0	0	0	0.93
1/4/2006 2:30	26	20.81	77.84	0.08	69	0.03	0	0	0	0.93
1/4/2006 3:00	24	20.86	78.07	0.08	66	0.05	0	0	0	0.93
1/4/2006 3:30	24	20.87	78.07	0.08	61	0.05	0	0	0	0.93
1/4/2006 4:00	23	20.87	78.07	0.08	58	0.05	0	0	0	0.93
1/4/2006 4:30	22	20.86	78.07	0.08	54	0.05	0	0	0	0.93
1/4/2006 5:00	21	20.87	78.07	0.08	51	0.05	0	0	0	0.93
1/4/2006 5:30	20	20.83	77.91	0.08	49	0.05	0	0	0	0.93
1/4/2006 6:00	20	20.82	77.89	0.08	49	0.05	0	0	0	0.93
1/4/2006 6:30	20	20.87	78.07	0.08	46	0.05	0	0	0	0.93
1/4/2006 7:00	19	20.87	78.07	0.08	43	0.05	0	0	0	0.93
1/4/2006 7:30	17	20.87	78.07	0.08	43	0.05	0	0	0	0.93
1/4/2006 8:00	18	20.87	78.07	0.08	39	0.05	0	0	0	0.93
1/4/2006 9:00	15	20.87	78.07	0.08	31	0.05	0	0	0	0.93
1/4/2006 10:00	15	20.85	78.08	0.08	26	0.05	0	0	0	0.93
1/4/2006 11:00	23	20.85	78.09	0.08	30	0.05	0	0	0	0.93
1/4/2006 12:00	24	20.83	78.10	0.09	27	0.05	0	0	0	0.93
1/4/2006 13:00	19	20.82	78.10	0.09	24	0.05	0	0	0	0.93
1/4/2006 14:00	18	20.82	78.11	0.09	24	0.05	0	0	0	0.93
1/4/2006 15:00	18	20.83	78.10	0.09	25	0.05	0	0	0	0.93
1/4/2006 16:00	17	20.81	78.13	0.09	22	0.05	0	0	0	0.93
1/4/2006 18:00	15	20.84	78.09	0.09	20	0.04	0	0	0	0.93
1/4/2006 20:00	14	20.85	78.08	0.09	18	0.05	0	0	0	0.93
1/4/2006 22:00	12	20.85	78.08	0.09	15	0.05	0	0	0	0.93
1/5/2006 0:00	10	20.84	78.10	0.09	13	0.04	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/5/2006 2:00	9	20.84	78.10	0.09	10	0.04	0	0	0	0.93
1/5/2006 4:00	8	20.85	78.09	0.08	10	0.04	0	0	0	0.93
1/5/2006 6:00	7	20.84	78.10	0.08	9	0.04	0	0	0	0.93
1/5/2006 8:00	7	20.85	78.09	0.08	8	0.04	0	0	0	0.93
1/5/2006 10:00	6	20.85	78.09	0.09	7	0.04	0	0	0	0.93
1/5/2006 12:00	6	20.85	78.09	0.09	6	0.04	0	0	0	0.93
1/5/2006 14:00	5	20.85	78.09	0.08	6	0.04	0	0	0	0.93
1/5/2006 16:00	5	20.85	78.10	0.08	5	0.04	0	0	0	0.93
1/5/2006 18:00	4	20.85	78.10	0.08	4	0.04	0	0	0	0.93
1/5/2006 20:00	3	20.85	78.10	0.08	4	0.04	0	0	0	0.93
1/5/2006 22:00	4	20.85	78.09	0.08	3	0.05	0	0	0	0.93
1/6/2006 0:00	3	20.85	78.10	0.08	4	0.04	0	0	0	0.93
1/6/2006 2:00	3	20.83	78.11	0.09	3	0.04	0	0	0	0.93
1/6/2006 4:00	3	20.85	78.09	0.09	3	0.04	0	0	0	0.93
1/6/2006 6:00	3	20.85	78.10	0.08	2	0.04	0	0	0	0.93
1/6/2006 8:00	2	20.86	78.09	0.08	2	0.04	0	0	0	0.93
1/6/2006 10:00	2	20.86	78.09	0.08	2	0.04	0	0	0	0.93
1/6/2006 12:00	2	20.86	78.08	0.08	2	0.04	0	0	0	0.93
1/6/2006 13:30	1	20.86	78.09	0.08	2	0.04	0	0	0	0.93
1/6/2006 15:30	1	20.85	78.02	0.08	1	0.04	0	0	0	0.93
1/6/2006 17:30	1	20.87	78.08	0.07	1	0.04	0	0	0	0.93
1/6/2006 19:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/7/2006 10:00	1	20.85	78.10	0.08	1	0.04	0	0	0	0.93
1/7/2006 10:30	1	20.87	78.09	0.08	1	0.04	0	0	0	0.93
1/7/2006 11:30	1	20.87	78.09	0.07	1	0.04	0	0	0	0.93
1/7/2006 12:30	1	20.86	78.10	0.07	1	0.04	0	0	0	0.93
1/7/2006 13:30	1	20.87	78.11	0.05	1	0.04	0	0	0	0.93
1/7/2006 14:30	1	20.85	78.10	0.08	1	0.04	0	0	0	0.93
1/7/2006 15:30	1	20.85	78.09	0.08	1	0.04	0	0	0	0.93
1/7/2006 17:30	1	20.85	78.10	0.08	1	0.04	0	0	0	0.93
1/7/2006 19:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/7/2006 21:30	1	20.85	78.10	0.08	1	0.04	0	0	0	0.93
1/7/2006 23:30	1	20.82	78.00	0.08	1	0.05	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/8/2006 1:30	1	20.85	78.10	0.08	1	0.04	0	0	0	0.93
1/8/2006 7:00	1	20.83	78.00	0.13	1	0.04	0	0	0	0.93
1/8/2006 9:00	1	20.86	78.10	0.08	1	0.04	0	0	0	0.93
1/8/2006 12:00	1	20.84	78.11	0.08	1	0.05	0	0	0	0.93
1/8/2006 14:30	1	20.74	77.74	0.08	1	0.04	0	0	0	0.93
1/8/2006 15:30	1	20.84	78.10	0.09	1	0.04	0	0	0	0.93
1/8/2006 17:30	1	20.85	78.09	0.09	1	0.04	0	0	0	0.93
1/8/2006 19:30	1	20.84	78.05	0.13	1	0.04	0	0	0	0.93
1/8/2006 21:50	1	20.85	78.08	0.10	0	0.04	0	0	0	0.93
1/9/2006 2:30	1	20.75	77.80	0.17	1	0.04	0	0	0	0.93
1/9/2006 4:30	0	20.69	77.60	0.16	0	0.03	0	0	0	0.93
1/9/2006 6:30	0	20.82	78.08	0.13	1	0.04	0	0	4	0.93
1/9/2006 8:30	1	20.85	78.09	0.09	0	0.04	0	0	0	0.93
1/9/2006 10:30	1	20.89	78.07	0.08	1	0.04	0	0	0	0.93
1/9/2006 12:30	1	20.88	78.08	0.08	2	0.03	0	0	0	0.93
1/9/2006 14:30	1	20.87	78.08	0.08	1	0.03	0	0	0	0.93
1/9/2006 16:30	1	20.88	78.08	0.08	1	0.03	0	0	0	0.93
1/9/2006 18:30	1	20.88	78.08	0.07	NDA	0.03	0	0	0	0.93
1/9/2006 20:30	NDA	20.88	78.07	0.09	1	0.04	0	0	0	0.93
1/9/2006 22:30	1	20.89	78.07	0.07	1	0.03	0	0	0	0.93
1/10/2006 2:30	0	20.83	77.89	0.07	2	0.04	0	0	0	0.93
1/10/2006 4:30	1	20.87	78.11	0.07	2	0.02	0	0	0	0.93
1/10/2006 6:30	0	20.85	78.04	0.14	2	0.04	0	0	0	0.93
1/10/2006 9:15	1	20.84	78.12	0.06	1	0.04	0	0	0	0.93
1/10/2006 11:15	1	20.87	78.09	0.07	1	0.04	0	0	0	0.93
1/10/2006 13:15	1	20.84	78.12	0.07	1	0.04	0	0	0	0.93
1/10/2006 15:15	1	20.85	78.11	0.07	1	0.04	0	0	0	0.93
1/10/2006 17:15	NDA	20.86	78.10	0.07	1	0.04	0	0	0	0.93
1/10/2006 19:15	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/10/2006 21:15	1	20.85	78.06	0.07	1	0.09	0	0	0	0.93
1/10/2006 23:30	1	20.83	78.12	0.08	1	0.04	0	0	0	0.93
1/11/2006 4:30	1	20.84	78.11	0.08	1	0.04	0	0	0	0.93
1/11/2006 6:30	0	20.84	78.10	0.08	1	0.04	0	0	0	0.93
1/11/2006 8:30	1	20.84	78.11	0.08	1	0.04	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

No. 1 Drift Opening

ICG, Inc. Sago Mine 46-08791 No. 1 Drift Opening Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/11/2006 10:30	0	20.90	78.05	0.07	1	0.04	0	0	0	0.93
1/11/2006 12:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/11/2006 14:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/11/2006 16:30	1	20.86	78.09	0.08	0	0.04	0	0	0	0.93
1/11/2006 18:30	1	20.88	78.08	0.07	1	0.04	0	0	0	0.93
1/11/2006 20:30	1	20.87	78.08	0.08	0	0.04	0	0	0	0.93
1/11/2006 22:30	2	20.86	78.09	0.07	1	0.04	0	0	0	0.93
1/12/2006 2:15	1	20.86	78.10	0.06	1	0.04	0	0	0	0.93
1/12/2006 9:30	1	20.86	78.10	0.07	1	0.04	0	0	0	0.93
1/12/2006 11:30	1	20.86	78.14	0.07	2	0.05	0	0	0	0.93
1/12/2006 13:30	1	20.85	78.10	0.07	0	0.05	0	0	0	0.93
1/12/2006 15:30	1	20.86	78.09	0.07	1	0.04	0	0	0	0.93
1/12/2006 17:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/12/2006 19:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/12/2006 21:30	1	20.86	78.09	0.07	0	0.04	0	0	0	0.93
1/12/2006 23:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/13/2006 5:30	0	20.84	78.09	0.09	1	0.05	0	0	0	0.93
1/13/2006 9:30	1	20.86	78.08	0.08	1	0.05	0	0	0	0.93
1/13/2006 11:30	0	20.85	78.10	0.08	1	0.05	0	0	0	0.93
1/13/2006 13:30	0	20.85	78.09	0.08	0	0.04	0	0	0	0.93
1/13/2006 15:30	1	20.86	78.08	0.09	1	0.04	0	0	0	0.93
1/13/2006 17:30	0	20.87	78.08	0.09	1	0.04	0	0	0	0.93
1/13/2006 21:30	0	20.85	78.08	0.09	0	0.05	0	0	0	0.93
1/13/2006 23:30	1	20.86	78.09	0.09	0	0.03	0	0	0	0.93
1/14/2006 4:00	0	20.85	78.09	0.09	1	0.04	0	0	0	0.93
1/14/2006 7:40	0	20.80	77.90	0.37	0	0.01	0	0	0	0.93
1/14/2006 8:15	1	20.86	78.08	0.09	0	0.04	0	0	0	0.93
1/14/2006 10:30	1	20.88	78.07	0.08	1	0.04	0	0	0	0.93
1/14/2006 12:30	1	20.89	78.06	0.08	0	0.04	0	0	0	0.93
1/14/2006 14:30	1	20.90	78.05	0.07	1	0.04	0	0	0	0.93
1/14/2006 16:30	1	20.91	78.06	0.07	0	0.03	0	0	0	0.93
1/14/2006 18:30	1	20.91	78.05	0.07	1	0.04	0	0	0	0.93
1/14/2006 20:30	0	20.91	78.05	0.07	0	0.04	0	0	0	0.93
1/15/2006 9:30	1	20.86	78.12	0.07	1	0.03	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

Borehole No. 1

ICG, Inc. Sago Mine 46-08791 Borehole No.1 Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/3/2006 5:53	1045	20.45	78.04	0.23	1052	0.14	16	0	0	0.93
1/3/2006 6:55	963	20.45	78.08	0.21	914	0.14	20	30	7	0.93
1/3/2006 10:45	713	20.66	78.04	0.16	508	0.09	10	14	4	0.93
1/3/2006 11:15	450	20.68	78.04	0.16	491	0.09	9	15	5	0.93
1/3/2006 12:45	377	20.70	78.05	0.15	411	0.08	11	11	4	0.93
1/3/2006 13:15	369	20.72	78.05	0.15	394	0.08	5	0	0	0.93
1/3/2006 14:30	339	20.73	78.05	0.15	341	0.07	11	13	5	0.93
1/3/2006 15:30	279	20.74	78.04	0.16	337	0.07	10	10	5	0.93
1/3/2006 16:33	274	20.73	78.07	0.15	305	0.07	8	0	0	0.93
1/3/2006 17:30	244	20.77	78.03	0.15	289	0.07	0	0	0	0.93
1/3/2006 19:40	334	20.77	78.02	0.15	254	0.06	14	0	0	0.93
1/3/2006 21:30	136	20.80	78.04	0.14	205	0.06	0	0	0	0.93
1/4/2006 8:30	39	20.82	78.02	0.16	125	0.05	8	4	0	0.93
1/4/2006 11:30	55	20.78	78.07	0.15	63	0.05	0	0	0	0.93
1/4/2006 15:30	46	20.79	78.06	0.17	55	0.05	0	0	0	0.93
1/5/2006 8:50	14	20.82	78.04	0.16	17	0.04	0	0	0	0.93
1/5/2006 8:55	14	20.80	78.07	0.15	18	0.04	0	0	0	0.93
1/5/2006 13:10	10	20.83	78.05	0.15	11	0.04	0	0	0	0.93
1/5/2006 13:50	10	20.83	78.05	0.15	11	0.04	0	0	0	0.93
1/5/2006 16:10	8	20.82	78.05	0.15	10	0.04	0	0	0	0.93
1/5/2006 16:15	9	20.79	77.88	0.15	9	0.04	0	0	0	0.93
1/5/2006 19:00	7	20.83	78.04	0.16	8	0.04	0	0	0	0.93
1/5/2006 22:00	6	20.83	78.05	0.15	6	0.04	0	0	0	0.93
1/6/2006 2:00	5	20.82	78.05	0.16	5	0.04	0	0	0	0.93
1/6/2006 5:00	4	20.82	78.05	0.16	4	0.04	0	0	0	0.93
1/6/2006 8:00	3	20.84	78.04	0.15	4	0.04	0	0	0	0.93
1/6/2006 11:00	3	20.84	78.04	0.15	3	0.04	0	0	0	0.93
1/6/2006 14:00	2	20.84	78.04	0.14	2	0.04	0	0	0	0.93
1/6/2006 17:00	2	20.84	78.04	0.15	2	0.04	0	0	0	0.93
1/6/2006 20:00	2	20.84	78.04	0.15	1	0.04	0	0	0	0.93
1/6/2006 23:00	2	20.84	78.05	0.15	2	0.04	0	0	0	0.93
1/7/2006 3:00	2	20.82	78.07	0.15	2	0.04	0	0	0	0.93
1/7/2006 8:00	1	20.84	78.05	0.15	1	0.04	0	0	0	0.93
1/7/2006 11:00	1	20.84	78.04	0.15	1	0.04	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

Borehole No. 1

ICG, Inc. Sago Mine 46-08791 Borehole No.1 Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/7/2006 14:00	2	20.83	78.05	0.15	1	0.04	0	0	0	0.93
1/7/2006 18:00	1	20.83	78.05	0.15	2	0.04	0	0	0	0.93
1/7/2006 22:00	1	20.83	78.04	0.15	1	0.04	0	0	0	0.93
1/8/2006 1:00	1	20.83	78.06	0.14	1	0.04	0	0	0	0.93
1/8/2006 8:30	1	20.84	78.05	0.14	1	0.04	0	0	0	0.93
1/8/2006 11:00	1	20.81	78.04	0.17	1	0.04	0	0	0	0.93
1/9/2006 8:00	1	20.82	78.02	0.18	1	0.04	0	0	0	0.93
1/9/2006 11:00	1	20.85	78.03	0.15	2	0.03	0	0	0	0.93
1/9/2006 14:00	1	20.85	78.04	0.15	2	0.03	0	0	0	0.93
1/9/2006 17:30	1	20.86	78.04	0.14	2	0.03	0	0	0	0.93
1/9/2006 20:30	1	20.86	78.04	0.14	1	0.03	0	0	0	0.93
1/10/2006 4:00	1	20.86	78.06	0.12	1	0.02	0	0	0	0.93
1/10/2006 8:17	1	20.81	78.09	0.12	1	0.04	0	0	0	0.93
1/10/2006 11:00	1	20.85	78.10	0.12	2	0.04	0	0	0	0.93
1/10/2006 14:15	1	20.82	78.08	0.13	1	0.04	0	0	0	0.93
1/10/2006 19:00	1	20.84	78.06	0.13	2	0.04	0	0	0	0.93
1/11/2006 4:00	1	20.82	78.07	0.14	2	0.04	0	0	0	0.93
1/11/2006 13:00	1	20.85	78.04	0.14	1	0.04	0	0	0	0.93
1/11/2006 16:15	1	20.84	78.05	0.14	1	0.04	0	0	0	0.93
1/11/2006 18:35	1	20.85	78.05	0.13	1	0.03	0	0	0	0.93
1/11/2006 20:50	1	20.86	78.08	0.13	1	0.00	0	0	0	0.93
1/11/2006 22:35	1	20.85	78.04	0.14	2	0.04	0	0	0	0.93
1/12/2006 0:35	1	20.82	78.06	0.15	1	0.04	0	0	0	0.93
1/12/2006 2:35	1	20.82	78.06	0.15	2	0.04	0	0	0	0.93
1/12/2006 4:30	1	20.83	78.05	0.16	2	0.04	0	0	0	0.93
1/12/2006 6:30	1	20.83	78.05	0.15	1	0.04	0	0	0	0.93
1/12/2006 8:32	1	20.83	78.05	0.15	1	0.04	0	0	0	0.93
1/12/2006 10:45	1	20.85	78.03	0.15	3	0.04	0	0	0	0.93
1/12/2006 12:29	1	20.81	78.06	0.15	1	0.04	0	0	0	0.93
1/12/2006 14:32	1	20.82	78.05	0.16	3	0.04	0	0	0	0.93
1/12/2006 16:25	1	20.82	78.05	0.16	1	0.04	0	0	0	0.93
1/12/2006 18:20	1	20.83	78.02	0.18	1	0.04	0	0	0	0.93
1/12/2006 20:20	1	20.83	78.03	0.17	1	0.04	0	0	0	0.93
1/12/2006 22:20	1	20.84	78.02	0.17	1	0.04	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

Borehole No. 1

ICG, Inc. Sago Mine 46-08791 Borehole No.1 Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/13/2006 0:35	1	20.81	78.05	0.16	1	0.04	0	0	0	0.93
1/13/2006 2:40	1	20.77	77.90	0.26	1	0.04	0	0	0	0.93
1/13/2006 4:34	1	20.82	78.04	0.16	1	0.05	0	0	0	0.93
1/13/2006 6:40	1	20.82	78.05	0.16	1	0.04	0	0	0	0.93
1/13/2006 8:38	1	20.85	78.01	0.17	1	0.04	0	0	0	0.93
1/13/2006 10:35	1	20.82	78.04	0.18	2	0.04	0	0	0	0.93
1/13/2006 12:32	1	20.79	78.04	0.20	1	0.04	0	0	0	0.93
1/13/2006 14:30	1	20.83	78.02	0.18	1	0.04	0	0	4	0.93
1/13/2006 16:30	1	20.82	78.02	0.19	2	0.04	0	0	0	0.93
1/13/2006 18:30	1	20.83	78.01	0.20	1	0.04	0	0	0	0.93
1/13/2006 20:30	1	20.86	78.09	0.08	1	0.04	0	0	0	0.93
1/13/2006 22:30	0	20.88	78.09	0.06	4	0.04	0	0	0	0.93
1/14/2006 0:30	0	20.85	78.12	0.05	0	0.04	0	0	0	0.93
1/14/2006 2:30	0	20.86	78.11	0.06	0	0.04	0	0	0	0.93
1/14/2006 4:30	0	20.86	78.11	0.06	1	0.04	0	0	0	0.93
1/14/2006 6:30	1	20.82	78.03	0.18	1	0.04	0	0	0	0.93
1/14/2006 8:30	1	20.82	78.02	0.19	1	0.04	0	0	0	0.93
1/14/2006 10:27	1	20.85	78.02	0.16	1	0.04	0	0	0	0.93
1/14/2006 12:31	1	20.87	77.99	0.17	2	0.04	0	0	0	0.93
1/14/2006 14:37	1	20.87	78.00	0.19	1	0.04	0	0	0	0.93
1/14/2006 16:29	1	20.88	77.98	0.17	1	0.04	0	0	0	0.93
1/14/2006 18:35	0	20.93	78.07	0.04	0	0.04	0	0	0	0.93
1/14/2006 20:28	0	20.93	78.07	0.03	0	0.04	0	0	0	0.93
1/14/2006 22:28	0	20.91	78.07	0.05	0	0.04	0	0	0	0.93
1/15/2006 0:31	1	20.95	78.04	0.04	0	0.04	0	0	0	0.93
1/15/2006 2:33	0	20.88	78.02	0.14	1	0.04	0	0	0	0.93
1/15/2006 4:37	1	20.91	78.09	0.04	0	0.04	0	0	0	0.93
1/15/2006 6:34	1	20.87	77.96	0.20	0	0.04	0	0	0	0.93
1/15/2006 8:31	1	20.88	78.00	0.15	1	0.04	0	0	0	0.93
1/15/2006 10:34	1	20.83	78.05	0.15	1	0.04	0	0	0	0.93
1/15/2006 12:33	1	20.84	78.03	0.16	1	0.04	0	0	0	0.93
1/15/2006 14:49	1	20.85	78.06	0.16	1	0.04	0	0	0	0.93
1/15/2006 16:34	1	20.84	78.03	0.16	1	0.04	0	0	0	0.93
1/15/2006 18:40	0	20.88	78.08	0.07	1	0.04	0	0	0	0.93

Appendix E - Gas Chromatograph Analysis Results

Borehole No. 1

ICG, Inc. Sago Mine 46-08791 Borehole No.1 Date and Time	GAS CONCENTRATIONS									
	H2	O2	N2	CH4	CO	CO2	C2H2	C2H4	C2H6	Ar
	ppm	%	%	%	ppm	%	ppm	ppm	ppm	%
1/15/2006 20:33	1	20.90	78.09	0.05	0	0.04	0	0	0	0.93
1/15/2006 22:37	1	20.87	78.08	0.08	1	0.04	0	0	0	0.93
1/16/2006 0:40	0	20.88	78.09	0.05	1	0.04	0	0	0	0.93
1/16/2006 2:42	0	20.86	78.08	0.09	1	0.04	0	0	0	0.93
1/16/2006 4:35	1	20.77	77.94	0.31	1	0.04	0	0	4	0.93
1/16/2006 6:40	1	20.82	78.03	0.16	1	0.04	0	0	0	0.93
1/16/2006 8:42	1	20.83	78.03	0.17	1	0.04	0	0	0	0.93
1/16/2006 10:38	1	20.83	78.01	0.18	2	0.04	0	0	4	0.93
1/16/2006 12:40	1	20.81	78.05	0.17	2	0.04	0	0	3	0.93
1/16/2006 14:31	1	20.82	78.05	0.17	1	0.04	0	0	0	0.93
1/16/2006 16:40	1	20.81	78.04	0.17	1	0.04	0	0	0	0.93
1/16/2006 18:30	1	20.82	78.04	0.17	1	0.04	0	0	0	0.93
1/16/2006 20:30	1	20.83	78.04	0.16	1	0.04	0	0	0	0.93
1/16/2006 22:28	1	20.79	77.96	0.28	1	0.04	0	0	4	0.93
1/17/2006 0:35	1	20.81	78.04	0.18	1	0.04	0	0	0	0.93
1/17/2006 2:33	1	20.80	78.05	0.18	1	0.04	0	0	0	0.93
1/17/2006 4:39	1	20.78	78.02	0.23	2	0.04	0	0	0	0.93
1/17/2006 6:35	2	20.80	78.05	0.17	1	0.04	0	0	0	0.93
1/17/2006 8:40	1	20.84	78.01	0.18	1	0.04	0	0	0	0.93
1/17/2006 10:45	1	20.85	78.00	0.18	1	0.04	0	0	0	0.93
1/17/2006 12:40	2	20.84	78.00	0.19	1	0.04	0	0	0	0.93
1/17/2006 14:40	1	20.84	78.00	0.20	2	0.04	0	0	0	0.93
1/17/2006 16:35	1	20.84	77.99	0.19	1	0.04	0	0	0	0.93
1/17/2006 18:40	1	20.84	77.99	0.19	1	0.04	0	0	0	0.93
1/17/2006 20:37	1	20.84	78.00	0.19	1	0.04	0	0	0	0.93
1/17/2006 22:23	1	20.83	78.00	0.19	1	0.04	0	0	0	0.93
1/18/2006 0:35	1	20.82	78.01	0.19	1	0.04	0	0	0	0.93
1/18/2006 2:35	1	20.82	78.01	0.20	1	0.04	0	0	0	0.93
1/18/2006 4:35	1	20.83	78.01	0.18	1	0.04	0	0	0	0.93
1/18/2006 6:35	1	20.84	77.99	0.19	1	0.04	0	0	0	0.93
1/18/2006 8:42	1	20.83	78.01	0.19	1	0.04	0	0	0	0.93
1/18/2006 10:26	1	20.82	78.01	0.20	0	0.04	0	0	0	0.93
1/18/2006 12:25	1	20.82	78.03	0.18	1	0.04	0	0	0	0.93

Appendix F - Accident Investigation Data - Victim Information

Accident Investigation Data - Victim Information

U.S. Department of Labor

Mine Safety and Health Administration



Event Number: **4 1 3 4 4 1 4**

Victim Information: 1

1. Name of Injured/III Employee: <i>Terry Helms</i>		2. Sex <i>M</i>	3. Victim's Age <i>50</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>195 Preshifter</i>			9. Work Activity when Injured: <i>092 walking</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No										
11. Experience a. This Work Activity: <i>11 0 0</i>	Years <i>11</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>0 26 0</i>	Years <i>0</i>	Weeks <i>26</i>	Days <i>0</i>	c. This Mine: <i>0 26 0</i>	Years <i>0</i>	Weeks <i>26</i>	Days <i>0</i>	d. Total Mining: <i>29 0 0</i>	Years <i>29</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide gas from an explosion</i>				13. Nature of Injury or Illness: <i>110 carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 2

1. Name of Injured/III Employee: <i>Jackie L. Weaver</i>		2. Sex <i>M</i>	3. Victim's Age <i>51</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/03/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>002 Electrician</i>			9. Work Activity when Injured: <i>076 traveling to work assignment</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No										
11. Experience a. This Work Activity: <i>26 0 0</i>	Years <i>26</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>26 0 0</i>	Years <i>2</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>2 0 0</i>	Years <i>2</i>	Weeks <i>0</i>	Days <i>0</i>	d. Total Mining: <i>26 0 0</i>	Years <i>26</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 3

1. Name of Injured/III Employee: <i>James A. Bennett</i>		2. Sex <i>M</i>	3. Victim's Age <i>61</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>050 Shuttle Car Operator</i>			9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No										
11. Experience a. This Work Activity: <i>23 0 0</i>	Years <i>23</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>23 0 0</i>	Years <i>0</i>	Weeks <i>20</i>	Days <i>0</i>	c. This Mine: <i>0 20 0</i>	Years <i>0</i>	Weeks <i>20</i>	Days <i>0</i>	d. Total Mining: <i>25 0 0</i>	Years <i>25</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>100 carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Appendix F - Accident Investigation Data - Victim Information

Accident Investigation Data - Victim Information

U.S. Department of Labor

Mine Safety and Health Administration



Event Number:

4	1	3	4	4	1	4
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Victim Information: 4

1. Name of Injured/III Employee: <i>Alva M. Bennett</i>		2. Sex <i>M</i>	3. Victim's Age <i>51</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>			7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>												
8. Regular Job Title: <i>036 Continuous Miner Operator</i>		9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <table style="width: 100%;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>		Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity: <i>25 0 0</i>	Years <i>25</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>25 0 0</i>	Years <i>25</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>2 26 0</i>	Years <i>2</i>	Weeks <i>26</i>	Days <i>0</i>	d. Total Mining: <i>29 0 0</i>	Years <i>29</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 5

1. Name of Injured/III Employee: <i>Thomas p. Anderson</i>		2. Sex <i>M</i>	3. Victim's Age <i>39</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>			7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>												
8. Regular Job Title: <i>050 Shuttle Car Operator</i>		9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <table style="width: 100%;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>		Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity: <i>2 0 0</i>	Years <i>2</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>2 0 0</i>	Years <i>2</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>0 16 0</i>	Years <i>0</i>	Weeks <i>16</i>	Days <i>0</i>	d. Total Mining: <i>10 0 0</i>	Years <i>10</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 6

1. Name of Injured/III Employee: <i>Martin Toler Jr.</i>		2. Sex <i>M</i>	3. Victim's Age <i>51</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>			7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>												
8. Regular Job Title: <i>049 Forman</i>		9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <table style="width: 100%;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>		Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity: <i>25 0 0</i>	Years <i>25</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>25 0 0</i>	Years <i>25</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>0 14 0</i>	Years <i>0</i>	Weeks <i>14</i>	Days <i>0</i>	d. Total Mining: <i>32 0 0</i>	Years <i>32</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Appendix F - Accident Investigation Data - Victim Information

U.S. Department of Labor

Mine Safety and Health Administration



Accident Investigation Data - Victim Information

Event Number: **4 1 3 4 4 1 4**

Victim Information: 7

1. Name of Injured/III Employee: <i>Fred G. Ware</i>		2. Sex <i>M</i>	3. Victim's Age <i>58</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>036 Continuous Miner Operator</i>			9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> X <input type="checkbox"/> No										
11. Experience a. This Work Activity: <i>15 0 0</i>	Years <i>15</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>15 0 0</i>	Years <i>15</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>1 36 0</i>	Years <i>1</i>	Weeks <i>36</i>	Days <i>0</i>	d. Total Mining: <i>37 0 0</i>	Years <i>37</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 8

1. Name of Injured/III Employee: <i>Jesse L. Jones</i>		2. Sex <i>M</i>	3. Victim's Age <i>44</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>046 Roof bolter operator</i>			9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> X <input type="checkbox"/> No										
11. Experience a. This Work Activity: <i>14 0 0</i>	Years <i>14</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>14 0 0</i>	Years <i>14</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>0 36 0</i>	Years <i>0</i>	Weeks <i>36</i>	Days <i>0</i>	d. Total Mining: <i>16 0 0</i>	Years <i>16</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information: 9

1. Name of Injured/III Employee: <i>Marshall Winans</i>		2. Sex <i>M</i>	3. Victim's Age <i>50</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>01 Fatal</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>028 Scoop Operator</i>			9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> X <input type="checkbox"/> No										
11. Experience a. This Work Activity: <i>5 0 0</i>	Years <i>5</i>	Weeks <i>0</i>	Days <i>0</i>	b. Regular Job Title: <i>5 0 0</i>	Years <i>5</i>	Weeks <i>0</i>	Days <i>0</i>	c. This Mine: <i>1 8 0</i>	Years <i>1</i>	Weeks <i>8</i>	Days <i>0</i>	d. Total Mining: <i>23 0 0</i>	Years <i>23</i>	Weeks <i>0</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Appendix F - Accident Investigation Data - Victim Information

Accident Investigation Data - Victim Information

U.S. Department of Labor

Mine Safety and Health Administration



Event Number:

4	1	3	4	4	1	4
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Victim Information: 10

1. Name of Injured/III Employee: <i>David W. Lewis</i>		2. Sex <i>M</i>	3. Victim's Age <i>28</i>		4. Last Four Digits of SSN:		5. Degree of Injury: <i>01 Fatal</i>												
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>					7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>														
8. Regular Job Title: <i>047 Roof Bolter Operator</i>				9. Work Activity when Injured: <i>076 Traveling to work assingment</i>			10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>				Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>					
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>																
11. Experience a. This		Years	Weeks	Days	b. Regular Job Title:		Years	Weeks	Days	c. This Mine:		Years	Weeks	Days	d. Total Mining:		Years	Weeks	Days
Work Activity:		<i>1</i>	<i>0</i>	<i>0</i>	<i>1</i>		<i>0</i>	<i>0</i>	<i>0</i>	<i>1</i>		<i>32</i>	<i>0</i>	<i>1</i>		<i>32</i>	<i>0</i>		
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>										13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>									
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:																			
15. Company of Employment: (If different from production operator) <i>Operator</i>										Independent Contractor ID: (if applicable)									
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:																			
17. Part 50 Document Control Number: (form 7000-1)										18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>									

Victim Information: 11

1. Name of Injured/III Employee: <i>Jerry L. Groves</i>		2. Sex <i>M</i>	3. Victim's Age <i>56</i>		4. Last Four Digits of SSN:		5. Degree of Injury: <i>01 Fatal</i>												
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>					7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>														
8. Regular Job Title: <i>047 Roof Bolter Operator</i>				9. Work Activity when Injured: <i>076 Traveling to work assignment</i>			10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>				Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>					
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>																
11. Experience: a. This		Years	Weeks	Days	b. Regular Job Title:		Years	Weeks	Days	c. This Mine:		Years	Weeks	Days	d. Total Mining:		Years	Weeks	Days
Work Activity:		<i>20</i>	<i>0</i>	<i>0</i>	<i>20</i>		<i>0</i>	<i>0</i>	<i>0</i>	<i>1</i>		<i>0</i>	<i>0</i>	<i>28</i>		<i>0</i>	<i>0</i>		
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>										13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>									
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:																			
15. Company of Employment: (If different from production operator) <i>Operator</i>										Independent Contractor ID: (if applicable)									
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:																			
17. Part 50 Document Control Number: (form 7000-1)										18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>									

Victim Information: 12

1. Name of Injured/III Employee: <i>George J. Hamner</i>		2. Sex <i>M</i>	3. Victim's Age <i>54</i>		4. Last Four Digits of SSN:		5. Degree of Injury: <i>01 Fatal</i>												
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death: <i>a. Date: 01/02/2006 b. Time: 17:00</i>					7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>														
8. Regular Job Title: <i>050 Shuttle Car Operator</i>				9. Work Activity when Injured: <i>076 Traveling to work assignment</i>			10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>				Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>					
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>																
11. Experience: a. This		Years	Weeks	Days	b. Regular Job Title:		Years	Weeks	Days	c. This Mine:		Years	Weeks	Days	d. Total Mining:		Years	Weeks	Days
Work Activity:		<i>13</i>	<i>0</i>	<i>0</i>	<i>13</i>		<i>0</i>	<i>0</i>	<i>0</i>	<i>1</i>		<i>26</i>	<i>0</i>	<i>26</i>		<i>0</i>	<i>0</i>		
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>										13. Nature of Injury or Illness: <i>110 Carbon monoxide intoxication</i>									
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:																			
15. Company of Employment: (If different from production operator) <i>Operator</i>										Independent Contractor ID: (if applicable)									
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:																			
17. Part 50 Document Control Number: (form 7000-1)										18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>									

Appendix F - Accident Investigation Data - Victim Information

U.S. Department of Labor

Mine Safety and Health Administration



Accident Investigation Data - Victim Information

Event Number:

4	1	3	4	4	1	4
---	---	---	---	---	---	---

Victim Information: **13**

1. Name of Injured/III Employee: <i>Randal McCloy</i>		2. Sex <i>M</i>	3. Victim's Age <i>26</i>	4. Last Four Digits of SSN:	5. Degree of Injury: <i>02 Permanent total or partial disability</i>										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death:				7. Date and Time Started: <i>a. Date: 01/02/2006 b. Time: 6:00</i>											
8. Regular Job Title: <i>046 Roof Bolter Operator</i>			9. Work Activity when Injured: <i>076 Traveling to work assignment</i>		10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input checked="" type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>	Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input checked="" type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity: <i>0 24 0</i>	Years <i>0</i>	Weeks <i>24</i>	Days <i>0</i>	b. Regular Job Title: <i>0 24 0</i>	Years <i>0</i>	Weeks <i>24</i>	Days <i>0</i>	c. This Mine: <i>1 16 0</i>	Years <i>1</i>	Weeks <i>16</i>	Days <i>0</i>	d. Total Mining: <i>4 12 0</i>	Years <i>4</i>	Weeks <i>12</i>	Days <i>0</i>
12. What Directly Inflicted Injury or Illness? <i>023 Carbon monoxide from explosion</i>				13. Nature of Injury or Illness: <i>110 Carbon monoxide poisoning</i>											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment:(If different from production operator) <i>Operator</i>			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: <input checked="" type="checkbox"/> First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim: <i>9999 None (No Union Affiliation)</i>												

Victim Information:

1. Name of Injured/III Employee:		2. Sex	3. Victim's Age	4. Last Four Digits of SSN:	5. Degree of Injury:										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death:				7. Date and Time Started:											
8. Regular Job Title:			9. Work Activity when Injured:		10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity:	Years	Weeks	Days	b. Regular Job Title:	Years	Weeks	Days	c. This Mine:	Years	Weeks	Days	d. Total Mining:	Years	Weeks	Days
12. What Directly Inflicted Injury or Illness?				13. Nature of Injury or Illness:											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment: (If different from production operator)			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim:												

Victim Information:

1. Name of Injured/III Employee:		2. Sex	3. Victim's Age	4. Last Four Digits of SSN:	5. Degree of Injury:										
6. Date(MM/DD/YY) and Time(24 Hr.) Of Death:				7. Date and Time Started:											
8. Regular Job Title:			9. Work Activity when Injured:		10. Was this work activity part of regular job? <table border="1" style="display: inline-table; border-collapse: collapse;"><tr><td>Yes</td><td><input type="checkbox"/></td><td>No</td><td><input type="checkbox"/></td></tr></table>	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>						
Yes	<input type="checkbox"/>	No	<input type="checkbox"/>												
11. Experience a. This Work Activity:	Years	Weeks	Days	b. Regular Job Title:	Years	Weeks	Days	c. This Mine:	Years	Weeks	Days	d. Total Mining:	Years	Weeks	Days
12. What Directly Inflicted Injury or Illness?				13. Nature of Injury or Illness:											
14. Training Deficiencies: Hazard: New/Newly-Employed Experienced Miner: Annual: Task:															
15. Company of Employment:(If different from production operator)			Independent Contractor ID: (if applicable)												
16. On-site Emergency Medical Treatment: Not Applicable: First-Aid: CPR: EMT: Medical Professional: None:															
17. Part 50 Document Control Number: (form 7000-1)			18. Union Affiliation of Victim:												

Appendix G - Lists of Individuals Who Assisted with the Investigation

International Coal Group, Inc.

Samuel R. Kitts	Senior VP of Operations WV & Maryland Region
John B. Stemple	Assistant Director of Safety and Employee Development
Charles C. Dunbar	General Manager, Buckhannon Division
Timothy A. Martin	Corporate Director of Health and Safety

Wolf Run Mining Company

Carl L. Crumrine	Richard Bragg
Jeffery Toler	Joseph Ryan
Burlin Wright	Joseph Myers
Bradley L. Hamrick	Ron Helmic
James A. Schoonover	William Saltis
Roger D. Hendrick	Ralph Tanner
Vaughn Miller	John Travise Jr.
Kermitt Melvin	Philip R. Clevenger
Gary D. Carpenter	

Sago Miners

Jeremy R. Toler	Travis J. Anderson
Brian E. Curtis	Craig D. Newson
Chester Runyon	Mike W. Butcher
Teddy J. Hickman	Harold Baisden Jr.
Basil J. Chidester	Kenneth Anderson
Chris Chisolm	Gary L. Marsh
Ronald E. Grall	Roger L. Shiflet
Joseph Runyon	Francis Johnson
Roy L. Williams	Denver D. Anderson
William L. Chisolm	Thomas L. Everson
Charles R. Wilson	Nathan H. Eye
Edmund B. Payne	Darrel Lucas

**Appendix G - Lists of Individuals Who Assisted with the Investigation
(Cont'd)**

United Mine Workers of America

Ron Bowersox
Max Kennedy
Ted Hapney
Dennis Bailey

Gary Trout
Butch Oldham
Mark Cochran

State of West Virginia

Brian Mills
Jeff Bennett
Mike Rutledge
Jim Hodges
J.D. Higginbotham
Monte Hieb

John Hall
Barry Fletcher
Phil Atkins
John Collins
John Cruse
Doug Conaway

MSHA - Educational Field Service

Preston T. White

MSHA - District 4

James D. Honaker

MSHA - National Mine Health and Safety Academy

Donald C. Starr
Theodore G. Farrish
Arthur D. Wooten

David S. Mandeville
Harold E. Newcomb

MSHA - Pittsburgh Safety and Health Technology Center

Thomas A. Morley
James D. Baca
Kim S. Diederich
Scott K. Johnson
Terence M. Taylor
Michael Gauna
Mark A. Pompei
William J. Francart
Dean Skorski

Dennis A. Beiter
Gary J. Shemon
Mark E. Schroeder
C.W. Moore
Richard Allwes
John R. Cook
George N. Aul
Donald A. Sulkowski
William Helfich

**Appendix G - Lists of Individuals Who Assisted with the Investigation
(Cont'd)**

MSHA - Approval and Certification Center

Kevin L. Hedrick

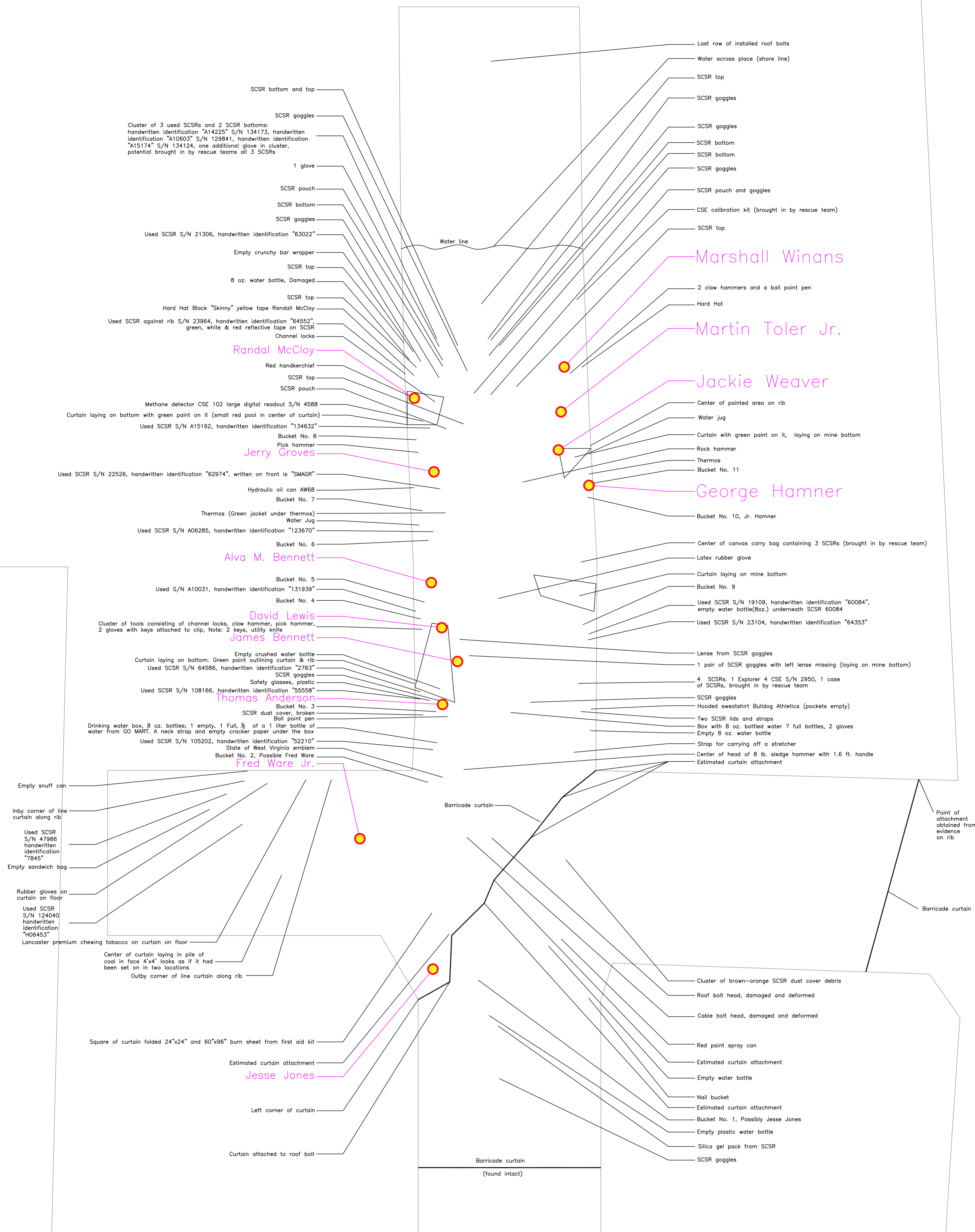
Robert J. Holubeck

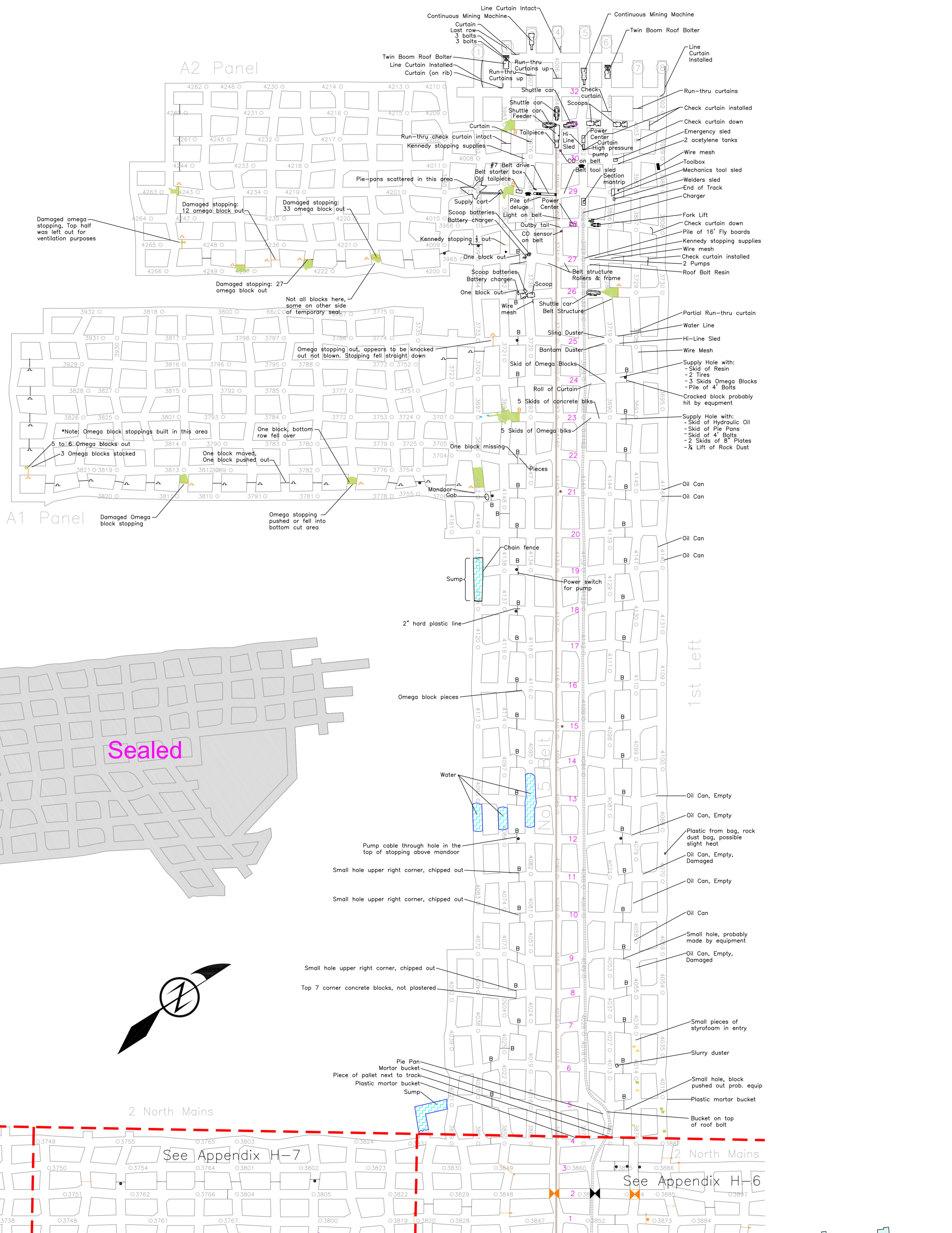
Department of Labor, Office of the Solicitor

James B. Crawford

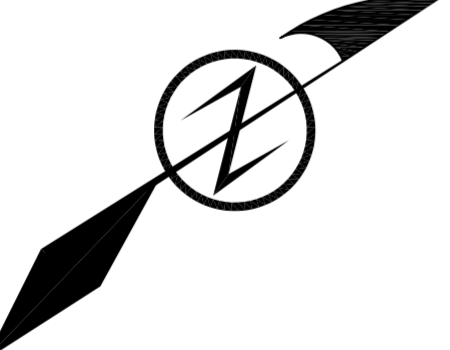
Timothy S. Williams

Robert S. Wilson

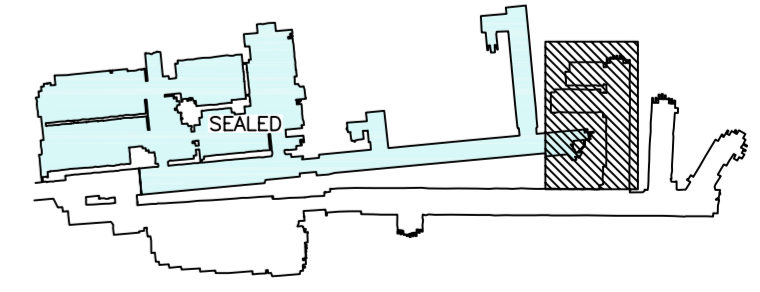




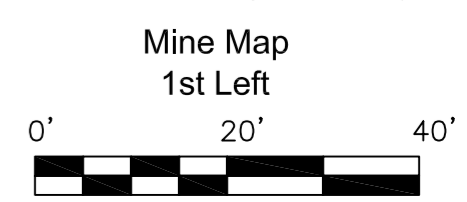
Sealed

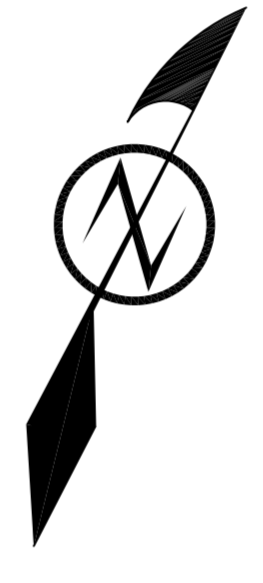
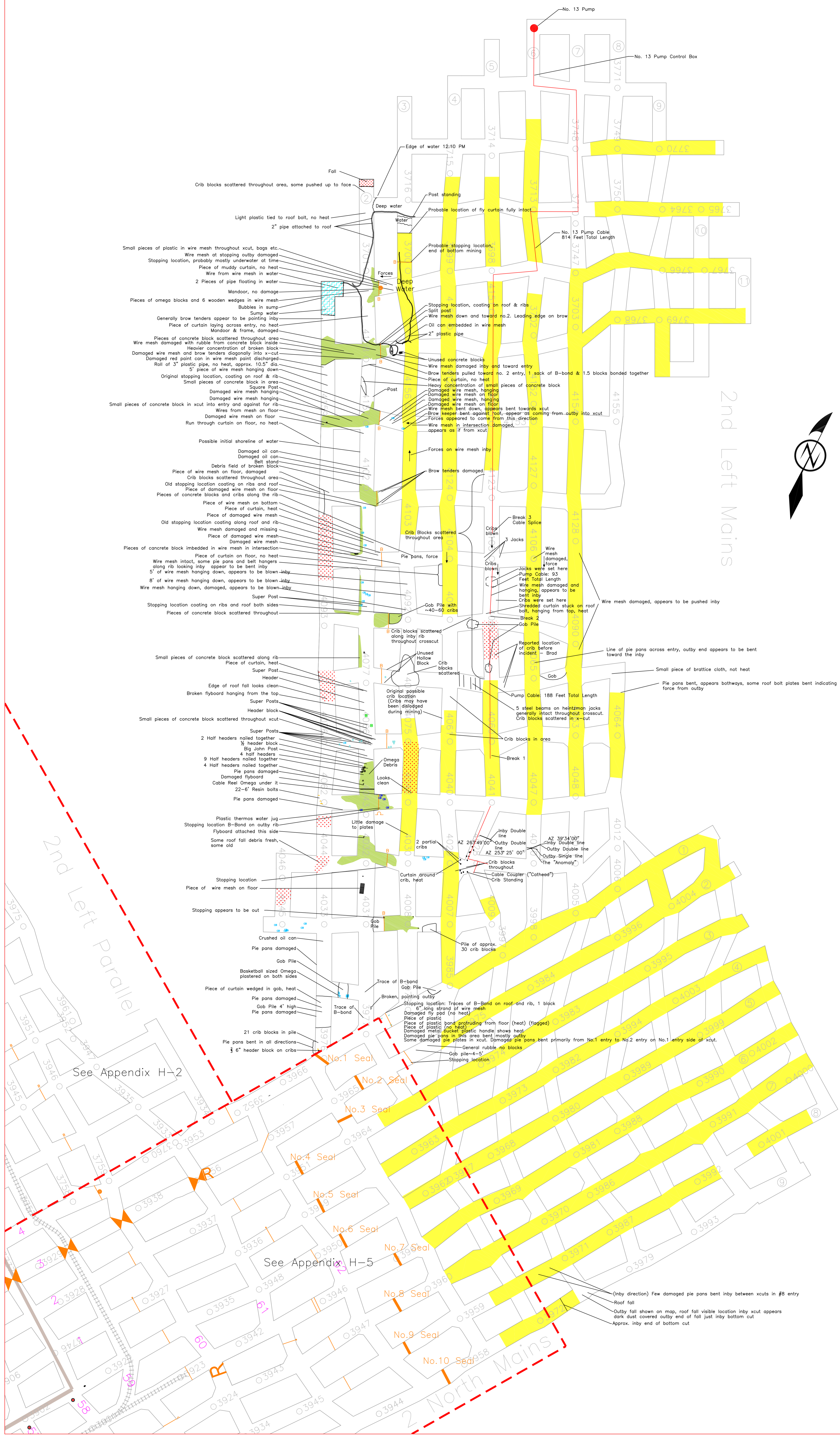


LEGEND			
	PLASTERED CONCRETE BLOCK STOPPING		EQUIPMENT DOOR
	PLASTERED OMEGA BLOCK STOPPING		STOPPING DEBRIS
	STOPPING WITH MANDOOR		FALL
	DAMAGED VENTILATION CONTROLS		WATER
	REGULATOR		CRIBS
	PERMANENT SEAL LOCATION		CONVEYOR BELT
	DAMAGED SEAL LOCATION		TRACK
	CHECK CURTAIN		BOTTOM MINING AREA
	OVERCAST		OMEGA BLOCK
	DAMAGED OVERCAST		PARTIAL OMEGA BLOCK
	FAN HOUSE		CONCRETE BLOCK
			PARTIAL CONCRETE BLOCK
			HALF HEADER
			OVERCAST DECKING
			WEDGE
			CRIB BLOCK
			I-BEAM
			ELONGATED OBJECT
			FLYBOARD
			FIRE EXTINGUISHER
			KENNEDY STOPPING PANEL
			PAGER LOCATION
			PAGER LINE CONNECTION
			CO SENSOR LOCATION

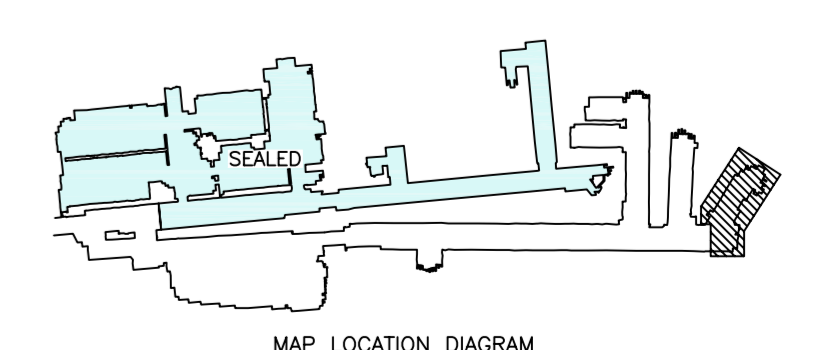


Appendix H-3
Sago Mine, MSHA ID 46-08791
Wolf Run Mining Company





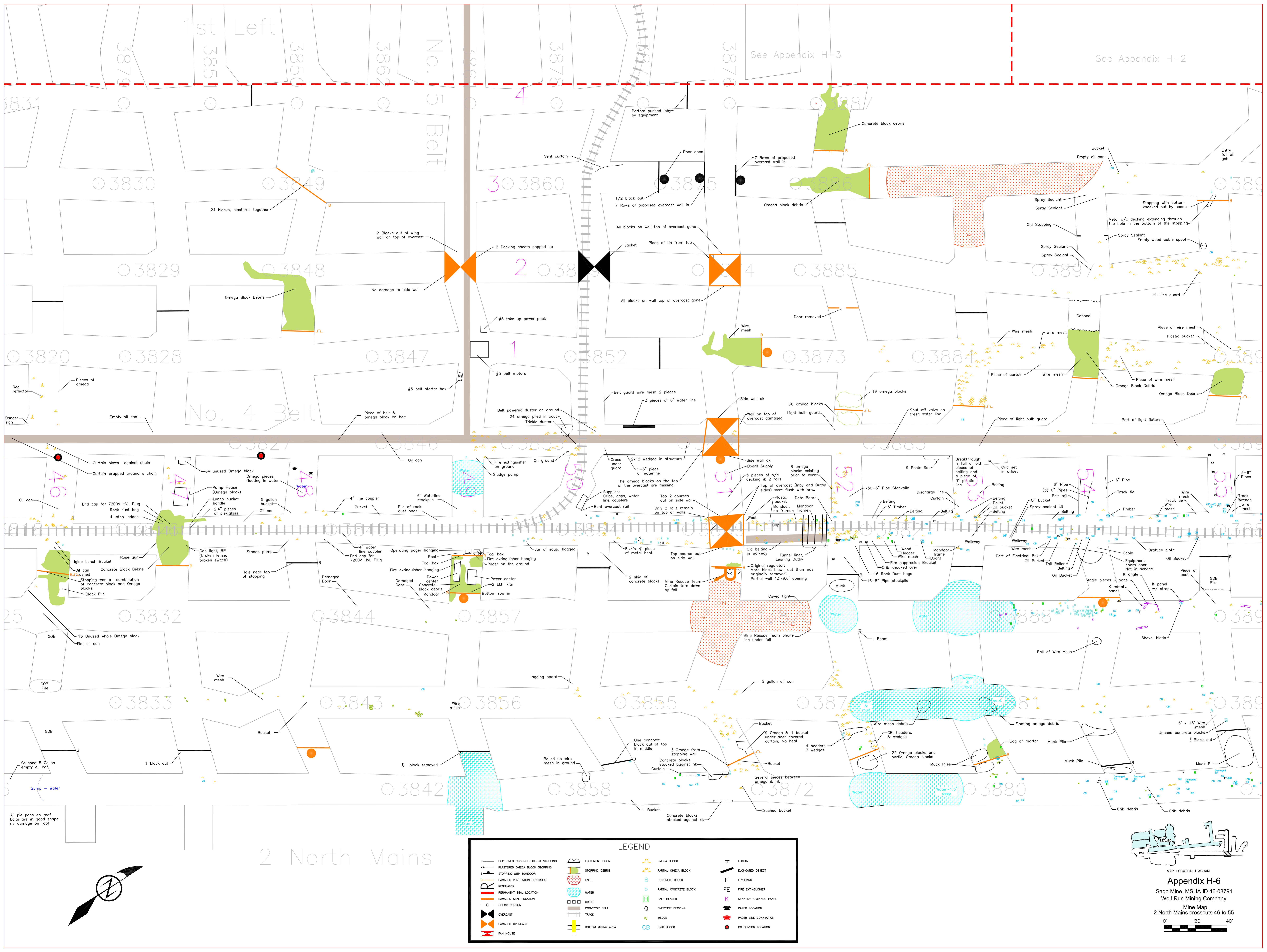
LEGEND	
	PLASTERED CONCRETE BLOCK STOPPING
	PLASTERED OMEGA BLOCK STOPPING
	STOPPING WITH MANDOOR
	DAMAGED VENTILATION CONTROLS
	REGULATOR
	PERMANENT SEAL LOCATION
	DAMAGED SEAL LOCATION
	CHECK CURTAIN
	OVERCAST
	DAMAGED OVERCAST
	FAN HOUSE
	EQUIPMENT DOOR
	STOPPING DEBRIS
	WATER
	CRIBS
	CONVEYOR BELT
	TRACK
	BOTTOM MINING AREA
	OMEGA BLOCK
	PARTIAL OMEGA BLOCK
	CONCRETE BLOCK
	PARTIAL CONCRETE BLOCK
	HALF HEADER
	OVERCAST DECKING
	WEDGE
	CRIB BLOCK
	I-BEAM
	ELONGATED OBJECT
	FLYBOARD
	FIRE EXTINGUISHER
	KENNEDY STOPPING PANEL
	PAGER LOCATION
	PAGER LINE CONNECTION
	CO SENSOR LOCATION



See Appendix H-2

See Appendix H-5

(Inby direction) Few damaged pie pans bent inby between xcuts in #8 entry
 Roof fall
 Outby fall shown on map, roof fall visible location inby xcut appears dark dust covered outby end of fall just inby bottom cut
 Approx. inby end of bottom cut



See Appendix H-3

See Appendix H-2

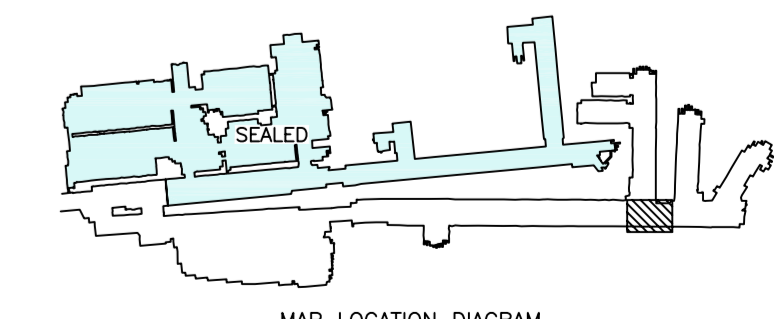
1st Left

No. 5 Belt

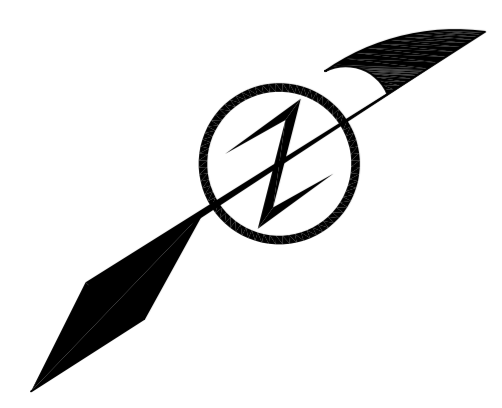
No. 4 Belt

2 North Mains

LEGEND

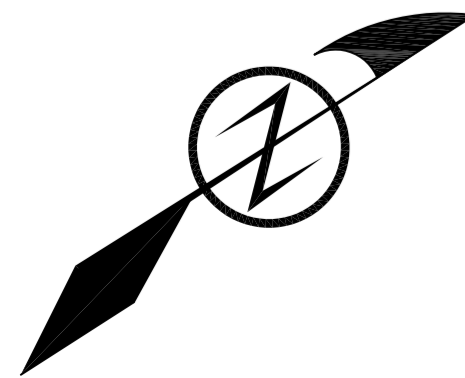


Appendix H-6
 Sago Mine, MSHA ID 46-08791
 Wolf Run Mining Company
 Mine Map
 2 North Mains crosscuts 46 to 55
 0' 20' 40'

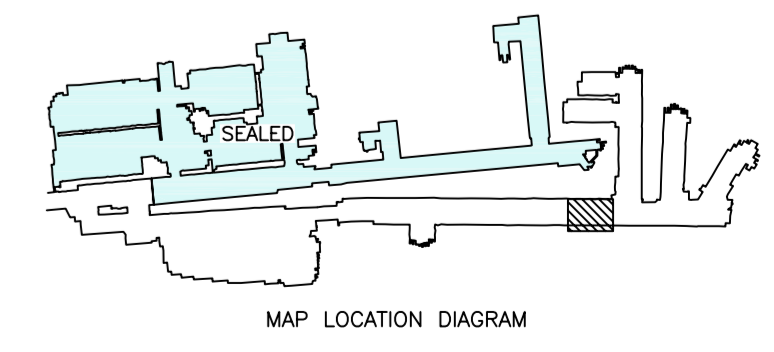


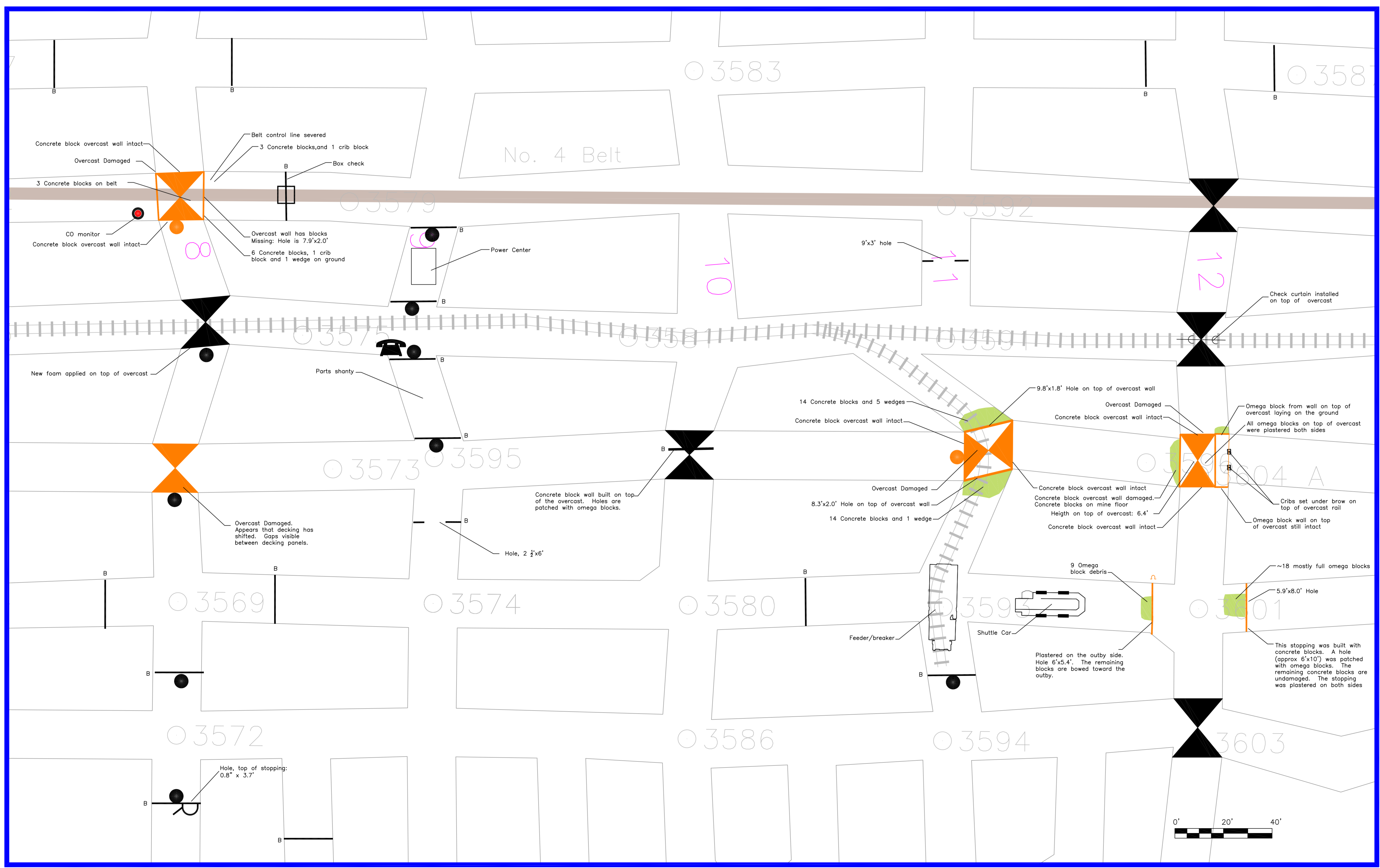
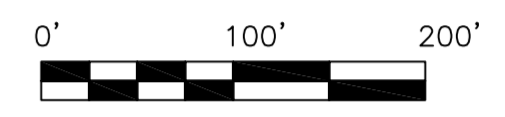
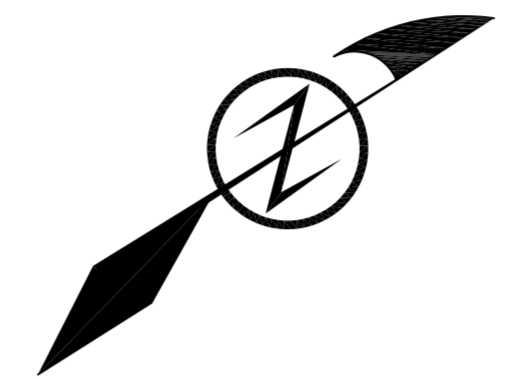
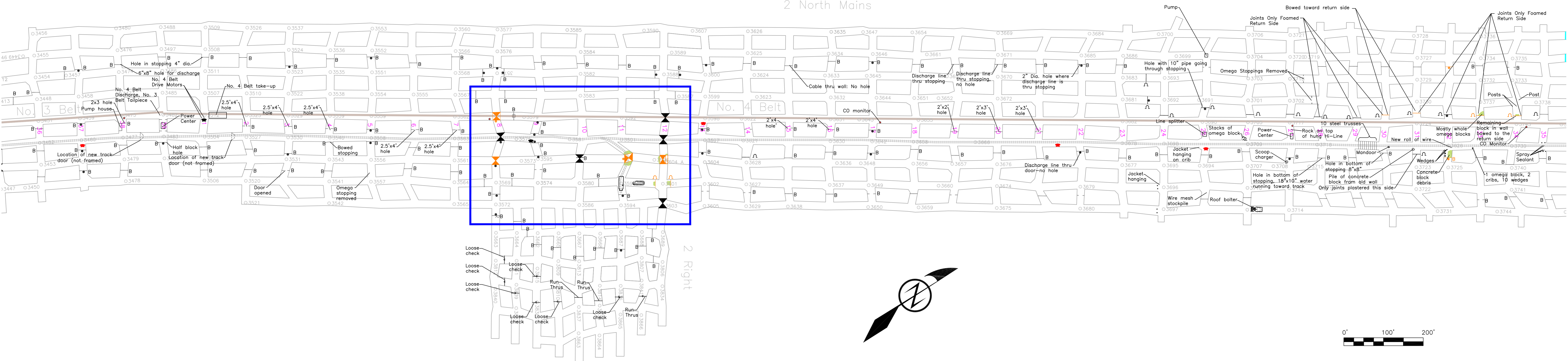


2 North Mains



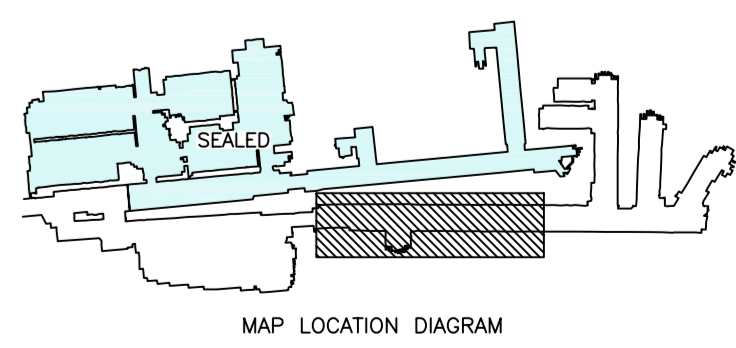
LEGEND			
FLASTERED CONCRETE BLOCK STOPPING	EQUIPMENT DOOR	OMEGA BLOCK	I-BEAM
PLASTERED OMEGA BLOCK STOPPING	STOPPING DEBRIS	PARTIAL OMEGA BLOCK	ELONGATED OBJECT
STOPPING WITH MANDOOK	CONCRETE BLOCK	CONCRETE BLOCK	FLYBOARD
DAMAGED VENTILATION CONTROLS	FALL	PARTIAL CONCRETE BLOCK	FIRE EXTINGUISHER
REGULATOR	WATER	HALF HEADER	KENNEDY STOPPING PANEL
PERMANENT SEAL LOCATION	CRIS	OVERCAST DECKING	PAGER LOCATION
DAMAGED SEAL LOCATION	CONVEYOR BELT	WEDGE	PAGER LINE CONNECTION
CHECK CURTAIN	TRACK	CRIB BLOCK	GD SENSOR LOCATION
OVERCAST	BOTTOM MINING AREA		
DAMAGED OVERCAST			
FAN HOUSE			

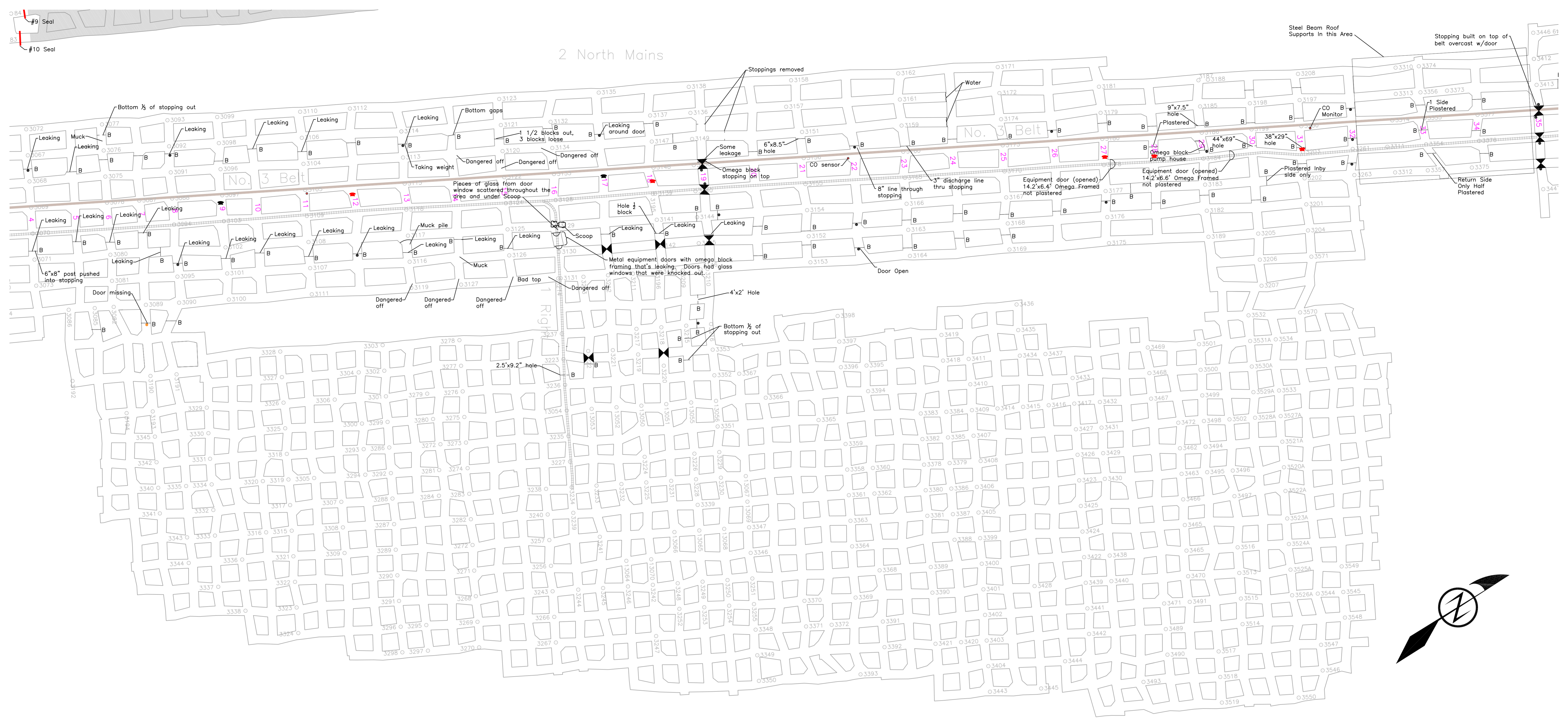




LEGEND

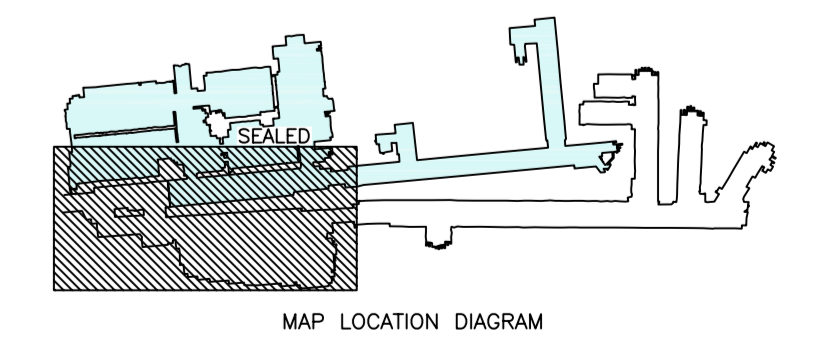
	PLASTERED CONCRETE BLOCK STOPPING		OMEGA BLOCK
	PLASTERED OMEGA BLOCK STOPPING		PARTIAL OMEGA BLOCK
	STOPPING WITH MANDOOR		CONCRETE BLOCK
	DAMAGED VENTILATION CONTROLS		PARTIAL CONCRETE BLOCK
	REGULATOR		HALF HEADER
	PERMANENT SEAL LOCATION		CHECK CURTAIN
	DAMAGED SEAL LOCATION		OVERCAST DECKING
	OVERCAST		WEDGE
	DAMAGED OVERCAST		CRIB BLOCK
	FAN HOUSE		I-BEAM
	EQUIPMENT DOOR		ELONGATED OBJECT
	STOPPING DEBRIS		FLYBOARD
	FALL		FIRE EXTINGUISHER
	WATER		KENNEDY STOPPING PANEL
	CRIBS		PAGER LOCATION
	CONVEYOR BELT		PAGER LINE CONNECTION
	TRACK		CO SENSOR LOCATION
	BOTTOM MINING AREA		





LEGEND

	PLASTERED CONCRETE BLOCK STOPPING		OMEGA BLOCK
	PLASTERED OMEGA BLOCK STOPPING		PARTIAL OMEGA BLOCK
	STOPPING WITH MANDOOR		CONCRETE BLOCK
	DAMAGED VENTILATION CONTROLS		PARTIAL CONCRETE BLOCK
	REGULATOR		HALF HEADER
	PERMANENT SEAL LOCATION		OVERCAST DECKING
	DAMAGED SEAL LOCATION		WEDGE
	CHECK CURTAIN		CRIB BLOCK
	OVERCAST		I-BEAM
	DAMAGED OVERCAST		ELONGATED OBJECT
	FAN HOUSE		FLYBOARD
	STOPPING DEBRIS		STOPPING PANEL
	EQUIPMENT DOOR		FIRE EXTINGUISHER
	FALL		KENNEDY STOPPING PANEL
	WATER		PAGER LOCATION
	CRIBBS		PAGER LINE CONNECTION
	CONVEYOR BELT		CO SENSOR LOCATION
	TRACK		
	BOTTOM MINING AREA		



U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



April 19, 2007

MEMORANDUM FOR RICHARD A. GATES

District Manager, Coal Mine Safety and Health District 11

FROM:

JOHN P. FAINI

A handwritten signature in blue ink, appearing to read "J. Faini".

Chief, Approval and Certification Center

SUBJECT:

Executive Summary of Investigation of Pyott-Boone Electronics
MineBoss Monitoring and Control System

A computerized monitoring system manufactured by Pyott-Boone Electronics was in use at Wolf Run Mining Company's Sago Mine at the time of an explosion on January 2, 2006. Portions of the hardware and software associated with this system, called 'MineBoss Monitoring and Control System,' were evaluated to determine operational status. Additionally, data associated with recordable events stored in the computer was extracted and a copy of the computer's hard disk drive was made.

On January 11 and 30, 2006 and February 1 and 2, 2006, the Pyott-Boone Electronics MineBoss Monitoring and Control System was inspected, tested, and evaluated to determine its operational status. The system was used to measure the carbon monoxide (CO) level in the conveyor belt haulage entries and near a battery charging station, in the mine and report those levels to a surface location. Certain events, such as CO concentrations above pre-defined alarm levels, were recorded by the system via a printer and stored on magnetic media. Visual and audible alarms were located underground at the 1 Left Section and 2 Left Section conveyor belt tailpieces, and mounted to an outside wall of the dispatcher's office trailer located on the surface.

The system was also used to monitor and control the operation of underground conveyor belts. Again, certain events associated with the operation of the conveyor belts were recorded and stored by the system.

The stored data, or 'event log,' was used in this evaluation. Additionally, the operation of the system was observed, and the CO monitors were inspected and tested by application of a known concentration of CO in air. All dates and times were those recorded in the event log; they were not revised to reflect the difference between actual time and the computer's real-time clock. However, it was reported by Marshall W. Robinson of Allegheny Surveys, Inc., that the computer's real-time clock, and therefore

the time recorded on the event log, was 4 minutes and 56 seconds ahead of the actual time.

The following are the significant findings of the investigation. Following these items is an approximate reproduction of the map of the underground components of the CO monitoring system, with graphical reproduction of each device.

- The Pyott-Boone Model 805C remote alarm located at the tailpiece of the 1 Left Section belt was not operational when tested. It was wired incorrectly, such that it would not provide visual or audible signals when manually operated by the dispatcher or automatically operated by the adjacent CO monitor. Based on a review of the event log, and assuming that the wiring had not been modified since the time of the accident, the alarm would not have provided audible or visual warnings at the time of the accident.
- The Pyott-Boone Model 1700 CO monitor located adjacent to the remote alarm at the tailpiece of the 1 Left Section belt did not operate properly when tested. It read '26' in clean air and '74' with 50 parts per million (ppm) CO applied to the sensor head. Additionally, it was improperly wired to the aforementioned Model 805C remote alarm, so that the alarm unit would not initiate. When wired properly, this CO monitor would cause the Model 805C remote alarm to give audible and visual warnings continuously, regardless of the CO reading. The data in the event log suggests that this condition existed at the time of the explosion. Furthermore, the data suggests that the response of this monitor was drifting, or changing without a corresponding change in the carbon monoxide content of the mine atmosphere. It appears that some corrective action was attempted on several occasions, most notably during the early morning hours of December 31, 2005. Also, it appears that the system operator had attempted to reset the device, by taking it 'off scan' and placing it back 'on scan,' at approximately 6:09 am on January 2, 2006.
- The CO monitor with address 1.34, located beside the #2 Belt near crosscut 7, was measuring CO properly on January 30, 2006, but was not reporting the value to the surface. Two fuses located in the 'Data +' and 'Data -' circuits were open-circuited. Review of the event log indicates that communications with this CO monitor were lost on January 2, 2006, at an indicated time of 6:32 am; this is most likely due to open-circuiting of the fuses. The event that caused the fuses to operate in the data communications circuitry is unknown.
- Nineteen (19) of the twenty-five (25) CO monitors inspected underground gave readings within 10% of the intended value when a test gas containing 50 ppm CO was applied to the sensor heads with the Pyott-Boone calibration adapter

and flow regulator. Additionally, one (1) of the CO monitors inspected underground was damaged, not connected to the system, and could not be tested underground.

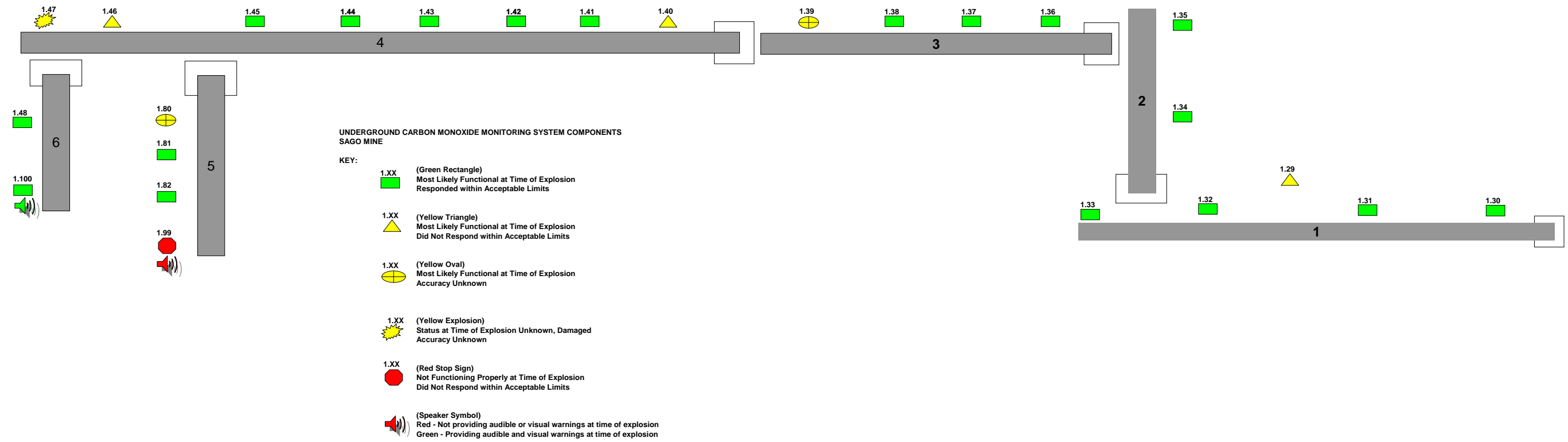
- The monitors that did not respond properly to the test gas, or were non-functional, were as follows:

Address	Location	Zero Reading	Span Reading	Comments
1.29	Motor Barn Spur	0	40	
1.39	#3 Belt near Crosscut 38	109	109	Device failed on January 30, 2006
1.40	#4 Belt near Crosscut 8	0	75	
1.46	#4 Belt near Crosscut 57	0	19	Found face down on mine floor, covered in soot
1.47	Tail #4 Belt (intended location)	-	-	Fragment found on mine floor beside # 4 Belt between crosscuts 44 and 45, Damaged, could not test in mine
1.80	#5 Belt near Crosscut 15	110	110	Device failed between Jan 2 and Jan 30, 2006.
1.99	5 Belt tailpiece just outby the section feeder	26	74	

- The event log indicates that, at the time of the explosion, conveyor belts identified as #1, #2, #3, and #4 were most likely running. It is not possible to determine the status of the #6 belt, because of damage in the area of the belt drive, but the event log does not include an entry that indicates that it was running at the time of the explosion. It's likely that the #5 belt was not running at the time of the explosion. The event log includes entries for Belt #7 before the time of the explosion and the last entry in the event log for this belt was on December 29, 2006. The physical evidence indicates that the equipment associated with this belt was in the process of being dismantled.
- The fragment of a Pyott-Boone CO monitor recovered from the mine was determined to be the unit with address 1.47. It is the subject of a separate investigation to determine if it contributed to the explosion.
- With the exception of the unit with address 1.47, Exhibit Number 114P, there was no evidence that any of the CO monitors produced conditions that would have provided enough energy to ignite a flammable methane-air mixture. The explosion risk of Exhibit Number 114P is the subject of a separate report.

- The entries in the event log that were recorded on the morning of January 2, 2006, were evaluated. Definitions of each entry were provided and the actions that could have caused those entries were described.

Comprehensive inspection and test results can be obtained from the Chief of the A&CC, RR 1, Box 251, Industrial Park Road, Triadelphia, West Virginia 26059.



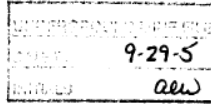
Appendix J - Bottom Mining Supplements to the Ventilation Plan

U.S. Department of Labor

Mine Safety and Health Administration
 604 Cheat Road
 Morgantown, West Virginia 26508



SEP 28 2005



SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:	
SURNAME	DATE
<i>Alanna / Tolner</i>	<i>9/26/05</i>
REVIEWED BY:	
<i>Alanna</i>	<i>9/26/05</i>
<i>Tolner</i>	<i>9-28-05</i>
<i>Mosley</i>	<i>9-28-05</i>

Mr. Jeffrey K. Toler
 Superintendent
 Anker WV Mining Company, Inc.
 Route 9, Box 507
 Buckhannon, West Virginia 26201

Dear Mr. Toler:

The request filed September 28, 2005, for a test area as shown on the accompanying map for the ventilation and evaluation of the worked-out area as a result of mining the lower bench of the Middle Kittanning seam of the 2nd Left Mains at the Sago Mine, I.D. No. 46-08791, has been reviewed and is approved. This information will be included in your currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370(d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
 District Manager

EParrish:aew

bcc:
 Bridgeport F/O (2)
 W. Ponceroff
 E. Parrish
 Health Section
 Map File
 Main File

Appendix J - Bottom Mining Supplements to the Ventilation Plan

**Anker West Virginia
Mining Company**

Rt.9 Box 507
Buckhannon, WV 26201

9-28-05
RECEIVED
2005 SEP 23 PM 1:06
DEPARTMENT OF LABOR, MINE HEALTH AND SAFETY ADMINISTRATION
BUCKHANNON, WV

September 28, 2005

Kevin Stricklin, District Manager
C/O Department of Labor, Mine Health and Safety Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Tom Hlavsa.
Submittal # 2a-2vent/Final.

Dear Mr. Stricklin:

The following correspondence is concerning amending our Sago Mines, {M.S.H.A. identification number 46-08791} approved ventilation control plan.

These proposed amendments will allow recovery of additional resources, in that the lower bench of the Middle Kittanning seam that is being proposed to be mined. This mining application will apply to the lower coal seam of the 2nd Left Mains at the Sago Mine, I.D.No.46-08791. Please refer the attached drawing (Number 1 Proposed Typical Ventilation Plan), which depicts the proposed ventilation plans for ventilating the area to be mined during the bottom split advancement. We also this time wish to utilize an evaluation point so as not to expose examiners to undue hazards of raised areas and heightened coal ribs. Be advised that we wish to respectfully submit for your review and subsequent approval a bleeder system for a non-pillared worked out area "Please refer to Evaluation Point Designation Plan "so as not to expose examiners to undue hazards of raised areas and heightened coal ribs.

In addition , this amendment will include the "Inactive Bleeder Systems and Non-Pillared Worked Out Areas" of the current approved ventilation control plan .The examiner will place his initials and date at the evaluation point and record the results in a book located outside for that purpose.

Appendix J - Bottom Mining Supplements to the Ventilation Plan

● Page 2

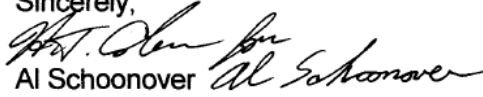
September 28, 2005

It should be noted that the proposed evaluation system is to be used only for a brief period of time as we plan to seal this area following the completion of the bottom split mining.

Please refer to the attached list of "Safety Provisions" that will address in detail safe work procedures for this mining process.

In closing, your prompt review and approval of this proposed amendment will be greatly appreciated. If you have any questions concerning this correspondence please feel free to contact me at 1-304-471-3400.

Sincerely,

Handwritten signature of Al Schoonover in cursive script.

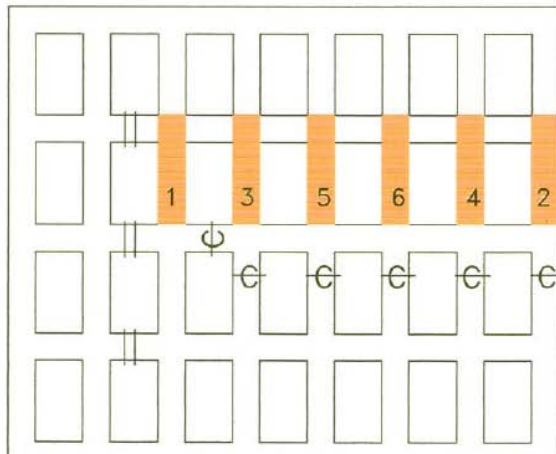
Al Schoonover

Safety Director

Appendix J - Bottom Mining Supplements to the Ventilation Plan

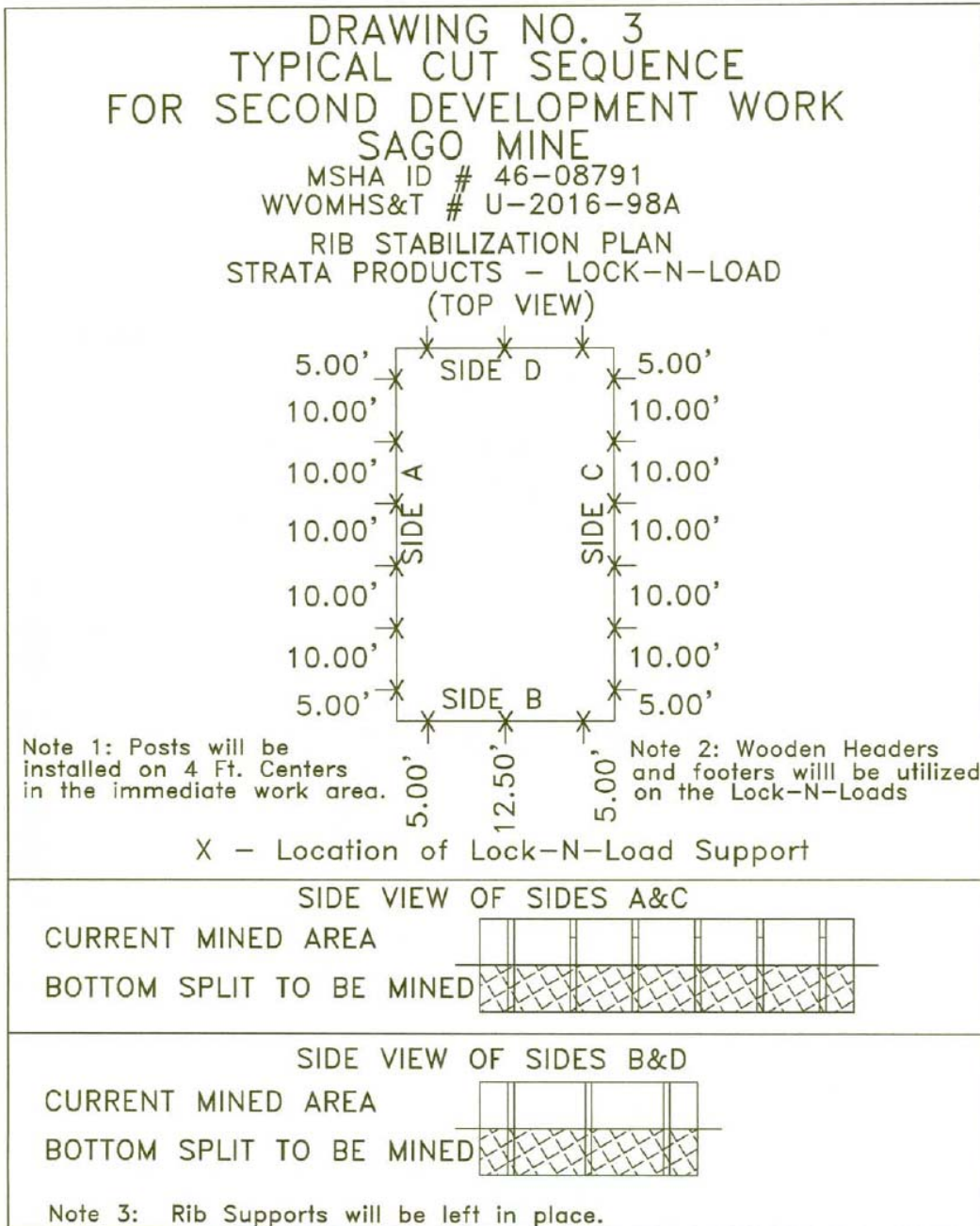
DRAWING NO. 1
PROPOSED TYPICAL VENTILATION PLAN
FOR BOTTOM SPLIT MINING

SAGO MINE
MSHA ID # 46-08791
WVOMHS&T # U-2016-98A

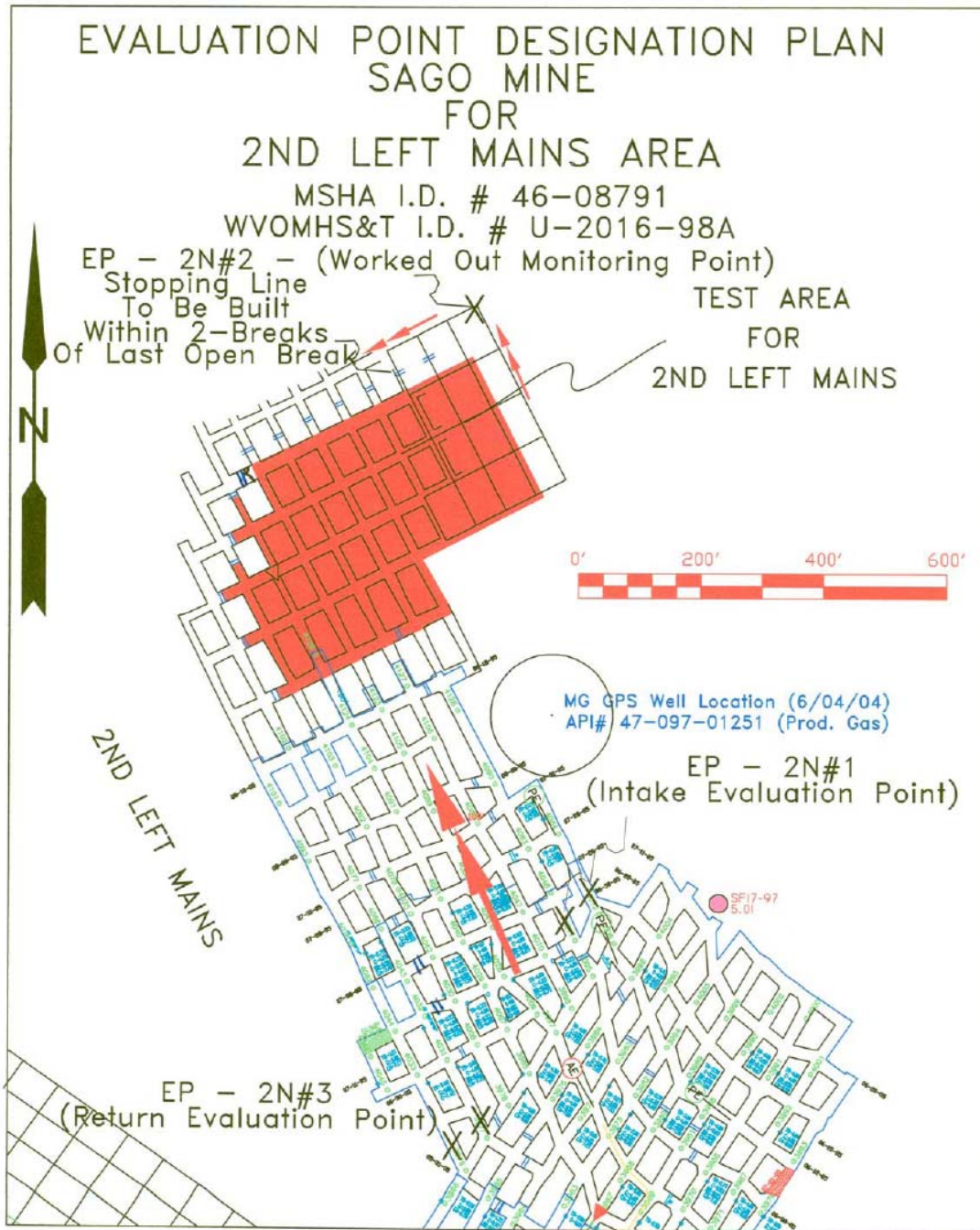


Note: This cycle may be repeated, as well as altered due to mining conditions.

Appendix J - Bottom Mining Supplements to the Ventilation Plan



Appendix J - Bottom Mining Supplements to the Ventilation Plan



Appendix J - Bottom Mining Supplements to the Ventilation Plan

Anker WV Mining Company, Inc.
Sago Mine

Page 8

Bleeder System

A description of the future bleeder system to be used is shown on the mine ventilation map submitted in accordance with 30 CFR § 75.372. The description includes; the bleeder system design, the location of the evaluation points for measurement of methane and oxygen concentrations and for test air quantity and direction, and the location of ventilation devices such as regulators, stoppings, and bleeder connectors used to control air movement through worked out areas.

Active Bleeder Systems:

Certified personnel designated by the operator will travel to the location of evaluation points and measuring points. Bleeder entries will be examined by traveling to the point of furthest penetration from the B.E.P. to check the quality of air. These travels will be made at least every seven days to determine the effectiveness of the bleeder system. The examinations will consist of measurements for methane, oxygen deficiency, air quality and a determination whether the air is flowing in the proper direction. At each underground monitoring point location the name of the monitoring point as well as the direction of the airflow will be identified. The examiner will place his initials and date at the evaluation point and record the results in a book located outside for the purpose. The examiner will notify the Shift or General Foreman immediately of significant changes (reversal of air flow direction, changes of more than 25% in the quantity of air, or more than 1% change in the content of methane or oxygen). If warranted, the Shift or General Mine Foreman will make an investigation into the cause of the changes and take action to correct any hazardous conditions found. This action will be recorded in the appropriate book on the surface.

Bleeder entries will be maintained free of obstructions through the use of: posts and cribs, to control the roof; and through ditches and/or dewatering pumps, to control water.

Prior to intersecting accessible areas such as bleeder entries or other splits of air, precautions will be taken to avoid adversely affecting the mine ventilation such as building stoppings, hanging check curtains, building and/or adjusting regulators.

Inactive Bleeder Systems and Non-Pillared Worked Out Areas:

Certified personnel designated by the operator will travel the perimeter of non-pillared worked out areas at least every seven days, examining for methane, oxygen deficiency, air quantity, air flowing in the proper direction, and hazardous conditions. These measurements shall be made at approved evaluation points and/or measurement point locations. The examiner will place his initials and date at the evaluation point and record the results in a book located outside for the purpose. All approved evaluation point and/or measurement point locations, shall, at all times, be maintained in a safe condition. Any hazardous condition will be recorded in a book located outside for that purpose.

For the purpose of ventilation of structures, area or installations that are required to be ventilated to return air courses, and for ventilation of seals, other air courses designated as return air courses are shown on the mine ventilation map submitted in accordance with 30CFR 75.372.

The location, if different from that submitted on the mine ventilation map, and sequence of construction of proposed seals will be submitted to the District Manager and approved prior to the construction of seals.

Appendix J - Bottom Mining Supplements to the Ventilation Plan

Sago Mine I.D. Number 46-08791

Safety Provisions:

Note: The safety provisions listed below will be reviewed with all persons working in the affected area prior to commencing work and record there of made.

- 1. No person will be allowed inby the second mining area so as to eliminate exposure of persons to heightened coal ribs.**
- 2. The Shuttle car operator will remain under the protective canopy at all times while inby the second mining area.**
- 3. The Shuttle cars will be equipped with "Back Boards" so as to protect the operator from lateral material falls. (Refer to the Attached Equipment Schematic) *See roof control plan JM***
- 4. All access points to raised areas created by second mining will be dangered off with yellow ribbon & or equivalent marterial. The ribbon will be affixed from rib to rib, and noted in the pre-shift /on-shift examination book.**
- 5. Tests for methane gas will be conducted prior to the cutting and loading of coal and every 20 minutes there after by remote means. This may be accomplished by utilizing a remote probe or by traveling inby on the upper level parallel and above the area to be mined.**
- 6. In the event mining equipment becomes disabled the ribs will be supported prior to commencing repairs to said piece of equipment. All work will be conducted under the direct supervision of a W.V. certified underground mine foreman.**
- 7. Cable handling will be accomplished via remote means utilizing pull ropes and additional personnel if needed. At no time will persons go inby to accomplish this task unless the coal ribs are supported.**
- 8. The lower level mining entries will not be wider than the upper level.**

Appendix J - Bottom Mining Supplements to the Ventilation Plan

U.S. Department of Labor

Mine Safety and Health Administration
 604 Cheat Road
 Morgantown, West Virginia 26508



UNDERGROUND MINE FILE
DATE FWD: 10-4-05
INITIALS: ai

OCT 4 2005

Mr. Jeffrey K. Toler
 Superintendent
 Anker West Virginia Mining Company, Inc.
 Route 9, Box 507
 Buckhannon, West Virginia 26201

SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:

SURNAME	DATE
Hayes/Saberfeld	10/4/05
REVIEWED BY:	
Hayes	10/4/05
Hayes for TCN	10/4/05
J. Omer	10-4-05
C. Mosley	10-4-05

Dear Mr. Toler:

The request filed October 4, 2005, to extend the test area as shown on the accompanying map for the ventilation and evaluation of the worked-out area as a result of additional mining of the lower bench of the Middle Kittanning seam of the 2nd Left Mains at the Sago Mine, I.D. No. 46-08791, has been reviewed and is approved. This information will be included in your currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370 (d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
 District Manager

JHayes:si

- bcc:
- Bridgeport Field Office (2)
 - W. Ponceroff
 - J. Hayes
 - Map File
 - ✓ Main File

Appendix J - Bottom Mining Supplements to the Ventilation Plan

**Anker West Virginia
Mining Company**

Rt.9 Box 507
Buckhannon, WV 26201



*aw
10-4-05*

October 3, 2005

Kevin Stricklin, District Manager
C/O Department of Labor, Mine Health and Safety Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Tom Hlavsa

Submittal # 3.

Dear Mr. Stricklin:

Anker West Virginia Mining Company wishes to amend our September 27, 2005 submittal which allowed our Sago Mine, (MSHA ID # 46-08791), and more specifically our 2nd Left Mains unit, to mine the lower bench of the Middle Kittanning Seam. We wish to modify this plan to allow for additional mining in this area. This additional area is shown on the attached map, and displayed and denoted with hatching.

It should be noted that we will comply with all details and information complied in the September 27, 2005 submittal. It should also be noted that we have moved both the intake, as well as the return monitoring points, EP-2N#1 and EP-2N#3 outby so as to cover the additional area we plan to add.

If you have any questions concerning this correspondence please feel free to contact me at 1-304-471-3300.

Sincerely,

James Al Schoonover
Al Schoonover

Safety Director

Appendix J - Bottom Mining Supplements to the Ventilation Plan

Sago Mine

MSHA I.D. Number 46-08791; WVOMHS&T ID No. U-2016-98A

Safety Provisions:

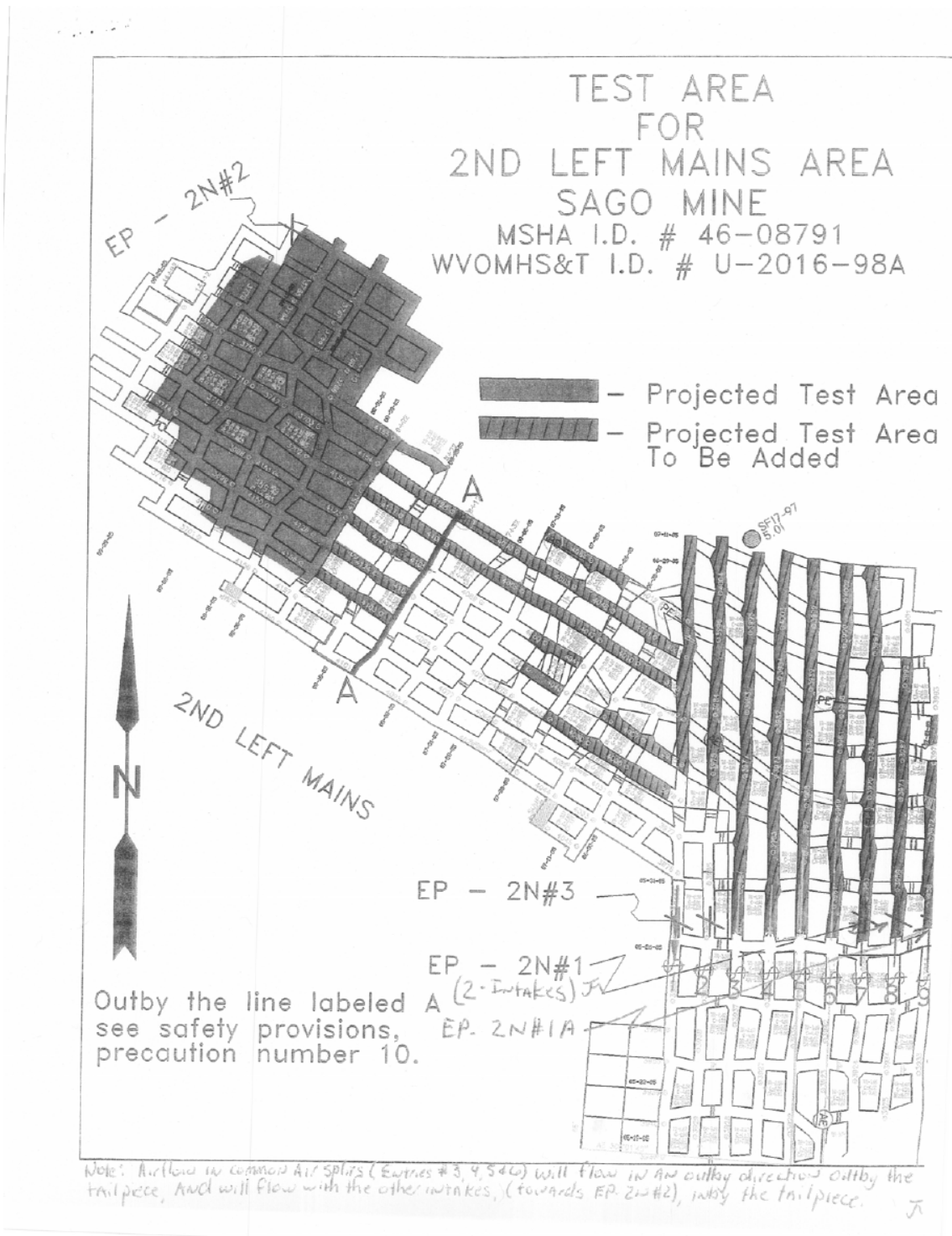
Note: The safety provisions listed below will be reviewed with all persons working in the affected area prior to commencing work and record there of made.

1. No person will be allowed inby the second mining area so as to eliminate exposure of persons to heightened coal ribs.
2. The shuttle car operator will be remain under the protective canopy at all times while inby the second mining area.
3. The Shuttle Car will be equipped with "Back Boards" so as to protect the operator from lateral material falls. (refer to the Attached Equipment Schematic).
4. All access points to raised areas created by second mining will be dangered off with yellow ribbon & or equivalent material. The ribbon will be affixed from rib to rib, and noted in the pre-shift/on-shift examination book.
5. Tests for methane gas will be conducted prior to cutting and loading of coal and every 20 minutes there after by remote means. This will be accomplished by utilizing a remote probe or by traveling inby on the upper level parallel and above the area to be mined.
6. In the event mining equipment becomes disabled the ribs will be supported prior to commencing repairs to said piece of equipment. All work will be conducted under the direct supervisions of a W.V. certified underground mine foreman.
7. Cable handling will be accomplished via remote means utilizing pull ropes and additional personnel if needed. At no time will persons go inby to accomplish this task unless the coal ribs are supported.
8. The lower level mining entries will not be wider that the upper level.
9. Persons will be withdrawn from the immediate area during second advance mining in the event of loose and or overhanging ribs are encountered.
10. Outby the line depicted as "A" on the attached map, additional rib/roof support will be added so as to provide additional roof support for the miner operator. This will be accomplished utilizing one of the methods shown below:
 - a). We will position one of our twin-head roof bolter in a crosscut to a point where the ATRS support is set at the junction of the crosscut and entry. Once the ATRS is set the roof bolters operator's canopy, nearest the corner in which the miner operator is going to position himself to operate, will be swung towards the inby corner and rib area. In doing such, this will create a protected area whereby the miner operator can operate the continuous miner from. This support will remain in place until the miner operator has completed the cut and has safely positioned himself in the main entry away, outby from the intersection.
 - b). Either 2, (two), Prop-setter supports or 2, (two) Lock-N-Load Supports will be installed on 5, (five) foot centers, with screen meshing being attached on the inby side. These supports will be installed with wedges being driven from the outby portion of the support towards the inby corner or rib line. By installing these supports in this fashion in conjunction with a removal rope, these supports can be remotely removed by using a scoop to safely remove these devices. Once removed, the rope, which had been previously attached to the sccop can be pulled taught in order to remove these supports to the middle of the intersection where they can be safely recovered.

Appendix J - Bottom Mining Supplements to the Ventilation Plan

c). Either the top will be screened to cover an area approximately 4' X 12', and installed utilizing 4, (four) roof bolts.

Appendix J - Bottom Mining Supplements to the Ventilation Plan



Appendix J - Bottom Mining Supplements to the Ventilation Plan

U.S. Department of Labor

Mine Safety and Health Administration
 604 Cheat Road
 Morgantown, West Virginia 26508



OCT 21 2005

Mr. Jeffrey K. Toler
 Superintendent
 Anker WV Mining Company, Inc.
 Route 9, Box 507
 Buckhannon, West Virginia 26201

UNDERGROUND MINE FILE	
DATE FWD.	10-21-05
INITIALS	aw

SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:	
SURNAME	DATE
<i>Sellars</i>	
REVIEWED BY:	
<i>Hayes</i>	10/21/05
<i>Blake to TCH</i>	10/21/05
<i>Hane R. Ford to M</i>	10/21/2005

Dear Mr. Toler:

The request filed October 17, 2005, for a test area as shown on the accompanying map for the ventilation and evaluation of the worked-out area as a result of mining the lower bench of the Middle Kittanning coal seam in the A-Panel at the Sago Mine, I.D. No. 46-08791, has been reviewed and is approved. This information will be included in your currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370(d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
 District Manager

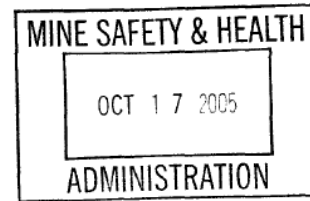
JHayes:aw

bcc:
 Bridgeport F/O (2)
 W. Ponceroff
 E. Parrish
 J. Hayes
 Health Section
 Map File
 Main File

Appendix J - Bottom Mining Supplements to the Ventilation Plan

**Anker West Virginia
Mining Company**

Rt.9 Box 507
Buchannon, WV 26201



October 16, 2005

Kevin Stricklin, District Manager
C/O Department of Labor, Mine Health and Safety Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Nelson Blake, Tom Hlavsa.
Submittal #1.

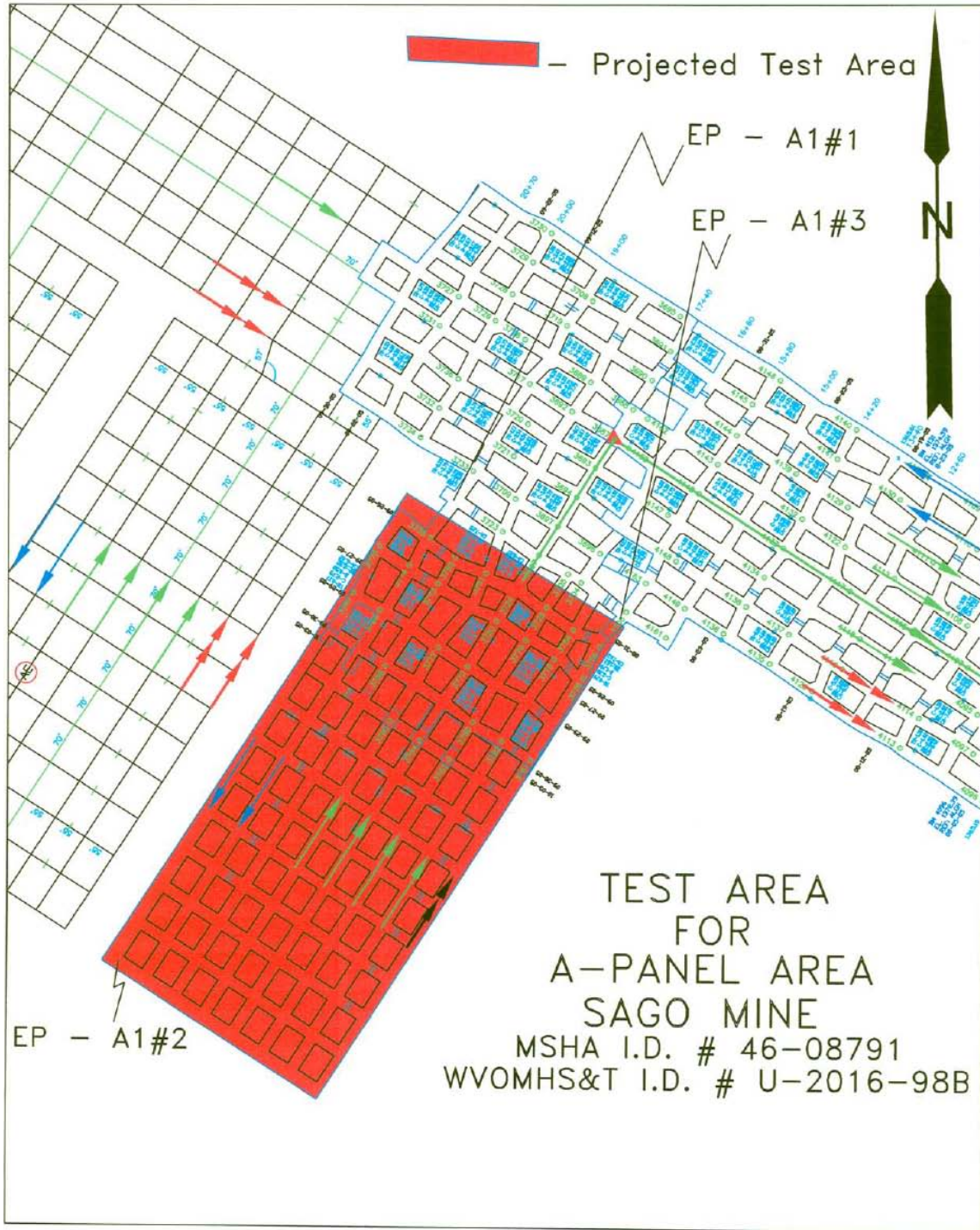
Dear Mr. Stricklin:

The following correspondence is concerning the second mining of our Sago Mine, {M.S.H.A. identification number 46-08791 & State I.D. # U-2016-98A}. We wish to respectfully request that a Test Area be approved for the A-Panel area of the Sago Mine for second mining of the lower bench of the Middle Kittanning Seam for both the entries and cross-cuts alike .Refer to attachment labeled {Projected Test Area} which shows proposed ventilation circuits and evaluation points. For your information I have attached a detailed cut sequence map that will eliminate exposure of persons to heightened areas. A list of the safety precautions that have been successfully utilized in previously mined areas has been included that will be in effect during this application.

All previously approved submittals concerning this mining application will still be in effect for this mining application.

In closing, your prompt review and approval of this request will be greatly appreciated by this department. If you have any questions concerning this correspondence please feel free to contact me at 1-304-471-3442.

Appendix J - Bottom Mining Supplements to the Ventilation Plan



Appendix J - Bottom Mining Supplements to the Ventilation Plan

Sago Mine

MSHA I.D. Number 46-08791; WVOMHS&T ID No. U-2016-98B

Safety Provisions:

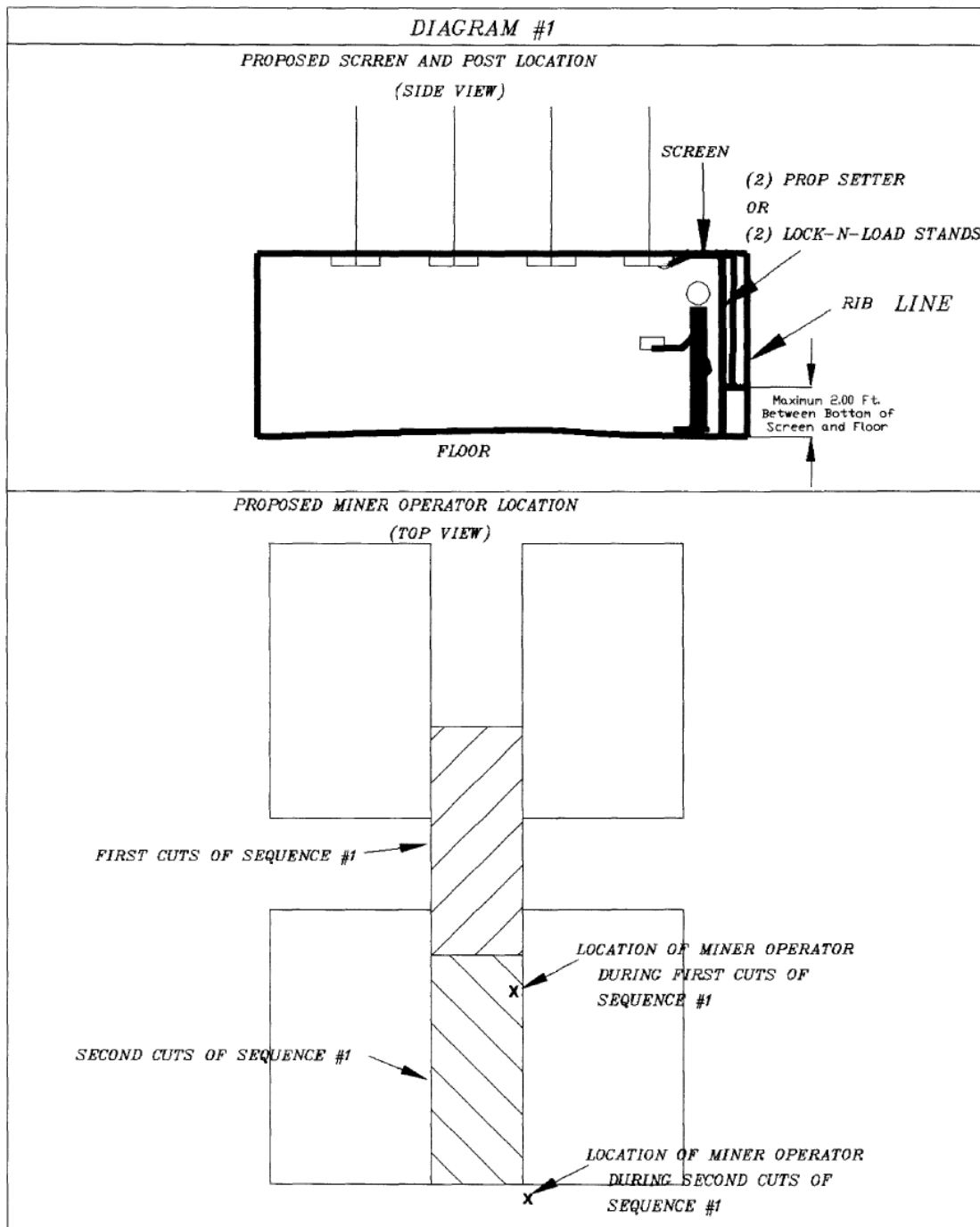
Note: The safety provisions listed below will be reviewed with all persons working in the affected area prior to commencing work and record there of made.

1. No person will be allowed inby the second mining area so as to eliminate exposure of persons to heightened coal ribs.
2. The shuttle car operator will be remain under the protective canopy at all times while inby the second mining area.
3. The Shuttle Car will be equipped with "Back Boards" so as to protect the operator from lateral material falls. (refer to the Attached Equipment Schematic).
4. All access points to raised areas created by second mining will be dangered off with yellow ribbon & or equivalent material. The ribbon will be affixed from rib to rib, and noted in the pre-shift/on-shift examination book.
5. Tests for methane gas will be conducted prior to cutting and loading of coal and every 20 minutes there after by remote means. This will be accomplished by utilizing a remote probe or by traveling inby on the upper level parallel and above the area to be mined.
6. In the event mining equipment becomes disabled the ribs will be supported prior to commencing repairs to said piece of equipment. All work will be conducted under the direct supervisions of a W.V. certified underground mine foreman.
7. Cable handling will be accomplished via remote means utilizing pull ropes and additional personnel if needed. At no time will persons go inby to accomplish this task unless the coal ribs are supported.
8. The lower level mining entries will not be wider that the upper level.
9. Persons will be withdrawn from the immediate area during second advance mining in the event of loose and or overhanging ribs are encountered.
10. Outby the line depicted as "A" on the attached map, additional rib/roof support will be added so as to provide additional roof support for the miner operator. This will be accomplished utilizing one of the methods shown below:
 - a). We will position one of our twin-head roof bolter in a crosscut to a point where the ATRS support is set at the junction of the crosscut and entry. Once the ATRS is set the roof bolters operator's canopy, nearest the corner in which the miner operator is going to position himself to operate, will be swung towards the inby corner and rib area. In doing such, this will create a protected area whereby the miner operator can operate the continuous miner from. This support will remain in place until the miner operator has completed the cut and has safely positioned himself in the main entry away, outby from the intersection.
 - b). Either 2, (two), Prop-setter supports or 2, (two) Lock-N-Load Supports will be installed on no more than 5, (five) foot centers, with screen meshing being attached on the inby side. These supports will be installed with wedges being driven from the outby portion of the support towards the inby corner or rib line. By installing these supports in this fashion in conjunction with a removal rope, these supports can be remotely removed by using a scoop to safely remove these devices. Once removed, the rope, which had been previously attached to the scoop can be pulled taught in order to remove these supports to the middle of the intersection where they can be safely recovered.

Appendix J - Bottom Mining Supplements to the Ventilation Plan

- c). Either the top will be screened to cover an area approximately 4' X 12', and installed utilizing a minimum of 4, (four ft.) roof bolts.
11. During the first cuts of Sequence #1, (See Diagram #1), the continuous miner operator can be positioned in by the corner of Sequence #1, provided the following measures have taken place:
- Prior to starting the first cuts a screen must be attached to at least two roof bolts along the row of roof bolts located closest to the right hand rib. Attachment can be by means of running a cable hanger through the screen and connect it to the hanger loop in the roof bolt plate.
 - Once this is completed, either two Prop-Setter Supports or two Lock-N-Load supports will be installed as close as possible to the rib and underneath the screen. By installing these supports in this fashion the screen will be forced to the top, as well as towards the rib line.
 - After the above actions have been completed the continuous miner operator can be taking the first cuts from Sequence #1.
-
- Removal of the screen and posts will occur as follows:
 - First the cable hooks will be unhooked from the roof bolt plates; then,
 - We will follow the removal action described in Item #10 above, with the exception that continuous miner may also be used to remotely remove the temporary supports.

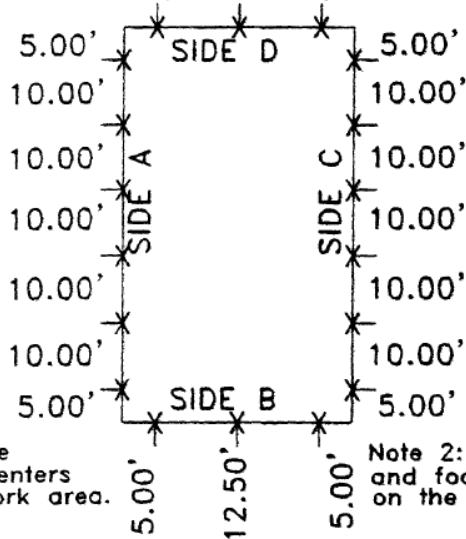
Appendix J - Bottom Mining Supplements to the Ventilation Plan



DRAWING NO. 3
 TYPICAL CUT SEQUENCE
 FOR SECOND DEVELOPMENT WORK
 SAGO MINE

MSHA ID # 46-08791
 WVOMHS&T # U-2016-98A

RIB STABILIZATION PLAN
 STRATA PRODUCTS - LOCK-N-LOAD
 (TOP VIEW)



Note 1: Posts will be installed on 4 Ft. Centers in the immediate work area.

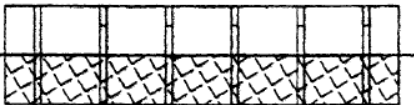
Note 2: Wooden Headers and footers will be utilized on the Lock-N-Loads

X - Location of Lock-N-Load Support

SIDE VIEW OF SIDES A&C

CURRENT MINED AREA

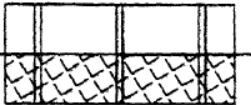
BOTTOM SPLIT TO BE MINED



SIDE VIEW OF SIDES B&D

CURRENT MINED AREA

BOTTOM SPLIT TO BE MINED



Note 3: Rib Supports will be left in place.

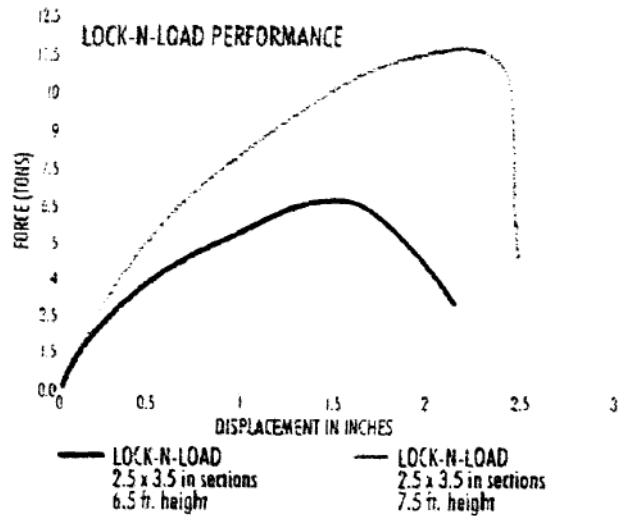
Appendix J - Bottom Mining Supplements to the Ventilation Plan

LOCK-N-LOAD SPECIFICATIONS 8 TON SUPPORT CAPACITY

Part #	Closed Height	Open Height	Weight
Lock 8/3-5	3 ft.	5 ft.	26 lbs.
Lock 8/4-6	4 ft.	6 ft.	32 lbs.
Lock 8/5-7	5 ft.	7 ft.	39 lbs.
Lock 8/6-8	6 ft.	8 ft.	45 lbs.
Lock 8/7-9	7 ft.	9 ft.	52 lbs.
Lock 8/8-10	8 ft.	10 ft.	58 lbs.
Lock 8/10-12	10 ft.	12 ft.	71 lbs.

LOCK-N-LOAD SPECIFICATIONS 20 TON SUPPORT CAPACITY

Part #	Closed Height	Open Height	Weight
Lock 20/3-5	3 ft.	5 ft.	54 lbs.
Lock 20/4-6	4 ft.	6 ft.	67 lbs.
Lock 20/5-7	5 ft.	7 ft.	80 lbs.
Lock 20/6-8	6 ft.	8 ft.	93 lbs.
Lock 20/7-9	7 ft.	9 ft.	106 lbs.
Lock 20/8-10	8 ft.	10 ft.	118 lbs.
Lock 20/9-11	9 ft.	11 ft.	131 lbs.
Lock 20/10-12	10 ft.	12 ft.	144 lbs.



Download Adobe pdf file of Lock-N-Load product sheet.

Strata Products USA Home | Strata Mine Services | Request More Information | News & Article

Appendix J - Bottom Mining Supplements to the Ventilation Plan

U.S. Department of Labor

Mine Safety and Health Administration
604 Cheat Road
Morgantown, West Virginia 26508



DEC 19 2005

Mr. Jeffrey K. Toler
Superintendent
Anker West Virginia Mining Company, Inc.
Route 9, Box 507
Buckhannon, West Virginia 26201

UNDERGROUND MINE FILE
DATE FWD. 12-19-05
INITIALS <i>all</i>

SENT TO AND/OR DISCUSSED WITH FIELD OFFICE

SURNAME	DATE
<i>Parrish</i>	<i>12-5-2005</i>
REVIEWED BY:	
<i>Parrish</i>	<i>12/12/05</i>
<i>Alkerson</i>	<i>12/13/05</i>
<i>Samen</i>	<i>12-13-05</i>
<i>Masley</i>	<i>12-14-05</i>

Dear Mr. Toler:

The request filed December 1, 2005, for a test area as shown in red on the accompanying map for the ventilation, evaluation to mine the lower bench of the Middle Kittanning seam and future seal locations of the A-2 Panel at the Sago Mine, I.D. No. 46-08791, has been reviewed and is approved. This information will be included in your currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370 (d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
District Manager

EParrish:si

bcc:
Bridgeport Field Office (2)
W. Ponceroff
E. Parrish
Health Group
Map File
Main File

Appendix J - Bottom Mining Supplements to the Ventilation Plan

**ANKER WEST VIRGINIA
MINING COMPANY**

RT. 9 BOX 507
BUCKHANNON, WV 26201

2005 DEC -1 PM 1:40
12-1-05
RECEIVED
CM

November 30, 2005

Mr. Kevin Stricklin
MSHA
604 Cheat Road
Morgantown, WV 26508

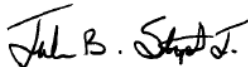
Dear Mr. Stricklin:

The following correspondence is concerning the second mining of our Sago Mine, (MSHA I. D. No. 46-08791 & State I. D. No. U-2016-98B). We wish to respectfully submit an amendment to our current approved ventilation and roof control plans for the A2-Panel area of the Sago Mine for second mining of the lower bench of the Middle Kittanning Seam for both the entries and cross-cuts alike. Refer to attachment labeled (Projected Area) which shows proposed ventilation circuits and evaluation points and future seal locations once the panel is abandoned. Note: In the set of seals labeled 1 through 5, seals 1 and 5 will be built last, and in the set of seals labeled 6 through 10, seals 6 and 10 will be built last. For your information I have attached a detailed cut sequence map that will eliminate exposure of persons to heightened areas. A list of the safety precautions that have been successfully utilized in previously mined areas has been included that will be in effect during this application.

All previously approved submittals concerning this mining application will still be in effect for this mining application.

In closing, your prompt review and approval of this request will be greatly appreciated by this department. If you have any questions concerning this correspondence please feel free to contact me at 1-304-471-3303.

John B. Stemple Jr.



Assistant Director of Safety
And Employee Development

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

U.S. Department of Labor

Mine Safety and Health Administration
 604 Cheat Road
 Morgantown, West Virginia 26508



OCT 24 2005

UNDERGROUND MINE FILE	
PERMITS	10-24-5
INITIALS	alw

SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:	
SURNAME	DATE
General Perry	10/13/2005
REVIEWED BY:	
Parrish	10/19/2005
Brooks for TH	10/20/05
Smith	10-20-05
Mosley	10-20-05

Mr. Jeffrey K. Toler
 Superintendent
 Anker WV Mining Company, Inc.
 Route 9, Box 507
 Buckhannon, West Virginia 26201

Dear Mr. Toler:

The request filed October 12, 2005, and revision filed October 19, 2005, to add an alternative method of seal construction to the ventilation plan for the Sago Mine, I.D. No. 46-08791, has been reviewed. The alternative method seal made with nonhitched-style Omega blocks is approved and will be included in your currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370(d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
 District Manager

EParrish:aew

bcc:
 Bridgeport F/O (2)
 W. Ponceroff
 E. Parrish
 Health Section
 Map File
 Main File

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

**Anker West Virginia
Mining Company**

Rt. 9 Box 507
Buckkannon, WV 26201

October 12, 2005

Kevin Stricklin, District Manager
Mine Health and Safety Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Tom Hlavsa

MINING SAFETY AND
HEALTH ADMINISTRATION
MORGANTOWN, WV

2005 OCT 12 PM 3:18

RECEIVED
cm

cm
10-13-05

RE: Sago Mine's Ventilation Plan Changes

Mr. Stricklin:

Anker West Virginia Mining Company wishes to add an Omega Concrete Block Seal Method and Plan to our current Ventilation Plan for our Sago Mine, MSHA ID # 46-08791. It should be noted, that at this time, we only wish to add the non-hitched style to our plan. (See attached diagrams).

If you have any questions on this matter, please feel free to contact me at 304-471-3300.

Sincerely,

Joe Myers
For: Al Schoonover
Safety Director

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

Guidelines for installation of Omega Block Concrete Seals

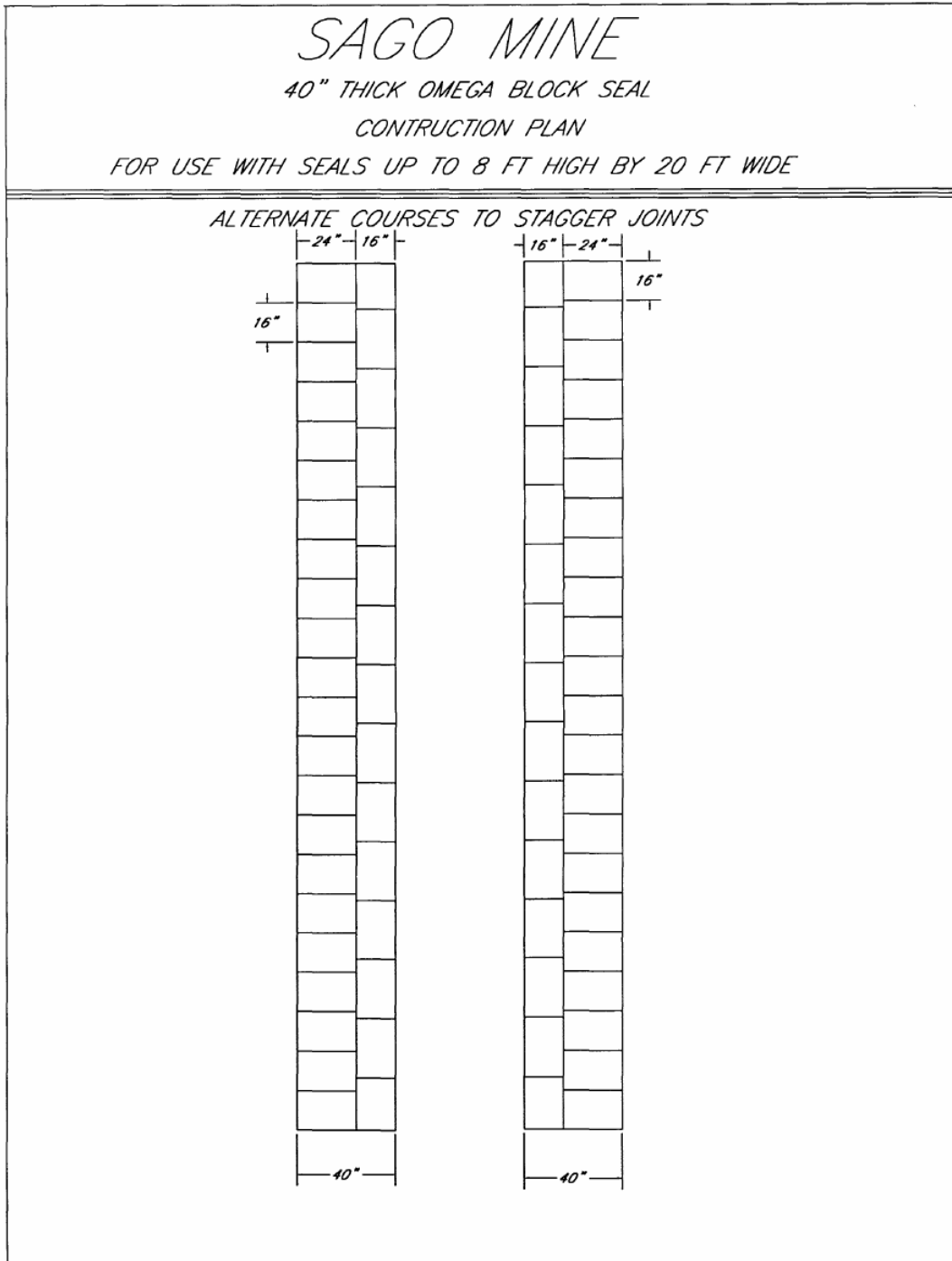
1. All loose material will be removed from the roof, ribs, and floor to accommodate seal construction and supplemental supports. The seals will be constructed at such a location so that a permanent block seal can be installed in front of the omega seal, if required in the future.
2. The seal will be constructed with Omega blocks using one of the following Methods:
 - A) Total thickness of 40"
 - B) No hitching required.
 - C) Joints must be staggered.
 - D) A bonding agent (Blockbond #122551), will be used to seal between each layer and joining edges of blocks at least ¼" thick and will be applied to the front and back of the seal.
 - E) The Omega blocks will be either be sawed or constructed so as to bring the top blocks to within 2" of the mine roof.
 - F) Three rows of wood planks running the entire length of the seal shall be installed across the top of the seal.
 - G) Wedges will be placed on 1 Foot centers or less, with an approved sealant used to fill the gaps.
 - H) An approved sealant shall be used as full face coating on both sides of the seal.
 - I) Seals shall be installed at least 10 feet from the corner of the pillar.
 - J) Sample pipes shall be installed as per 75.335.
 - K) Water traps will be installed within 12" of the bottom or floor.

RECEIVED

2015 OCT 19 PM 12:49

VENTILATION

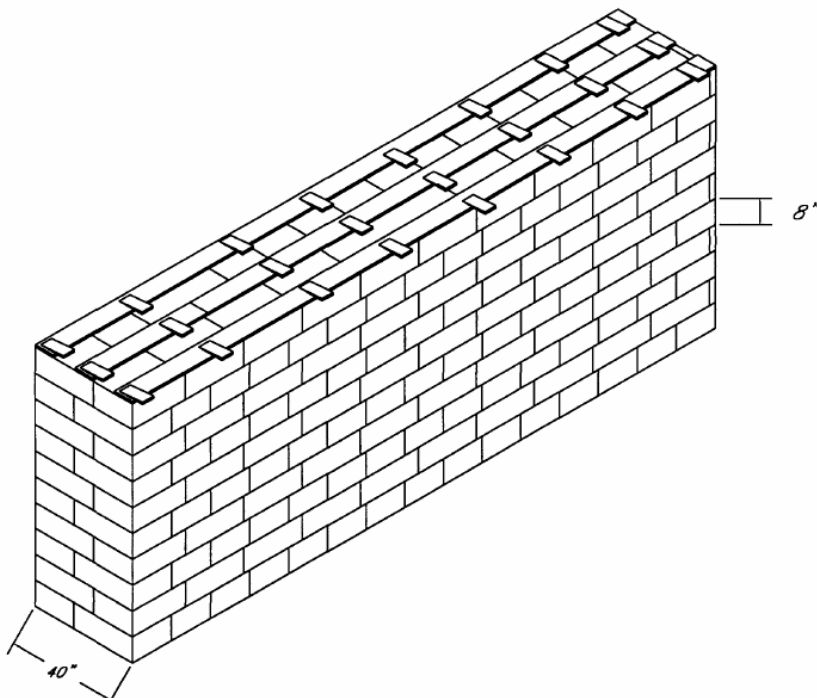
Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals



Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

SAGO MINE
40" THICK OMEGA BLOCK SEAL
FOR USE WITH SEALS UP TO 8 FT HIGH BY 20 FT WIDE

1. Total thickness 40 inches
2. No hitching required
3. Joints must be staggered
4. All joints shall be a minimum $\frac{1}{4}$ inch thick and be motared using an approved mortar/sealant
5. Three rows of wood planks running the entire length of the seal shall be installed across the top of the seal
6. Wedges will be placed on 1' centers or less with an approved sealant used to fill the gaps
7. An approved sealant shall be used as full face coating on both sides of the seal.



- Seals shall be at least 10 feet from the corner of the pillar
- Sampling pipes shall be installed as per 75.335

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

U.S. Department of Labor

Mine Safety and Health Administration
 604 Cheat Road
 Morgantown, West Virginia 26508



UNDEGROUND MINING
 DATE FILED 10-24-05
 INITIALS aew

OCT 24 2005

SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:

SURNAME	DATE
Parrish/Terry	10/13/2005
REVIEWED BY:	
Parrish	10/18/2005
Hawson	10/19/05
Shady	10-20-05
Mosley	10-20-05

Mr. Jeffrey K. Toler
 Superintendent
 Anker WV Mining Company, Inc.
 Route 9, Box 507
 Buckhannon, West Virginia 26201

Dear Mr. Toler:

The proposed location and sequence of seal construction across North East Mains and the intentional ventilation change filed October 12, 2005, at the Sago Mine, I.D. No. 46-08791, has been reviewed. The request is approved and will be included as a supplement to the mine ventilation map filed pursuant to 30 CFR 75.372.

You are reminded that this ventilation change must be conducted in accordance with 30 CFR 75.324.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
 District Manager

EParrish:aew

bcc:
 Bridgeport F/O (2)
 E. Parrish
 Map File
 Main File

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

**Anker West Virginia
Mining Company**

Rt. 9 Box 507
Buckkannon, WV 26201

October 12, 2005

Kevin Stricklin, District Manager
Mine Health and Safety Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Tom Hlavsa

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND
HEALTH ADMINISTRATION
MORGANTOWN, WV

2005 OCT 12 PM 3:18

RECEIVED

CM

OK
10-13-05

RE: Sago Mine's Ventilation Plan Changes

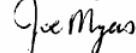
Mr. Stricklin:

Anker West Virginia Mining Company wishes to seek approval relative to installing nine mine seals across our North-East Mains in our Sago Mine, MSHA ID # 46-08791.

The mine seals being proposed will be constructed across our North East Mains, just inby the area that will be the future location of the 2nd Mains Unit. The proposed seals will be constructed across the North East Mains area in such a manner that the No. 2-9 seals will be constructed first, with seal numbers 1 and 10 be constructed simultaneously. It should be noted that for a temporary time frame, (not to exceed a four week period after the construction of said seals), that we will course air from a left-to-right direction, (from the number 1 entry towards the number 9 entry), in order to ventilate these seals; however, once we have constructed the necessary overcasts on the future 2nd Left Mains the air flow direction will be switched to a right-to-left direction, (From the number 9 entry towards the number 1 entry). See attached mapping to see air flow direction and ventilation control devices.

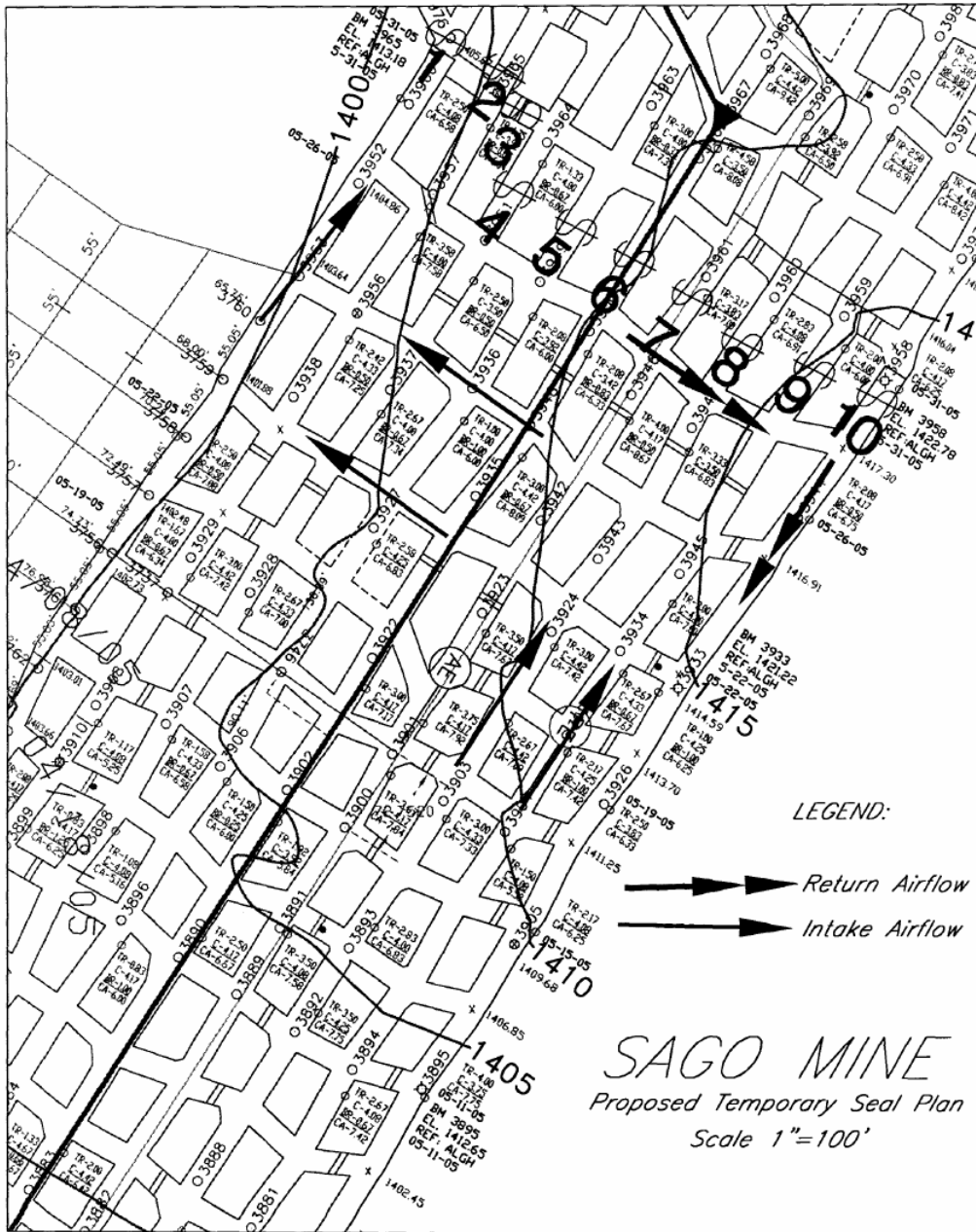
If you have any questions on this matter, please feel free to contact me at 304-471-3300.

Sincerely,



For: *Joe Myers*
Al Schoonover
Safety Director

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals



Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

U.S. Department of Labor

Mine Safety and Health Administration
604 Cheat Road
Morgantown, West Virginia 26508



SENT TO AND/OR DISCUSSED WITH FIELD OFFICE:

SURNAME	DATE
Parrish/Terry	11-01-2005
REVIEWED BY:	
Parrish	12-8-2005
Alana	12/6/05
Stamen	12-6-05
C. Morley	12-6-05

12-12-5
aw

DEC 8 2005

Mr. Jeffrey K. Toler
Superintendent
Anker WV Mining Company, Inc.
Route 9, Box 507
Buckhannon, West Virginia 26201

Dear Mr. Toler:

The request filed October 31, 2005, to add an alternative method of seal construction to the ventilation plan for the Sago Mine, I.D. No. 46-08791, has been reviewed. The alternative method seal with non-hitched style Omega blocks is approved and will be included in the currently approved mine ventilation plan.

You are reminded that all changes or revisions to the mine ventilation plan, as specified in 30 CFR 75.370(d), must be submitted to and approved in writing by this office before they are implemented.

If you have any questions, please feel free to contact this office.

Sincerely,

Kevin G. Stricklin

Kevin G. Stricklin
District Manager

EParrish:aw

bcc:
Bridgeport F/O (2)
W. Ponceroff
E. Parrish
Health Section
Map File
~~Main File~~

Appendix _____

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

09-29-05
19-6-05



ANKER WEST VIRGINIA MINING COMPANY INC.
Spruce Fork Division
1 Edmiston Way
Buckhannon, WV 26201
Phone 304-471-3300
Fax Phone 304-471-6011

205 OCT 31 PM 3:41

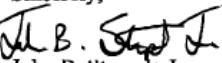
RECEIVED

October 28, 2005

Kevin Stricklin, District Manager
Mine Safety and Health Administration
604 Cheat Road
Morgantown, WV 26508
Attn: Tom Hlavsa
Re: Sago Mine's Proposed Seal Plan Amendment

Mr. Stricklin:

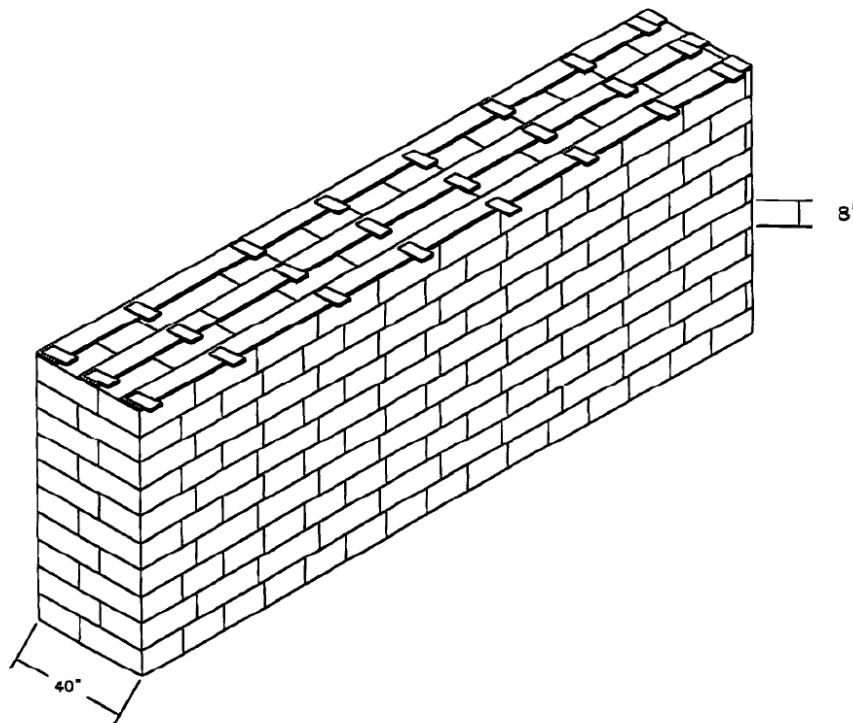
Anker West Virginia Mining Company wishes to submit an amendment to the proposed mine seal plan that was submitted to your office on 09-29-05 for the Sago Mine, MSHA ID # 46-08791. This proposal will address the addition of utilizing pilasters with the Omega Mine Seals when the mined height exceeds eight foot. Please refer to the attached technical drawing depicting construction and dimensions of this application. In closing if you have questions concerning this matter please feel free to contact me at 1-304-471-3300.

Sincerely,

John B. Sterple Jr.
Assistant Director of Safety
and Employee Development

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

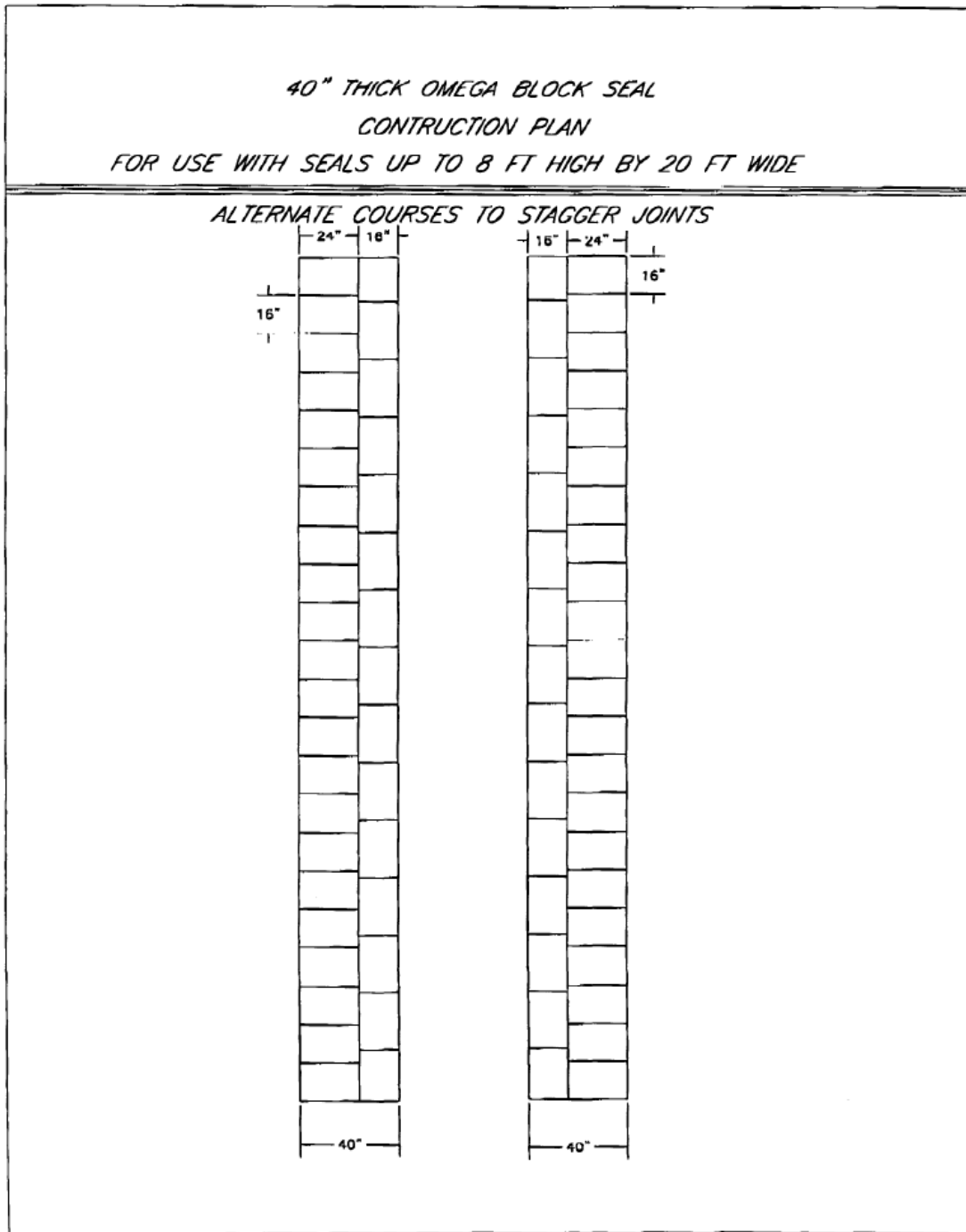
*40" THICK OMEGA BLOCK SEAL
FOR USE WITH SEALS UP TO 8 FT HIGH BY 20 FT WIDE
NO HITCHING REQUIRED*

1. Total thickness of completed seal shall be 40 inches
2. No hitching required
3. Joints must be staggered
4. All joints shall be a minimum $\frac{1}{4}$ inch thick and be motared using "BlockBond"
5. Three rows of wood planks running the entire length of the seal shall be installed across the top of the seal
6. Wedges will be placed on 1' centers or less with "BlocBond" used to fill the gaps
7. "BlocBond" shall be used as full face coating on both sides of the seal.



- seals shall be at least 10 feet from the corner of the pillar
- Sampling pipes shall be installed as per 75.335

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals



PAGE 04/09

ICG SPRUCE-FORK

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10/31/2005 14:36

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

11/30/2005 11:05 3044713442

ICG SPRUCE-FORK

PAGE 02/02

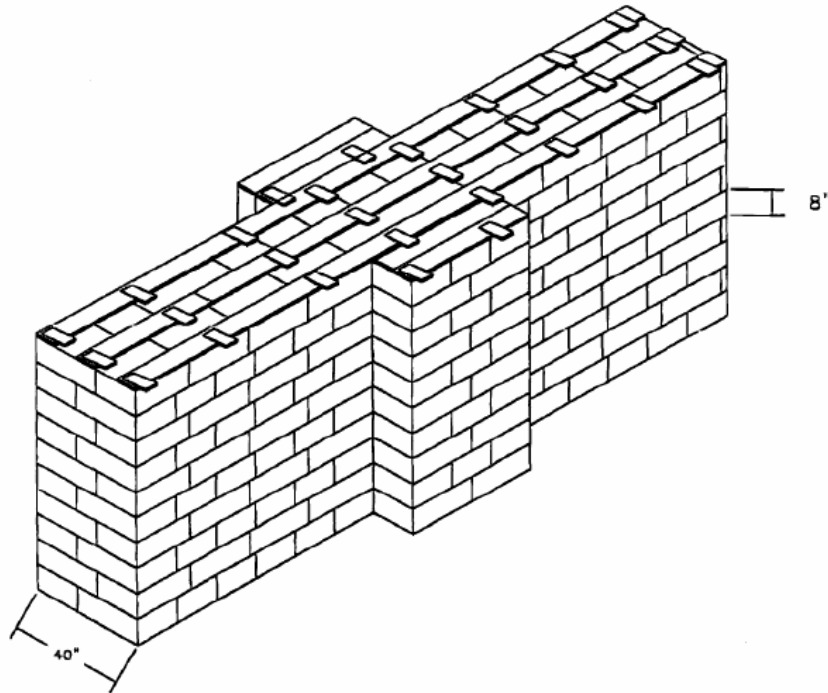
PROPOSED PLAN FOR CONSTRUCTION OF NON-HITCHED OMEGA BLOCK SEALS

1. Each seal shall be substantially constructed of (8" X 16" X 24") Omega Blocks with joints plastered with "BlocBond" and all joints shall be adequately mortared. Inby and outby face of completed seal shall be fully coated with "BlocBond"
2. Seals shall be at least forty (40) inches thick.
3. Seals shall be at least ten (10) or more feet from the corners of a pillar.
4. Seals shall be constructed in solid floor that remains unbroken. Where this is not possible, preferred site is floor that is settled. All loose broken material shall be removed from the ribs, roof and floor for at least three (3) feet on both sides of the point where the seal is to be built. All cracks shall be grouted in the site preparation area.
5. Water shall be drained from the inby face of the seal (where standing water could weaken the seal or floor) into the open portion of the mine by using a sized for drainage non-corrosive pipe with a minimum twelve (12) inches deep water trap.
6. Seals must be protected from adverse roof and floor conditions by no less than two (2) rows of timbers on four (4) foot centers or three (3) cribs on both sides of the seal.
7. TEST PIPE: Sample pipes will be installed as per SOCFR 75.335

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

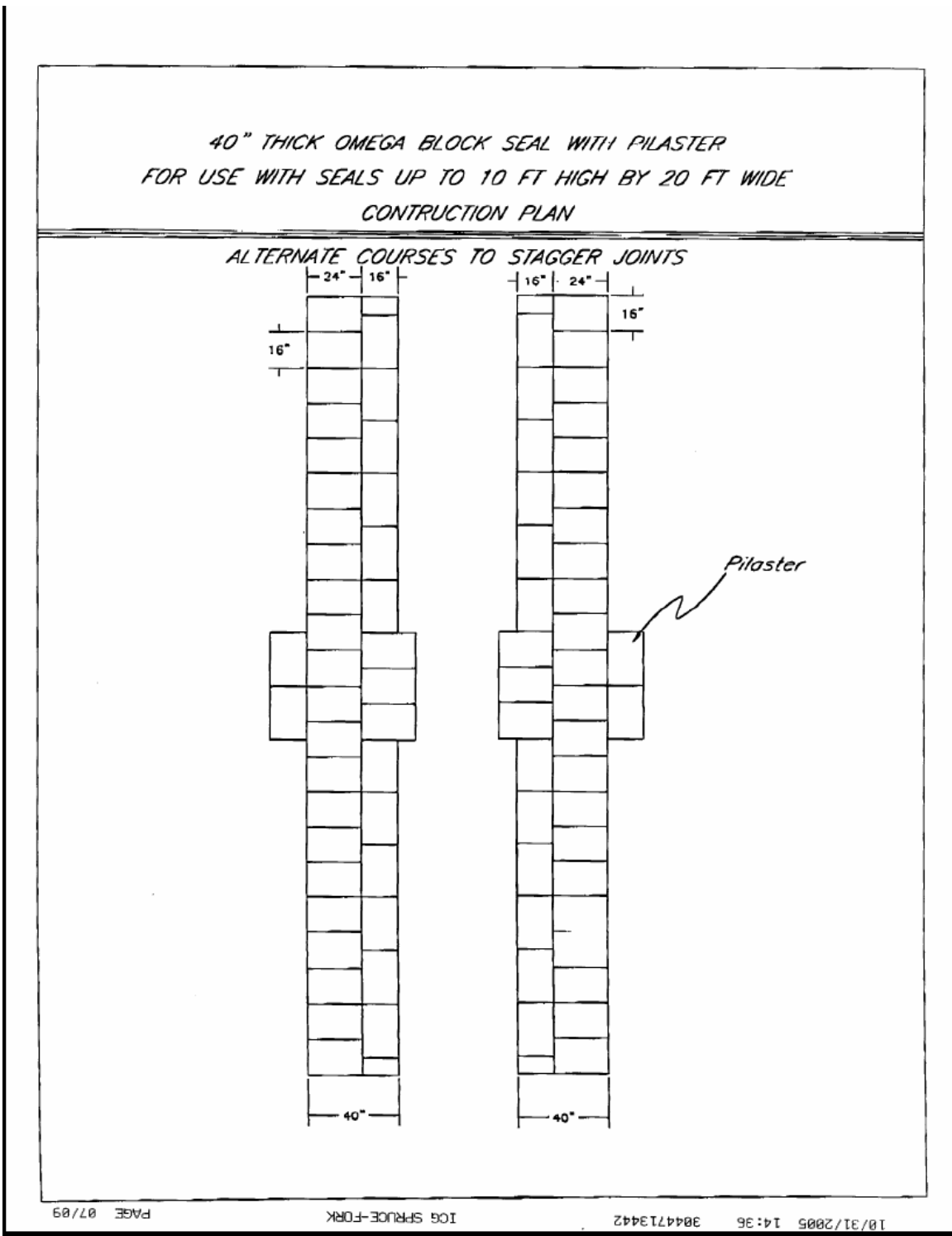
*40" THICK OMEGA BLOCK SEAL WITH PILASTER
FOR USE WITH SEALS UP TO 10 FT HIGH BY 20 FT WIDE*

1. Total thickness of completed seal shall be 40 inches
2. No hitching required
3. Joints must be staggered
4. All joints shall be a minimum $\frac{1}{8}$ inch thick and be motared using "BlocBond"
5. Three rows of wood planks running the entire length of the seal shall be installed across the top of the seal
6. Wedges will be placed on 1' centers or less with "BlocBond" used to fill the gaps
7. "BlocBond" shall be used as full face coating on both sides of the seal.

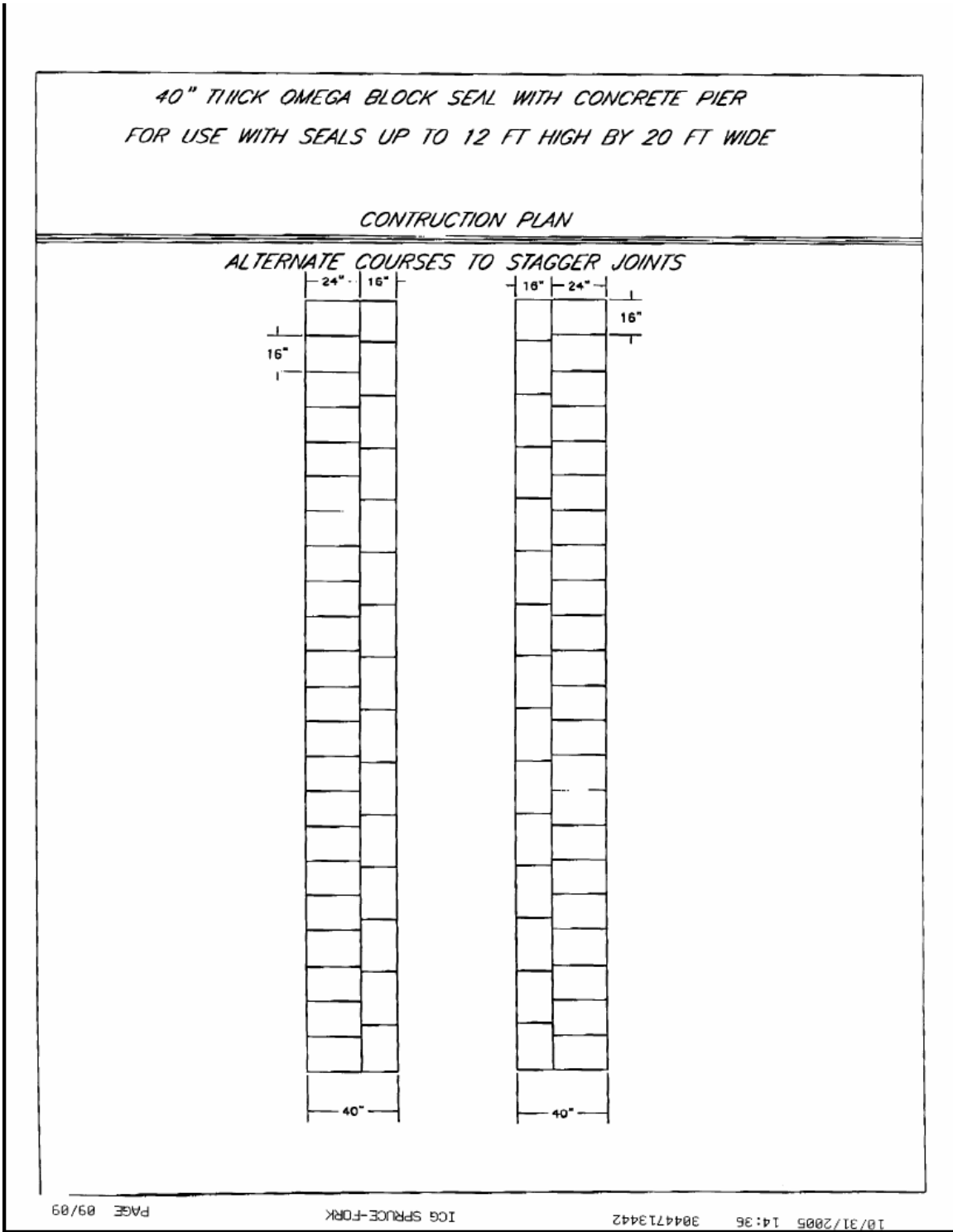


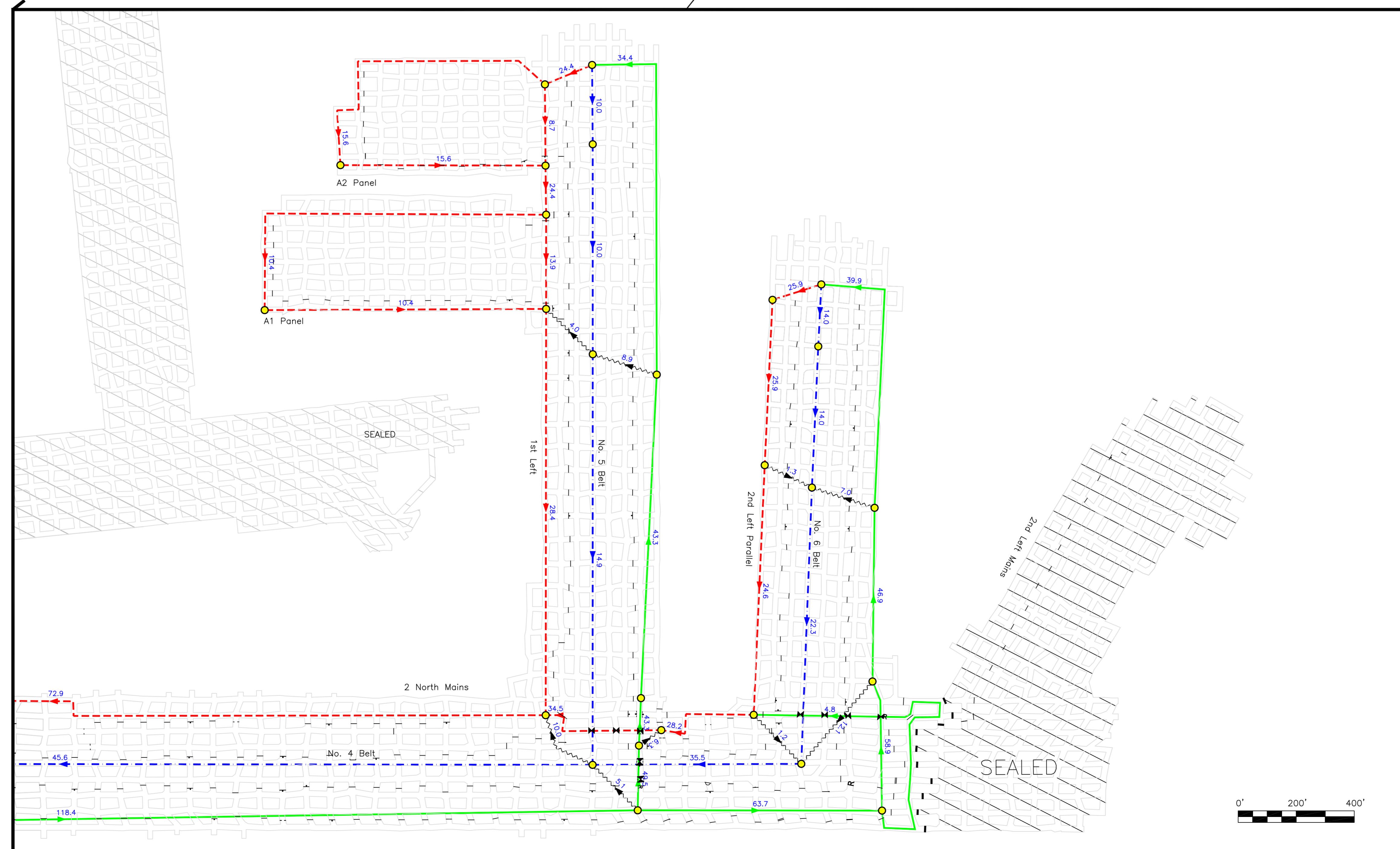
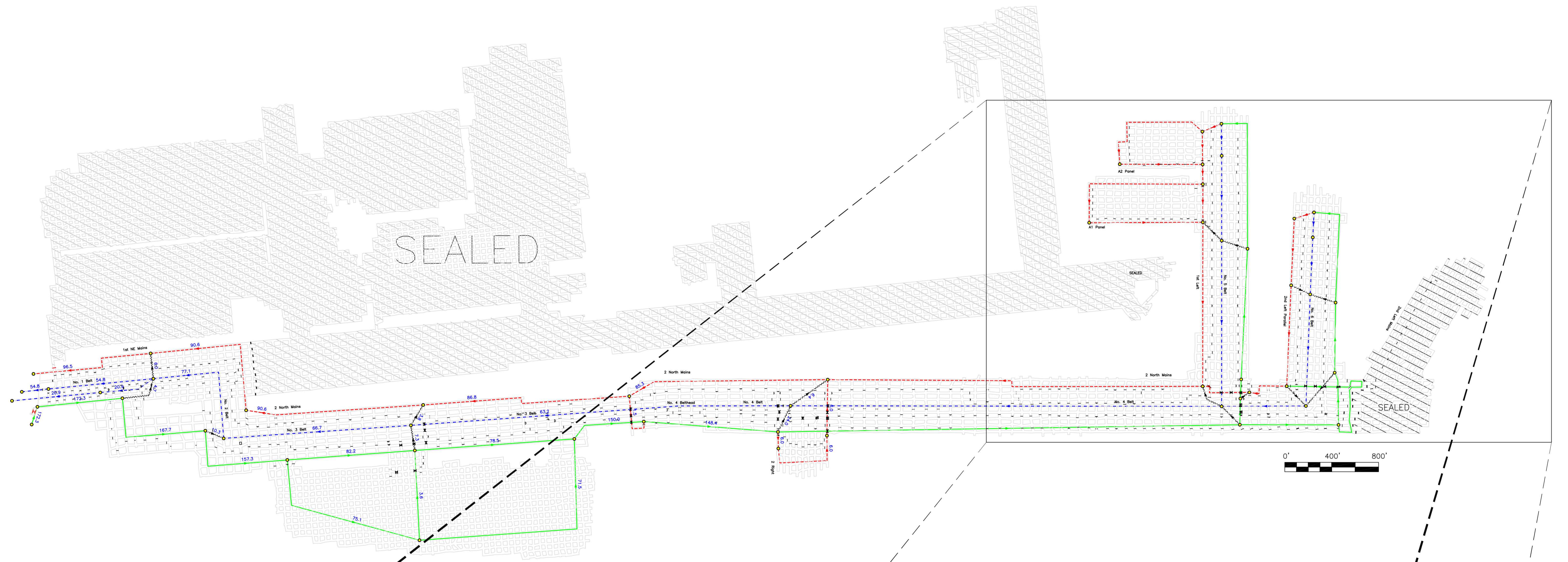
- seals shall be at least 10 feet from the corner of the pillar
- Sampling pipes shall be installed as per 75.335

Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals



Appendix K - Three Supplements to the Ventilation Plan Concerning Omega Block Seals

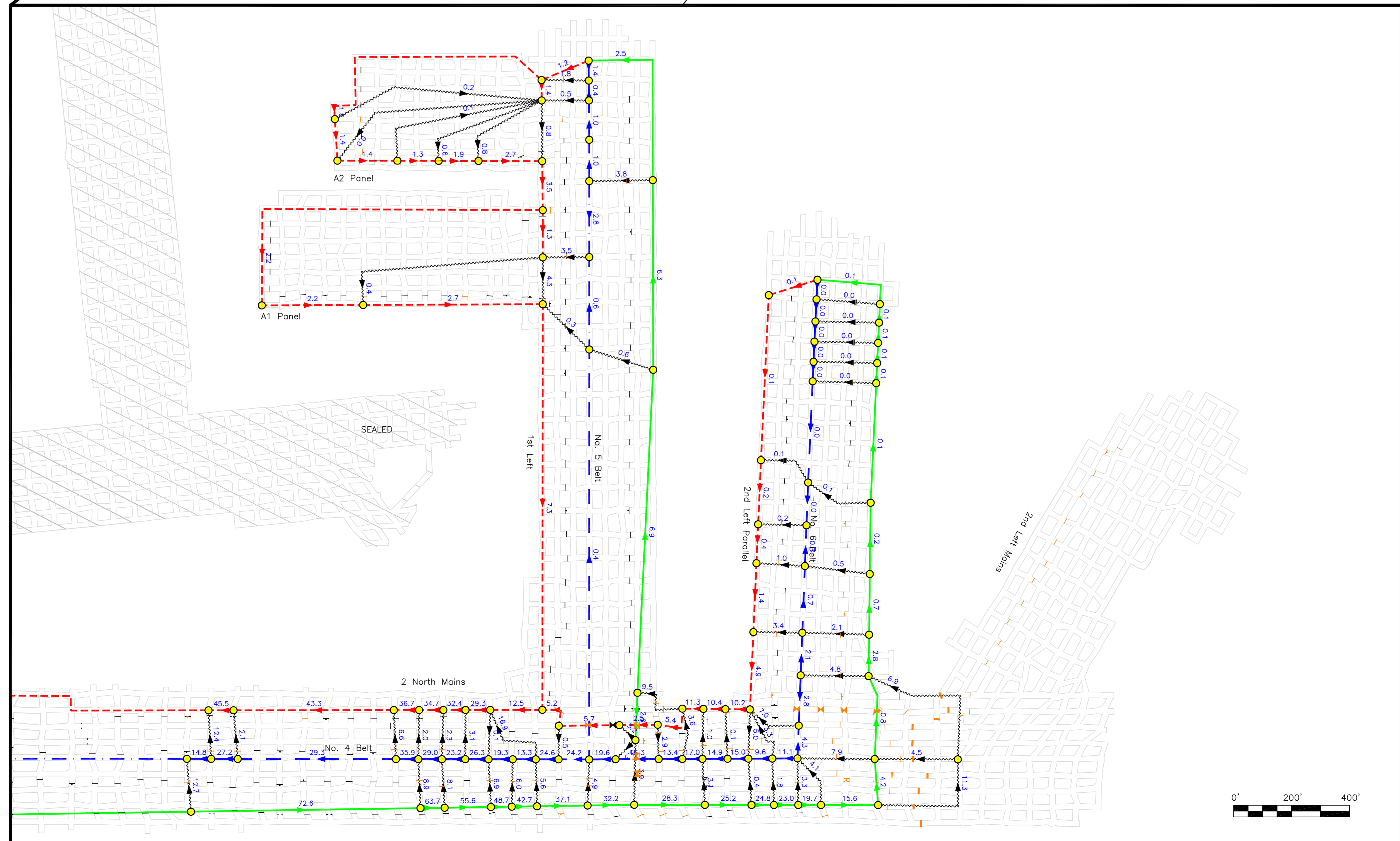
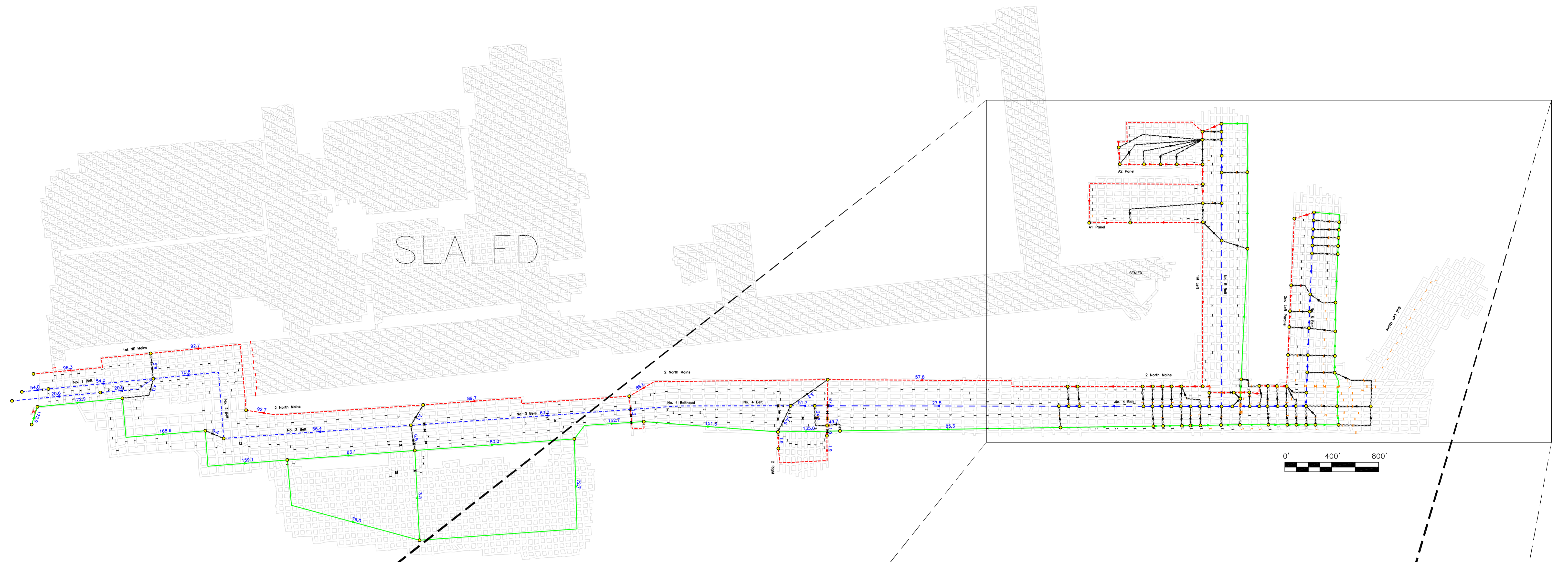




LEGEND

- STOPPING WITH MANDOOK
- STOPPING WITH MANDOOK
- OVERCAST
- PERMANENT SEAL
- REGULATOR
- FAN HOUSE
- INTAKE AIRFLOW (KCFM)
- RETURN AIRFLOW (KCFM)
- BELT/TRACK AIRFLOW (KCFM)
- LEAKAGE AIRFLOW (KCFM)





LEGEND

- STOPPING WITH MANDOOR
- DAMAGED VENTILATION CONTROL
- DAMAGED SEAL
- OVERCAST
- PERMANENT SEAL
- REGULATOR
- FAN HOUSE

30.0 INTAKE AIRFLOW (KCFM)
30.0 RETURN AIRFLOW (KCFM)
30.0 BELT/TRACK AIRFLOW (KCFM)
30.0 LEAKAGE AIRFLOW (KCFM)

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division



06AA23(d)

September 7, 2006

MEMORANDUM FOR RICHARD A. GATES
District Manager, CMS&H District 11

THROUGH: *Kelvin K. Wu*
KELVIN K. WU
Acting Chief, Pittsburgh Safety and Health Technology Center

M. Terry Hoch
M. TERRY HOCH
Chief, Roof Control Division

FROM: *Michael Gauna/mgj*
MICHAEL GAUNA
Mining Engineer, Roof Control Division

John R. Cook/mgj
JOHN R. COOK
Mining Engineer, Roof Control Division

SUBJECT: Evaluation of the Potential for a Roof Fall to Ignite a Methane-Air Mixture at the Wolf Run Mining Company, Sago Mine, Upshur County, West Virginia, MSHA I. D. No. 46-08791

An explosion initiated in the sealed 2 Left area in the northern portion of the Sago Mine on January 2, 2006. Maps indicate that three roof falls occurred in this area prior to seal construction. Examinations after the explosion determined that additional roof falls had occurred that were not shown on the mine maps. The precise timing of these falls relative to the mine explosion is not known.

The Sago Accident Investigation Team requested that Roof Control Division (RCD) personnel assess the likelihood that these roof falls ignited explosive concentrations of methane at the Sago Mine. The RCD evaluated the possibility of a roof fall initiation through background literature searches and in-mine investigations.

Background

Roof Control - The primary roof support consisted of 3/4-in. x 6-ft., fully grouted bolts on approximately 4-ft. centers. The bolts were installed with 8- x 8-in. bearing plates which were typically supplemented with larger "Spider" or "Pizza Pan" plates for additional surface control. In some areas, welded wire mesh was installed with the 8- x 8-in. plates for improved roof surface control. Cable bolts also were noted in the sealed 2 Left area. In the areas investigated by RCD, the cable bolts were only used occasionally and there was evidence that wood cribs and wood Propsetter standing supports also had been used on an infrequent basis. Explosive forces had warped and folded the "Spider" and "Pizza Pan" plates, torn welded wire mesh from the roof in places, and dislodged wood supports.

Pillar stability was evaluated using Analysis of Retreat Mining Pillar Stability (ARMPS) software. For the typical 55- x 80-ft. center pillar, 18-ft. mining width, 15-ft. bench mining height, and 320-ft. overburden, the pillar stability factor (SF) is 2.2. The effective pillar stability is actually higher because the 15-ft. mined height only applies to the panel entries and not the crosscuts. The crosscut mining height of only 7 to 8 ft. serves to reinforce and improve the pillar stability. In the areas traveled, no evidence of abnormal pillar stress or pillar dilation was encountered. This observation is consistent with the satisfactory SF value. The pillar rib conditions in the entries and crosscuts appeared to be stable.

2 Left Roof Falls

Mining was completed in 2 Left in late October and the seals were completed on December 11, 2005. Prior to the January 2nd explosion, three pre-sealing roof falls had been identified on the mine map. Roof Control Division personnel visited the mine on January 30, 2006, and observed that these three pre-sealing roof falls had extended (see Drawing 1). Also, four additional roof falls were observed that were not shown on the mine map prior to seal completion (see Drawing 1 green shaded falls labeled "Before 1/27/06"). It is not known exactly when these four newer roof falls occurred. The roof fall areas observed were consistent with roof fall information collected by other investigators during initial exploration on January 27, 2006. Roof Control Division personnel again observed the 2 Left area on May 11, 2006, and found additional roof falls that were not present on January 27 or 30 (see Drawing 1 purple shaded falls labeled "After 1/27/06").

Other investigators have determined that the explosive forces propagated in every direction from the area near surveying spads 4010, 4011, 4047, and 4048 (see Drawing 1). The seven roof falls that were observed during the January 30 investigation range in distance from approximately 150 ft. to 470 ft. from this area. The

rubble and exposed fall cavity of the five closest roof falls (within 440 ft.) were inspected. Access to the two roof falls beyond 450 ft., was obstructed by deep water in bench mined entries.

The roof falls extended 7 to 12 ft. above the mining horizon. Gray shale was the predominant rock type visible in the fall rubble and in the exposed cavity of the roof falls. However, thinly bedded sandstone beds, interspersed with shale layers were exposed at the top of the fall rubble, roughly 8 to 12 ft. into the immediate roof in three locations (see Drawing 1).

The fall rubble consisted of rock slabs of varying thickness and geometry. The falls encompassed the entire entry width and primarily affected the entries and adjoining intersection(s) as opposed to crosscuts. Thus, there appears to be a general tendency for north-south migration of the roof fall areas (see Drawing 1). Roof support in the vicinity of the roof falls consisted of ¾-in.-diameter, 6-ft.-long, fully grouted resin bolts installed with 8- x 8-in. roof bearing plates and "Spider" or "Pizza Pan" plates. Cable bolts were installed near some of these roof falls, wire mesh had been installed near the perimeter of two of the roof fall cavities, and wire mesh was noted under the fall rubble of a third roof fall. The fully grouted bolts were the only roof support that could be observed within the roof fall rubble.

Geology

The Sago Mine is developed in the Middle Kittanning coal seam. The overburden, measured from the base of the seam to the surface, ranges from 230 to 320 ft. in 2 Left and the immediate roof consists of gray shale grading upward into sandy shale and sandstone with shale bedding.

Exploratory Drill Hole SF17-97 is situated immediately adjacent to the sealed area (Drawing 1). Drill core from this hole was used to assess the stratigraphy above the Middle Kittanning coal seam (see Table 1). The roof falls noted in the course of the investigations are within an 800-ft. radius of this hole. It is reasonably likely that the same sequence of units is present above the coal seam in the vicinity of the roof falls in the sealed area. Coal measure geology is known to change substantially over short distances (e.g. due to depositional features such as sand channels). However, the rubble observed in the falls appeared to be gray shale overlain by bedded sandstone (i.e. generally consistent with Table 1). Table 1 provides an example of the thickness of individual lithologic units, the distance from the top of the Middle Kittanning seam, and the distance from the top of the typical mining horizon to the lithologic units based on information from Drill Hole SF17-97. In much of 2 Left, 3 to 5 ft. of shale roof (3.6 ft. average) typically was mined with the coal.

Table 1
Drill Hole SF17-97 Lithology
Example of Immediate 40 ft. of Roof above Middle Kittanning Coal Seam

Lithologic Description	Thickness, ft.	Distance to Lithologic Unit from Top of Coal Seam, ft.	Distance to Lithologic Unit from Top of Mining Horizon ⁽¹⁾ , ft.
Dark Gray Shale	15.70	41.39	37.8
Dark Gray Sandy Shale	9.30	32.09	28.5
Shale	5.30	26.79	23.2
Dark Gray Shale	5.40	21.39	17.8
Sandstone with Shale Streaks	3.30	18.09	14.5
Dark Gray Sandy Shale	7.20	10.89	7.3
Dark Gray Shale	8.30	2.59	Top of Mining Typically Within this Unit
Shale	2.59	0	Typically Mined
Bone - top unit of coal seam	0.30		

Note (1) = Top of mining at 3.6 ft. average depth into overlying shale

Shale Description - Shale samples from the immediate roof in the vicinity of spad 4010 were studied microscopically for the Sago Mine explosion investigation. The samples were classified based on grain size and bedding spacing as "laminated siltstone" according to Potter's 1980 textural classification of shales. They are characterized by very similar textures having a matrix composed of very fine-grained (0.005-0.2 mm) muscovite lathes, which are randomly oriented, but arranged in thin bedding layers. Contacts between adjacent bedding layers are gradational, defined by different grain sizes or mineral contents. The very fine-grained, muscovite-dominated layers host approximately 8-12% angular quartz grains, which are approximately 0.01 mm in diameter and isolated by the surrounding matrix. Coarser-grained layers are dominated by angular quartz grains, which are approximately 0.1 mm in diameter and touch along tangential contacts to leave angular interstices that are filled with finer-grained muscovite. The very finest-grained layers host very fine-grained, clay sized (<0.003 mm) muscovite with no quartz, and represent planes of preferential weakness along which delamination preferentially occurs.

Sandstone Description - Three sandstone samples (RCD-SSA, RCD-SSC, and RCD-SSD) collected from the fringe of the roof fall rubble are described below. The sample locations are depicted in Drawing 1.

Sample RCD-SSA is characterized by 1/16-in. to 1/8-in. crossbedded laminations of light-colored, fine-grained quartz sandstone that form beds ¼ in. to ½ in. thick, and are bounded by 1/64-in. dark-colored laminations that host abundant muscovite and biotite flakes. The sandstone laminations are well indurated, although scratch marks from a knife blade are visible. Sandstone laminations commonly pinch down from ¼ in. to 1/16 in. over a distance of 3 in., to be bounded by dark-colored micaceous laminations.

Sample RCD-SSC is characterized by 1/16-in. to 1/32-in. laminations of alternating light-colored, fine-grained quartz sandstone and dark-colored siltstone. The light-colored quartz sandstone laminations are well indurated, and alternate with moderately indurated dark-colored siltstone laminations, which host very fine-grained flakes of biotite mica. Fine-grained flakes of muscovite mica are commonly distributed within the light-colored quartz laminations, which may also host microcline or orthoclase grains, due to a faint pink tint. Very thin (1/64-in.) carbonaceous bedding partings are distributed at approximate 1½-in. intervals. Laminations of all compositions can be easily scratched with a knife blade, indicating that quartz grains are not sutured.

Sample RCD-SSD is characterized by 1/16-in. to 1/8-in. crossbedded laminations of light-colored, fine-grained quartz sandstone that alternate with 1/32-in. dark-colored laminations of very fine-grained siltstone, which hosts abundant 1/16-in. flakes of muscovite mica. The sample also hosts a ¾-in.-thick bed of fine-grained, dark-colored, well indurated siltstone that hosts fine-grained biotite and muscovite mica, and contains 1/64-in. stringers of light-colored quartz siltstone. The entire sample is approximately 2 in. thick, and is bounded by muscovite-rich bedding partings.

Historical Research on Roof Falls and Ignitions

The majority of methane-air ignitions can be attributed to frictional ignitions by some form of machine or mechanical action. ^(d,f) However, within the time frame from 1960 to present, four instances were found where the most likely source for the ignition was a roof fall ^(c, d, k, l). One instance involved a roof fall on a mining section and three instances referred to falls of ground within the extracted area of a longwall panel. The precise ignition mechanisms could not be determined conclusively. However, the most likely scenario from these cases was determined to be ignition through rock-on-rock frictional forces.

The factors involving ignition from roof falls have been studied with laboratory testing where the ignition capability (incendivity) of both mine roof rock and steel roof support materials were investigated. In addition, the ignition potential from compression of methane-air-coal dust mixtures has been studied in the laboratory.

Steel Roof Support Incendivity - Tests have been performed in which roof bolts and cable bolts were broken in tension and roof bolt heads were pulled through plates in an explosive methane-air mixture. Tests on roof bolts and plates produced no sparks or ignitions ^(c). However, sparking was observed in tests on cable bolts. In fact, sparking had been observed from breaking cable bolts in underground coal mines in the U. S. in the early 1990's. In response to these observations, laboratory testing was conducted to assess cable bolt failure incendivity. The test results indicated that although sparks are produced by breaking cable bolts these sparks are not hot enough, not large enough and are not of sufficient duration to ignite an explosive methane-air mixture ^(a, b).

Tests have also been performed to try to determine the possibility of igniting an explosive methane-air mixture by impact friction. These tests evaluated the incendivity of various combinations of materials when impacted together (i.e. by dropping one from a fixed height onto another). Samples included sandstone, shale, roof bolt steel and aluminum. Several combinations produced sparks, but the only ignitions were initiated by dropping aluminum on a rusty steel plate ^(c). Despite these findings, however, the researchers determined that sparks from failing steel roof supports cannot be conclusively ruled-out as an ignition source because of the limitations of laboratory testing simulating the actual underground environment.

Rock-on-Rock Frictional Incendivity - Laboratory work indicates that specific rock types (e.g. sandstones) do have an incendivity potential ^(c, d, f). Studies have attempted to determine whether or not an ignition could occur due to heat and/or sparks produced by the friction of rocks rubbing together during a roof fall. In laboratory settings, two rock specimens have been rubbed together by pressing a rock against another rotating rock wheel. Ignitions have been produced in these experiments with varying rock types under varying test conditions. Video records of these experiments indicate that the ignitions appeared to be from the heat trail behind the hot spot on the rocks and not the sparks that are produced ^(d). Rocks high in quartz content appear to be most susceptible to producing the friction required for heating but, rock composition is also a large factor ^(d). The study indicated that the rock composition, (ie. the overall proportion of quartz, feldspar and rock fragments in the grain framework) was a better indicator than quartz content alone of the incendivity of a particular rock ^(d).

It has been noted that quartz-rich rock types (sandstones and quartzites) can produce a voltage when minutely deformed by applied mechanical stress. The mechanism known as piezoelectricity was discovered in 1880 by Pierre and Paul-Jacques Curie. They found that when certain types of crystals including quartz, tourmaline, and Rochelle salt, were compressed along certain axes, a voltage was produced on the surface of the crystal. In a piezoelectric crystal, the positive and negative electrical charges are separated, but symmetrically distributed, so that the crystal overall is electrically neutral. When a mechanical stress is applied, this symmetry is disturbed and the crystals are polarized, and the charge asymmetry generates a voltage across the

material. The charge separation may be described as a resultant electric field and may be detected by a voltmeter as a voltage between the opposite crystal faces. The phenomenon of piezoelectricity is widely used in a variety of electronic devices, including igniters. Currently, synthetic material such as carefully prepared ceramics are used as igniters since they exhibit the most efficient piezoelectric properties (g.i).

As a geologic phenomenon, piezoelectricity has been invoked to explain certain effects associated with earthquakes, such as “earthquake lights”, the lightning or fireballs that have been reported in the vicinity of earthquake epicenters. Piezoelectricity also has received some attention in the field of earthquake prediction, where some suggest that the mechanical stress imparted by shifting tectonic plates may induce voltages in rocks, which might be recorded as a precursor to earthquakes. Although it is thought that in rock types where crystals are randomly oriented the piezoelectric effect is self canceling, it may be that in rock types with preferentially oriented quartz crystals (such as gneiss or quartzite), such voltages may be generated (i).

Methane-Air and Coal Dust Compression - Computer simulations have predicted that air temperature could increase rapidly to the point of igniting methane or coal dust during a roof fall. Subsequently, laboratory tests simulated air compression from a confined falling object and verified that ignitions could occur with certain methane and coal dust mixtures. The laboratory tests had no ignitions with any methane-air mixture in the absence of coal dust. Also, the numerical simulation for a full-scale mine scenario indicated that ignition could only be achieved with a falling block of at least 65- x 65-ft. planar area falling simultaneously (e).

Summary

It is difficult to definitively exclude a roof fall as a potential ignition source for the explosion at Sago Mine. However, it appears to be an unlikely source for the following reasons:

- Shale is the predominant rock type visible in the roof fall rubble. Specifically, the material referred to as shale is classified as “laminated siltstone” with low quartz content in a soft matrix that inhibits quartz grain-to-grain contact. This rock type is not as conducive to frictional heating or piezoelectric sparking as sandstones that have been suspected as ignition sources in roof falls (d). An exploration drill hole in the vicinity indicates that rock classified by core logging as sandstone exists above the mining horizon. Three roof fall cavities had sandstone beds exposed at the top of the fall rubble roughly 8 to 12 ft. into the immediate roof above the underlying shale. The samples collected from the roof fall rubble are a variety of sandstone that is micaceous, and characterized by thin, alternating laminations of fine sand, silt, and mica partings. In contrast, the sandstones associated with piezoelectric sparking and rock-on-rock frictional heating are

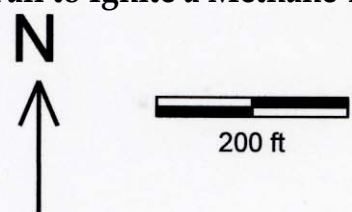
commonly considered to be dominated by quartz, exhibit stronger cementing or even quartz grain fusing (i.e. the metamorphic rock "quartzite"), and occur in more massive beds. Furthermore, the roof falls observed are outside the area where the explosion is inferred to have originated. Thus, rock-on-rock or piezoelectric ignitions are unlikely ignition sources.

- The only metal roof supports noted in the fall rubble were fully grouted bolts and the wire mesh noted under the rubble of one fall. These steel roof support materials have not been associated with ignitions in experiments or in documented observations of gob ignitions. It was not possible to determine whether cable bolts noted near the roof falls could be hidden in the fall rubble. However, previous laboratory testing of the sparks from cable bolt failure did not ignite methane-air explosive mixtures.
- All of the roof falls observed in the 2 Left seal area that were not noted on the mine maps prior to sealing, encompassed a much smaller area than the 65- x 65-ft. highly confined area required in computer simulations to ignite methane by compression.

Attachment

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Drawing 1. Roof Falls in the Sago Mine 2 Left Seal Area.

Orange = Roof fall areas noted prior to sealing (**Pre-Sealing**)

Green = Roof fall areas noted as having occurred before 1/27/06 during exploration after the explosion (**Before 1/27/06**)

Purple = Roof Falls noted during investigations after 1/27/06 (**After 1/27/06**)

X = Sandstone beds noted in top of roof fall cavity & sample collected

Appendix P - An Evaluation of Features & Description of Features Observed Inby Spad 4010
U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division




06AA23(a)

August 31, 2006

MEMORANDUM FOR RICHARD A. GATES

District Manager, CMS&H District 11

THROUGH:


KELVIN K. WU

Acting Chief, Pittsburgh Safety and Health Technology Center


M. TERRY HOCH

Chief, Roof Control Division.

FROM:


SANDIN E. PHILLIPSON

Geologist, Roof Control Division

SUBJECT:

Evaluation of Features at Wolf Run Coal Company, Sago Mine,
MSHA I. D. No. 46-08791

Observations

As requested by the MSHA Accident Investigation Team (Sago), observations of geologic features were performed in the formerly sealed 2nd Left Mains, in the vicinity of spad 4010 on February 21, 2006. The purpose of the observations was to evaluate and document two linear features in the mine roof in the vicinity of spad 4010.

Observations were restricted to the #5, #6, and #7 Entries, between the 1st and 3rd Crosscut from the #1 Entry of the Main. The 2nd Left Mains are developed at an approximate 60° angle from the left side of the Mains, such that the first crosscut in the 2nd Left Main in the #6 Entry is actually the third crosscut in the #1 Entry.

Observations began just inby spad 4010, in the #6 Entry, and proceeded down-grade into the next, benched intersection at spad 4047. The observation traverse proceeded east from spad 4010 into the #7 Entry through the intersection with spad 4011, and then inby along the benched #7 Entry for two crosscuts to the spad 4063 intersection. Observations continued in the unbenched crosscut between spads 4045 and 4047.

Detailed observations concluded just inby the spad 4010 intersection, where the two linear roof features were scrutinized. A similar feature was briefly examined in the neighboring #5 Entry, just inby the spad 4028 intersection.

The observation area is characterized by a variety of abundant structural geologic features and stress-related features. Abundant, very well developed joints were observed in the roof (Figure 1). The dominant joint set is oriented with a strike of N 85°E, and is characterized by nearly vertical joints that are spaced approximately 12-20 inches apart. Joints of this set were present across the entire observation area, from the spad 4010 intersection to the spad 4063 intersection, a distance of two crosscuts. Two minor, irregularly spaced sets of joints, oriented respectively at N 57°W and N 30°E, are aligned parallel to the trend of slickenside planes. A prominent slickenside plane that controlled a zone of buckled roof strata was oriented N 30°E, with a dip of 35° toward the southeast, and is located in the southeast corner of the spad 4047 intersection. A pair of slickenside planes, oriented N 67°W and dipping 50° NE, formed a linear, coffin-shaped roof cavity that trended through the spad 4045 intersection, crosscutting a wide, deep horizontal stress pot-out.



Figure 1. Very well developed joint set, characterized by N 85°E-striking joints spaced 12-20 inches apart. Photo taken in the crosscut between spads 4010 and 4011.

Horizontal stress pot-outs were common in the observed area, and were consistently oriented with a long axis aligned along a bearing of approximately N 5-7°E (Figure 2). Long-running cutters, localized at the intersection between the roof and rib, were consistently located along the west rib of the observed entries. In the #7 Entry, a long-running cutter left the rib and crossed through the spad 4063 intersection along a bearing of N 10°E.



Figure 2. Downward-buckled zone of thinly laminated shale represents a stress pot-out that follows a trend of approximately N 5-7°E. Other linear buckled zones of shale are aligned along the same bearing throughout the observed area.

Ground conditions were particularly degraded in the observed portion of the #7 Entry, with abundant stress pot-outs and cutters developed at the projected intersection of the mutually perpendicular slickenside planes.

Detailed observations concluded just inby the spad 4010 intersection, where a small scaffold was constructed to reach the roof and observe two linear features that were present (Figure 3). Each linear feature was characterized by a pair of parallel ridges that trended across the exposed flat plane of the roof. One pair of parallel ridges was oriented along a bearing of N 43°E, while the other pair of parallel ridges was oriented along a bearing of N 70°E. The parallel ridges were spaced approximately 2-3 inches apart, and protruded approximately ¼ inch below the flat roof horizon. The roof horizon is characterized by thinly laminated, muscovite-rich gray shale that in the immediate vicinity of the area hosts oval-shaped, downward-buckled stress pot-outs.

The parallel ridges are characterized by an irregular, rough texture, but are bounded by immediately adjacent patchy areas of approximately 5-10 cm² that represent a flat, smooth, slickenside plane that follows the base of the muscovite-rich gray shale (Figure 4). No part of the linear ridges appeared to extend upward into the thin shale layers of the roof, as indicated by a thin brow that intersected the edge of the linear features along the trend of a prominent stress cutter. The collection of a piece of the protruding ridge was attempted with a knife blade, but the ridge represents only a very thin (<1 mm) coating of slickensided shale, and scratching with the knife blade immediately exposed the overlying muscovite-rich gray shale above the thin coating. This resulted in the whitish streaks shown in Figure 5.



Figure 3. Two pairs of parallel ridges exposed on the underside of the shale roof, and disrupted where a shallow stress pot has broken out of the roof. No evidence of the linear features was found in the thin brow of the stress pot along the trend of the linear feature, indicating that it does not extend upward into the rock.



Figure 4. Two pairs of linear, parallel ridges exposed on the bottom surface of the gray shale. Center feature lies along a trend of N 70°E, forming an acute angle with the feature at left, which is oriented along a trend of N 43°E. There is no indication of the linear features extending above the thinly laminated immediate layer of the roof, as exposed in the thin brow formed by the stress pot-out.



Figure 5. Light brown linear streaks along the trend of the parallel linear ridges represent knife scratch marks from an attempt to collect fossil material. Location is the vicinity just inby the spad 4010 intersection. Twin parallel ridges pass beneath the embossed, square skin control plate.

Discussion

The purpose of the February 21st mine visit was to observe and identify two pairs of linear features located in the vicinity of spad 4010, in the 2nd Left Mains. Although there are abundant structural geologic discontinuities in the surrounding area, including joints and slickensided faults, the pair of linear features in question is not structural geologic features. Instead, the linear features observed just inby spad 4010 in the #6 Entry, and portrayed in Figures 3-5, represent the remnants of a pair of fossilized trees, with each linear feature representing the top, tangential edge of a single tree. The rough texture of the linear feature represents the trace fossil impression of the tree bark as preserved against the bottom layer of the overlying muscovite-rich gray shale, and the pair of parallel ridges represents compaction of the muscovite-rich gray shale downward around the formerly circular boundary of the tree trunk. Although the fossil tree was removed by mining the immediate shale roof, the linear features represent the expression of the top edge of the tree where it tangentially contacted the bottom of the bedding plane exposed in the shale roof.

If you should have any questions regarding this report, or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.

Appendix P - An Evaluation of Features & Description of Features Observed Inby Spad 4010

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division



06AA23(c)

September 1, 2006

MEMORANDUM FOR RICHARD A. GATES

District Manager, CMS&H District 11

THROUGH:

KELVIN K. WU

Acting Chief, Pittsburgh Safety and Health Technology Center

M. TERRY HOCH

Chief, Roof Control Division

FROM:

SANDIN E. PHILLIPSON

Geologist, Roof Control Division

SUBJECT:

Description of Features Observed in the Roof Inby Spad 4010,
2 Left Mains, in Wolf Run Mining Company, Sago Mine, MSHA
I. D. No. 46-08791

Background

As requested by the Sago Accident Investigation Team, the author witnessed the extraction of a mine roof sample on March 1, 2006 by personnel from R. J. Lee consultants. The sample extraction area is located just inby spad 4010 (Figure 1) where two prominent features are located in the roof (Figure 2). The features generated interest because they are located in the area where the explosion in 2nd Left Mains is believed to have originated. Because the features were not recognized as being widespread, they were quickly referred to as "anomalies." Due to their location in the area interpreted as the explosion site, some parties speculated that the linear "anomalies" might represent the effects of lightning arcing across the mine roof. Although initial observations conducted by Roof Control Division (RCD) personnel on February 21, 2006 (RCD February 27, 2006 Draft Memo) indicate that the linear features represent compaction along the length of a tree fossil, consultants retained by the mine collected samples of the features in order to document any possible effects of lightning.

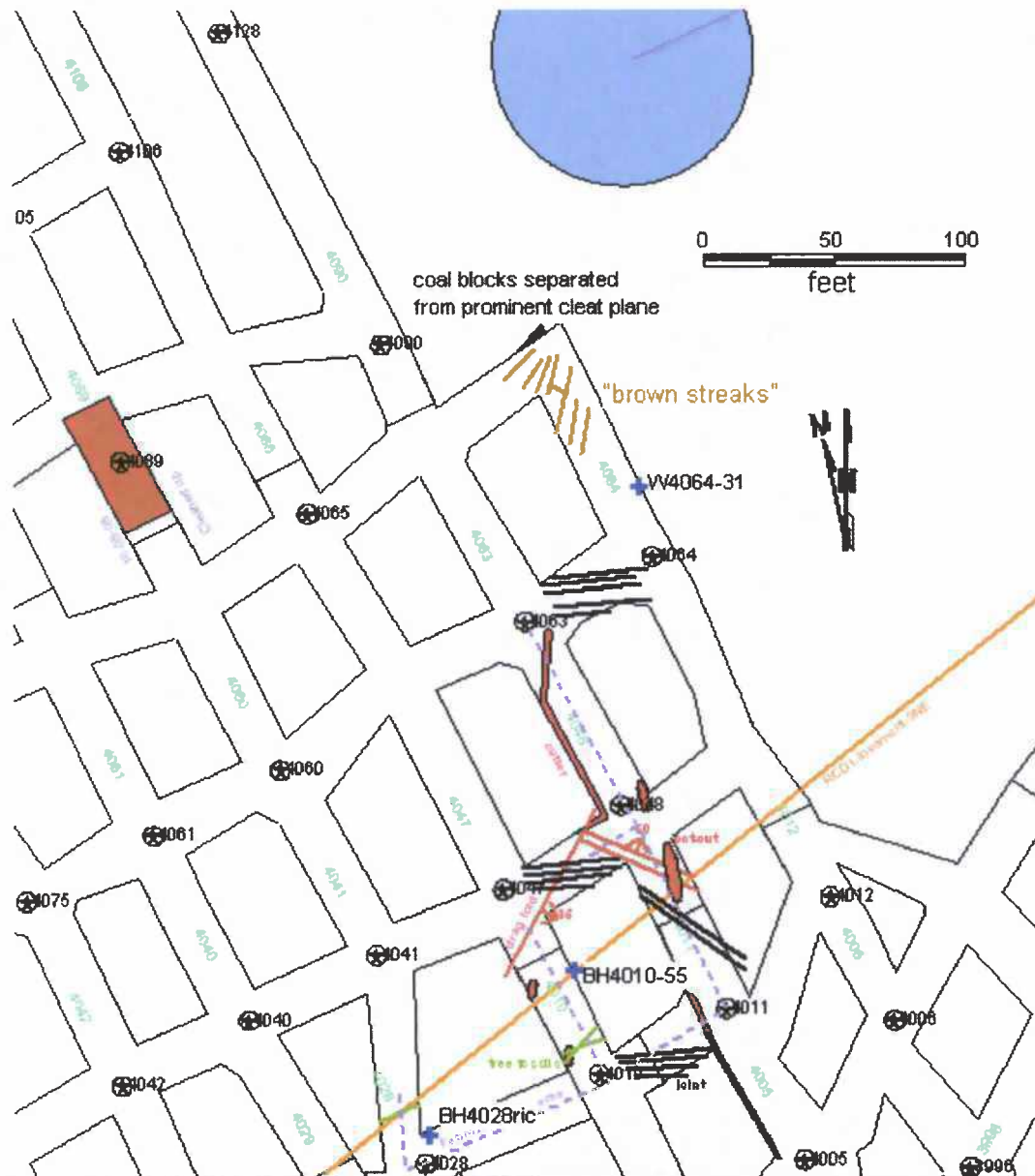


Figure 1. Map of geologic features in a portion of the 2nd Left Mains, showing results of mapping from February 21 and March 20, 2006. Sample collection area is centered on dark green features just inby spad 4010. Dashed purple line indicates February 21, 2006 observation traverse.



Figure 2. Two sets of paired, linear ridges define an acute angle in the roof horizon just inby spad 4010. R. J. Lee sample collection effort on March 1, 2006 extracted samples of this feature. In this photo, the linear feature is truncated by a shallow stress pot-out.

The effects of lightning have been documented in unconsolidated soil, loose sand, and solid rock. The preserved effects of lightning on rock and soil can form silica glass known as “fulgurite”. Fulgurite has been found in soil and sand dunes, forming a small tunnel with walls of silica glass, presumably formed by high temperature melting and fusing of quartz sand grains (Figure 3). Other experiments documented on various websites indicate that fulgurite can be formed in any rock composition with sufficient voltage. The longest fulgurite tunnel was reportedly approximately 20 feet long, and a search of available literature suggests that the fulgurite tunnels are 2-3 inches in diameter. Photos available on websites indicate that the cylindrical, glass-walled tunnels undulate, twist, and turn, commonly branching or bifurcating through the unconsolidated soil material. Although lightning can affect solid rock, available observations indicate that fulgurites in rock are restricted to the top several feet of mountain peaks, and seldom penetrate more than a few inches into the rock. Lightning can magnetize iron minerals in rock outcrop, as observed by the author at a location in the Colorado Rocky Mountains.



Figure 3. Sample of fulgurite for sale on internet website, showing branching texture of bubbled silica glass.

Thus, visible effects of lightning on a rock would be expected to include the formation of silica glass or quartz grains that showed signs of partial melting or fusing. Glass, of which volcanic obsidian is an example, is very distinctive in the geological environment. Most geologically formed glass is associated with volcanism, in which high-temperature molten rock is frozen before crystals can nucleate and grow.

Methodology

The mine's consultants obtained four rectangular samples from the roof and retained three for testing. Samples were obtained using a battery operated "ripsaw" to define a rectangular cut sequence to delineate the sample. After a notch was cut to provide working room, a wide, flat chisel was used to force separation along a delamination plane along bedding to remove the sample from the roof (Figure 4).



Figure 4. Shallow rectangular box remains where samples of the linear "anomaly" were retrieved on April 6, 2006 (center). Samples were collected from the same "anomaly" on March 1, 2006 by R. J. Lee as indicated by shallow box located at right of photo. Samples 3045477 and 3045475 were retrieved from the box on the right side of the field of view.

Splits of the three samples obtained by R. J. Lee were passed to MSHA on March 13, 2006, and obtained by the author on March 16, 2006. Two of the samples were cut with a water-cooled, diamond blade rock saw at the Approval and Certification Center (A&CC) to obtain a cross section through the area where the linear feature appears (Figure 4). The cross section slice was annotated with five rectangular blocks to be prepared for thin sections. Locations of the rectangular blocks were marked on the mating surface of the original sample split (Figure 5). Each outlined block was then sawed from the cross section slice to define an individual sample (Figure 6). The chips were then sent via FedEx to Spectrum Petrographics in Vancouver, Washington, to prepare thin sections of the samples. Thin sections are slices of the rock that are ground so thin that light can pass through the sample, while glued to a microscope slide so that microscopic textures and details can be documented. The completed thin sections were received on April 7, 2006 (Figure 7).



Figure 5. Split of Sample 3045477 obtained by R. J. Lee on March 1, 2006 at A&CC, showing cross section across the linear feature observed inby spad 4010, 2nd Left Mains. The work shown was performed at the Approval and Certification Center.



Figure 6. Cross section slice from Sample 3045477 (top pair) and Sample 3045475 (bottom pair) further separated into individual chips ready to be made into thin sections for detailed study. The work shown was performed at the Approval and Certification Center.



Figure 7. Completed thin sections (glass microscope slides) and original sample chips prepared at A&CC returned by Spectrum Petrographics laboratory on April 7, 2006.

Summary of Rock Texture Observations

Subsequent to sample preparation at A&CC, the chip from Sample 3045475 was observed to exhibit a striking texture. The sample hosts a very thin layer of black, coal-like material that appears to represent carbonized (coalified) plant bark, as indicated by a series of parallel lines that are similar to the cellulose of plant fibers (Figure 8). The carbonized, fossilized plant material is located at the core of the twin, parallel linear ridges that trend across the roof of the area inby spad 4010 in 2nd Left Mains.

The thin sections of Samples 3045477 and 3045475 were studied with a Meiji 9400 Series polarizing light microscope at viewing scales of 40X to 100X.

The samples of shale are classified based on grains size and bedding spacing as “laminated siltstone” according to Potter’s 1980 textural classification of shales. Because all six samples were collected from the same sedimentary horizon, within approximately 2 inches from the mine roof, they are characterized by very similar textures. Each of the six samples is characterized by a matrix composed of very fine-grained (0.005-0.2 mm) muscovite lathes, which are randomly oriented but arranged in thin bedding layers. Contacts between adjacent bedding layers are gradational, defined by different grain sizes or mineral contents. The very fine-grained, muscovite-

dominated layers host approximately 8-12% angular quartz grains, which are approximately 0.01 mm in diameter and isolated by the surrounding matrix. Coarser-grained layers are dominated by angular quartz grains, which are approximately 0.1 mm in diameter and touch along tangential contacts to leave angular interstices that are filled with finer-grained muscovite. The very finest-grained layers host very fine-grained, clay sized (<0.003 mm) muscovite with no quartz, and represent planes of preferential weakness along which delamination preferentially occurs.

Textures in all samples are very similar, characterized by muscovite-dominated layers corresponding to alternating grain sizes of "fine silt" and "medium silt". This material represents approximately 80% of the layers in each small, rectangular thin section. The remaining approximately 20% of layers are represented by "very fine quartz sand". Bedding layers are generally of uniform thickness, remaining parallel in relation to the bedding parting that represented the mine roof horizon. One notable exception to this is represented by Sample 3045477-4, which hosts a series of thin, discontinuous iron hydroxide stringers that suddenly ramp up away from the mine roof horizon, such that the stringers become closer together as they rise into the roof. This texture is characteristic of compaction of unconsolidated sediments around obdurate objects, and is referred to as draping. The parallel bands of "very fine sand" quartz, located approximately 5 mm higher in the section, exhibit the same rising at the same point on the traverse. The area defined by the compaction texture is at the margin of one of the two protruding ridges, which define the "linear anomaly" observed in the mine roof just inby spad 4010. The presence of the compaction texture, combined with the thin layer of carbonized plant material, suggest that the twin linear ridges observed in the mine roof represent local compaction of the muscovite-rich laminated siltstone immediate roof around a linear tree trunk. No silica glass or magnetite was observed in any of the thin sections, and no textural evidence was observed to indicate that grains have been fused together.



Figure 8. Enlarged view of a small, rectangular sample chip prior to being sent for thin section preparation. This piece of Sample 3045475 exhibits a black area that represents carbonized fossil plant bark. Parallel lines are interpreted to represent cellulose plant fiber. The pair of linear features observed inby spad 4010 in 2nd Left Mains is cored by this carbonized fossil material. The sample is approximately 7/8 inch wide x 1 3/4 inches long.

Appendix of Thin Section Descriptions

Sample 3045477-1 (Figures 9 and 10)

The sample is composed of fine laminations of randomly oriented, fine-grained, ragged muscovite lathes. Although muscovite lathes appear randomly oriented in detail, partings between some laminations are sharp and distinct. Most micaceous bedding layers host isolated grains of angular quartz that are diffusely scattered parallel to bedding laminations. Individual quartz grains are commonly surrounded by a thin, diffuse halo of very fine-grained muscovite that may represent diagenetic sericitization. Locally, angular quartz grains occur in sufficient quantity to define quartz-dominated interbeds that are parallel to bedding laminations. Quartz grains in the discontinuous interbeds touch along tangential contacts, and individual grains remain partially surrounded by a matrix of fine-grained muscovite lathes that are randomly oriented. Laminations defined by very fine-grained muscovite commonly represent preferential delamination horizons.

The sample contains approximately 15% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 85% of rock volume is represented by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.04 mm ("medium silt"). Based on the size of grains, thickness and nature of bedding layers, and content of clay-sized material, the shale sample is classified as a muscovite-rich laminated siltstone.

Textures suggest a low degree of compaction because individual mineral grain long axes are not strongly aligned with bedding planes. Long axes of angular quartz grains commonly form an obtuse angle with bedding laminations, indicating that grains were not forced to rotate. Although bedding textures are commonly diffuse, thin, discontinuous stringers of iron hydroxide are aligned parallel to bedding and highlight laminations. Despite the presence of iron hydroxide, no magnetism is present, as tested with a small, powerful magnet that is weakly attracted to samples with as little as <1% magnetite.



Figure 9. Lowest layer of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered in a matrix of very fine-grained lathes of muscovite (rectangular, brightly colored yellow/pink/blue). Brown represents patchy iron staining. Field of view 2.4 mm at 40X, taken under crossed polars.



Figure 10. Lamination of angular quartz grains of "very fine sand" size. Angular grains touch along tangential contacts. Long axes of quartz grains and rectangular muscovite lathes are not strongly oriented parallel to bedding, indicating that burial compaction was not intense enough to force grain rotation. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045477-2 (Figures 11 and 12)

This sample is characterized by a matrix of fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Two beds are dominated by angular quartz grains that are sporadically distributed within a very fine sand-sized band. In the muscovite-dominated portion of the rock, angular quartz grains are sporadically distributed, with individual grains isolated by the muscovite-dominated matrix. In the quartz-dominated bed, angular quartz grains touch along tangential boundaries, and are intermixed with coarser-grained, randomly oriented, thin muscovite lathes. The finest-grained portions of the muscovite-dominated matrix host bedding-parallel delamination zones that are planes of preferential weakness. Discontinuous stringers of iron hydroxide, which may represent alteration of original biotite, are aligned parallel along diffuse bedding laminations. Despite the abundance of the discontinuous, bedding-parallel iron hydroxide stringers, a powerful magnet is not attracted to the sample.

The sample contains approximately 19% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 81% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.04 mm ("medium silt"). Based on the size of grains, thickness and nature of bedding layers, and the content of clay-sized material, the shale sample is classified as muscovite-rich laminated siltstone.

In coarser-grained interbeds, the long axes of quartz grains are not strongly aligned with bedding laminations, forming obtuse angles, which indicates a low degree of compaction. In the fine-grained matrix, muscovite lathes are randomly oriented.

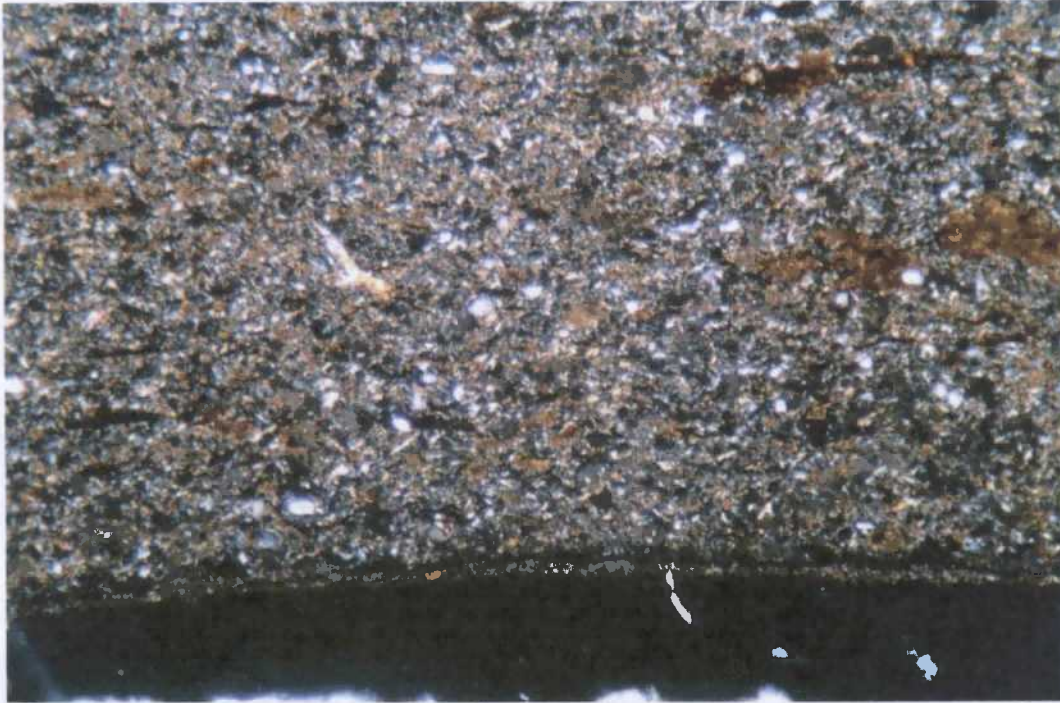


Figure 11. Lowest layer of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered throughout a matrix of very fine-grained muscovite (brightly colored pink/yellow). The muscovite-dominated matrix hosts patchy iron staining (brown) that is oriented along bedding laminations, and may represent leached original biotite flakes. Field of view 2.4 mm at 40X, taken under crossed polars.

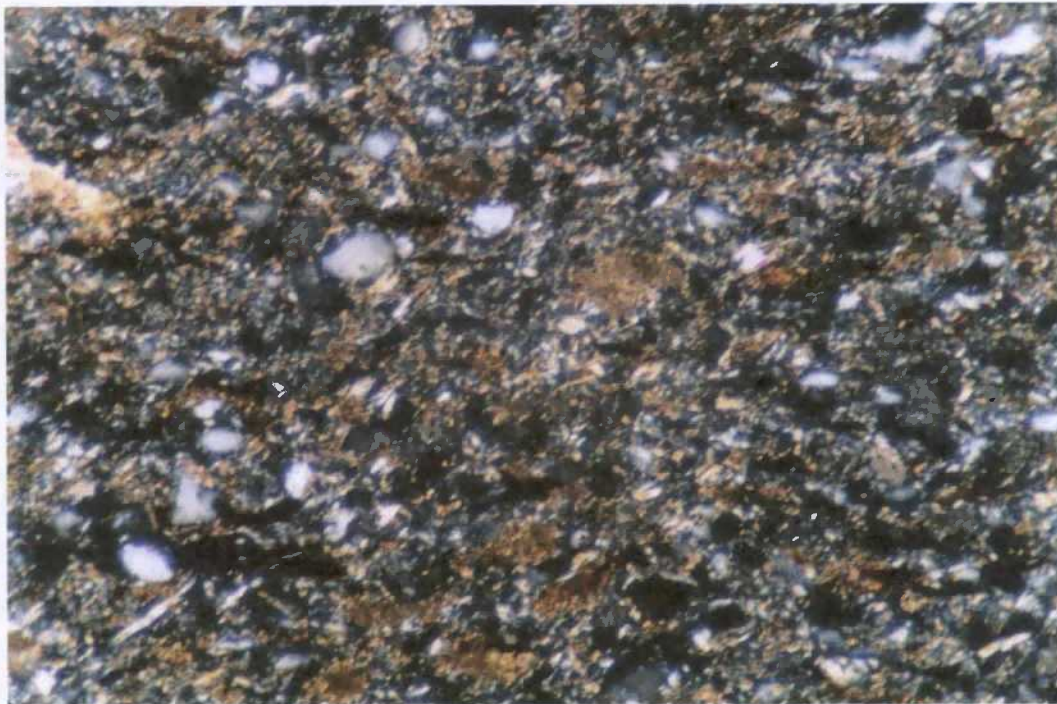


Figure 12. Same area as previous photo, showing individual, angular quartz grains (white and gray) isolated by surrounding, randomly oriented ragged flakes of muscovite (yellow/pink). Brown patchy areas represent iron staining. Field of view 1 mm at 100X, taken under crossed polars.

Sample 3045477-3 (Figures 13 and 14)

This sample is characterized by a matrix of fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Contacts between laminations are generally gradational, characterized by a changing grain size or mineral content. Several thin laminations are dominated by grains of angular quartz that are coarser-grained than those found in the muscovite-dominated portions of the rock. In the fine-grained, muscovite-dominated portion, angular quartz grains are sporadically scattered, with individual grains isolated by the surrounding muscovite matrix. In coarse-grained layers, quartz grains touch along angular, tangential boundaries or are more commonly slightly separated by a rim of very fine-grained muscovite. This sample exhibits more quartz-dominated laminations that are more sharply defined with respect to alternating muscovite layers, compared to the other samples. Thin, discontinuous stringers of iron hydroxide are abundantly distributed, aligned parallel to the bedding laminations that are defined by grains size and mineral content. The stringers may represent diagenetically altered biotite flakes. Despite the abundance of the stringers, a powerful magnet is not attracted to the sample. Very fine-grained laminations represent delamination horizons that are planes of preferential weakness.

The sample contains approximately 23% quartz, which ranges in size from 0.02 mm ("medium silt") to 0.2 mm ("fine sand"). The remaining 73% of the rock is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").

The matrix of randomly oriented muscovite lathes, and the poorly aligned long axes of individual quartz grains in coarser-grained laminations indicates that the sample was not strongly compacted enough to force grain rotation.



Figure 13. Lowest layer of shale immediate roof exposed at mine roof horizon, showing gradational contact between very fine-grained, muscovite-dominated layer and overlying, coarser layer that hosts greater quartz content and larger grain sizes. Lower, very fine-grained layer localizes delamination zones (parallel black lines represent glass of microscope slide where rock separated).

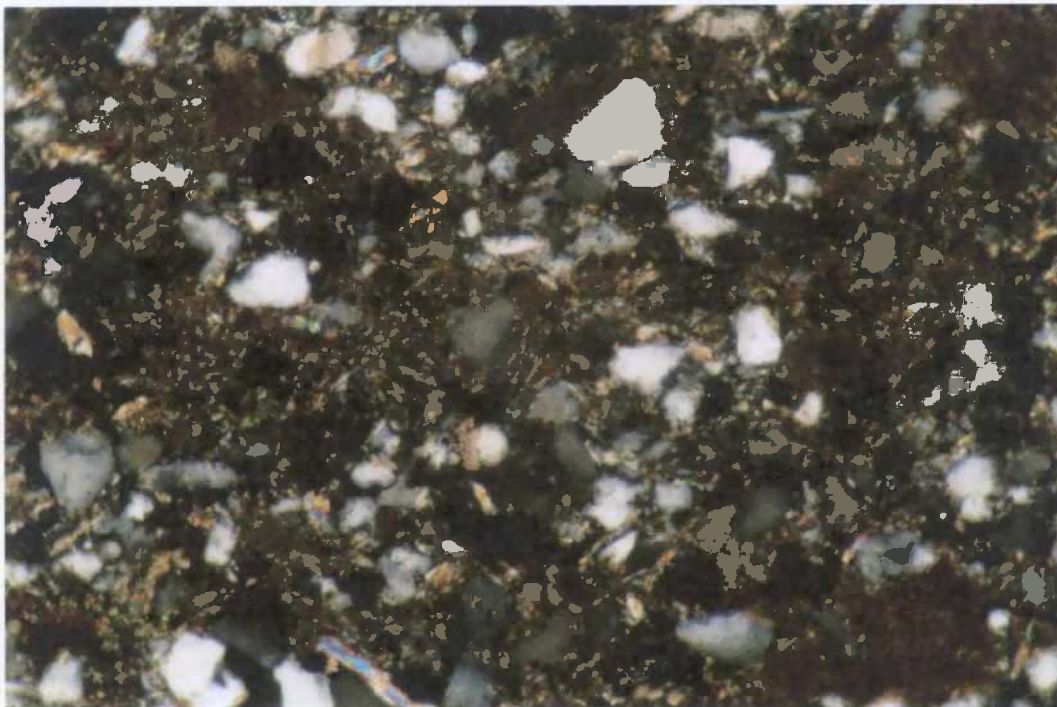


Figure 14. View of a coarser-grained, quartz-rich lamination, showing angular quartz grains (white and gray) isolated by the surrounding matrix of fine-grained muscovite lathes (pink/blue/yellow/green). Brown areas represent patchy iron staining. Field of view 1 mm at 100X, taken under crossed polars.

Sample 3045477-4 (Figures 15 and 16)

This sample is characterized by a matrix composed of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Contacts between laminations are generally diffuse, characterized by a gradational change in grain size and mineral content. In general, the very finest laminations host only muscovite, with increasing grain size associated with increasing quartz content, until some laminations are dominated by quartz. In fine-grained layers, angular quartz grains are sporadically distributed, with individual grains isolated by the surrounding matrix of fine-grained, randomly oriented muscovite. In coarser-grained layers, angular quartz grains dominate and touch along angular, tangential boundaries, or may be slightly separated by a rim of very fine-grained muscovite. The very finest layers host bedding-parallel delamination horizons that are planes of preferential weakness. Thin, discontinuous stringers of iron hydroxide are abundantly distributed, aligned parallel to bedding laminations. The stringers may represent diagenetically altered biotite flakes. Despite the presence of abundant stringers, a powerful magnet is not attracted to the sample. At the mine roof horizon, several of the thin stringers abruptly change their distance from each other along traverse, defining a compaction zone. This sample was collected from a portion of the R. J. Lee sample along which one of the pair of linear ridges ("anomalies") is located. A quartz-dominated lamination located 5 mm higher than the mine roof horizon also mirrors the iron hydroxide stringer-defined compaction zone. Although these textures suggest draping around an obdurate object, the matrix of randomly oriented muscovite lathes and layers of moderately aligned quartz grains indicate that the rock was not subjected to burial compaction significant enough to force grains to rotate into parallelism.

The sample hosts approximately 13% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.09 mm ("very fine sand"). The remaining 87% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").

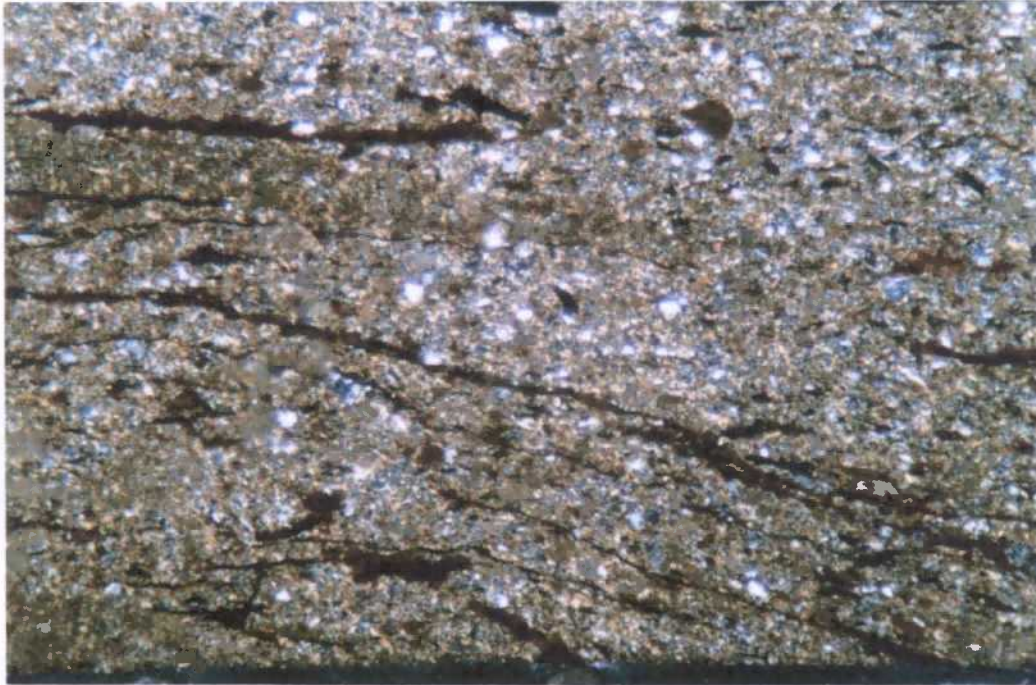


Figure 15. Long stringers of iron hydroxide (black, very dark brown) define bedding laminations in a compaction zone located near the margin of one of the linear ridges in Sample 3045477. Angular quartz grains (bright white) are scattered throughout the matrix of fine-grained muscovite (speckled pink/yellow with brown iron staining). Field of view 2.4 mm at 40X, taken under crossed polars.

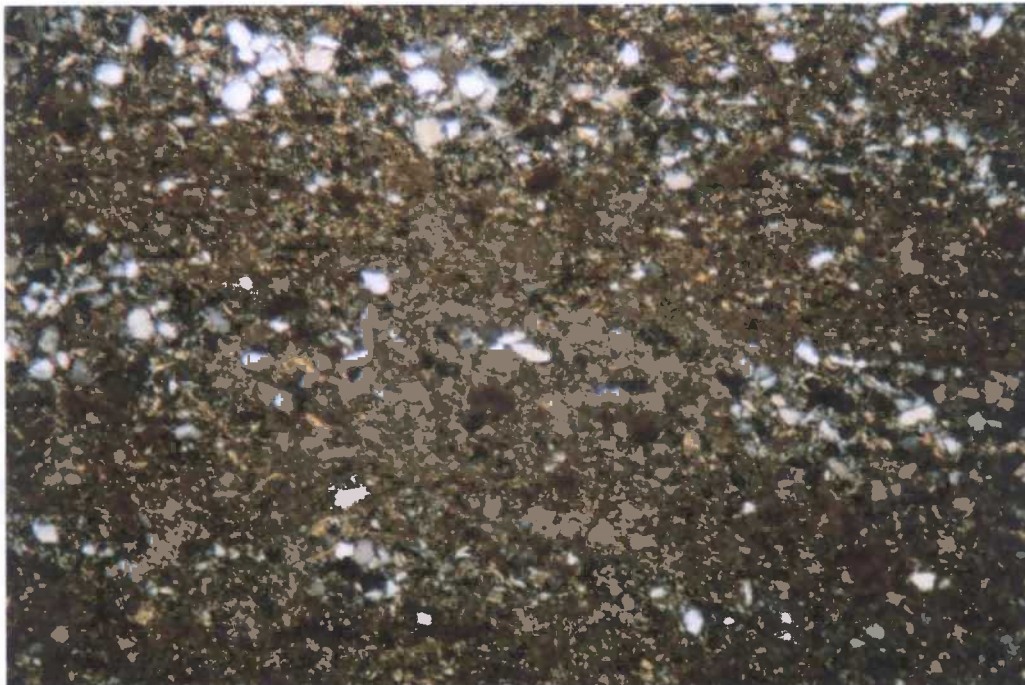


Figure 16. Field of view approximately 5 mm above the area in Figure 15, showing interbeds of quartz that gently rise from right to left above the compaction zone. Although locally a compaction zone, the long axes of quartz grains and muscovite lathes are not strongly oriented parallel to bedding, indicating that burial compaction was not sufficient to force grain rotation. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045477-5 (Figures 17 and 18)

This sample is characterized by a matrix of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations that exhibit gradational contacts based on changes in grain size and mineral content. The fine-grained laminations host scattered, fine-grained, angular quartz grains, with individual grains isolated by the surrounding muscovite matrix. Coarser-grained layers are dominated by angular quartz grains that touch along angular, tangential boundaries that are parallel to bedding contacts. Abundant, thin stringers of iron hydroxide are aligned parallel to bedding laminations and may represent diagenetic alteration of original biotite flakes. Despite the presence of abundant iron hydroxide, a powerful magnet is not attracted to the sample. In this sample, bedding contacts are particularly continuous and parallel. The finest-grained layers host delamination horizons that are planes of preferential weakness. Although bedding layers maintain constant thickness, the randomly oriented muscovite lathes and moderately aligned long axes of quartz grains indicate that the rock was not subjected to significant burial compaction.

The sample contains approximately 16% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.2 mm ("very fine sand"). The remaining approximately 84% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").



Figure 17. Lowest level of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (white) scattered and isolated in the very fine-grained, muscovite-dominated matrix. Field of view 2.4 mm at 40X, taken under crossed polars.



Figure 18. Very regular, continuous bedding contact between lower, fine-grained lamination characterized by scattered, angular quartz grains (bright white) in a very fine-grained matrix of muscovite (speckled yellow/pink), grading upward into lamination with abundant, angular quartz grains. Some quartz grains touch along tangential contacts, while most are isolated by surrounding muscovite. Discontinuous stringers of iron hydroxide (black to very dark brown), which may represent diagenetic alteration of original biotite flakes, are aligned parallel to define bedding. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045475 (Figures 19 and 20)

This sample is characterized by a matrix composed of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations that are gradational, based on changes in grain size and mineral content. Finer-grained layers host scattered grains of angular quartz, which are isolated by the surrounding, muscovite-dominated matrix. Coarser-grained layers are dominated by angular quartz grains, which touch along angular, tangential contacts. Thin stringers of iron hydroxide are abundantly distributed and aligned parallel to bedding laminations. The stringers have a crystal habit similar to mica suggesting that they represent diagenetic alteration of original biotite. Other stringers are very continuous and follow bedding laminations and pre-existing micro fractures, representing precipitation of iron along open-aperture planes. Despite the presence of abundant iron hydroxide, a powerful magnet is not attracted to the sample.

The sample contains approximately 17% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 83% of the rock's volume is dominated by muscovite, which ranges in size from 0.003 mm ("clay") to 0.1 mm ("very fine sand").



Figure 19. Lowest level of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered throughout a matrix composed of fine-grained muscovite lathes (speckled yellow/blue/pink/green). Wispy stringers of iron hydroxide (black to very dark brown) are aligned along bedding laminations, and may represent diagenetic alteration of original biotite flakes. Field of view 2.4 mm at 40X, taken under crossed polars.

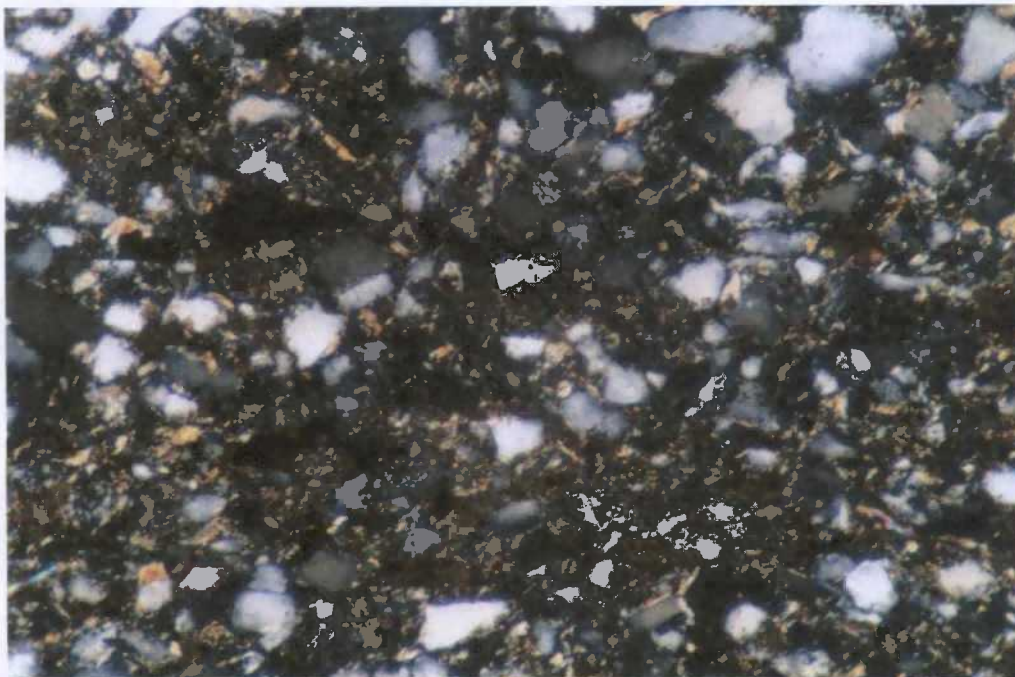


Figure 20. Angular quartz grains (white and gray) touch along tangential contacts nearly isolated in a matrix of randomly oriented muscovite lathes (yellow). Field of view 1 mm at 100X, taken under crossed polars.

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681608	1A21	Floor	0 + 5326	79.1	Trace
681609	1A21	Floor	0 + 5326 1/2" Sample	79.0	Trace
681610	1A22	Floor	0 + 5400	78.3	Trace
681611	1A22	Floor	0 + 5400 1/2" Sample	80.2	Trace
681612	1A23	Band	0 + 5500 2/02/06 GI	80.2	Trace
681613	1A23	Band	0 + 5500 2/02/06 GI 1/2" Sample	79.9	Small
681614	1A24	Rib/Floor	0 + 5625 2/03/06 GI	76.9	Trace
681615	1A25	Floor	0 + 5728 1" Sample	77.7	Small
681616	1A25	Floor	0 + 5728 1/2" Sample	76.8	Small
681617	1A26X	Floor	0 + 5852 2/01/06 GI	70.2	Small
681618	1A26X	Floor	0 + 5852 2/01/06 GI 1/2" Sample	68.3	Small
681619	1B1	Band	0 + 00 1" Band	45.2	None
681620	1B1	Band	0 + 00 1/2" Band	45.6	None
681621	1B2	Band	0 + 520 1" Band	69.3	None
681622	1B2	Band	0 + 520 1/2" Band	71.4	None
681623	1B10	Band	0 + 4186 1" Band	74.1	None
681624	1B10	Band	0 + 4186 1/2" Band	77.8	None
681625	1B11	Band	0 + 4426 1" Band	72.0	None
681626	1B11	Band	0 + 4426 1/2" Band	73.8	None
681627	1B13	Band	0 + 4700 2/02/06 GI	78.0	None
681628	1B13	Band	0 + 4700 2/02/06 GI 1/2" Band	76.5	None
681629	1B20X	Rib/Floor	0 + 5285	73.5	Trace
681630	1B20X	Rib/Floor	0 + 5285 1/2" Sample	77.1	Trace
681631	1B21	Floor	0 + 5326	73.2	Trace
681632	1B21X	Floor	0 + 5368	74.2	Trace

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Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681633	1B21X	Floor	0 + 5368 1/2"	72.4	Trace
681634	1B22	Floor	0 + 5400	73.0	Trace
681635	1B22	Floor	0 + 5400 1/2"	71.1	Trace
681636	1B22X	Roof/Rib	0 + 5430 2/02/06 GI	69.7	Trace
681637	1B22X	Roof/Rib	0 + 5430 2/02/06 GI 1/2"	71.5	Trace
681638	1B23	Rib/Floor	0 + 5500 2/02/06 GI	76.6	Trace
681639	1B23	Rib/Floor	0 + 5500 2/02/06 GI 1/2"	73.2	Trace
681640	1B24	Floor	0 + 5625 2/03/06 GI	74.6	Trace
681641	1B24	Floor	0 + 5625 2/03/06 GI 1/2"	74.8	Trace
681642	1B24X	Band	0 + 5660	68.8	Trace
681867	S1B24X	Band	0 + 5660 1/2"	73.5	Small
681643	1B25	Floor	0 + 5728 1" Sample	71.4	Trace
681644	1B25	Floor	0 + 5728 1/2" Sample	72.1	Small
681645	1B26	Floor	0 + 5822 1" Sample	66.6	Large
681646	1B26	Floor	0 + 5822 1" Sample	66.8	Large
681647	1B26	Floor	0 + 5822 1/2" Sample	66.7	Large
681648	1B26X	Floor	0 + 5852	59.4	Large
681649	1B26X	Floor	0 + 5852 1/2"	58.9	Large
681650	1C1	Band	0 + 00 1" Band	47.2	None
681651	1C1	Band	0 + 00 1/2" Band	42.9	None
681652	1C2	Band	0 + 520 1" Band	57.9	None
681653	1C2	Band	0 + 520 1/2" Band	60.8	None
681654	1C5	Band	0 + 2000 1" Band	62.4	None
681655	1C5	Band	0 + 2000 1/2" Band	45.1	None
681656	1C9	Band	0 + 3946 1" Band	88.8	None
681657	1C9	Band	0 + 3946 1/2" Band	88.3	None
681658	1C11	Band	0 + 4426 1" Band	62.0	None
681659	1C11	Band	0 + 4426 1/2" Band	60.4	None
681660	1C22	Rib/Floor	0 + 5400	70.5	Trace
681661	1C22	Rib/Floor	0 + 5400 1/2"	71.6	Trace
681662	1C23	Roof/Rib	0 + 5500 2/02/06 GI	72.5	Trace

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

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SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681663	1C23	Roof/Rib	0 + 5500 2/02/06 GI 1/2"	70.7	Trace
681664	1C24	Rib/Floor	0 + 5625 2/03/06 GI	65.8	Trace
681665	1C24X	Band	0 + 5657	74.2	Small
681868	S1C24X	Band	0 + 5657 1/2"	74.6	Trace
681666	1C25	Floor	0 + 5728 1" Sample	56.9	Small
681667	1C25	Floor	0 + 5728 1/2" Sample	60.4	Small
681668	1D1	Band	0 + 00 1" Band	51.6	None
681669	1D1	Band	0 + 00 1/2" Band	49.9	None
681670	1D2	Band	0 + 520 1" Band	74.1	None
681671	1D2	Band	0 + 520 1/2" Band	75.7	None
681672	1D5	Band	0 + 2000 1" Band	58.9	None
681673	1D5	Band	0 + 2000 1/2" Band	64.3	None
681674	1D7	Band	0 + 2982 1" Band	49.9	None
681675	1D7	Band	0 + 2982 1/2" Band	57.7	None
681676	1D8	Band	0 + 3464 1" Band	85.1	None
681677	1D8	Band	0 + 3464 1/2" Band	78.3	None
681678	1D20	Band	0 + 5255	73.0	Trace
681679	1D20	Band	0 + 5255 1/2"	69.5	Trace
681680	1D21	Rib/Floor	0 + 5326	74.3	Trace
681681	1D21	Rib/Floor	0 + 5326 1/2"	73.6	Trace
681682	1D22	Rib/Floor	0 + 5400	72.4	Trace
681683	1D22	Rib/Floor	0 + 5400 1/2"	70.2	Trace
681684	1D23	Rib/Floor	0 + 5500 2/02/06 GI	67.9	Trace
681685	1D23	Rib/Floor	0 + 5500 2/02/06 GI 1/2"	66.1	Trace
681686	1D24	Rib/Floor	0 + 5625	64.6	Trace
681687	1D24	Rib/Floor	0 + 5625 1/2"	64.8	Small
681688	1D24X	Band	0 + 5658	74.0	Small
681869	S1D24X	Band	0 + 5658 1/2"	74.1	Small
681689	1D25	Floor	0 + 5728 1" Sample	60.1	Small
681690	1D25	Floor	0 + 5728 1/2" Sample	59.4	Small

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681691	1D25X	Rib/Floor	0 + 5770 1" Sample	51.6	Large
681692	1D25X	Rib/Floor	0 + 5770 1/2" Sample	53.1	Large
681693	1E1	Band	0 + 00 1" Band	96.3	None
681694	1E1	Band	0 + 00 1/2" Band	97.0	None
681695	1E2	Band	0 + 520 1" Band	55.4	None
681696	1E2	Band	0 + 520 1/2" Band	64.8	None
681697	1E3	Band	0 + 1050 1" Band	84.4	None
681698	1E3	Band	0 + 1050 1/2" Band	72.1	Trace
681699	1E5	Band	0 + 2000 1" Band	87.7	None
681700	1E5	Band	0 + 2000 1/2" Band	86.9	None
681701	1E6	Band	0 + 2522 1" Band	87.1	None
681702	1E6	Band	0 + 2522 1/2" Band	91.2	None
681703	1E8	Band	0 + 3464 1" Band	80.5	None
681704	1E8	Band	0 + 3464 1/2" Band	88.8	None
681705	1E10	Band	0 + 4186 1" Band	87.0	None
681706	1E10	Band	0 + 4186 1/2" Band	81.2	None
681707	1E20	Rib/Floor	0 + 5255 2/02/06 GI	83.0	Trace
681708	1E20	Rib/Floor	0 + 5255 2/02/06 GI 1/2"	80.4	Trace
681709	1E22	Rib/Floor	0 + 5400	65.4	Trace
681710	1E22	Rib/Floor	0 + 5400 1/2"	63.0	Trace
681711	1E23	Rib/Floor	0 + 5500 2/02/06 GI	69.2	Small
681712	1E23	Rib/Floor	0 + 5500 2/02/06 GI 1/2"	65.7	Small
681713	1E24	Rib/Floor	0 + 5625	65.1	Small
681714	1E24	Rib/Floor	0 + 5625 1/2"	64.1	Small
681715	1E24X	Band	0 + 5665	78.7	Small
681870	S1E24X	Band	0 + 5665 1/2"	81.7	Small
681716	1E25	Floor	0 + 5728 1" Sample	57.4	Large
681717	1E25	Floor	0 + 5728 1/2" Sample	57.4	Large
681718	1E25X	Floor	0 + 5768 1" Sample	52.5	Large
681719	1E25X	Floor	0 + 5768 1/2" Sample	54.2	Large

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681720	1F1	Band	0 + 00 1" Band	90.4	None
681721	1F1	Band	0 + 00 1/2" Band	90.3	None
681722	1F2	Band	0 + 520 1" Band	70.7	None
681723	1F2	Band	0 + 520 1/2" Band	72.7	None
681724	1F3	Band	0 + 1050 1" Band	89.9	None
681725	1F3	Band	0 + 1050 1/2" Band	85.5	None
681726	1F4	Band	0 + 1474 1" Band	86.0	None
681727	1F4	Band	0 + 1474 1/2" Band	87.5	None
681728	1F5	Band	0 + 2000 1" Band	76.1	None
681729	1F5	Band	0 + 2000 1/2" Band	81.2	None
681730	1F6	Band	0 + 2522 1" Band	86.8	None
681731	1F6	Band	0 + 2522 1/2" Band	84.3	None
681732	1F7	Band	0 + 2982 1" Band	80.9	None
681733	1F7	Band	0 + 2982 1/2" Band	66.9	None
681734	1F8	Band	0 + 3464 1" Band	88.7	None
681735	1F8	Band	0 + 3464 1/2" Band	88.3	None
681736	1F10	Band	0 + 4186 1" Band	86.3	None
681737	1F10	Band	0 + 4186 1/2" Band	86.8	None
681738	1F13	Band	0 + 4700 1" Band	79.6	Trace
681739	1F13	Band	0 + 4700 1/2" Band	77.9	Trace
681740	1F14	Band	0 + 4780 1" Band	83.5	Trace
681741	1F14	Band	0 + 4780 1/2" Band	80.3	Trace
681742	1F15	Band	0 + 4851 1" Band	71.6	Trace
681743	1F15	Band	0 + 4851 1/2" Band	78.4	Trace
681744	1F16	Band	0 + 4934 1" Band	79.6	Trace
681745	1F16	Band	0 + 4934 1/2" Band	81.6	Trace
681746	1F17	Band	0 + 5011 1" Band	74.8	Trace
681747	1F17	Band	0 + 5011 1/2" Band	78.1	Trace
681748	1F18	Band	0 + 5100 1" Band	73.4	Trace
681749	1F18	Band	0 + 5100 1/2" Band	76.4	Trace

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681750	1F19	Band	0 + 5176 1" Band	76.5	Trace
681751	1F19	Band	0 + 5176 1/2" Band	76.1	Trace
681752	1F20	Band	0 + 5255 1" Band	73.6	Trace
681753	1F20	Band	0 + 5255 1/2" Band	73.9	Trace
681754	1F21	Band	0 + 5326 1" Band	77.5	Small
681755	1F21	Band	0 + 5326 1/2" Band	70.9	Trace
681756	1F22	Band	0 + 5400 1" Band	72.1	Small
681757	1F22	Band	0 + 5400 1/2" Band	73.8	Trace
681758	1F23	Band	0 + 5500 1" Band	67.2	Trace
681759	1F23	Band	0 + 5500 1/2" Band	68.0	Small
681760	1F24	Band	0 + 5625 1" Band	72.8	Small
681761	1F24	Band	0 + 5625 1/2" Band	73.7	Small
681762	1F24X	Band	0 + 5658 1" Band	76.3	Small
681763	1F24X	Floor	0 + 5658 2/03/06 GI 1/2"	77.7	Small
681764	1F25	Band	0 + 5728 1" Band	64.9	Small
681765	1F25	Band	0 + 5728 1/2" Band	66.9	Small
681766	1F25X	Floor	0 + 5771 1" Sample	52.5	Small
681767	1F25X	Floor	0 + 5771 1/2" Sample	53.2	None
681768	1G1	Band	0 + 00 1" Band	58.4	None
681769	1G1	Band	0 + 00 1/2" Band	59.8	None
681770	1G2	Band	0 + 520 1" Band	75.6	None
681771	1G2	Band	0 + 520 1/2" Band	76.0	None
681772	1G3	Band	0 + 1050 1" Band	56.4	None
681773	1G3	Band	0 + 1050 1/2" Band	60.4	None
681774	1G4	Band	0 + 1474 1" Band	61.8	None
681775	1G4	Band	0 + 1474 1/2" Band	54.7	None
681776	1G5	Band	0 + 2000 1" Band	66.4	None
681777	1G5	Band	0 + 2000 1/2" Band	66.6	None
681778	1G6	Band	0 + 2522 1" Band	76.2	None
681779	1G6	Band	0 + 2522 1/2" Band	75.7	None

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681780	1G8	Band	0 + 3464 1" Band	51.8	None
681781	1G8	Band	0 + 3464 1/2" Band	61.8	None
681782	1G9	Band	0 + 3946 1" Band	61.8	None
681783	1G9	Band	0 + 3946 1/2" Band	65.1	None
681784	1G10	Band	0 + 4186 1" Band	72.3	None
681785	1G10	Band	0 + 4186 1/2" Band	67.6	None
681871	S1G14	Band	0 + 4780 1/2"	75.6	None
681786	1G14X	Band	0 + 4813	72.6	Trace
681872	S1G14X	Band	0 + 4813 1/2"	68.4	None
681787	1G15	Band	0 + 4851	75.5	Trace
681873	S1G15	Band	0 + 4851 1/2"	75.0	Trace
681788	1G15X	Band	0 + 4886	69.6	Trace
681874	S1G15X	Band	0 + 4886 1/2"	70.8	Trace
681789	1G16	Band	0 + 4934	75.5	Trace
681875	S1G16	Band	0 + 4934 1/2"	75.2	Trace
681790	1G16X	Band	0 + 4974	64.7	Trace
681876	S1G16X	Band	0 + 4974 1/2"	63.9	Trace
681791	1G17	Band	0 + 5011	76.2	Trace
681877	S1G17	Band	0 + 5011 1/2"	72.8	Trace
681792	1G17X	Band	0 + 5046	73.6	Trace
681878	S1G17X	Band	0 + 5046 1/2"	71.7	Trace
681793	1G18	Band	0 + 5100	74.4	Trace
681879	S1G18	Band	0 + 5100 1/2"	74.1	Trace
681794	1G18X	Band	0 + 5130	63.0	Trace
681880	S1G18X	Band	0 + 5130 1/2"	69.1	Trace
681795	1G19	Band	0 + 5176	72.3	Trace
681881	S1G19	Band	0 + 5176 1/2"	74.8	Trace
681796	1G19X	Band	0 + 5208	66.9	Trace
681882	S1G19X	Band	0 + 5208 1/2"	63.2	Trace
681797	1G20	Band	0 + 5255	72.1	Trace
681883	S1G20	Band	0 + 5255 1/2"	72.2	Trace
681798	1G20X	Band	0 + 5287	68.1	Small
681884	S1G20X	Band	0 + 5287 1/2"	67.5	Small

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681799	1G21	Band	0 + 5326	67.5	Small
681800	1G21	Band	0 + 5326	67.3	Small
681801	1G21X	Band	0 + 5361	67.4	Small
681802	1G21X	Band	0 + 5361 1/2"	66.3	Small
681803	1G22	Band	0 + 5400	66.3	Small
681885	S1G22	Band	0 + 5400 1/2"	66.6	Small
681804	1G23	Band	0 + 5500	59.4	Large
681886	S1G23	Band	0 + 5500 1/2"	61.8	Small
681805	1G24X	Rib/Floor	0 + 5658	72.3	Large
681806	1G24X	Rib/Floor	0 + 5658 1/2"	74.1	Large
681807	1G25X	Floor	0 + 5768 1" Sample	56.9	Large
681808	1G25X	Floor	0 + 5768 1/2" Sample	54.4	Large
681809	1H1	Band	0 + 00 1" Band	64.0	None
681810	1H1	Band	0 + 00 1/2" Band	66.0	None
681811	1H2	Band	0 + 520 1" Band	46.3	None
681812	1H2	Band	0 + 520 1/2" Band	55.4	None
681813	1H3	Band	0 + 1050 1" Band	70.8	None
681814	1H3	Band	0 + 1050 1/2" Band	67.9	None
681815	1H4	Band	0 + 1474 1" Band	54.1	None
681816	1H4	Band	0 + 1474 1/2" Band	45.2	None
681817	1H5	Band	0 + 2000 1" Band	62.9	None
681818	1H5	Band	0 + 2000 1/2" Band	45.6	None
681819	1H6	Band	0 + 2522 1" Band	68.4	None
681820	1H6	Band	0 + 2522 1/2" Band	68.0	None
681821	1H7	Band	0 + 2982 1" Band	70.4	None
681822	1H7	Band	0 + 2982 1/2" Band	85.7	None
681823	1H9	Band	0 + 3946 1" Band	78.4	None
681824	1H9	Band	0 + 3946 1/2" Band	74.1	None
681825	1H10	Band	0 + 4186 1" Band	52.8	None
681826	1H10	Band	0 + 4186 1/2" Band	64.3	None
681827	1H15	Band	0 + 4851 1" Band	77.4	None
681828	1H15	Band	0 + 4851 1/2" Band	76.9	Trace
681887	S1H15X	Band	0 + 4891 1/2"	77.6	Trace
681829	1H18	Band	0 + 5100 1" Sample	75.4	Trace
681830	1H18	Band	0 + 5100 1/2" Sample	74.5	Trace
681831	1H19	Band	0 + 5176 1" Sample	75.8	Small

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(a): Sampling Area: Mains Collected 1/30/06 - 2/03/06 by Clay Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681832	1H19	Band	0 + 5176 1/2" Sample	76.1	Trace
681833	1H20	Band	0 + 5255 1" Sample	72.6	Small
681834	1H20	Band	0 + 5255 1/2" Sample	71.9	Trace
681835	1H21	Rib/Floor	0 + 5326 1" Sample	77.1	Small
681836	1H24	Floor	0 + 5625 2/02/06 GI	75.6	Small
681837	1H24	Floor	0 + 5625 2/02/06 GI 1/2"	74.4	Small
681838	1H24X	Floor	0 + 5655	86.1	Small
681839	1H24X	Floor	0 + 5655 1/2"	82.3	Small
681840	1H25	Floor	0 + 5728 2/02/06 GI	64.8	Large
681841	1H25	Floor	0 + 5728 2/02/06 GI 1/2 "	66.3	Large
681842	1H25X	Floor	0 + 5760 1" Sample	66.3	Large
681843	1H25X	Floor	0 + 5760 1/2" Sample	66.4	Large
681844	1I2	Band	0 + 520 1" Band	63.0	None
681845	1I2	Band	0 + 520 1/2" Band	59.9	None
681846	1I3	Band	0 + 1050 1" Band	56.4	None
681847	1I3	Band	0 + 1050 1/2" Band	59.5	None
681848	1I4	Band	0 + 1474 1" Band	55.9	None
681849	1I4	Band	0 + 1474 1/2" Band	46.5	None
681850	1I5	Band	0 + 2000 1" Band	44.9	None
681851	1I5	Band	0 + 2000 1/2" Band	48.5	None
681852	1I6	Band	0 + 2522 1" Band	69.3	None
681853	1I6	Band	0 + 2522 1/2" Band	67.4	None
681854	1I18	Band	0 + 5100 1" Band	74.4	Trace
681855	1I18	Rib/Floor	0 + 5100 1/2" Sample	73.6	Trace
681856	1I19	Rib/Floor	0 + 5176 1" Sample	75.4	Trace
681857	1I19	Rib/Floor	0 + 5176 1/2" Sample	75.0	Trace
681858	1I20	Rib/Floor	0 + 5255 1" Sample	72.7	Trace
681859	1I20	Rib/Floor	0 + 5255 1/2" Sample	73.2	Trace
681860	1I21	Rib/Floor	0 + 5326 1" Sample	78.2	Trace
681861	1I21	Rib/Floor	0 + 5326 1/2" Sample	77.9	Trace
681862	1I22	Rib/Floor	0 + 5400 1" Sample	77.8	Trace
681863	1I24	Floor	0 + 5625	79.3	Trace
681864	1I24	Floor	0 + 5625 1/2"	77.0	Trace
681865	1I25	Floor	0 + 5728	65.5	Small
681866	1I25	Floor	0 + 5728 1/2"	64.1	Small

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #1(b): Sampling Area: Mains Collected 2/16/06 by Cook/Hicks Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681888	1A25X	Band	0 + 5748 JC	92.0	Trace
681889	1A26	Band	0 + 5822 JC	70.0	Large
681890	1A27	Band	0 + 5880 JC	69.1	Large
681891	1A28	Band	0 + 5980 JC	62.4	X-Large
681892	1A29	Band	0 + 6043 JC	60.6	X-Large
681893	1A30	Band	0 + 6135 JC	56.3	X-Large
681894	1B25X	Band	0 + 5748 JC	66.3	Small
681895	1B27	Band	0 + 5880	58.7	X-Large
681896	1B28	Band	0 + 5980 JC	58.5	X-Large
681897	1B29	Band	0 + 6043 JC	54.0	X-Large
681898	1B30	Band	0 + 6135 JC	60.0	X-Large
681899	1C25X	Band	0 + 5748 JC	63.4	Large
681900	1C27	Band	0 + 5880 JC	50.9	X-Large
681901	1C28	Band	0 + 5980 JC	51.3	X-Large
681902	1C29	Band	0 + 6043 JC	58.1	X-Large
681903	1C30	Band	0 + 6135 JC	54.6	X-Large
681904	1D26	Band	0 + 5822	50.1	Large
681905	1D27	Band	0 + 5880	56.3	X-Large
681906	1D28	Band	0 + 5980	57.2	X-Large
681907	1E26	Band	0 + 5822	59.2	Large
681908	1E27	Band	0 + 5880	59.3	X-Large
681909	1F26	Band	0 + 5822 JC	54.3	X-Large
681910	1F27	Band	0 + 5880	54.6	X-Large
681911	1F28	Band	0 + 5980	56.9	X-Large
681912	1G26	Band	0 + 5822	56.9	X-Large
681913	1G27	Band	0 + 5880	50.8	X-Large
681914	1G28	Band	0 + 5980	53.3	X-Large
681915	1H26	Band	0 + 5822 JC	59.3	X-Large
681916	1H28	Band	0 + 5980 JC	45.0	Large

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #2: Sampling Area: 1st Left Collected 1/30/06 by Sparks Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681917	2F1	Roof & Ribs	0 + 00	87.3	None
681918	2F1	Roof & Ribs	0 + 00 1/2" Sample	93.6	None
681919	2G2	Ribs & Floor	0 + 474	89.8	None
681920	2G2	Ribs & Floor	0 + 474 1/2" Sample	86.0	None
681921	2H4	Band	0 + 1424	58.5	None
681922	2H4	Band	0 + 1424 1/2" Sample	66.4	None
681923	2H5	Ribs & Floor	0 + 1898	47.7	None
681924	2H5	Ribs & Floor	0 + 1898 1/2" Sample	36.8	None

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #3: Sampling Area: 2nd Left Collected 1/30/06 - 2/03/06 by Ison/Sturgill Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681925	3A1X	Floor	0 + 40	85.7	Trace
681926	3A1X	Floor	0 + 40 1/2"	85.8	Trace
681927	3A6X	Floor	0 + 408 0" to 1/4" deep	71.4	Trace
681928	3A6X	Floor	0 + 408 0" to 1/4" deep	70.1	None
681929	3A13X	Floor	0 + 908 0" to 1/4" deep off floor	65.9	None
681930	3A13X	Floor	0 + 908 0" to 1/4" deep off floor	65.6	None
681931	3A14	Floor	0 + 945 0" to 3/8" deep	64.7	None
681932	3A14	Floor	0 + 945 1/2"	66.2	None
681933	3A14X	Floor	0 + 973 0" to 1/4" deep on mine floor	64.6	None
681934	3A14X	Floor	0 + 973 1/2"	61.8	None
681935	3A15	Floor	0 + 1030 0" to 1/4" deep on mine floor	59.7	None
681936	3A15	Floor	0 + 1030	61.1	None
681937	3A15X	Floor	0 + 1045 0" to 1/4" deep on mine floor	59.8	None
681938	3A15X	Floor	0 + 1045 0" to 1/4" deep on mine floor	59.4	None
681939	3A16X	Floor	0 + 1125 0" to 3/8" deep on mine floor	89.1	Trace
681940	3A16X	Floor	0 + 1125 0" to 3/8" deep on mine floor	89.4	None
681941	3B8	Floor	0 + 526 0" to 1/4" deep	81.7	None
681942	3B8	Floor	0 + 526 1/2"	83.1	None
681943	3B13	Roof & Floor	0 + 877 0' to 1/3" off mine floor	71.9	None
681944	3B13	Roof & Floor	0 + 877 0" to 1/3' deep off bottom	71.6	None
681945	3B14	Floor	0 + 945 0" to 1/3" deep off mine floor	83.9	None
681946	3B14	Floor	0 + 945 1/2"	75.1	None
681947	3B15	Floor	0 + 1013 0" to 1/4" deep on mine floor	91.5	None
681948	3B15	Floor	0 + 1013	91.7	None
681949	3B16	Floor	0 + 1083 0" to 3/8" deep on mine floor	66.3	None

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Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #3: Sampling Area: 2nd Left Collected 1/30/06 - 2/03/06 by Ison/Sturgill Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
681950	3B16	Floor	0 + 1083 1/2"	55.2	None
681951	3C6	Floor	0 + 378	70.1	None
681952	3C6	Floor	0 + 378 1/2"	73.5	None
681953	3C7	Floor	0 + 453	69.0	None
681954	3C7	Floor	0 + 453 1/2"	65.8	None
681955	3C8	Floor	0 + 526	68.7	None
681956	3C8	Floor	0 + 526 1/2"	70.6	None
681957	3C13	Floor	0 + 877	71.6	None
681958	3C13	Floor	0 + 877 1/2"	68.4	None
681959	3C15	Floor	0 + 1013	75.0	None
681960	3C15	Floor	0 + 1013 1/2"	73.9	None
681961	3C16	Roof & Floor	0 + 1083	73.7	None
681962	3C16	Roof & Floor	0 + 1083 1/2"	73.7	None
681963	3C16X	Roof & Floor	0 + 1125	50.7	None
681964	3C16X	Roof & Floor	0 + 1125 1/2"	51.0	None
681965	3C17	Floor	0 + 1152	69.3	None
681966	3C17	Floor	0 + 1152 1/2"	75.2	None
681967	3D1	Ribs & Floor	0 + 00	82.5	Trace
681968	3D1	Ribs & Floor	0 + 00 1/2"	82.7	Trace
681969	3D12X	Ribs & Floor	0 + 845 2/01/06 GI	67.8	None
681970	3D12X	Ribs & Floor	0 + 845 2/01/06 GI 1/2"	60.0	None
681971	3D13X	Floor	0 + 908 1/31/06	74.6	None
681972	3D13X	Floor	0 + 908 1/31/06 GI 1/2"	71.3	None
681973	3E17	Floor	0 + 1152 1/31/06 GI	75.5	None
681974	3E17	Floor	0 + 1152 1/31/06 GI 1/2"	75.5	None
681975	3G1	Ribs	0 + 00 1/30/06 Intake GI	78.0	None
681976	3G1	Ribs	0 + 00 1/30/06 Intake GI 1/2"	78.7	None
681977	3G1X	Ribs & Floor	0 + 40 1/30/06 Intake GI	71.2	Trace
681978	3G1X	Ribs & Floor	0 + 40 1/30/06 Intake GI 1/2"	72.4	None
681979	3G2	Ribs & Floor	0 + 80 1/30/06 Intake GI	71.7	None
681980	3G2	Ribs & Floor	0 + 80 1/30/06 Intake GI 1/2"	70.2	Trace

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #3: Sampling Area: 2nd Left Collected 1/30/06 - 2/03/06 by Ison/Sturgill Rec. 2/17/06 from Cook/Hicks

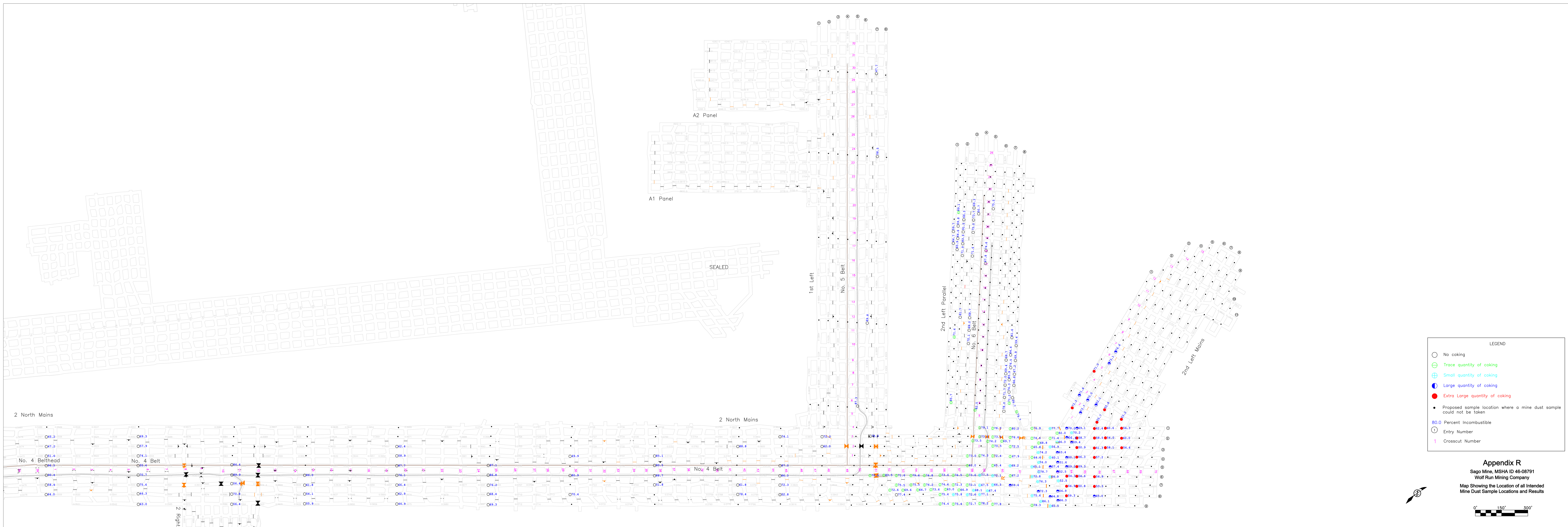
Lab No.	Bag No.	Sample Type	Location in Mine				Dust Analysis	Coke Content
681981	3G2X	Ribs & Floor	0 + 110	1/30/06	Intake	GI	76.3	None
681982	3G2X	Ribs & Floor	0 + 110	1/30/06	Intake	GI 1/2"	76.4	None
681983	3G3	Ribs & Floor	0 + 150	1/30/06	Intake	GI	72.0	None
681984	3G3	Ribs & Floor	0 + 150	1/30/06	Intake	GI 1/2"	74.8	None
681985	3G3X	Ribs & Floor	0 + 180	1/30/06	Intake	GI	85.9	None
681986	3G4	Ribs & Floor	0 + 215	1/30/06	Intake	GI	69.4	None
681987	3G4	Floor	0 + 215	1/30/06	Intake	GI 1/2"	71.5	None
681988	3G4X	Floor	0 + 265	1/30/06	Intake	GI	76.5	None
681989	3G4X	Floor	0 + 265	1/30/06	Intake	GI	76.0	None
681990	3G5	Floor	0 + 293	1/30/06	Intake	GI	69.7	None
681991	3G5	Ribs & Floor	0 + 293	1/30/06	Intake	GI 1/2"	72.7	None
681992	3G5X	Ribs & Floor	0 + 343	1/30/06	Intake	GI	64.4	None
681993	3G5X	Ribs & Floor	0 + 343	1/30/06	Intake	GI 1/2"	66.1	None
681994	3G6X	Floor	0 + 408	1/30/06	Intake	GI	61.6	None
681995	3G6X	Floor	0 + 408	1/30/06	Intake	GI 1/2"	70.7	Trace
681996	3H1	Ribs & Floor	0 + 00	1/30/06	Intake	GI	74.7	Trace
681997	3H1	Ribs & Floor	0 + 00	1/30/06	Intake	GI 1/2"	73.1	None
681998	3H2	Ribs & Floor	0 + 80	1/30/06	Intake	GI	64.7	None
681999	3H2	Ribs & Floor	0 + 80	1/30/06	Intake	GI 1/2"	71.7	Trace
682000	3H3	Ribs & Floor	0 + 150	1/30/06	Intake	GI	66.8	None
682001	3H3	Ribs & Floor	0 + 150	1/30/06	Intake	GI 1/2"	67.1	None
682002	3H4	Floor	0 + 215	1/30/06	Intake	GI	67.2	None
682003	3H4	Floor	0 + 215	1/30/06	Intake	GI 1/2"	68.1	None
682004	3H5	Ribs & Floor	0 + 293	1/30/06	Intake	GI	69.9	None
682005	3H5	Ribs & Floor	0 + 293	1/30/06	Intake	GI 1/2"	68.5	None
682006	3H6	Ribs & Floor	0 + 378	1/31/06	Intake	GI	59.4	None
682007	3H6	Ribs & Floor	0 + 378	1/31/06	Intake	GI 1/2"	60.2	None

Appendix Q - Mine Dust Survey Sago Mine Explosion Investigation

Sago Mine - Wolf Run Mining Company - Mine ID# 4608791

SURVEY #4: Sampling Area: 2nd Left Mains Collected 2/01-16/06 by Sparks/Hicks Rec. 2/17/06 from Cook/Hicks

Lab No.	Bag No.	Sample Type	Location in Mine	Dust Analysis	Coke Content
682008	4B1	Ribs & Floor	0 + 00 1" Sample	73.3	X-Large
682009	4B1	Ribs & Floor	0 + 00 1/2" Sample	74.1	X-Large
682010	4B2	Floor	0 + 83	71.8	Large
682011	4B2	Floor	0 + 83 1/2"	75.5	X-Large
682012	4B4	Floor	0 + 242 2/01/06 GI	71.0	X-Large
682013	4B4	Floor	0 + 242 2/01/06 GI 1/2"	76.7	X-Large
682014	4C1	Floor	0 + 00 1" Sample	73.7	Large
682015	4C1	Floor	0 + 00 1/2" Sample	72.8	Large
682016	4C2	Floor	0 + 83 1" Sample	70.5	Large
682017	4C2	Floor	0 + 83 1/2" Sample	71.5	Large
682018	4C5	Floor	0 + 324	73.1	Large
682019	4C5	Floor	0 + 324 1/2"	72.4	Large
682020	4C6	Floor	0 + 401	76.6	Large
682021	4C6	Floor	0 + 401 1/2"	71.8	Large
682022	4D2	Band	0 + 83	52.1	Large
682023	4E1	Band	0 + 00	55.7	X-Large
682024	4E2	Band	0 + 83	55.8	X-Large
682025	4G2	Band	0 + 83	53.2	X-Large



LEGEND

- No coking
- ⊖ Trace quantity of coking
- ⊕ Small quantity of coking
- ⊗ Large quantity of coking
- Extra Large quantity of coking
- Proposed sample location where a mine dust sample could not be taken
- 80.0 Percent Incombustible
- ① Entry Number
- 1 Crosscut Number

Appendix R
 Sago Mine, MSHA ID 46-08791
 Wolf Run Mining Company
 Map Showing the Location of all Intended Mine Dust Sample Locations and Results

0' 150' 300'

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"
U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



K. HERRICK

December 21, 2006

MEMORANDUM FOR RICHARD A. GATES

Manager, Coal Mine Safety and Health, District 11

FROM:

JOHN P. FAINI 
Chief, Approval and Certification Center

SUBJECT:

Executive Summary of Inspection of Sago Mine Voice
Communications Equipment

Coal Mine Safety and Health, through Robert L. Phillips, requested that (a) the mine phones at Wolf Run Mining Company's Sago Mine, I.D. No. 46-08791, be identified by model and (b) a brief description of how they were interconnected with each other be prepared. Table 1 describing the telephones is attached as is Table 2 showing unused pager connections, and a diagram of their locations.

Multiple communications systems were in place at Sago Mine at the time of inspection. These included:

- paging loudspeaking telephones located in various areas, both underground and on the surface;
- a distributed antenna radio system allowing for communications between the surface and mobile underground equipment (trolleyphones);
- a commercial telephone system on the surface; and
- portable two-way radios.

These systems were interconnected on the surface. Hardware used for connection of the paging system to an extension of the mine's telephone system were provided. An additional interface was used to connect the paging system to a radio transceiver, which allowed for two-way communication with portable VHF radios used on the surface. Portable two-way VHF radios were apparently used for point-to-point communications underground, but this was not observed during the post-accident investigation. Portions of the hardware associated with these systems were evaluated and inspected to determine operational status. It was determined that:

- When inspected between January 27, 2006, and February 4, 2006, the underground portion of the paging telephone system featured eighteen (18)

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

individual telephones. Three (3) of these were not connected to the system; two of these were in the area of damage caused by the explosion and the third was found on top of a piece of mobile equipment. As detailed in attached Table 1, the functionality of the units varied from normal to non-functional. The two units found in the area of explosion damage were not tested.

The pager line was found to be intact except in the area of explosion damage. Leading from the surface, the most inby end of the undamaged line was located near the 1 Left Section track switch in the 2 North Main track entry. Additionally, the pager line was not damaged from a point near the #4 crosscut of the No. 6 belt on the 2 Left Section, and leading inby.

In the damaged areas, the cable was found to be cut or pulled apart, especially where it traversed crosscuts, exposing it to the apparent forces from the explosion. Repairs had been affected to these areas by splices or replacement of the cable with twisted-pair wiring.

Additionally, at least nine (9) unused facilities for connection to the underground pager line were found. It is not known, for specific locations, if telephones were present at the time of the explosion, if they were moved during the mine rescue, or if telephones were ever connected.

Not all of the paging telephones found connected to the system were permissible. The only devices found in areas where permissibility was required were assumed to have been installed during mine rescue.

- The underground trolleyphone system consisted of the signal line, the track as a return line, a repeater, terminating resistors, and trolleyphones carried on the track-mounted mobile equipment. The repeater did not function when inspected; laboratory testing of the unit is the subject of another report titled "Gai-Tronics Corporation Trolleyphone Carrier Repeater, Exhibit No. GH-91P."

The signal line was severely damaged in the area affected by the explosion. It had apparently been repaired to allow for communications before the inspection occurred. The repair consisted of termination of the line to the track approximately 20 feet inby spad 3854, at the 50 block of the No. 4 belt. This was the most outby undamaged area.

The trolleyphones found on the #6 and #8 mantrips were found with depleted batteries, and were not tested for function. They appeared to be complete, and with minimal damage. It should be noted that, if the signal cable had been damaged and the line was not terminated, the trolleyphones would most likely not have been able to provide communications with the surface.

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

- None of the conductors associated with the trolleyphone system or the paging telephone systems showed any signs of burning or charring associated with excessive current. However, it should be noted that ignition-capable sparking can occur without leaving marks on conductive elements such as these.

Comprehensive test results can be obtained from the Chief of the A&CC, RR 1, Box 251, Industrial Park Road, Triadelphia, West Virginia 26059.

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

TABLE 1. SAGO MINE UNDERGROUND PAGING TELEPHONES INSPECTED, PAGE 1 of 3

Location	Identifying Marking	Approval Marking	Receive Page?	Provide Page?	Talk to surface?	Listen to surface, handset?	Battery Voltage	Comments
#1 Belt, #1 Block	Case: None PCB: WBA1501A	None	Yes	Yes	Yes	Yes	Top: 12.93 Bottom: 9.95	Case is green and yellow
#1 Belt, 13 Block	Femco Telephone, PCB: WBA3422A	None	No	Yes	Yes	Yes	Top: 11.1 Bottom: 11.1	Stainless steel case
#2 Belt, 22 Block	Femco Telephone, Model 821301, P/N AM7021, S/N 307003	9B-155-1	Yes	Yes	Yes	Yes	Top: 10.4 Bottom: 10.45	
#3 Belt head	PCB: WBA1598	None	Yes	Yes	Yes	Yes	Inside: 10.47 Outside: 10.47	Stainless steel case
#3 Belt drive starter	Pyott-Boone Page Boss, Model 112 PCB: 005-0077-003	9B-102-2	Yes	Yes	Yes	Yes	9.47	
#3 Belt, 9 Break	Pyott-Boone PageBoss PCB: 005-0077-003 Rev Q		No	No	No	Yes	9.51	Audible hum from handset
#3 Belt, 17 Break	Pyott-Boone PageBoss, Model 112, S/N 12927, PCB: 005-0077-003 Rev Q	9B-102-2	Yes	Yes (muffled)	Yes (muffled)	Yes	8.82	
#4 Belt, 1 Block	PCB: WBA3422A		Yes	Yes	Yes	Yes	Top: 11.31 Bottom: 11.31	Yellow and black case
'Supply hole,' #4 Belt, 9 Block	Gulton Femco Division, Permissible Paging Telephone, Model 821301, p/n AM7011, S/N 045291	9B-155-0	Yes	Yes	Yes	Yes	11.61	
#4 Belt, 40 Block	'Spruce', AEI Paging Phone, P/N 755-1		No	No	No	Yes	Top: 7.88 Bottom: 10.17	Yellow and black case, Page Speaker missing

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

TABLE 1. SAGO MINE UNDERGROUND PAGING TELEPHONES INSPECTED, PAGE 2 of 3

Location	Identifying Marking	Approval Marking	Receive Page?	Provide Page?	Talk to surface?	Listen to surface, handset?	Battery Voltage	Comments
#4 Belt, 49 Block, near spad 3845	'Sago', pcb WBA3422		No	No	No	No	11.84	Stainless steel case, dirty (earpiece and mic holes are filled with dirt)
#4 Belt, 49 Block, near spad 3845	"A687JK", pcb WBA3422		Yes	Yes	Yes	Yes	11.22	Yellow and black case, clean, installed in close proximity to unit detailed above
#4 Belt, 57 Break	Femco Model 741301/402 Pcb 3422	9B-34(illegible)5	N/A	N/A	N/A	N/A	11.12	Unit not tested for voice function because pager line was disconnected, but remnants of wiring presumed to be associated with pager line found in terminals; audible click heard when page switch operated.
Crosscut near #6 Belt drive	Calibration sticker "Date 10-5-05 by RH"; Pcb WBA3422A		N/A	N/A	N/A	N/A	12.27	Unit covered in soot and found in rubble; not connected to pager line; Handset was missing; handset cord was flexible and appeared to have been mechanically separated from handset; an audible click heard when page switch operated; interior of unit clean and apparently undamaged.
1 Left Section, at Power Center	Femco Model No (illegible); Serial No. 23(illegible); Two Battery Telephone Permissible: pcb WBA4097 Repair Job 35867 Date Rec'd 10-10-05; Date repaired 10-12-05; Hughes Supply Co.	Illegible	Yes	Yes	Yes	Yes	Top: 11.99 Bottom: 11.96	When first inspected, voice communications with this unit were not possible. After a break in the pager line at 21 Block of #5 belt was located and repaired, the unit worked.

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

TABLE 1. SAGO MINE UNDERGROUND PAGING TELEPHONES INSPECTED, PAGE 3 of 3

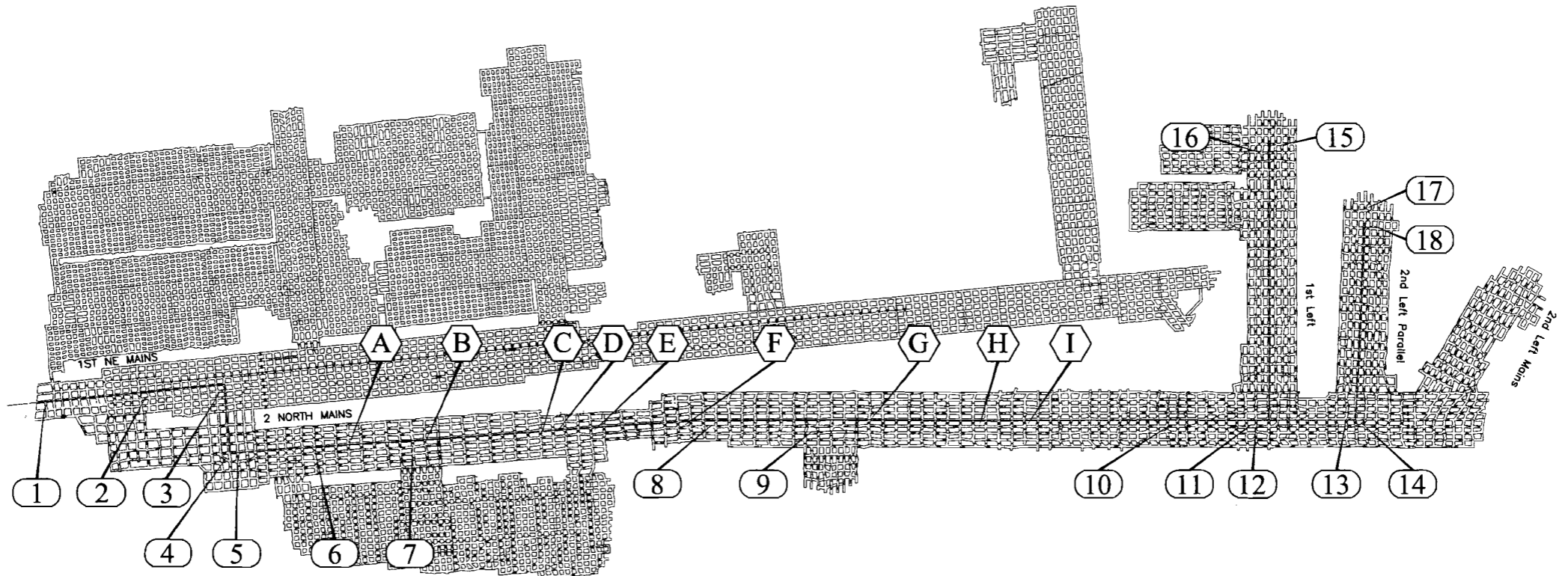
Location	Identifying Marking	Approval Marking	Receive Page?	Provide Page?	Talk to surface?	Listen to surface, handset?	Battery Voltage	Comments
1 Left Section, #3 entry, Near old #7 belt drive	Gulton, Femco Division, National Mine Service, Gulton Permissible Paging Telephone, Model 821301, P/N AM7020, S/N 028020, 2 battery permissible phone, PCB: WBA4097 Rev B	Illegible	No	Noisy	No	No	Top: 8.90 Bottom: 10.59	
2 Left Section, Entry #4, near spad 4276	PCB: WBA4097, 'Spruce'		Yes	Yes	Yes (low volume)	Yes	Top: 10.54 Bottom: 10.38	Phone was located at end of twisted pair cable that was apparently added by rescue teams from end of mine phone cable at power center
On top of shuttle car canopy near 2 Left power center	PCB: WBA 3422A, 'Sago'		Yes	Yes	Yes (low volume)	Yes	Top: 11.45 Bottom: 11.47	Phone was not connected, but was believed to have been the phone connected at the power center before the explosion and subsequent rescue. Phone was connected to line for testing

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"

TABLE 2. UNUSED PAGER CONNECTIONS, SAGO MINE, FEBRUARY 4, 2006

Location	Comments
#3 Belt, 12 Break, Belt entry	6 inches long
#3 Belt, 18 Break, Belt entry	
#3 Belt, 27 Break, Track entry	Branch line drop. Ends appeared to be cut out of the jacket.
#3 Belt, 28 Break, Track entry	Cable spliced into main cable. The ends of the cable had been stripped of insulation and covered with black tape.
#3 Belt, 31 Break, Track entry	Pigtail connector for branch line.
#3 Belt, 37 Break, Track entry	Pigtail connector for branch line, covered with black tape.
#4 Belt, 13 Break, Belt entry	Cable splice in track entry was clean, appearing to have been new. Bare ends of branch line in belt entry.
#4 Belt, Between 21 and 22 Break, Track entry	Wires covered by tape.
#4 Belt, 25 Break, Track entry	Branch line drop with bare ends. Mr. Denver Wilfong indicated that he thought he used phone at this location on morning of accident.

Appendix S - Executive Summary of "Inspection of Sago Mine Voice Communication Equipment"



⑩ Pager locations as defined in Table 1

Ⓘ Unused pager connections as defined in Table 2

Scale: 1" = 800'

Appendix T - Executive Summary of the "Trolleyphone Repeater Report"
U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



March 30, 2007

MEMORANDUM FOR RICHARD A. GATES

District Manager, Coal Mine Safety and Health, District 11

FROM:

JOHN P. FAINI 
Chief, Approval and Certification Center

SUBJECT:

Executive Summary of Investigation of Gai-Tronics Corporation
Trolleyphone Carrier Repeater

A trolleyphone communications system utilizing components manufactured by Gai-Tronics Corporation was installed at Wolf Run Mining Company's Sago Mine at the time of an explosion on January 2, 2006. One of the components, a Trolleyphone Carrier Repeater, was found to be nonfunctional during underground inspection on January 28, 2006. The device was recovered, and inspected and tested in the Electrical Safety Division laboratory to (a) determine the operational status of the repeater, and, if appropriate, (b) determine the cause of the failure.

In the laboratory, the Trolleyphone Carrier Repeater, Exhibit Number GH-91P, did not repeat the behavior observed at the Sago Mine on January 28, 2006. It was able to receive and re-transmit signals in the laboratory, although the measured signal voltage was sub-optimal. The reduced measured carrier voltage level is most likely due to the method of testing in the laboratory, specifically the impedance mismatch between the external load resistor, 25 ohms, and the measured internal terminating resistance of 46.3 ohms. Inspection and testing revealed no damaged components; all fuses were intact, suggesting that the carrier repeater was not subject to high voltage surges at the power supply terminals.

The definitive cause of the malfunction observed in the underground mining environment could not be determined by laboratory testing of the trolleyphone carrier repeater.

Comprehensive test results can be obtained from the Chief of the A&CC, RR 1, Box 251, Industrial Park Road, Triadelphia, West Virginia 26059.

Appendix U - An Executive Summary of Investigation of the Motorola Two-way Radios

U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



MEMORANDUM FOR RICHARD A. GATES

District Manager, Coal Mine Safety and Health, District 11

FROM:

JOHN P. FAINI 
Chief, Approval and Certification Center

SUBJECT:

Executive Summary of Investigation of the Motorola Incorporated, Model PR400 Portable Two Way Radios recovered from the Sago Mine

The Approval and Certification Center (A&CC), as requested by Coal Mine Safety and Health, conducted a laboratory investigation of five (5) radios recovered from a fatal explosion at Wolf Run Mining Company's Sago Mine, Mine I.D. No. 46-08791 on January 2, 2006. The request was to determine the following: (A) the operational status of the radios above ground, (B) whether the radios show evidence of a possible source for initiating an explosion, (C) differences between MSHA-approved radios and the recovered radios, and (D) the operational range limitations in under ground mines.

The examination and testing of the radios determined the following:

- The functionality of the radios recovered from Sago were compared with two new Motorola PR400 radios and functioned as well above ground as the new units did.
- None of the radios exhibited visual signs that the radio produced a spark or thermal ignition source for the ignition of coal dust or methane-air mixture.
- The Motorola PR400 radio is not MSHA approved for use in permissible areas of underground coal mines, but is approved by Factory Mutual as Intrinsically Safe for use in above ground explosive atmospheres, including methane-air mixtures. MSHA does not accept the Factory Mutual approval in lieu of an MSHA approval.
- Information obtained through the A&CC's Emergency Communications and Tracking System Committee indicates that radios operating in the UHF band communicate an approximate maximum distance of 1500 feet within the same entry, with severely limited propagation around corners. This is highly dependent on coal seam height, entry geometry, and infrastructure within the entry.

See the attached report for details of the tests and evaluation.

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division




06AB82

March 16, 2007

MEMORANDUM FOR RICHARD A. GATES
Lead Accident Investigator

FROM:


JOSEPH C. ZELANKO
Acting Chief, Roof Control Division

SUBJECT: Evaluation of the Uniaxial Compressive Strength of Burrell
"Omega" Blocks

As requested, laboratory tests were conducted to determine the uniaxial compressive strength of "Omega" block samples obtained from various sources. The procedures used to prepare specimens and perform the laboratory tests are presented in the attached report, along with the raw test results and a statistical interpretation of the results. An executive summary is included below for your convenience.

Executive Summary

At the request of the MSHA team investigating the January 2, 2006, fatal accident at the Sago Mine, Roof Control Division (RCD) personnel conducted uniaxial compressive strength tests on Burrell "Omega Block" samples. Samples were provided from a variety of sources, including multiple production facilities and the Sago Mine.

Representative specimens were prepared and tested from these samples by RCD personnel. There is no specific American Society for Testing and Materials (ASTM) standards for this material. However, portions of several pertinent standards were used to develop appropriate preparation and test procedures.

Two sets of data were generated to evaluate the uniaxial compressive strength of Omega blocks. One set of data was developed using a factorial experimental design. This design provided an evaluation of the influence of sample source (e.g. production facility), moisture condition, and orientation. The second set of data represents the uniaxial compressive

strength of numerous individual blocks (or block remnants) recovered from the failed seals at Sago Mine. In all cases, statistical analyses were performed using a commercial software package called "Statistix."

Analyses of test results indicate that there are no differences in the average compressive strengths between wet and dry specimens or between core drilled horizontally and vertically. There appears to be a difference in strength between blocks U/H (i.e. those produced in the west) and SY (blocks obtained from the supply yard at Sago). However, there is no significant difference between blocks recovered underground at Sago Mine and blocks evaluated from any other location. Blocks from the failed seals at Sago Mine that were tested "as received" (regarding moisture condition) yielded the highest average uniaxial compressive strength of any group.

If you have any questions regarding this work or any additional testing needs, you can reach me at 412-386-6169.

cc: R. Stoltz, PSHTC, Ventilation Division

Appendix W - Sampling and Testing of Mortar Bed Cores Taken from Failed Ventilation Seals

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236



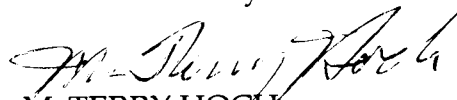
Mine Waste and Geotechnical Engineering Division

April 13, 2007

MEMORANDUM FOR RICHARD A. GATES

District Manager, District 11
Coal Mine Safety and Health

THROUGH:


M. TERRY HOCH

Chief, Pittsburgh Safety and Health Technology Center


STANLEY J. MICHALEK

Acting Chief, Mine Waste and Geotechnical Engineering
Division

FROM:



TERENCE M. TAYLOR

Senior Civil Engineer, Mine Waste and Geotechnical
Engineering Division

SUBJECT:

Sampling and Testing of Mortar Bed Cores Taken From
Failed Ventilation Seals at Wolf Run Coal Company's
Sago Mine, Mine ID No. 46-08791, Buckhannon, West
Virginia

On January 2, 2006, a fatal explosion occurred at the Sago Mine, owned by the International Coal Group and operated by Wolf Run Coal Company. Ten 40-inch-thick Omega block ventilation seals failed as a result of the explosion. During the course of the initial investigation, the Sago Investigation Team raised concerns about the quality of the mortar beds located beneath the seals as the remnant mortar on the mine floor appeared to be discolored and friable. On March 26, 2006, I was contacted and asked to travel to the mine and determine how samples could be removed from the mine floor using coring or other methods to determine the depth of the remaining Blocbond and to establish the competency of this material. The setting bed beneath the seals had reportedly been constructed by placing a dry mixture of Blocbond powder on the moist to wet mine floor at each seal location. A 40-inch-thick Omega block seal was then constructed on top of the setting bed.

Following a site visit on March 29, 2006, this office arranged a contract with Professional Service Industries, Incorporated (PSI) to sample the remnant Blocbond setting beds and mine floor at each seal location so that further examination and testing could be conducted in a laboratory. On June 13 and 14, 2006, Paul Sanchez from PSI conducted the mine floor coring using a portable drill unit with a 3-inch-diameter drill bit. The following individuals observed the sampling:

Terence M. Taylor - MSHA, Technical Support
Russell Dresch - MSHA, Sago Investigation Team
Johnny Stemple - International Coal Group, Inc.
Chuck Dunbar - International Coal Group, Inc.
Brian Curtis - Miners' Representative, International Coal Group, Inc.
Ron Bowersox- United Mine Workers of America
John Cruse - West Virginia MHST

The cores were taken up to a depth of 6 inches using a dry drilling method. Wet drilling was not used as it was felt that the use of water could lead to further hydration of the cementitious materials in the Blocbond samples. The samples were placed in sealed plastic bags and wrapped in bubble wrap to prevent sample disturbance during transport. A log was kept to describe details of each of the sample locations. Also, a chain of custody was maintained for all the samples.

The samples were designated as follows: S1 refers to a sample taken from Seal 1, S2 refers to a sample taken from Seal 2, etc. The number following the dash refers to the number of the sample taken at a given seal location. The first three samples taken at each seal location were consistently 5, 10, and 15 feet, respectively, from the left rib (as designated looking inby). As the mine entries were between 18 and 21 feet wide, this represented taking samples at the middle and quarter points along the seals. The fourth, fifth, or any additional samples are followed by an "R" designation. This indicates that the sample location within the footprint of the seal was random, rather than one of the first three pre-selected locations at each seal. For example, S6-4R refers to the fourth sample taken from the mine floor at Seal 6 and that the sample was at a random location on the floor beneath the seal. Note that the contents at a few of the core locations were further designated as being either the top or bottom of the core. As the cores were generally friable and in multiple pieces, the upper portion of the core typically contained the Blocbond. All samples are listed in Table 1.

Table 1: Floor Core Samples from Sago Mine Ventilation Seals

Sample I.D.	Location	Evaluated by Consultant
SEAL 1		
S1-1	5' from left rib	X
S1-2	10' from left rib	
S1-3	15' from left rib	
S1-4R	1' from right rib	
S1-5R	1' 4" from left rib	
S1-6R	9' 4" from left rib	X
S1-7R	7' from left rib	
S1-8R	4' 8" from left rib	
SEAL 2		
S2-1	5' from left rib	X
S2-2	10' from left rib	
S2-3	15' from left rib	X
S2-4R	2' 6" from left rib	
SEAL 3		
S3-1	5' from left rib	X
S3-2	10' from left rib	
S3-3	15' from left rib	X
S3-4R	1' 6" from left rib	
SEAL 4		
S4-1	5' from left rib	
S4-2	10' from left rib	
S4-3	15' from left rib	
S4-4R	1' 6" from left rib	X
SEAL 5		
S5-1	5' from left rib	X
S5-2	10' from left rib	
S5-3	15' from left rib	
S5-4R	1' from left rib	
SEAL 6		
S6-1	5' from left rib	X
S6-2	10' from left rib	X
S6-3	15' from left rib	
S6-4R	15' from left rib (grab sample next to S6-3)	X
S6-5R	1' 1" from right rib	
SEAL 7		
S7-1	5' from left rib	X
S7-2	10' from left rib	
S7-3	15' from left rib	
S7-4R	3' 6" from right rib	

S7-5R	10" from left rib	
S7-6R	3' 8" from right rib	X
SEAL 8		
S8-1	5' from left rib	
S8-2	10' from left rib	
S8-3	15' from left rib	X
S8-4R	16" from right rib	X
SEAL 9		
S9-1	5' from left rib	
S9-2	10' from left rib	
S9-3	15' from left rib	X
S9-4R	1' 3" from right rib	
SEAL 10		
S10-1	5' from left rib	X
S10-2	10' from left rib	
S10-3	15' from left rib	
S10-4R	16" from right rib	X

Petrographic Evaluation

A contract was entered into with Mark E. Patton, LTD, a materials consultant, to evaluate the quality and composition of the Bloclbond setting bed samples. Mr. Patton was charged with conducting petrographic examinations, visual examinations, and compression strength testing of select samples from the ten seal locations. The samples given for evaluation were representative of the better quality samples collected and therefore represent an upper bound on the quality of the setting beds. The lower quality samples did not contain intact pieces large enough to conduct testing or examination. A bag of Bloclbond was given to the consultant to prepare control samples that were used for comparison in both the examination and testing phases of the study.

A full copy of the petrographic study report has been forwarded to your office. Attached to this memorandum is a copy of the executive summary from that report. Based on the findings of the consultant's study, the Bloclbond setting beds beneath the ten failed ventilation seals were not properly mixed, placed, and cured, which resulted in a generally weak, friable material.

If there are any questions, please contact this office.

Attachment

cc: M. Skiles - Director, TS
M. Kalich - Acting Chief, Safety Div., CMS&H

EXECUTIVE SUMMARY

MSHA personnel from the Pittsburgh Technical Support, Mine Waste and Geotechnical Engineering Division, Pittsburgh, Pennsylvania submitted eighteen samples and requested an assessment of the composition, quality and strength of the mortar in the setting beds from ten ventilation seals at the Sago Mine. In addition to a laboratory prepared sample of mortar, laboratory studies were done on 17 core samples and one grab sample of setting bed mortar taken through mortar beds under ten ventilation seals from the Sago Mine. The laboratory studies include: (1) petrographic examinations of one laboratory prepared sample of mortar, the grab sample and two cores from the mortar beds at ventilation seals; (2) visual examinations of 15 core samples through the mortar beds, and (3) compressive strength testing of laboratory prepared mortar cubes and mortar cubes saw cut from the core samples from the ventilation seals.

The petrographic examinations were done using applicable methods outlined in ASTM C856, "Petrographic Examination of Hardened Concrete." Scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDS) were used in addition to the optical microscopes. Visual examinations of the samples were limited to viewing the samples with the unaided eye; no microscopy was performed on the samples visually examined.

Based on the petrographic examinations, Samples S2-3 Top, S4-4R, and S6-4R were all made using the BlocBond material and contain similar amounts of fly ash, portland cement and glass fibers as the Control Sample made with the BlocBond in the laboratory. Except for Sample S1-1, all of the samples visually examined appear similar to the samples made with BlocBond and contain glass fiber bundles. Sample S1-1 is not made from BlocBond, but is similar to a prepackaged concrete mix.

The petrographic examination of the Control Sample demonstrates that when mixed for the recommended two minutes, the BlocBond material produces a

mortar that is consistent, well-hydrated, dense, medium gray and hard. The mixing of the BlocBond entrains some amount of air that occurs mainly as small, fine and microscopic spherical voids characteristic of entrained air and minor amounts of coarse spherical and non-spherical voids. All portland cement products will contain some small amount of air that will occur as spherical or rounded voids from the mixing operations. The other feature that results from adequate mixing is the distribution of the glass fiber bundles. The glass fiber bundles are not only distributed throughout the Control Samples, many of the bundles are broken up and there are numerous smaller bundles and individual fibers present throughout the samples.

The compressive strength tests of the Control Samples confirmed that adequately mixed and cured BlocBond will attain compressive strengths in excess of 8,000 psi at ages beyond 28-days. The features of the hardened BlocBond Control Samples and the compressive strength results were used to assess the adequacy of the mixing of the samples taken from the mine.

The petrographic examinations show that all three samples, S2-3 Top, S4-4R and S6-4R, have some amount of entrained air that occurs as small, fine and microscopic spherical voids that are characteristic of entrained air voids. The presence of spherical void indicates that the samples were mixed either by hand or mechanically.

The Control Sample was made using the entire 50-pound bag of BlocBond with the prescribed 1³/₄ gallons of water, which correlates to a water cementitious materials ratio of 0.29. Paste in Sample S4-4R is hard, firm and slightly darker than paste in the Control Sample. Compositional and textural features of the paste in S4-4R indicate that S4-4R is made using a water cementitious materials ratio that is lower than the Control Sample and is well mixed. A few fiber bundles are present but most of the original fiber bundles are distributed into smaller bundles and individual fibers dispersed throughout the sample. The distribution of fibers in S4-4R is similar to the distribution obtained in the Control Sample. Based on

the known water cementitious materials ratio of the Control Sample, the water cementitious materials ratio of S4-4R is estimated to be 0.25 to 0.26. The compressive strength of S4-4R is similar to that of the Control Samples, 8,370 psi.

The paste in Sample S6-4R is variable in quality, with small areas of dense paste distributed throughout a matrix of soft paste. The water to cementitious materials ratio in the sample varies on a microscale and is estimated to vary from 0.25 to 0.26 in the dense areas to 0.29 to 0.34 in the remainder of the paste. The variation is due to incomplete intermixing of the components. Overall, the water content used to make the sample is estimated to be the same or slightly higher than the Control Sample, but incomplete intermixing resulted in the variable water cementitious ratios. Incomplete mixing does not completely and intimately intermix the water and cementitious materials into a consistent mass. The incomplete intermixing of water with the cementitious material results in small areas of dense paste distributed throughout, while the remainder of the paste is soft and has a higher water cement ratio.

Sample S2-3 Top is mainly crumbly, friable and weak with few small inclusions of dark hard paste. Most of the paste can be scratched easily with a fingernail and fresh fracture surfaces have textures that are dull and earthy. Some carbonation of the porous paste is present throughout the sample. Numerous fine and coarse residual portland cement particles are present and indicate that hydration of the cement was restricted. Weak friable paste that is carbonated can be explained by a high water content and rapid drying of the paste that results in restricted hydration and carbonation, or the presence of a contaminant that restricts hydration. The water cementitious materials ratio of the sample is not easily estimated, but based on the friable nature of the paste, the water cementitious materials ratio is estimated to be moderate, e.g. 0.40, based on the known water cementitious materials ratio of the Control Sample.

The average compressive strength of the mortar cast in the laboratory exceeds 8,000 psi. The mortar from sample S4-4R has a compressive strength of 8,370 psi. The mortars from the remaining six mine samples tested have strengths from 830 to 2,810 psi.

Of the 17 core samples and one grab sample of mortar submitted for the studies, cubes could only be recovered from 7 of the samples or less than 40 percent. Fractures in the samples or inclusions that caused fracturing of the sample during saw cutting were the reasons that cube samples as small as 1 inch could not be recovered in 11 of the samples. Except for the cube sample from S4-4R, all of the cube samples remained moist and did not dry during the 1 hour drying period after preparation. This is due to either a porous microstructure or the presence of fine contaminants in the mortar that would retain moisture. The petrographic examination demonstrated that S2-3 Top has a porous microstructure. The cause of the lower strengths in all of the compressive strength cubes from the mine sample, except for S4-4R, include: (1) sometime higher than desired water cementitious materials ratios; (2) the presence of fractures, fissures or inclusions of coal and multiple layers of mortar, and (3) incomplete intermixing that resulted in variations in mortar quality within a sample.

Of the 17 core samples visually examined, evidence of inadequate mixing (large fiber bundles) is present in Samples S1-6R, S2-1 Top, S3-3 Top, S6-2 and S10-1. Variations in paste quality (hard and soft paste) are present in Samples S6-2, S7-6R, S8-4R and S10-4R. Overall soft paste is present in Samples S1-6R, S2-1 Top, S3-3 Top, S5-1 and S7-6R. Inclusions of coal or cementitious foam block are present in the mortar of Samples S3-1, S8-3, S8-4R, S9-3 and S10-4R. Finally fractures are present in Samples S7-1 and S9-3.

The visual and petrographic examinations show that, except for the mortar from S4-4R, the mortars from the ventilation seals do not have the same characteristics as the mortar produced in the laboratory. Sample S4-4R demonstrates that it is possible to construct a mortar bed for the ventilation seals that has strength similar to that of samples made in the laboratory. Based on the results of the testing and examinations, the mortar beds beneath the ventilation seals were significantly weaker than the mortar bed represented in S4-4R due to issues related to mixing, placement and curing of the BlocBond material. Strength of the mortar from the ventilation seals is affected by factors that include: (1) inadequate mixing that is characterized in some samples as numerous intact fiber bundles and/or variable paste quality such as inclusions of dense hard paste in softer paste; (2) higher than desired water contents and in the case of S2-3 rapid drying and carbonation

of a mortar with a higher than desired water content; (3) inclusions of coal, and (4) fissures or tears that occurred in the mortar after it had stiffened. These tears or fissures are characteristic of plastic cracks that can occur if the mortar is manipulated for a prolonged time period. The randomly oriented fine cracks that are sometimes interconnected (for example as in Samples S6-4R and S7-1) are characteristic of drying shrinkage cracks, but the coring operations and stress related phenomena can not be ruled out as having contributed to these cracks.

Table– Summary of information from the laboratory studies.

Sample I.D.	Remarks	Compressive Strength, psi
S2-3 Top	Dark, hard inclusions of good quality paste distributed throughout a weak matrix. Weak matrix porous with numerous residual portland cement particles. Much higher w/cm ratio than Control Sample or S4-4R. Rapid drying and carbonation also probable contributors to weak matrix. Mixing is variable, fibers are distributed in some areas, but not in others. Spherical air voids are present.	1,064
S4-4R	Well mixed, low water to cement ratio estimated to be lower than the control sample. Fibers well distributed and spherical air voids are present.	8,340
S6-4R	Paste varies from soft to moderately hard. Paste with a slightly higher w/cm ratio than the Control Sample distributed throughout with channels of friable, soft porous paste running through the sample, indicative of incomplete intermixing of the mixing water. Spherical air voids present indicating some mixing, but fibers are mainly present in large intact bundles.	--
Visual Examinations		
S1-1	Loose material that contains fine and coarse aggregate and trace amount of fly ash, not BlocBond. Non-spherical moderately hard agglomerations of cementitious material and aggregate are indicative of exposure to moisture resulting in hydration of some material. Agglomerations are indicative of exposure to water but no mechanical intermixing of the water and cement has occurred.	--
S1-6R	Extensively fractured moderately soft paste that can be scratched with a fingernail. Inclusions of hard paste indicative of incomplete intermixing of water. Fibers occur mainly in large intact bundles also indicate incomplete mixing.	--
S2-1 Top	Paste is medium gray and hard at the top and grades to soft, light gray paste at bottom. Paste at bottom can be scratched with fingernail. Placing and intermixing mixed mortar in standing water can explain soft mortar on bottom. Fibers are distributed but there are many large intact bundles of fibers present, which is an indication of incomplete mixing.	--
S3-1	Mortar is firm and hard with fiber well dispersed indicating adequate mixing. Numerous inclusions of coal throughout sample and one inclusion of a fragment of a foam block.	1,050
S3-3 Top	Mortar can be scratched with a fingernail. Fibers occur mainly as intact large bundles, one indication of incomplete intermixing.	--
S3-1	Mortar is firm and hard with fiber well dispersed indicating adequate mixing. Numerous inclusions of coal throughout sample and one inclusion of a fragment of a foam block.	1,050

Table (cont'd) – Summary of information from laboratory studies.

Sample I.D.	Remarks	Compressive Strength, psi
S3-3 Top	Mortar is soft and can be scratched with a fingernail. Fibers occur mainly as intact large bundles, one indication of incomplete intermixing.	--
S5-1	Mortar is mainly soft, friable and can be crushed with firm finger pressure. Fibers are distributed and occur mainly as small bundles and individual fibers, indicative of adequate mixing.	--
S6-1	Mortar is hard and firm. Fibers are well distributed indicating adequate mixing.	--
S6-2	Mortar is soft and can be scratched with a fingernail. There are a few small inclusions of dark hard and firm paste. Fibers are distributed in large intact bundles, which is one indication of incomplete mixing.	--
S7-1	Mortar is hard and firm. Fibers are well distributed with some larger bundles present indicating adequate mixing. Small, fine randomly oriented fractures that are sometimes interconnected are present in the sample.	1,960
S7-6R	Mortar is variable from light to medium gray, and is moderately hard and moderately firm. Some portions are soft enough to be scratched with a fingernail. Fibers are well distributed with a few intact bundles present indicating adequate mixing.	--
S8-3	Mortar is moderately hard and firm and cannot be scratched with a fingernail. Fibers are well distributed with a few intact large bundles visible indicating adequate mixing. Inclusions of coal are visible in the mortar.	830
S8-4R	Mortar is moderately hard and firm with a few small areas that are soft and can be scratched with a fingernail. Inclusions of coal are visible in the mortar and the fibers are well dispersed indicating adequate mixing.	1,690
S9-3	Two distinct mortars are present, a moderately hard and firm light gray and mainly a dark gray hard and firm mortar. Numerous fissures and plastic settlement cracks are present as are inclusions of coal. Good fiber distribution in dark mortar is an indication of adequate mixing.	2,810
S10-1	Mortar is hard and firm. Thin layers of separated mortar are present on the bottom surface. Intact bundles of fiber are present on the bottom surface, one indication of incomplete intermixing.	--
S10-4R	Mortar is mainly hard and firm with a few small areas of moderately soft mortar. Rock and coal inclusions are present and fibers are well distributed. Well-distributed fibers are one indication of adequate mixing.	--

Experimental Study of the Effect of LLEM Explosions on Various Seals and Other Structures and Objects¹

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Pittsburgh Research Laboratory
Pittsburgh, PA

February 2007

¹ This report details work performed at the request of the Mine Safety and Health Administration and the West Virginia Office of Miners' Health, Safety, and Training in support of their investigations into the Sago mine explosion. This report has not undergone external peer review.

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Appendix C - Air-Leakage Data for Seals

Experimental Study of the Effect of LLEM Explosions on Various Seals and Other Structures and Objects²

by Kenneth L. Cashdollar, Eric S. Weiss, Samuel P. Harteis, and Michael J. Sapko³
National Institute for Occupational Safety and Health,
Pittsburgh Research Laboratory, Pittsburgh, PA

Executive Summary

The Mine Safety and Health Administration (MSHA) and the West Virginia Office of Miners' Health, Safety, and Training (WVOMHS&T) have been investigating the January 2006 Sago coal mine explosion in West Virginia, which resulted in 12 fatalities. In early Spring 2006 the MSHA and the WVOMHS&T requested the Pittsburgh Research Laboratory (PRL) of the National Institute for Occupational Safety and Health (NIOSH) to evaluate the effects of explosions on specific mine ventilation seals and other structures and objects at the NIOSH Lake Lynn Experimental Mine (LLEM) to help answer questions that arose during their investigations of the Sago coal mine explosion. Six large-scale explosion tests were conducted in the LLEM from April to October 2006. The protocols for these tests, and in particular the procedures for constructing the various Omega block seals, were primarily developed by MSHA and WVOMHS&T. NIOSH developed the experimental procedures at the LLEM that would provide the required range of explosion pressures against the seals. Three 40-inch thick seal designs using Omega 384 low-density block were constructed at the LLEM and exposed to various explosion pressures. These seal designs are identified in the report as the 2001 design, the "hybrid" design, and the "Sago" design.

The 2001 design Omega block seal (80 inches high) located in crosscut 2 survived all six LLEM explosions, with maximum pressures up to 51 psi. The 2001 design Omega block seal (88 inches high) in C-drift was destroyed during Test 2, which had a maximum explosion pressure of 51 psi. The difference in heights between these two seals was a contributing factor to the fact that the crosscut 2 seal survived an explosion at 51 psi and the C-drift seal was destroyed during Test 2 at 51 psi. The higher seal would be weaker for the same seal thickness. The "hybrid" Omega block seal in crosscut 3 survived an explosion at a pressure of 25 psi and failed during another explosion at a maximum pressure of 39 psi at the seal. Based on these LLEM tests, it appears that the hybrid seal design is weaker than the 2001 seal design. The "Sago Omega block seals" were constructed in crosscut 3 and C-drift before Test 3. The crosscut 3 seal survived an explosion pressure of 18 psi and was destroyed during an explosion with a maximum pressure of 35 psi at the seal. The C-drift seal survived an explosion pressure of 21 psi and was destroyed during an explosion with a maximum pressure of 57 psi at the seal.

² This report details work performed at the request of the Mine Safety and Health Administration and the West Virginia Office of Miners' Health, Safety, and Training in support of their investigations into the Sago mine explosion. This report has not undergone external peer review.

³ Retired from NIOSH in January 2007.

Based on these LLEM tests, it appears that the “Sago” seal design is weaker than the 2001 seal design, yet it still complies with the requirements of 30 CFR 75.335(a)(2).

During these LLEM explosion tests, the distance of seal debris travel was also measured. In Test 5, the C-drift seal was destroyed during an explosion with a maximum pressure of 57 psi, and the seal debris was thrown over 500 ft. In Test 6, the C-drift seal was destroyed during an explosion with a maximum pressure of 93 psi, and the Omega block debris was thrown over 900 ft. During these LLEM tests, the explosion pressure effects on other structures and objects were also documented, as described in the text.

The information in this report will be used as supporting data for the MSHA and WVOMHS&T investigation reports of the Sago coal mine explosion.

Summary and Conclusions

Several seal designs using Omega 384 block were constructed at the LLEM during 2006 and exposed to various explosion pressures. All of the seals were constructed of Omega low-density blocks with nominal dimensions of 8-in by 16-in by 24-in. The blocks were alternated to stagger the joints. In the 2001 design, properly mixed BlocBond mortar was applied to all of the block-to-block interfaces and all the block-to-strata interfaces, including the floor. There were some differences between the 2001 design and the “hybrid” and “Sago” designs. The main differences between the “hybrid” design and the 2001 design were that the “hybrid” design was installed on a ¼-in thick layer of dry BlocBond and that the entire first course of block was put into position prior to any mortar being applied to the block. For all subsequent courses with the “hybrid” design, the mortar was applied by gloved hand to the block joints prior to placement of each block. The main differences between the “Sago” design and the 2001 design were that the “Sago” design was installed on a 1½-in thick layer of dry BlocBond and that the mortar was forced into the vertical joints after the blocks were positioned for all courses of blocks. Comprehensive details of the three seal construction procedures are in Appendix B.

A summary of the results of the explosions against the three seal designs is listed in table 13. The first two columns list the type of seal design and the location in a crosscut or in C-drift at the LLEM. The next two columns list the seal height and width. All the seals were nominally 40 in thick. When the coating thickness on the faces of the seal and the mortar thickness are included, the total seal thickness was about 41 in. The next column lists the highest explosion pressure at which a particular seal survived. The final column lists the explosion pressure at which a particular seal was destroyed. This value is the maximum pressure measured during a particular explosion at the middle front of the seal. If a particular design of seal was destroyed during more than one explosion, the lower explosion pressure is listed. For example, a “Sago” seal in C-drift was destroyed at 57 psi during Test 5 and at 93 psi during Test 6, so only the lower pressure of 57 psi is listed in Table 13. The ultimate strength of a particular seal would be somewhere between the values in columns five and six. For example, the 81-in high “hybrid” seal survived an explosion pressure of 25 psi and was destroyed during a later explosion at 39 psi. Therefore, its ultimate strength is greater than 25 psi but less than 39 psi.

Table 13 – Summary of explosion pressures on various seals

Seal Design	Location	Height, in	Width, in	Highest Pressure at which seal survived	Explosion Pressure at which seal was destroyed
2001	X-2	80	226	51	n/a
	C-drift	88	224	n/a	51
“hybrid”	X-3	81	226	25	39
“Sago”	X-3	80	226	18	35

	C-drift	88	224	21	57
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Note: n/a means that no data were available for this scenario.

The 2001 design Omega block seal (see Appendix B1 for construction details) located in X-2 survived all six LLEM explosions, with maximum side-on pressures of 13, 15, 22, 23, and 51 psi. Note that all the explosion pressure values were smoothed data that were averaged over 10 ms. The pressure data here are all from transducers near the geometric center in front the seals. The 2001 design Omega block seal (Appendix B3) in C-drift was destroyed during Test 2, which had a maximum head-on explosion pressure of 51 psi. The difference in heights between these two seals was a contributing factor to the fact that the X-2 seal survived Test 6 at 51 psi and the C-drift seal was destroyed during Test 2 at 51 psi. The C-drift seal was ~88 in high and the X-3 seal was ~80 in high. The higher seal would be weaker for the same seal thickness [Anderson 1984]. The “hybrid” Omega block seal (Appendix B2) in X-3 survived Test 1 at an explosion pressure of 25 psi and failed during Test 2 at an explosion pressure of 39 psi. Based on these LLEM tests, it appears that the hybrid seal design is weaker than the 2001 seal design.

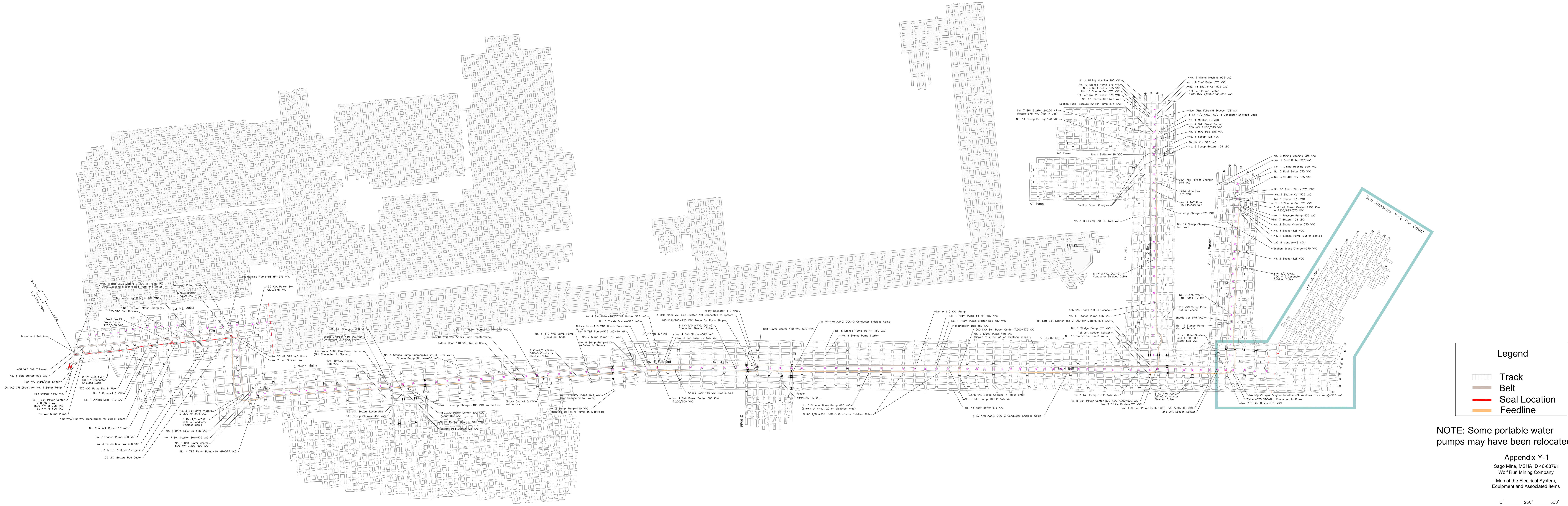
The “Sago Omega block seals” were constructed in X-3 and C-drift before Test 3, as described in Appendixes B4 and B5. The X-3 seal survived Tests 3 and 4 at explosion pressures of 16 and 18 psi, respectively. It was destroyed during Test 5 at an explosion pressure of 35 psi. The C-drift seal survived Tests 3 and 4 at explosion pressures of 17 and 21 psi, respectively. It was destroyed during Test 5 at an explosion pressure of 57 psi. During these three tests, the X-3 seal experienced the side-on explosion pressure and the C-drift seal experienced the head-on explosion pressure. The X-3 and C-drift “Sago Omega block seals” both survived Test 4 at explosion pressures of 18 and 21 psi, respectively. The X-3 and C-drift seals both were destroyed during Test 5 at higher explosion pressures of 35 and 57 psi, respectively. This indicates that the magnitude of the explosion pressure is more important than the direction of the explosion propagation in regard to seal survival or failure. Another “Sago Omega block seal” was constructed in C-drift for Test 6, and it was destroyed at an explosion pressure of 93 psi, as expected. Based on these LLEM tests, it appears that the “Sago” seal design is weaker than the 2001 seal design.

During these LLEM explosion tests, the distance of seal debris travel was also measured. The C-drift seal was exposed to an explosion pressure of 51 psi in Test 2 and the seal debris was thrown over 800 ft. In Test 2, there was no significant obstacle beyond the C-drift seal that would restrict the debris travel. In Tests 5 and 6, there were two wood cribs and a block stopping beyond the C-drift seal. Even though the cribs and stopping were destroyed in both tests, they would absorb blast energy and therefore limit the debris travel distance. In Test 5, the C-drift seal was exposed to an explosion pressure of 57 psi and the seal debris was thrown over 500 ft. In Test 6, the C-drift seal was exposed to an explosion pressure of 93 psi and the Omega block debris was thrown over 900 ft. During these LLEM tests, the explosion pressure effects on other structures and objects were also documented, as described in the text.





The purpose of these LLEM explosion tests in 2006 was to assist the Mine Safety and Health Administration (MSHA) and the West Virginia Office of Miners’ Health, Safety, and Training (WVOMHS&T) in determining the explosion pressures at which

Appendix X - Experimental Study of the Effect of LLEM Explosions on Various Seals and Other Structures and Objects

various 40-in thick Omega block seal designs would fail and studying the explosion effects on various mine items, including the debris fields resulting from the destroyed seals. The information in this report will be used as supporting data for the MSHA and WVOMHS&T investigation reports of the Sago coal mine explosion.



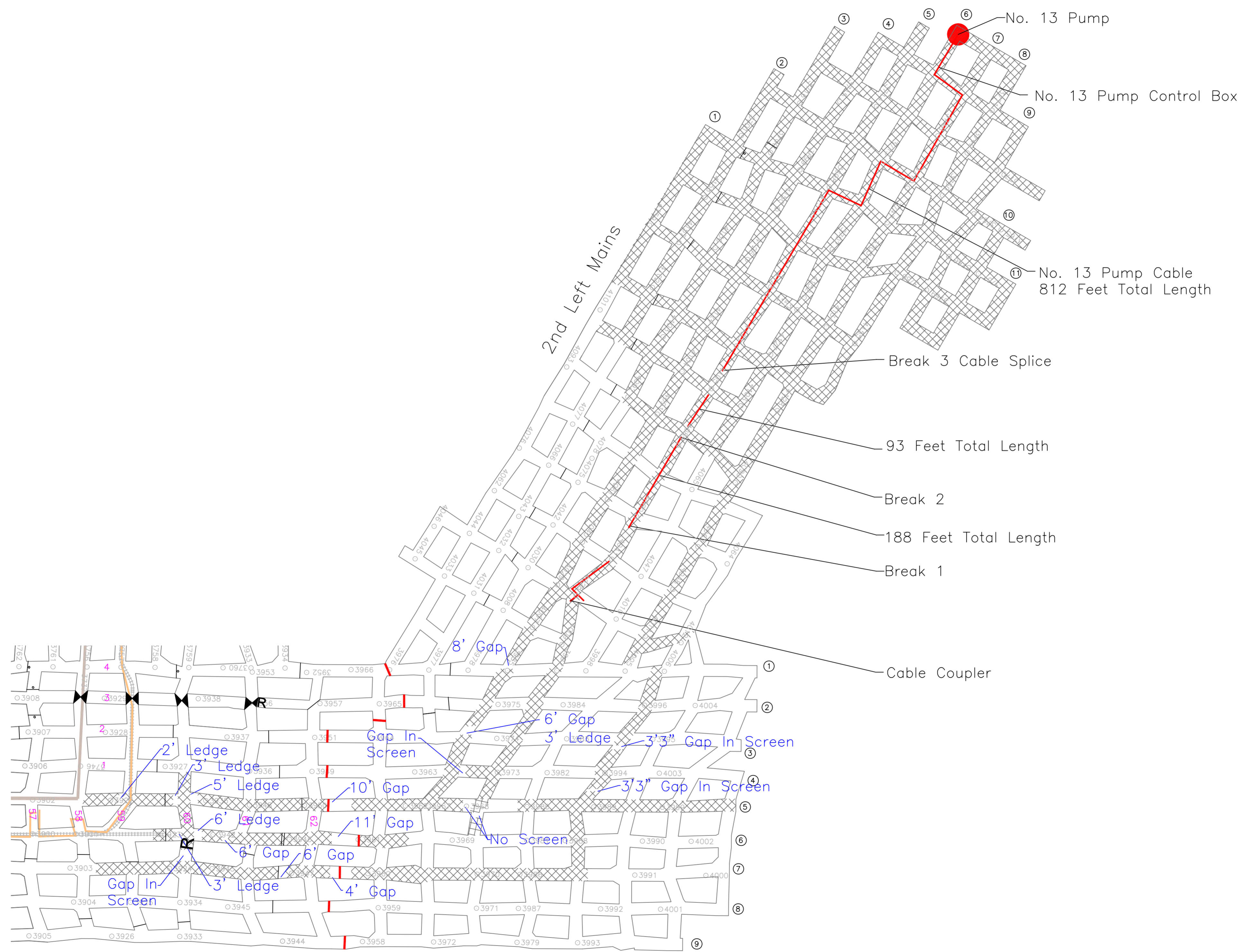
Legend

-  Track
-  Belt
-  Seal Location
-  Feedline

NOTE: Some portable water pumps may have been relocated.

Appendix Y-1
 Sago Mine, MSHA ID 46-08791
 Wolf Run Mining Company
 Map of the Electrical System,
 Equipment and Associated Items





LEGEND

- Water Pump
- Wire Mesh
- Pump Cable
- Track
- Belt
- Seal Location

Appendix Y-2
 Sago Mine, MSHA ID 46-08791
 Wolf Run Mining Company
 Map of the Electrical System,
 Equipment and Associated Items

2nd Left Mains and
 2 North Mains Inby Crosscut 57

0' 100' 200'

Appendix Z - Executive Summary of "Portable Gas Detector Testing"
U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



January 26, 2007

MEMORANDUM FOR RICHARD A. GATES

District Manager, Coal Mine Safety and Health District 11

FROM:

JOHN P. FAINI 
Chief, Approval and Certification Center

SUBJECT:

Executive Summary of Investigation of Portable Gas Detectors
Recovered from the Sago Mine

The Approval and Certification Center (A&CC), as requested by Coal Mine Safety and Health, conducted a laboratory investigation of gas detectors recovered from a fatal explosion at Wolf Run Mining Company's Sago Mine, Mine I.D. No. 46-08791 on January 2, 2006. These devices were:

- two (2) Industrial Scientific Corporation (ISC) Model iTX Multi-Gas Monitors;
- three (3) ISC Model LTX310 Multi-Gas Monitors; and
- seven (7) CSE Corporation Model 102LD Methane Detectors.

The two ISC Model iTX devices and one of the ISC Model LTX310 units, with Exhibit Numbers beginning with 'ACC', were recovered separately from the others. They were apparently not in the mine at the time of the explosion, but were taken into the mine by mine personnel during attempted rescue operations.

The investigation identified several permissibility discrepancies that were attributable to improper maintenance (overdue calibrations, carrying strap grommet displaced and holes in instrument case allowing dust to enter the instrument, and missing case securing screws) or manufacturing discrepancies that deviated from the approved design.

There was no evidence that any component of any of the pieces of evidence would have produced conditions that would have provided enough energy to ignite a flammable methane-air mixture.

The following sections summarize the testing and inspection of each of the twelve instruments.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

ISC Model iTX Multi-Gas Monitor, ACC-2

This ISC Model iTX Multi-Gas Monitor, Serial No. 0408001-374, carried Unique Identifier "RH". Exhibit Number ACC-2 was assigned to this exhibit by A&CC personnel. The unit was marked with MSHA Approval Number 8C-78-0. It was inspected and compared with approval documentation. Operational and performance tests were also conducted.

The Software Version displayed by the monitor during startup was "2.4" and the display indicated that the battery was nearly fully charged. The following instrument Peaks were displayed during startup:

PEAK READINGS		
CH ₄	O ₂	CO
.2	.0	FAIL

The "Peak" oxygen reading stored in the monitor "as-received" is a minimum value that had been measured by the monitor; the reading indicated that the monitor was exposed to low concentrations of oxygen. The "Peak" methane reading stored in the monitor indicated that the monitor was not exposed to high concentrations of a combustible gas.

The monitor reported "No Data Available to download," indicating that it was not configured to log data. This means that no periodic readings of methane, oxygen, and CO were recorded during use. Therefore, it could not be determined when the 'Peak' readings occurred.

FRESH AIR READINGS:		
CH ₄	O ₂	CO
.0	OR (flashing)	FAIL

Prior to calibration, the unit indicated over range conditions at oxygen concentrations greater than 19.15%. At lower oxygen concentrations, the monitor read much higher than the sampled concentration. For example, at the lowest sampled concentration (13.04%) the monitor displayed 20.9. The monitor could not detect various concentrations of carbon monoxide (CO) as-received; it would only display "FAIL". The manufacturer's representative said that this most likely indicated that the monitor's calibration settings were adjusted in an environment that contained a high concentration of CO in air, resulting in a significant offset in the zero calibration.

The methane display readings were lower than the sampled concentration. Readings of

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

methane concentrations that were 2% and greater were not within the limits of error specified in 30 CFR Part 22. After calibration of the monitor, it:

- detected methane within the allowable limits of error;
- detected oxygen within the $\pm 0.5\%$ requirement; and
- accurately detected carbon monoxide.

The last calibration date for the monitor was given as 11-16-05. This was 47 days before the accident.

The time reading from the monitor was approximately one hour and 41 minutes ahead of the actual time.

There were minor discrepancies between this monitor and the documentation file. There were bar code labels on the various assemblies of the monitor that are not specified on documentation. There were two cylindrical pieces of foam used as "dummy" sensors in two unused sensor slots in the monitor that are not shown on the documentation.

ISC Model iTX Multi-Gas Monitor, ACC-3

This ISC Model iTX Multi-Gas Monitor, Serial No. 0309270-042 was assigned Exhibit Number ACC-3. The unit was marked with MSHA Approval Number 8C-78-0. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

The Software Version displayed by the monitor during startup was "2.2". The battery indicator status gave an indication of fully charged. The following Instrument Peaks were displayed during startup:

PEAK READINGS		
CH ₄	O ₂	CO
.2	20.3	FAIL

The "Peak" oxygen reading stored in the monitor, as received, indicated the monitor did not measure low concentrations of oxygen since the last calibration. The "Peak" methane reading stored in the monitor "as-received" indicates that the monitor was not exposed to high concentrations of a combustible gas. Since the monitor reported "No Data Available to download", it could not be determined when these Peak readings occurred.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

FRESH AIR READINGS:

CH ₄	O ₂	CO
.0	20.9	FAIL

Prior to calibration, the unit detected four of the sampled oxygen concentrations within the $\pm 0.5\%$ requirement. The only reading that was greater than $\pm 0.5\%$ tolerance was the reading of 13.6 when sampling 13.04%. The monitor could not detect various concentrations of carbon monoxide "as-received". It would only display "FAIL". The methane display readings were significantly lower than the sampled concentration. For example, the monitor displayed 3.1 when sampling 4% methane. After calibration of the monitor, it:

- detected methane within the allowable limits of error;
- detected oxygen as it did before calibration with the only reading greater than $\pm 0.5\%$ tolerance was the reading of 13.6 when sampling 13.04% Oxygen; and
- accurately detected carbon monoxide.

The last calibration date for the monitor was given as 3-1-04. This was 672 days before the accident.

The time reading from the monitor was approximately two hours and 6 minutes ahead of the actual time.

There were minor discrepancies between this monitor and the documentation file. There were bar code labels on the various assemblies of the monitor that are not specified on documentation. There were two cylindrical pieces of foam used as "dummy" sensors in two unused sensor slots in the monitor that are not shown on the documentation.

ISC Model LTX310 Multi-Gas Monitor, ACC-1

This ISC Model LTX310 Multi-Gas monitor, Serial No. 9710027-116 was assigned Exhibit Number ACC-1. The unit was marked with MSHA Approval Number 8C-65-2. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the monitor did not operate due to a depleted battery. After charging, the monitor was in operational status. However, it was programmed to display the reading of combustible gas concentration as percent LEL (Lower Explosive Limit). The

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

following Instrument Peaks were displayed during startup:

PEAK READINGS		
LEL/CH ₄	Oxygen	Toxic
+OR	18.4	+OR

The "Peak" oxygen reading stored in the monitor "as-received" indicated the monitor was exposed to a low concentration of oxygen since the last calibration. The "Peak" LEL/CH₄ reading stored in the monitor "as-received" indicated that the monitor was exposed to a high concentration of a combustible gas. The "Peak" carbon monoxide reading indicated that the monitor was exposed to a high level of carbon monoxide. It could not be determined when these Peak readings occurred.

FRESH AIR READINGS:		
LEL/CH ₄	O ₂	Toxic
0	20.9	CO-15

Prior to calibration, the unit detected five sampled oxygen concentrations within the $\pm 0.5\%$ requirement. The monitor could accurately detect the two sample concentrations of carbon monoxide "as-received" even with the -15 offset in fresh air. The methane display readings were significantly lower than the sampled concentration and were displayed as percent LEL.

The monitor was programmed to display the combustible gas readings as % methane by volume, and the monitor was calibrated. After calibration of the monitor, it:

- detected methane within MSHA requirements at 0.25%, 0.50%, and 1.00% only. It read significantly lower at the higher sampled concentrations;
- detected oxygen within the $\pm 0.5\%$ requirement; and
- accurately detected carbon monoxide and no longer had the zero offset.

A calibration label could not be found on the monitor. It could not be determined when the monitor was last calibrated.

There were minor discrepancies between this monitor and the documentation file. There were bar code labels on the various assemblies of the monitor that are not specified on documentation. There were labels on the monitor that were probably applied by the mine for identification purposes that are not on the documentation.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

ISC Model LTX310 Multi-Gas Monitor, KLH-4

The serial number on this unit is 9609008-244. The unit was marked with MSHA Approval Number 8C-65-0. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the monitor did not operate due to a depleted battery. After charging, the monitor was in operational status. The following instrument Peaks were displayed during startup:

PEAK READINGS		
LEL/CH ₄	Oxygen	Toxic
1.7	18.7	59

The oxygen "Peak" reading stored in the monitor "as-received" indicates the monitor was exposed to a low concentration of oxygen. The LEL/CH₄ "Peak" reading stored in the monitor "as-received" indicates that the monitor was exposed to a high concentration of a combustible gas. The carbon monoxide "Peak" reading indicates that the monitor was exposed to a high level of carbon monoxide. It could not be determined when these Peak readings occurred.

FRESH AIR READINGS:		
LEL/CH ₄	O ₂	Toxic
-.8	20.4	CO-45

Prior to performance testing, the monitor no longer displayed a reading for the oxygen sensor and oxygen accuracy testing could not be conducted.

Prior to calibration, the monitor could not accurately detect two sampled concentrations of carbon monoxide. It gave a display reading of 198 with 50ppm of CO applied and a display reading of 402 with 100 ppm of CO applied. The methane display readings were higher than the MSHA limits of error at 0.50%, 1.00%, and 2.00%.

After calibration of the monitor, it:

- did not detect methane within MSHA requirements at 0.50%, 1.00%, and 2.00%. It read higher at all the other sampled concentrations;
- accurately detected carbon monoxide; and
- the oxygen sensor could not be calibrated due to the blank display for oxygen.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

A calibration label could not be found on the monitor. It could not be determined when the monitor was last calibrated.

There were minor discrepancies between this monitor and the documentation file. The part number of the combustible gas sensor (1704-6269) did not agree with the part number (1704A1856) shown on the approval documentation. The part number 1704-6269 sensor assembly is approved in other ISC instruments and the 1704A1856 sensor is a sub-assembly of the part number 1704-6269 sensor assembly. One of the case securing screws was missing.

ISC Model LTX310 Multi-Gas Monitor, KLH-15

The unit was marked with MSHA Approval Number 8C-65-2. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the monitor did not operate due to a depleted battery. After charging, the monitor was in operational status. The following instrument Peaks were displayed during startup:

PEAK READINGS		
LEL/CH ₄	Oxygen	Toxic
+OR	14.6	+OR

The "Peak" oxygen reading stored in the monitor is a minimum value that had been measured by the monitor; the reading indicated that the monitor was exposed to a very low concentration of oxygen. The "Peak" LEL/CH₄ reading stored in the monitor indicated that the monitor was exposed to a high concentration of a combustible gas. The "Peak" carbon monoxide reading indicated that the monitor was exposed to a high level of carbon monoxide. It could not be determined when these Peak readings occurred.

FRESH AIR READINGS:		
LEL/CH ₄	O ₂	Toxic
-.3	21.3	CO-1

Prior to calibration, the monitor detected the five sampled oxygen concentrations within the $\pm 0.5\%$ of reading requirement. The monitor could not accurately detect the sampled concentrations of carbon monoxide. It gave a display reading of 102 with 50ppm of CO applied and a display reading of 191 with 100 ppm of CO applied. The methane display readings were lower than the sampled concentrations and not within MSHA limits of error at all sampled concentrations. After calibration of the monitor, it:

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

- detected methane accurately at all sampled concentrations;
- accurately detected carbon monoxide; and
- accurately detected the various oxygen concentrations.

A partial calibration label was found on the monitor with only the month (7) and day (22) legible on it. It could not be determined when the monitor was last calibrated.

There were discrepancies between this monitor and the documentation file. The identifying part number on the buzzer in the monitor (PB-1220P) did not agree with the buzzer part number (QMB-11PXI) specified on the documentation. There was a jumper wire on the bottom side of the main PCB that is not shown on the documentation. One of the case securing screws was missing. The part number on the oxygen sensor in the unit (1703-5114) did not agree with the part number (1702-3516) specified for the sensor on the documentation.

CSE Model 102LD Methane Detector, KLH-2

The serial number on this unit is 4421. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.0 in fresh air and 2.3 with 2.5% calibration gas applied. It detected all sampled methane concentrations accurately except for the 4.00% methane concentration. It read low (3.6) at the 4.00% concentration.

After calibration, the instrument detected methane accurately at all sampled concentrations.

A CSE calibration label was found on the instrument with a calibration date of 12/21/05. At the time of the accident, this instrument had a valid calibration meeting the MSHA requirement of being calibrated every 31 days.

There were minor discrepancies between this Detector and the documentation file. The revision level of the main PCB assembly in the instrument was marked Revision C. The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 4310R-102-124 which disagrees with the documentation which specifies part number 43-06-R-102-124.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

CSE Model 102LD Methane Detector, KLH-10

The serial number on this unit is 1870. The unit was marked with MSHA Approval Number 8C-37-4. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.1 in fresh air and 1.9 with 2.5% calibration gas applied. The only sampled methane concentration that it read accurately was the 0.25% methane concentration. It read low at all the other sampled concentrations.

After calibration, the instrument detected methane accurately at all sampled concentrations.

A CSE calibration label was found on the instrument with a calibration date of 11/7/05. This was 56 days before the accident.

There were very minor discrepancies between this Detector and the documentation file.

CSE Model 102LD Methane Detector, KLH-21

The serial number on this unit is 4277. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.1 in fresh air and 3.4 with 2.5% calibration gas applied. The instrument did not read any of the sampled methane concentrations accurately. It read high at all sampled concentrations.

After calibration, the instrument detected methane accurately at all sampled concentrations.

A calibration label could not be found on the instrument. It could not be determined when the instrument was last calibrated.

The revision level of the main PCB assembly in the instrument was marked Revision C.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 4310R-102-124 which disagrees with the documentation which specifies part number 43-06-R-102-124. The grommet that surrounds the carrying strap was displaced from the case and was not located as shown on the documentation.

CSE Model 102LD Methane Detector, GH-45P

The serial number on this unit is 2064. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.0 in fresh air and 1.4 with 2.5% calibration gas applied. The only sampled concentration that the instrument read accurately was the 0.25% methane concentration. It read low at all other sampled concentrations.

After calibration, the instrument read accurately at the 0.25%, 0.50%, and 1.00% methane concentrations. It read low at the other higher concentrations.

A CSE calibration label was found on the instrument with a calibration date of 06/10/05. This was 206 days before the accident.

The revision level of the main PCB assembly in the instrument was marked Revision C. The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 10X-2-124-9287 which disagrees with the documentation which specifies part number 43-06-R-102-124. The two screws that secure the detector assembly to the instrument are flat head instead of the specified Phillips head.

CSE Model 102LD Methane Detector, GH-55P

The serial number on this unit is 4588. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.0 in fresh air and 2.6 with 2.5% calibration gas

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

applied. It read accurately at all sampled concentrations.

After calibration, the instrument continued to read all sampled concentrations accurately.

A CSE calibration label was found on the instrument with a calibration date of 12/12/05. At the time of the accident, this instrument had a valid calibration meeting the MSHA requirement of being calibrated every 31 days.

The revision level of the main PCB assembly in the instrument was marked Revision C. The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 4310R-102-124 which disagrees with the documentation which specifies part number 43-06-R-102-124.

CSE Model 102LD Methane Detector, GH-86P

The serial number on this unit is 4961. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation. Operational and performance tests were also conducted.

As-received, the instrument did not operate due to a depleted battery. After charging, the instrument was in operational status.

Prior to calibration, the instrument read 0.2 in fresh air and 2.2 with 2.5% calibration gas applied. The only sampled concentrations that were within the MSHA limits of error were the readings at 1.00%, 2.00%, and 3.00%. It read low at the other measured concentrations.

After calibration, the instrument read all sampled concentrations accurately.

A CSE calibration label was found on the instrument with a calibration date of 10/18/05. This was 76 days before the accident.

The revision level of the main PCB assembly in the instrument was marked Revision C. The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 4310R-102-124 which disagrees with the documentation which specifies part number 43-06-R-102-124.

CSE Model 102LD Methane Detector, GH-87P

The serial number on this unit is 4843. The unit was marked with MSHA Approval Number 8C-37-7. The unit was inspected and compared with approval documentation.

Appendix Z - Executive Summary of "Portable Gas Detector Testing"

Operational and performance tests were also conducted.

As-received, the instrument had sufficient charge on the battery and was in operational status.

Prior to calibration, the instrument read 0.0 in fresh air and 2.4 with 2.5% calibration gas applied. The only sampled concentration that was not within the MSHA limits of error was the reading at 4.00%.

After calibration, the instrument read all sampled concentrations accurately.

A calibration label could not be found on the instrument. It could not be determined when the instrument was last calibrated.

The revision level of the main PCB assembly in the instrument was marked Revision C. The latest revision level of the documentation on file for the main PCB is B. The markings on R3 on the main PCB in the instrument are 4310R-102-124 which disagrees with the documentation which specifies part number 43-06-R-102-124. One of the two screws that secure the detector assembly to the instrument was a flat head instead of the specified Phillips head.

Comprehensive test results can be obtained from the Chief of the A&CC, RR 1, Box 251, Industrial Park Road, Triadelphia, West Virginia 26059.

STRIKE[®]net

Aug 11 2006 6:46:06 PM

Nicole Ferro

Thank you for using Vaisala's STRIKE[®]net to validate the referenced claim. Your report was generated using data from Vaisala's National Lightning Detection Network[®], the most comprehensive archive database in North America.

STRIKE[®]net Report 168384

Claim Number:

Insured/Claimant Name:

Approx. Claim/Loss Value:

Items Damaged/Loss Type:

Claim Address:

Search Period: Jan 1 2006 10:00:00 PM US/Eastern

Jan 2 2006 10:00:00 PM US/Eastern

Search Center Point: 38.940940° N (Latitude), 80.202310° W (Longitude)

Search Radius: 15 mi/25 km around the given location.

Comments: 162 strikes were detected by the National Lightning Detection Network for the given time period and location.

Thank you again for selecting STRIKE[®]net. If you have any questions please contact us at 1 800 283 4557 or thunderstorm.support@vaisala.com.

Best Regards,

The Vaisala STRIKE[®]net Team

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STRIKEnet Report 168384

Report Title: 60-06MR-308

Total Lightning Strokes Detected: 162

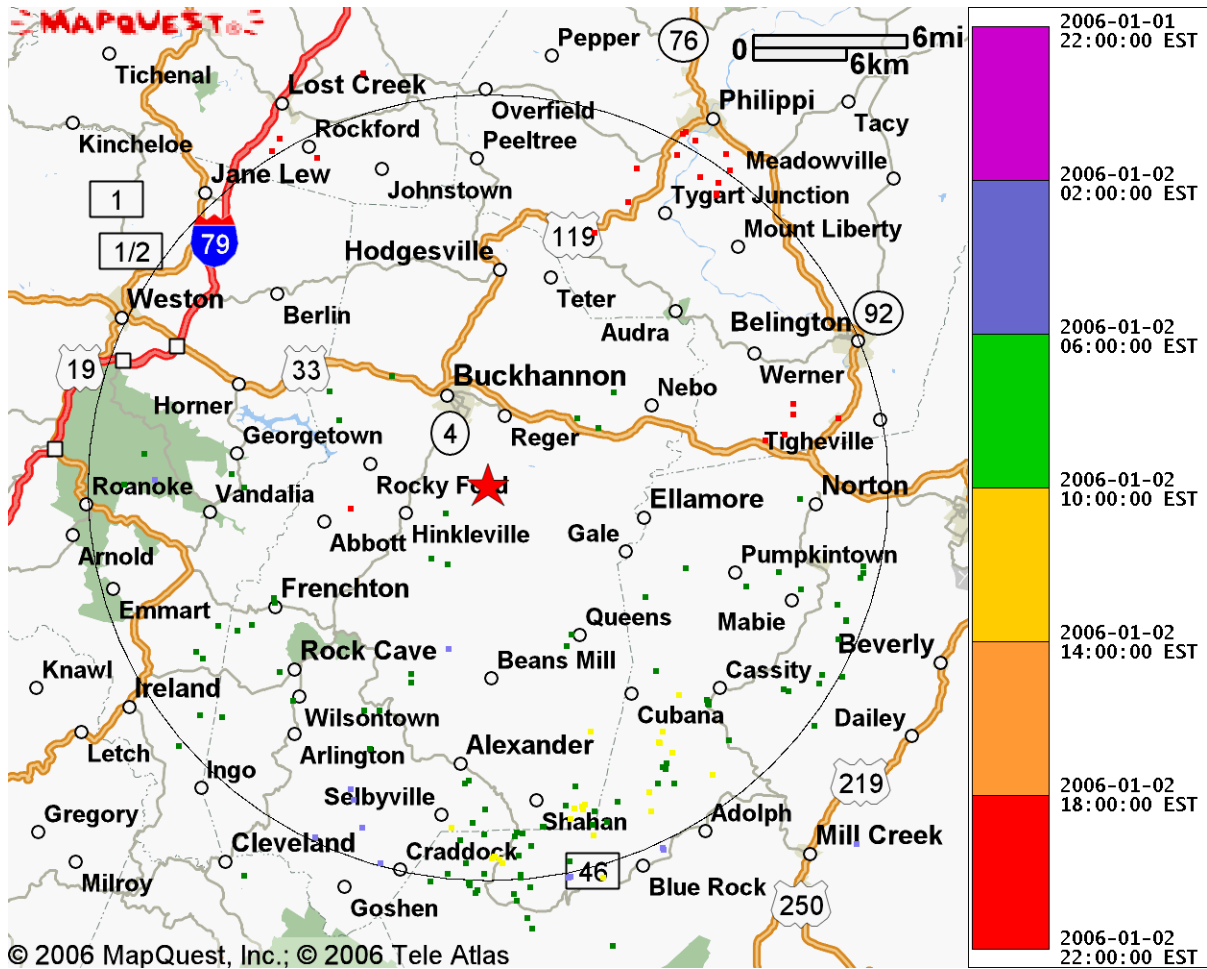
Lightning Strokes Detected within 15 mi/25 km radius: 128

Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34

Search Radius: 15 mi/25 km

Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Location Points For Lightning Strokes



Lightning data provided by Vaisala's NLDN® and/or Environment Canada's CLDN.

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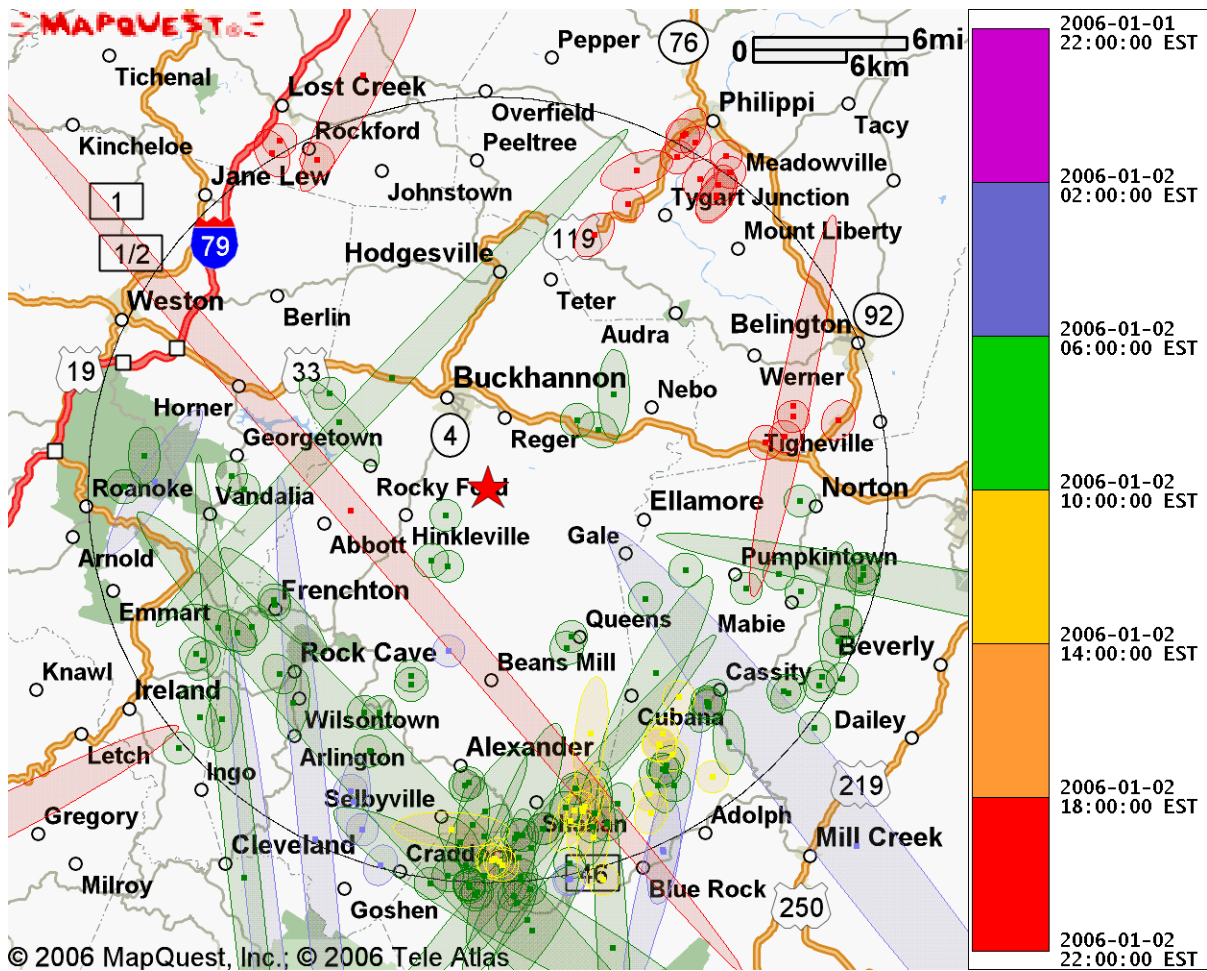
Aug 11 2006 6:46:06 PM GMT

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STRIKEnet Report 168384

Report Title: 60-06MR-308
 Total Lightning Strokes Detected: 162
 Lightning Strokes Detected within 15 mi/25 km radius: 128
 Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34
 Search Radius: 15 mi/25 km
 Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Confidence Ellipses For Lightning Strokes



Lightning data provided by Vaisala's NLDN® and/or Environment Canada's CLDN. Note: These ellipses indicate a 99% certainty that the recorded lightning event contacted the ground within the bounds of the ellipse.

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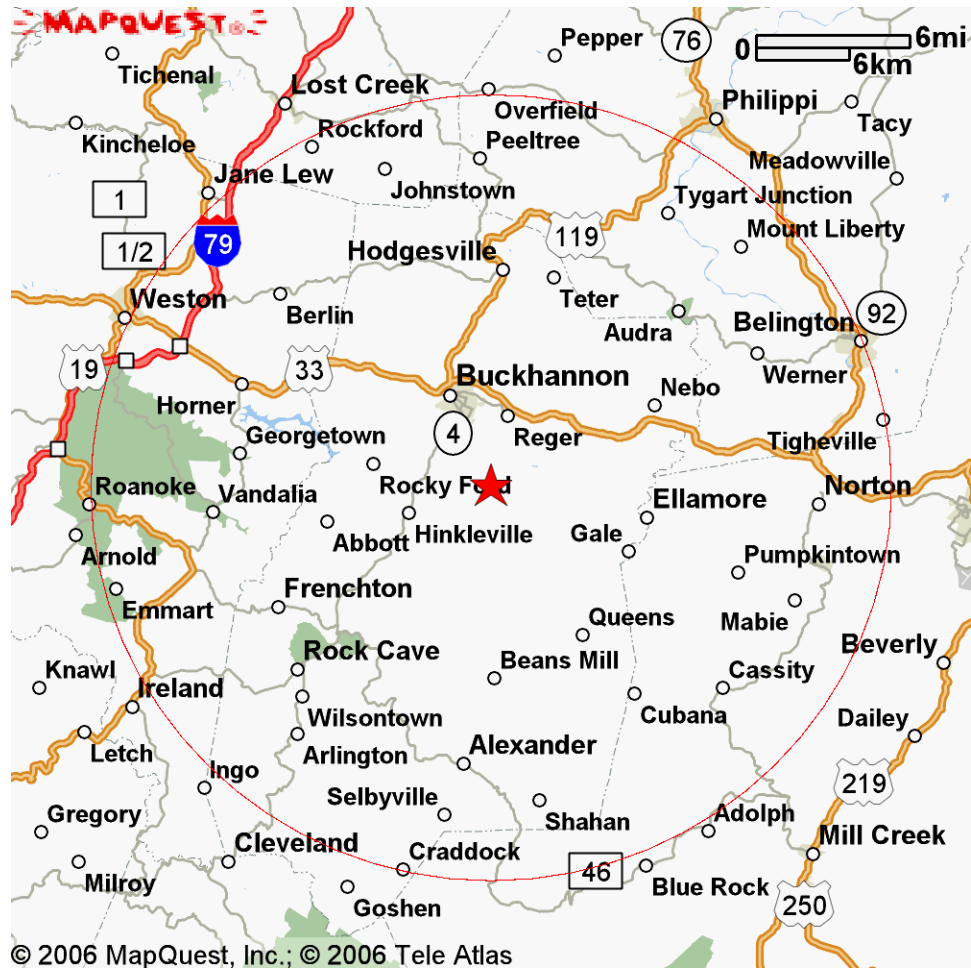


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STRIKEnet Report 168384

Area Of Study With Center Point



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STRIKEnet®**STRIKE**net Report 168384

Report Title: 60-06MR-308

Total Lightning Strokes Detected: 162

Lightning Strokes Detected within 15 mi/25 km radius: 128

Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34

Search Radius: 15 mi/25 km

Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Lightning Stroke Table (Note: Earliest 50 events shown. Events ordered by time.)

Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	4:14:03 AM	-5.3	22.1/35.7	38.6437	-80.3571
Jan 2, 2006	5:33:58 AM	26.5	15.4/24.8	38.7260	-80.2798
Jan 2, 2006	5:35:41 AM	-29.1	15.7/25.3	38.7178	-80.1439
Jan 2, 2006	5:35:41 AM	-16.7	15.7/25.3	38.7181	-80.1427
Jan 2, 2006	5:36:14 AM	-61.8	14.3/23.0	38.7462	-80.2931
Jan 2, 2006	5:36:14 AM	-12.1	13.0/21.0	38.7684	-80.3012
Jan 2, 2006	5:36:14 AM	-8.3	13.4/21.6	38.7619	-80.2993
Jan 2, 2006	5:43:55 AM	-5.7	15.8/25.6	38.7334	-80.0757
Jan 2, 2006	5:43:55 AM	-4.0	15.7/25.4	38.7347	-80.0765
Jan 2, 2006	5:51:33 AM	12.6	12.9/20.8	38.9451	-80.4429
Jan 2, 2006	5:55:25 AM	-5.8	15.3/24.7	38.7407	-80.3269
Jan 2, 2006	5:57:41 AM	-7.8	20.1/32.4	38.7366	-79.9362
Jan 2, 2006	5:57:48 AM	25.1	6.5/10.6	38.8487	-80.2310
Jan 2, 2006	6:00:09 AM	12.5	10.0/16.2	38.8131	-80.2920
Jan 2, 2006	6:04:01 AM	-60.5	15.9/25.6	38.7107	-80.2097
Jan 2, 2006	6:04:01 AM	-11.9	16.0/25.8	38.7090	-80.2116
Jan 2, 2006	6:04:01 AM	-15.8	15.6/25.2	38.7150	-80.2163
Jan 2, 2006	6:04:12 AM	23.9	13.4/21.6	38.9601	-80.4506
Jan 2, 2006	6:04:12 AM	-33.9	14.1/22.7	38.9427	-80.4652
Jan 2, 2006	6:05:30 AM	-6.0	14.6/23.5	38.7303	-80.1803
Jan 2, 2006	6:06:16 AM	-7.5	17.1/27.5	38.6943	-80.1740
Jan 2, 2006	6:06:16 AM	-9.3	15.2/24.6	38.7200	-80.2049
Jan 2, 2006	6:07:26 AM	-48.8	15.9/25.6	38.7122	-80.1721
Jan 2, 2006	6:08:29 AM	-88.7	9.9/16.0	38.9486	-80.3875
Jan 2, 2006	6:08:29 AM	-15.3	9.5/15.3	38.9408	-80.3788
Jan 2, 2006	6:09:23 AM	-23.7	16.1/25.9	38.7083	-80.1837
Jan 2, 2006	6:09:23 AM	-7.1	16.3/26.4	38.7045	-80.1816
Jan 2, 2006	6:09:23 AM	-15.3	14.0/22.5	38.7388	-80.2225
Jan 2, 2006	6:10:32 AM	-12.7	15.7/25.4	38.7151	-80.2443
Jan 2, 2006	6:10:32 AM	-5.9	15.4/24.9	38.7177	-80.1791
Jan 2, 2006	6:10:32 AM	-8.9	15.4/24.8	38.7190	-80.1787
Jan 2, 2006	6:10:32 AM	-8.6	13.8/22.3	38.7413	-80.1827

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:10:32 AM	-15.6	12.3/19.8	38.7698	-80.1395
Jan 2, 2006	6:12:16 AM	14.0	11.8/19.1	38.8615	-80.3974
Jan 2, 2006	6:12:16 AM	-27.8	13.0/21.0	38.8467	-80.4129
Jan 2, 2006	6:12:16 AM	-8.3	13.0/20.9	38.8431	-80.4086
Jan 2, 2006	6:13:08 AM	-19.1	13.7/22.0	38.7436	-80.1817
Jan 2, 2006	6:13:08 AM	-17.6	13.7/22.1	38.7427	-80.1775
Jan 2, 2006	6:13:08 AM	-16.0	6.3/10.2	38.9792	-80.3097
Jan 2, 2006	6:13:08 AM	-10.8	7.2/11.6	38.9956	-80.3168
Jan 2, 2006	6:14:27 AM	-35.8	9.7/15.7	38.8361	-80.0813
Jan 2, 2006	6:14:27 AM	6.3	14.2/23.0	38.7359	-80.1713
Jan 2, 2006	6:15:13 AM	20.5	9.4/15.2	38.8770	-80.3572
Jan 2, 2006	6:15:13 AM	-133.9	9.4/15.2	38.8775	-80.3573
Jan 2, 2006	6:15:13 AM	-35.9	9.4/15.2	38.8751	-80.3565
Jan 2, 2006	6:15:13 AM	-5.4	10.6/17.2	38.8620	-80.3729
Jan 2, 2006	6:15:14 AM	-8.1	11.2/18.1	38.8588	-80.3835
Jan 2, 2006	6:15:22 AM	-34.8	13.6/21.9	38.7465	-80.1619
Jan 2, 2006	6:15:23 AM	-11.1	13.5/21.8	38.7469	-80.1628
Jan 2, 2006	6:17:13 AM	-14.2	12.1/19.5	38.8164	-80.0430

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STRIKEnet®**STRIKE**net Report 168384

Report Title: 60-06MR-308

Total Lightning Strokes Detected: 162

Lightning Strokes Detected within 15 mi/25 km radius: 128

Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34

Search Radius: 15 mi/25 km

Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Lightning Stroke Table (Note: Closest 50 events shown. Events ordered by distance.)

Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:26:35 AM	101.0	1.9/3.1	38.9260	-80.2331
Jan 2, 2006	6:26:35 AM	38.8	3.4/5.5	38.8968	-80.2313
Jan 2, 2006	9:30:44 AM	27.5	3.6/5.7	38.9003	-80.2431
Jan 2, 2006	6:38:51 AM	85.7	4.4/7.1	38.9805	-80.1380
Jan 2, 2006	6:38:51 AM	-12.6	4.9/7.8	38.9748	-80.1227
Jan 2, 2006	8:30:44 PM	18.1	5.4/8.7	38.9289	-80.3014
Jan 2, 2006	7:36:46 AM	-5.7	5.8/9.3	39.0048	-80.2719
Jan 2, 2006	6:38:51 AM	-86.0	6.2/9.9	38.9954	-80.1113
Jan 2, 2006	6:13:08 AM	-16.0	6.3/10.2	38.9792	-80.3097
Jan 2, 2006	5:57:48 AM	25.1	6.5/10.6	38.8487	-80.2310
Jan 2, 2006	7:22:01 AM	23.7	6.6/10.7	38.8570	-80.1420
Jan 2, 2006	7:22:01 AM	-19.4	7.0/11.2	38.8500	-80.1457
Jan 2, 2006	6:13:08 AM	-10.8	7.2/11.6	38.9956	-80.3168
Jan 2, 2006	6:29:42 AM	19.3	7.5/12.1	38.8782	-80.0886
Jan 2, 2006	7:11:49 AM	87.8	7.9/12.8	38.8344	-80.2577
Jan 2, 2006	7:03:33 AM	-20.9	8.3/13.3	38.8292	-80.2578
Jan 2, 2006	7:52:21 AM	47.4	8.3/13.4	38.8949	-80.0595
Jan 2, 2006	6:15:13 AM	-133.9	9.4/15.2	38.8775	-80.3573
Jan 2, 2006	6:15:13 AM	20.5	9.4/15.2	38.8770	-80.3572
Jan 2, 2006	6:15:13 AM	-35.9	9.4/15.2	38.8751	-80.3565
Jan 2, 2006	6:08:29 AM	-15.3	9.5/15.3	38.9408	-80.3788
Jan 2, 2006	6:14:27 AM	-35.8	9.7/15.7	38.8361	-80.0813
Jan 2, 2006	7:09:31 AM	178.8	9.8/15.8	38.8130	-80.2805
Jan 2, 2006	6:08:29 AM	-88.7	9.9/16.0	38.9486	-80.3875
Jan 2, 2006	6:00:09 AM	12.5	10.0/16.2	38.8131	-80.2920
Jan 2, 2006	10:52:47 AM	-5.4	10.4/16.8	38.8012	-80.1279
Jan 2, 2006	6:15:13 AM	-5.4	10.6/17.2	38.8620	-80.3729
Jan 2, 2006	6:57:04 AM	-9.3	10.7/17.3	38.8845	-80.0159
Jan 2, 2006	7:35:11 PM	-6.0	10.9/17.5	39.0867	-80.1257
Jan 2, 2006	7:03:33 AM	77.4	10.9/17.5	38.8354	-80.3530
Jan 2, 2006	7:33:54 PM	-14.6	10.9/17.6	38.9679	-80.0018
Jan 2, 2006	10:56:18 AM	32.5	11.1/17.8	38.8218	-80.0641

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:15:14 AM	-8.1	11.2/18.1	38.8588	-80.3835
Jan 2, 2006	7:07:03 AM	-198.4	11.3/18.2	38.7912	-80.2878
Jan 2, 2006	7:03:33 AM	-35.7	11.3/18.2	38.8191	-80.3433
Jan 2, 2006	7:54:44 AM	-9.0	11.6/18.7	38.7732	-80.2165
Jan 2, 2006	7:35:55 PM	-8.6	11.7/18.8	38.9710	-79.9878
Jan 2, 2006	7:54:44 AM	-23.3	11.7/18.9	38.7714	-80.2190
Jan 2, 2006	7:54:44 AM	-17.8	11.7/18.9	38.7714	-80.2191
Jan 2, 2006	6:57:04 AM	-20.7	11.7/18.9	38.8925	-79.9923
Jan 2, 2006	10:57:53 AM	-51.1	11.8/19.0	38.8009	-80.0760
Jan 2, 2006	6:12:16 AM	14.0	11.8/19.1	38.8615	-80.3974
Jan 2, 2006	6:17:13 AM	-10.9	11.9/19.2	38.8195	-80.0443
Jan 2, 2006	10:56:18 AM	-47.4	12.0/19.4	38.7952	-80.0790
Jan 2, 2006	6:17:13 AM	-9.3	12.0/19.4	38.8183	-80.0427
Jan 2, 2006	6:17:13 AM	-7.5	12.1/19.5	38.8170	-80.0436
Jan 2, 2006	6:37:59 AM	-27.8	12.1/19.5	38.9342	-79.9771
Jan 2, 2006	10:56:18 AM	18.1	12.1/19.5	38.7945	-80.0782
Jan 2, 2006	6:17:13 AM	-14.2	12.1/19.5	38.8164	-80.0430
Jan 2, 2006	7:37:00 PM	-8.4	12.2/19.6	38.9826	-79.9816

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STRIKEnet®**STRIKE**net Report 168384

Report Title: 60-06MR-308

Total Lightning Strokes Detected: 162

Lightning Strokes Detected within 15 mi/25 km radius: 128

Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34

Search Radius: 15 mi/25 km

Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Lightning Stroke Table (Note: All events shown. Events ordered by time.)

Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	4:14:03 AM	-5.3	22.1/35.7	38.6437	-80.3571
Jan 2, 2006	5:33:58 AM	26.5	15.4/24.8	38.7260	-80.2798
Jan 2, 2006	5:35:41 AM	-29.1	15.7/25.3	38.7178	-80.1439
Jan 2, 2006	5:35:41 AM	-16.7	15.7/25.3	38.7181	-80.1427
Jan 2, 2006	5:36:14 AM	-61.8	14.3/23.0	38.7462	-80.2931
Jan 2, 2006	5:36:14 AM	-12.1	13.0/21.0	38.7684	-80.3012
Jan 2, 2006	5:36:14 AM	-8.3	13.4/21.6	38.7619	-80.2993
Jan 2, 2006	5:43:55 AM	-5.7	15.8/25.6	38.7334	-80.0757
Jan 2, 2006	5:43:55 AM	-4.0	15.7/25.4	38.7347	-80.0765
Jan 2, 2006	5:51:33 AM	12.6	12.9/20.8	38.9451	-80.4429
Jan 2, 2006	5:55:25 AM	-5.8	15.3/24.7	38.7407	-80.3269
Jan 2, 2006	5:57:41 AM	-7.8	20.1/32.4	38.7366	-79.9362
Jan 2, 2006	5:57:48 AM	25.1	6.5/10.6	38.8487	-80.2310
Jan 2, 2006	6:00:09 AM	12.5	10.0/16.2	38.8131	-80.2920
Jan 2, 2006	6:04:01 AM	-60.5	15.9/25.6	38.7107	-80.2097
Jan 2, 2006	6:04:01 AM	-11.9	16.0/25.8	38.7090	-80.2116
Jan 2, 2006	6:04:01 AM	-15.8	15.6/25.2	38.7150	-80.2163
Jan 2, 2006	6:04:12 AM	23.9	13.4/21.6	38.9601	-80.4506
Jan 2, 2006	6:04:12 AM	-33.9	14.1/22.7	38.9427	-80.4652
Jan 2, 2006	6:05:30 AM	-6.0	14.6/23.5	38.7303	-80.1803
Jan 2, 2006	6:06:16 AM	-7.5	17.1/27.5	38.6943	-80.1740
Jan 2, 2006	6:06:16 AM	-9.3	15.2/24.6	38.7200	-80.2049
Jan 2, 2006	6:07:26 AM	-48.8	15.9/25.6	38.7122	-80.1721
Jan 2, 2006	6:08:29 AM	-88.7	9.9/16.0	38.9486	-80.3875
Jan 2, 2006	6:08:29 AM	-15.3	9.5/15.3	38.9408	-80.3788
Jan 2, 2006	6:09:23 AM	-23.7	16.1/25.9	38.7083	-80.1837
Jan 2, 2006	6:09:23 AM	-7.1	16.3/26.4	38.7045	-80.1816
Jan 2, 2006	6:09:23 AM	-15.3	14.0/22.5	38.7388	-80.2225
Jan 2, 2006	6:10:32 AM	-12.7	15.7/25.4	38.7151	-80.2443
Jan 2, 2006	6:10:32 AM	-5.9	15.4/24.9	38.7177	-80.1791
Jan 2, 2006	6:10:32 AM	-8.9	15.4/24.8	38.7190	-80.1787
Jan 2, 2006	6:10:32 AM	-8.6	13.8/22.3	38.7413	-80.1827

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:10:32 AM	-15.6	12.3/19.8	38.7698	-80.1395
Jan 2, 2006	6:12:16 AM	14.0	11.8/19.1	38.8615	-80.3974
Jan 2, 2006	6:12:16 AM	-27.8	13.0/21.0	38.8467	-80.4129
Jan 2, 2006	6:12:16 AM	-8.3	13.0/20.9	38.8431	-80.4086
Jan 2, 2006	6:13:08 AM	-19.1	13.7/22.0	38.7436	-80.1817
Jan 2, 2006	6:13:08 AM	-17.6	13.7/22.1	38.7427	-80.1775
Jan 2, 2006	6:13:08 AM	-16.0	6.3/10.2	38.9792	-80.3097
Jan 2, 2006	6:13:08 AM	-10.8	7.2/11.6	38.9956	-80.3168
Jan 2, 2006	6:14:27 AM	-35.8	9.7/15.7	38.8361	-80.0813
Jan 2, 2006	6:14:27 AM	6.3	14.2/23.0	38.7359	-80.1713
Jan 2, 2006	6:15:13 AM	20.5	9.4/15.2	38.8770	-80.3572
Jan 2, 2006	6:15:13 AM	-133.9	9.4/15.2	38.8775	-80.3573
Jan 2, 2006	6:15:13 AM	-35.9	9.4/15.2	38.8751	-80.3565
Jan 2, 2006	6:15:13 AM	-5.4	10.6/17.2	38.8620	-80.3729
Jan 2, 2006	6:15:14 AM	-8.1	11.2/18.1	38.8588	-80.3835
Jan 2, 2006	6:15:22 AM	-34.8	13.6/21.9	38.7465	-80.1619
Jan 2, 2006	6:15:23 AM	-11.1	13.5/21.8	38.7469	-80.1628
Jan 2, 2006	6:17:13 AM	-14.2	12.1/19.5	38.8164	-80.0430
Jan 2, 2006	6:17:13 AM	-9.3	12.0/19.4	38.8183	-80.0427
Jan 2, 2006	6:17:13 AM	-7.5	12.1/19.5	38.8170	-80.0436
Jan 2, 2006	6:17:13 AM	-10.9	11.9/19.2	38.8195	-80.0443
Jan 2, 2006	6:17:14 AM	-9.1	12.9/20.8	38.7586	-80.1463
Jan 2, 2006	6:18:11 AM	-17.9	13.9/22.5	38.7477	-80.1268
Jan 2, 2006	6:18:11 AM	-14.9	14.0/22.6	38.7492	-80.1164
Jan 2, 2006	6:18:11 AM	-4.8	13.4/21.7	38.7555	-80.1257
Jan 2, 2006	6:19:55 AM	-7.9	13.4/21.6	38.7612	-80.1087
Jan 2, 2006	6:21:23 AM	8.8	13.7/22.1	38.7715	-80.0681
Jan 2, 2006	6:22:15 AM	-9.4	12.9/20.8	38.7832	-80.0733
Jan 2, 2006	6:22:15 AM	-19.5	13.1/21.1	38.7797	-80.0738
Jan 2, 2006	6:22:15 AM	8.3	12.9/20.9	38.7808	-80.0763
Jan 2, 2006	6:26:35 AM	38.8	3.4/5.5	38.8968	-80.2313
Jan 2, 2006	6:26:35 AM	101.0	1.9/3.1	38.9260	-80.2331
Jan 2, 2006	6:29:42 AM	19.3	7.5/12.1	38.8782	-80.0886
Jan 2, 2006	6:34:55 AM	-116.3	15.6/25.2	38.8325	-79.9468
Jan 2, 2006	6:37:59 AM	-27.8	12.1/19.5	38.9342	-79.9771
Jan 2, 2006	6:38:51 AM	-12.6	4.9/7.8	38.9748	-80.1227
Jan 2, 2006	6:38:51 AM	85.7	4.4/7.1	38.9805	-80.1380
Jan 2, 2006	6:38:51 AM	-86.0	6.2/9.9	38.9954	-80.1113
Jan 2, 2006	6:49:31 AM	-13.4	14.9/24.0	38.8643	-79.9435
Jan 2, 2006	6:49:31 AM	-23.4	14.8/23.9	38.8650	-79.9439
Jan 2, 2006	6:51:41 AM	-5.9	14.3/23.1	38.8741	-79.9501
Jan 2, 2006	6:51:41 AM	-8.0	14.8/24.0	38.8539	-79.9492
Jan 2, 2006	6:53:39 AM	-12.7	14.9/24.0	38.8956	-79.9316

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:55:33 AM	-57.6	14.3/23.1	38.8105	-80.4102
Jan 2, 2006	6:55:33 AM	-8.0	13.7/22.1	38.8093	-80.3942
Jan 2, 2006	6:55:33 AM	81.5	15.8/25.4	38.7927	-80.4256
Jan 2, 2006	6:57:04 AM	-20.7	11.7/18.9	38.8925	-79.9923
Jan 2, 2006	6:57:04 AM	-9.3	10.7/17.3	38.8845	-80.0159
Jan 2, 2006	6:57:04 AM	-12.8	12.8/20.6	38.8824	-79.9765
Jan 2, 2006	7:02:39 AM	-10.5	18.7/30.2	38.6788	-80.1120
Jan 2, 2006	7:03:33 AM	-20.9	8.3/13.3	38.8292	-80.2578
Jan 2, 2006	7:03:33 AM	77.4	10.9/17.5	38.8354	-80.3530
Jan 2, 2006	7:03:33 AM	-35.7	11.3/18.2	38.8191	-80.3433
Jan 2, 2006	7:07:03 AM	-198.4	11.3/18.2	38.7912	-80.2878
Jan 2, 2006	7:09:31 AM	178.8	9.8/15.8	38.8130	-80.2805
Jan 2, 2006	7:11:49 AM	87.8	7.9/12.8	38.8344	-80.2577
Jan 2, 2006	7:22:01 AM	-19.4	7.0/11.2	38.8500	-80.1457
Jan 2, 2006	7:22:01 AM	23.7	6.6/10.7	38.8570	-80.1420
Jan 2, 2006	7:25:06 AM	-11.3	13.4/21.6	38.7715	-80.0796
Jan 2, 2006	7:25:35 AM	-9.9	14.8/23.9	38.8894	-79.9337
Jan 2, 2006	7:34:50 AM	-8.6	14.1/22.8	38.8245	-79.9853
Jan 2, 2006	7:35:26 AM	-4.9	18.0/29.0	38.7189	-80.3784
Jan 2, 2006	7:36:15 AM	-16.7	14.9/24.0	38.8337	-79.9613
Jan 2, 2006	7:36:15 AM	-14.9	15.0/24.2	38.8287	-79.9632
Jan 2, 2006	7:36:46 AM	-5.7	5.8/9.3	39.0048	-80.2719
Jan 2, 2006	7:41:00 AM	-8.5	15.3/24.7	38.7197	-80.2313
Jan 2, 2006	7:42:35 AM	-5.6	13.3/21.4	38.7489	-80.2137
Jan 2, 2006	7:42:35 AM	-8.7	14.9/24.0	38.7257	-80.2184
Jan 2, 2006	7:42:35 AM	-9.8	15.6/25.2	38.7148	-80.2158
Jan 2, 2006	7:42:35 AM	-12.0	15.6/25.2	38.7145	-80.2161
Jan 2, 2006	7:42:35 AM	-21.5	15.7/25.3	38.7133	-80.2154
Jan 2, 2006	7:42:35 AM	-9.1	12.7/20.5	38.7567	-80.2043
Jan 2, 2006	7:42:35 AM	10.6	13.7/22.1	38.7425	-80.2052
Jan 2, 2006	7:50:24 AM	-9.1	17.5/28.2	38.6882	-80.1707
Jan 2, 2006	7:52:21 AM	47.4	8.3/13.4	38.8949	-80.0595
Jan 2, 2006	7:54:44 AM	-17.8	11.7/18.9	38.7714	-80.2191
Jan 2, 2006	7:54:44 AM	-23.3	11.7/18.9	38.7714	-80.2190
Jan 2, 2006	7:54:44 AM	-9.0	11.6/18.7	38.7732	-80.2165
Jan 2, 2006	7:56:59 AM	35.3	15.1/24.4	38.7267	-80.1431
Jan 2, 2006	8:03:36 AM	69.4	14.9/24.1	38.8919	-79.9315
Jan 2, 2006	9:16:58 AM	-12.5	13.7/22.0	38.7963	-80.0283
Jan 2, 2006	9:19:08 AM	-30.1	13.9/22.5	38.8256	-79.9888
Jan 2, 2006	9:30:44 AM	27.5	3.6/5.7	38.9003	-80.2431
Jan 2, 2006	9:32:24 AM	-10.5	15.8/25.4	38.8046	-79.9663
Jan 2, 2006	9:45:50 AM	-11.4	30.4/49.0	38.8504	-79.6481
Jan 2, 2006	10:43:53 AM	-18.1	13.1/21.1	38.7571	-80.1397

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	10:46:01 AM	58.3	14.7/23.7	38.7283	-80.1940
Jan 2, 2006	10:46:01 AM	-23.3	13.5/21.7	38.7464	-80.2287
Jan 2, 2006	10:46:01 AM	19.0	14.8/23.9	38.7261	-80.1922
Jan 2, 2006	10:46:02 AM	-26.7	14.6/23.6	38.7287	-80.1995
Jan 2, 2006	10:46:02 AM	-8.0	14.5/23.5	38.7300	-80.1976
Jan 2, 2006	10:50:58 AM	-6.0	14.3/23.1	38.7415	-80.1264
Jan 2, 2006	10:51:58 AM	-6.6	13.1/21.1	38.7591	-80.1325
Jan 2, 2006	10:51:58 AM	-13.2	13.1/21.1	38.7585	-80.1346
Jan 2, 2006	10:51:58 AM	-7.3	13.2/21.3	38.7568	-80.1335
Jan 2, 2006	10:51:58 AM	-8.0	13.5/21.7	38.7511	-80.1430
Jan 2, 2006	10:52:47 AM	-5.4	10.4/16.8	38.8012	-80.1279
Jan 2, 2006	10:54:41 AM	-31.1	13.5/21.8	38.7668	-80.0861
Jan 2, 2006	10:54:41 AM	-7.2	14.3/23.0	38.7557	-80.0844
Jan 2, 2006	10:56:18 AM	-47.4	12.0/19.4	38.7952	-80.0790
Jan 2, 2006	10:56:18 AM	18.1	12.1/19.5	38.7945	-80.0782
Jan 2, 2006	10:56:18 AM	-12.5	12.7/20.4	38.7894	-80.0693
Jan 2, 2006	10:56:18 AM	32.5	11.1/17.8	38.8218	-80.0641
Jan 2, 2006	10:57:53 AM	-51.1	11.8/19.0	38.8009	-80.0760
Jan 2, 2006	10:57:53 AM	-9.7	14.3/23.1	38.7766	-80.0399
Jan 2, 2006	11:33:33 AM	34.0	16.1/25.9	38.7174	-80.1189
Jan 2, 2006	7:22:07 PM	-10.6	15.7/25.3	39.1332	-80.3585
Jan 2, 2006	7:24:01 PM	-20.7	16.0/25.7	39.1406	-80.3531
Jan 2, 2006	7:26:41 PM	-34.0	14.6/23.6	39.1298	-80.3258
Jan 2, 2006	7:30:10 PM	-9.9	17.0/27.5	39.1779	-80.2922
Jan 2, 2006	7:33:54 PM	-14.6	10.9/17.6	38.9679	-80.0018
Jan 2, 2006	7:35:11 PM	-6.0	10.9/17.5	39.0867	-80.1257
Jan 2, 2006	7:35:55 PM	-8.6	11.7/18.8	38.9710	-79.9878
Jan 2, 2006	7:37:00 PM	-8.4	12.2/19.6	38.9826	-79.9816
Jan 2, 2006	7:37:00 PM	-4.2	12.3/19.8	38.9890	-79.9819
Jan 2, 2006	7:38:14 PM	-20.4	12.5/20.1	39.1042	-80.1014
Jan 2, 2006	7:38:37 PM	-6.2	13.8/22.3	38.9805	-79.9491
Jan 2, 2006	7:43:10 PM	-6.4	14.6/23.5	39.1090	-80.0371
Jan 2, 2006	7:43:10 PM	-5.7	14.5/23.5	39.1083	-80.0370
Jan 2, 2006	7:43:10 PM	-8.3	15.0/24.1	39.1151	-80.0359
Jan 2, 2006	7:45:43 PM	-14.1	15.6/25.2	39.1224	-80.0278
Jan 2, 2006	7:51:16 PM	-8.3	14.8/23.8	39.1187	-80.0490
Jan 2, 2006	7:53:38 PM	-22.7	15.0/24.2	39.1313	-80.0657
Jan 2, 2006	7:53:38 PM	-15.1	16.1/25.9	39.1319	-80.0306
Jan 2, 2006	7:55:27 PM	18.0	24.6/39.6	38.7418	-80.5816
Jan 2, 2006	7:56:00 PM	-51.1	15.9/25.6	39.1394	-80.0525
Jan 2, 2006	7:56:00 PM	-13.4	15.9/25.6	39.1434	-80.0613
Jan 2, 2006	7:56:00 PM	-6.9	16.0/25.8	39.1445	-80.0597
Jan 2, 2006	8:00:54 PM	22.7	13.8/22.3	39.1238	-80.0953

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	8:30:44 PM	18.1	5.4/8.7	38.9289	-80.3014

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STRIKEnet®**STRIKE**net Report 168384

Report Title: 60-06MR-308

Total Lightning Strokes Detected: 162

Lightning Strokes Detected within 15 mi/25 km radius: 128

Lightning Strokes Detected beyond 15 mi/25 km whose confidence ellipse overlaps the radius: 34

Search Radius: 15 mi/25 km

Time Span: Jan 1 2006 10:00:00 PM US/Eastern to Jan 2 2006 10:00:00 PM US/Eastern

Lightning Stroke Table (Note: All events shown. Events ordered by distance.)

Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:26:35 AM	101.0	1.9/3.1	38.9260	-80.2331
Jan 2, 2006	6:26:35 AM	38.8	3.4/5.5	38.8968	-80.2313
Jan 2, 2006	9:30:44 AM	27.5	3.6/5.7	38.9003	-80.2431
Jan 2, 2006	6:38:51 AM	85.7	4.4/7.1	38.9805	-80.1380
Jan 2, 2006	6:38:51 AM	-12.6	4.9/7.8	38.9748	-80.1227
Jan 2, 2006	8:30:44 PM	18.1	5.4/8.7	38.9289	-80.3014
Jan 2, 2006	7:36:46 AM	-5.7	5.8/9.3	39.0048	-80.2719
Jan 2, 2006	6:38:51 AM	-86.0	6.2/9.9	38.9954	-80.1113
Jan 2, 2006	6:13:08 AM	-16.0	6.3/10.2	38.9792	-80.3097
Jan 2, 2006	5:57:48 AM	25.1	6.5/10.6	38.8487	-80.2310
Jan 2, 2006	7:22:01 AM	23.7	6.6/10.7	38.8570	-80.1420
Jan 2, 2006	7:22:01 AM	-19.4	7.0/11.2	38.8500	-80.1457
Jan 2, 2006	6:13:08 AM	-10.8	7.2/11.6	38.9956	-80.3168
Jan 2, 2006	6:29:42 AM	19.3	7.5/12.1	38.8782	-80.0886
Jan 2, 2006	7:11:49 AM	87.8	7.9/12.8	38.8344	-80.2577
Jan 2, 2006	7:03:33 AM	-20.9	8.3/13.3	38.8292	-80.2578
Jan 2, 2006	7:52:21 AM	47.4	8.3/13.4	38.8949	-80.0595
Jan 2, 2006	6:15:13 AM	-133.9	9.4/15.2	38.8775	-80.3573
Jan 2, 2006	6:15:13 AM	20.5	9.4/15.2	38.8770	-80.3572
Jan 2, 2006	6:15:13 AM	-35.9	9.4/15.2	38.8751	-80.3565
Jan 2, 2006	6:08:29 AM	-15.3	9.5/15.3	38.9408	-80.3788
Jan 2, 2006	6:14:27 AM	-35.8	9.7/15.7	38.8361	-80.0813
Jan 2, 2006	7:09:31 AM	178.8	9.8/15.8	38.8130	-80.2805
Jan 2, 2006	6:08:29 AM	-88.7	9.9/16.0	38.9486	-80.3875
Jan 2, 2006	6:00:09 AM	12.5	10.0/16.2	38.8131	-80.2920
Jan 2, 2006	10:52:47 AM	-5.4	10.4/16.8	38.8012	-80.1279
Jan 2, 2006	6:15:13 AM	-5.4	10.6/17.2	38.8620	-80.3729
Jan 2, 2006	6:57:04 AM	-9.3	10.7/17.3	38.8845	-80.0159
Jan 2, 2006	7:35:11 PM	-6.0	10.9/17.5	39.0867	-80.1257
Jan 2, 2006	7:03:33 AM	77.4	10.9/17.5	38.8354	-80.3530
Jan 2, 2006	7:33:54 PM	-14.6	10.9/17.6	38.9679	-80.0018
Jan 2, 2006	10:56:18 AM	32.5	11.1/17.8	38.8218	-80.0641

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	6:15:14 AM	-8.1	11.2/18.1	38.8588	-80.3835
Jan 2, 2006	7:07:03 AM	-198.4	11.3/18.2	38.7912	-80.2878
Jan 2, 2006	7:03:33 AM	-35.7	11.3/18.2	38.8191	-80.3433
Jan 2, 2006	7:54:44 AM	-9.0	11.6/18.7	38.7732	-80.2165
Jan 2, 2006	7:35:55 PM	-8.6	11.7/18.8	38.9710	-79.9878
Jan 2, 2006	7:54:44 AM	-23.3	11.7/18.9	38.7714	-80.2190
Jan 2, 2006	7:54:44 AM	-17.8	11.7/18.9	38.7714	-80.2191
Jan 2, 2006	6:57:04 AM	-20.7	11.7/18.9	38.8925	-79.9923
Jan 2, 2006	10:57:53 AM	-51.1	11.8/19.0	38.8009	-80.0760
Jan 2, 2006	6:12:16 AM	14.0	11.8/19.1	38.8615	-80.3974
Jan 2, 2006	6:17:13 AM	-10.9	11.9/19.2	38.8195	-80.0443
Jan 2, 2006	10:56:18 AM	-47.4	12.0/19.4	38.7952	-80.0790
Jan 2, 2006	6:17:13 AM	-9.3	12.0/19.4	38.8183	-80.0427
Jan 2, 2006	6:17:13 AM	-7.5	12.1/19.5	38.8170	-80.0436
Jan 2, 2006	6:37:59 AM	-27.8	12.1/19.5	38.9342	-79.9771
Jan 2, 2006	10:56:18 AM	18.1	12.1/19.5	38.7945	-80.0782
Jan 2, 2006	6:17:13 AM	-14.2	12.1/19.5	38.8164	-80.0430
Jan 2, 2006	7:37:00 PM	-8.4	12.2/19.6	38.9826	-79.9816
Jan 2, 2006	7:37:00 PM	-4.2	12.3/19.8	38.9890	-79.9819
Jan 2, 2006	6:10:32 AM	-15.6	12.3/19.8	38.7698	-80.1395
Jan 2, 2006	7:38:14 PM	-20.4	12.5/20.1	39.1042	-80.1014
Jan 2, 2006	10:56:18 AM	-12.5	12.7/20.4	38.7894	-80.0693
Jan 2, 2006	7:42:35 AM	-9.1	12.7/20.5	38.7567	-80.2043
Jan 2, 2006	6:57:04 AM	-12.8	12.8/20.6	38.8824	-79.9765
Jan 2, 2006	6:22:15 AM	-9.4	12.9/20.8	38.7832	-80.0733
Jan 2, 2006	5:51:33 AM	12.6	12.9/20.8	38.9451	-80.4429
Jan 2, 2006	6:17:14 AM	-9.1	12.9/20.8	38.7586	-80.1463
Jan 2, 2006	6:22:15 AM	8.3	12.9/20.9	38.7808	-80.0763
Jan 2, 2006	6:12:16 AM	-8.3	13.0/20.9	38.8431	-80.4086
Jan 2, 2006	5:36:14 AM	-12.1	13.0/21.0	38.7684	-80.3012
Jan 2, 2006	6:12:16 AM	-27.8	13.0/21.0	38.8467	-80.4129
Jan 2, 2006	6:22:15 AM	-19.5	13.1/21.1	38.7797	-80.0738
Jan 2, 2006	10:51:58 AM	-6.6	13.1/21.1	38.7591	-80.1325
Jan 2, 2006	10:51:58 AM	-13.2	13.1/21.1	38.7585	-80.1346
Jan 2, 2006	10:43:53 AM	-18.1	13.1/21.1	38.7571	-80.1397
Jan 2, 2006	10:51:58 AM	-7.3	13.2/21.3	38.7568	-80.1335
Jan 2, 2006	7:42:35 AM	-5.6	13.3/21.4	38.7489	-80.2137
Jan 2, 2006	6:19:55 AM	-7.9	13.4/21.6	38.7612	-80.1087
Jan 2, 2006	6:04:12 AM	23.9	13.4/21.6	38.9601	-80.4506
Jan 2, 2006	5:36:14 AM	-8.3	13.4/21.6	38.7619	-80.2993
Jan 2, 2006	7:25:06 AM	-11.3	13.4/21.6	38.7715	-80.0796
Jan 2, 2006	6:18:11 AM	-4.8	13.4/21.7	38.7555	-80.1257
Jan 2, 2006	10:51:58 AM	-8.0	13.5/21.7	38.7511	-80.1430

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	10:46:01 AM	-23.3	13.5/21.7	38.7464	-80.2287
Jan 2, 2006	10:54:41 AM	-31.1	13.5/21.8	38.7668	-80.0861
Jan 2, 2006	6:15:23 AM	-11.1	13.5/21.8	38.7469	-80.1628
Jan 2, 2006	6:15:22 AM	-34.8	13.6/21.9	38.7465	-80.1619
Jan 2, 2006	6:13:08 AM	-19.1	13.7/22.0	38.7436	-80.1817
Jan 2, 2006	9:16:58 AM	-12.5	13.7/22.0	38.7963	-80.0283
Jan 2, 2006	7:42:35 AM	10.6	13.7/22.1	38.7425	-80.2052
Jan 2, 2006	6:21:23 AM	8.8	13.7/22.1	38.7715	-80.0681
Jan 2, 2006	6:55:33 AM	-8.0	13.7/22.1	38.8093	-80.3942
Jan 2, 2006	6:13:08 AM	-17.6	13.7/22.1	38.7427	-80.1775
Jan 2, 2006	6:10:32 AM	-8.6	13.8/22.3	38.7413	-80.1827
Jan 2, 2006	8:00:54 PM	22.7	13.8/22.3	39.1238	-80.0953
Jan 2, 2006	7:38:37 PM	-6.2	13.8/22.3	38.9805	-79.9491
Jan 2, 2006	6:18:11 AM	-17.9	13.9/22.5	38.7477	-80.1268
Jan 2, 2006	9:19:08 AM	-30.1	13.9/22.5	38.8256	-79.9888
Jan 2, 2006	6:09:23 AM	-15.3	14.0/22.5	38.7388	-80.2225
Jan 2, 2006	6:18:11 AM	-14.9	14.0/22.6	38.7492	-80.1164
Jan 2, 2006	6:04:12 AM	-33.9	14.1/22.7	38.9427	-80.4652
Jan 2, 2006	7:34:50 AM	-8.6	14.1/22.8	38.8245	-79.9853
Jan 2, 2006	6:14:27 AM	6.3	14.2/23.0	38.7359	-80.1713
Jan 2, 2006	10:54:41 AM	-7.2	14.3/23.0	38.7557	-80.0844
Jan 2, 2006	5:36:14 AM	-61.8	14.3/23.0	38.7462	-80.2931
Jan 2, 2006	6:51:41 AM	-5.9	14.3/23.1	38.8741	-79.9501
Jan 2, 2006	10:57:53 AM	-9.7	14.3/23.1	38.7766	-80.0399
Jan 2, 2006	6:55:33 AM	-57.6	14.3/23.1	38.8105	-80.4102
Jan 2, 2006	10:50:58 AM	-6.0	14.3/23.1	38.7415	-80.1264
Jan 2, 2006	7:43:10 PM	-5.7	14.5/23.5	39.1083	-80.0370
Jan 2, 2006	10:46:02 AM	-8.0	14.5/23.5	38.7300	-80.1976
Jan 2, 2006	6:05:30 AM	-6.0	14.6/23.5	38.7303	-80.1803
Jan 2, 2006	7:43:10 PM	-6.4	14.6/23.5	39.1090	-80.0371
Jan 2, 2006	7:26:41 PM	-34.0	14.6/23.6	39.1298	-80.3258
Jan 2, 2006	10:46:02 AM	-26.7	14.6/23.6	38.7287	-80.1995
Jan 2, 2006	10:46:01 AM	58.3	14.7/23.7	38.7283	-80.1940
Jan 2, 2006	7:51:16 PM	-8.3	14.8/23.8	39.1187	-80.0490
Jan 2, 2006	6:49:31 AM	-23.4	14.8/23.9	38.8650	-79.9439
Jan 2, 2006	10:46:01 AM	19.0	14.8/23.9	38.7261	-80.1922
Jan 2, 2006	7:25:35 AM	-9.9	14.8/23.9	38.8894	-79.9337
Jan 2, 2006	6:51:41 AM	-8.0	14.8/24.0	38.8539	-79.9492
Jan 2, 2006	6:53:39 AM	-12.7	14.9/24.0	38.8956	-79.9316
Jan 2, 2006	6:49:31 AM	-13.4	14.9/24.0	38.8643	-79.9435
Jan 2, 2006	7:42:35 AM	-8.7	14.9/24.0	38.7257	-80.2184
Jan 2, 2006	7:36:15 AM	-16.7	14.9/24.0	38.8337	-79.9613
Jan 2, 2006	8:03:36 AM	69.4	14.9/24.1	38.8919	-79.9315

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	7:43:10 PM	-8.3	15.0/24.1	39.1151	-80.0359
Jan 2, 2006	7:36:15 AM	-14.9	15.0/24.2	38.8287	-79.9632
Jan 2, 2006	7:53:38 PM	-22.7	15.0/24.2	39.1313	-80.0657
Jan 2, 2006	7:56:59 AM	35.3	15.1/24.4	38.7267	-80.1431
Jan 2, 2006	6:06:16 AM	-9.3	15.2/24.6	38.7200	-80.2049
Jan 2, 2006	7:41:00 AM	-8.5	15.3/24.7	38.7197	-80.2313
Jan 2, 2006	5:55:25 AM	-5.8	15.3/24.7	38.7407	-80.3269
Jan 2, 2006	6:10:32 AM	-8.9	15.4/24.8	38.7190	-80.1787
Jan 2, 2006	5:33:58 AM	26.5	15.4/24.8	38.7260	-80.2798
Jan 2, 2006	6:10:32 AM	-5.9	15.4/24.9	38.7177	-80.1791
Jan 2, 2006	6:04:01 AM	-15.8	15.6/25.2	38.7150	-80.2163
Jan 2, 2006	7:42:35 AM	-9.8	15.6/25.2	38.7148	-80.2158
Jan 2, 2006	7:45:43 PM	-14.1	15.6/25.2	39.1224	-80.0278
Jan 2, 2006	6:34:55 AM	-116.3	15.6/25.2	38.8325	-79.9468
Jan 2, 2006	7:42:35 AM	-12.0	15.6/25.2	38.7145	-80.2161
Jan 2, 2006	7:22:07 PM	-10.6	15.7/25.3	39.1332	-80.3585
Jan 2, 2006	5:35:41 AM	-16.7	15.7/25.3	38.7181	-80.1427
Jan 2, 2006	5:35:41 AM	-29.1	15.7/25.3	38.7178	-80.1439
Jan 2, 2006	7:42:35 AM	-21.5	15.7/25.3	38.7133	-80.2154
Jan 2, 2006	6:10:32 AM	-12.7	15.7/25.4	38.7151	-80.2443
Jan 2, 2006	5:43:55 AM	-4.0	15.7/25.4	38.7347	-80.0765
Jan 2, 2006	6:55:33 AM	81.5	15.8/25.4	38.7927	-80.4256
Jan 2, 2006	9:32:24 AM	-10.5	15.8/25.4	38.8046	-79.9663
Jan 2, 2006	5:43:55 AM	-5.7	15.8/25.6	38.7334	-80.0757
Jan 2, 2006	6:07:26 AM	-48.8	15.9/25.6	38.7122	-80.1721
Jan 2, 2006	7:56:00 PM	-51.1	15.9/25.6	39.1394	-80.0525
Jan 2, 2006	7:56:00 PM	-13.4	15.9/25.6	39.1434	-80.0613
Jan 2, 2006	6:04:01 AM	-60.5	15.9/25.6	38.7107	-80.2097
Jan 2, 2006	7:24:01 PM	-20.7	16.0/25.7	39.1406	-80.3531
Jan 2, 2006	7:56:00 PM	-6.9	16.0/25.8	39.1445	-80.0597
Jan 2, 2006	6:04:01 AM	-11.9	16.0/25.8	38.7090	-80.2116
Jan 2, 2006	11:33:33 AM	34.0	16.1/25.9	38.7174	-80.1189
Jan 2, 2006	7:53:38 PM	-15.1	16.1/25.9	39.1319	-80.0306
Jan 2, 2006	6:09:23 AM	-23.7	16.1/25.9	38.7083	-80.1837
Jan 2, 2006	6:09:23 AM	-7.1	16.3/26.4	38.7045	-80.1816
Jan 2, 2006	7:30:10 PM	-9.9	17.0/27.5	39.1779	-80.2922
Jan 2, 2006	6:06:16 AM	-7.5	17.1/27.5	38.6943	-80.1740
Jan 2, 2006	7:50:24 AM	-9.1	17.5/28.2	38.6882	-80.1707
Jan 2, 2006	7:35:26 AM	-4.9	18.0/29.0	38.7189	-80.3784
Jan 2, 2006	7:02:39 AM	-10.5	18.7/30.2	38.6788	-80.1120
Jan 2, 2006	5:57:41 AM	-7.8	20.1/32.4	38.7366	-79.9362
Jan 2, 2006	4:14:03 AM	-5.3	22.1/35.7	38.6437	-80.3571
Jan 2, 2006	7:55:27 PM	18.0	24.6/39.6	38.7418	-80.5816

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Date	Time	Peak Current (kA)	Distance From Center (mi/km)	Latitude	Longitude
Jan 2, 2006	9:45:50 AM	-11.4	30.4/49.0	38.8504	-79.6481

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SAGO MINE EXPLOSION

January 2, 2006

Investigative Review, Research & Findings

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- Confidential -

Overview

On January 2, 2006 at approximately 6:30am, an explosion at the Sago coal mine in Tallmansville, West Virginia filled a mine shaft with poisonous gas, killing 12 miners and leaving another in critical condition. Although, the cause of the explosion has not yet been determined, it has been widely reported that lightning near the mine could be one of the contributing causes of the incident. Lightning in the area could have detonated elevated methane levels in the mine caused by changes in the barometric pressure that are more common in the winter months or other factors.

The United States Precision Lightning Network (USPLN) detected a single, powerful lightning stroke at or near the mouth of the Sago mine at 6:26:36 (6:26am and 36 seconds). Through additional research initiated by WeatherBug it was discovered that Dr. Martin Chapman, PhD, a research assistant professor from Virginia Tech, analyzed the seismic data and found that two independent seismic sensors read a minor seismic event, possibly from the explosion, two seconds after that stroke at 6:26:38 (6:26am and 38 seconds). The lightning stroke held a particularly strong positive charge of 35 kAmps, compared to a typical stroke of 20 kAmps. Overall, the USPLN detected 100 lightning strokes in the region within a two hour time period around the explosion (6:30am plus or minus one hour). The USPLN network has a verified accuracy of 250 meters on average.

The documents and findings in this report represent our data and analysis of the Sago Mine Explosion. It is our hope that this information will help your investigation into this matter and that WeatherBug can serve as a resource for determining the cause of this accident and for any preventive measures that may prevent future incidents of this nature to protect lives and property.

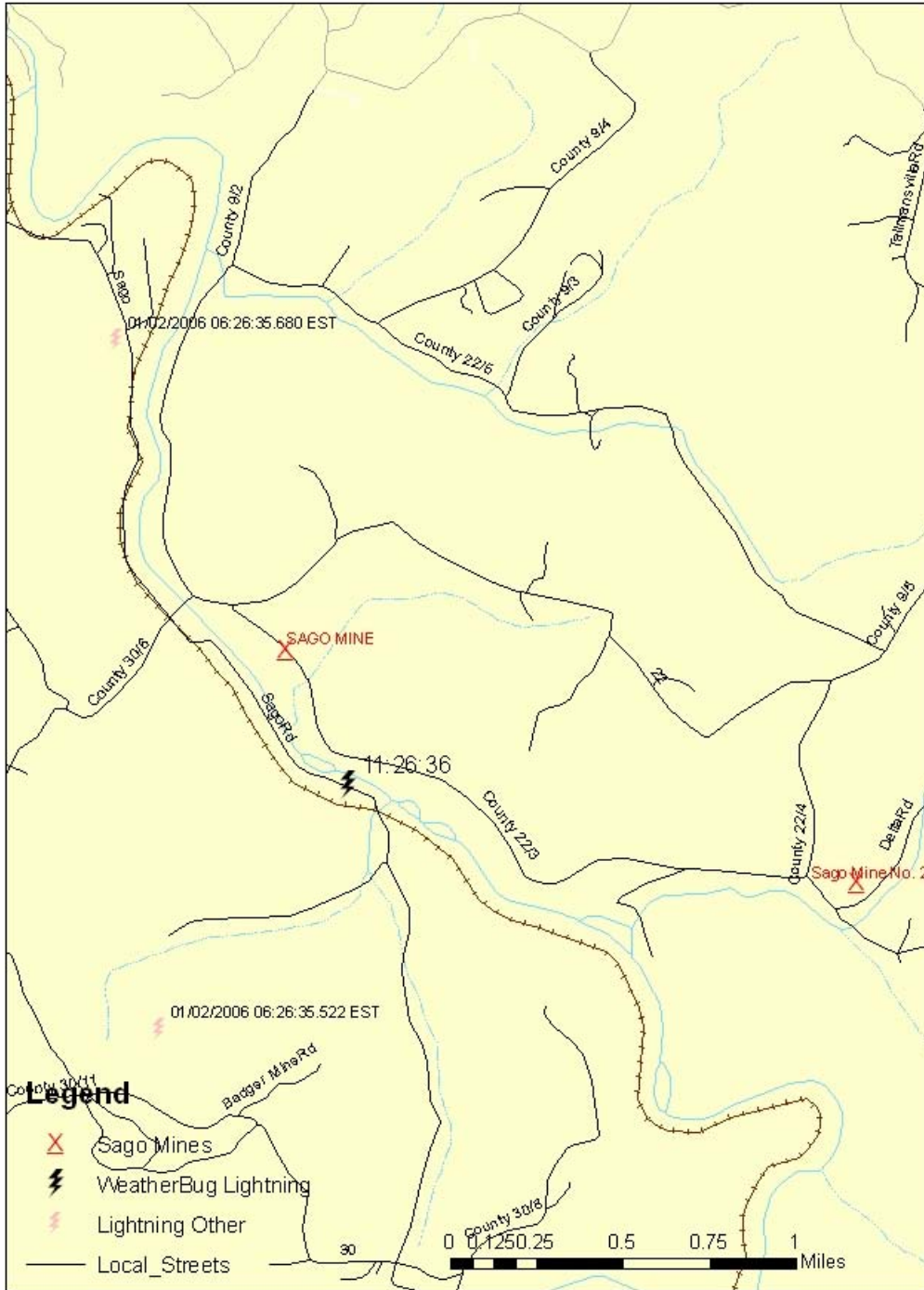
United States Precision Lightning Network (USPLN)

About the Lightning Detected and the Lightning Network

- The USPLN, which is owned and operated by TOA Systems and Weather Decision Technologies, consists of 100 sensors deployed throughout the U.S.
 - These sensors are antennas that detect the radio wave pulse generated by lightning strokes
 - On average 9 sensors detect an individual lightning stroke, and only 3 are needed to accurately determine the location of a stroke – providing redundancy and excess capacity
- The USPLN uses a Time of Arrival technology similar to GPS (used for OnStar or other navigation systems) and advanced signal processing to determine the time, location, strength and charge of the lightning strokes.
 - The USPLN utilizes a fully redundant and fault tolerant IT infrastructure
 - USPLN uses newer and more advanced technology than that used by the competing lightning detection network
 - The USPLN is capable of differentiating between cloud-to-cloud lightning and cloud-to-ground lightning
 - Individual lightning “Flashes” often contain multiple branches called “Strokes”. The USPLN can detect these strokes in real-time
- The USPLN has a verified accuracy of 250 meters on average (RMS), the competing network is reported to have accuracy of 500 meters.
- The USPLN detected 100 strokes within 1 hour before and after the explosion within a 35 mile radius of the mine.
 - The flash/stroke that struck closest to the mine is estimated to have hit 450 meters from the mine entrance. It carried a charge of +35 kAmps. Positive strokes are often more destructive than negative strokes. This was a very powerful stroke. The average stroke is about 20 kAmps. It takes about 100 Amps to run all the appliances in an average home, so this would be over 200 times more powerful than that and all the energy is delivered in a millisecond.

- o Individual storms have different ratios of positive and negative strokes, but typically only 10% of strokes are positive. The stroke closest to the mine was an unusual positive stroke.

The image below shows the location of the lightning stroke in relation to the mine as reported by the USPLN.



Within a 10 mile radius in the 2 hour period around the explosion, the USPLN detected 59 lightning strokes. It should be noted that only the USPLN detects strokes in real-time. The NLDN Network detects Flashes and can count the number of strokes but not locate them in real-time; they provide stroke data to their clients only after further signal processing and usually delayed by a day.

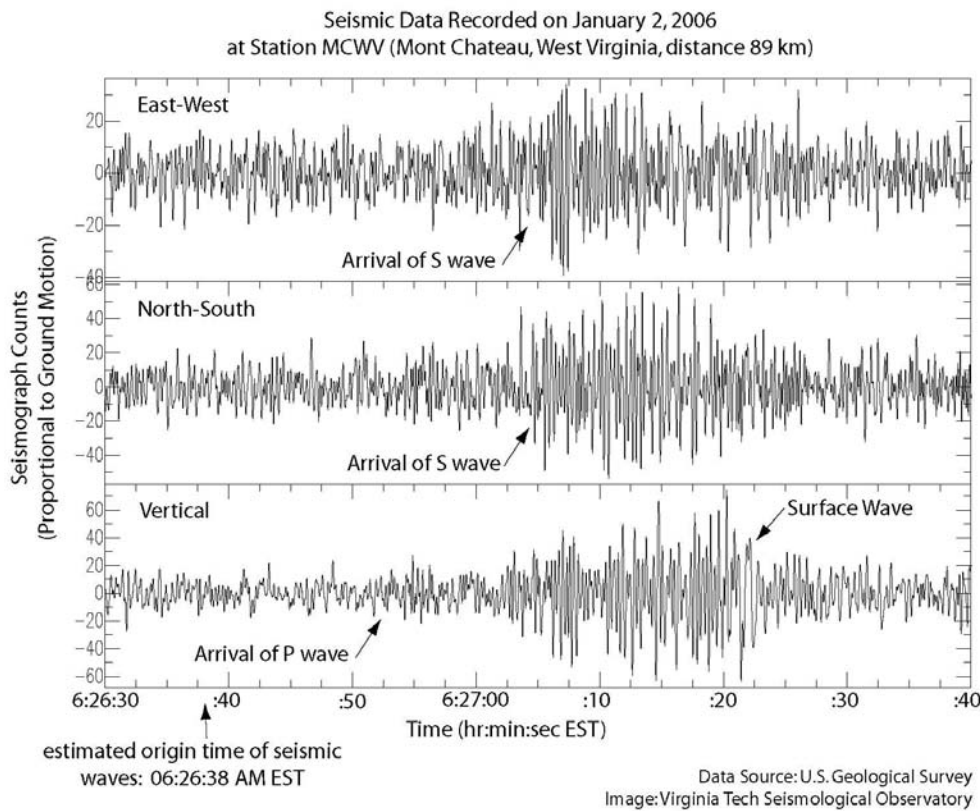
There is some uncertainty on our part about where the exact entrance of the mine is, so in the Table below distances from the mine entrance are calculated to three locations (A, B, C) where the latitude of each are: A (38.941N, 80.202W), B (38.906N, 80.219W), and C (38.851N, 80.159W). The Table includes all lightning STROKES detected by the USPLN within a 10 mile radius of either A, B or C.

USPLN Strokes Detected Within 10 miles of locations A, B, or C for 2 hour Period Centered on Time of Explosion								
Date	Time (UTC)	ms	Latitude	Longitude	kAmps	Distance (miles) from		
						A	B	C
1/2/2006	10:35:41	308	38.7256813	-80.1397018	-29.2	15.2	13.1	8.7
1/2/2006	10:35:41	333	38.7263298	-80.137291	-17	15.2	13.1	8.7
1/2/2006	10:36:14	404	38.7643547	-80.2599258	-49.8	12.6	10	8.1
1/2/2006	10:36:14	504	38.7682266	-80.30616	33.4	13.2	10.6	9.8
1/2/2006	10:36:14	581	38.7627296	-80.2898941	-7.8	13.2	10.6	9.3
1/2/2006	10:57:48	353	38.8658638	-80.2489243	0	5.8	3.2	4.9
1/2/2006	10:57:48	375	38.8514175	-80.2336044	24.6	6.4	3.8	4
1/2/2006	11:00:09	219	38.8187141	-80.2847443	13.7	9.5	7	7.1
1/2/2006	11:04:01	373	38.7195168	-80.199173	-55	15.3	12.9	9.3
1/2/2006	11:04:01	415	38.7145233	-80.2081985	-10.3	15.6	13.2	9.8
1/2/2006	11:04:01	455	38.7198029	-80.2114258	-14.9	15.3	12.8	9.5
1/2/2006	11:06:16	272	38.8094749	-80.2173615	8.2	9.1	6.6	4.2
1/2/2006	11:07:26	446	38.7319336	-80.1406555	-42.1	14.8	12.7	8.3
1/2/2006	11:07:26	465	38.7228661	-80.1519928	-11.6	15.3	13.1	8.9
1/2/2006	11:07:26	493	38.7229614	-80.1611481	-16.6	15.2	13	8.8
1/2/2006	11:08:29	431	38.9610901	-80.3887711	-70.7	10.2	9.9	14.5
1/2/2006	11:08:29	445	38.9581146	-80.3610382	-13.7	8.6	8.4	13.1
1/2/2006	11:09:22	982	38.7323303	-80.1612625	-88.9	14.5	12.4	8.2
1/2/2006	11:09:23	3	38.7115021	-80.1793137	-20.5	15.9	13.6	9.7
1/2/2006	11:09:23	67	38.7313423	-80.2371216	27.6	14.6	12.1	9.3
1/2/2006	11:09:23	72	38.7474098	-80.215271	15.6	13.4	10.9	7.8
1/2/2006	11:09:23	247	38.7327232	-80.1151581	0	15.1	13.2	8.5

USPLN Strokes Detected Within 10 miles of locations A, B, or C for 2 hour Period Centered on Time of Explosion								
Date	Time (UTC)	ms	Latitude	Longitude	kAmps	Distance (miles) from		
						A	B	C
1/2/2006	11:10:32	102	38.708683	-80.1775665	12.6	16.1	13.8	9.9
1/2/2006	11:10:32	428	38.7793159	-80.1447983	-14.3	11.6	9.6	5
1/2/2006	11:13:08	30	38.7285919	-80.1767654	28	14.7	12.4	8.5
1/2/2006	11:13:08	243	38.9870758	-80.3248367	0	7.3	8	12.9
1/2/2006	11:14:27	704	38.7603951	-80.1751938	0	12.5	10.3	6.3
1/2/2006	11:14:27	763	38.7609596	-80.1472244	7.8	12.8	10.7	6.3
1/2/2006	11:15:13	768	38.887516	-80.3489304	0	8.7	7.1	10.5
1/2/2006	11:15:13	783	38.8016663	-80.0149536	63.7	13.9	13.2	8.5
1/2/2006	11:15:14	106	38.866375	-80.3815384	-6.9	11	9.2	12
1/2/2006	11:15:22	844	38.757637	-80.1463165	-32.1	13	11	6.5
1/2/2006	11:15:23	106	38.7530136	-80.1476288	-10.2	13.3	11.2	6.8
1/2/2006	11:17:13	30	38.8184853	-80.0413284	-12.3	12.1	11.3	6.8
1/2/2006	11:17:13	81	38.8194199	-80.0407715	-8.8	12.1	11.3	6.8
1/2/2006	11:17:13	92	38.8250198	-80.0415115	-6.2	11.8	11.1	6.6
1/2/2006	11:17:13	119	38.8213539	-80.0394287	-10.1	12	11.3	6.8
1/2/2006	11:17:14	728	38.7708473	-80.1356812	-8.1	12.3	10.3	5.7
1/2/2006	11:18:11	419	38.756115	-80.1195526	-16.6	13.5	11.6	6.9
1/2/2006	11:18:11	443	38.7548027	-80.1096191	-12.5	13.8	12	7.2
1/2/2006	11:19:55	468	38.7682266	-80.1063004	-7	13	11.3	6.4
1/2/2006	11:22:15	388	38.7882881	-80.0673065	-8.7	12.8	11.5	6.6
1/2/2006	11:22:15	425	38.7905159	-80.0675964	-16.7	12.7	11.4	6.5
1/2/2006	11:22:15	580	38.7889099	-80.0668335	9.2	12.8	11.5	6.6
1/2/2006	11:26:35	522	38.9071693	-80.220871	35	2.5	0.1	5.1
1/2/2006	11:29:42	454	38.8838577	-80.0839996	20	7.5	7.4	4.7
1/2/2006	11:29:42	938	39.0450668	-80.0777817	-15.8	9.8	12.3	14.1
1/2/2006	11:38:51	846	38.9996719	-80.042984	93	9.5	11.5	12
1/2/2006	11:57:04	758	38.8792191	-79.9833374	-11.6	12.5	12.9	9.7
1/2/2006	12:03:33	399	38.8381348	-80.2485428	0	7.5	4.9	4.9
1/2/2006	12:03:33	441	38.8451958	-80.2446899	12.8	7	4.4	4.6
1/2/2006	12:03:33	445	38.8097878	-80.3446274	6.3	11.9	9.5	10.4
1/2/2006	12:09:31	753	38.8004189	-80.0074463	-73.4	14.3	13.5	8.9
1/2/2006	12:11:49	823	38.8285065	-80.2458344	0	8.1	5.5	4.9
1/2/2006	12:13:49	886	38.8299713	-80.250267	-22.3	8.1	5.5	5.1
1/2/2006	12:17:56	482	38.8618698	-80.1765823	0	5.6	3.8	1.2
1/2/2006	12:17:56	498	38.8562851	-80.1635132	-9.8	6.2	4.6	0.4
1/2/2006	12:22:01	325	38.8690491	-80.1388321	-15.3	6	5	1.7
1/2/2006	12:22:01	364	38.8736839	-80.1124039	22.7	6.7	6.2	3

Seismic Data

Coincident with the reported lightning strokes, WeatherBug brought in expertise from the Virginia Tech Department of Geosciences to examine whether there was seismic activity in the mine region at 6:26:38 that may have been caused by the explosion. The seismic readings have a timing error of plus or minus 3 seconds. The evidence suggests that the lightning stroke could have caused the explosion due to the correlation between the timing and location of the lightning stroke and seismic activity.



USPLN versus Vaisala’s NLDN Network

It is important to note that two separate lightning networks reported lightning data related to the Sago Mine Explosion – The USPLN and Vaisala’s NLDN Network. These networks are different, based on different technologies, and do not have the same accuracy. Since lightning is a potential cause of the explosion, it is important to note the differences between these networks and evaluate their validity.

It was reported in the Charleston Gazette that, Vaisala, a federal government contractor, reported lightning strikes within 1.5 miles of the mine.

“Three lightning strikes hit within five miles of the Sago Mine within a half-hour of Monday morning’s deadly explosion, according to a federal government contractor that monitors thunderstorms.

Two of the strikes, including one that was four to 10 times stronger than average, hit within 1 1/2 miles of the center of the Upshur County mine, according to the contractor.”

<http://www.wvgazette.com/section/News/2006010439>

- The USPLN can detect both the Flash from the main bolt of lightning, and the individual Strokes, all the little forks in the lightning bolt, some of which can strike the ground many miles from the main Flash.
- Visalia’s published accuracy of 500 meters on average for the National Lightning Data Network (NLDN) versus 250 meters for the USPLN.

About WeatherBug

- WeatherBug's mission is to protect lives and property by providing the most precise weather available
- WeatherBug owns and manages the largest and most advanced weather network in the U.S. --- totaling 8,000
- WeatherBug technology can provide advance warning of all types of weather threats, including lightning
- Only WeatherBug offers live, neighborhood level weather – vs. hourly weather reports from area airports
- WeatherBug partners with local TV broadcasters, the National Weather Service, government agencies and private organizations

APENDIX

Dow Jones Article -

http://www.aws.com/aws_2005/releases/2006/release_01062006.asp

WeatherBug Press Release

http://www.aws.com/aws_2005/releases/2006/release_01062006b.asp

Pittsburgh Tribune Article

http://pittsburghlive.com/x/tribune-review/trib/regional/s_412305.html

**The Occurrence of Lightning near
Lat: 30.2002997 Lon: -85.6244055
West Virginia**

**For the Period
5:00 AM EST January 2, 2006 to 5:00 AM EST January 3,
2006**

Prepared by

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Date Prepared: January 11, 2006



INTRODUCTION

This report describes the identified cloud-to-ground and cloud-to-cloud lightning activity within a 10 mile radius centered on the location of interest in West Virginia (Lat: 30.2002997, Lon: -85.6244055). Expert meteorologists at Weather Decision Technologies, Inc. (WDT) have carefully examined the archived record of cloud-to-ground and cloud-to-cloud lightning strikes within this area of interest for the time period 5:00 AM EST January 2, 2006 to 5:00 AM EST January 3, 2006. This report describes the results of our investigation.

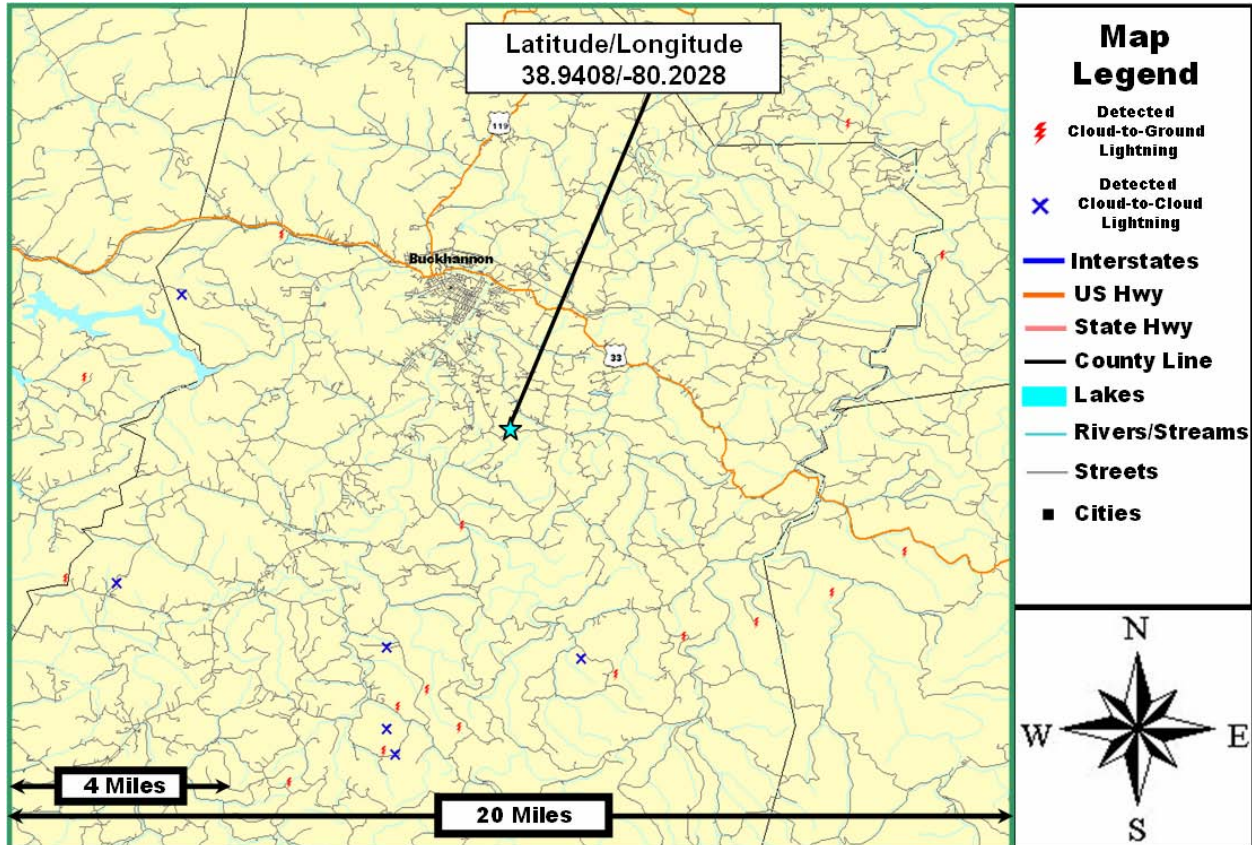
LIGHTNING ANALYSIS/CONCLUSION

The purpose of this investigation is to determine the closest lightning strike to the location of interest. The source of lightning data for this investigation is the United States Precision Lightning Network (USPLN) which is maintained and operated by WDT and TOA systems Inc. The USPLN lightning data archive consists of identified cloud-to-ground lightning strikes since May 28, 2004, and the location accuracy of cloud-to-ground lightning data detected by USPLN is 250 meters (.076 miles).

An examination of the lightning strikes during the 24 hour period of interest reveals that seventeen cloud-to-ground lightning strikes and six cloud-to-cloud lightning strikes occurred within the 10 mile radius centered on the address of interest (Figure 1). In addition, the closest cloud-to-ground lightning strike occurred 2.5 miles south-southwest of the address of interest at 6:26 EST on January 2, 2006. All other identified lightning strikes are shown in Figure 1 as well as in Table 1.

Appendix AA - Vaisala Group and AWS Convergence Technologies, Inc. Reports

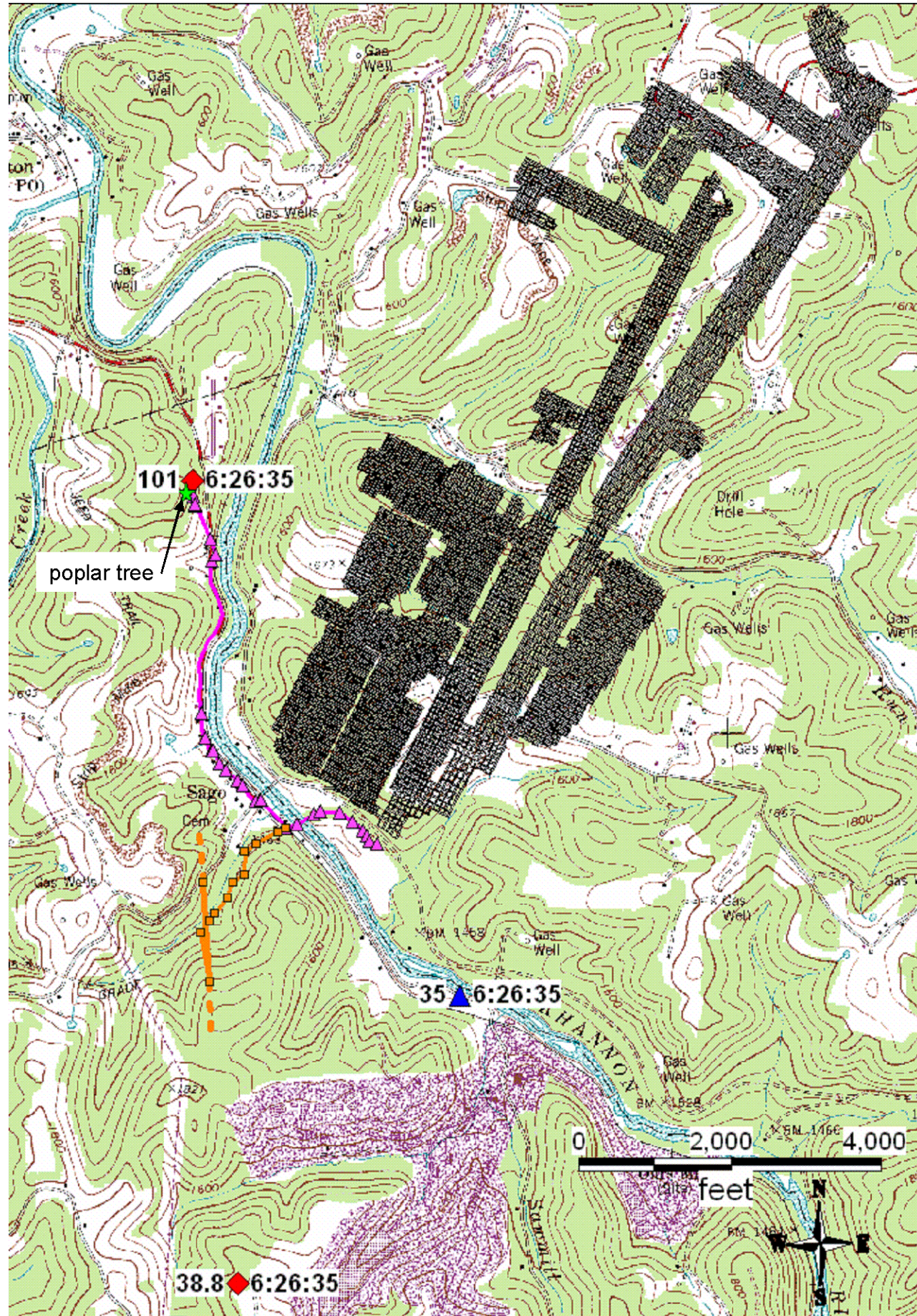
Figure 1. Map centered on the location of interest. The identified cloud-to-ground lightning strikes are depicted with red "bolts". The identified cloud-to-cloud lightning strikes are depicted with a blue "X". The light blue star depicts the location of interest. The areal extent is 2 miles by 20 miles (400 mi²). (Lightning data source: USPLN)




Appendix AA - Vaisala Group and AWS Convergence Technologies, Inc. Reports


Appendix 1. Cloud-to-ground and cloud-to-cloud lightning strikes for the period of 5:00 AM EST January 2, 2006 to 5:00 AM EST January 3, 2006 and within 10 miles of the address of interest. Time is in 24-hour Eastern Standard Time (EST) format. Bearing is relative to due north from the location of interest. For example, 90 degrees = east, 180 degrees = south, 270 degrees = west, 0 degrees = north. (Lightning data source: USPLN)

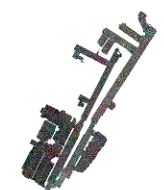
Date-Time (EST)	Amplitude	Latitude	Longitude	Bearinging (°)	Distance (mi.)
1/2/2006 5:57	24600	38.851	-80.234	195	6.4
1/2/2006 5:57	0	38.866	-80.249	206	5.7
1/2/2006 6:00	13700	38.819	-80.285	208	9.5
1/2/2006 6:06	8200	38.809	-80.217	185	9.1
1/2/2006 6:08	-13700	38.958	-80.361	278	8.6
1/2/2006 6:13	0	38.987	-80.325	296	7.3
1/2/2006 6:15	0	38.888	-80.349	245	8.7
1/2/2006 6:15	-125100	38.889	-80.368	248	9.6
1/2/2006 6:26	35000	38.907	-80.221	203	2.5
1/2/2006 6:29	20000	38.884	-80.084	122	7.5
1/2/2006 6:29	-15800	39.045	-80.078	43	9.9
1/2/2006 6:38	93000	39	-80.043	65	9.5
1/2/2006 6:38	-35800	39.007	-80.288	315	6.5
1/2/2006 7:03	0	38.838	-80.249	199	7.5
1/2/2006 7:03	12800	38.845	-80.245	199	7
1/2/2006 7:11	0	38.829	-80.246	197	8.1
1/2/2006 7:13	-22300	38.83	-80.25	198	8.1
1/2/2006 7:13	-22700	38.838	-80.222	188	7.2
1/2/2006 7:17	-9800	38.856	-80.164	160	6.2
1/2/2006 7:17	0	38.862	-80.177	165	5.6
1/2/2006 7:22	-15300	38.869	-80.139	145	6
1/2/2006 7:22	22700	38.874	-80.112	134	6.7
1/2/2006 7:52	43500	38.898	-80.057	111	8.4

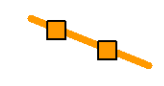


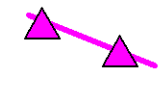
Explanation


-  **101 6:26:35** Location of lightning strike reported by Vaisala's National Lightning Detection Network (NLDN). Number to left of symbol represents the peak current in kilo-amps; number to right of symbol represents the time that the peak current was recorded.

-  **35 6:26:35** Location of lightning strike reported by Weather Decision Technologies, Inc.'s U.S. Precision Lightning Network (USPLN). Number to left of symbol represents the peak current in kilo-amps; number to right of symbol represents the time that the peak current was recorded.

-  Sago Mine workings.

-  Locations of power line poles, with trace of power line (dashed where main line is projected).

-  Locations of telephone poles and junction boxes, with trace of phone line.

-  Location of large poplar tree shattered by lightning.

Appendix BB

Sago Mine MSHA ID 46-08791

Wolf Run Mining Company

Sago Mine in relation to recorded locations of lightning strikes, a lightning-damaged poplar tree, and the mine's phone and power lines.

Results from Analysis of Seismic Data for the January 2, 2006 event near Sago, WV

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Introduction

The author examined regional seismic network recordings for the time interval around 6:30 AM, EST January 2, 2006 to determine if the event at the Sago mine was seismically recorded.

A small amplitude signal was identified on records at broadband station MCWV, near Mont Chateau, WV, the nearest seismic station to the mine. This station is part of the U.S. Geological Survey Advanced National Seismic System (ANSS) which is designed to record world-wide seismic activity as well as to monitor shocks in all regions of the U.S. The signal was also recorded at larger distances by three stations to the south: FWV, ELN and BLA. These more distant stations use short period sensors and are operated by Virginia Tech as part of the ANSS.

The following is a summary of the results pertaining to the location and time of the event that generated the seismic signals.

Data

Figures 1 through 4 show the data recorded at stations MCWV, FWV, ELN and BLA respectively. The signals have been bandpass-filtered using a 3 pole Butterworth prototype with corner frequencies 1.0 and 5.0 Hz. The signal/noise ratios of these data are small, however, measurement of arrival times for P and S waves was possible. The estimated arrival times are given below in Table 1, *in Eastern Standard Time*.

The coordinates of the recording stations are as follows:

BLA:	37.2113 deg N	80.4202 deg W
ELN:	37.2805 deg N	80.7517 deg W
FWV:	37.5810 deg N	80.8118 deg W
MCWV:	39.6582 deg N	79.8457 deg W

Appendix CC - Results from Analysis of Seismic Data

Results

Figure 5 shows the epicenter estimated using the arrival time data in Table 1. The locations were determined using the velocity model in Table 2, in conjunction with the computer program **Hypoellipse**. Table 3 gives hypocenter and origin time estimates for 3 cases.

The first case assumes that the focal depth of the source is near the ground surface, consistent with a mining-related source, but not necessarily located near the Sago mine. Latitude, longitude and origin time are treated as unknowns to be determined from the arrival time data. The origin time estimate in this case is 06:26:38.29 EST with standard error 1.65 seconds. The 68% confidence ellipse for the epicenter determined from the seismic data includes the Sago mine location (Figure 5). A 68% confidence interval for the origin time is 06:26:36.60 to 06:26:39.94 EST, assuming no systematic bias due to uncertainty associated with the velocity model in Table 2 or in phase arrival time measurement.

The second case is a completely un-constrained location, in which the latitude, longitude, focal depth and origin time are treated as unknowns to be determined. The computed epicenter is very near the Sago Mine location in this case (figure 5). The estimated focal depth is shallow (2.5 km) but very poorly determined (68% confidence: 0 to 34 km). The 68% confidence interval for the origin time is 06:26:35.35 - 06:26:41.21 EST.

The third case assumes that the source occurred at the Sago mine, (Latitude 38.9407°N; Longitude 80.2030°W) with zero focal depth. The only free parameter to be determined is the origin time. The 68% confidence interval for the origin time is 06:26:36.46 - 06:26:40.00 EST.

Conclusions

The seismic signal recorded on January 2, 2006 at approximately 06:26 EST was caused by an underground disturbance at or near the Sago mine. Assuming that the source was at the Sago mine, a 68% confidence interval for the origin time is 06:26:36.46 - 06:26:40.00 EST. Simply put, the event most likely occurred within a 4 second interval centered at 06:26:38.2 AM. This estimate assumes no systematic error in phase arrival time determination, and/or bias in the seismic wave velocity model used for analysis. It is possible that the origin time estimate is slightly late, due to the very emergent nature of the P and S wave arrivals because of low signal/noise ratios at all the recording stations.

Appendix CC - Results from Analysis of Seismic Data

Table 1

Station	P arrival*			S arrival*		
	Hour	Minute	Second	Hour	Minute	Second
MCWV	06	26	52.6	06	27	3.5
FWV	06	27	5.1	06	27	24.1
ELN	06	27	9.0	06	27	32.7
BLA	06	27	9.7	06	27	32.2

* All times are Eastern Standard Time.

Table 2

P wave velocity (km/sec)	S wave velocity (km/sec)	Layer thickness (km)
5.63	3.43	5.7
6.05	3.52	9.0
6.53	3.84	36.0
8.18	4.78	-

Table 3

	Latitude	Longitude	Focal Depth	Origin Time*	Standard Error of Origin Time	Azimuth of Error Ellipse Semi-Major Axis	Major Axis Length	Minor Axis Length
Depth constrained	38.9243°N	80.1169°W	0 km (fixed)	06:26:38.29	1.65 s	286°	23 km	4.4 km
Depth unconstrained	38.9465°N	80.1920°W	2.45 km	06:26:38.28	2.93 s	289°	23 km	4.0 km
Depth and location constrained	38.9407°N (fixed)	80.2030°W (fixed)	0 km (fixed)	06:26:38.23	1.77 s			

* All times are Eastern Standard Time.

Appendix CC - Results from Analysis of Seismic Data

Seismic Data Recorded on January 2, 2006
at Station MCWV (Mont Chateau, West Virginia, distance 85 km)

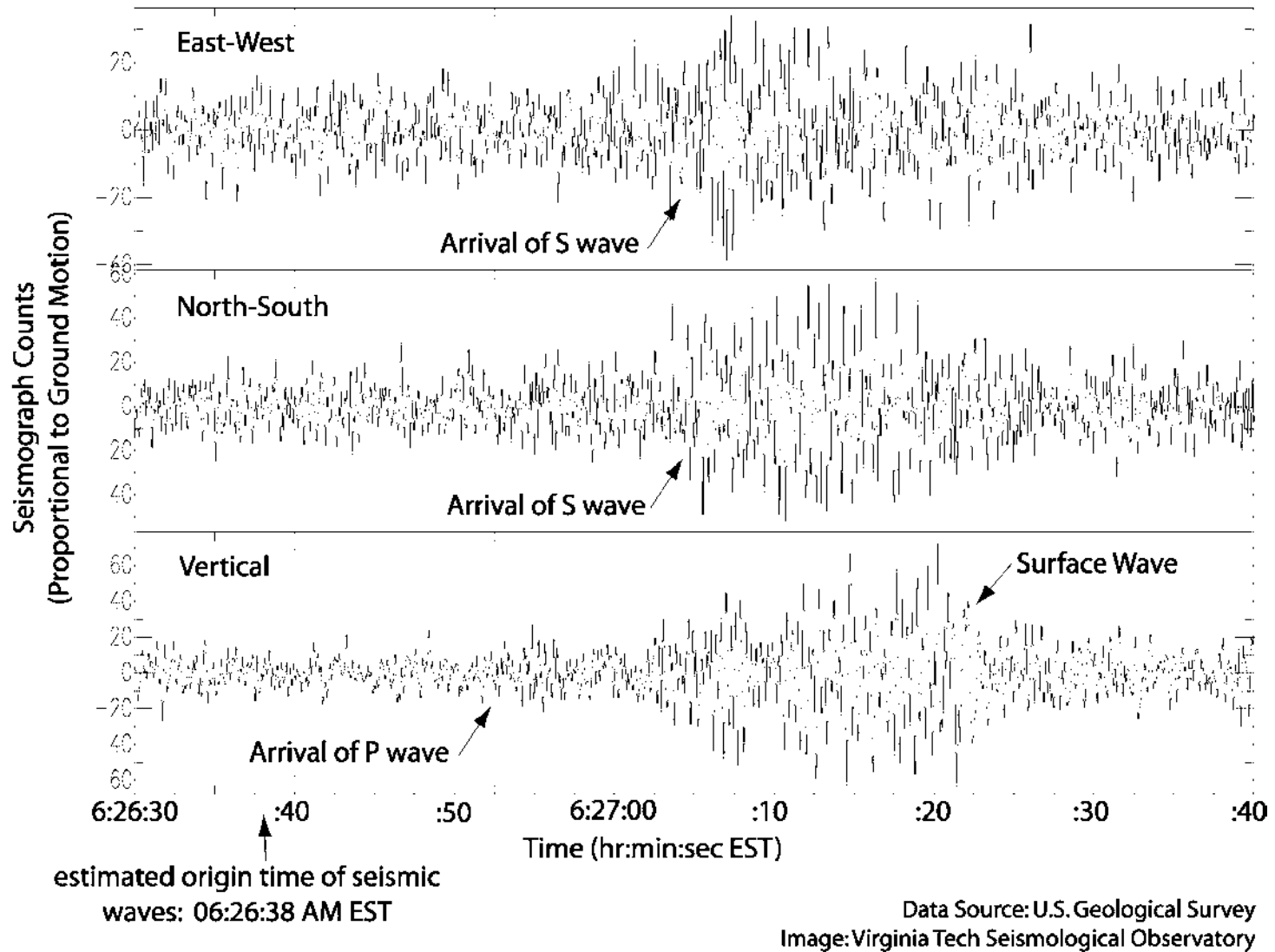


Figure 1. Waveforms recorded at station MCWV, 85.4 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

Appendix CC - Results from Analysis of Seismic Data
Seismic Data Recorded on January 2, 2006
at Station FWV (Forest Hill, West Virginia, distance 160 km)

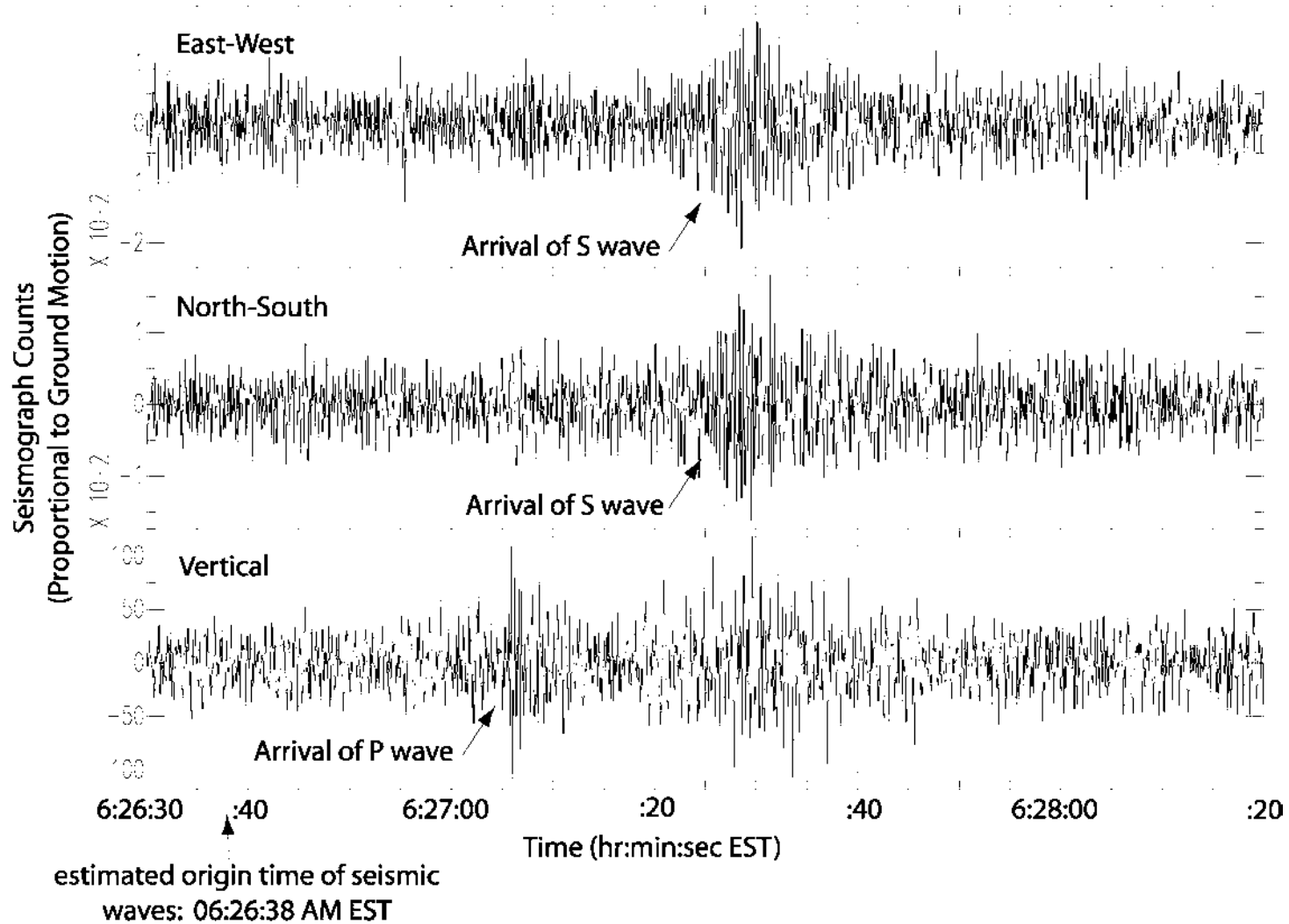


Figure 2. Waveforms recorded at station FWV, 160.1 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

Appendix CC - Results from Analysis of Seismic Data
Seismic Data Recorded on January 2, 2006
at Station ELN (Prospectdale, Virginia, distance 191 km)

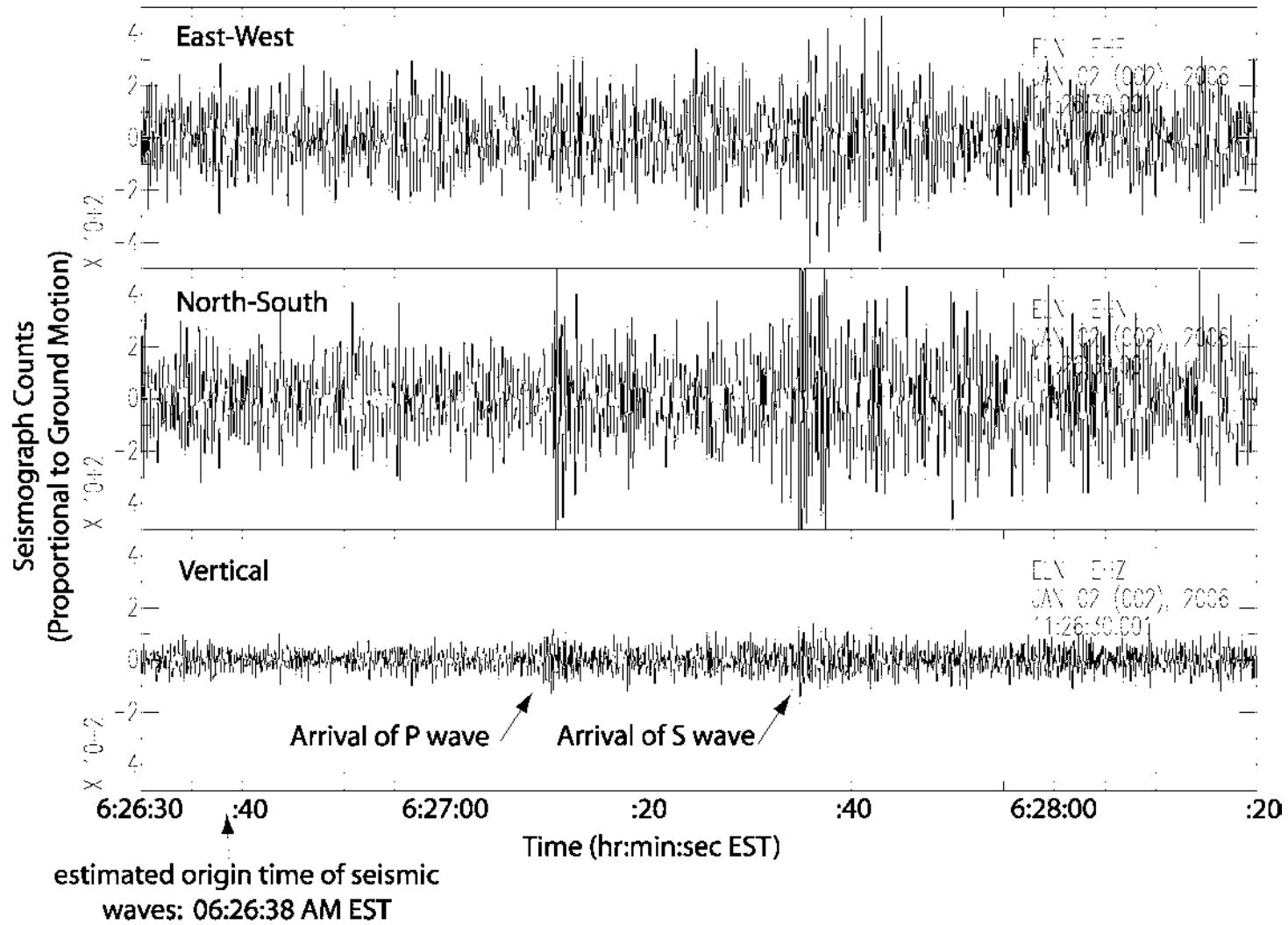


Figure 3. Waveforms recorded at station ELN, 190.5 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

Appendix CC - Results from Analysis of Seismic Data
Seismic Data Recorded on January 2, 2006
at Station BLA (Blacksburg, Virginia, distance 193 km)

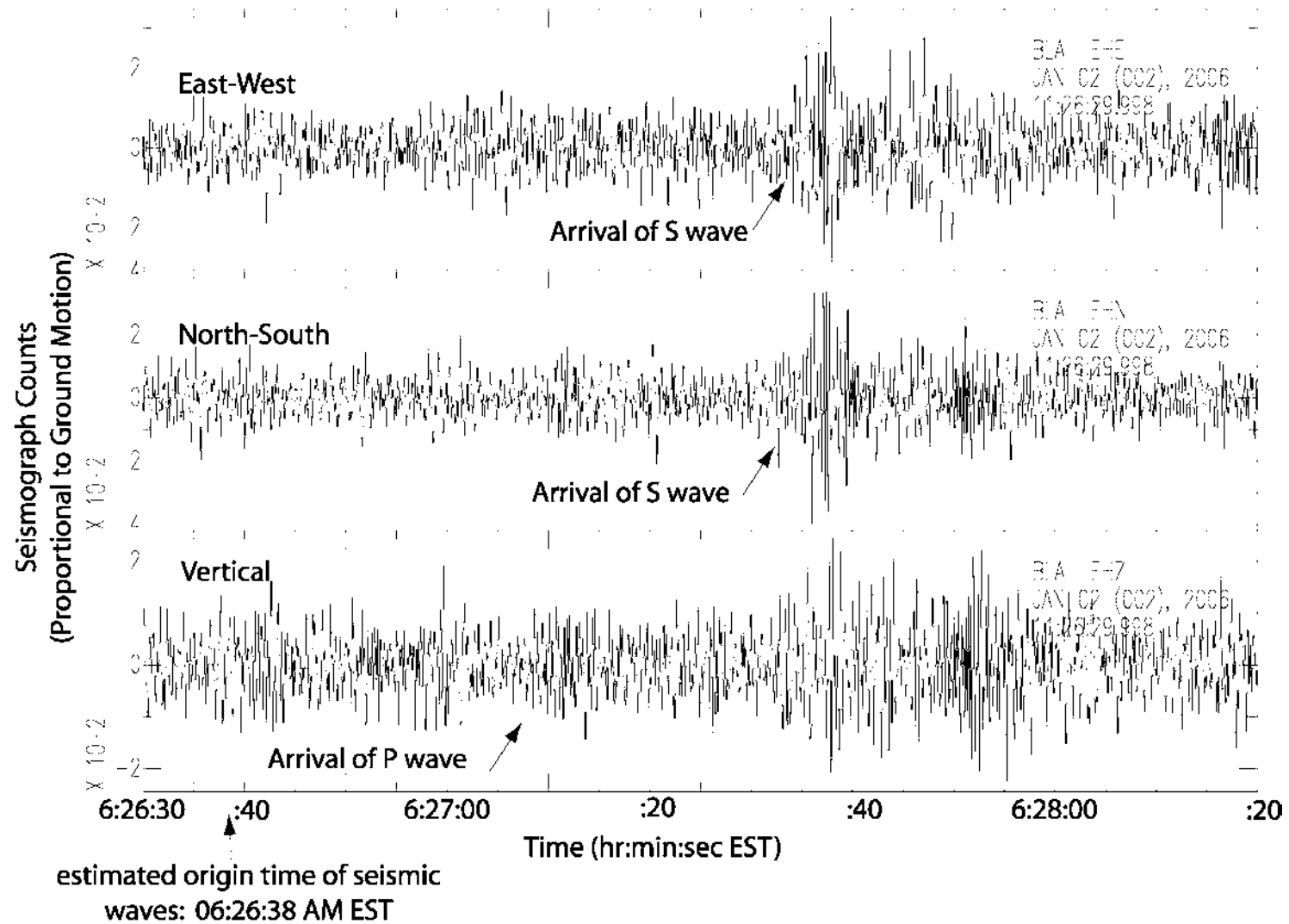


Figure 4. Waveforms recorded at station BLA, 192.9 km from the assumed epicenter at 38.94065 degrees N, 80.20295 degrees W.

Appendix CC - Results from Analysis of Seismic Data

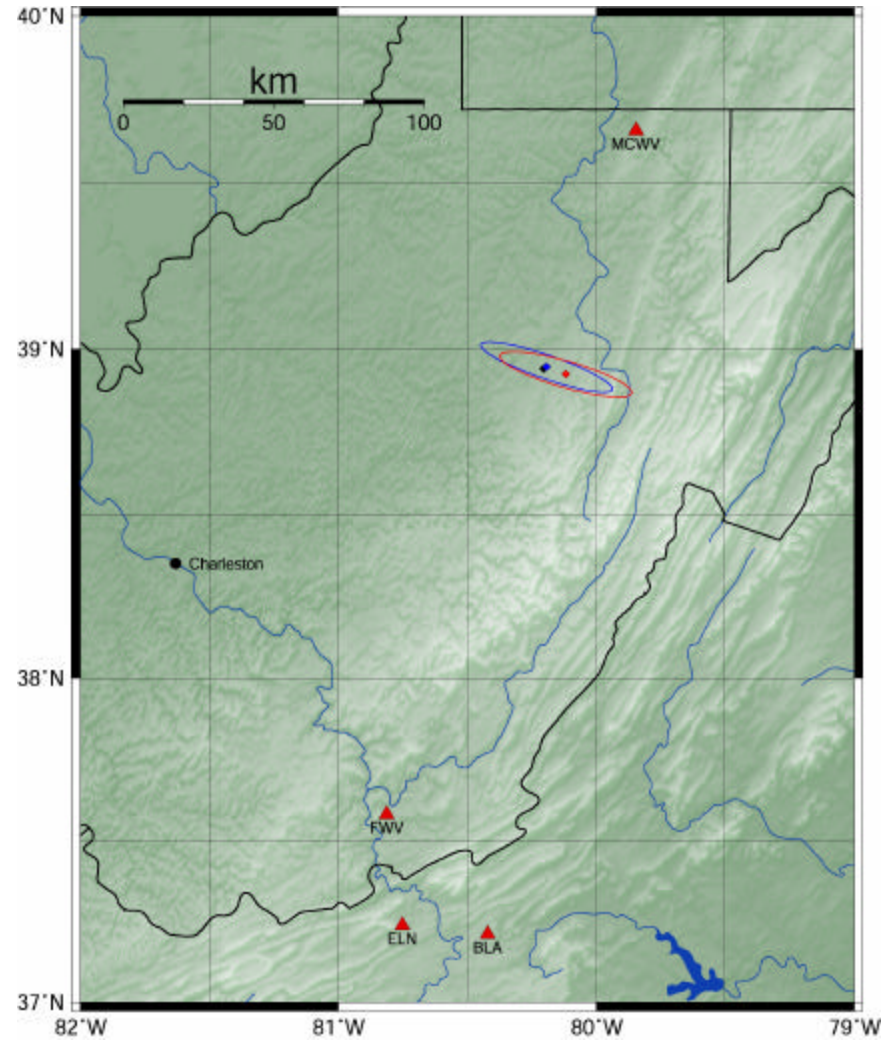


Figure 5. Map showing as a black diamond the assumed location of the Sago mine event (38.94065 degrees N, 80.20295 degrees W). The red diamond shows the epicenter determined using the arrival time data in Table 1 with focal depth fixed at the ground surface. The red line indicates 68% confidence ellipse for the epicenter location. The blue diamond is the epicenter estimated with the depth unconstrained. The blue line shows the corresponding 68% confidence ellipse. Seismic stations used in the location are indicated by the red triangles.

SANDIA REPORT

SAND2006-7976

Unlimited Release

Printed April 2007

Measurement and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine

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Contributing Editors: Michele Caldwell and Larry X. Schneider

Prepared by Sandia National Laboratories
Albuquerque, New Mexico 87185, and Livermore, California 94550

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Appendix DD - Measurements and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine

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Abstract

This report documents measurements and analytical modeling of electromagnetic transfer functions to quantify the ability of cloud-to-ground lightning strokes (including horizontal arc-channel components) to couple electromagnetic energy into the Sago mine located near Buckhannon, WV. Two coupling mechanisms were measured: direct and indirect drive. These transfer functions are then used to predict electric fields within the mine and induced voltages on conductors that were left abandoned in the sealed area of the Sago mine.

ACKNOWLEDGEMENTS

A complex project of this type could not have been undertaken without the funding, coordination, and hard work of the MSHA staff that were involved. We wish to thank MSHA staff William Helfrich, Richard Gates, Robert Phillips, Harold Newcomb, Russell Dresch, Dean Skorski, Joseph O'Donnell, and Arthur Wooten for their support of this project. Jurgen Brune and Eric Weiss of NIOSH generously provided their Lake Lynn facility for initial trials of the measurement techniques used at the Sago mine. We thank the ICG staff, Chuck Dunbar, Al Schoonover, Johnny Stemple, Larry Dean, Kermit Melvin, and Brittany Bolyard, for their generous help in arranging access and for providing the services we needed to accomplish the measurement tasks. In spite of our obvious interruptions to their operations as well as extensive demands on their time, they generously provided the services we needed in a timely manner. We are grateful for the support of Dr. E. Philip Krider and Dr. Martin Uman, who independently reviewed the lightning database information for this report. We also wish to thank the consultants, Dr. Tom Novak, Dr. E. Philip Krider, Elio Checca, and Dr. Martin Uman for freely sharing their thoughts on this project. Monte Hieb and John Scott of the State of WV Office of Miners' Health, Safety, and Training provided additional useful information and help to accomplish the work. Finally, we would like to thank the property owners of the land above the sealed area, Mrs. Goldie Gooden, Tim and Chris Leggett, Bill Patterson, and George Roessing, for generously allowing us access to their property in order to drive ground rods, string wires, and operate our equipment despite obvious interruptions to their lives. Most importantly, we would like to thank our measurement team, Dawna R. Charley and Leonard Martinez, for their extraordinary work in the field. Without their hard work and long hours the measurements could not have been completed.

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Executive Summary

This report documents measurements and analytical modeling of electromagnetic transfer functions to quantify the ability of cloud-to-ground lightning strokes (including horizontal arc-channel components) to couple electromagnetic energy into the Sago mine located near Buckhannon, WV. These transfer functions, coupled with mathematical representations of lightning strokes, are then used to predict electric fields within the mine and induced voltages on a cable that was left abandoned in the sealed area of the Sago mine. If voltages reach high enough levels, electrical arcing could occur from the abandoned cable. Electrical arcing is known to be an effective ignition source for explosive gas mixtures, and corona discharge has been postulated to be so as well. However, given the time scale of lightning (~100 μ s), it is unlikely that corona would develop before an electrical arc. Corona is due to ionization of surrounding air and usually a precursor to arcing, given sufficient voltage.

Two coupling mechanisms were measured: direct and indirect drive. Direct coupling results from the injection or induction of lightning current onto metallic conductors such as the conveyors, rails, trolley communications cable, and AC power shields that connect from the outside of the mine to locations deep within the mine. Indirect coupling results from electromagnetic field propagation through the earth as a result of a cloud-to-ground lightning stroke or a long, low-altitude horizontal current channel from a cloud-to-ground stroke. Unlike direct coupling, indirect coupling does not require metallic conductors in a continuous path from the surface to areas internal to the mine.

Based on the *direct* coupling measurements, lightning currents attenuate rapidly on the conductors as a function of distance into the mine. It is highly unlikely that a worst-case lightning stroke could generate sufficient voltage on a cable within the sealed area to cause concern – even if the lightning stroke directly attached to physical conductors at the entrance to the mine.

Results from the *indirect* coupling measurements and analysis are of great concern. The field measurements and analysis indicate that significant energy can be coupled directly into the sealed area of the mine. Due to the relatively low frequency content of lightning (< 100 kHz), electromagnetic energy can readily propagate through hundreds of feet of earth. Indirect transfer function measurements compare extremely well with analytical models developed for the Sago site which take into account measured soil properties. Lightning stroke data recorded by the National Lightning Detection Network and the United States Precision Lightning Network at the time of the explosion does not support the conclusion that high enough voltage to provide a source of ignition could be generated in the sealed area. However, analyses of credible hypothetical scenarios (an undetected stroke closer to the sealed area or a horizontal arc channel of a recorded stroke above the sealed area) indicate voltages large enough on the abandoned cable in the sealed area to be of concern for electrical arcing. Eyewitness accounts of simultaneous lightning and thunder above the sealed area at the time of the explosion lends further credence to these hypotheses.

This work was sponsored by the Mine Safety and Health Administration. Due to the complexity of lightning interactions with large multi-path structures and the limited duration of this project, it was not possible to address the full intricacies of potential lightning interactions at the Sago mine. However, results cited in this report can be considered as a significant indicator of the potential for lightning to couple energy into underground mining structures. Significant follow-on research would be required to address the complexity of mining structures to an extent to fully characterize these energy coupling mechanisms. Once achieved, it is reasonable to expect that mitigation techniques and safety standards could be developed to secure mining structures from future lightning threats.

ABBREVIATIONS, ACRONYMS AND INITIALIZATIONS

CW	Continuous Wave
dB	deciBel
DOE	Department of Energy
FFT	Fast Fourier Transform
IFFT	Inverse Fast Fourier Transform
NLDN	National Lightning Detection Network
USPLN	United States Precision Lightning Network

Measurement and Modeling of Electrical Transfer Functions for Lightning Coupling into the Sago Mine

1 Introduction

On January 2, 2006, an explosion was initiated in a methane-air mixture within a sealed area at the Sago underground coal mine near Buckhannon, WV that resulted in the deaths of twelve miners. The approximate location of the initiation of the explosion is shown in Figure 1-1.

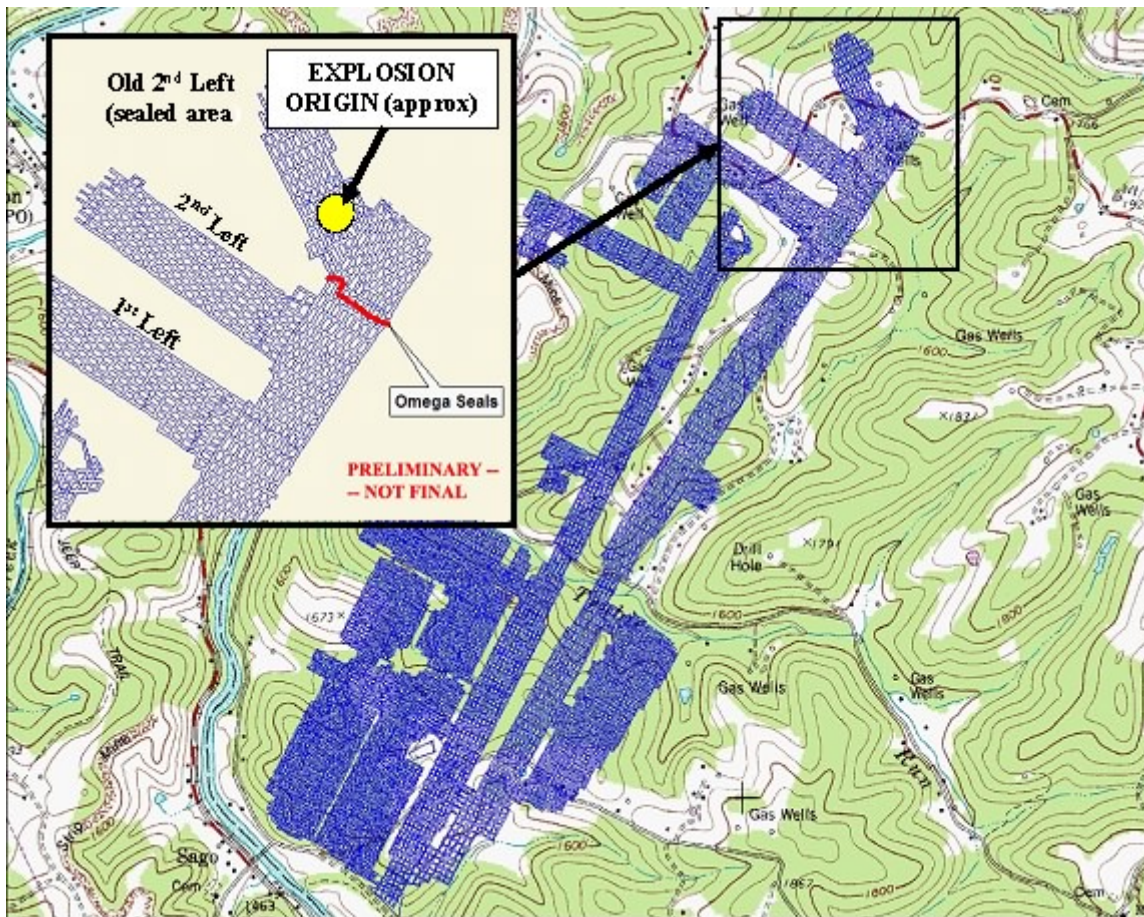


Figure 1-1 Approximate Location of Initiation of Explosion in Sealed Area of Sago Mine.

Because of the fraction of a second simultaneity of the explosion and nearby lightning strokes recorded by the National Lightning Detection Network (NLDN) and the United States Precision Lightning Network (USPLN), lightning is strongly suspected to have caused the explosion. Additional eyewitness reports of other lightning not recorded by NLDN and USPLN further these suspicions [21]. If the timing of the recorded lightning strokes and the underground mine explosion are considered independent statistical events, then the probability that such a combined event would occur at random in a given year is extremely low. When this highly improbable event is coupled with the fact that at least eleven underground coal mine explosions have occurred since 1990 (see Appendix D) in which lightning is suspected of being the cause, it further supports the need to understand the potential role of lightning in the Sago disaster [1-4]. The coupling mechanisms that may have brought lightning energy into the sealed area at Sago were unclear and complicated by the fact that there were no known metallic penetrations into the sealed area of the Sago mine, unlike other sealed area explosions. Prior to 1990, lightning location

and timing data was unavailable, leaving the possibility that many earlier mine explosions would also be correlated to lightning events.

The goal of this project was to perform field measurements at the Sago site and to develop analytical models to quantify potential lightning coupling mechanisms that are capable of delivering significant energy into the sealed area of the Sago mine.

1.1 Motivation for Research and Measurements

Over the last decade, Sandia National Laboratories (Sandia) has developed unique capabilities to characterize and mitigate lightning effects on high value assets within the Department of Energy (DOE) and other agencies as part of a national security mission in nuclear weapons stockpile stewardship. Additionally, the history of potential lightning induced mine explosions suggested that a program using modern electromagnetic measurement techniques and analysis could be valuable during the investigation at the Sago mine. These modern lightning coupling measurement techniques were developed by DOE/NNSA specifically for the evaluation of the performance of lightning protection systems on buried, explosive storage structures, nuclear weapons assembly and dismantlement facilities, and at tunneling systems at the DOE Nevada Test Site. These Sandia developed techniques have been compared and validated using rocket-triggered lightning measurements [5-7] and have undergone significant technical review within the DOE and by the Defense Nuclear Facility Safety Board, an independent federal agency established by Congress in 1988.

1.2 Objectives of Measurements

The principal objectives of this program were to identify, characterize, and quantify the electromagnetic paths of lightning electrical energy into the sealed area of the Sago underground coal mine. These paths include direct coupling through metallic penetrations into the operating area of the mine and indirect coupling through the earth overburden to conductors in the sealed area. Measurement results are compared with basic analytical models to confirm the validity of proposed lightning coupling mechanisms. The measured transfer functions were then used to predict the voltages generated on a cable left abandoned within the sealed area from the lightning stroke locations and amplitudes determined by the NLDN and the USPLN. In addition, the raw lightning event data from the NLDN and USPLN was analyzed to ascertain if there were any instances of data at the correct time that did not meet all of the criteria to be recorded as a lightning stroke.

1.3 Previous Work on Lightning Induced Mine Explosions

Recent previous works by Novak and others [8,9] have utilized commercial, numerical electromagnetic codes to calculate the voltages on metal-cased boreholes connecting the surface with the sealed areas in mines. They have postulated corona discharge as an initiating mechanism based on experimental work by combustion researchers [10,11]. Berger, Geldenhuys, Golledge, Zeh, and others have analyzed the specific situation of lightning-caused explosions in shallow South African underground coal mines [12-16]. The Australian, German, and Chinese literature on lightning initiated underground coal mine explosions has not been thoroughly explored.

1.4 Measurement Method and Analysis

The coupling mechanisms of lightning energy into the Sago mine have been divided into (1) direct coupling via metallic penetrations from the outside of the mine that are terminated immediately outside

the sealed area, and (2) indirect coupling through the soil and rock overburden above the sealed area. The metallic penetrations analyzed and measured were the AC power shields, the coal conveyer system, the transportation rail system, and the mine trolley communication cable. The primary focus of this study was to determine electric fields within the mine and the resulting induced voltage on a cable within the sealed area due to both the direct and indirect coupling mechanisms. Electrical arcing is known to be an effective ignition source for explosive gas mixtures, and corona discharge has been postulated to be so as well. However, given the timescale of lightning ($\sim 100 \mu\text{s}$) it is unlikely that corona would develop before an electrical arc. Corona is due to ionization of surrounding air and usually a precursor to arcing, given sufficient voltage.

Lightning coupling mechanisms were characterized by driving potential pathways with low-level, continuous sinusoidal signals and measuring the resultant signals at distant locations. The resultant data when divided by the input signal produces a transfer function that can be coupled with a mathematical representation of lightning strokes to calculate a resultant signal at points inside the mine. The advantages of using this technique are as follows:

- Measurements can be made without waiting for a natural or triggered lightning in the vicinity.
- Safety is not compromised due to use of low-level signals and interference with ongoing mine operations is minimized.
- The frequency content of the low-level drive signal can be tailored to that of natural lightning.
- Many data points can be taken with this method which enhances the precision of the transfer functions.

The disadvantage is that the nonlinear effects of high-voltage arcing cannot be taken into account.

1.4.1 Direct Coupling Transfer Function Measurements and Analysis

Because all metallic conductors into the Sago mine were terminated outside the sealed area of the mine, current cannot be injected from outside the sealed area directly into the sealed area. However, currents flowing on conductors inside the mine, but outside of the sealed area, may be able to induce voltage on a cable inside the sealed area through electromagnetic coupling. To determine the amplitude of these currents, attenuation on each conductor entering the mine was measured using transfer function techniques. Low-level direct coupling transfer function measurements were made by injecting current onto metallic penetrations at the entrance to the mine and then measuring the voltage and current levels on these penetrations at various points within the mine, up to immediately outside the sealed area. The voltage induced on conductors inside the sealed area could then be calculated based on the projected current level on conductors outside the sealed area and an analytical estimate of the electromagnetic coupling between this current and the conductors inside the sealed area. The measurements were made over a frequency range from 10 Hz to 100 kHz, corresponding to wavelengths in air of 3×10^7 meters to 3000 meters respectively. We are able to use very small signals because our instrumentation is very sensitive and has a large dynamic range. We demonstrated that we could measure input currents and at some distance and from the source even with significant attenuation.

Because the direct-drive measurements are taken as a function of frequency, the mathematical representation of a lightning stroke is transformed as a function of frequency. To use the data, the direct-drive transfer functions were multiplied by the frequency representation of a lightning stroke. The product was inverse Fourier transformed to represent the resultant signals inside the mine from a lightning event outside the mine, as a function of time. To represent the worst-case scenario input for the purpose of these calculations, an assumption was made that the lightning stroke attached to the metallic penetrations at the entrance of the mine.

1.4.2 Indirect Coupling Transfer Function Measurements and Analysis

The large currents in a lightning stroke have an associated magnetic field. When a lightning stroke attaches to the earth, this creates a magnetic field tangential to the ground. For a fully developed lightning stroke, it is reasonable to approximate this magnetic field as

$$H(r) = \frac{I}{2\pi r}$$

over a distance of 30 m – 1000 m, where I = lightning current and r = distance from stroke attachment. For distances within 30 m of the attachment, magnetic field calculations are more complex and this approximation is incomplete. To a first order of approximation and as a bound, the magnetic field is calculated above a perfectly conducting ground plane, as above. This approximate tangential magnetic field is used as a drive to generate current in the finitely conducting earth. The calculations in this report do not deal with magnetic fields generated in the immediate vicinity of lightning strokes; therefore, these interactions will not be evaluated here. For distances greater than 1000 m from the attachment, the approximation for the magnetic field at the surface may be an overestimation, but can be considered a reasonable upper bound.

When lightning attaches to the ground, the magnetic field tangential to the ground creates currents not only on the surface, but deeper in the earth as well. It is a fundamental principle of electromagnetics that magnetic fields on the surface of a conductor can generate currents within the conductor of some depth. For frequencies sufficiently low that displacement currents can be neglected, this is called the *skin effect* and is dependent upon the resistivity of the conductor. When displacement currents are neglected, the electromagnetic coupling phenomena are called *diffusion coupling* or, equivalently, *eddy current coupling*. The skin depth characterizes the exponential decay of these currents in planar geometries. Resistivity measurements have shown the soil in the vicinity of the sealed area of the Sago mine to be a fairly good conductor; therefore, it is reasonable to assume that some electromagnetic energy can propagate from the surface of the earth into the sealed area of the mine. This effect is similar to propagating radio waves through seawater, also a fairly good conductor, and communicating with submarines.

The methodology used to measure the electromagnetic coupling through the earth is to simulate magnetic fields in the earth by connecting a frequency variable voltage source via straight wires on the surface between ground rods at either end of the wires. The ground rods are placed a significant distance from each other, approximately 100 m on either side of the region where the electric fields are measured, or where voltage is induced on an insulated wire. The electric field and the voltage on a cable are measured over a frequency range from 10 Hz to 100 kHz. At this point we have the electric field and voltage response on the pump cable in the sealed area from a known linear current distribution on the surface.

Two steps are involved in calculating the response of a lightning stroke attachment at a distance from the sealed area. The first step involves estimating the magnetic field (or surface current) above the sealed area from a lightning attachment to the ground at a distance from the sealed area. The second step involves calculating the electric field in the sealed area of the mine due to the uniform magnetic field (or surface current) on the surface using the parameters determined from the coupling measurements. Once these connections are made with data in the frequency domain, then the Fourier transform of the lightning stroke can be multiplied by the transfer function. The inverse Fourier transform of the product can be taken to determine the peak electric field and peak voltages that would be caused by a lightning attachment of a given amplitude at a given location with respect to the sealed area. If the peak induced voltages are significant, arcing between conductors could occur. A few tenths of a milliJoule of energy in the arc would be a sufficient ignition source for a combustible methane-air mixture [17]. This amount of

energy is readily available from almost any arcing process envisioned in a lightning induced event. Bulk air breakdown in small gaps (several millimeters) occurs at average electric field values of approximately 10 kV/cm with standard lightning waveforms [18]. Surface arcing can occur at electric field values in the 5 kV/cm range.

1.5 Soil and Rock Site Data

The soil and rock resistivity play a major role in determining the amplitude and frequency dependence of indirect coupling into the sealed mine area. Several studies provide resistivities measured with different techniques and equipment. The resistivities determined by the different measurements appear to be somewhat inconsistent. However, resistivities in [19] match the numbers that give us the best fit for our analysis of electromagnetic coupling through the ground. The resistivities in [19], using a best fit to electromagnetic sounding data, are 100 Ohm-m from 0 to 40 feet, 10 Ohm-m from 40 to 120 feet, and 100 Ohm-m from 120 to 350 feet deep, yielding an average of 77.3 Ohm-m above the sealed area at the borehole. In this study an average resistivity of 80 Ohm-m is used to characterize the soil and rock overburden atop the sealed area of the Sago mine.

1.6 Lightning Event Information

Three positive polarity lightning strokes were identified by the NLDN and the USPLN that were coincident with the Sago underground coal mine sealed area explosion. Their location, polarity, and amplitude are shown in Figure 1-2.

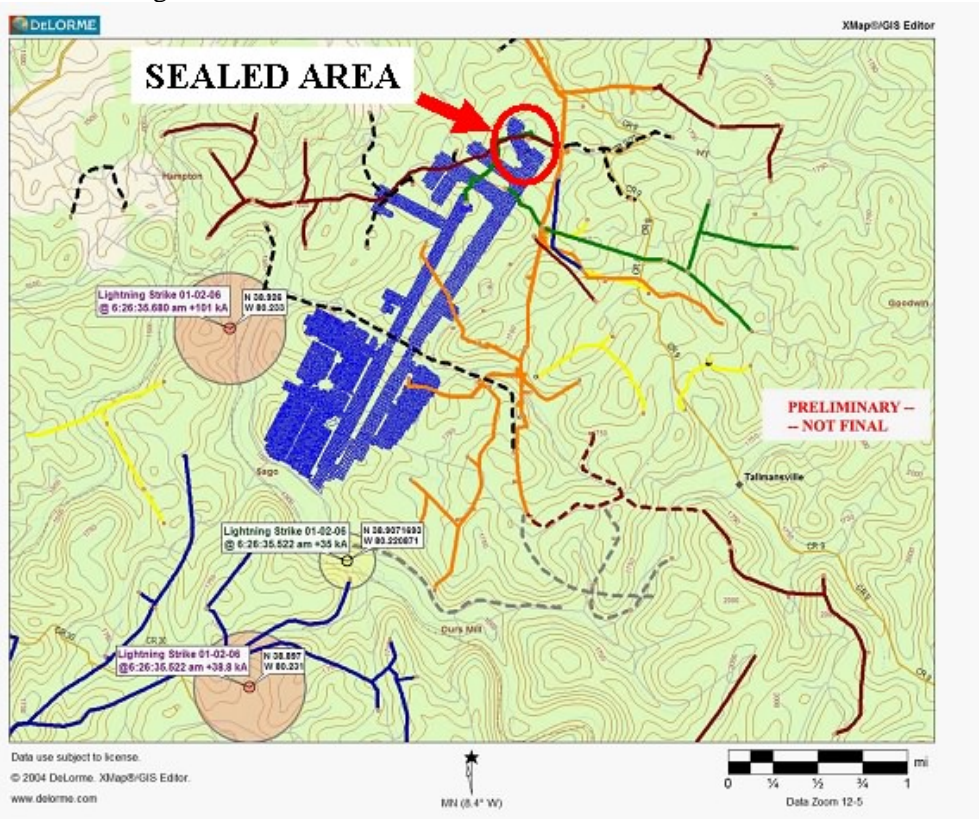


Figure 1-2 Location of Lightning Strokes at Sago Mine Contemporaneous with Sealed Area Explosion.

Table 1-1 gives the location, polarity, and amplitude of the identified strokes. Also provided in the table are the distances from the stroke locations to the sealed area, and the angle that a line between the stroke location and the borehole above the sealed area makes with the pump cable in the sealed area. It should be noted that physical evidence of only stroke number 3 was found after several searches of each attachment area. An analysis of the USPLN and NLDN data strongly suggest that stroke number 1 and 2 in Table 1-1 represent a single stroke, and not two separate events [20,21].

Table 1-1 Lightning Detection Network Data, January 2, 2006

Stroke No.	Time	Longitude/ Latitude	Polarity	Amplitude (kA)	Distance to Borehole (km)	Angle with Cable (Degrees)	Detection System
1	6:26:35.522am	N38.897/ W80.231	Positive	38.8	5.44	52.8	NLDN
2	6:26:35.522am	N38.9071693/ W80.2201	Positive	35	4.02	49.3	USPLN
3	6:26:35.680am	N38.926/ W80.233	Positive	101	2.91	85.5	NLDN

The accuracy of the NLDN is shown in general by the confidence ellipses drawn around the most probable locations. The ellipses give the probability that the lightning is actually inside the ellipse. The estimated 99% location uncertainty for both strokes detected by NLDN was better than 1.1 km (0.7 miles). The fact that the tree was found damaged approximately 197 feet (59 m) from the most probable location of the 101 kA stroke further demonstrates the NLDN location accuracy near the Sago mine [20, 21, 35]. Recent validation experiments on the NLDN have shown stroke detection efficiencies between 70 – 85% and flash detection efficiencies of 90 – 95% [34]. (Lightning flashes are typically comprised of multiple strokes.) It is believed that the two strokes (1 and 3 from Table 1-1) at Sago were part of the same flash [35].

Several other possibilities exist that were not, or could not, be confirmed by the lightning detection network data. Although quite reliable and accurate, the possibility exists of strokes not being detected. Simultaneous thunder and flash were reported by residents living on top of or nearby the sealed area [21]. In addition, the lightning detection networks are designed to locate the ground strike points of cloud-to-ground strokes and do not provide information about the channel geometry above those points, such as if a stroke had a long, low horizontal component that could be important in radiating fields into the mine. Also, upward discharges that are initiated by tall vertical structures will not be detected by the systems unless the initial continuous current phase is followed by at least one leader-return stroke sequence [20, 35]. There were several tall communication towers (the tallest being ~ 200 ft.) within a mile of the sealed area, the closest being approximately 0.5 miles.

1.7 Other Site Information

Measurements discussed in this report were made on the most likely coupling paths into the sealed area. Other potential conduits of lightning energy are mentioned in this section, but were not characterized due to the limited budget and schedule of this project. While they are mentioned here for completeness, the lack of measured data on them does not change the conclusions in this report. If it is desired to develop an overall lightning protection scheme specific to the Sago mine, it would be useful to characterize these potential conduits in the future.

All vertical pipes in the vicinity of the sealed area are shown in Figure 1-3. The vertical pipe closest to the sealed area of the mine is the gas well pointed out in Figure 1-3. It is unlikely that any field enhancements due to the vertical pipes would induce a significant amount of voltage onto the pump cable in the sealed area because the cable is orthogonal to the pipes. However, as potential conduits for lightning energy, they are mentioned here for completeness.

The horizontal gas pipes that are in the vicinity of the sealed area are also shown in Figure 1-3. These pipes are in general buried at a depth of 2 feet from the surface. The response on the pump cable, or electric fields in the sealed area, due to the current drive of the horizontal gas pipes was not characterized because it was not planned for and was not characterized because of liability issues. The gas pipes, if driven locally to the sealed area, would have similar coupling characteristics to the pump cable as that of the indirect drive experimental setup. If the gas pipes were driven remotely, the amount of attenuation from one point on the pipes to another point is mostly dependent upon the resistivity of the soil surrounding the pipes. If the soil surrounding the pipes has low resistivity, a majority of current injected onto the pipes would attenuate in a short distance. However, if the pipes are either not in contact with the soil or the resistivity of the soil is large, then the pipes would act as insulated conductors. Attenuation on the pipes in this case would be much less.

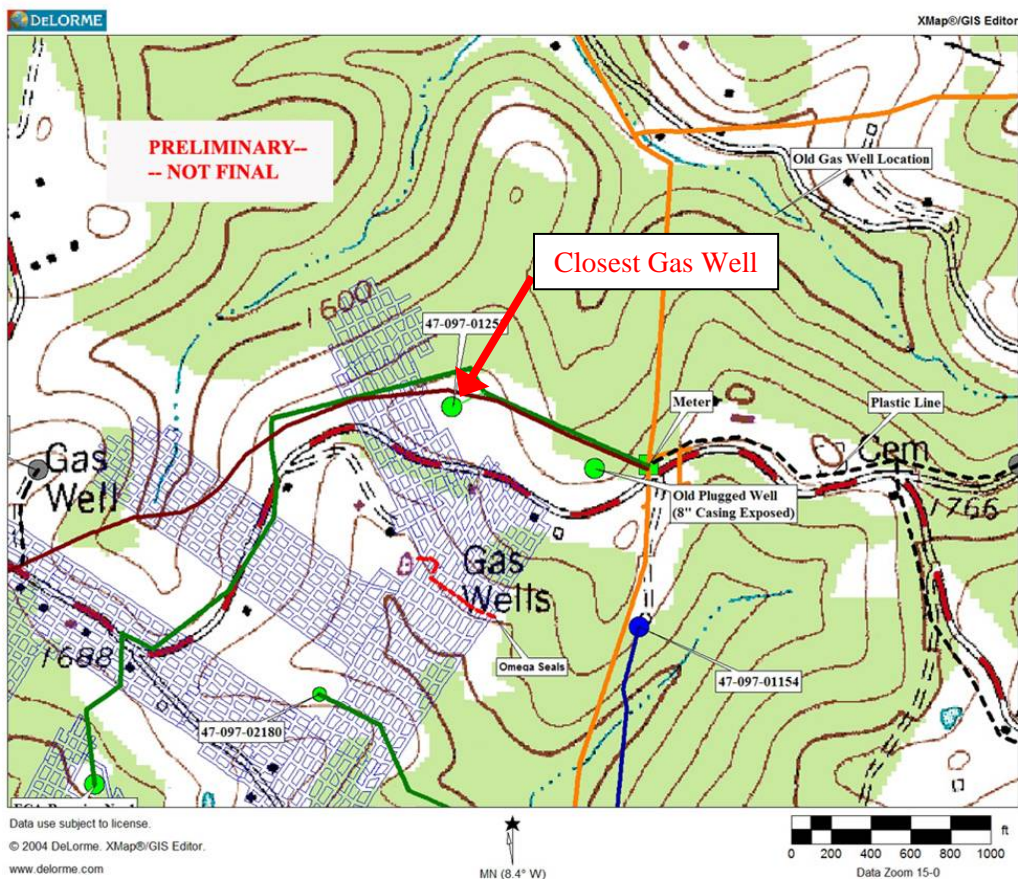


Figure 1-3 Vertical Pipes in Vicinity of Sealed Area of Sago Mine.

Both telephone wires and AC power lines were in the vicinity of the 101 kA positive stroke and could have provided metallic conduction paths into the Sago mine AC power system, or the telephone communication system, or to other metallic penetrations into the mine. The location and routing of this wiring with respect to the stroke are shown in Figure 1-4. The direct-drive measurements discussed in

Section 3.1 lead to the conclusion that even if the power and telephone lines were conduits of the lightning energy, they would not be a plausible source of energy to cause high voltage in the sealed area.

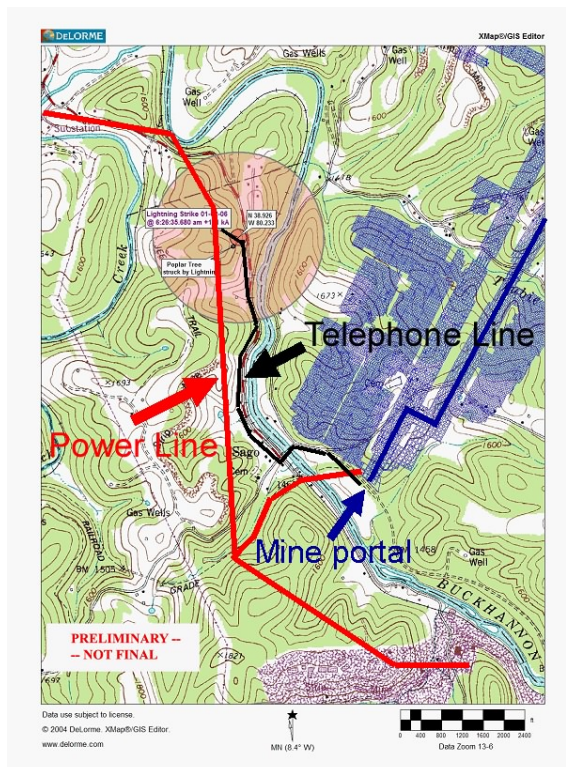


Figure 1-4 AC Power Distribution Lines and Telephone Lines near Positive 101 kA Stroke.

The presence of metallic roof mesh and pump cabling and its relationship to the approximate location of initiation of the explosion are shown in Figure 1-5. The pump cable is shown as the red line and the green shaded area depicts the metallic mesh. The pump cable is noted because indirect coupling measurements are made on it. With these measurements, the voltages induced on the pump cable due to lightning strokes on the surface are calculated in this report.

The metallic mesh is noted because it is used in some of the measurements for grounding purposes. It was not considered a plausible receiver or antenna of the electromagnetic energy that propagates underground because it appears to be well grounded at regular intervals to the roof of the sealed area, and, therefore, would not support a large voltage potential.

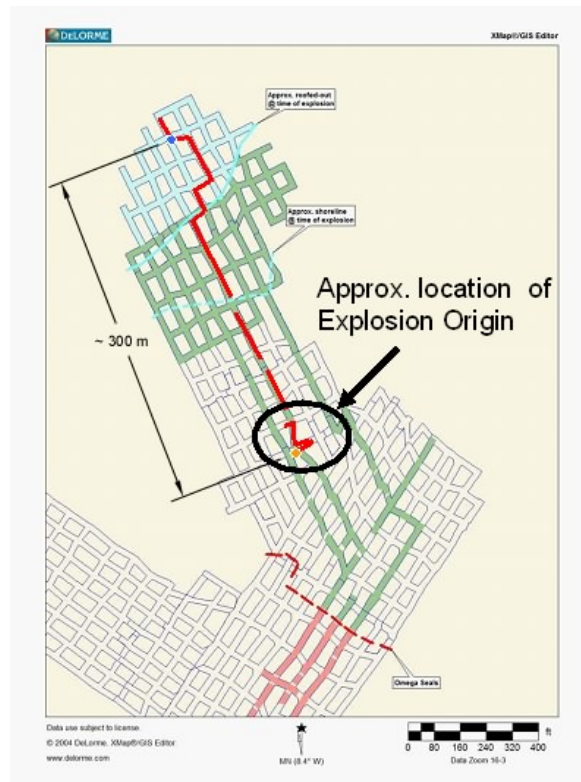


Figure 1-5 Roof Mesh and Cable in Sealed Area Where Explosion Was Initiated. The red line represents a cable from a water pump located at the top of the figure. The green lines represent metallic roof mesh.

1.8 Fidelity Issues of Study

To have confidence in the measured results, several fidelity issues were addressed to ensure that the measurements could be used to calculate a realistic natural lightning response.

1.8.1 Current Flow on the Surface from a Real Lightning Stroke and the Indirect-drive Test Setup

Consideration was given here to two issues that could limit the applicability of the indirect measurements. The first consideration is whether the current flow pattern in the earth is sufficiently similar to lightning. The electric and magnetic fields near rocket-triggered lightning have been measured, and the current flow in the soil out to 30 m distance from the attachment can be inferred [22,23]. Nonlinearities at the lightning attachment point often cause arcing either on the surface of the soil or into the soil that are not duplicated by the low-level drive current measurement method. Because these arcs are limited to the attachment area, they do not affect the overall current flow at large distances to a significant degree. We are not modeling the stroke attachment region, as stated previously.

A second, more significant consideration is that the near-surface current flow pattern produced by these measurement techniques may not accurately represent natural lightning current flow patterns. This is possible because either the current flow at large distances from the attachment point is not duplicated due to the use of ground rods as a return current path during the measurement, or because resistive inhomogeneities in the soil and rock overburden can perturb the flow pattern. However, good correlation between the measured results and the homogeneous earth models suggest these deviations are negligible for this particular project.

1.8.2 Physical Changes to the Sago Site after the Accident

Physical changes were made at the site after the explosion occurred and before Sandia researchers arrived at Sago. These changes do not impact the validity of these measurements, but they are included here for completeness. A three-inch borehole was drilled into the sealed area of the mine immediately above where the explosion is likely to have been initiated. The borehole has only fourteen feet of steel casing from the surface downward, which should not affect the measurements significantly. Also, two eighteen-inch steel casings were added to connect water pumps in the north end of the sealed area to the surface. Because these pipes are a large distance from the region of the sealed area where the explosion originated and are orthogonal to the pump cable, they are not expected to affect the measurements significantly. The pump cable in the sealed area was modified for the indirect drive measurements. The pump cable was spliced with 12-gauge wire to recreate the length of pump cable believed to have been there during the explosion¹. For the measurements, the pump cable was connected with 12-gauge wire to the ceiling mesh and the exposed conductors were placed underwater approximately four crosscuts from the back of the sealed area. The approximate total length of the recreated cable was 300 m (984 ft).

1.9 Potential Further Areas of Study

The following items are potential areas for further study. Their effects on the coupling mechanisms characterized in this report are unknown, but believed to be of minimal effect. Evaluating these areas will not change the basic conclusions in this report.

1.9.1 Nonlinearities

Surface arcing and arcing through soil and rock are well-known phenomena that can propagate lightning energy over a distance of a hundred feet or less. Because these phenomena occur only at the full amplitudes of natural or triggered lightning strokes, their behavior and effect on coupling could not be studied using the low-amplitude transfer function measurement techniques of this study. There is no evidence an arc can travel a distance of 300 feet through soil and rock, therefore, it is unlikely this would have any effect on this analysis.

1.9.2 Coupling from Vertical Pipes near Sealed Areas

The effect on the coupled electromagnetic field caused by direct drive of the vertical gas well that passed near the sealed area was not measured or modeled in this study. Because we could not guarantee that damage to cathodic protection systems or other instrumentation would not be caused by our drive system, the owners of the system would not allow attachment to the pipe without indemnification. Direct drive of the vertical pipe could have caused some enhancement of the coupled electric fields in the sealed area, but would not change the conclusions of this report.

1.9.3 Distributed Drives for Metallic Penetrations

Although the localized drive at the entrance to the mine of all metallic penetrations to the mine was studied (except pager communication line), the propagation of voltages and currents on these penetrations

¹ As a note, there is some disagreement as to the length and positioning of the pump cable at the time of the explosion. The test team used information provided at the time of the measurements, which was that the pump cable was intact and the cable shield was grounded to the submerged pump.

can be enhanced by current flow on the surface of the earth above the penetrations. Simple considerations indicate that the voltage and current amplitudes are not enhanced significantly. The measurement that could have elucidated this phenomenon was cancelled because of the physical and political impracticality of stringing a wire from the entrance of the mine through dense forests and livestock-occupied pastureland to a location above the sealed area.

1.9.4 Amplification Effects of Wiring Resonances

Several coupling resonances were identified on the mine trolley communication and power wiring that could enhance lightning coupled voltages in sealed and unsealed areas of the mine. The characteristics of the resonances were so small that the enhancement would not be significant; however, the maximum extent to which this factor could amplify voltages in sealed areas was not studied.

1.9.5 Effect of Grounded Roof Meshes

Voltages induced between sections of roof meshes in the sealed area were not measured because the substantial grounding of these meshes via rods driven every three feet or so to provide roof support was thought to prevent buildup of voltages. We found at the site that the use of nonconductive epoxies may prevent good contact between the epoxy bolts and the rock. The voltage buildup between sections of roof mesh and the effect of the roof mesh on electric fields and voltages within the sealed area was not studied in this project. [36]

1.9.6 Coupling Paths Not Present in Sago Mine

Lightning coupling paths into sealed areas that are common in other underground coal mines but are absent from the Sago mine, such as coupling along metal-cased boreholes that extend from the surface into the sealed area and coupling through other metallic penetrations used for monitoring or other instrumentation were not studied in this project.

1.9.7 Geologic Irregularities Affecting Coupling

The extent to which geologic irregularities such as faults and mineral deposits that affect the coupling of lightning energy into underground coals was not quantified in this study.

1.9.8 Lightning Current Return Path Assumptions

The analysis used in this report assumes that lightning current is uniform in the radial direction. The extent to which large-scale inhomogenities affect the current paths, and the extent to which the variation with depth affects the coupling, were not quantified in this study.

2 Electromagnetic Coupling Phenomenology Models

Modeling was included in this project to compare the measurements with theoretical calculations. The results for mathematical modeling of coupling of electromagnetic energy into the mine by direct coupling and by indirect coupling are now given. The details of the derivations and derivations of more complicated models are given in Appendix A.

2.1 Direct Coupling via Metallic Penetrations into Mine

The conductive penetrations into the mine can be modeled as transmission lines, or lines of distributed impedance (i.e., the combination of resistance, capacitance, and inductance). It is helpful to model the penetrations as transmission lines, because then their behavior over a wide frequency range, such as the measurements made here, can be analyzed. The classic theory of transmission lines is detailed by King in [24]. Useful formulas for calculating the transmission-line parameters in situations similar to those at the Sago mine are given by Warne and Chen in [25].

2.1.1 Localized Drive Transmission-line Theory

Using the differential circuit representation in Figure 2-1, the equations of transmission-line theory can be developed [24].

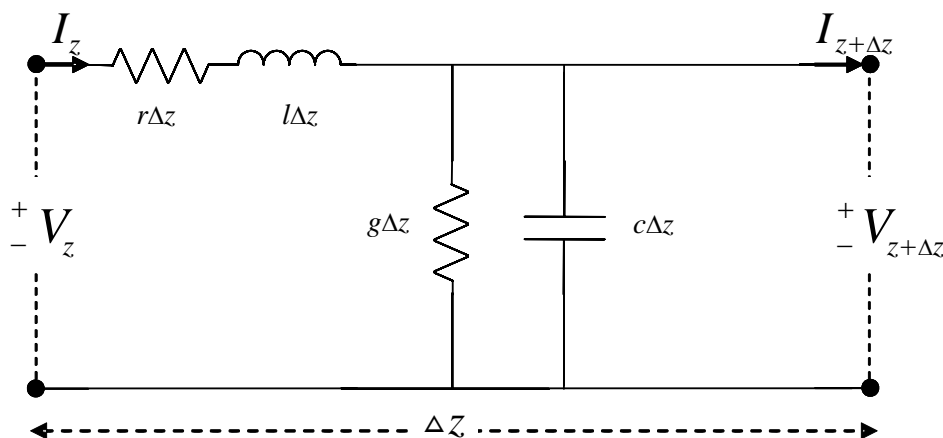


Figure 2-1 Equivalent Circuit of a Section of Transmission Line.

The transmission-line equations are given by

$$\left. \frac{d^2 V}{dz^2} \right|_z = yzV$$

$$\left. \frac{d^2 I}{dz^2} \right|_z = yzI$$

$$y = g + i\omega c$$

$$z = r + i\omega l$$

The complex propagation constant is given by

$$\gamma^2 = yz = (g + i\omega c)(r + i\omega l)$$

These equations along with current or voltage source terms corresponding to localized current or voltage drives and appropriate loads have been used to develop a formal theory of transmission lines [24], which, along with properly determined transmission line parameters, is appropriate to the study of the propagation of lightning currents along direct coupling paths on metallic conductors into the Sago mine. Note that the variable z is used both as the distance along the transmission line and as the impedance parameter for the transmission line.

2.1.2 Distributed Drive Transmission-line Theory

In many situations the current and voltage sources driving the transmission line of Figure 2-1 are not localized to a small volume but are distributed incremental current and/or voltage sources generated along the length of the transmission-line. An appropriate theory for this type of drive has also been developed in [24]. This type of transmission-line treatment is appropriate if the stroke does not directly attach to or is not conducted via metallic connections to the transmission-line.

2.2 Indirect Electromagnetic Coupling via Soil and Rock

To calculate the electric fields in the earth induced by a current on the surface, the problem is simplified by representing the earth as a homogeneous material with a constant resistivity. Section 2.2.1 calculates the simplest case given a finite-length, DC current drive. The calculations become more complex in Sections 2.2.2 and 2.2.3 as the current drive is assumed to be of infinite length and time-varying, as more appropriate for lightning currents on the surface. These results are used to compare to the indirect measurements of the electric field in the sealed area as a function of the drive current on the surface.

2.2.1 Static Coupling Model for Current Injected into Homogeneous Half-Space

The geometry for the simplest model for DC current coupling is shown in Figure 2-2 and is analyzed in [26].

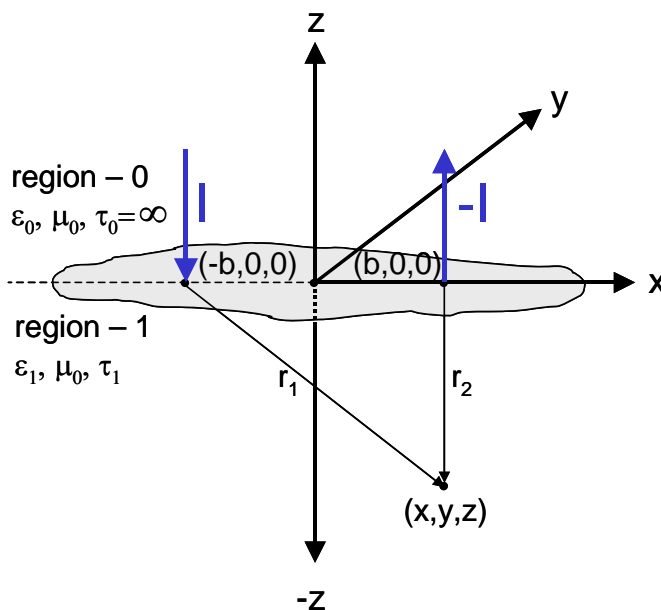


Figure 2-2 DC Current Drive with Homogeneous Conducting Half-Space.

Current I is driven into the conductive half-space at Cartesian coordinate (-b,0,0) and the current is extracted at Cartesian coordinate (b,0,0). The upper half-space, region-0, has infinite resistivity and the lower half-space, region-1 has resistivity, τ_1 . From simple considerations, $V(x,y,z)$, the potential at Cartesian coordinate (x,y,z) with respect to infinity is given by

$$V(x, y, z) = \frac{\tau_1 I}{2\pi} \left(\frac{1}{\sqrt{(x+b)^2 + y^2 + z^2}} - \frac{1}{\sqrt{(x-b)^2 + y^2 + z^2}} \right)$$

The electric field at point (x,y,z) is easily calculated from

$$\vec{E}(x, y, z) = -\nabla V(x, y, z)$$

And calculating the x-component of interest

$$\begin{aligned} E_x(x, y, z) &= -\frac{\partial}{\partial x} V(x, y, z) \\ &= \frac{\tau_1 I}{2\pi} \left(\frac{(x+b)}{\left[(x+b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} - \frac{(x-b)}{\left[(x-b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} \right) \end{aligned}$$

The next coupling models to be considered are generalizations where the current is time varying say as with $e^{i\omega t}$ and the displacement currents are neglected because region-1 is assumed to be a good conductor. This generalization turns out to be more difficult than one might expect because the current in the earth depends on the geometry of the current path above the earth. A simpler model that corresponds to the electromagnetic coupling below an infinitely long, horizontal wire grounded at a large distance away and driven by a voltage source is, however, developed in the next section.

2.2.2 Infinite Line Source above Homogeneous Half-Space

The current drive geometry of an infinitely long, horizontal wire placed a distance, h, above a conductive half-space is shown on the left side of Figure 2-3. A side view is shown on the right side of Figure 2-3. Similar configurations are analyzed in [27-31].

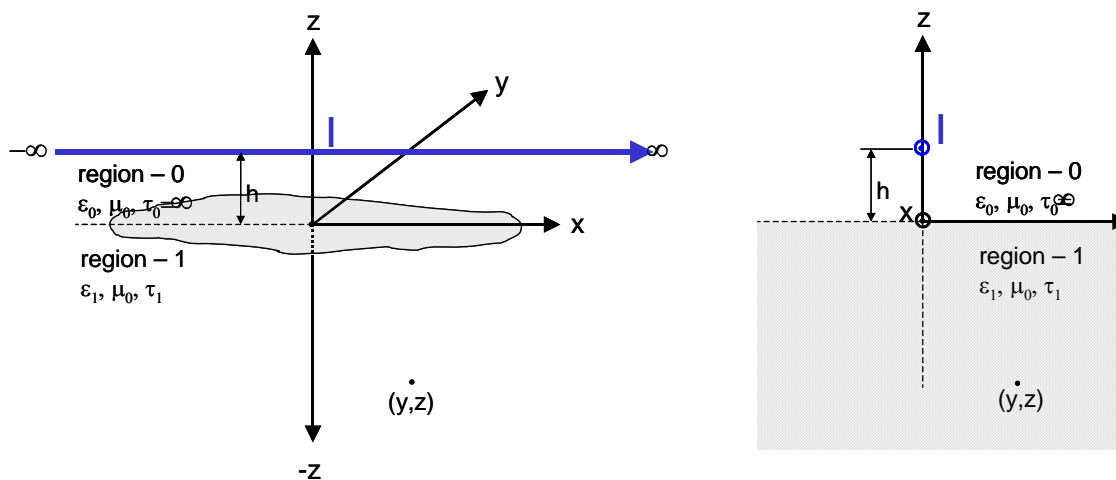


Figure 2-3 Infinite Length, Harmonically Time Varying Horizontal Current Drive over a Conductive Half-Space.

The current drive is harmonically time-varying and is directed along the positive x-axis at height, h, above it. The upper half-space has infinite resistivity and the lower half-space has resistivity, τ_j . If one neglects displacement current and relates current density, $i_x(x,y,z)$ and electric field, $E_x(x,y,z)$, in region-1 through, $E_x(x,y,z) = \tau_j i_x(x,y,z)$, then the current density in the lower half-space, region-1, can be determined to be

$$E_x(y, z) = \frac{ik\epsilon_0}{\pi} \int_0^\infty \frac{e^{qz} e^{-uh}}{u+q} \cos uy du$$

where

$$k = \omega \sqrt{\mu_0 \epsilon_0}$$

$$q = \sqrt{u^2 + ip^2}$$

$$p^2 = \frac{\omega \mu_0}{\tau_1} = \frac{2}{\delta_1^2}$$

$$\delta_1 = \sqrt{\frac{2\tau_1}{\omega \mu_0}}$$

Numerical calculations of this integral are carried out in Appendix A.

Note that the skin depth, δ , plays an important role as a parameter in all diffusion coupling calculations. For convenience it is plotted for resistivities of 10, 100, and 1000 Ohm-m in Figure 2-4. At a given frequency, the lower the resistivity the smaller the skin depth, meaning a majority of the current is contained closer to the surface. Hence, there will be better coupling deeper underground for ground with resistivity of 100 Ohm-m than for ground with resistivity of 10 Ohm-m.

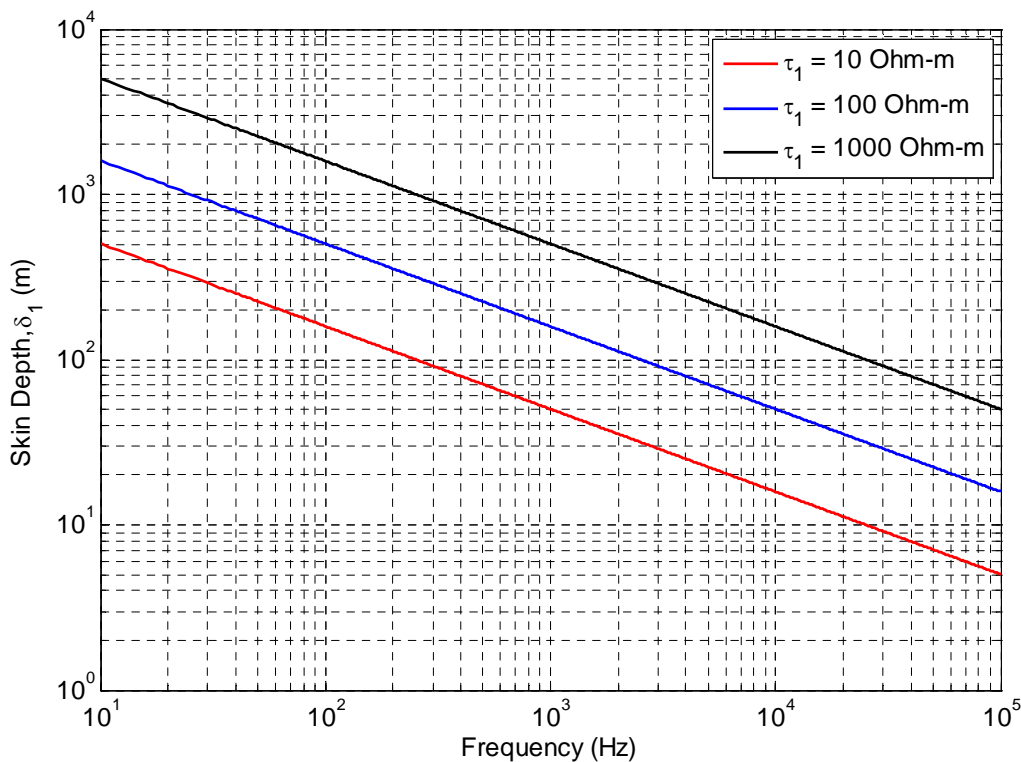


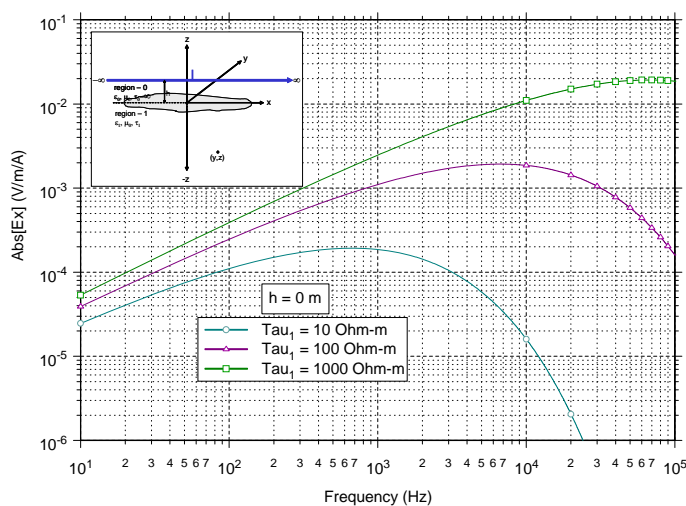
Figure 2-4 Skin Depth, δ_1 , as a Function of Frequency for Resistivities of 10, 100, and 1000 Ohm-m.

2.2.3 Infinite Line Source at Surface of Homogeneous Half-Space

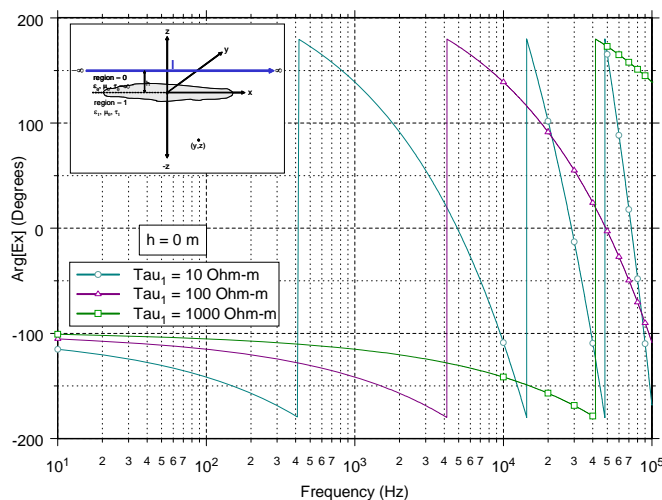
If the line current source is brought to the surface of the conducting homogeneous half-space, where $h=0$, integrating this result for $y=0$ to get the horizontal electric field immediately below the current source yields

$$E_x(y=0, z) = \frac{\tau_1 I}{\pi \delta_1^2} \left\{ \left[(1+i) \frac{1}{\left(\frac{z}{\delta_1}\right)} + \frac{1}{\left(\frac{z}{\delta_1}\right)^2} \right] e^{-\frac{(1+i)z}{\delta_1}} - i2K_0 \left[(1+i) \frac{z}{\delta_1} \right] - (1+i) \frac{1}{\left(\frac{z}{\delta_1}\right)} K_1 \left[(1+i) \frac{z}{\delta_1} \right] \right\}$$

where K_0 and K_1 are modified Bessel functions. Note that we are now using positive z in the downward direction in the formula. A plot of the electric field at $z=100$ m depth for resistivities of 10, 100, and 1000 Ohm-m is shown in Figure 2-5.



a.) Amplitude of E_x



b.) Phase of E_x

Figure 2-5 Amplitude and Phase of Electric Field as a Function of Frequency at Depth of 100m with Resistivities of 10, 100 and 1000 Ohm-m.

2.2.4 Uniform Magnetic Field at Surface above Homogeneous Half-Space

Assume that a uniform y-directed magnetic field of intensity, H_0 , is instantaneously applied above a conducting half-space, as shown in Figure 2-6.

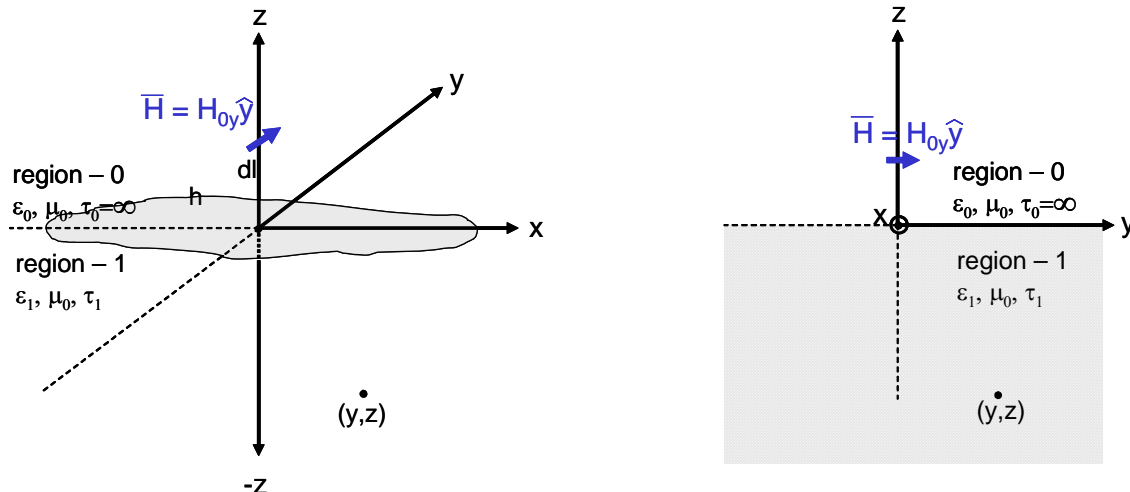


Figure 2-6 Harmonically Time-Varying Magnetic Field Drive over Conductive Half-Space.

If displacement current is neglected, the horizontal electric field below the surface of the conductive half-space is given by

$$E_x(z) = \tau_1 \frac{(1+i)}{\delta_1} H_{0y} e^{-(1+i)\frac{z}{\delta_1}}$$

Note that positive z is used in the downward direction in the formula. Also note that this formulation describes the electric field due to the uniform surface current produced by a cloud-to-ground lightning stroke.

3 Measurement Methods

3.1 Direct Drive

The goal of direct drive is to characterize the attenuation or decrease in signal from the entrance of the mine to various distances into the mine. This is accomplished by directly injecting a current on various conductive lines going into the mine and measuring the current at points further in the mine.

Ideally, the transfer functions of each conductive line going into the mine would be measured in the same configuration as it was during the time of the explosion. However, the grounding at the entrance of the mine was changed following the explosion. Changing back to the old grounding state required the power to the mine be removed, thus stopping all mining operations. A small set of measurements were made while power was disconnected on Sunday, November 5th. It was not possible to conduct all measurements in the one day when the power was disconnected, and stopping mine operations for three days was not feasible. Therefore, the rail, trolley communication line, and conveyor belt structure were measured at six locations at a later time (November 8th and 9th), with the mine grounding system in its current state. The transfer function of the shield on the power cables could not be measured while power was energized.

3.1.1 The Differences and Similarities between Conductive Penetrations

The four conductive penetrations going into the entrance of the mine that were measured were 1) the shield on the power cable, 2) the rail, 3) the trolley communication line, and 4) the metallic structure of the belt conveyor. The conveyor structure and the rail both appeared to be grounded frequently (the rail by surface contact with the ground and periodic bolts), and the conveyor structure by periodic legs bolted to the ground. The shield on the power conductor appeared to be grounded at each power center. The trolley communication cable was an isolated wire running the length of the mine and was only grounded at the entrance. Because of this, at low frequencies the attenuation on the trolley communication line is quite small.

3.1.2 Setup/Equipment Layout with Photos

The principal measurement method used to characterize the coupling through metallic penetrations into the mine is shown in Figure 3-1. Current is driven onto the metallic penetration with an audio amplifier and is returned through either a local ground or a "fence" ground. The local ground consisted of three 18-inch long conductive ground rods driven into the top soil. Each rod was approximately five feet from the other rods and 20 feet away from the driving point. The "fence" ground was long wire attached to the chain link fence that runs along the hillside above the entrance of the mine.

The reasoning for the two grounding techniques was to help show the difference between a local point source drive and a distributed current source drive. A lightning stroke drive could be a distributed current source. The fence drive provided a distributed source for at least several hundred meters. The fence ground also provided a lower ground resistance, which in turn allowed more current to be driven on the lines. By driving more current on the line, the dynamic range of the measurement system was increased. The resistance of the local ground with respect to the rail was 90.2 Ω and the resistance of the fence ground with respect to the rail was 3.68 Ω . It is easy to see from this DC measurement that 20 to 30 times the amount of current could be driven on the fence ground than the local ground. The resistance of the local ground with respect to the conveyor structure was 97.5 Ω , and the resistance of the fence ground

with respect to the conveyor structure was 10.08Ω . All DC ground measurements were made with a Megger DET 5/2 Earth Tester.

The direct-drive system is broken into two parts, the drive end and the measurement end. The drive end consists of a 12 V marine battery and a 120 VAC inverter to provide isolated power for the measurement equipment, a fiber optic receiver, an audio amplifier driven by a network analyzer, connecting wires to the conductor being driven, and wires to a ground (local or fence). The drive signal produced by the network analyzer is optically coupled to the audio amplifier allowing the signals to be phase-locked to increase the sensitivity of the measurements and allow for phase measurements. The technique of phase-locked detection allows measurement of voltages as low as 10s of nanoVolts. The measurement end consists of a 12 V battery and a 120 VAC inverter for isolated power for the measurement equipment, a fiber optic transmitter, a network analyzer, and current and voltage measurement probes. The voltage measurements on the rail, power, and conveyor were made with respect to the roof mesh. Voltage measurements were not made on the trolley communication line because it was isolated without an exposed conductor.

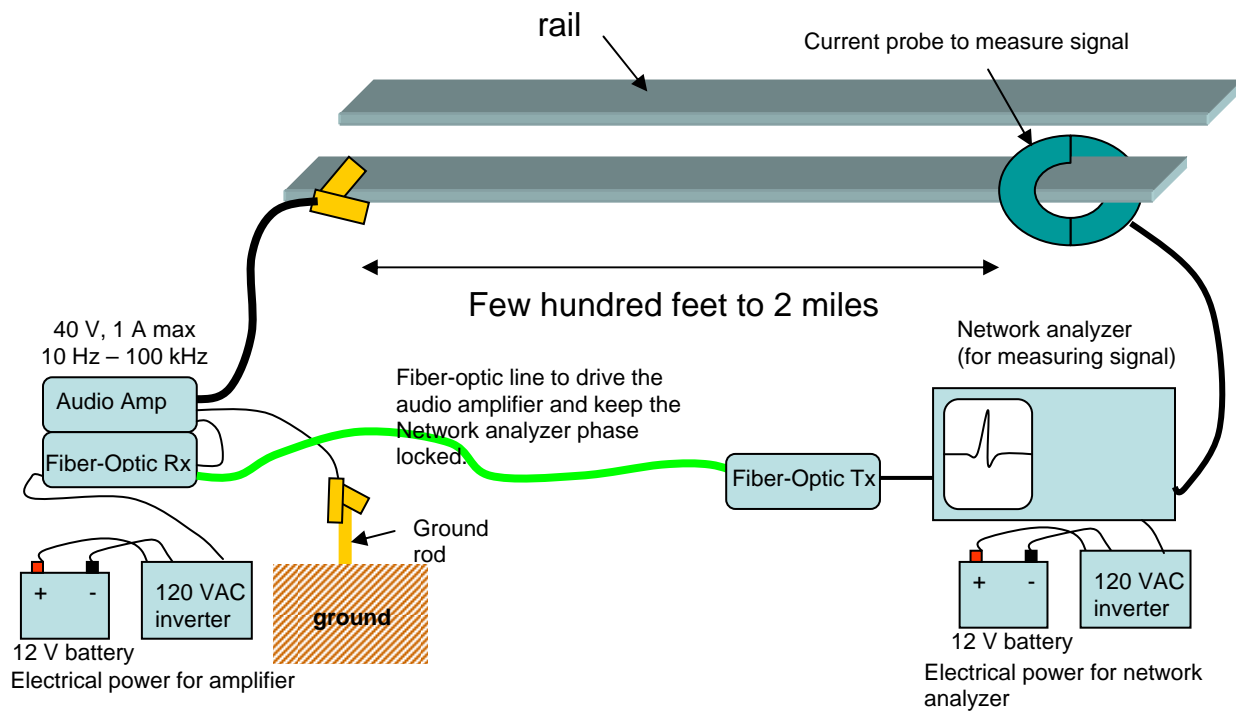


Figure 3-1 Direct Drive Conceptual Drawing.

The measurements were conducted at seven locations along the left rail, trolley communication line, and the conveyor belt structure as they proceeded into the mine. Measurements were conducted at the first three locations for the power cable shield. The power cable shield measurements were completed on Sunday, November 5th while the power was turned off. The power cable shield was not measured during regular mine operation due to safety concerns. Table 3-1 lists mine features at each measurement location, the approximate distance to the entrance (drive location), and the conductors measured. The measurement locations are also shown on the map of the mine in Figure 3-2.

Table 3-1 Direct Drive Measurement Locations

Location	Mine Feature	Break Number	Approximate Distance from Entrance	Conductors Measured: Voltage (V) & Current (I)	
				Grounding System in Configuration 1 ²	Grounding System in Configuration 2 ³
1	#1 Power Center	Belt 1, Break 1	30 m (98 ft.)	Power Cable Shield (V&I)	Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
2	#2 Power Center	Belt 2, Break 1	459 m (1506 ft.)	Power Cable Shield (V&I) Trolley Comm Line (I) Rail (V&I)	Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
3	#3 Power Center	Belt 3, Break 1	669 m (2195 ft.)	Power Cable (V&I) Trolley Comm Line (I) Rail (V&I)	Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
4	1 st Right Spur	Belt 3, Break 16	1076 m (3530 ft.)		Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
5	2 nd Right Spur	Belt 4, Break 11	2178 m (1.35 miles)		Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
6	1 st Left Switch	Belt 4, Break 50	3255 m (2.02 miles)		Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)
7	2 nd Left Switch	Belt 4, Break 59	3491 m (2.17 miles)		Trolley Comm Line (I) Rail (V&I) Conveyor (V&I)

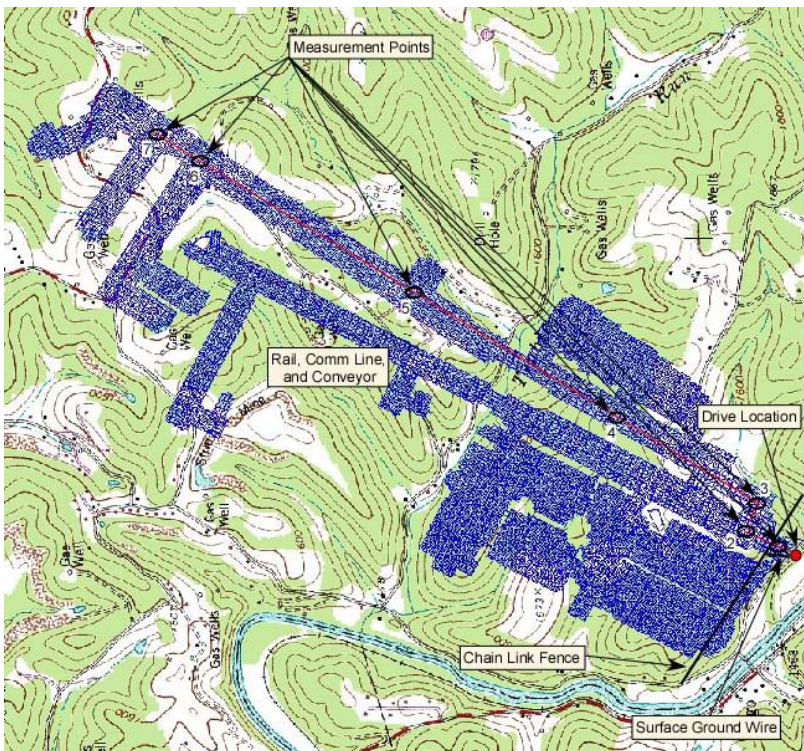


Figure 3-2 Direct Drive Measurement Locations.

² Mine grounding system similar to the grounding scheme in place during explosion.

³ Mine grounding system in current state.

Appendix DD - Measurements and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine

Three current probes were used for the various measurements: a Pearson model 110A; a Pearson model 4688; and a LEM-flex model RR3035 current probe. The voltage was measured with a high-impedance voltage probe model P601 made by Nanofast. The current and voltage probes are shown on the various conductive penetrations in Figure 3-3. The calibration curves for each probe versus frequency are located in Appendix B.

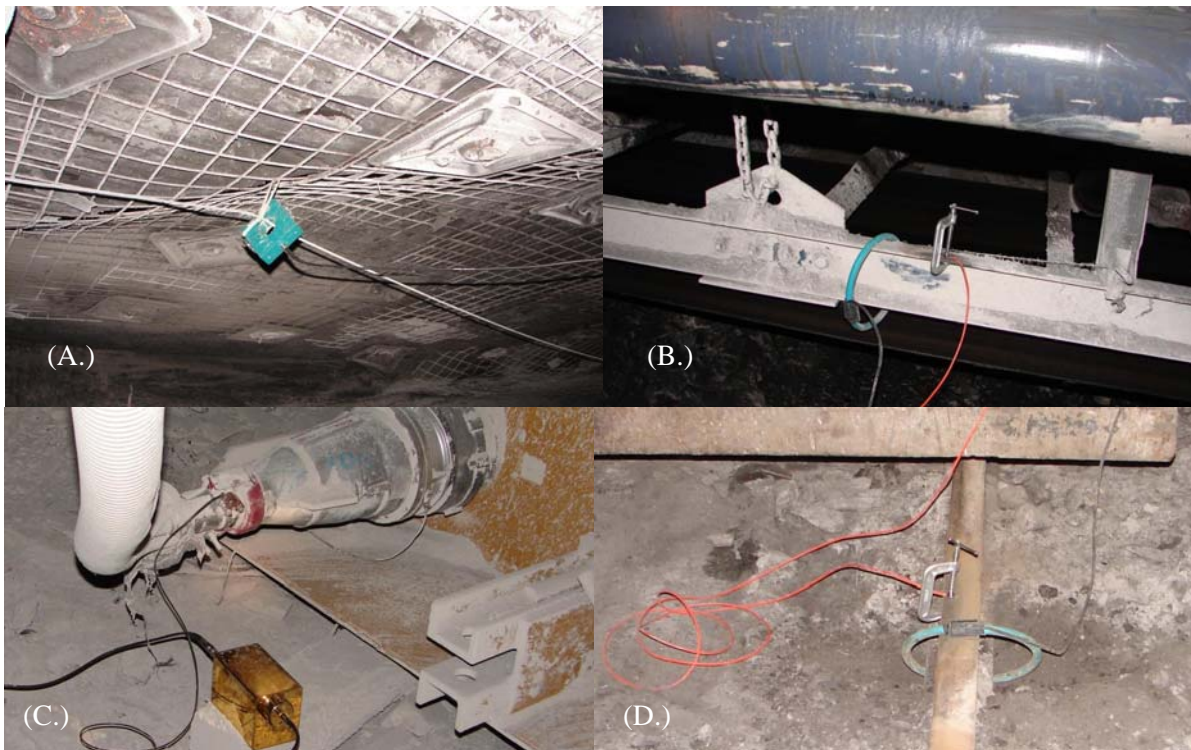


Figure 3-3 (A.) Current probe on trolley communication cable. (B.) Current probe and voltage connection on conveyor belt structure. (C.) Voltage probe on power cable. (D.) Current probe and voltage connection on rail.

3.1.3 Results

The results from the direct drive measurements were consistent with expectations. All of the processed spectral, or frequency-domain, voltage, and current transfer functions for each conductive penetration at each location can be found in Appendix C. For clarity, only a summary of the results is shown here. The summary tables show the attenuation of the peak amplitude of a positive and negative lightning-like pulse attached at the entrance of the mine. This quantity is calculated by multiplying the spectral representation of the current of a positive/negative lightning pulse by the current transfer function measured of a given conductor at a given location (that was measured in the mine). This product is then transformed to the time-domain by an inverse fast Fourier transform (IFFT). The attenuation listed in the tables is then simply the peak output divided by the peak input.

The peak current output to peak current input attenuation, for the various conductors at the measured locations, given a positive lightning waveform, are shown in Table 3-2 and Table 3-3 and, given a negative lightning waveform, are shown in Table 3-4 and Table 3-5. Table 3-2 and Table 3-4 show the attenuation with the mine grounding system in its current state, while Table 3-3 and Table 3-5 show the attenuation with the mine grounding system like it was during the explosion. The darkened cells of the tables indicate no measurements were recorded in the given locations.

Table 3-2 Summary of current transfer functions, using positive lightning waveform, for conductive penetrations with current mine grounding

Location	Trolley Comm Line		Conveyor		Rail		Power Cable Shield	
	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd
1	1.7×10^{-3}	2.9×10^{-3}	2.2×10^{-2}	2.9×10^{-2}	8.9×10^{-2}	1.4×10^{-1}		
2								
3	1.8×10^{-3}	2.8×10^{-3}	3.2×10^{-3}	4.9×10^{-3}	3.6×10^{-4}	9.2×10^{-5}		
4	1.7×10^{-3}	2.8×10^{-3}	5.6×10^{-4}	1.1×10^{-4}	3.8×10^{-4}	9.4×10^{-5}		
5	1.4×10^{-3}	2.2×10^{-3}	7.2×10^{-4}	2.7×10^{-4}	3.9×10^{-4}	3.0×10^{-4}		
6	1.2×10^{-3}	1.9×10^{-3}	4.0×10^{-4}	1.1×10^{-4}	5.5×10^{-4}	4.2×10^{-4}		
7	1.2×10^{-3}	2.0×10^{-3}	3.0×10^{-4}	9.3×10^{-5}	2.3×10^{-4}	3.5×10^{-4}		

Table 3-3 Summary of current transfer functions, using positive lightning waveform, for conductive penetrations with former mine grounding

Location	Trolley Comm Line		Conveyor		Rail		Power Cable Shield	
	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd
1							4.6×10^{-2}	6.2×10^{-2}
2	1.3×10^{-3}	1.6×10^{-3}			2.6×10^{-4}	3.7×10^{-4}	1.8×10^{-2}	2.8×10^{-2}
3	1.3×10^{-3}	1.5×10^{-3}			1.4×10^{-4}	1.7×10^{-4}	1.6×10^{-2}	2.5×10^{-2}
4								
5								
6								
7								

Table 3-4 Summary of current transfer functions, using negative lightning waveform, for conductive penetrations with current mine grounding

Location	Trolley Comm Line		Conveyor		Rail		Power Cable Shield	
	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd
1	2.4×10^{-3}	4.3×10^{-3}	2.2×10^{-2}	2.9×10^{-2}	8.4×10^{-2}	1.4×10^{-1}		
2								
3	2.7×10^{-3}	4.7×10^{-3}	3.7×10^{-3}	5.2×10^{-3}	3.2×10^{-4}	1.3×10^{-4}		
4	2.4×10^{-3}	4.2×10^{-3}	5.7×10^{-4}	1.4×10^{-4}	3.1×10^{-4}	1.7×10^{-4}		
5	2.0×10^{-3}	3.4×10^{-3}	8.1×10^{-4}	3.1×10^{-4}	4.3×10^{-4}	3.4×10^{-4}		
6	1.8×10^{-3}	3.2×10^{-3}	4.4×10^{-4}	2.9×10^{-4}	5.3×10^{-4}	5.4×10^{-4}		
7	1.7×10^{-3}	3.0×10^{-3}	2.9×10^{-4}	8.7×10^{-5}	2.6×10^{-4}	1.9×10^{-4}		

Table 3-5 Summary of current transfer functions, using negative lightning waveform, for conductive penetrations with former mine grounding

Location	Trolley Comm Line		Conveyor		Rail		Power Cable Shield	
	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd	Local Gnd	Fence Gnd
1							4.7×10^{-2}	6.2×10^{-2}
2	2.2×10^{-3}	3.0×10^{-3}			4.0×10^{-4}	6.0×10^{-4}	1.8×10^{-2}	2.7×10^{-2}
3	2.2×10^{-3}	2.8×10^{-3}			1.6×10^{-4}	2.2×10^{-4}	1.6×10^{-2}	2.4×10^{-2}
4								
5								
6								
7								

3.2 Indirect Drive

3.2.1 Setup/Equipment Layout with Photos

The method used to characterize indirect electromagnetic coupling into the sealed area is shown in Figure 3-4 and Figure 3-5. The current from the audio amplifier (which is driven by the output from the network analyzer) is driven on to a long wire above the ground which is terminated at each end with ground rods. The ground rods are placed so as to produce a current distribution in the ground that simulates a linear current drive.

Two configurations were used for the indirect drive measurements. One configuration was through ground rods placed so as to drive the current parallel to the sealed area of the mine and over the area where the explosion occurred as shown in Figure 3-5A. The surface drive wire was approximately 500 m long. A second configuration was through ground rods placed so as to drive the current perpendicular to the sealed area of the mine and over the area where the explosion occurred as shown in Figure 3-5B. In this case the surface drive wire was only 200 m long.

Two types of measurements were made to characterize the indirect coupling into the sealed area. The more time consuming of the two was the electric field mapping measurements made in the vicinity of the explosion ignition area, where the core hole is located. The other measurement was the induced voltage on a spliced intact pump cable going from the back of the sealed area to the location of the core hole. The pump cable was spliced with 12-gauge wire to recreate the length of pump cable believed to have been there during the explosion⁴. The end of the pump cable at the back of the mine was originally attached to the pump which was submerged underwater and chained to the ceiling mesh. For the measurements, the pump cable was connected with 12-gauge wire to the ceiling mesh and the exposed conductors were placed under water approximately four crosscuts from the back of the sealed area⁵. The approximate total length of the recreated cable was 300 m (984 ft).

The electric field at various locations in the sealed area of the mine was measured with an active dipole antenna connected to a receiver via fiber optics. The fiber-optic receiver is connected to the network analyzer measurement port so that the signals are phase-locked in order to measure very small signals in the microVolt/meter range. The three polarizations of the electric field were measured at a total of 15 locations for both the parallel and perpendicular wire current drives. The three polarizations measured were the vertical, P-directed (parallel to the length of the sealed area), and X-directed (transverse to the length of the sealed area). A photo of the dipole antenna in horizontal and vertical polarization is shown in Figure 3-7. The exact locations of the measured electric field are shown in Figure 3-6 where the distance between locations was approximately 10 m. The figure shows 17 total locations; however, positions P1 and P9 were not measured due to water hazards. Because of the amount of data taken and the spacing between measurement points, the lack of these two points does not impact the results.

The induced voltage measurements were taken on the pump cable with both a parallel and perpendicular surface wire drive. These measurements were also conducted using the instrumentation system shown in Figure 3-4. The induced cable voltage was measured with a Nanofast high-impedance probe in the vicinity of the core hole, and transmitted to the surface with fiber optics.

⁴ As a note, there is some disagreement as to the length and positioning of the pump cable at the time of the explosion. The test team used information provided at the time of the measurements, which was that the pump cable was intact and the cable shield was grounded to the submerged pump.

⁵ Test team was unable to reach the back of the sealed area where the pump would have been (it was removed after the explosion) due to water.

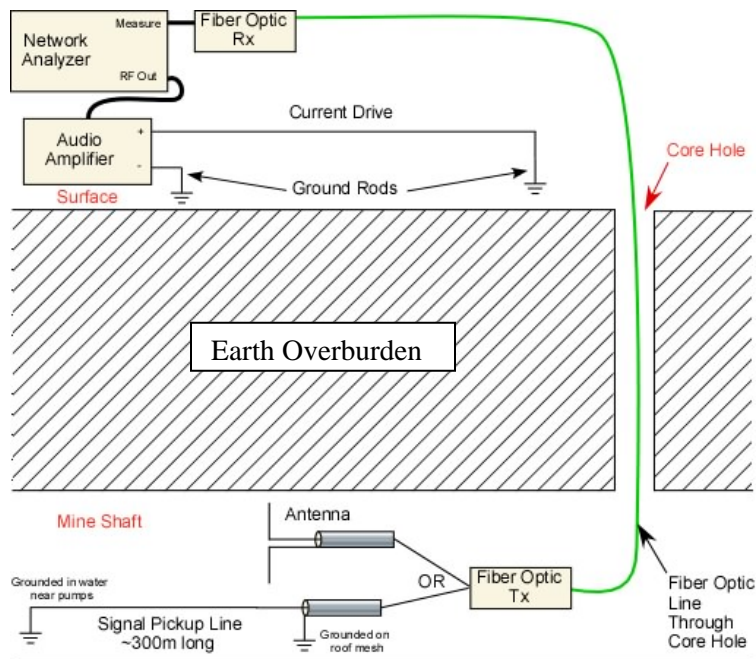


Figure 3-4 Indirect Drive Conceptual Drawing.

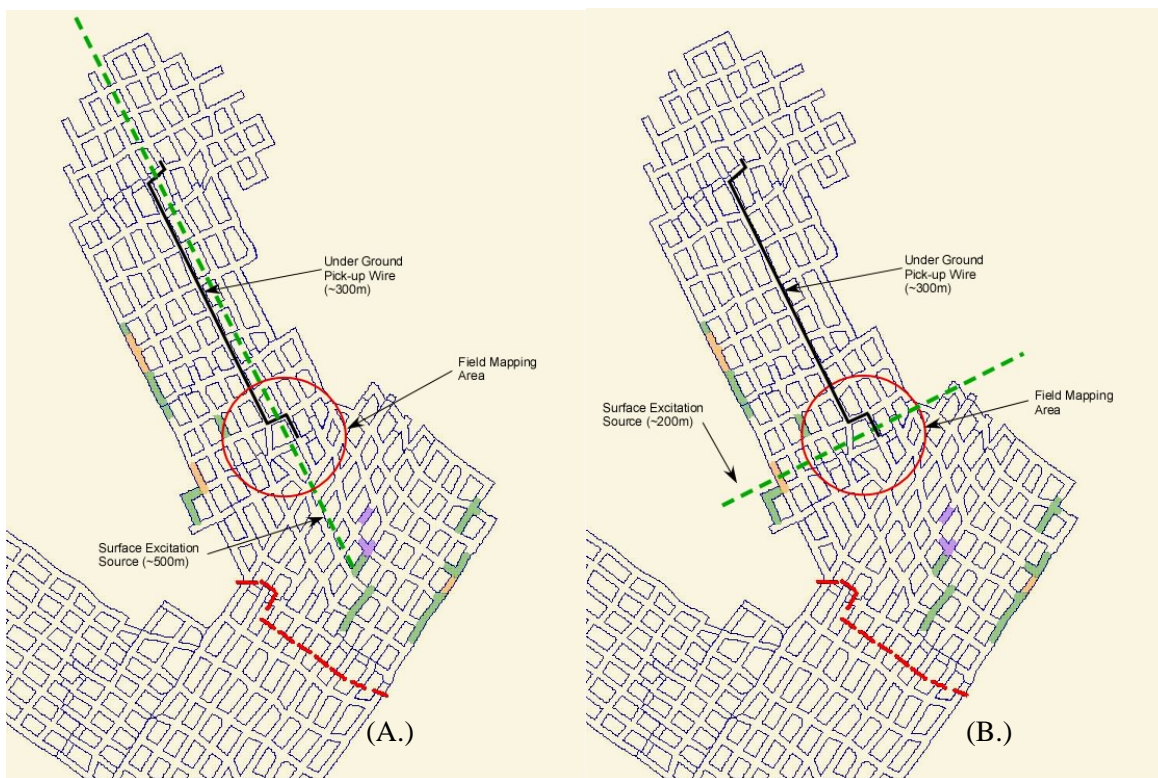


Figure 3-5 Parallel (A.) and perpendicular (B.) surface current drive for indirect drive measurements.

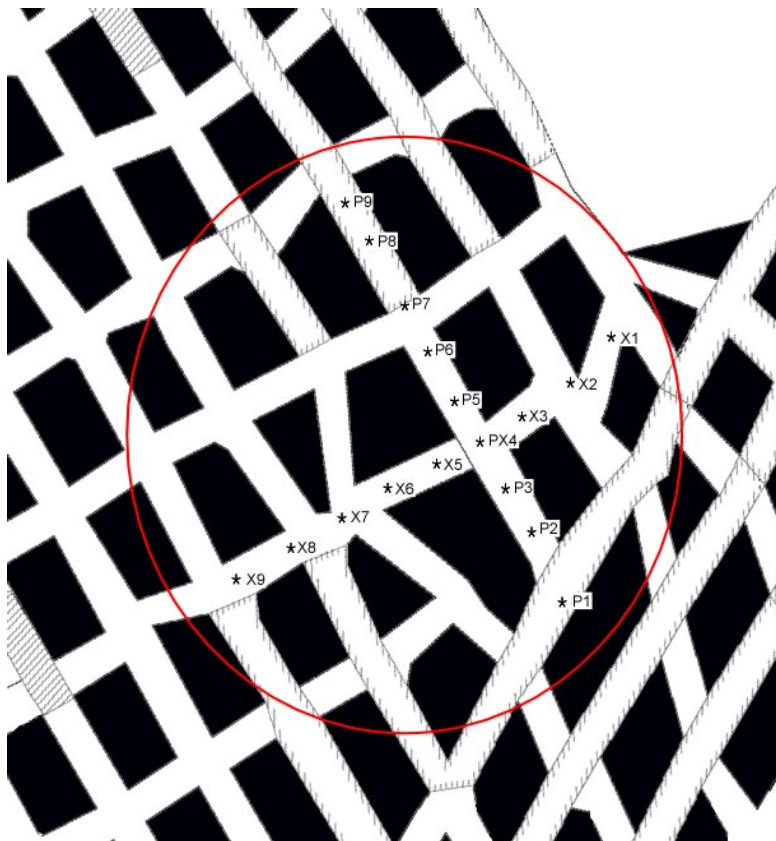


Figure 3-6 Electric field measurement locations.

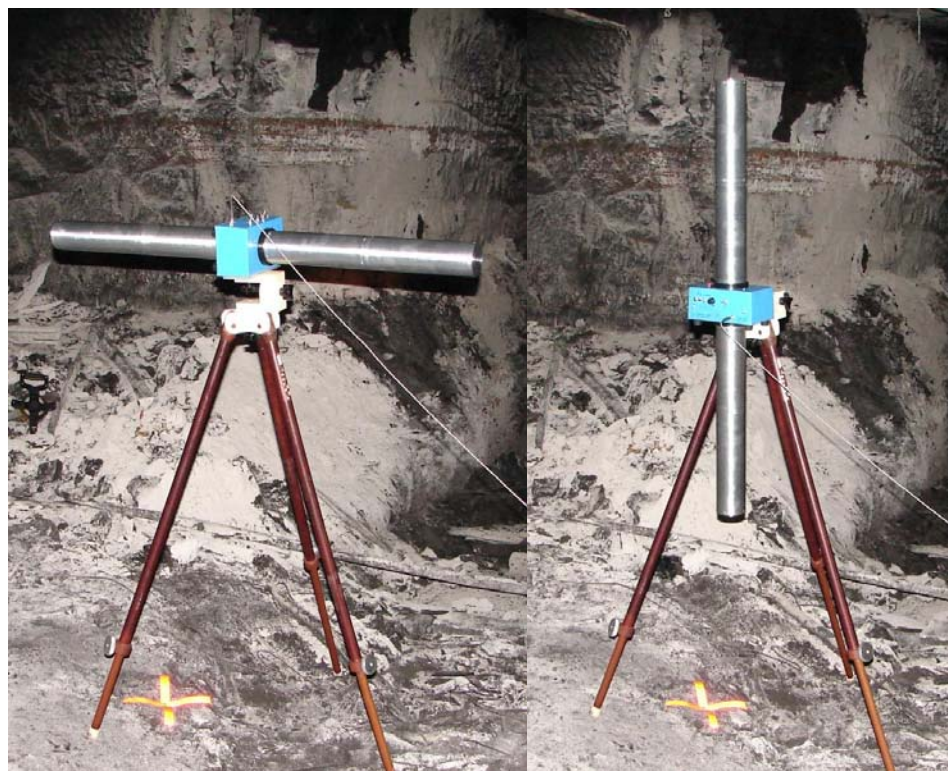


Figure 3-7 Sandia dipole antenna in horizontal and vertical polarizations inside previously sealed area.

3.2.2 Results

The purpose of the electric field mapping of the explosion area was to first look for any field inhomogeneities due to geological features, and second to compare to the analytical model. An added benefit was the ability to verify the induced voltage on the pump cable by integrating the parallel component of the electric field across it. The electric field measurements are shown first and then the induced cable voltage is plotted. The electric field results did show an enhanced electric field at the P5 and the X7 locations (this is noted for general interest,) but do not impact the cable results. The cable integrates or averages the fields over the cable length to build-up a potential difference or voltage.

The data collected for the indirect drive tests from the dipole antenna was only usable above 100 Hz. This was due to a very large 60 Hz clutter signal from surrounding power lines and the high noise level from the network analyzer below 40 Hz. Both of these factors were overcome for the long wire voltage measurement by reducing the IF bandwidth of the network analyzer from 10 Hz to 2 Hz. The reduction of the IF bandwidth lowered the noise floor considerably and reduced the sensitivity of the transfer function to the 60 Hz clutter; however, the time for a single swept measurement increased from ~1.5 minutes to ~10 minutes. With the large number of measurements desired for characterizing the electric field in the sealed area, the higher IF bandwidth was used for the majority of the data collected. The overall effect on the data was minimal. As a result, only data from frequencies above 100 Hz are plotted for the dipole measurements in the body of this report. The full spectrum of the data collected can be found in Appendix C.

The normalized composite electric fields from the dipole antenna at various locations are plotted in this section. The composite electric field is simply the root-sum-square or amplitude of the electric field vector. The measured electric field is normalized by the current in the drive wire on the surface, so that the units are V/m/A.

The normalized electric fields due to the wire current drive parallel to the P-direction, measured at locations P2 through P8 and X1 through X9, are shown in Figure 3-8 and Figure 3-9, respectively. Similarly, the fields due to the wire current drive perpendicular to the P-direction, measured at locations P2 through P8 and X1 through X9, are shown in Figure 3-10 and Figure 3-11, respectively. This information is summarized in Table 3-6.

Table 3-6 Summary of figures for drive configurations

Drive Configuration	Electric Field at P locations	Electric Field at X locations
P-directed Current Drive (Parallel)	Figure 3-8	Figure 3-9
X-directed Current Drive (Perpendicular)	Figure 3-10	Figure 3-11

Referring to Figure 3-8, note that the composite electric fields measured in a path parallel to and immediately below the drive are about the same amplitude. The presence of metal objects near the antenna affects the local fields somewhat. The measurement at P5 was made in the area between unconnected sections of roof mesh. The slight resonance at about 60 kHz in the P5 measurement was probably caused by a resonance of the cable that was attached for the voltage measurements. This cable was not removed for the electric field measurements, and high electric fields may have been induced on the disconnected end of the cable at resonance.

Referring to Figure 3-9, note that the low-frequency amplitude tended to decrease as the electric field antennas were moved away from the center line immediately below the drive line.

Appendix DD - Measurements and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine

Referring to Figure 3-10, the composite electric fields measured in a path perpendicular to the drive cable are reduced significantly from the field due to a parallel drive cable. Again, a slight resonance was seen at P5.

Referring to Figure 3-11, the fields measured parallel to and below the perpendicular drive are comparable in amplitude to those shown in Figure 3-8. Because of the closer spacing of the ground rods on the surface, more variation was shown in the individual measurements.

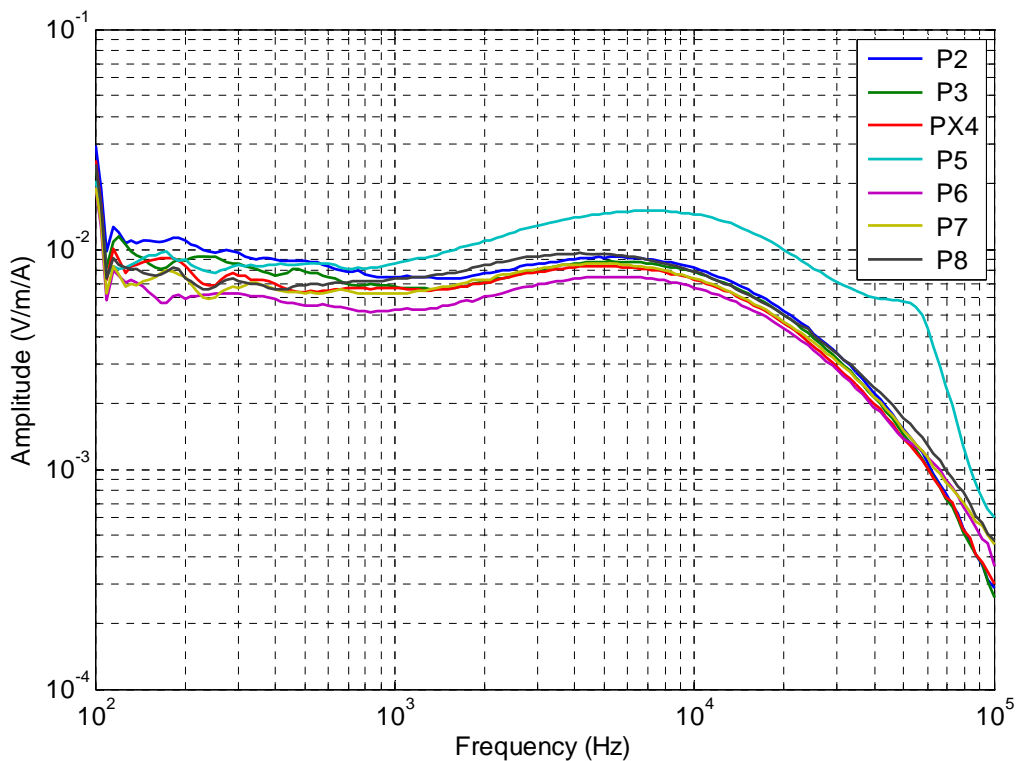


Figure 3-8 Composite Electric Field along P-direction with parallel line drive on surface.

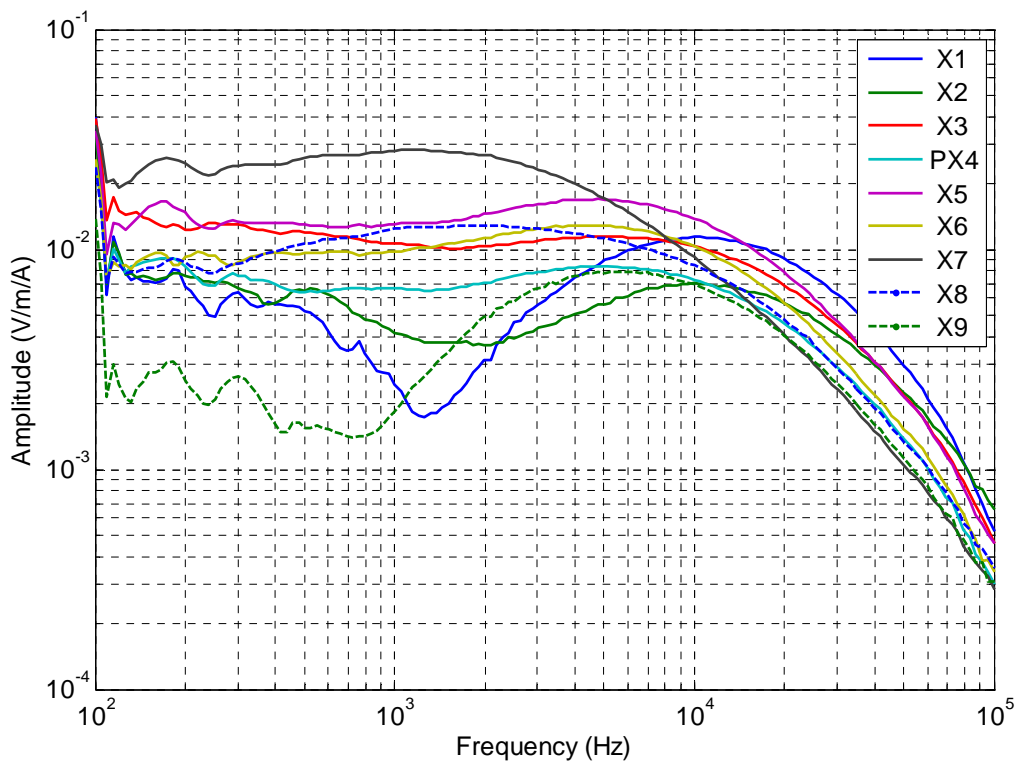


Figure 3-9 Composite Electric Field along X-direction with parallel line drive on surface.

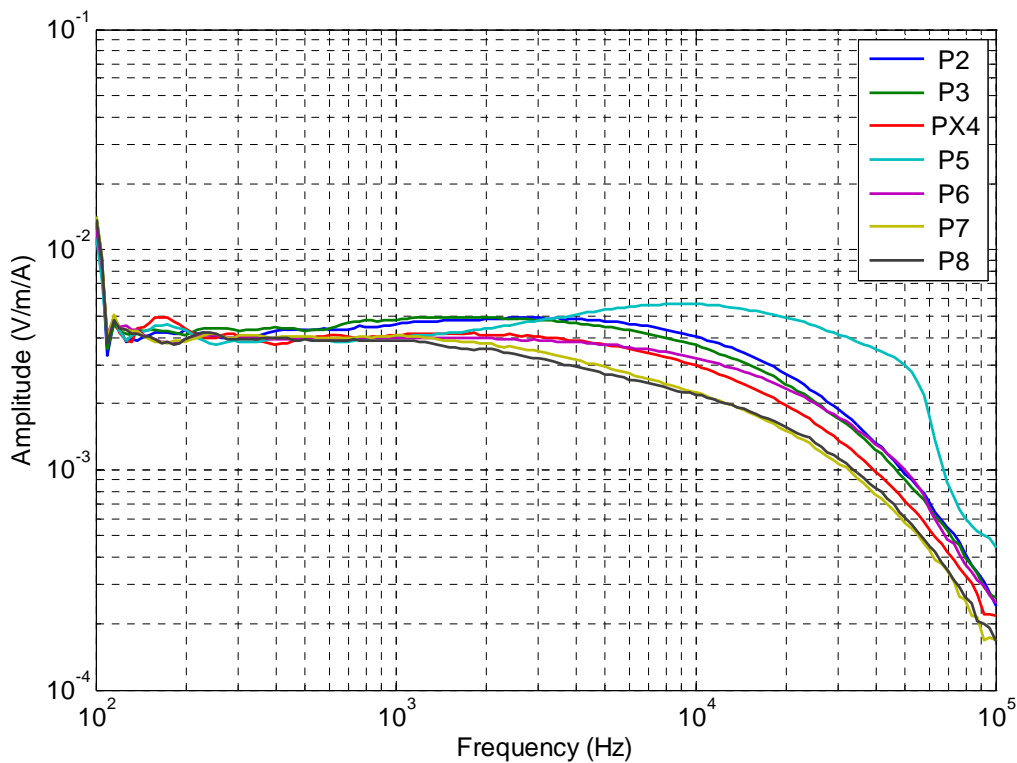


Figure 3-10 Composite Electric Field along P-direction with perpendicular line drive on surface.

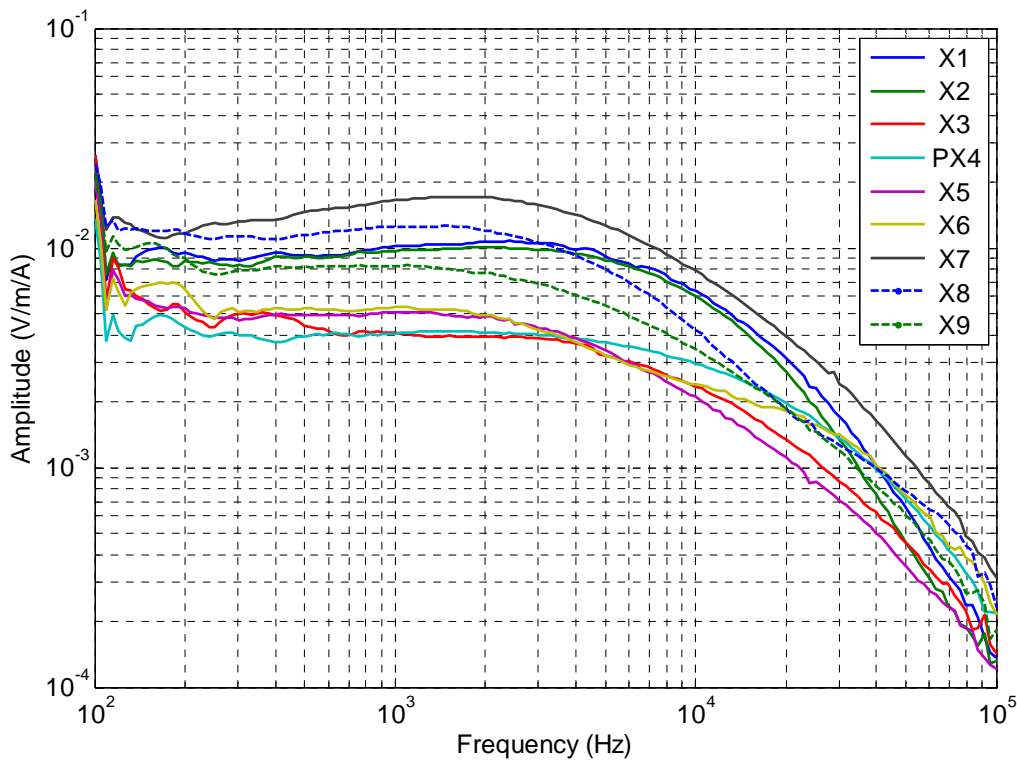


Figure 3-11 Composite Electric Field along X-direction with perpendicular line drive on surface.

The voltage on the pump cable was measured with a high-impedance voltage probe and the network analyzer set to a 2 Hz IF bandwidth. The normalized results of the voltage amplitude plotted relative to the drive current on the surface wire, with units of Volts per Amp (V/A), are shown in Figure 3-12. There is a spike at 60 Hz due to stray signals from power lines. The data is skewed by noise only below 20 Hz.

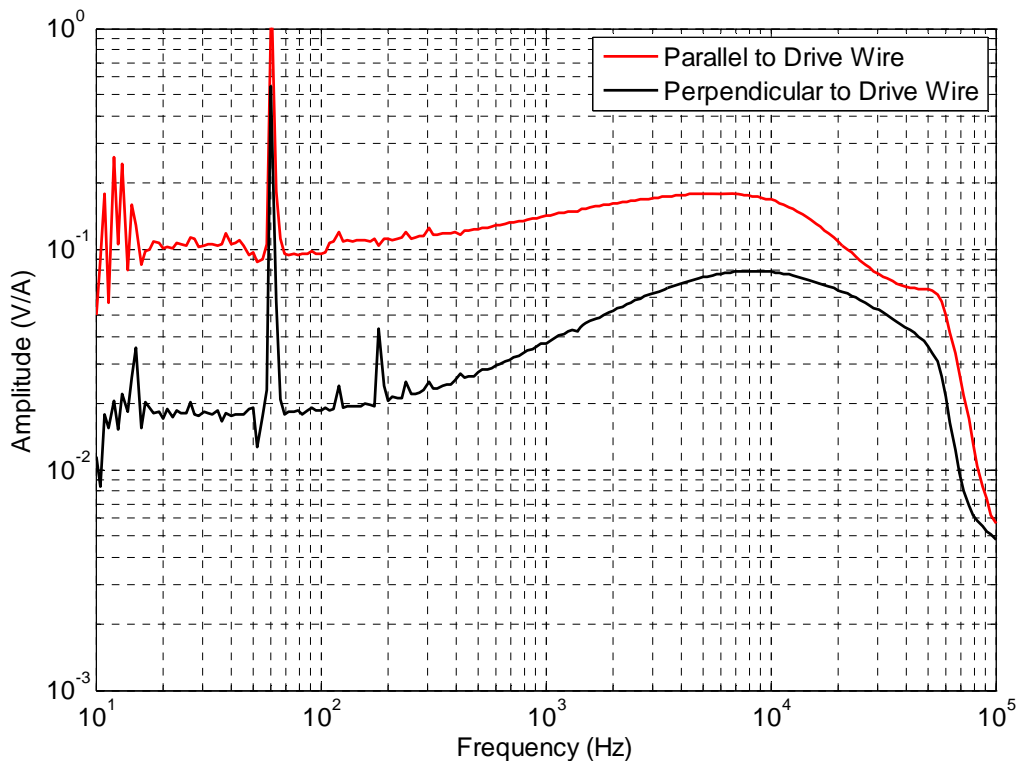


Figure 3-12 Induced voltage on pump cable (~300 m or 984 ft. long) due to wire current drives on surface.

To compare the induced voltage measured on the pump cable with the field measurements, we will look only at the parallel surface drive induced fields from P2 to P8. Furthermore, we will only look at the horizontal polarization directed along the P-axis, parallel to the direction of the drift. The horizontal polarized electric fields are shown in Figure 3-13. The normalized electric fields are in units of Volts per meter per Amp (V/m/A) while the normalized induced voltage on the pump cable are in units of Volts per Amp (V/A). If we integrate the electric fields over the length of the pump cable, we should obtain the induced voltage from Figure 3-12. Assuming a simple uniform distribution we can simply multiply the electric field by a length. The effective length of cable (similar to the effective area of an antenna) needed to match the electric fields measured with the induced voltage measured was found to be approximately 120 m (394 ft). This means that only the 120 m (394 ft) closest to the measurement end of the cable contribute to the induced voltage. The comparison between the measured induced voltage and the electric field multiplied by the effective length of 120 m (394 ft) is shown in Figure 3-14.

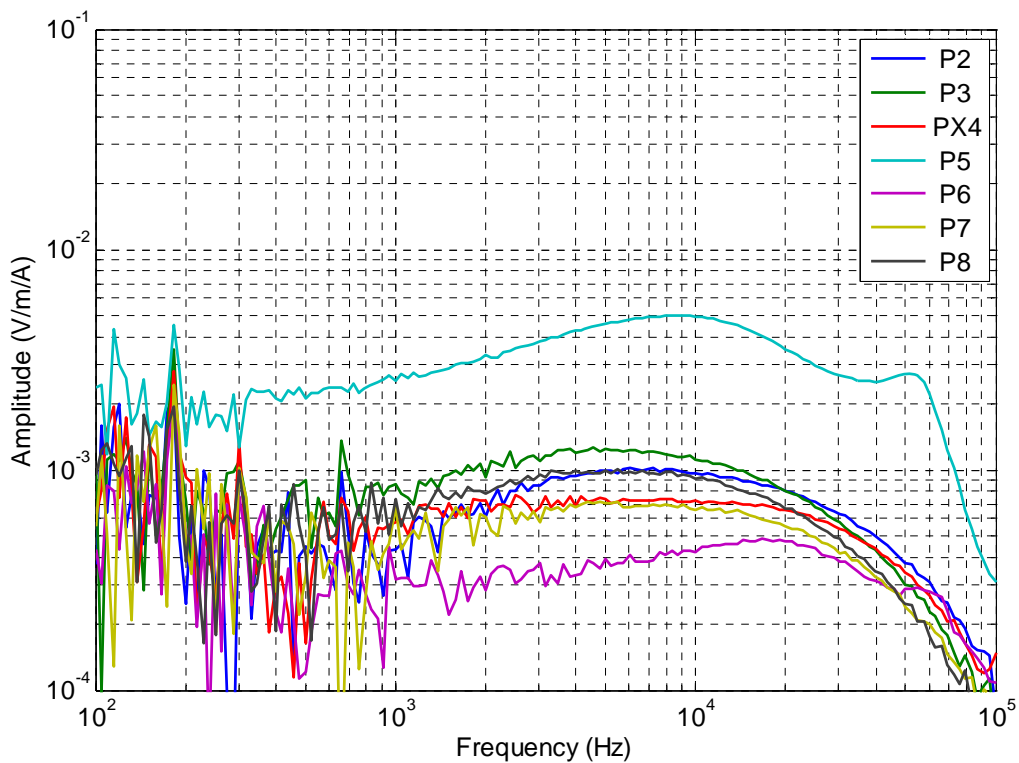


Figure 3-13 P-directed Electric Field along P-direction with parallel line drive on surface.

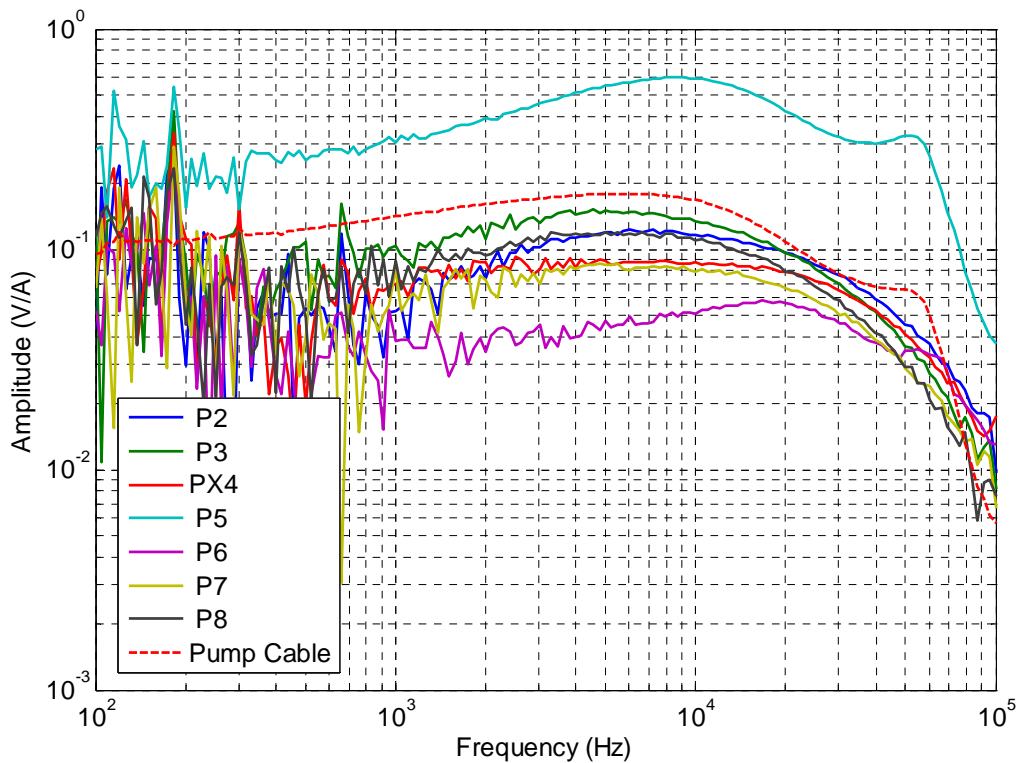


Figure 3-14 P-directed Electric Fields multiplied by an effective cable length of 120 m (394 ft) compared with the induced voltage on the pump cable.

3.2.3 Results Compared with Diffusion Model

The model for diffusion coupling from an infinite current source above a homogeneous half-space was presented in Section 2.2.3. This model is compared with the measured electric field and induced voltage on the pump cable. Using an effective soil resistivity of $80 \Omega\text{-m}$, the analytic model plotted in Figure 3-15 matches very closely the horizontal (P-directed) electric field measured with a parallel current drive. The correlation between model and measured data is extremely good from 10 to 100 kHz. This confirms that the major coupling mechanism from the surface to the sealed area is field diffusion coupling. The measured data is contaminated by 60 Hz resonances and clutter below 1 kHz for this polarization. The data deviates from the model of coupling beneath an infinite line at frequencies below 1 kHz. The measured data stays at a constant level of approximately 0.0006 V/m/A , whereas the analytical model predicts a downward slope. Much of this deviation can be attributed to the field caused by the DC component from the finite spacing of the ground rods. An estimate of this component of the electric field is shown below 1 kHz, where the skin depth is much larger than the depth to the measurement antennas. A comparison of the average of the P-directed electric field measurements from P2 to P8 with the analytic diffusion model is shown in Figure 3-16. The average field is a more meaningful value to compare since it has local variations removed. The amplitude and shape show amazing correlation.

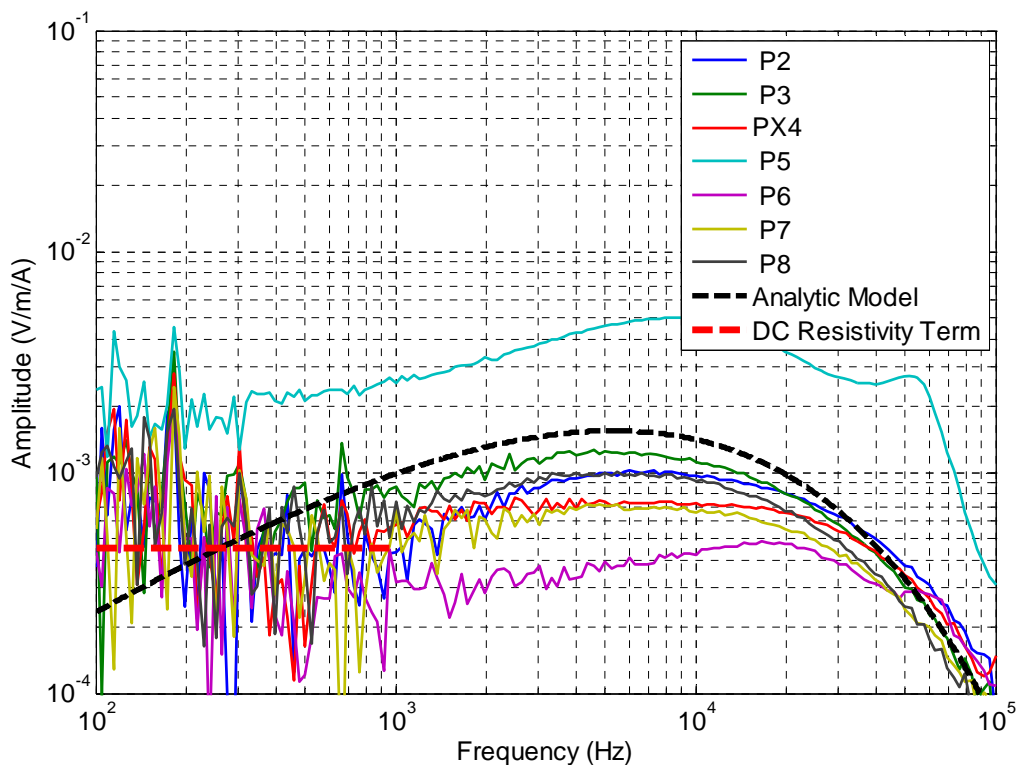


Figure 3-15 P-directed Electric Fields compared with the diffusion model with an effective resistivity of $80 \Omega\text{-m}$.

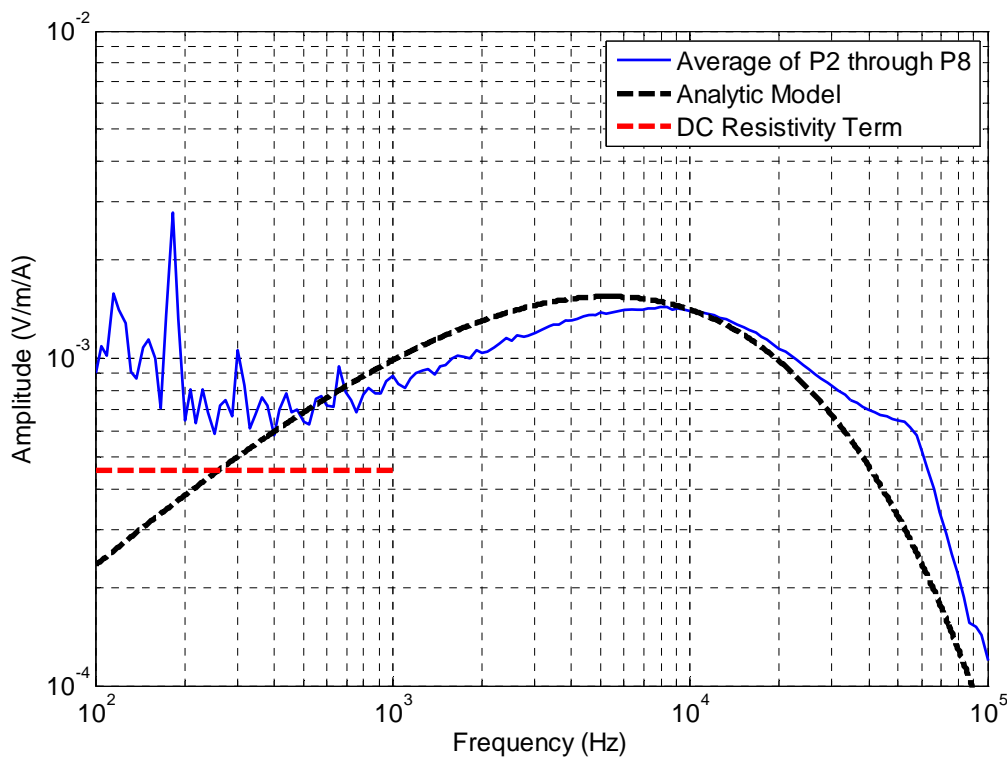


Figure 3-16 Average of P-directed fields from P2 to P8 compared with diffusion model.

To compare the analytic model with the measured induced cable voltage, we simply integrate over the effective length of cable discussed in the previous section, 120 m (394 ft). Again, the model shows excellent agreement with the measured voltage from 1 to 100 kHz. There is a deviation from the model of coupling beneath an infinite line at frequencies below 1 kHz, where the measured data stays at a constant level of approximately 0.1 V/A. Much of this deviation is caused by the field caused by the DC component from the finite spacing of the ground rods. An estimate of this component of the electric field is shown below 1 kHz where the skin depth is much larger than the depth to the cable. The measured data has been processed to remove the 60 Hz clutter signal and its harmonics.

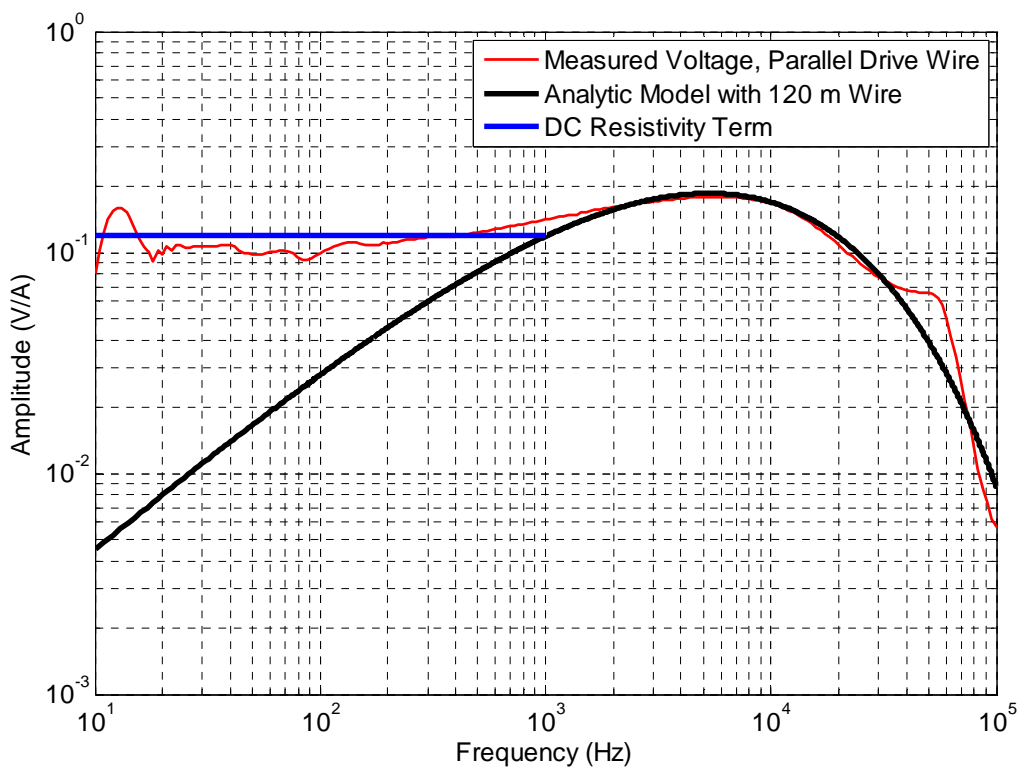


Figure 3-17 Induced voltage on pump cable due to parallel wire current drive on surface (with 60 Hz and harmonics removed) compared with analytic diffusion model of 120 m (394 ft) long cable and an effective soil resistivity of 80 Ω-m and the DC Resistivity term.

4 Results Coupled with Lightning

The results from the direct drive measurements, and the indirect coupling measurements and analysis are coupled with recorded and hypothetical lightning strokes in this section. The analysis performed in this section uses the recorded amplitudes, when appropriate; however, for all other cases, nominal amplitudes of 100 kA were used. The value of 100 kA was used for two reasons: first, there was a cloud-to-ground stroke recorded close in time and distance to the explosion area on the order of 100 kA; and second, the value of 100 kA is easy to scale. It should be noted that the voltages presented in Section 4.2 and 4.3 were calculated using the uniform magnetic field excitation formulation shown in Section 2.2.4. The voltages from a hypothetical long, low altitude horizontal current channel from a cloud-to-ground stroke of Section 4.4 were calculated using infinite line current source above a half-space shown in Section 2.2.2. The basic lightning waveforms used in this section as inputs into the transfer functions are shown in Figure 4-1. The negative lightning waveform was created using a double exponential formula found in [32]. There is no analytic or mathematical model for a positive lightning waveform found in published literature. Hence, a positive lightning waveform was created using a 15th order polynomial of the author's design and appending a 100 ms tail on the backend. The positive lightning waveform characteristics were tailored from values found in [33,20]. Some pertinent waveform characteristics of the modeled lightning waveforms are shown in Table 4-1.

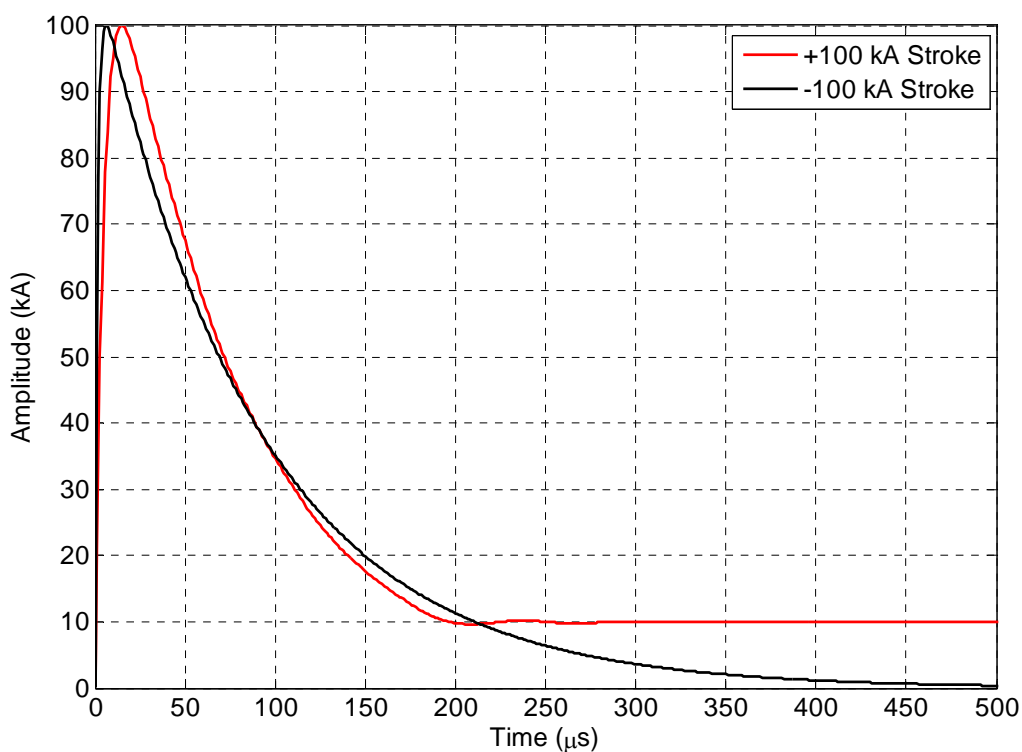


Figure 4-1 Basic positive and negative lightning waveforms used as inputs for analysis.

Table 4-1 Characteristics of positive and negative lightning waveforms used in analysis

Amplitude (kA)	Full Width at Half Maximum, FWHM (μ s)	dI/dt (kA/ μ s)
-100	68	16.7
+100	69	6.5
+30	69	2.0

4.1 Direct Drive Transfer Functions Coupled with Lightning Strokes

If we assume that lightning directly coupled onto the conductive penetrations into the entrance of the Sago mine with either a positive or negative 100 kA stroke, then peak voltages and currents can be calculated. Only the direct drive transfer functions measured with the fence ground are used in this analysis because the fence ground is more representative of a current distribution due to a real lightning stroke.

The peak currents and voltages on the trolley communication line, conveyor, rail, and power cable shield were calculated using the following procedure. First, the lightning waveforms shown in Figure 4-1 were transformed into the frequency domain with a fast Fourier transform (FFT). Then the lightning data was multiplied by the complex transfer function of a given conductor to a given location. The resulting frequency waveform was then transformed back into the time domain with an inverse fast Fourier transform (IFFT). The peak voltage or current was recorded for each waveform. This was then repeated for each conductor at each location measured. Voltage was not measured on the trolley communication line because it was an insulated cable. The measurement locations cross-referenced to break number and approximate distance from the entrance are summarized in Table 4-2 for convenience.

Since the transfer function of the shield of the power cable was only measured out to the #3 power center, an extrapolation was performed to estimate the voltage and current at location 7 (at the 2nd Left Switch). The extrapolated values of voltage and current on the shield of the power cable are shown in the green highlighted cells of the “Power Cable Shield” columns of Table 4-3 and Table 4-5. The voltage was extrapolated using an exponential curve fit, while the current was extrapolated using a simple logarithmic curve fit. These extrapolations were matched with the trend of the first three points, and are a best-guess speculation. The peak current and voltage from a positive 100 kA lightning stroke attached directly to the entrance of the mine for each conductor at each location are shown in Table 4-3 and Table 4-4. The peak currents and voltages due to a negative 100 kA stroke are shown in Table 4-5 and Table 4-6.

Table 4-2 Direct Drive Measurement Locations

Location	Mine Feature	Break Number	Approximate Distance from Entrance
1	#1 Power Center	Belt 1, Break 1	30 m (98 ft.)
2	#2 Power Center	Belt 2, Break 1	459 m (1506 ft.)
3	#3 Power Center	Belt 3, Break 1	669 m (2195 ft.)
4	1 st Right Spur	Belt 3, Break 16	1076 m (3530 ft.)
5	2 nd Right Spur	Belt 4, Break 11	2178 m (1.35 miles)
6	1 st Left Switch	Belt 4, Break 50	3255 m (2.02 miles)
7	2 nd Left Switch	Belt 4, Break 59	3491 m (2.17 miles)

Table 4-3 Peak currents and voltages from a positive 100 kA lightning stroke, for conductive penetrations with old mine grounding

	Trolley Comm Line	Conveyor	Conveyor	Rail	Rail	Power Cable Shield	Power Cable Shield
Location	I _{max} (A)	I _{max} (A)	V _{max} (V)	I _{max} (A)	V _{max} (V)	I _{max} (A)	V _{max} (V)
1						6213	8369
2	162			37	643	2841	3229
3	154			17	233	2547	1582
4							
5							
6							
7						480*	1*

* Extrapolated values.

Table 4-4 Peak currents and voltages from a positive 100 kA lightning stroke, for conductive penetrations with current mine grounding

	Trolley Comm Line	Conveyor	Conveyor	Rail	Rail	Power Cable Shield	Power Cable Shield
Location	I_{max} (A)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)
1	293	2884	10931	14087	136693		
2							
3	279	495	881	9	996		
4	279	11	62	9	436		
5	220	27	11	30	1079		
6	190	11	2	42	321		
7	198	9	1	35	106		

Table 4-5 Peak currents and voltages from a negative 100 kA lightning stroke, for conductive penetrations with old mine grounding

	Trolley Comm Line	Conveyor	Conveyor	Rail	Rail	Power Cable Shield	Power Cable Shield
Location	I_{max} (A)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)
1						6193	7989
2	295			60	668	2711	3078
3	279			22	218	2417	1438
4							
5							
6							
7						280*	1*

* Extrapolated values.

Table 4-6 Peak currents and voltages from a negative 100 kA lightning stroke, for conductive penetrations with current mine grounding

	Trolley Comm Line	Conveyor	Conveyor	Rail	Rail	Power Cable Shield	Power Cable Shield
Location	I_{max} (A)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)	I_{max} (A)	V_{max} (V)
1	434	2926	11279	13606	143340		
2							
3	467	515	1052	13	1615		
4	417	14	77	17	934		
5	343	31	13	34	1367		
6	320	29	3	54	650		
7	301	9	1	19	62		

An item of interest is the relatively high current on the shield of the power cable (480 A) at the 2nd left switch (location 7) in Table 4-3. The power cable does not stop at the 2nd left switch, but turns approximately 90 degrees to the left and travels down the 2nd Left Main and onto the 2 Left Power Center. This presents a similar coupling mechanism as the indirect case where a long line current drive on the surface produces electromagnetic fields that propagate through earth. Only in this case, instead of the lightning currents on the surface being the drive, the induced current on the shield of the power cable inside the mine provides the drive mechanism for coupling onto the pump cable. Assuming a direct 100

kA positive stroke onto the shield of the power cable at the entrance to the mine, an analysis of this scenario results in <50 V peak induced on the pump cable, too low to be of concern.

4.2 Indirect Drive from NLDN and USPLN Positive Stroke 1-3

The locations of the three recorded lightning strokes, on the NLDN and USPLN, are shown in Figure 4-2 with the calculated distances and angles. Note that it is highly probable that the 38.8 kA and 35 kA strokes represent a single stroke with a location discrepancy, as discussed in Section 1.6. The angles shown are the angles between the line made up from the lightning stroke to the center of the pump cable, and the line formed by the direction where the pump cable lay. The first stroke analyzed is the 38.8 kA positive lightning stroke, 5.44 km (3.4 miles) away from the sealed area and an angle of 52.8 degrees. The second stroke has an amplitude of 35 kA at a distance of 4.02 km (2.5 miles) away from the sealed area and an angle of 49.3 degrees. The last stroke has an amplitude of 101 kA, a distance of 2.91 km (1.8 miles), and an angle of 85.5 degrees. The resulting induced voltage pulses on the pump cable (at the end of the cable nearest the explosion area) are shown in Figure 4-3, with peak amplitudes of 25.7 V, 33.8 V, and 16.2 V for the three strokes, respectively. The effective length of 120 m (394 ft.) was used for the length of the pump cable in Figure 4-3. Since there is concern about the actual length of intact pump cable present at the time of the explosion, analysis was performed on a pump cable with a length of 61 m (200 ft.) to account for the length of the cable piece found closest to the explosion area. The resulting induced voltage pulses on the 61 m (200 ft.) length of pump cable are shown in Figure 4-4. None of the induced voltages from these recorded strokes have the necessary amplitude to cause an arc inside the sealed area. It should be noted that taking the indirect coupling model approximation out to 3 km and beyond represents an upper bound on the coupling.

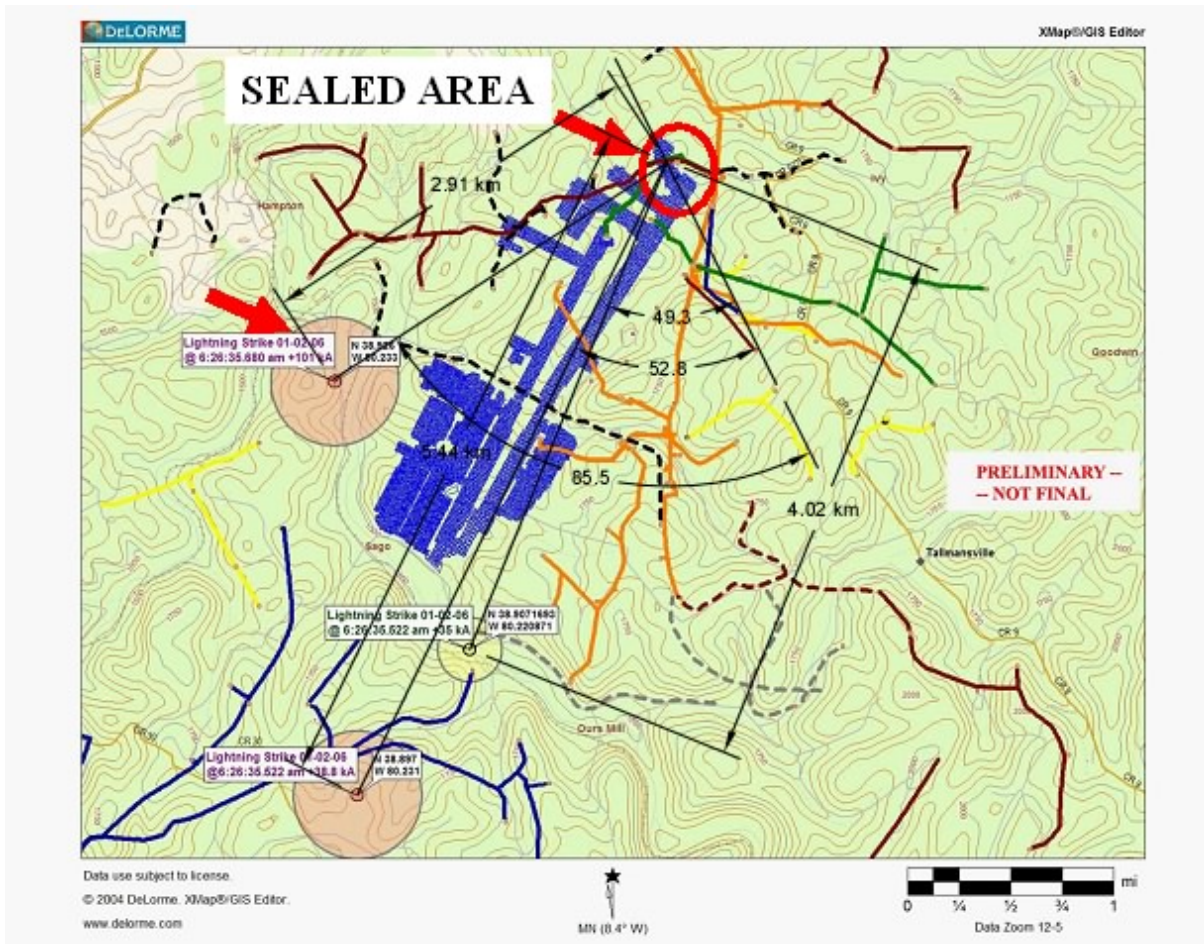


Figure 4-2 Locations of recorded lightning strokes with respect to the sealed area, with distances and angles.

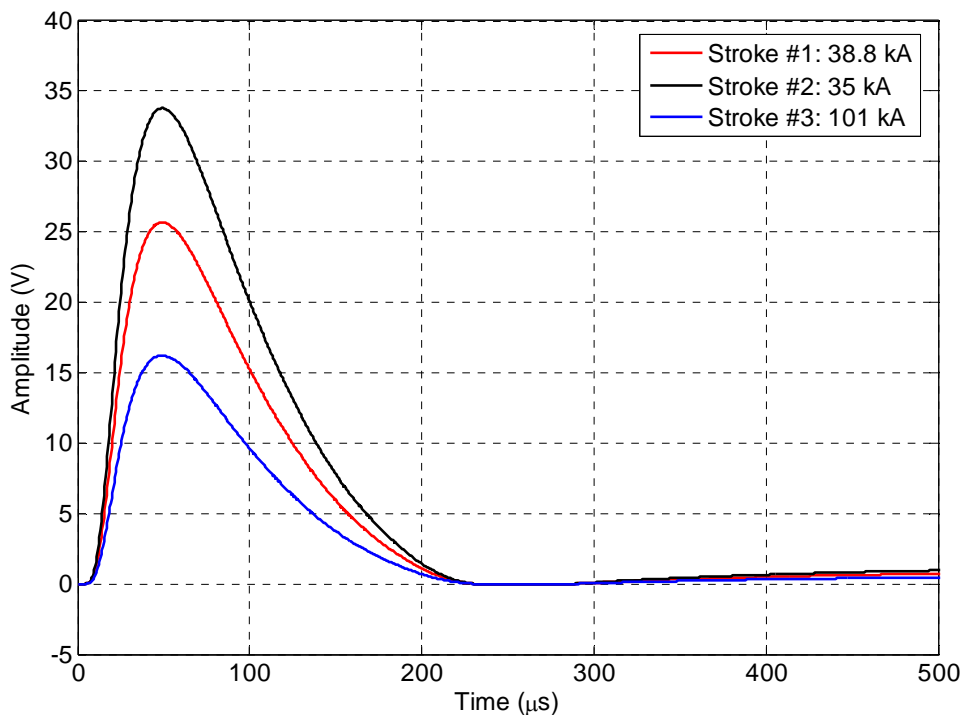


Figure 4-3 Voltage induced on pump cable (using an effective length of 120 m or 394 ft.) due to the three positive lightning strokes recorded on the NLDN and USPLN.

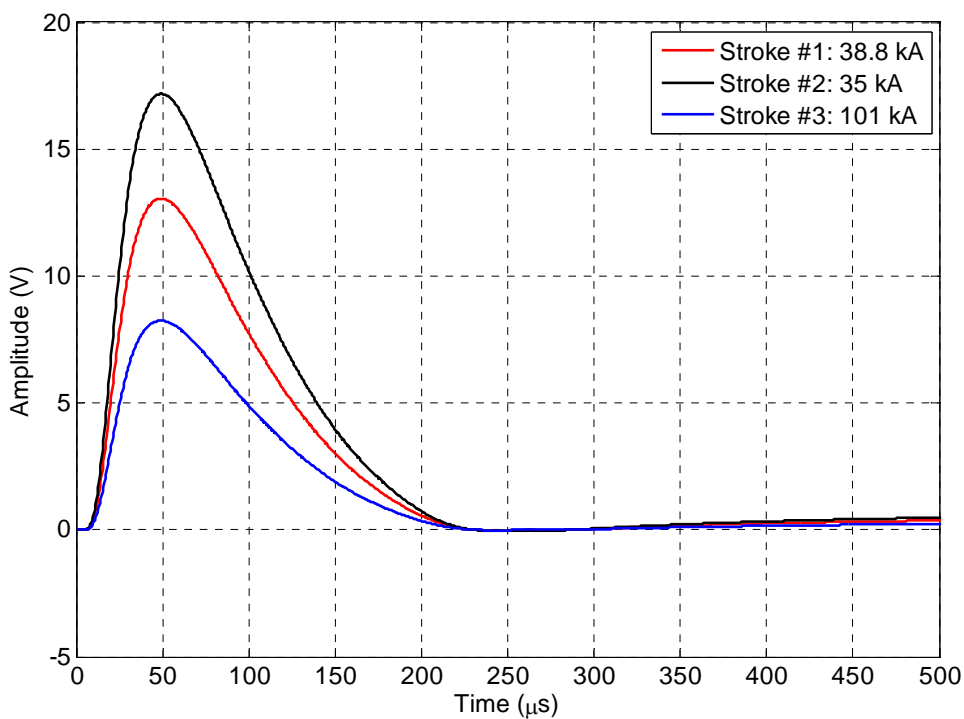


Figure 4-4 Voltage induced on pump cable (length of 61 m or 200 ft.) due to the three positive lightning strokes recorded on the NLDN and USPLN.

4.3 Indirect Drive from Hypothetical Stroke Directly over Sealed Area

If we assume a 100 kA negative or positive lightning stroke attached within 100 m (328 ft.) from directly over the center of the pump cable in the sealed area on the surface, it could induce a sufficiently high voltage in conductors in the sealed area to cause an electrical arc. This effect would be maximized if the stroke were directly inline with the pump cable direction at an angle of zero degrees. The induced voltage on the pump cable (with an effective length of 120 m or 394 ft.) from a 100 kA positive and negative cloud-to-ground stroke is shown in Figure 4-5. The maximum voltages are 23.8 kV from the positive pulse and 22.3 kV from the negative lightning pulse. Again, since there is concern about the actual length of intact pump cable present at the time of the explosion, analysis was performed on a pump cable with a length of 61 m (200 ft.) to account for the cable piece found closest to the explosion area. The resulting induced voltage pulses on the 61 m (200 ft.) length of pump cable are shown in Figure 4-6. The maximum voltages expected on the shorter cable length are 20.5 kV from the positive pulse and 19.1 kV from the negative lightning pulse.

Lightning currents as low as 20 kA (either positive or negative), which is closer to the statistical average peak current of cloud-to-ground lightning strokes, can produce thousands of Volts on the pump cable. This level of voltage is more than capable of initiating an electrical arc under the right conditions. The peak voltage amplitude expected on the pump cable scales linearly with the peak current amplitude of the driving lightning stroke. The results from the 100 kA case shown in Figure 4-5 can be scaled to the 20 kA case by dividing the peak amplitude of the voltage on the cable by a factor of five.

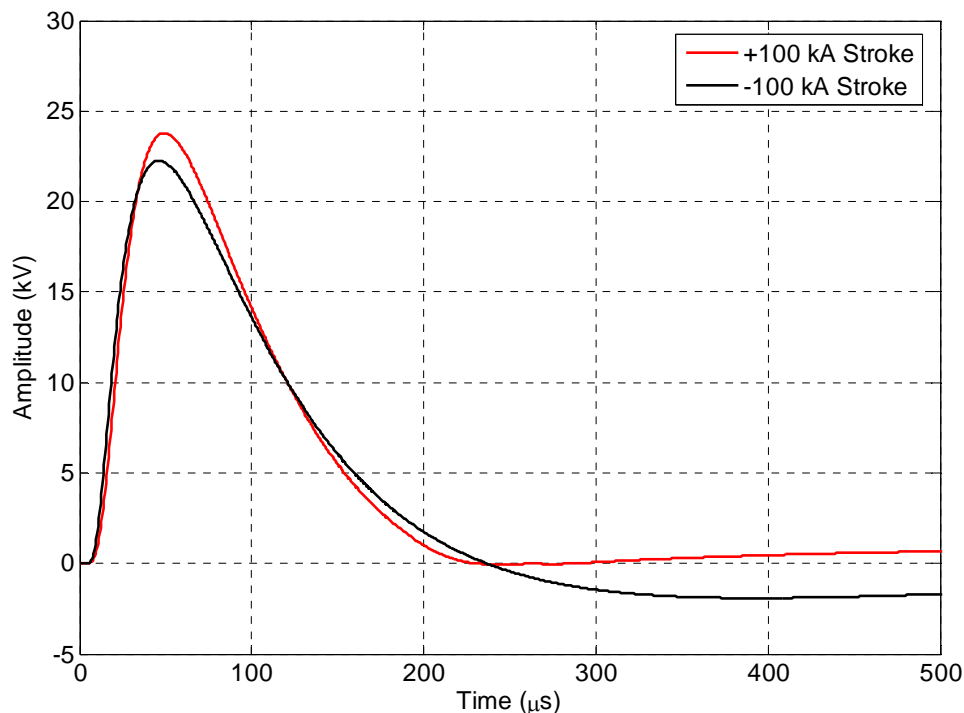


Figure 4-5 Induced voltage pulse on pump cable (using an effective length of 120 m or 394 ft.) due to a hypothetical positive and negative 100 kA cloud-to-ground lightning stroke 100 m from directly above sealed area.

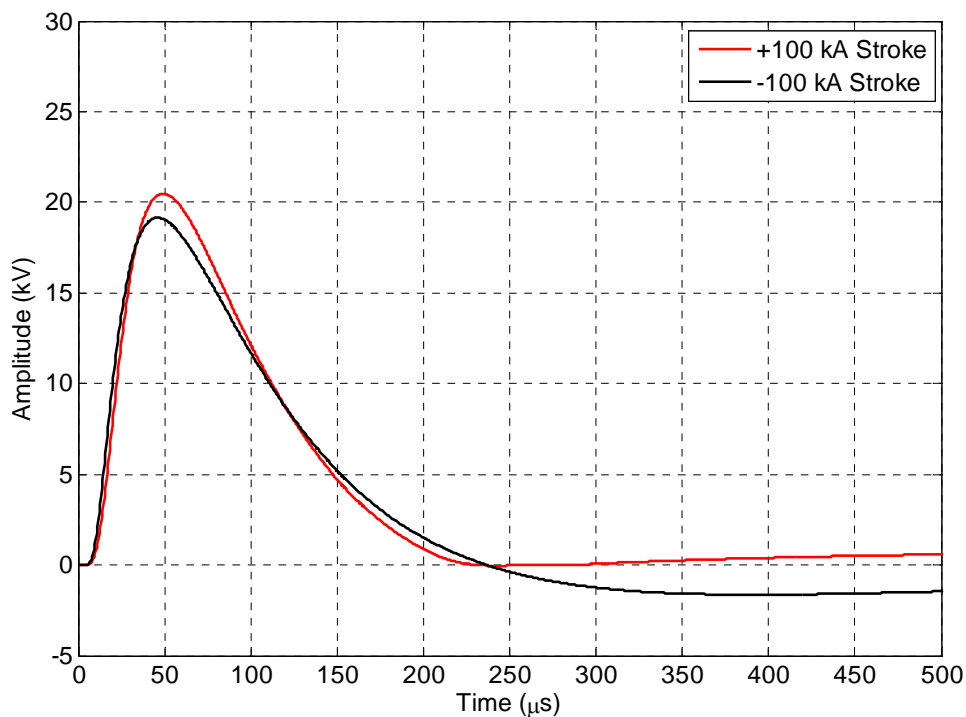


Figure 4-6 Induced voltage pulse on pump cable (length of 61 m or 200 ft.) due to a hypothetical positive and negative 100 kA cloud-to-ground lightning stroke 100 m from directly above sealed area.

4.4 Indirect Drive from a Hypothetical Cloud-to-Ground Stroke with a Current Channel over Sealed Area

If we assume a 100 kA positive cloud-to-ground stroke with a long, low altitude horizontal current channel directly over the sealed area and inline with the pump cable direction at an angle of zero degrees, it could be capable of inducing voltages on the pump cable sufficient to produce electrical arcing. Pump cable (with an effective length of 120 m or 394 ft.) voltages are shown for a positive cloud-to-ground stroke with horizontal current channel at heights (H) of 0, 100 m (328 ft.), 200 m (656 ft.), 500 m (1640 ft.), and 1000 m (3281 ft.) above the surface in Figure 4-7. The maximum voltages from the positive current channel at the heights given are 15.3 kV, 7.2 kV, 4.6 kV, 2.1 kV, and 1.1 kV, respectively. Induced voltages for a negative cloud-to-ground stroke with a current channel directly over the sealed area are shown in Figure 4-9. The maximum voltages from the negative current channel at the heights given are 14.3 kV, 6.7 kV, 4.3 kV, 2 kV, and 1.1 kV, respectively.

Again, since there is concern about the actual length of intact pump cable present at the time of the explosion, analysis was performed on a pump cable with a length of 61 m (200 ft.) to account for the cable piece found closest to the explosion area. The resulting induced voltage pulses on the 61 m (200 ft.) length of pump cable are shown for a positive cloud-to-ground stroke with horizontal current channel at heights (H) of 0, 100 m (328 ft.), 200 m (656 ft.), 500 m (1640 ft.), and 1000 m (3281 ft.) above the surface in Figure 4-8. The maximum voltages from the positive current channel at the heights given are 7.8 kV, 3.7 kV, 2.3 kV, 1.1 kV, and 0.6 kV, respectively. Induced voltages for a negative cloud-to-ground stroke with a current channel directly over the sealed area are shown in Figure 4-10. The maximum voltages from the negative current channel at the heights given are 7.3 kV, 3.4 kV, 2.2 kV, 1 kV, and 0.5 kV, respectively.

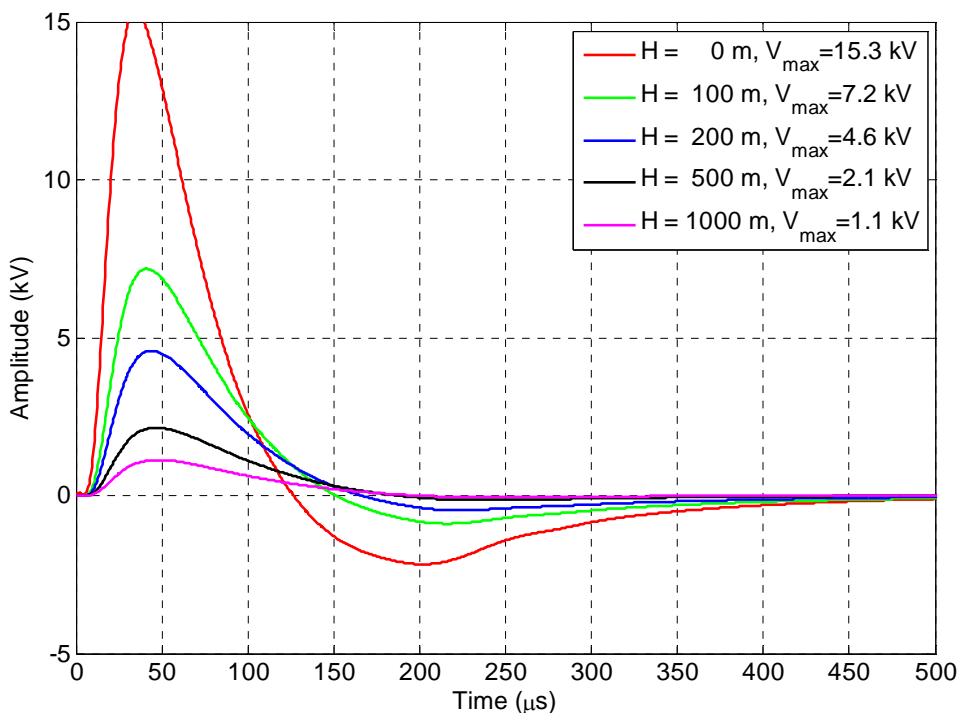


Figure 4-7 Induced Voltage Pulse on Pump Cable (with an effective length of 120 m or 394 ft.) from Hypothetical Horizontal Current Channel from a Cloud-to-Ground +100 kA Stroke, H is distance of the Current Channel above the Ground.

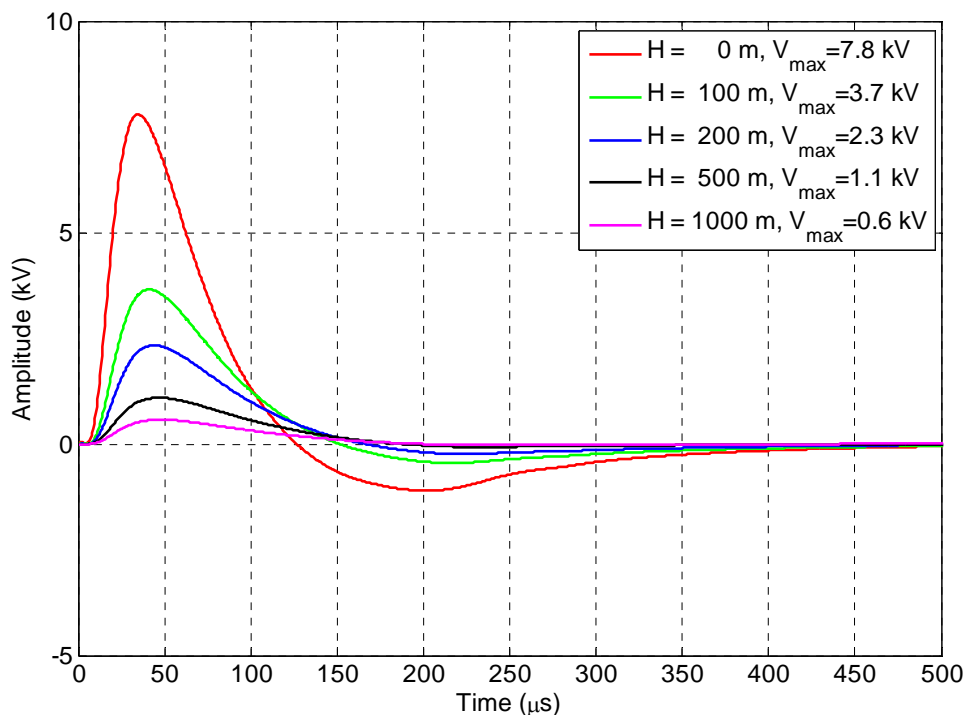


Figure 4-8 Induced Voltage Pulse on Pump Cable (length of 61 m or 200 ft.) from Hypothetical Horizontal Current Channel from a Cloud-to-Ground +100 kA Stroke, H is distance of the Current Channel above the Ground.

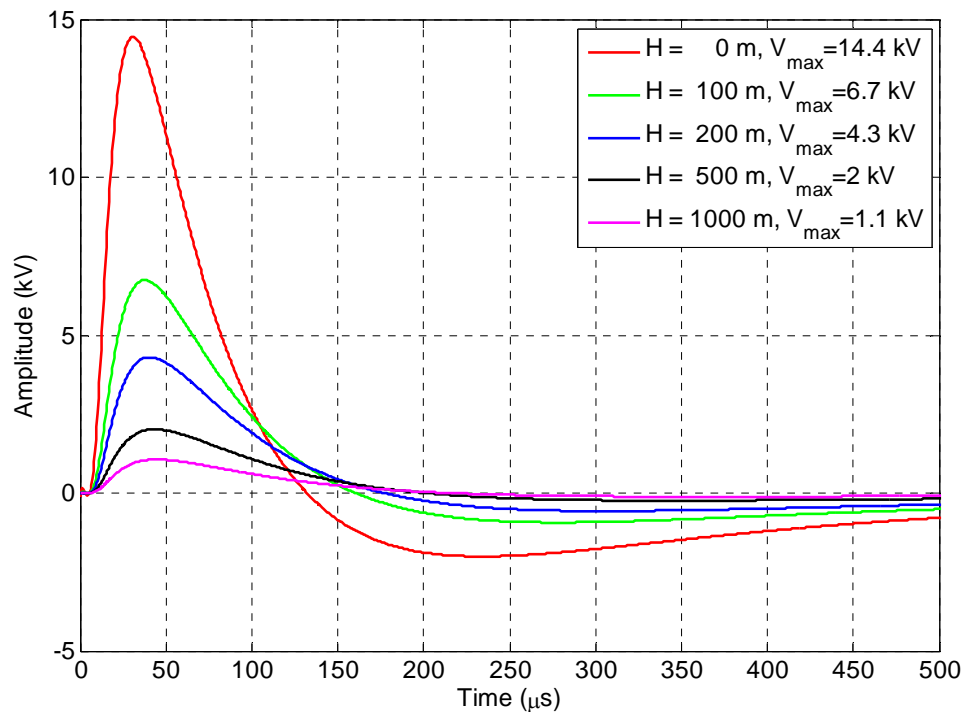


Figure 4-9 Induced Voltage Pulse on Pump Cable (with an effective length of 120 m or 394 ft.) from Hypothetical Horizontal Current Channel from a Cloud-to-Ground -100 kA Stroke, H is distance of the Current Channel above the Ground.

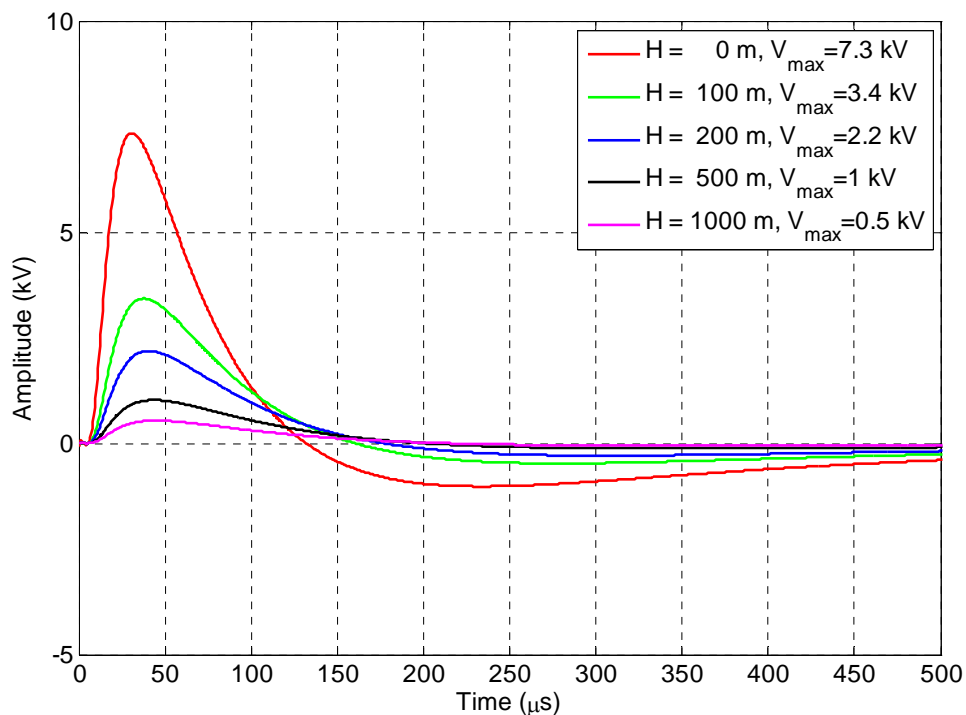


Figure 4-10 Induced Voltage Pulse on Pump Cable (length of 61 m or 200 ft.) from Hypothetical Horizontal Current Channel from a Cloud-to-Ground -100 kA Stroke, H is distance of the Current Channel above the Ground.

5 Conclusions

The conclusions made in this report are specific to the geometry of the Sago mine site where measurements were taken. The results cannot and should not be generalized to any other mining systems.

5.1 Direct Coupling

The current and voltage on metallic penetrations into the mine were calculated given the direct drive transfer functions and a mathematical representation of a positive-polarity, 100 kA peak cloud-to-ground lightning stroke. This calculation assumes that the lightning stroke attaches directly onto the metallic penetration at the entrance to the mine. While there is no evidence that lightning struck the entrance of the mine, this assumption represents the worst-case placement of an attachment for this analysis.

The farthest point into the mine that the direct drive measurements were made was at the entrance to the 2nd Left Parallel, 3,491 m (or 2.17 miles) into the mine, as close to the seal that was breached by the explosion as possible. At this location, the peak currents and voltages calculated at this location given the input of a positive 100 kA peak lightning stroke attaching at the mine entrance are shown in Table 5-1. The voltage was not measured for the trolley communication line because it was insulated and not an exposed conductor.

Table 5-1 Current and voltage at the 2nd Left Switch due to a 100 kA peak, positive cloud-to-ground lightning stroke at the entrance of the mine

Metallic penetration	Current	Voltage
Trolley Communication line	198 A	Not measured
Conveyor Structure	9 A	1 V
Rail	35 A	106 V
Shield of Power Cable ⁶	480 A	1 V

The voltages and currents on the conveyor, rail, and shield of the power cable outside the sealed area are incapable of coupling sufficient energy into the sealed area to cause an electrical arc in the sealed area. The voltage on the trolley communication line is not anticipated to be significantly larger than those of the conveyor, rail, and power cable shield.

- *It is highly unlikely that direct drive coupling, even under a worst-case scenario, could have initiated electrical arcing on the cable in the sealed area.*

Because of the substantial initial grounding of metallic penetrations that enter the mine, and because of the multiplicity of grounding points of these systems as they penetrate into the mine, the lightning current is divided sufficiently so that only a relatively small amount of current is injected into the mine near the sealed area. All metallic penetrations were intentionally terminated outside the sealed area.

Consequently, the amplitude of current flowing on conductors outside the sealed area is insufficient to generate adequate voltage on the cable inside the sealed area to cause arcing. At low frequencies, the parallel nature of the multiplicity of grounding points is sufficient to divide the lightning current. At higher frequencies, the metallic penetrations can be treated as non-ideal (lossy) transmission lines with periodic grounding that attenuates the high-frequency components of the current even more than lower frequencies. *Although this coupling mechanism is likely insufficient to cause arcing, the voltage and*

⁶ The current and voltage for the shield of the power cable were extrapolated from measurements made at the Power Centers 1, 2, and 3.

current is sufficient to cause electrical shocks to personnel contacting these metallic penetrations, even miles back into the mine.

5.2 Indirect Coupling

Three things are needed to conclude that indirect coupling of lightning energy into the sealed area produced high voltage and an electrical arc that could have been the initiation source of a methane-air explosion in the sealed area of the Sago mine on the morning of January 2, 2006. They are:

- lightning energy propagating from the surface through the overburden into the sealed area;
- an antenna, or receiver (such as a cable), of this energy present in the sealed area; and
- lightning of sufficient magnitude and proximity to the sealed area at the time of the explosion.

The indirect measurements coupled with analytical models discussed in this report confirm that electromagnetic energy with the frequency content of lightning driven on the surface penetrates the ground into the sealed area. Measurements and analyses also confirm that the pump cable acts as a receiver of this energy and is the most likely coupling agent in the sealed area.

Two cloud-to-ground lightning strokes were recorded in the vicinity of the Sago mine within one second of the explosion in the sealed area. Based on the results in this report, these lightning strokes were too far away to have generated enough voltage on the pump cable to create an electrical arc in the sealed area. A thorough, expert analysis of the raw data provided by several lightning detection databases did not uncover evidence to support the detection of another cloud-to-ground stroke in the correct timeframe.

- *It is unlikely that indirect drive from the **vertical components** of the **recorded lightning strokes** (recorded amplitude and location) around the Sago mine could have initiated electrical arcing on the cable present in the sealed area.*

The simultaneous events of recorded lightning strokes and the explosion in the sealed area of the mine; the multiple personal accounts above the sealed area describing simultaneous flash and thunder [21] (indicating extremely close lightning); the lack of data from the lightning detection networks from upward positive lightning initiated from tall structures [20, 35]; the inability of the lightning detection networks to resolve the presence of horizontal lightning arc channels [20, 35]; and the unlikely, but possible, scenario of an undetected cloud-to-ground lightning flash [34] of sufficient magnitude and proximity to the sealed area at the time of the explosion led to the investigation of various hypothetical lightning stroke events. The expected voltage on the abandoned cable was calculated for each scenario using the indirect coupling models developed in this report.

The first hypothetical case explores the possibility of the presence of a horizontal lightning arc channel acting as a source of energy. For this scenario, a 100 kA-peak horizontal arc channel is assumed to be parallel to the pump cable in the sealed area at distances of 100 m (328 ft), 200 m (656 ft), 500 m (1,640 ft), and 1000 m (3,281 ft) above the ground above the sealed area. For a positive-polarity flash, the resultant voltages on the pump cable were 7.2 kV, 4.6 kV, 2.1 kV, and 1.1 kV, respectively. For a negative-polarity flash, the resultant voltages on the pump cable were 6.7 kV, 4.3 kV, 2 kV, and 1.1 kV, respectively. While these calculations use favorable coupling circumstances (high peak arc-channel current and parallel orientation of the arc channel to the pump cable and 120 m cable effective length), this hypothetical scenario presents a reasonable case for high-voltage electrical arcing.

Appendix DD - Measurements and Modeling of Transfer Functions for Lightning Coupling into the Sago Mine

- *It is reasonable to assume that if a horizontal, low-altitude arc channel occurred from one of the lightning strokes recorded by the NLDN (or USPLN) or from an unrecorded lightning stroke, it could have initiated electrical arcing on the cable in the sealed area.*

The second hypothetical case explores the possibility of an undetected cloud-to-ground stroke of sufficient magnitude and proximity to the sealed area. Applying a 100 kA-peak, cloud-to-ground stroke of optimum orientation to the pump cable (61 m length) within 100 m (328 ft) of the sealed area, the results are peak voltages on the pump cable of 19.1 kV for a negative-polarity flash, and 20.5 kV for a positive-polarity flash. For the same conditions, the induced voltage decreases as distance of a lightning stroke from the sealed area increases.

- *It is reasonable to assume that if an average or above average cloud-to-ground lightning stroke occurred above the sealed area at Sago, that it could initiate electrical arcing on the cable in the sealed area.*

Recent discussions led to a third hypothetical case, which is not examined in detail in the report, of upward-going positive lightning initiating from tall structures. Four tall communication towers (heights of approximately 200 ft or less) are within approximately 1 mile of the sealed area, the closest being about 0.5 miles. If we hypothesize an upward-going positive lightning stroke from the closest tower, (recalling that these type of events are not typically captured by the current lightning detection networks), the induced voltage on the pump cable would be 763 V.

The conclusions of this report are that lightning of sufficient magnitude and proximity to the sealed area would create high voltage on the pump cable to create an electrical arc. The simultaneity in time of recorded lightning strokes and the explosion occurring is very strong evidence of cause and effect. Furthermore, eyewitness accounts of simultaneous lightning and thunder at the time of the explosion, plus the analysis of credible hypothetical scenarios which cannot be confirmed by lightning detection networks, lend credibility to the idea that lightning-induced electrical arcing was not only plausible, but highly likely.

6 Recommendations

The results of this short-term project demonstrate the usefulness of transfer function measurement techniques and analytical modeling to evaluate lightning effects in mining environments. The effects described in this report are significant. A more comprehensive research and development program should be conducted to expand on this work to extend this research for use in other underground coal mining operations. The research program would be conducted using similar transfer function measurement techniques, experiments at other sites with rocket-triggered and natural lightning, and analytical and computational modeling using validated state-of-the-art codes adapted for this application. Once completed, it is reasonable to expect that mitigation techniques and safety standards could be developed to secure coal mining systems from future lightning threats.

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8 Appendix A — Analytical and Numerical Models for Voltage and Current Used to Determine Electromagnetic Coupling into the Sago Mine

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February 11, 2007

Abstract

The purpose of this appendix is to document the relevant analytical models to be used to predict the voltages and currents produced in the Sago mine by current drive sources used to simulate the effects of a lightning stroke attachment near the mine or on the surface of the earth above the mine. Also considered are horizontal arcs above the surface of the mine.

8.1 Introduction

The purpose of this appendix is to document the relevant analytical models to be used to predict the voltages and currents produced in the Sago mine by current drive sources used to simulate the effects of a lightning stroke attachment near the mine or on the surface of the earth above the mine. Subsequent measurements corresponding to these models will be used to identify coupling paths and quantify coupling amplitudes of the lightning energy into the sealed area of the mine where the explosion was thought to have been initiated. The initial section of the appendix documents the DC drive current models for both a homogeneous half-space and for a two layer half-space. The next section of the appendix documents the eddy current models for an infinite length horizontal drive wire over both a homogeneous half-space and a two layer half-space. The next section documents the eddy current coupling into a homogeneous half-space from a uniform magnetic field at the surface. The final section of the appendix references the literature for eddy current models for an infinitesimal length and a finite length horizontal wire over both a homogeneous half-space and a two layer half-space. Computer codes have been implemented in Fortran and Mathematica to calculate the resulting potentials and fields and the resulting voltages generated within the earth.

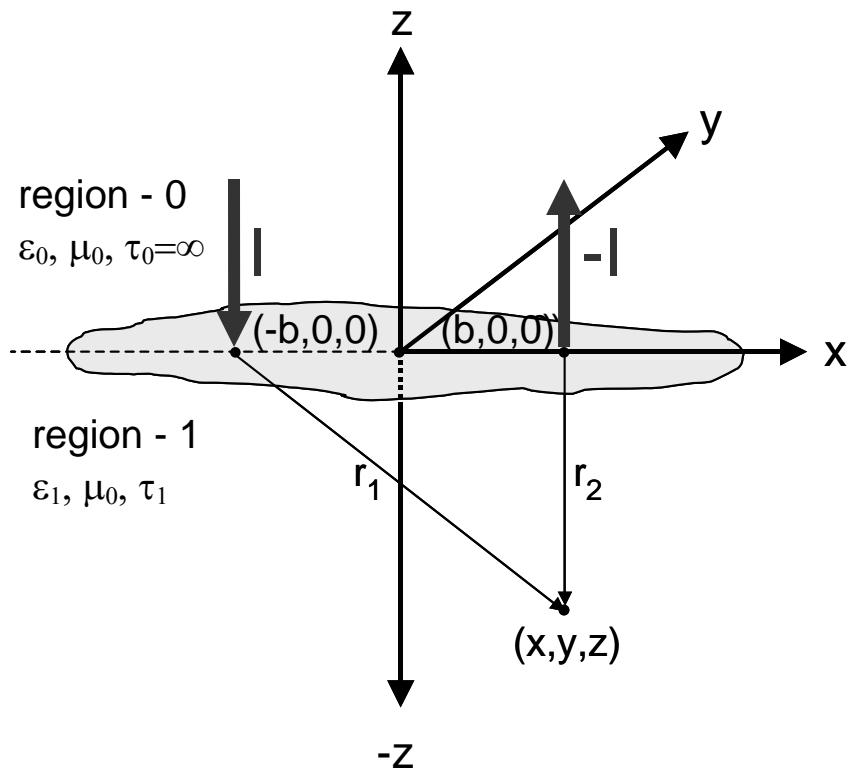


Figure 8-1 DC Current Drive with Homogeneous Half-Space Geometry.

8.2 Static Current Drive Models

The simplest model for current coupling into a conductive earth is the DC conduction of current into a conductive half-space. The models for this are well known.

8.2.1 Homogeneous Half-Space

The DC or very low-frequency situation to be modeled is shown in Figure 8-1.

Current I is driven into the conductive half-space at Cartesian coordinate $(-b, 0, 0)$ and the current is removed at Cartesian coordinate $(b, 0, 0)$. The upper half-space, region-0, has infinite resistivity τ_0 and the lower half-space, region-1, has resistivity τ_1 . From simple considerations, $V(x, y, z)$, the potential at Cartesian coordinate (x, y, z) with respect to infinity, is given by

$$V(x, y, z) = \frac{\tau_1 I}{2\pi} \left(\frac{1}{\sqrt{(x+b)^2 + y^2 + z^2}} - \frac{1}{\sqrt{(x-b)^2 + y^2 + z^2}} \right)$$

The difference in potential between two points can be calculated by taking the difference of the potentials at the two points calculated with the above formula.

The electric field at point (x, y, z) is easily calculated from

$$\bar{E}(x, y, z) = -\nabla V(x, y, z)$$

and calculating the x-component of interest

$$E_x(x, y, z) = -\frac{\partial}{\partial x} V(x, y, z) = \frac{\tau_1 I}{2\pi} \left(\frac{(x+b)}{\left[(x+b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} - \frac{(x-b)}{\left[(x-b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} \right)$$

8.2.2 Two Layer Half-Space

Because there is often a less resistive layer of topsoil above the more resistive layer, which includes the mine, it is necessary to generalize the above homogenous half-space model to a two layer half-space model. The DC or very low-frequency situation to be modeled is shown in Figure 8-2.

Current I is driven into the conductive half-space at Cartesian coordinate (-b, 0, 0) and the current is removed at Cartesian coordinate (b, 0, 0). The upper half-space, region-0 has infinite resistivity τ_0 and region-1, the layer of thickness, a, has resistivity τ_1 . The infinitely thick layer region-2 has resistivity τ_2 . From more complicated considerations, V (x, y, z), the potential at Cartesian coordinate (x, y, z) with respect to infinity, is given by

$$V(x, y, z) = \frac{I}{2\pi} \left(\frac{2\tau_1\tau_2}{\tau_1 + \tau_2} \right) \left(\frac{1}{\sqrt{(x+b)^2 + y^2 + z^2}} - \frac{1}{\sqrt{(x-b)^2 + y^2 + z^2}} \right)$$

in region-2.

The difference in potential between two points can be calculated by taking the difference of the potentials at the two points calculated with the above formula.

The electric field at point (x, y, z) is easily calculated from

$$\bar{E}(x, y, z) = -\nabla V(x, y, z)$$

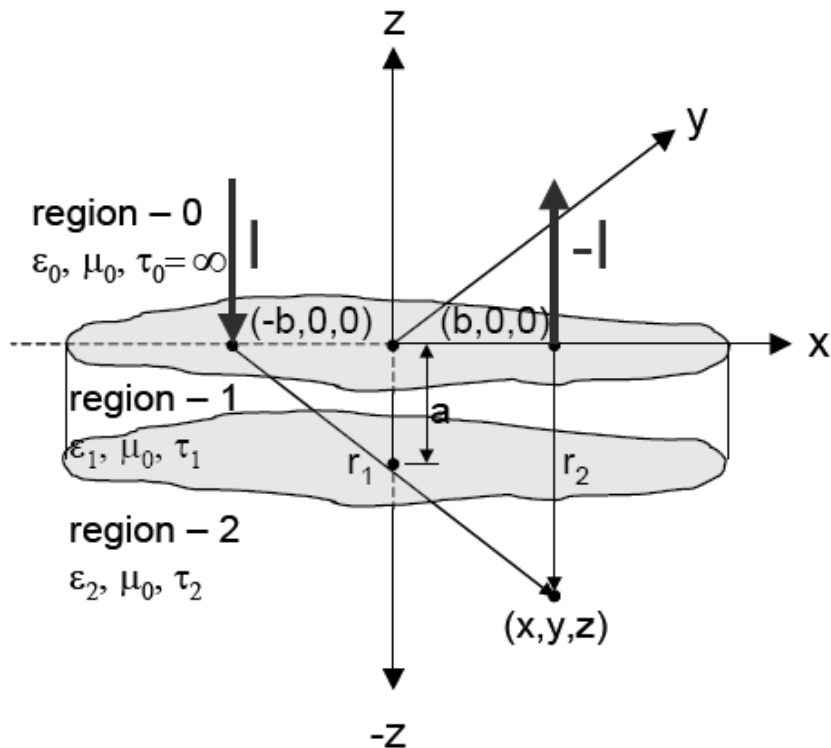


Figure 8-2 DC Current Drive with Two Layer Half-Space Geometry.

and calculating the x-component of interest

$$E_x(x, y, z) = -\frac{\partial}{\partial x} V(x, y, z)$$

$$= \frac{I}{2\pi} \left(\frac{2\tau_1\tau_2}{\tau_1 + \tau_2} \right) \left(\frac{(x+b)}{\left[(x+b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} - \frac{(x-b)}{\left[(x-b)^2 + y^2 + z^2 \right]^{\frac{3}{2}}} \right)$$

8.3 Eddy Current, Infinite Horizontal Drive Wire Models

The next obvious generalization of the above model is to make the current injected into the earth time varying, say $I = I_0 e^{i\omega t} \hat{x}$ and to neglect displacement current. This generalization turns out to be more difficult than one might think because the current in the earth depends on the geometry of the current path above the earth. A simpler model that corresponds the electromagnetic coupling below a long, horizontal wire grounded at both ends and driven by a voltage source can, however, be developed.

8.3.1 Homogeneous Half-Space

The current drive geometry of an infinitely long, horizontal wire placed a distance, h , above a conductive half-space is shown on the left side of Figure 8-3. A side view is shown on the right side of Figure 8-3.

The current drive is harmonically time-varying and directed along the x - axis at height, h , above it. The upper half-space has permittivity ϵ_0 and infinite resistivity and the lower half-space has permittivity ϵ_1 and resistivity, τ_1 . Both regions have free space permeability, μ_0 .

If one neglects displacement current and relates current density, $i_x(y, z)$, and electric field, $E_x(y, z)$, in region-1 through, $E_x(y, z) = \tau_1 i_x(y, z)$, then the current density in the lower half-space, region-1, can be determined to be

$$i_x(y, z) = -\frac{i\omega\mu_0 I}{\pi\tau_1} \int_0^\infty \frac{e^{qz} e^{-uh}}{u+q} \cos uy du = \frac{i2}{\pi} \frac{I}{\delta_1^2} \int_0^\infty \frac{e^{qz} e^{-uh}}{u+q} \cos uy du$$

$$E_x(y, z) = \tau_1 i_x(y, z) = \frac{ik\epsilon_0}{\pi} \int_0^\infty \frac{e^{qz} e^{-uh}}{u+q} \cos uy du$$

where

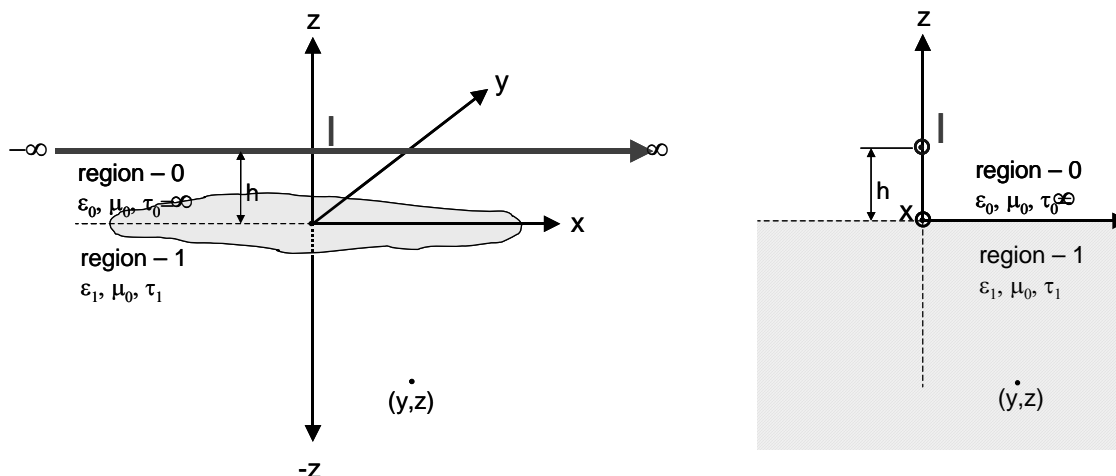


Figure 8-3 Infinite Horizontal Current Drive, Eddy Current Coupling Geometry.

$$k = \omega\sqrt{\mu_0\epsilon_0}$$

$$q = \sqrt{u^2 + ip^2}$$

$$p^2 = \frac{\omega\mu_0}{\tau_1} = \frac{2}{\delta_1^2}$$

$$\delta_1 = \sqrt{\frac{2\tau_1}{\omega\mu_0}}$$

This or similar expressions are given in [A1-A3].

Note that the skin depth, $\delta_1 = \sqrt{\frac{2\tau_1}{\omega\mu_0}}$, plays an important role as a parameter in all diffusion coupling calculations. For convenience it is plotted for various values of resistivity.

Integrating this result for $y=0$ and for $h=0$ yields the closed form result:

$$E_x(y=0, z) = i_x(y, z) = \frac{\tau_1 I}{\pi \delta_1^2} \left\{ \left[(1+i) \frac{1}{\left(\frac{z}{\delta_1}\right)} + \frac{1}{\left(\frac{z}{\delta_1}\right)^2} \right] e^{-\frac{(1+i)z}{\delta_1}} - i2K_0\left(\frac{z}{\delta_1}\right) - (1+i) \frac{1}{\left(\frac{z}{\delta_1}\right)} K_1\left(\frac{z}{\delta_1}\right) \right\}$$

where K_0 and K_1 are modified Bessel Functions.

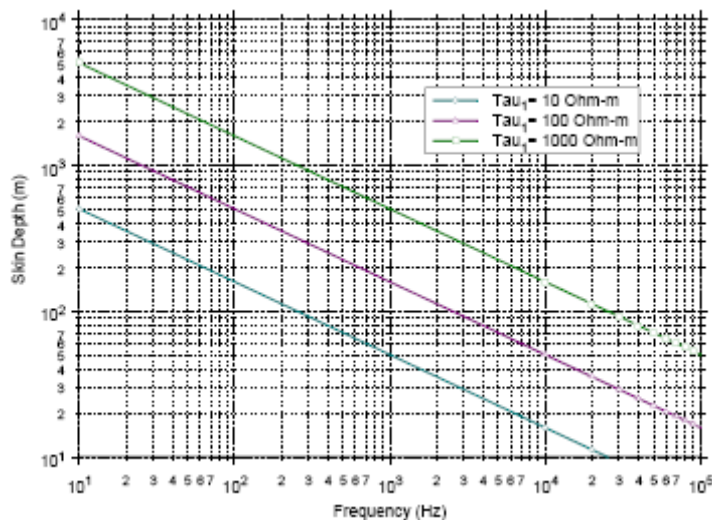


Figure 8-4 Skin Depth as a Function of Frequency for Resistivities, $\tau_1 = 10, 100, 1000 \Omega\text{-m}$.

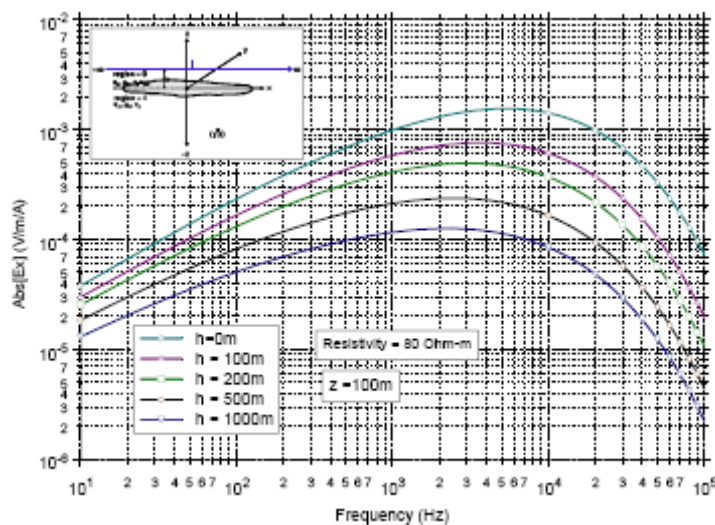


Figure 8-5 Amplitude of Electric Field from a Line Source Placed at Heights, $h = 0\text{m}, 100\text{m}, 200\text{m}, 500\text{m},$ and 1000m , at $z = 100\text{m}$ with $\tau_1 = 80 \Omega\text{-m}$.

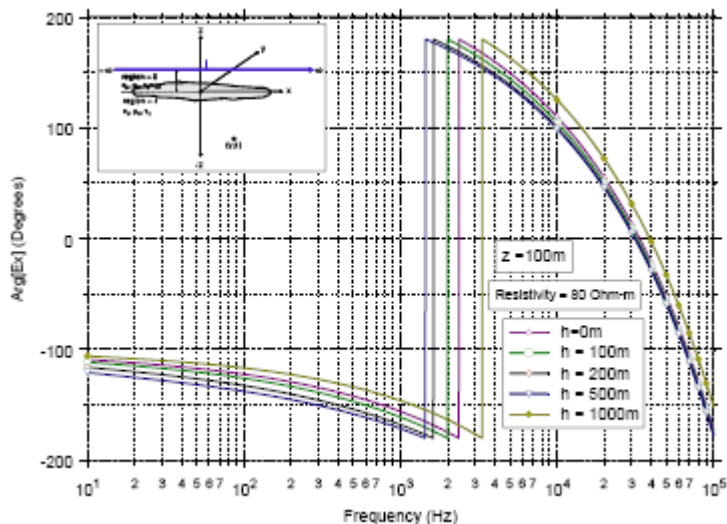


Figure 8-6 Phase of Electric Field from a Line Source Placed at Heights, $h = 0\text{m}$, 100m , 200m , 500m , and 1000m , at $z = 100\text{m}$ with $\tau_1 = 80 \Omega\text{-m}$.

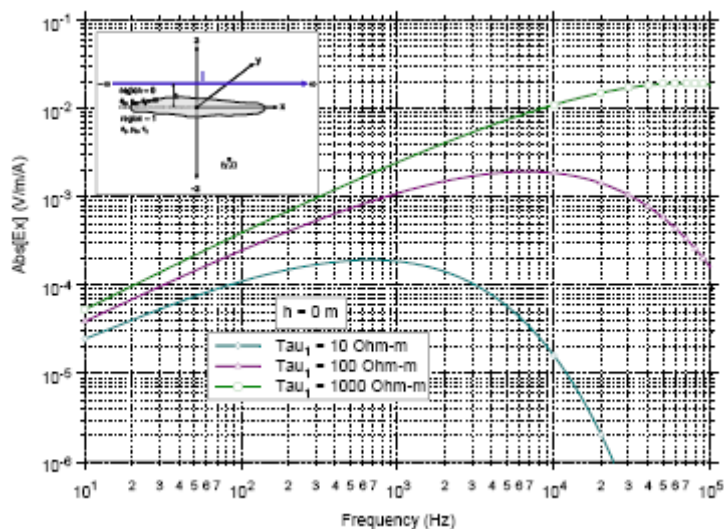


Figure 8-7 Amplitude of the Electric Field at $z = 100\text{m}$ from a Line Source Placed the Surface of a Homogeneous Half-Space with $\tau_1 = 10, 100, 1000 \Omega\text{-m}$.

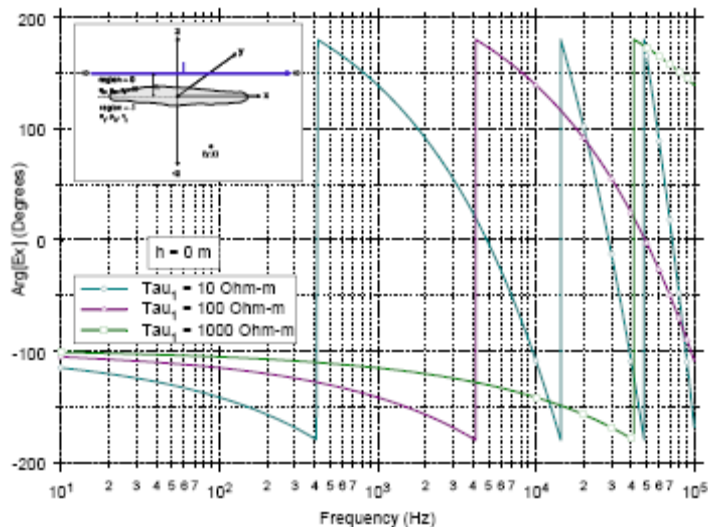


Figure 8-8 Phase of the Electric Field at $z = 100\text{m}$ from a Line Source Placed the Surface of a Homogeneous Half-Space with $\tau_1 = 10, 100, 1000 \Omega\text{-m}$

8.3.2 Two Layer Half-Space

The current drive geometry of an infinitely long, horizontal wire placed a distance, h , above a conductive half-space is shown on the left side of Figure 8-9. A side view is shown on the right side of Figure 8-9.

The current drive is harmonically time varying and directed along the x - axis at height, h , above it. The upper half-space has permittivity ϵ_0 and infinite resistivity, the layer of thickness h_1 has permittivity ϵ_1 and resistivity, τ_1 , and the lower region has permittivity ϵ_2 and resistivity, τ_2 . All regions have free space permeability, μ_0 .

If one neglects displacement current and relates current density, $i_x(y, z)$, and electric field, $E_x(y, z)$, in region-2 through, $E_x(y, z) = \tau_2 i_x(y, z)$, then the current density in the lower half-space, region-2, then for $h = 0$ and $y = 0$ can be determined to be

$$E_x(y = 0, z) = -\frac{i4\tau_2 I}{\pi} \frac{1}{\delta_2^2} \int_0^\infty \frac{u_1 e^{u_2 h}}{(u + u_1)(u_1 + u_2) e^{u_1 h} + (u - u_1)(u_1 - u_2) e^{-u_1 h}} e^{-u_2 z} du$$

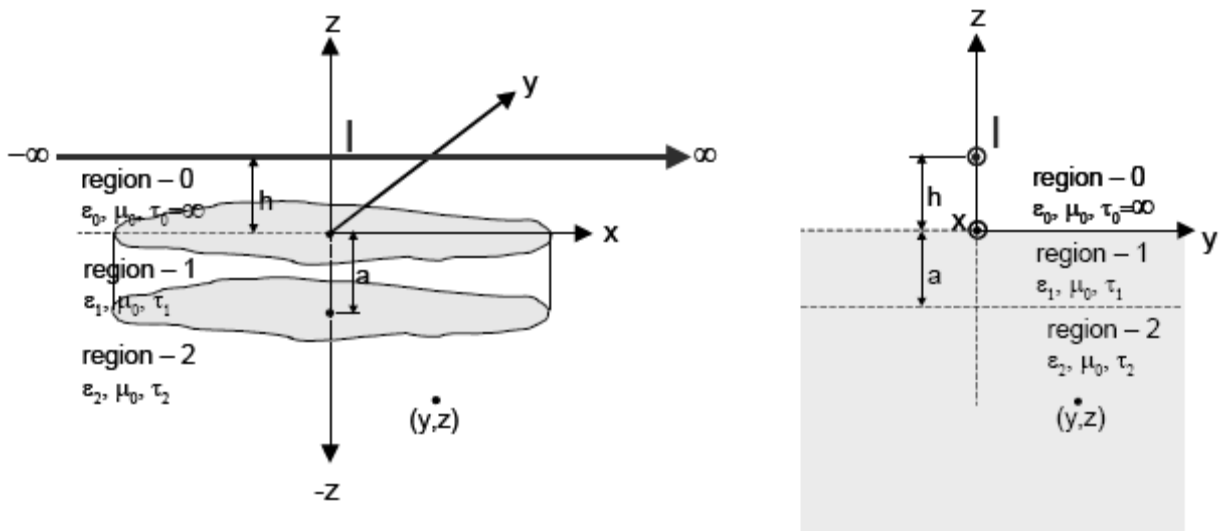


Figure 8-9 Infinite Horizontal Current Drive, Two-Layered, Eddy Current Coupling Geometry.

$$\begin{aligned}
 u_1 &= \sqrt{u^2 + ip_1^2} \\
 p_1^2 &= \frac{\omega\mu_0}{\tau_1} = \frac{2}{\delta_1^2} \\
 \delta_1 &= \sqrt{\frac{2\tau_1}{\omega\mu_0}} \\
 u_2 &= \sqrt{u^2 + ip_2^2} \\
 p_2^2 &= \frac{\omega\mu_0}{\tau_2} = \frac{2}{\delta_2^2} \\
 \delta_2 &= \sqrt{\frac{2\tau_2}{\omega\mu_0}}
 \end{aligned}$$

Similar expressions are developed in [A1-A3], but I am aware of no closed form expression for the above integral. The formula must be integrated numerically to obtain results. Note that the variable of integration is on the positive real axis and that no singularities are present on the positive real axis. As the skin depths get longer and longer, the branch cuts get closer to the real axis. If we consider the asymptotic behavior of the integrand as $u \rightarrow \infty$, then

$$E_x(y, z) = -\frac{i4\tau_2 I}{\pi} \frac{1}{\delta_2^2} \left[\int_0^c \frac{u_1 e^{u_2 h}}{(u + u_1)(u_1 + u_2)e^{u_1 h} + (u - u_1)(u_1 - u_2)e^{-u_1 h}} e^{-u_2 z} du \right] + \frac{1}{4} E_1(cz) + \frac{i}{4\delta_1^2} (2h_1 - z) \frac{1}{c} E_2(cz)$$

to the first two terms in $\frac{e^{-uz}}{u}$ and $\frac{e^{-uz}}{u^2}$ where $c \gg \max[\delta_1, \delta_2]$.

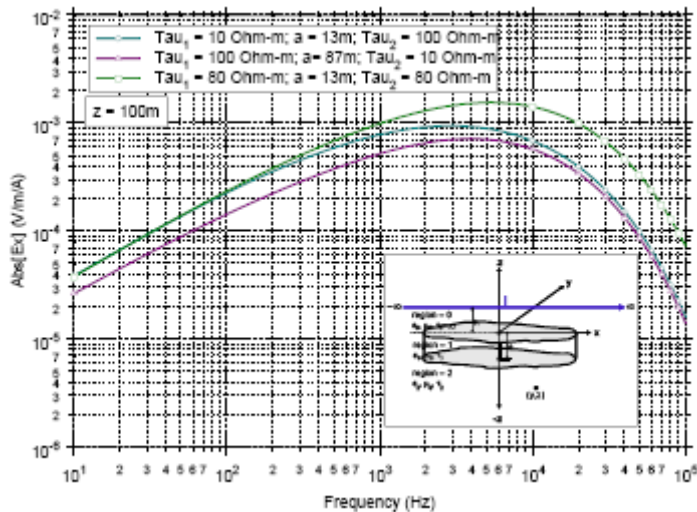


Figure 8-10 Amplitude of the Electric Field at $z = 100\text{m}$ from a Line Source at the Surface of a Two-Layered Half-Space.

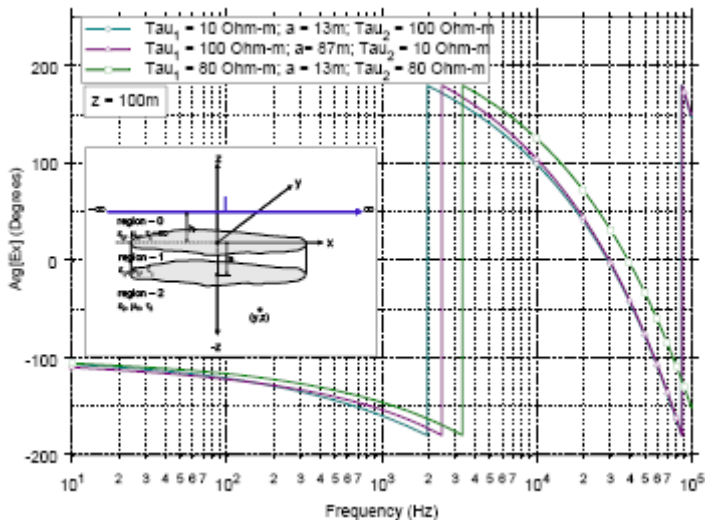


Figure 8-11 Phase of the Electric Field at $z = 100\text{m}$ from a Line Source at the Surface of a Two-Layered Half-Space.

8.4 Eddy Current Coupling into Homogeneous Half-Space from Uniform Magnetic Field at Surface

If we consider the geometry shown in Figure 8-12,

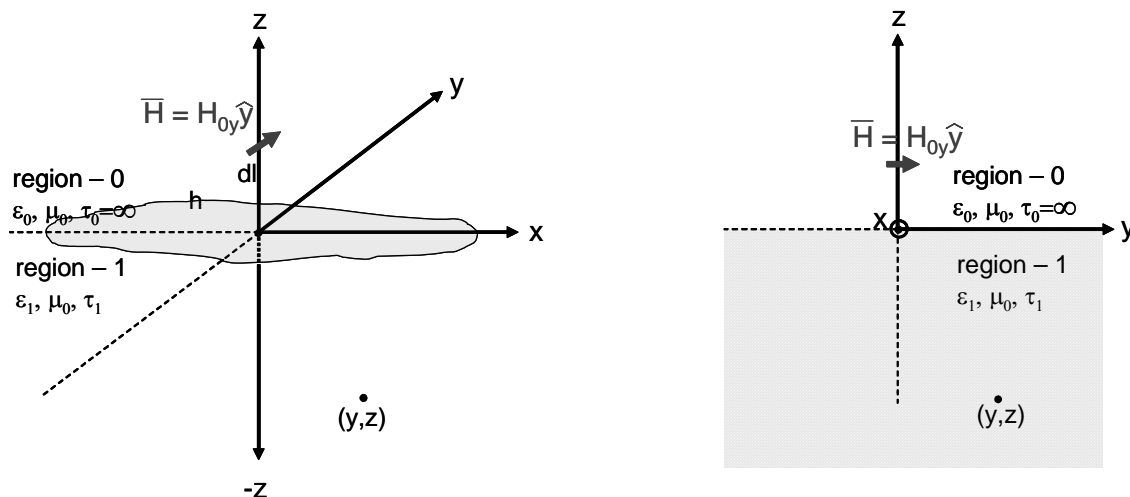


Figure 8-12 Geometry for Eddy Current Field Calculations in Homogeneous Half-Space Driven by Uniform Magnetic Field at the Surface.

with uniform harmonic magnetic field with time harmonic variation $e^{i\omega t}$, $\bar{H} = H_{0y}\hat{y}$, in the y-direction, then the electromagnetic field equations, neglecting displacement current can be developed directly from Maxwell's equations.

$$\frac{\partial j_x(z)}{\partial y} = i\omega\sigma_1\mu_0 H_y(z)$$

where $j_x(z)$ is the current density in region-1 and $H_y(z)$ is the magnetic field in region-1. The second equation is given by

$$\frac{\partial H_y(z)}{\partial y} = j_x(z)$$

Substituting one equation into the other yields

$$\frac{\partial^2 H_y(z)}{\partial y^2} = \alpha^2 H_y(z)$$

where

$$\alpha = \frac{(1+i)}{\delta_1}$$

$$\delta_1 = \sqrt{\frac{2}{\omega\mu_0\sigma_1}}$$

where δ_1 is the skin depth in region-1. The general solution of the above equation is

$$H_y(z) = K_1 e^{\alpha z} + K_2 e^{-\alpha z}$$

Choosing the properly decaying solution as $z \rightarrow -\infty$, and using the boundary condition at the surface of $H_y(0) = H_{0y}$

$$H_y(z) = H_{0y} e^{\alpha z}$$

$$j_x(z) = \frac{\partial H_y(z)}{\partial y}$$

$$= \alpha H_{0y} e^{\alpha z}$$

Because

$$E_x(z) = \tau_1 j_x(z)$$

where

$$\tau_1 = \frac{1}{\sigma_1}$$

$$E_x(z) = \tau_1 \alpha H_{0y} e^{\alpha z}$$

is the only component of the electric field in region-1.

Because a surface current density is related to the magnetic field immediately below a perfect conductor by the relationship

$$j_{0x} = -2\hat{n} \times H_{0y}$$

the above solution could also be considered to be the electric field of a homogeneous half-space excited by a uniform x-directed current flowing on the bottom surface of a perfectly conducting sheet on the surface of the homogeneous half-space, but electrically isolated from it. The exciting current on the sheet to produce the field in the equations would be

$$j_{0x} = -2H_{0y}$$

in the x-direction, or alternatively

$$H_{0y} = -\frac{1}{2} j_{0x}$$

in the above formulas.

8.5 Eddy Current, Infinitesimal and Finite Length Horizontal Drive Wire Models

Eddy current models for infinitesimal and finite length horizontal drive wires over a homogeneous half-space have been developed in [A4-A7]. The x-directed electric field immediately below the wire can be expressed in closed form for the infinitesimal length dipole [A7]. Expressions for the electric field in a two-layer half-space excited by an infinitesimal horizontal drive wire have been developed in [A8]. These models are quite complicated and were not further developed for this program because of lack of time and resources.

8.6 References for Appendix A

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- A8. Riordan, John, and Erling D. Sunde, *Mutual Impedance of Grounded Wires for Horizontally Stratified Two-Layer Earth*, Bell System Technical Journal, Vol 12, pp162-177, 1933.

9 Appendix B –Calibration Documentation of Measurement Equipment

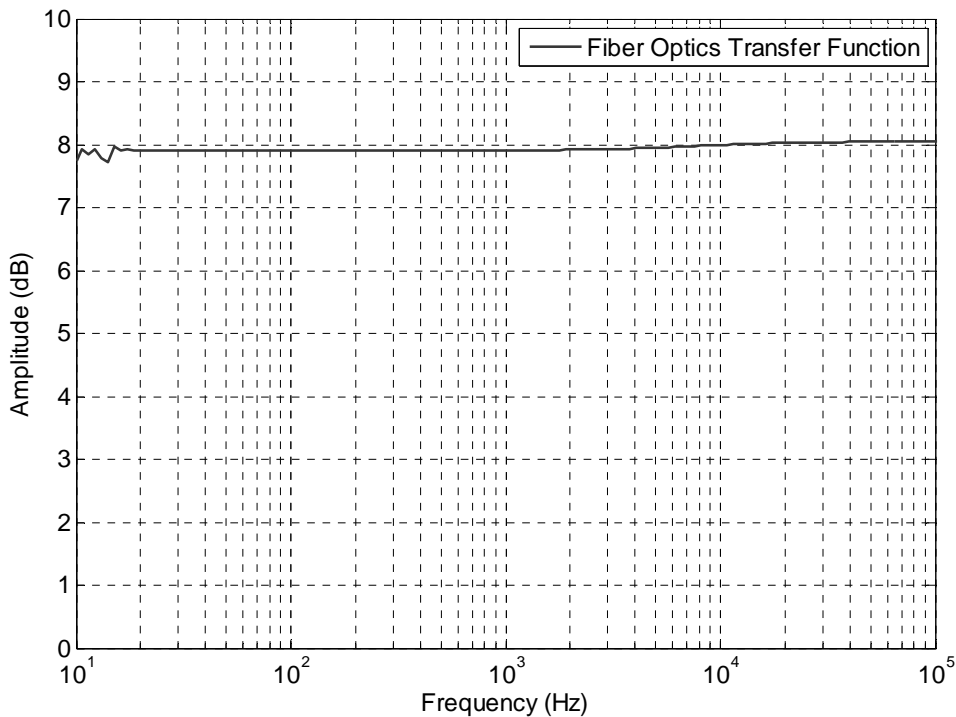


Figure 9-1 Calibration Frequency Response of Fiber-optic Transmitter/Receiver Pair.

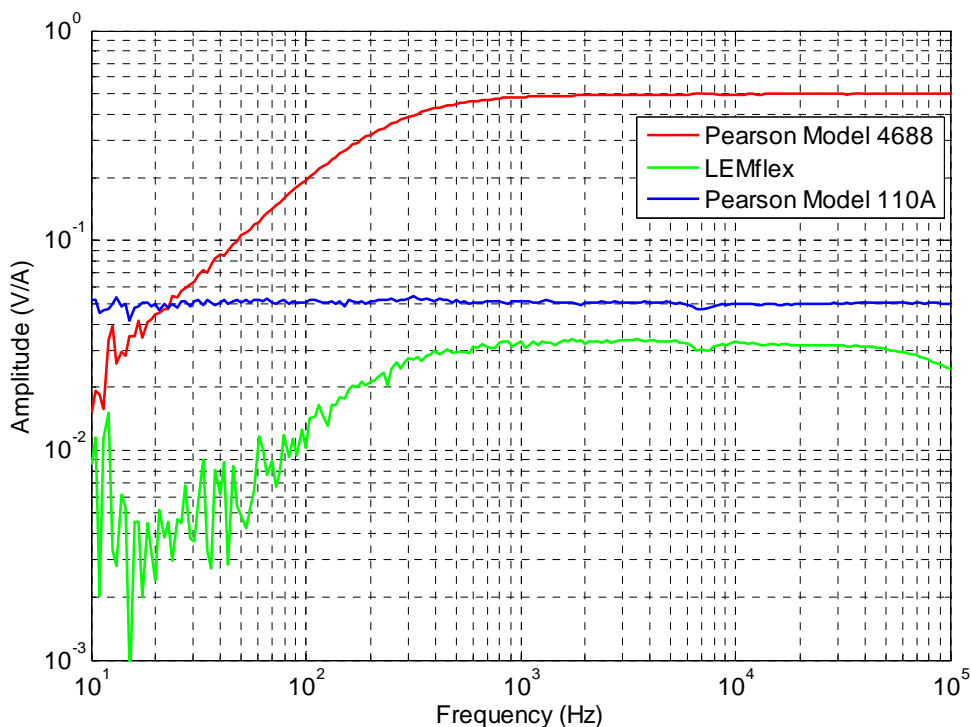


Figure 9-2 Calibration Frequency Response of Current Probes used.

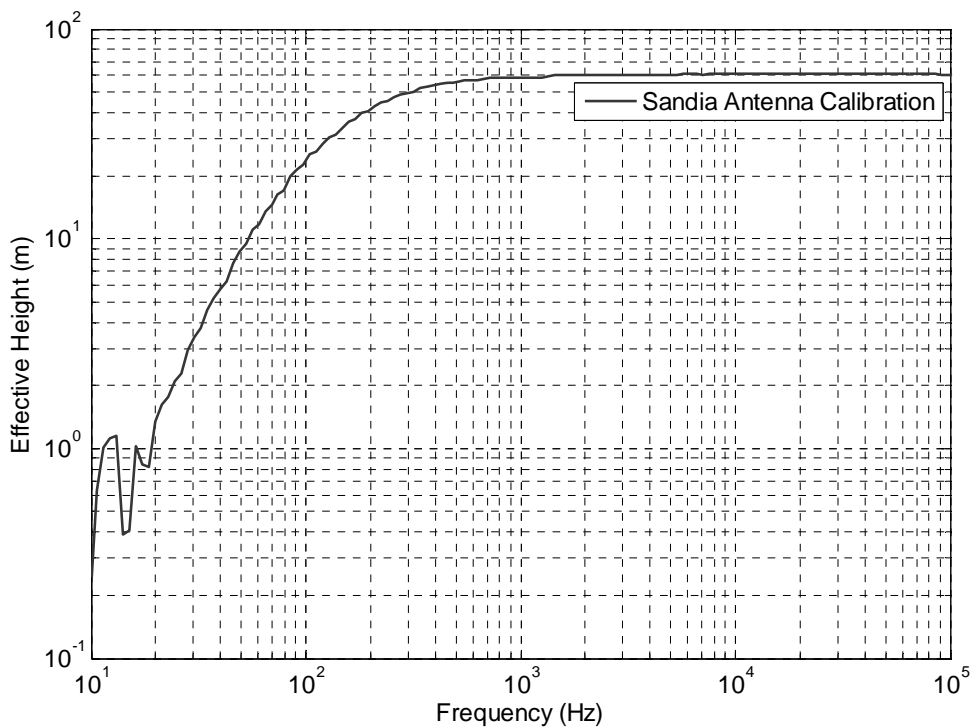


Figure 9-3 Calibration Frequency Response of Sandia Dipole Antenna.

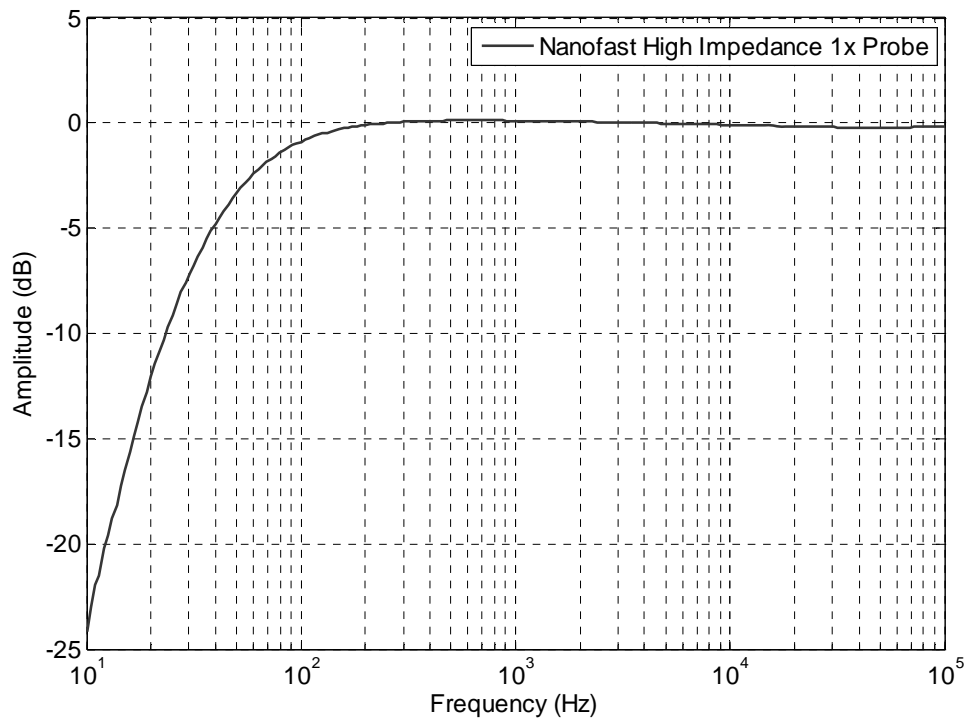


Figure 9-4 Calibration Frequency Response of Nanofast High-Impedance Probe.

PRIMARY STANDARDS LABORATORY

Sandia National Laboratories, Albuquerque, New Mexico 87185



Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002

CERTIFICATE

NETWORK ANALYZER (Type N)

Manufacturer: Agilent
Model: 4395A
Serial Number: SG41100394
Property Number: S853091

Test Set Model No.: 87511A
Test Set Serial No.: 3026J00604

Cal. Kit Model No.: 85054A
Cal. Kit Serial No.: 2345A00121

Submitted by: 01653
P.O. Box 5800 M/S 1152
Albuquerque, NM 87185-1152

Certification performed on August 7, 2006.
Certified: August 7, 2006
Expires: August 7, 2007

The attached data sheets tabulate uncertainties expected from the Network Analyzer system defined above and in the data sheets; the uncertainties do not apply to any other configuration or system. The uncertainties and errors of the complex S-parameters derive from an assumed mathematical model based on measurements of suitably chosen standards. These standards - air line(s), 10 dB fixed attenuator, and when applicable, mismatches - are directly traceable to NIST. The frequency reference for the Network Analyzer synthesizer during calibration was the internal 10 MHz frequency reference of the 4395A. The certification was performed at $23 \pm 2^\circ\text{C}$ and $40 \pm 10\% \text{ RH}$.

4395A File 51649 Frequency TimeBase Error is 0.288 ± 0.191 ppm.

Program: CERTVANA B12 Version date is April 3, 2006

Metrologist: J. A. Woods - 2542

Approved by Project Leader: R. D. Moyer - 2542

Copy to:
01653 (2)
2542 File <<<<<<

Page 1 of 12

File No. 51649

PRIMARY STANDARDS
LABORATORY

Sandia National Laboratories

CALIBRATION

File No. 51649
Certified: 08/07/06
Expires: 08/07/07
NETWORK/SPECTRUM/IMPEDA
Hewlett Packard Co.
Model: 4395A
Serial: SG41100394
See Certificate
By: JAW

Figure 9-5 Certificate of Calibration for 4395A Network Analyzer.

10 Appendix C – Compilation of Measured Data

Direct Drive Transfer Function Data:

The following transfer functions were measured with the mine grounding system in current state.

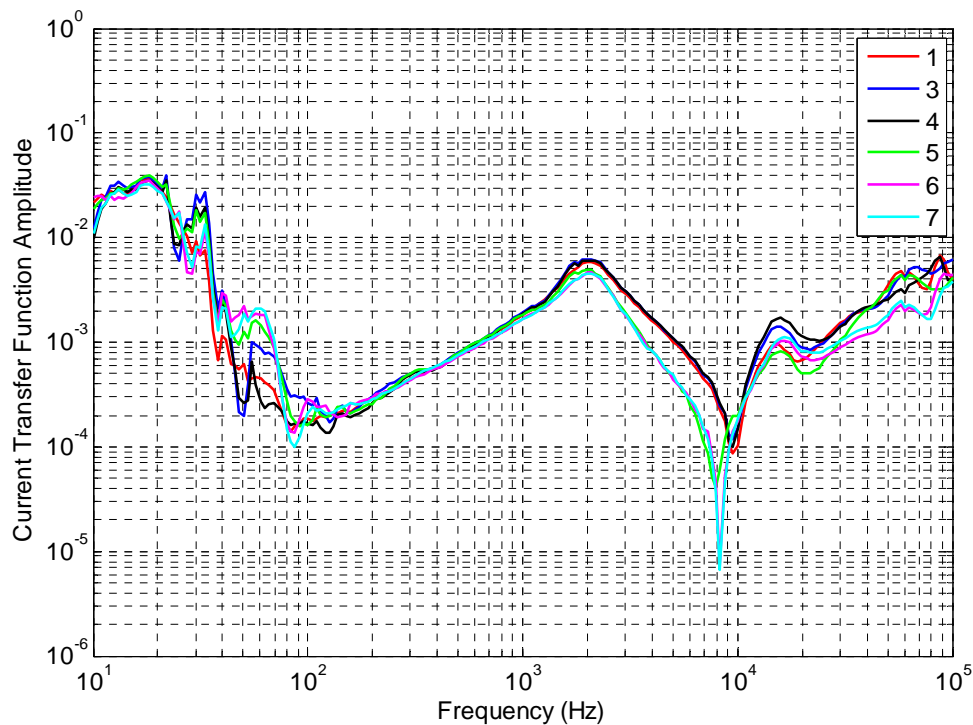


Figure 10-1 Direct Drive Current Transfer Function of Trolley Communication Line with a Local Ground.

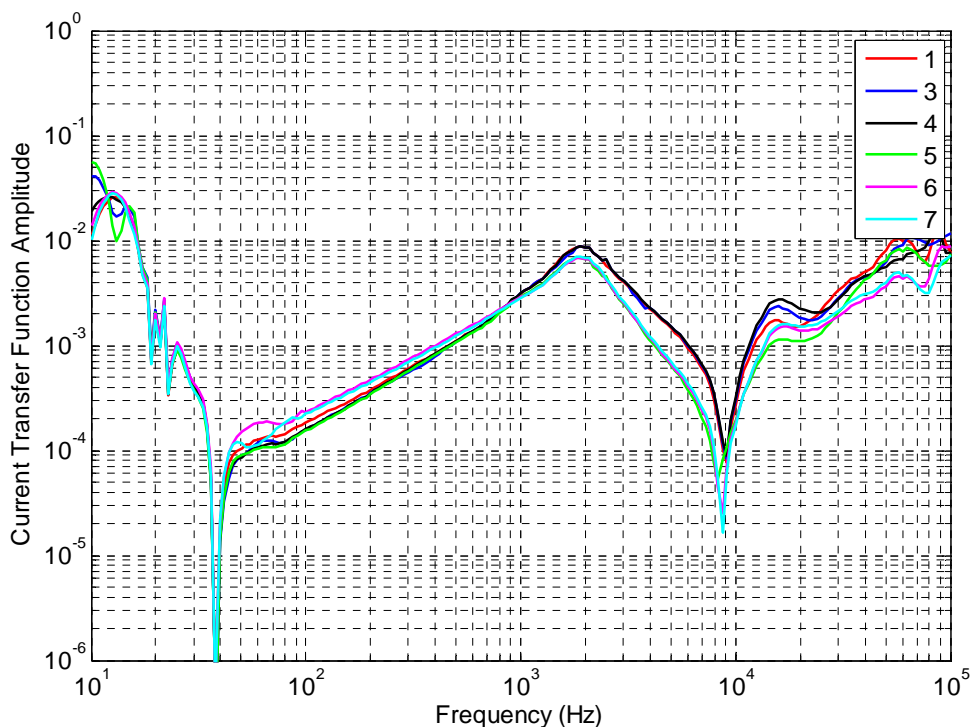


Figure 10-2 Direct Drive Current Transfer Function of Trolley Communication Line with a Fence Ground.

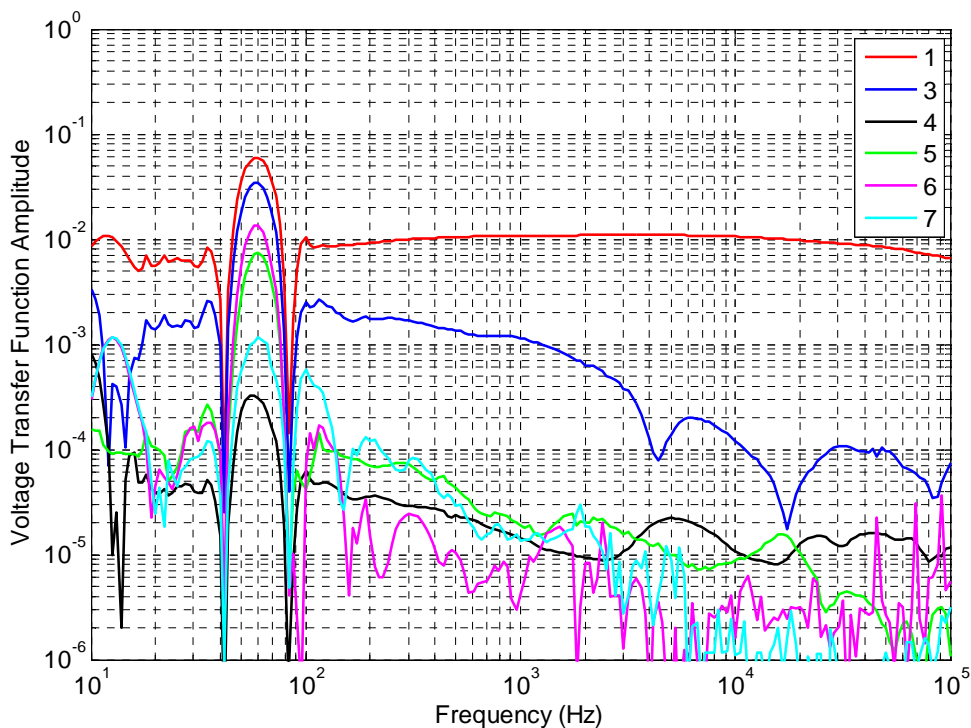


Figure 10-3 Direct Drive Voltage Transfer Function of Conveyor Structure with a Local Ground.

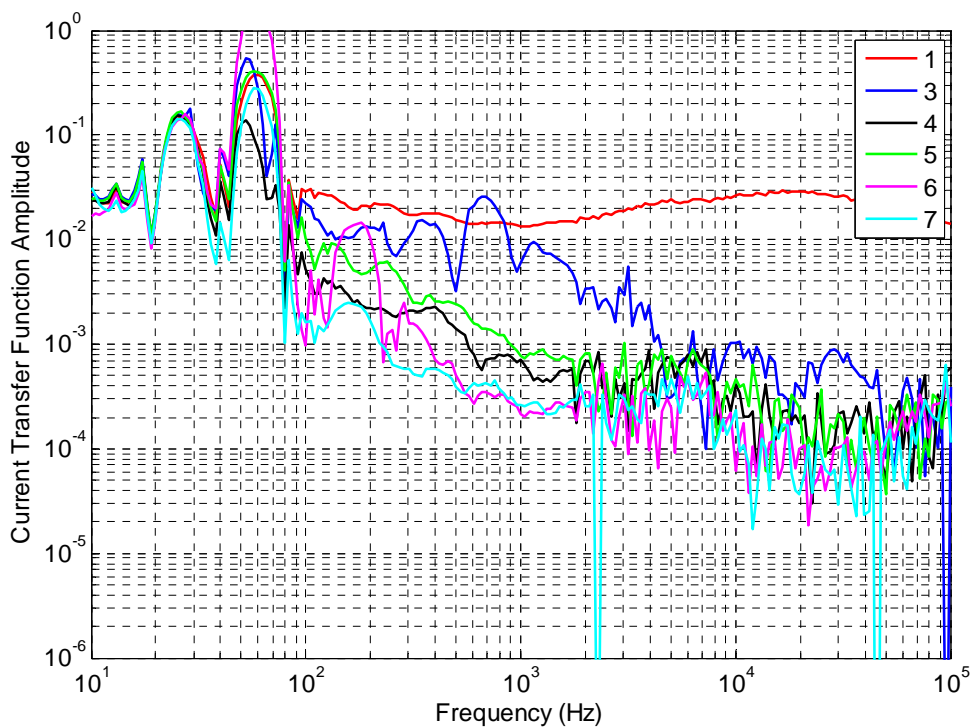


Figure 10-4 Direct Drive Current Transfer Function of Conveyor Structure with a Local Ground.

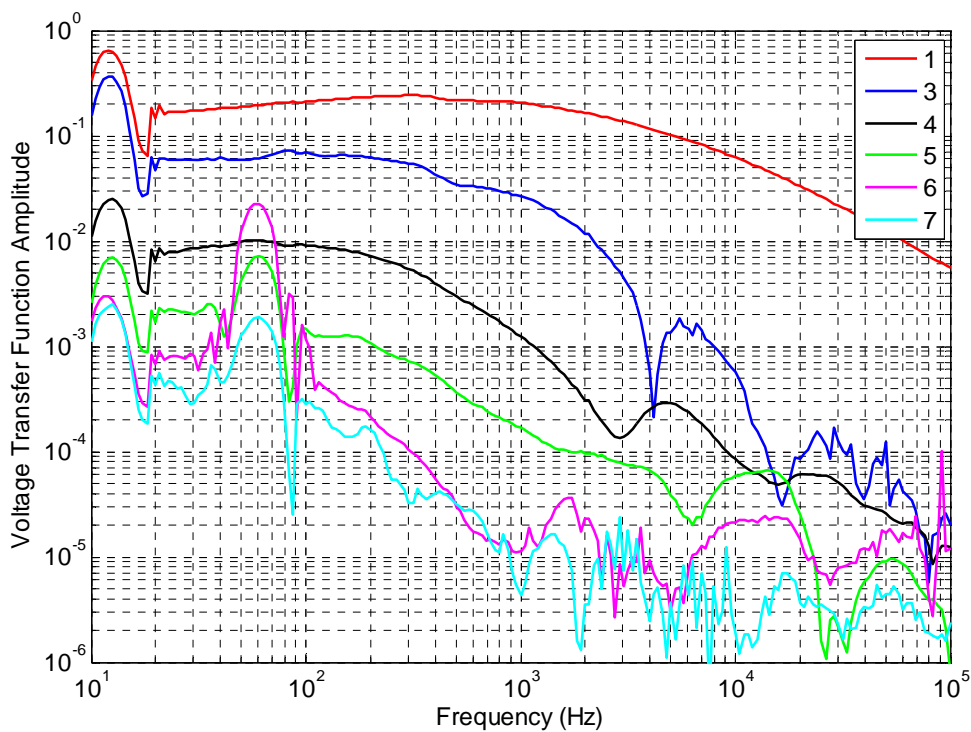


Figure 10-5 Direct Drive Voltage Transfer Function of Conveyor Structure with a Fence Ground.

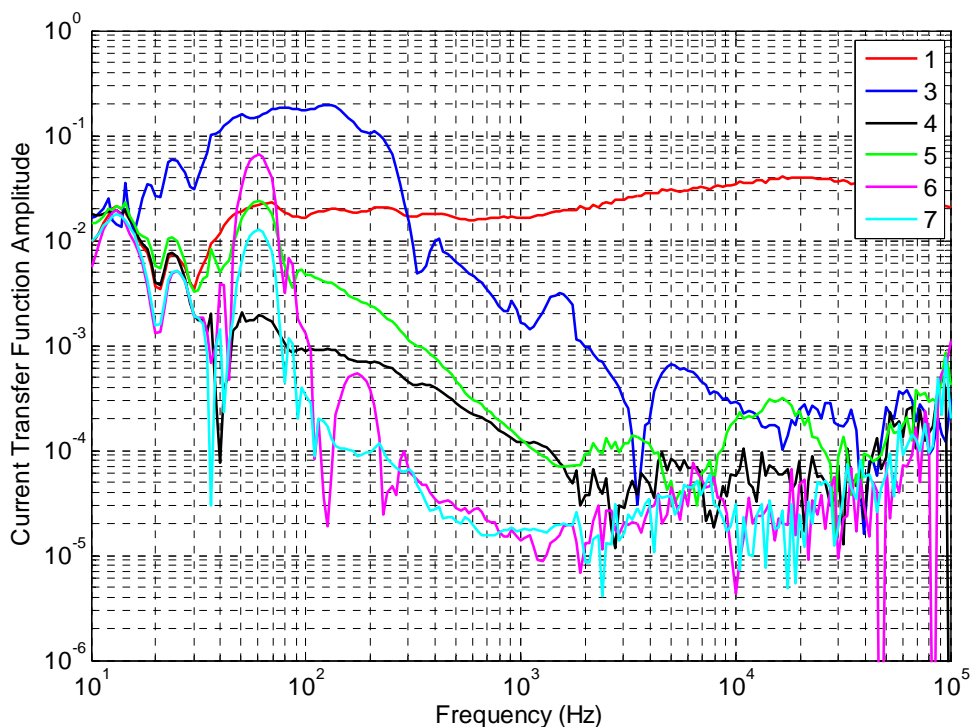


Figure 10-6 Direct Drive Current Transfer Function of Conveyor Structure with a Fence Ground.

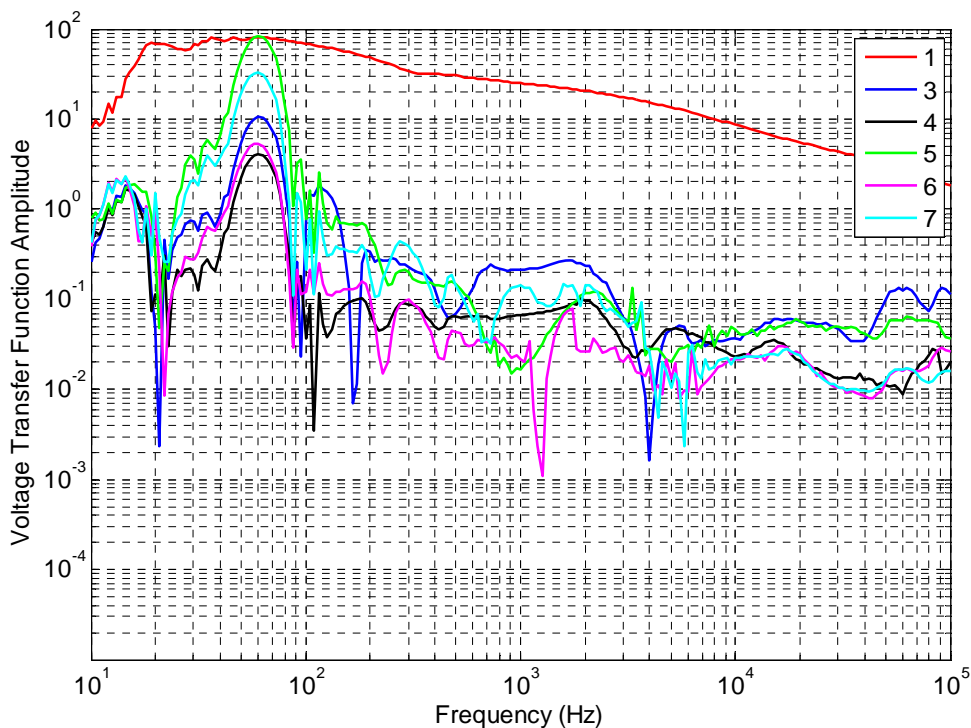


Figure 10-7 Direct Drive Voltage Transfer Function of Rail Structure with a Local Ground.

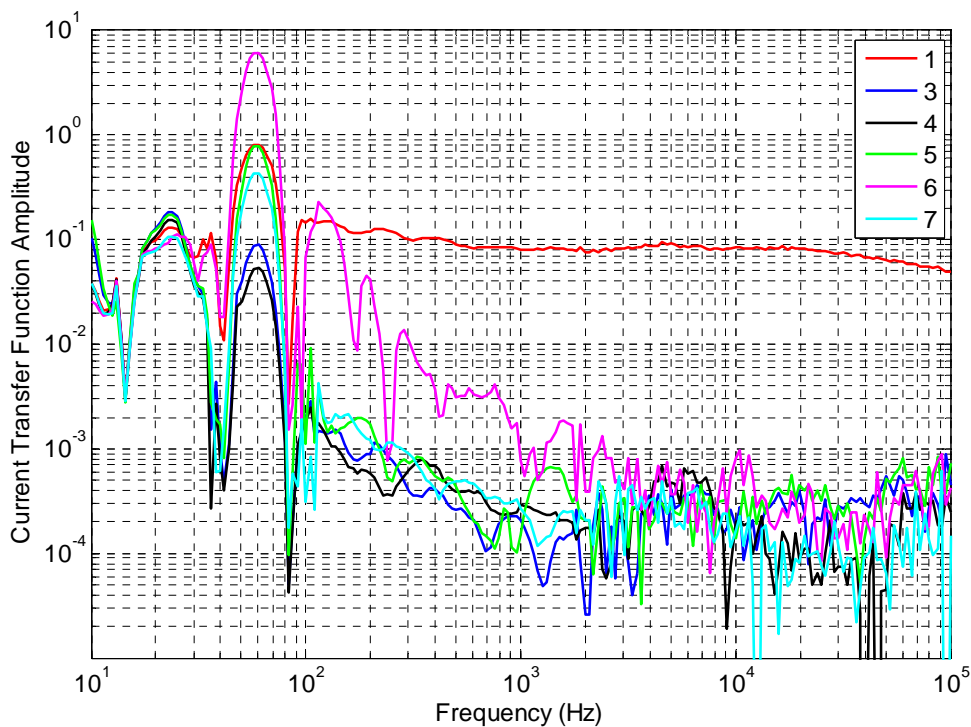


Figure 10-8 Direct Drive Current Transfer Function of Rail Structure with a Local Ground.

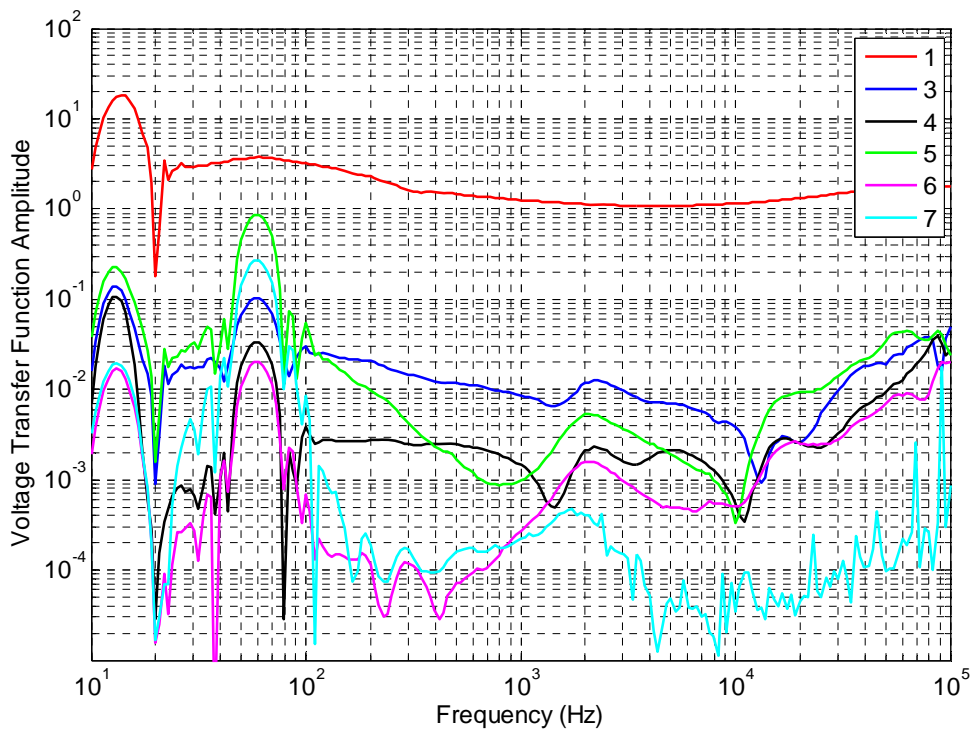


Figure 10-9 Direct Drive Voltage Transfer Function of Rail Structure with a Fence Ground.

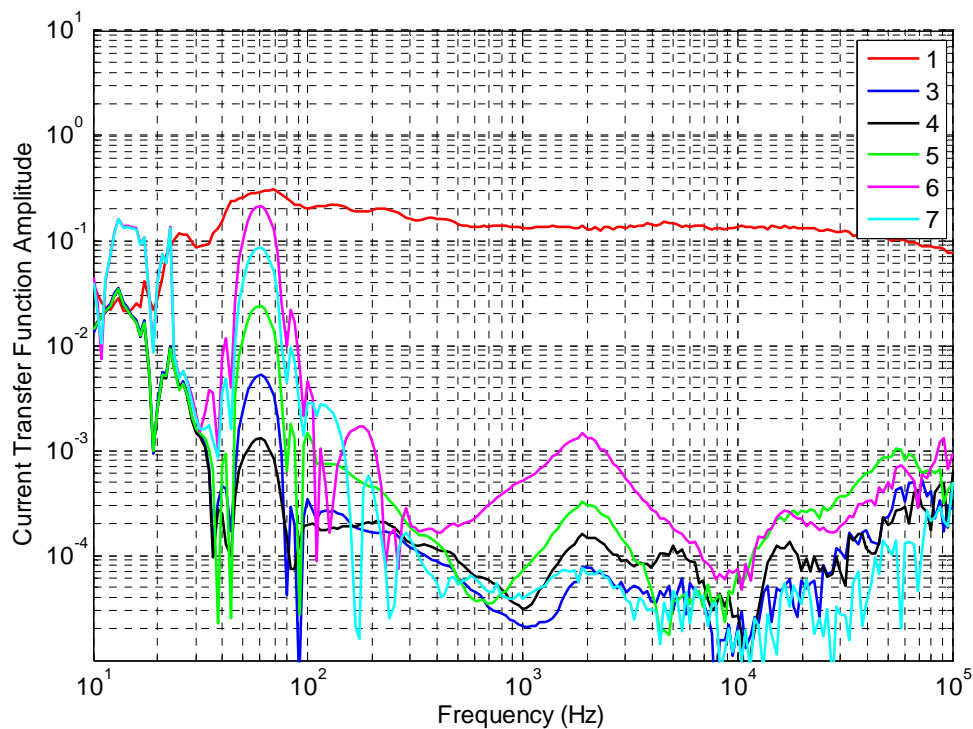


Figure 10-10 Direct Drive Current Transfer Function of Rail Structure with a Fence Ground.

The following transfer functions were measured with the mine grounding system similar to the grounding scheme in place during explosion.

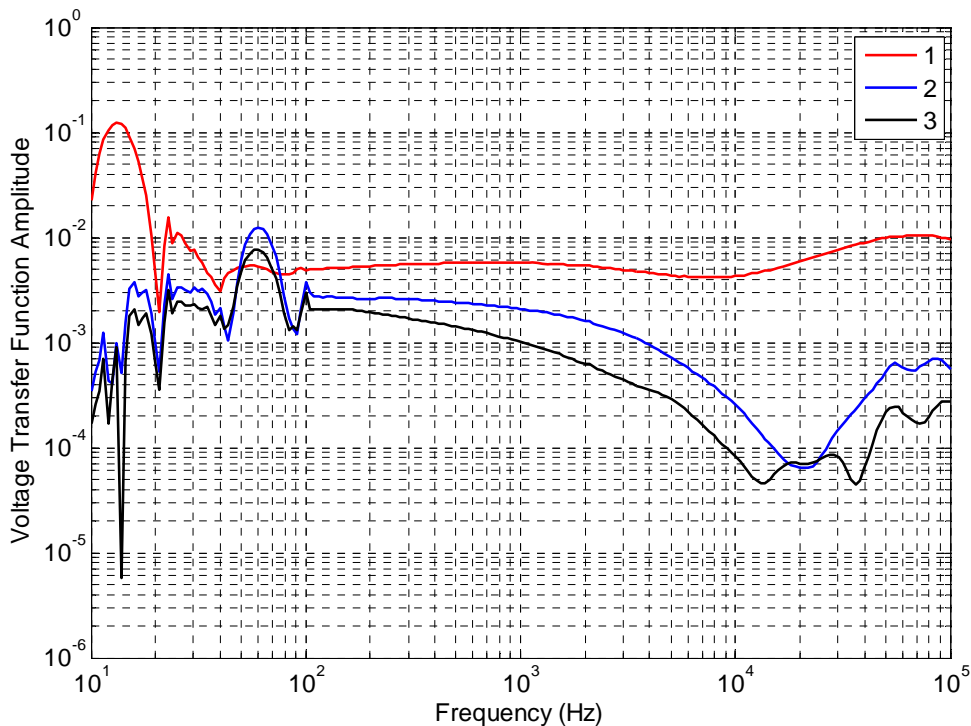


Figure 10-11 Direct Drive Voltage Transfer Function of Power Cable Shield with a Local Ground.

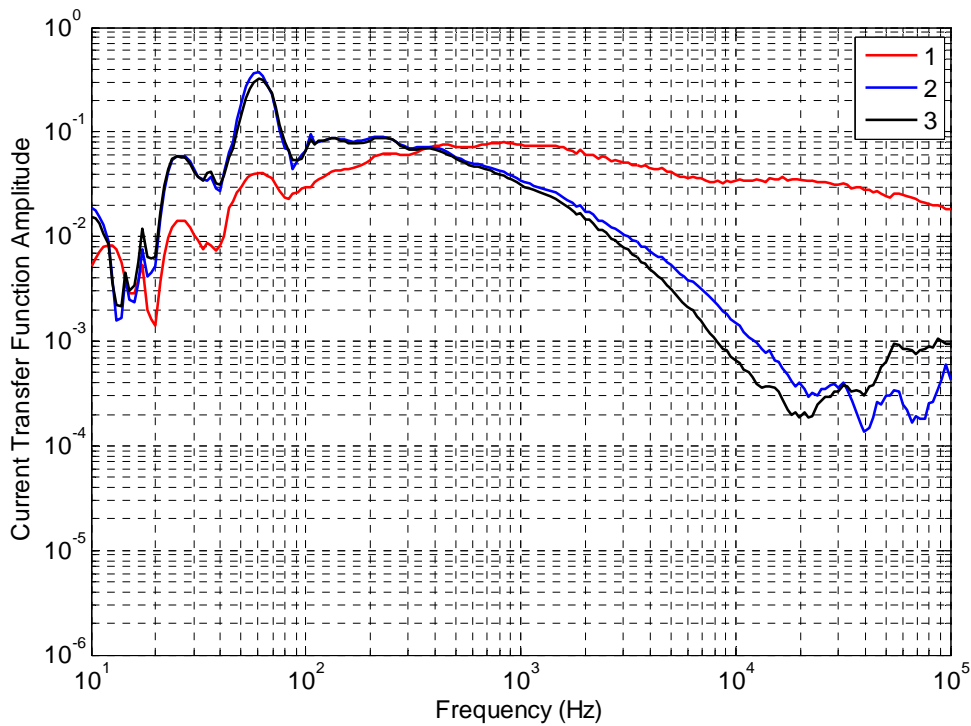


Figure 10-12 Direct Drive Current Transfer Function of Power Cable Shield with a Local Ground.

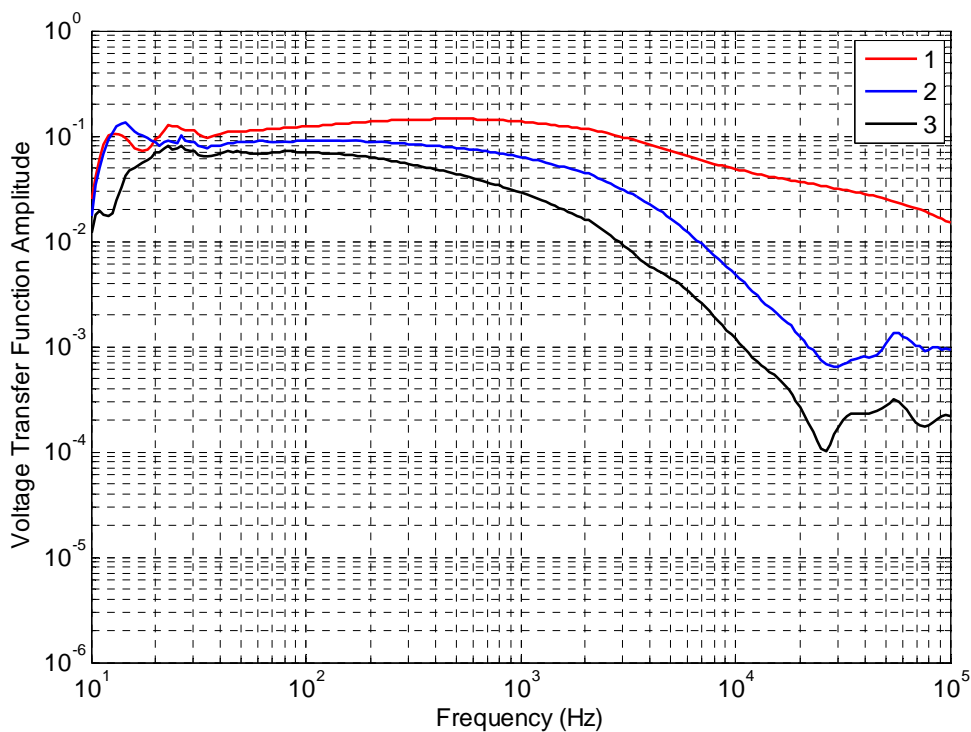


Figure 10-13 Direct Drive Voltage Transfer Function of Power Cable Shield with a Fence Ground.

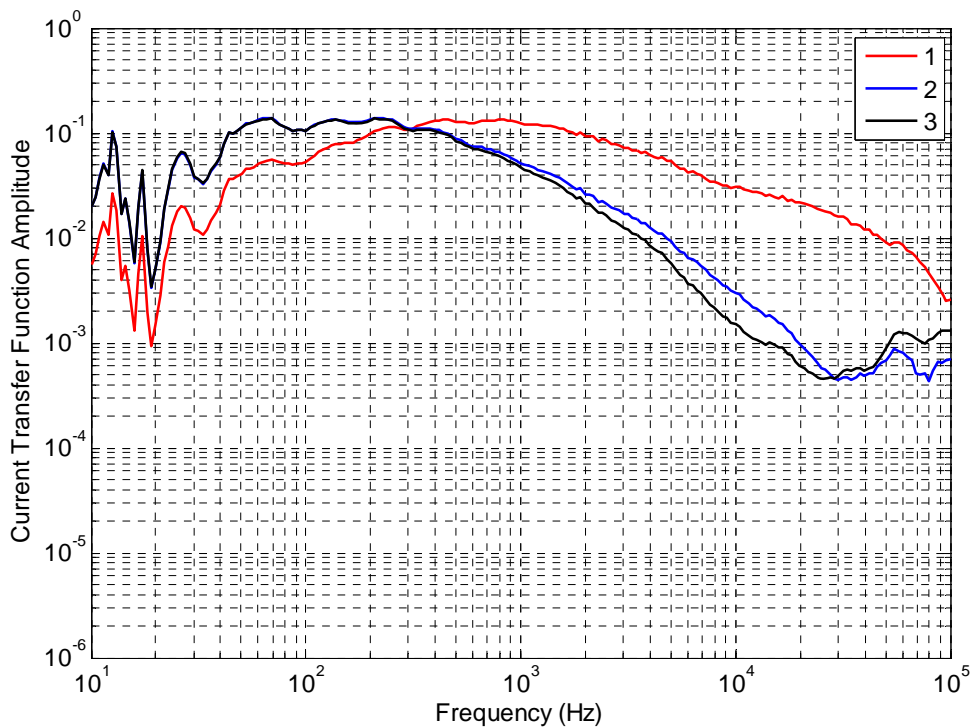


Figure 10-14 Direct Drive Current Transfer Function of Power Cable Shield with a Fence Ground.

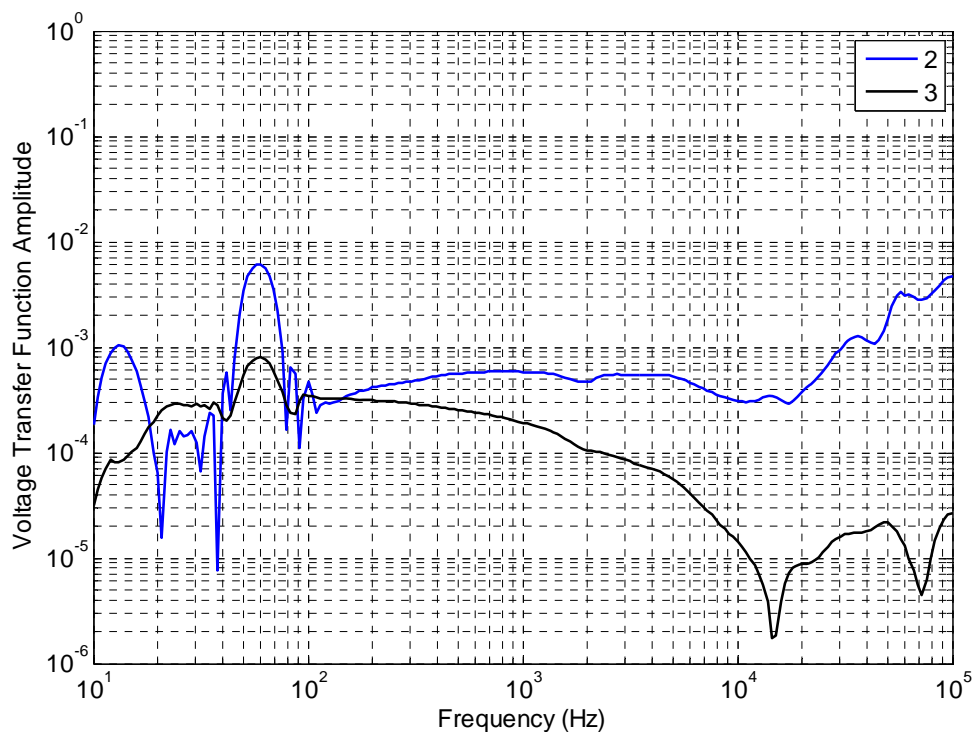


Figure 10-15 Direct Drive Voltage Transfer Function of Rail Structure with a Local Ground.

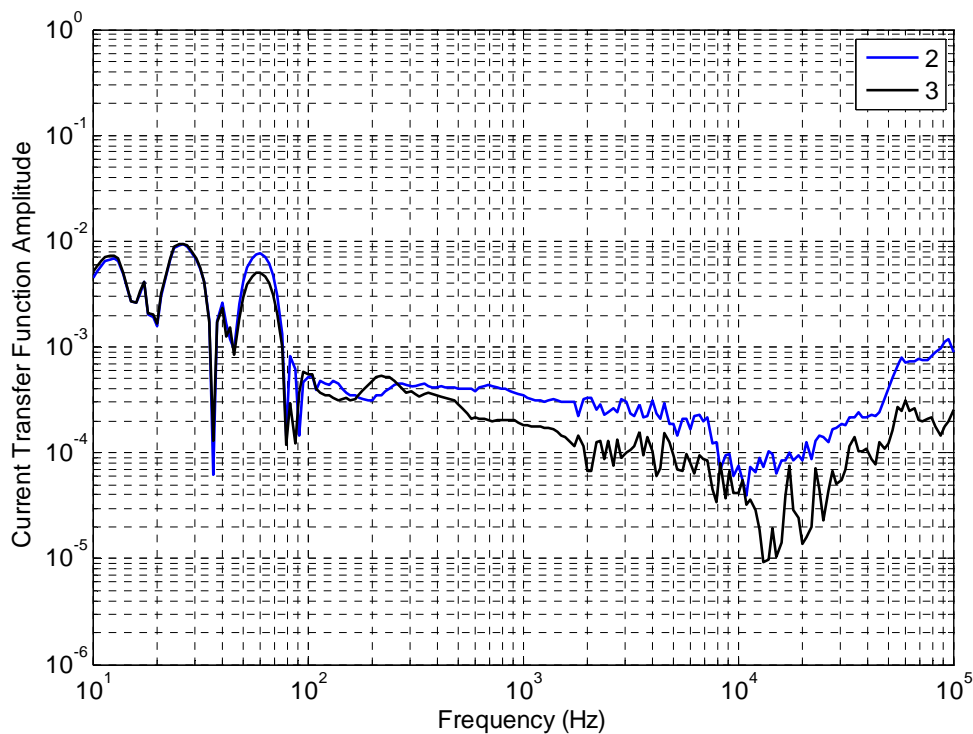


Figure 10-16 Direct Drive Current Transfer Function of Rail Structure with a Local Ground.

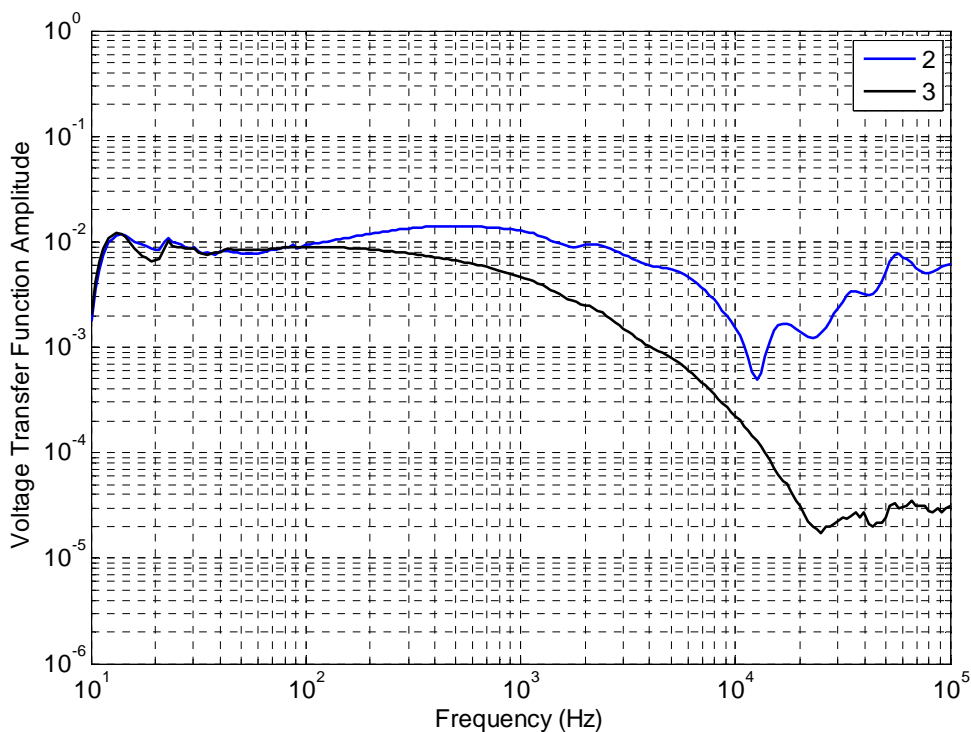


Figure 10-17 Direct Drive Voltage Transfer Function of Rail Structure with a Fence Ground.

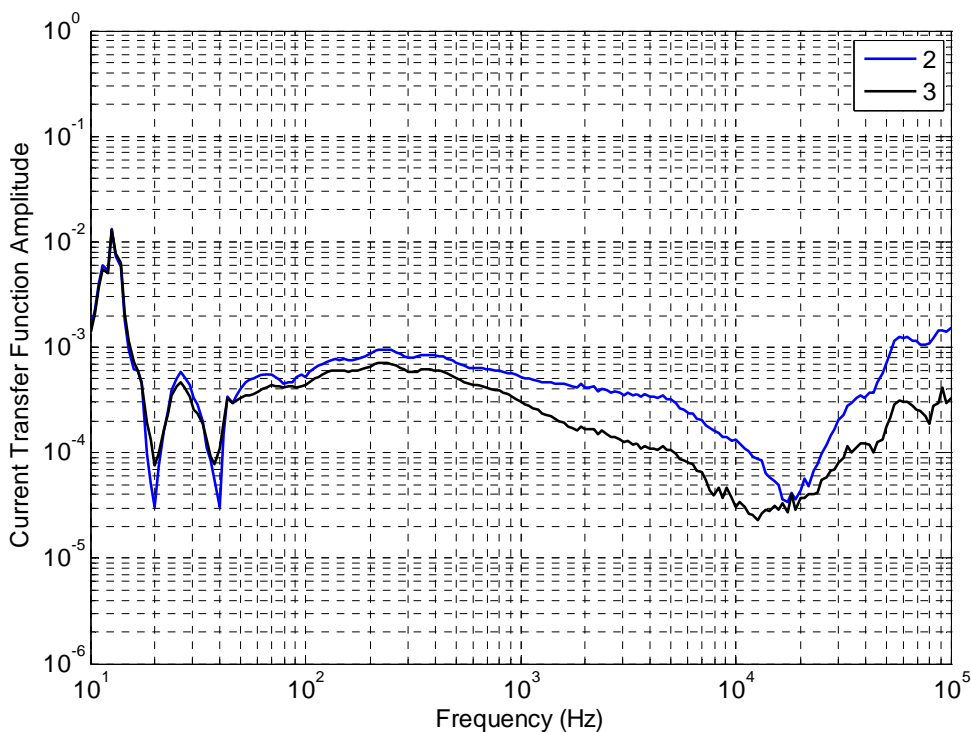


Figure 10-18 Direct Drive Current Transfer Function of Rail Structure with a Fence Ground.

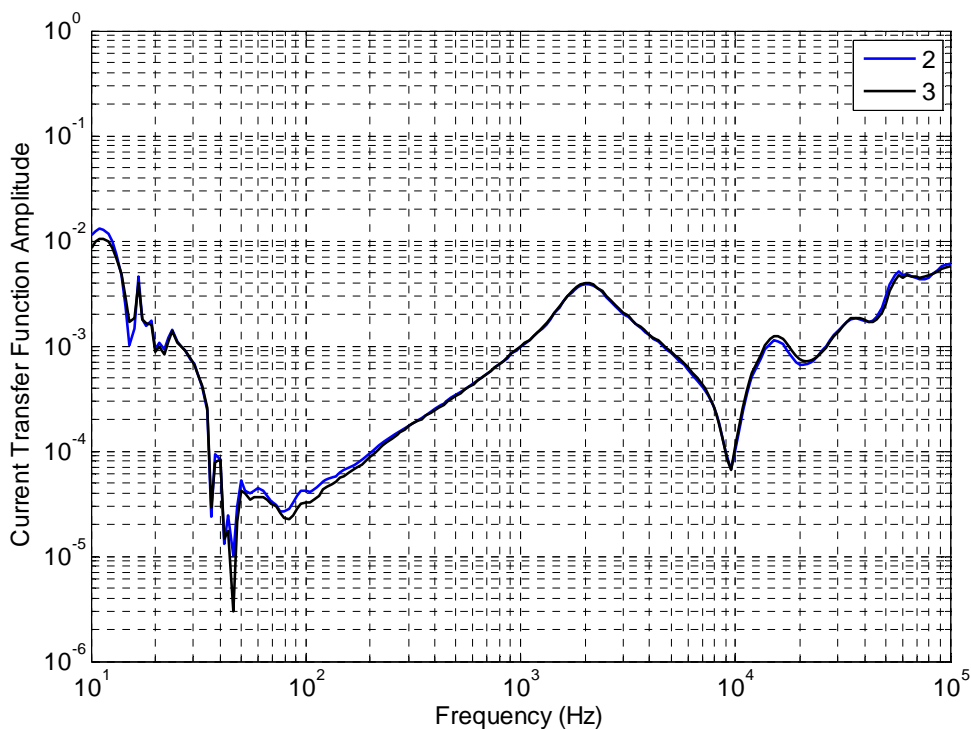


Figure 10-19 Direct Drive Current Transfer Function of Trolley Communication Line with a Local Ground.

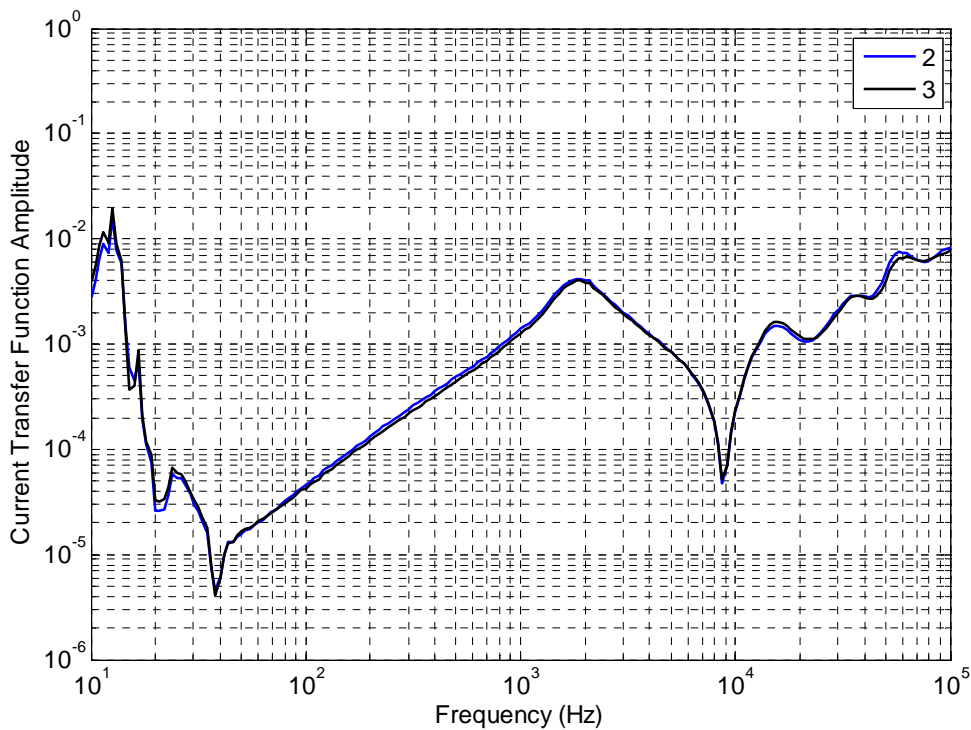


Figure 10-20 Direct Drive Current Transfer Function of Trolley Communication Line with a Fence Ground.

Indirect Drive Transfer Function Data: Surface current drive in the P-direction

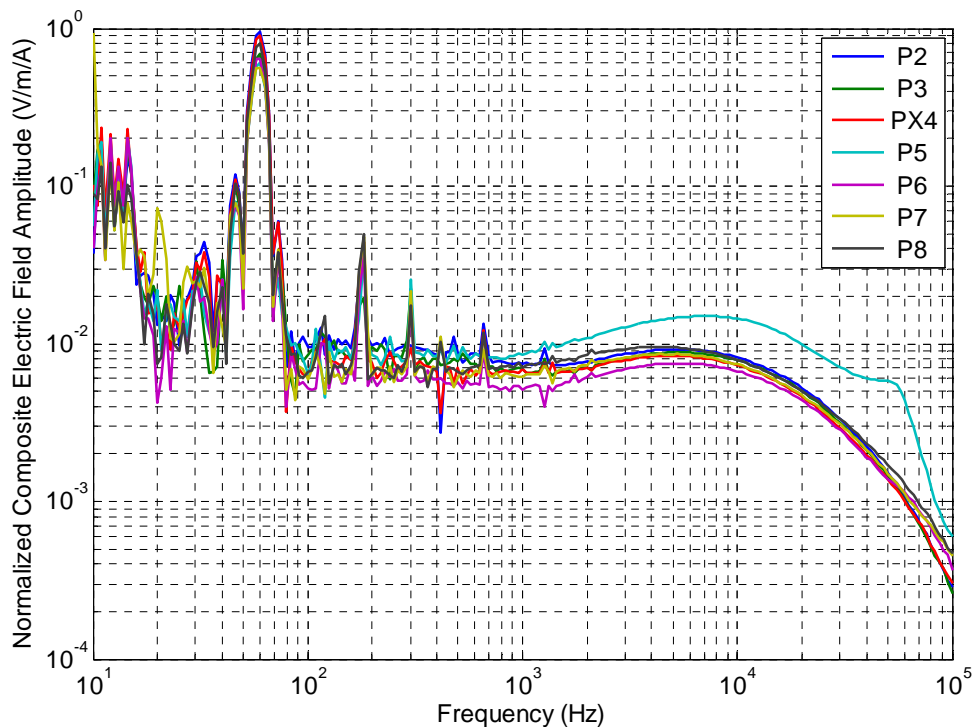


Figure 10-21 Normalized Composite Electric Field for P-Directed Surface Current Drive at Positions from P2 to P8.

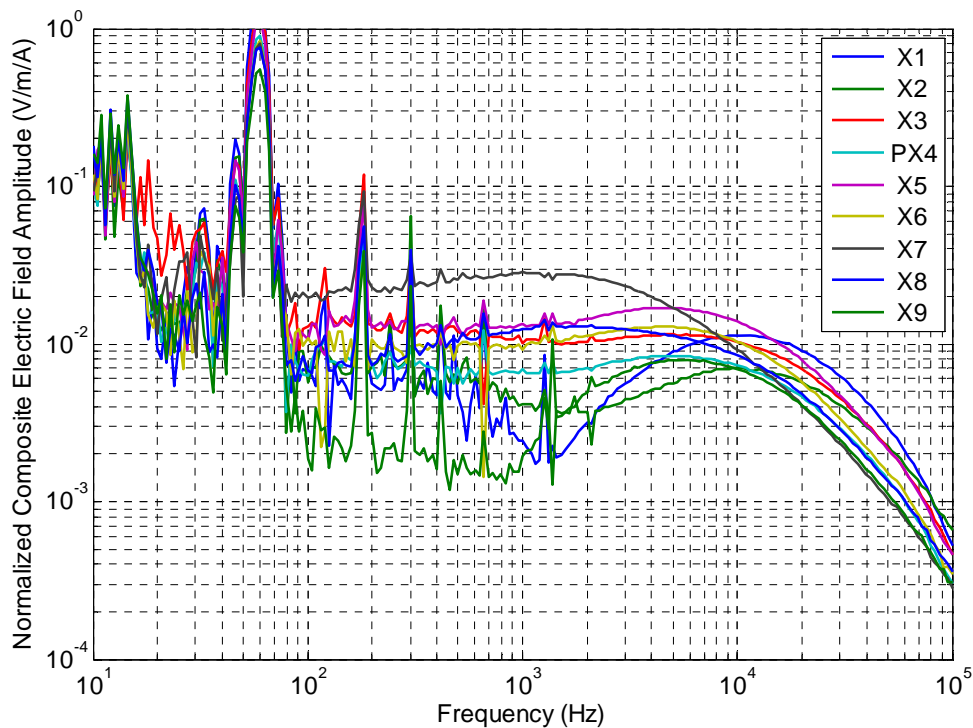


Figure 10-22 Normalized Composite Electric Field for P-Directed Surface Current Drive at Positions from X1 to X9.

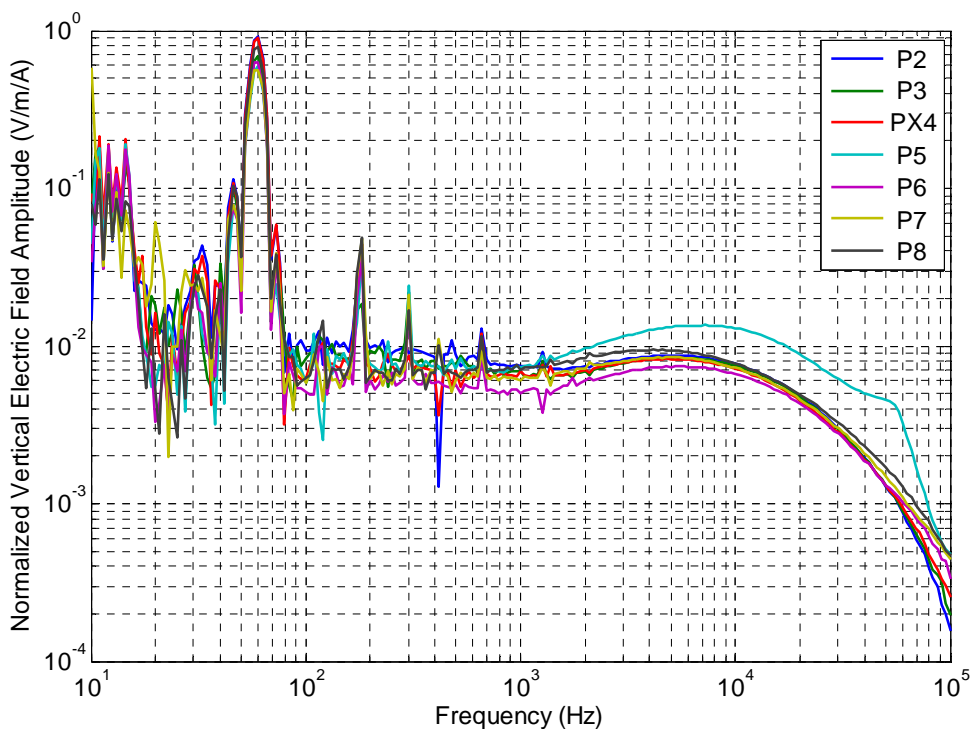


Figure 10-23 Normalized Vertical Electric Field for P-Directed Surface Current Drive at Positions from P2 to P8.

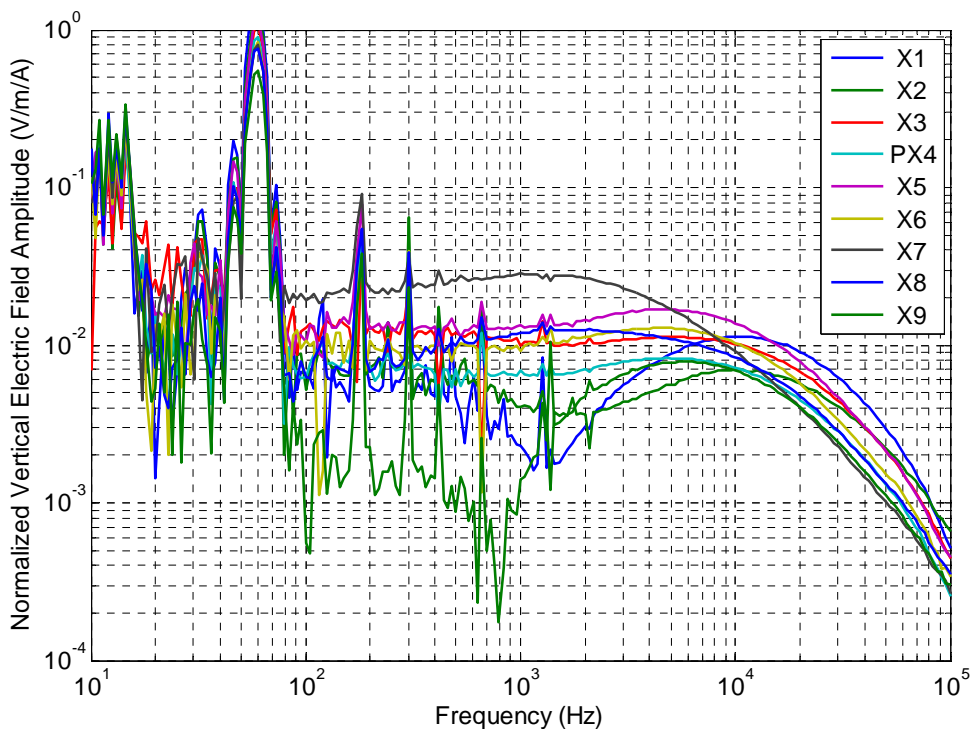


Figure 10-24 Normalized Vertical Electric Field for P-Directed Surface Current Drive at Positions from X1 to X9.

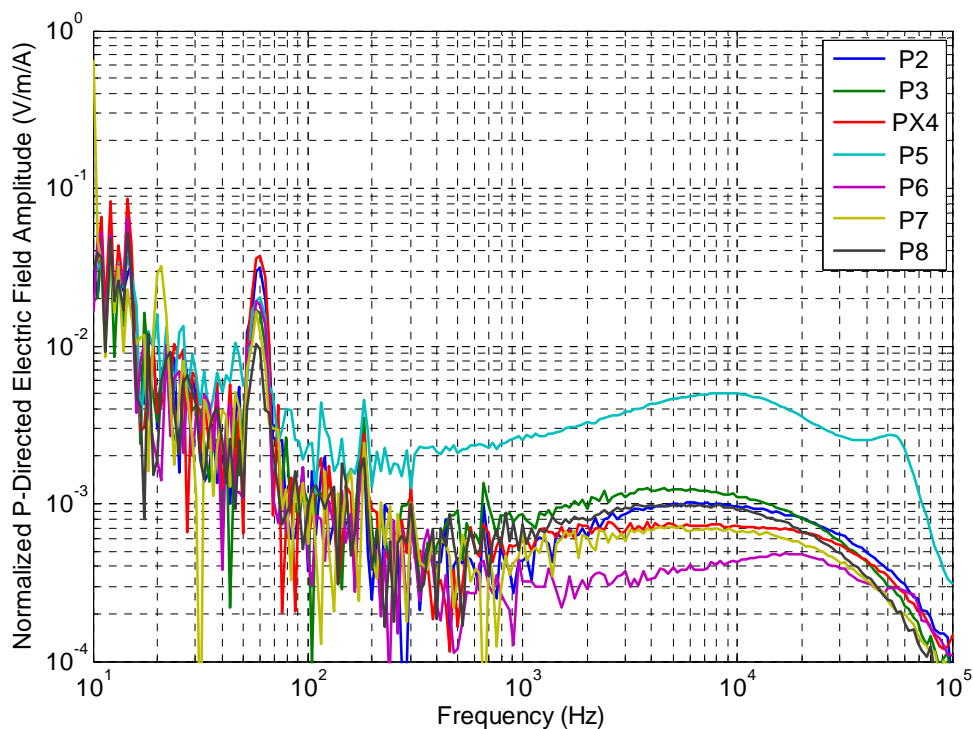


Figure 10-25 Normalized P-Directed Electric Field for P-Directed Surface Current Drive at Positions from P2 to P8.

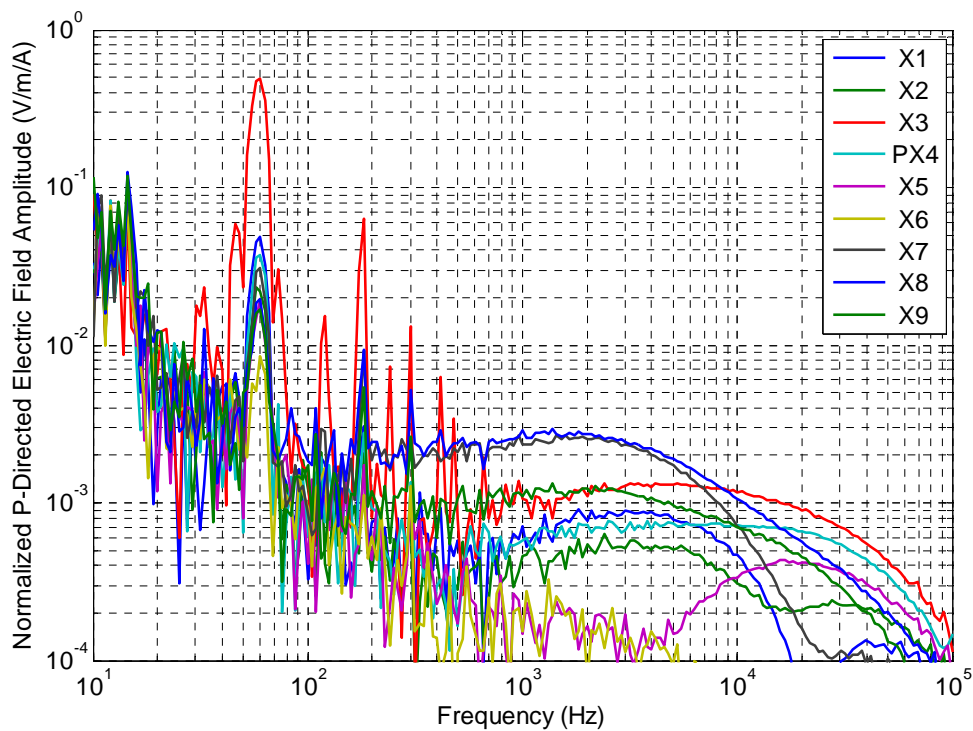


Figure 10-26 Normalized P-Directed Electric Field for P-Directed Surface Current Drive at Positions from X1 to X9.

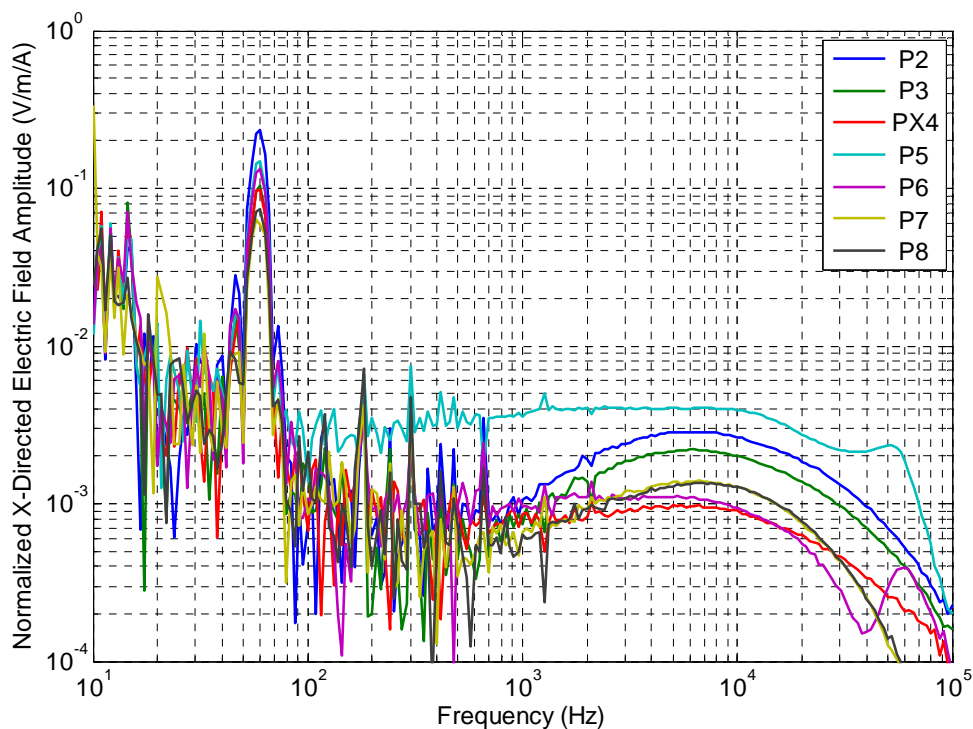


Figure 10-27 Normalized X-Directed Electric Field for P-Directed Surface Current Drive at Positions from P2 to P8.

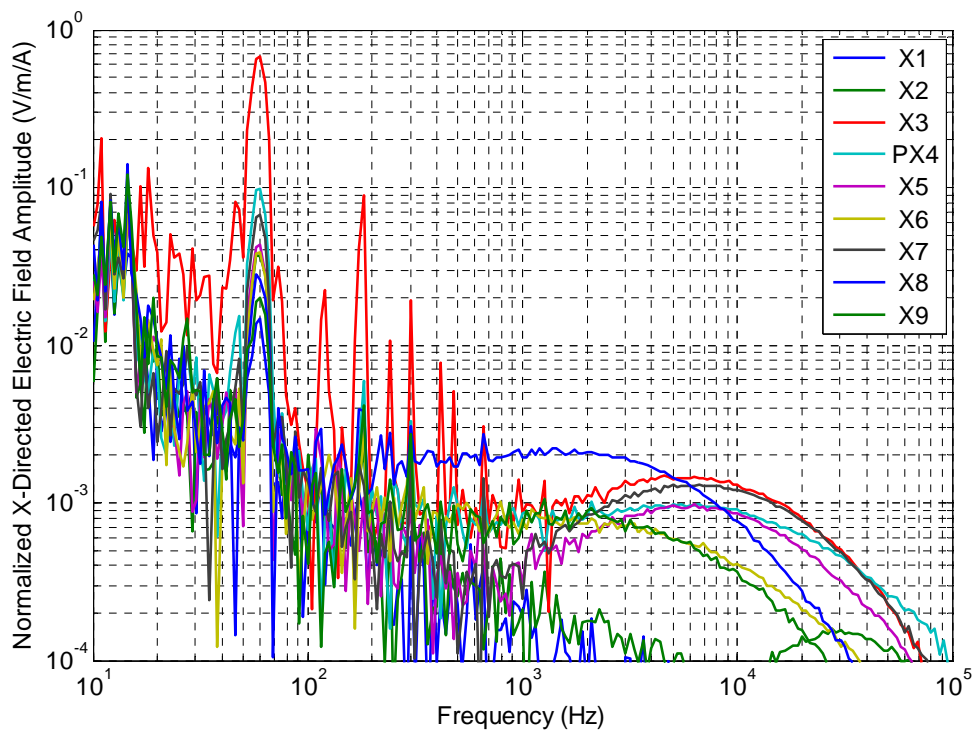


Figure 10-28 Normalized P-Directed Electric Field for P-Directed Surface Current Drive at Positions from X1 to X9.

Indirect Drive Transfer Function Data: Surface current drive in the X-direction

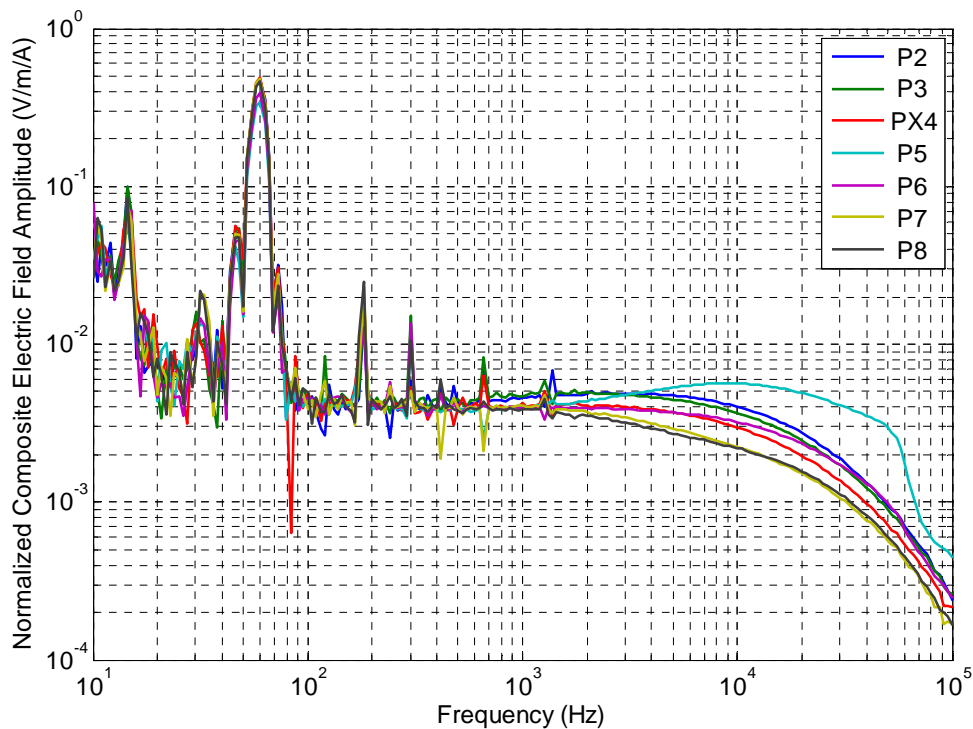


Figure 10-29 Normalized Composite Electric Field for X-Directed Surface Current Drive at Positions from P2 to P8.

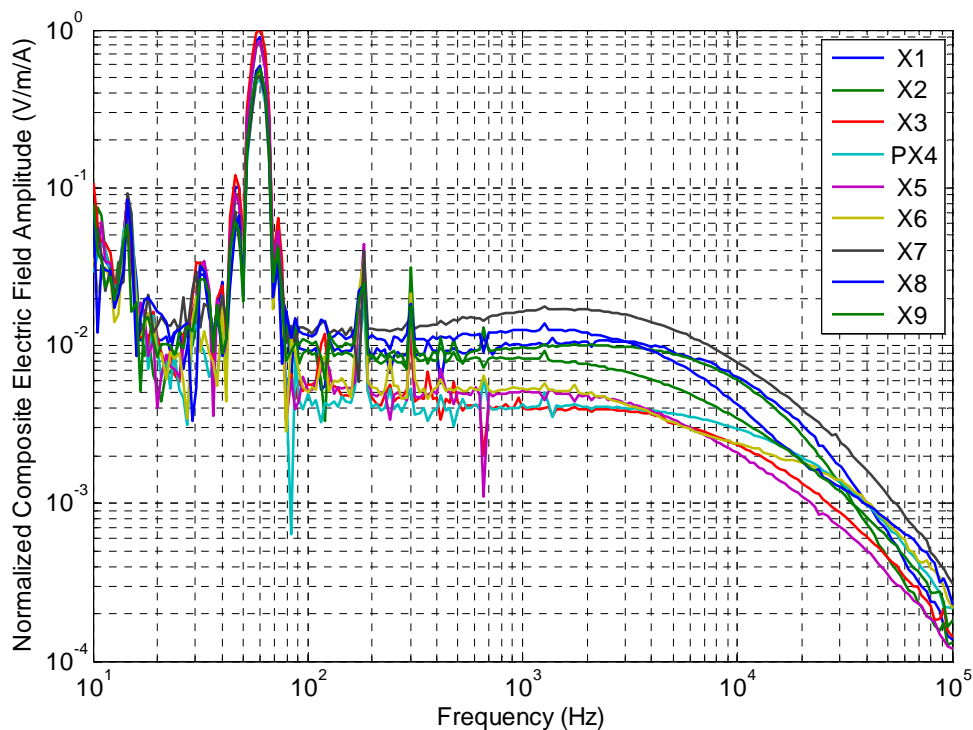


Figure 10-30 Normalized Composite Electric Field for X-Directed Surface Current Drive at Positions from X1 to X9.

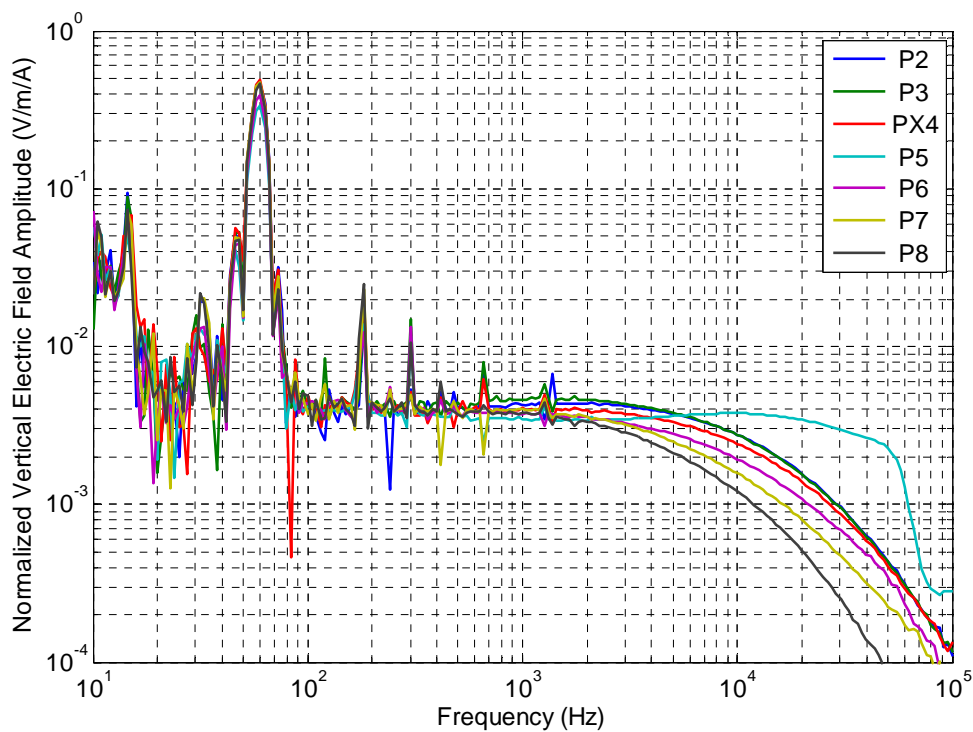


Figure 10-31 Normalized Vertical Electric Field for X-Directed Surface Current Drive at Positions from P2 to P8.

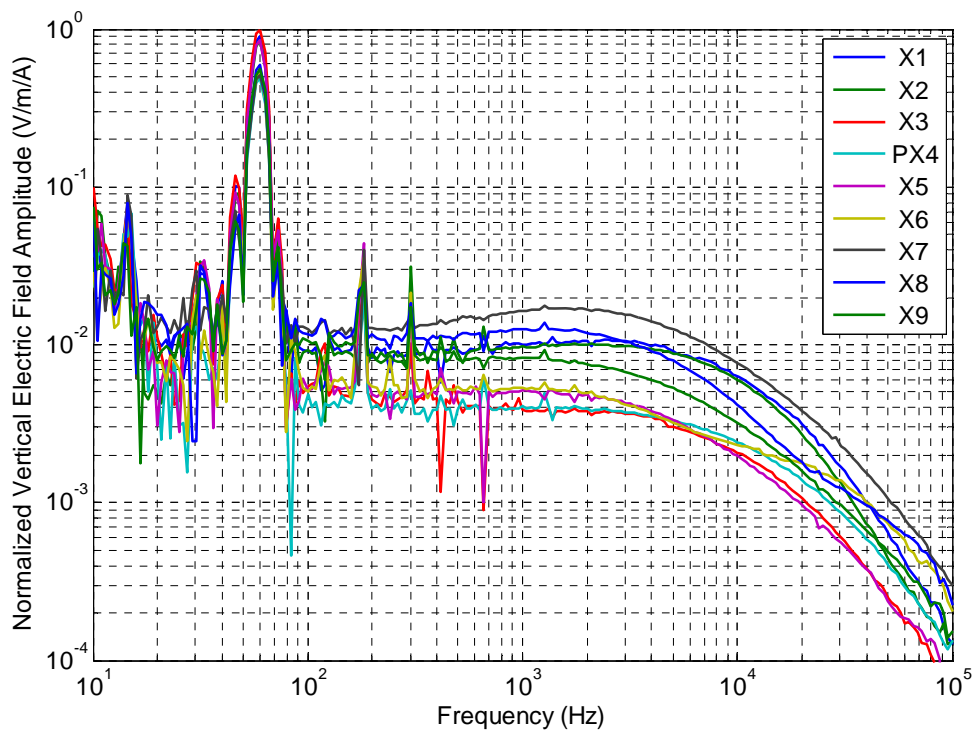


Figure 10-32 Normalized Vertical Electric Field for X-Directed Surface Current Drive at Positions from X1 to X9.

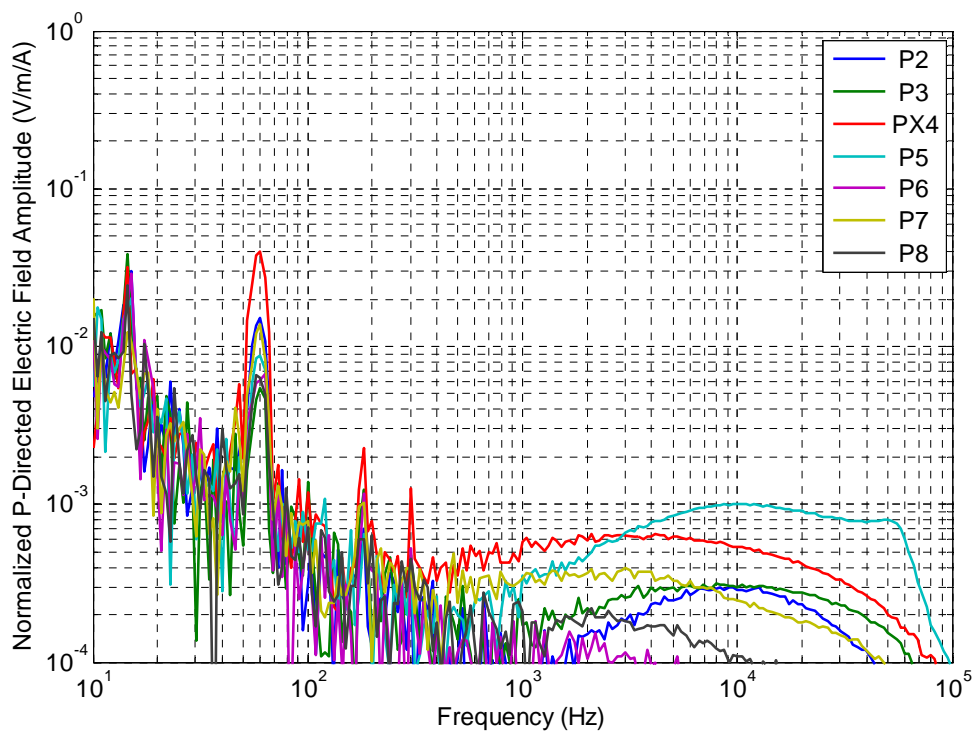


Figure 10-33 Normalized P-Directed Electric Field for X-Directed Surface Current Drive at Positions from P2 to P8.

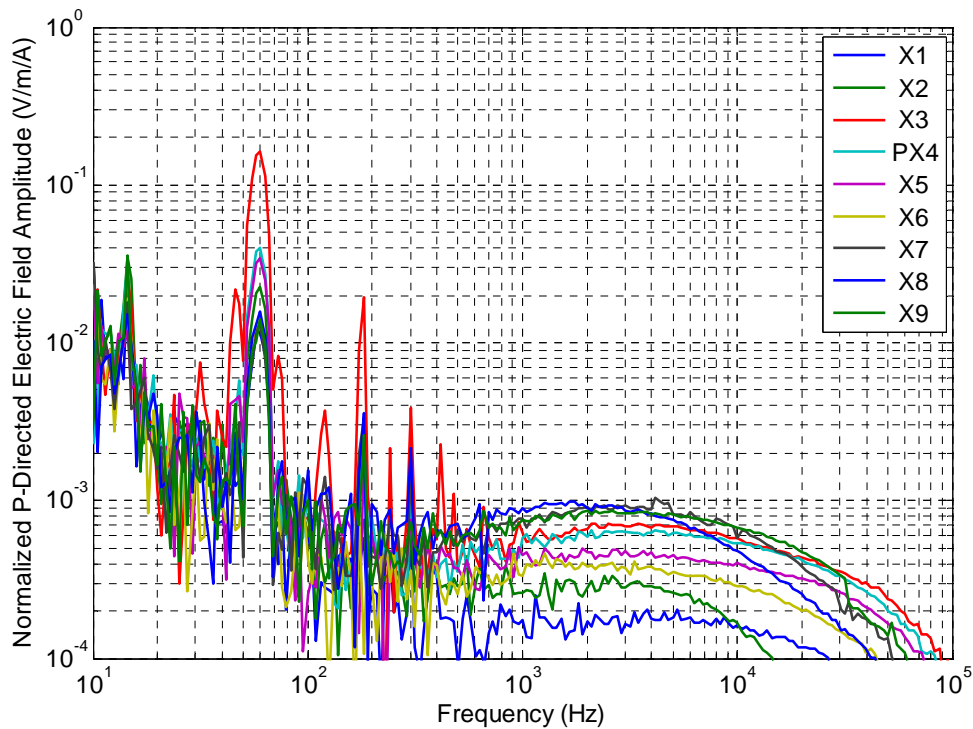


Figure 10-34 Normalized P-Directed Electric Field for X-Directed Surface Current Drive at Positions from X1 to X9.

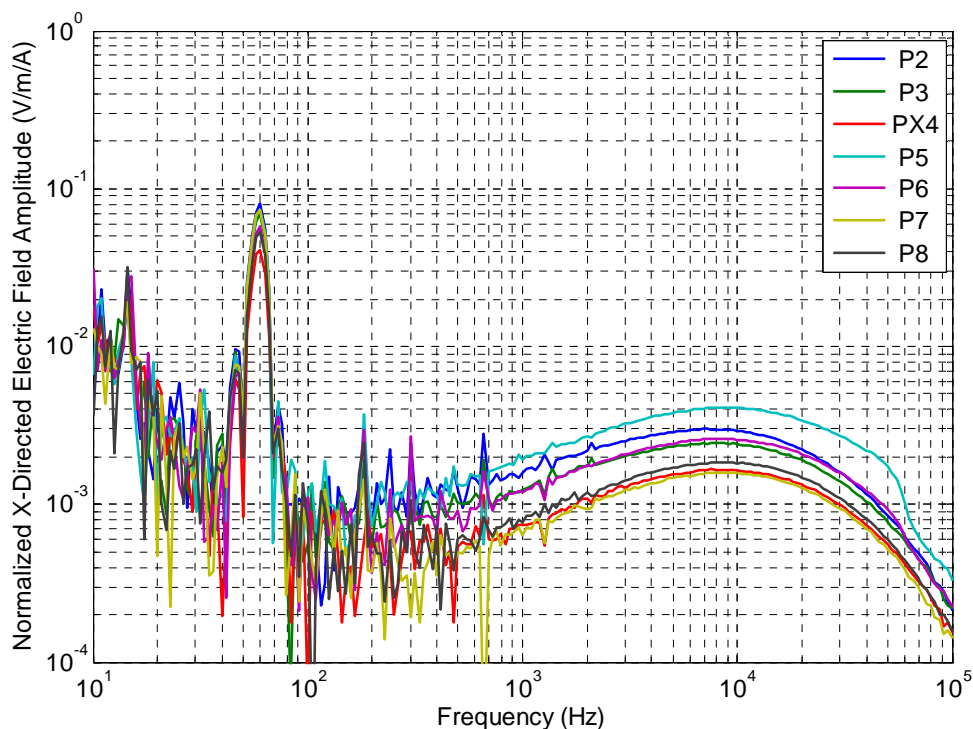


Figure 10-35 Normalized X-Directed Electric Field for X-Directed Surface Current Drive at Positions from P2 to P8.

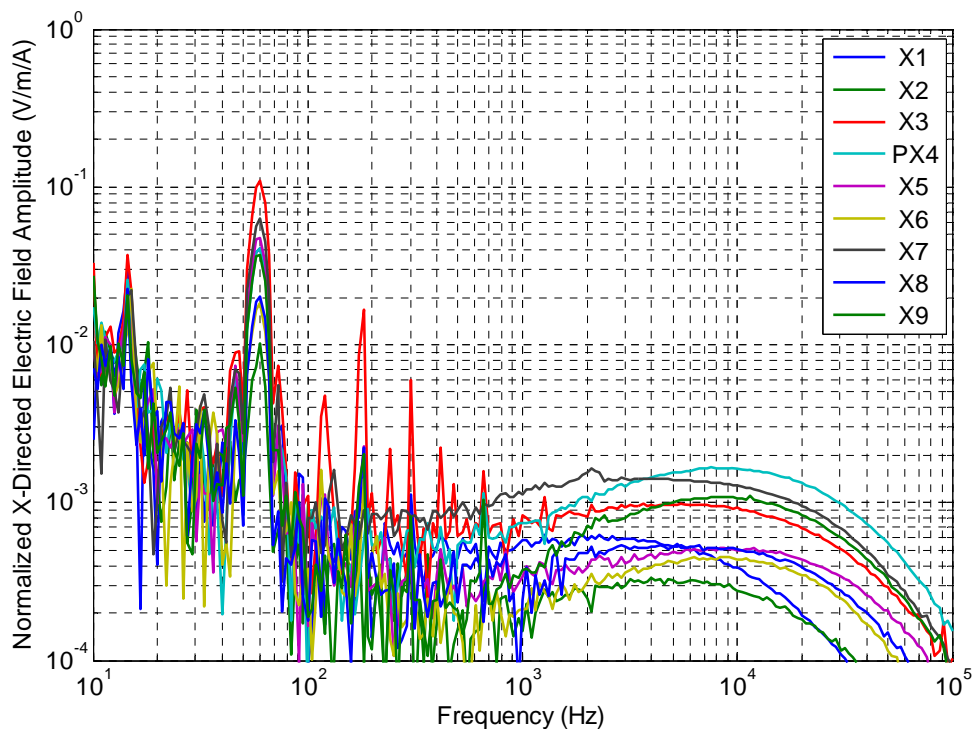


Figure 10-36 Normalized X-Directed Electric Field for X-Directed Surface Current Drive at Positions from X1 to X9.

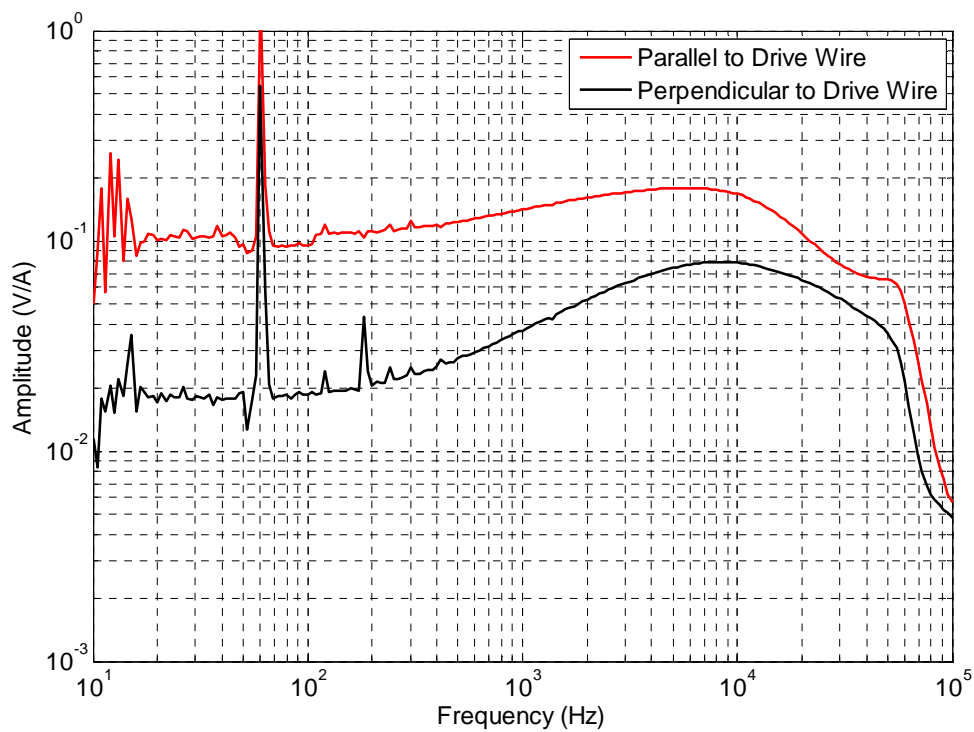


Figure 10-37 Induced Voltage on Pump Cable (~300 m long) due to Wire Current Drives on Surface.

11 Appendix D – List of Underground Sealed Area Coal Mine Explosions Suspected of Lightning Initiation

1. Mary Lee #1 – August 22, 1993, Walker County, AL
2. Oak Grove Mine – April 5, 1994, Jefferson County, AL
3. Gary 50 – Between June 9 and 16, 1995
4. Oak Grove Mine – January 29, 1996, Jefferson County, AL
5. Oasis Contracting Mine # 1 – May 22, 1996, Boone County, WV
6. Oasis Contracting Mine # 1 – June 15, 1996, Boone County, WV
7. Oak Grove Mine – July 9, 1997, Jefferson County, AL
8. Soldier Canyon Mine – July, 2001, Wellington, UT
9. Pinnacle Mine – September 1, 2003, Wyoming County, WV
10. Pinnacle Mine – August 30, 2005, WV, Wyoming County, WV
11. Sago Mine – January 2, 2006, Tallmansville, WV

12 Appendix E – Memorandum from Dr. Krider

Department of Atmospheric Sciences
Institute of Atmospheric Physics



PO Box 210081, Room 542
Tucson, AZ 85721-0081
Telephone: (520) 621-6831
FAX: (520) 621-6833
atmosci@atmo.arizona.edu

MEMORANDUM

Date: 17 April 2007

TO: Matthew B. Higgins
Sandia National Laboratories

From: E. Philip Krider, Ph.D.
Professor and Consultant

On 2 January 2006, an explosion occurred at the Sago coal mine in West Virginia. The NLDN lightning detection network reported two large, positive cloud-to-ground (CG) strokes within 5.5 km of the sealed area of the Sago mine about the time of the explosion.

The data provided by the NLDN show that:

-The first stroke occurred at 06:26:35.523 EST and had an estimated peak current of about +39 kA.

-The estimated uncertainty in the location (50% confidence) was better than 400 meters, and the 99% location uncertainty was better than 1.1 km.

-The second stroke occurred at 6:26:35.680 EST and had an estimated peak current of about +101 kA, with the same location uncertainty as the first stroke.

Further examination of the individual NLDN sensor reports showed no evidence of any other cloud-to-ground strokes during the time-window of interest in proximity to the sealed area of the Sago mine.

There are some limitations in the NLDN lightning detection system. Upward, ground-to-ground discharges, such as are frequently initiated by tall vertical structures, will not be detected by the NLDN if the initial, continuous current phase is not followed by at least one leader-return stroke sequence. Also, the NLDN will not report most intracloud or cloud-to-air discharges, and such flashes often have extensive horizontal development.

Distribution

Internal:

5	MS1152	M. B. Higgins, 1653
2	MS1152	M. E. Morris, 1652
2	MS1182	L. X. Schneider, 1650
3	MS1152	M. Caldwell, 1653
1	MS1152	D. R. Charley, 1653
1	MS1152	L. Martinez, 1653
2	MS9018	Central Technical Files, 08944
2	MS0899	Technical Library, 04536

External:

20	William Helfrich Mine Safety & Health Administration Pittsburgh Safety & Health Technology Center P.O. Box 18233 626 Cochrans Mill Road – Bldg. 151 Pittsburgh, PA 15236
1	E. Philip Krider Institute of Atmospheric Physics The University of Arizona P.O. Box 210081, Rm. 542 1118 E. 4th Street Tucson, AZ 85721-0081
1	Martin A. Uman Department of Electrical and Computer Engineering University of Florida P.O. Box 116200 311 Larsen Hall Gainesville, FL 32611

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division



06AA23(e)

September 7, 2006

MEMORANDUM FOR RICHARD A. GATES
District Manager, CMS&H District 11

THROUGH: *Kelvin K. Wu*
KELVIN K. WU
Acting Chief, Pittsburgh Safety and Health Technology Center

M. Terry Hoch
for M. TERRY HOCH
Chief, Roof Control Division

FROM: *Sandin E. Phillipson*
SANDIN E. PHILLIPSON
Geologist, Roof Control Division

SUBJECT: Evaluation of Possible Lightning Damage to Gas Wells and
Evaluation of Lightning Strike Locations near Wolf Run Coal
Company, Sago Mine, MSHA I. D. No. 46-08791

Observations

August 8 Gas Well Evaluation

As requested by the Sago Accident Investigation Team, selected gas wells were evaluated near Wolf Run Coal Company's Sago Mine on August 8, 2006, to document any visible physical evidence of lightning strikes near the wells or gas lines. The evaluation area was defined by the proximity of gas wells to the 101 kA lightning strike recorded by Vaisala's National Lightning Detection Network on January 2, 2006 at 6:26:35 a.m. The wells were selected for evaluation because they are interconnected via metal gas lines to a main line that runs two miles east, passing a cased gas well adjacent to the abandoned 2nd Left section, where the January 2 explosion occurred. The main gas line and the wells it services are owned by a different company than the well adjacent to 2nd Left, and the well adjacent to 2nd Left may not be directly connected to the metal gas line that services the other wells. The evaluation was conducted to assess the possibility that an unreported lightning branch associated with the 6:26:35 a.m. strike may have struck in the vicinity of a well located 2,800 feet north-northwest of the

6:26:35 a.m. strike location and passed current along the buried metal gas line, traveling approximately two miles to the cased gas well adjacent to the abandoned 2nd Left section, subsequently igniting methane in the sealed area (Figure 1). The obvious limitation on this evaluation is that over seven months of snow, rain, and vegetation growth could have obscured or obliterated physical evidence of a January lightning strike.

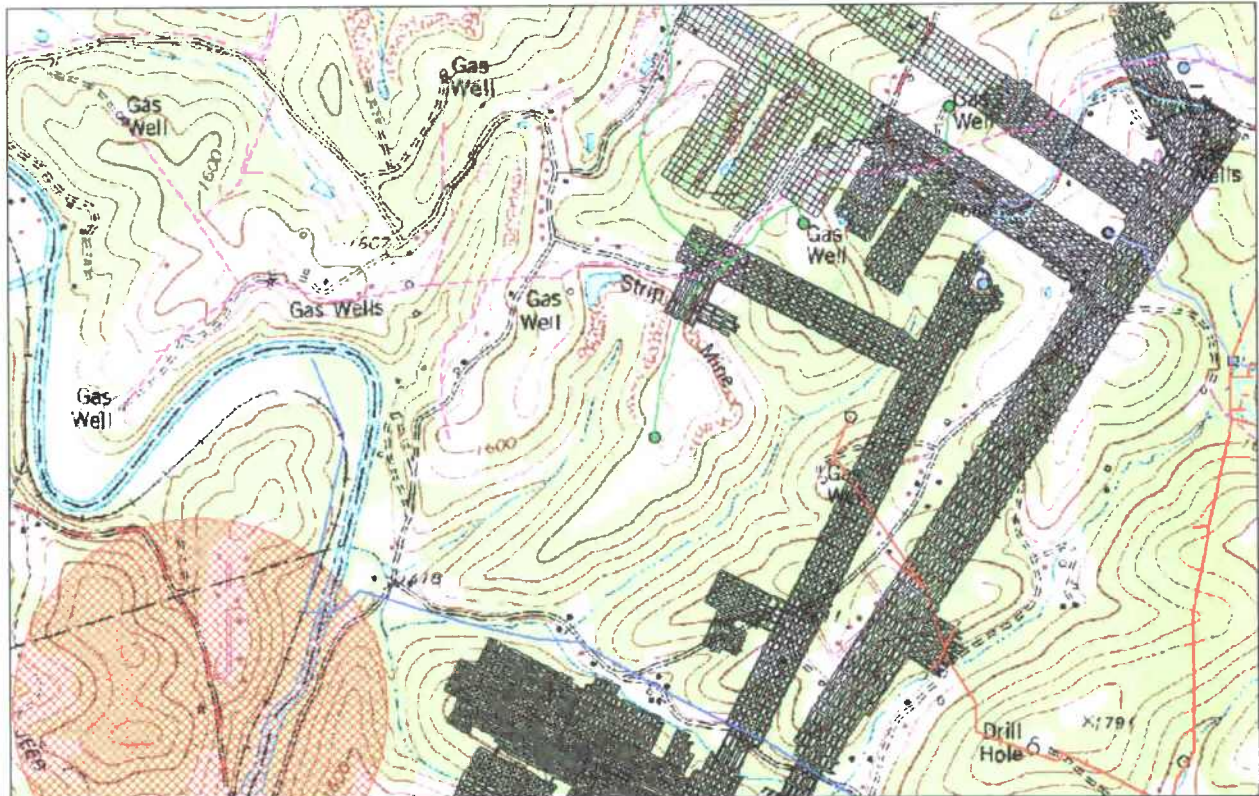


Figure 1. Red star at center of red crosshatch area (highlighting 500-meter 50% confidence interval) indicates position of 101 kA lightning strike reported by Vaisala at 6:26:35 a.m., January 2, 2006. Dashed purple lines represent buried metal gas lines owned by Keyspan. Red, blue, and green lines represent gas lines owned by other companies. Active gas well located on promontory 2,800 feet north-northwest of lightning strike is serviced by purple dashed Keyspan line, which runs approximately two miles east past gas well (light blue dot) that is adjacent to abandoned 2nd Left area.

Observations began at the well located 2,800 feet north-northwest of the lightning strike recorded by Vaisala at 6:26:35 a.m. on January 2, 2006 (Figure 2). No visible damage that might be expected of high heat flow such as searing, discolored metal, or molten/beaded metal was apparent at the gas well, exposed piping, or holding tank (Figure 3). The surrounding area in an approximately 200-foot radius was visually inspected for damaged trees or fulgurite formation (glass formed from melted and recrystallized soil or rock as a result of a lightning strike). No obvious lightning damage to trees was apparent, although some small, dead trees were shedding bark. Additionally, a number of trees, identified as sycamore trees by the mine engineer, were shedding thin sheets of bark, although this appeared to be a common occurrence for

this kind of tree because several in different parts of the observed area were in the same condition. No areas of glassy sand or soil, or holes that might indicate the presence of a fulgurite were noted in the surrounding ground. The ground along the trend of the buried metal gas line was scrutinized for similar possible effects of lightning, but no scarred, scorched, or glassy patches of ground were noted along the length of buried pipe until it connected with the exposed monitoring station approximately 300 feet northeast of the well (Figure 2).

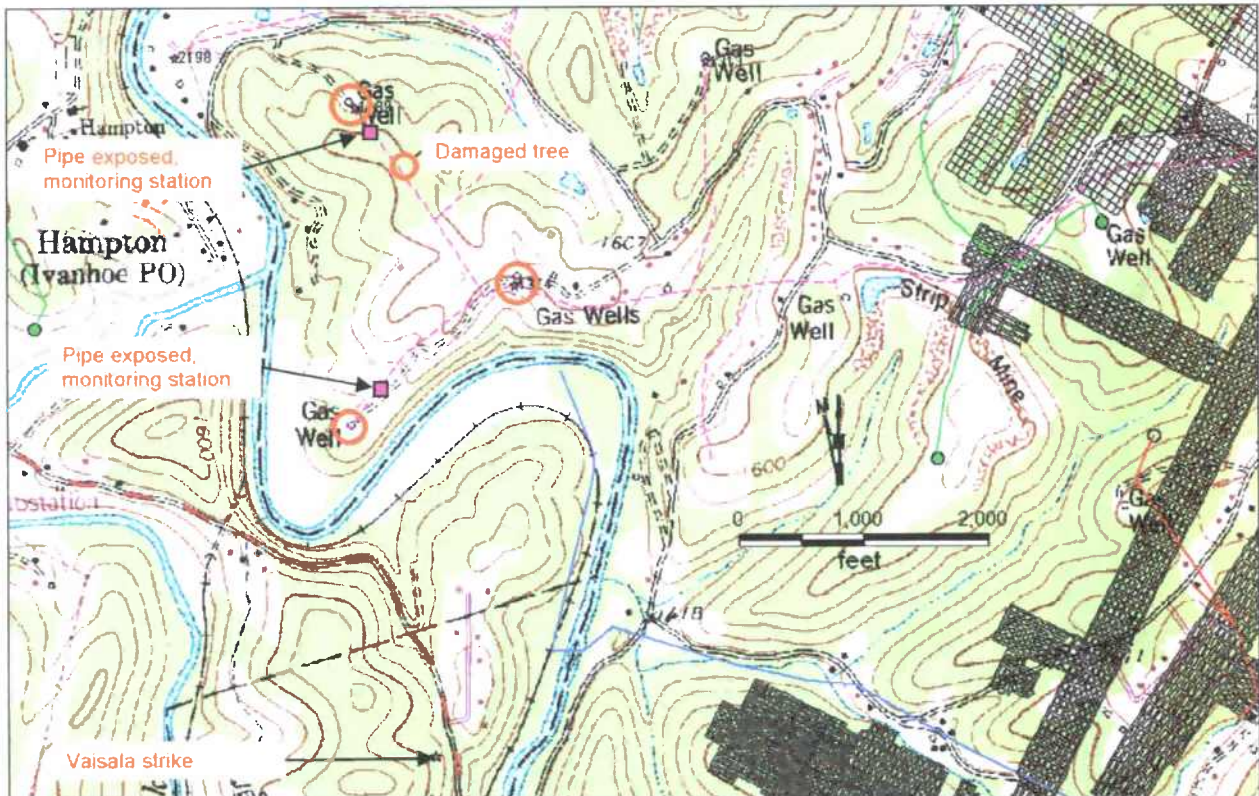


Figure 2. Gas wells (circled red) visited for this evaluation. Purple boxes represent monitoring stations for gas wells where metal gas lines are exposed at surface. A damaged tree was observed along the trend of a connecting gas line (purple dashed line), but appeared to be old damage. No lightning strike was reported at this location on January 2, 2006.

Observations continued along a dirt farm road (shown as a double dashed line on the topographic map), which followed the trend of the buried Keyspan gas line, until connecting with another gas well approximately 1,800 feet northeast of the initial Keyspan well (Figure 2). No evidence of lightning damage was observed at this location, either to the metal well, tank, or piping, or to the surrounding trees or ground. Similarly, no obvious damage such as scorched ground, fulgurite formation, or damaged trees was observed along the length of the buried gas line between the two wells.



Figure 3. Keyspan well located 2,800 feet north-northwest of 6:26:35 a.m. Vaisala lightning strike location that shattered a large tree. Well is serviced by an approximate 3-inch diameter metal pipe that is buried until exposed at a monitoring station 300 feet to the northeast. No evidence of lightning damage was apparent to the metal, or the surrounding trees and ground.

Observations continued on the north side of the hill, where a third Keyspan well was located approximately 2,600 feet Due North of the first well visited, and serviced by a metal pipe from a spur that ties into the line the connects the first two wells (Figure 2). This well did not have an exposed surface tank, although a buried metal pipe trended from the well to a monitoring station approximately 200 feet up the hill slope, where the gas line was exposed. Surface erosion had exposed the rusted metal pipe, which is believed to represent the active gas line (Figure 4). The observation traverse continued up-hill along the trend of the gas line, past the exposed monitoring station, to the top of the hill approximately 600 feet southeast of the well. At the crown of the hilltop, within approximately 50 feet of the buried gas line, a damaged tree was located that appeared to exhibit the effects of a lightning strike (Figures 2 and 5). The damaged tree appeared to represent either an old lightning strike or some other storm damage, although the age of the tree's damage is unknown. The tree was characterized by two forks, one of which was vertical, with a papery, rotten texture pock-marked with insect or bird holes and sloughed-off bark. The other fork was composed of solid but splintered wood, and had fallen to the ground along a cantilever hinge. The wood was weathered brown and appeared to represent an old event, although the age could not be determined.

Subsequent inspection of the locations of lightning strikes in the vicinity of the mine, as recorded by the Vaisala and Weather Decision Technologies networks, discussed below, indicated that no strikes were recorded in this immediate vicinity on January 2, 2006.



Figure 4. Rusted metal gas line exposed by erosion in slope adjacent to third Keyspan gas well visited, located approximately 2,600 feet Due North of the first well. Gas line trends from well to monitoring station approximately 200 feet southeast, and then continues underground to tie in with line that connects first two wells visited (compare to Figures 1 and 2).



Figure 5. Tree along trend of buried metal gas line on hilltop approximately 4,600 feet Due North of 6:26:35 a.m. Vaisala strike location suggests damage by storm or lightning. Unlike the shattered poplar tree near the 6:26:35 a.m. strike location determined by Vaisala's NLDN, this tree did not exhibit blown-off shards or slivers of wood. The age of the damage is unknown. Compare to Figures 1 and 2 for perspective.

Lightning Strike Location Evaluation

In order to more fully evaluate the possibility that lightning may have triggered the January 2nd explosion at the Sago Mine, the locations and times of lightning strikes within an approximate 15-mile radius of the mine were requested from two different lightning detection networks. The explosion site in the abandoned 2nd Left section represented the center of the search area, and includes lightning strikes recorded by

Vaisala, which operates the National Lightning Detection Network (NLDN), and from Weather Decision Technologies, which operates the U. S. Precision Lightning Network (USPLN). These two commercial ventures operate different networks that utilize slightly different methods to locate the positions of lightning strikes.

Figure 6 shows the locations of cloud-to-ground strikes recorded by Vaisala within approximately 15 miles of the abandoned 2nd Left explosion area during the time between 4:00 a.m. and 7:15 a.m. on January 2, 2006. The location points are labeled with the time of the strike, as determined by Vaisala. Of all the lightning strikes recorded during this time frame, only two, both at 6:26:35 a.m., occur anywhere near the vicinity (within six miles) of the explosion site in 2nd Left. A cluster of three strikes located between approximately 4.5-6.25 miles northeast of the abandoned 2nd Left area occurred 12 minutes after the inferred time of the explosion, at 6:38:51 a.m. The next nearest lightning strikes are located approximately 6.5 miles to the south and northwest, but from between approximately 15-30 minutes before the explosion. The strike recorded at 5:57:48 a.m. occurred within ½ mile of a power line that connects to the mine, and is located approximately 4.4 miles south of the mine portal. It is interesting to note that there are several examples of clusters of strike locations that occur at the same time, but are separated by distances of between 0.3-2 miles.

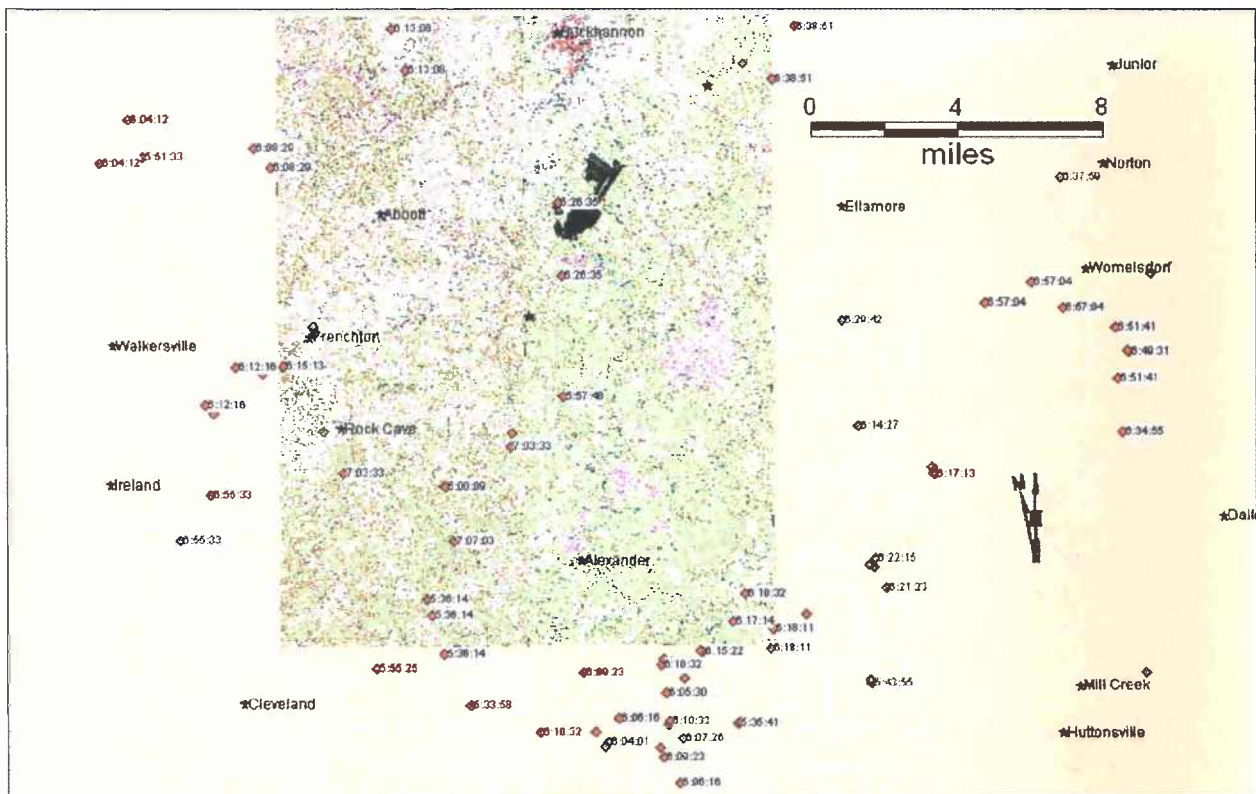


Figure 6. Location of Sago Mine on topographic background, with plotted locations of lightning strikes recorded by Vaisala's NLDN system between 4:00 a.m. and 7:15 a.m. on January 2, 2006 within 15 miles of the 2nd Left explosion site.

Figure 7 shows the locations of cloud-to-ground lightning strikes determined by Weather Decision Technologies, Inc.'s U. S. Precision Lightning Network (USPLN) within approximately 15 miles of the abandoned 2nd Left area during the time frame between 5:30 a.m. and 7:15 a.m. on January 2, 2006. It appears that, similarly to the data reported by Vaisala, the only lightning strike in the vicinity (within six miles) of the 2nd Left section occurred at 6:26:35 a.m. The next nearest strikes, again similarly to that reported by Vaisala, occurred approximately 6.5 miles south and northwest of the explosion site at 5:57:48 a.m. and 6:38:51 a.m., respectively, approximately half an hour before, and 12 minutes after, the explosion.

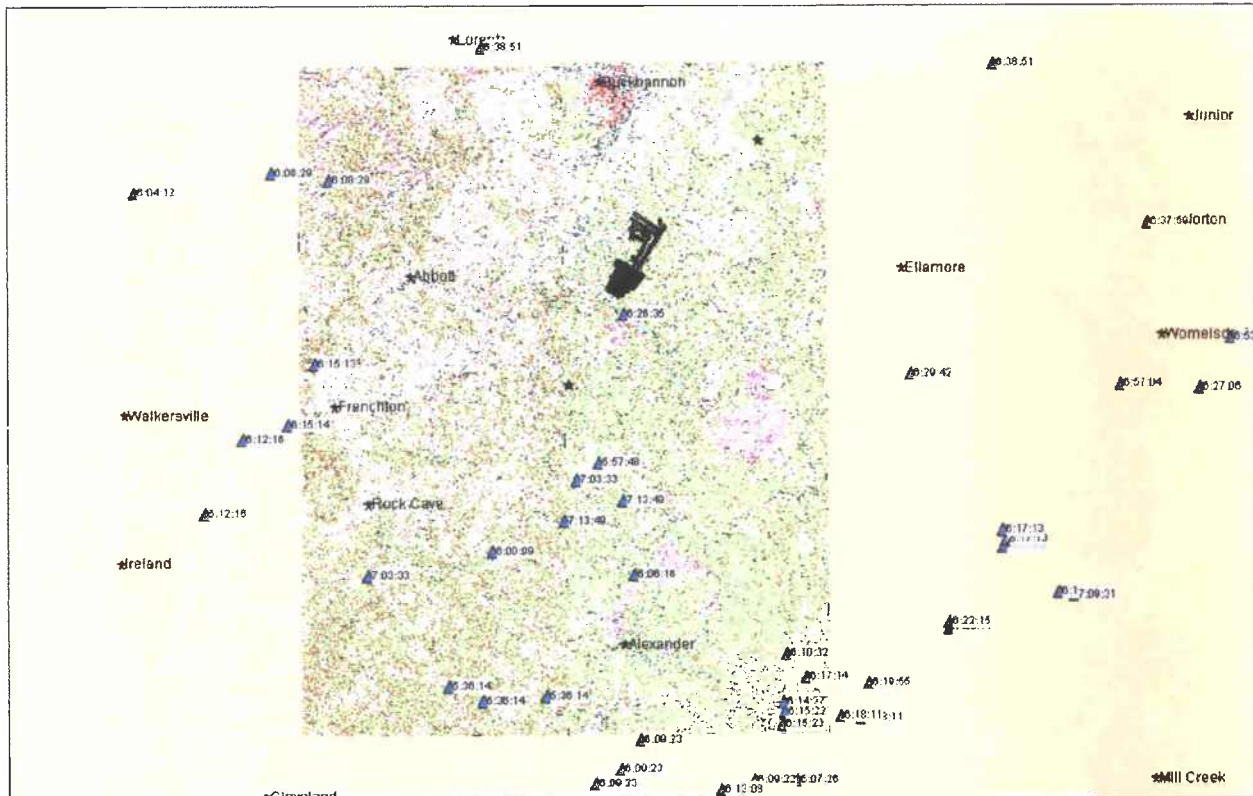


Figure 7. Locations of lightning strikes from USPLN between 5:30 a.m. and 7:15 a.m., January 2, 2006, within approximately 15 miles of the 2nd Left explosion area at Sago Mine.

Figure 8 represents a plot of the lightning strike locations reported by Vaisala's NLDN displayed together with those reported by Weather Decision Technologies' USPLN. It appears that not only are there fewer data points represented by the USPLN records compared to the Vaisala records, but that the data points do not generally display an overlap.

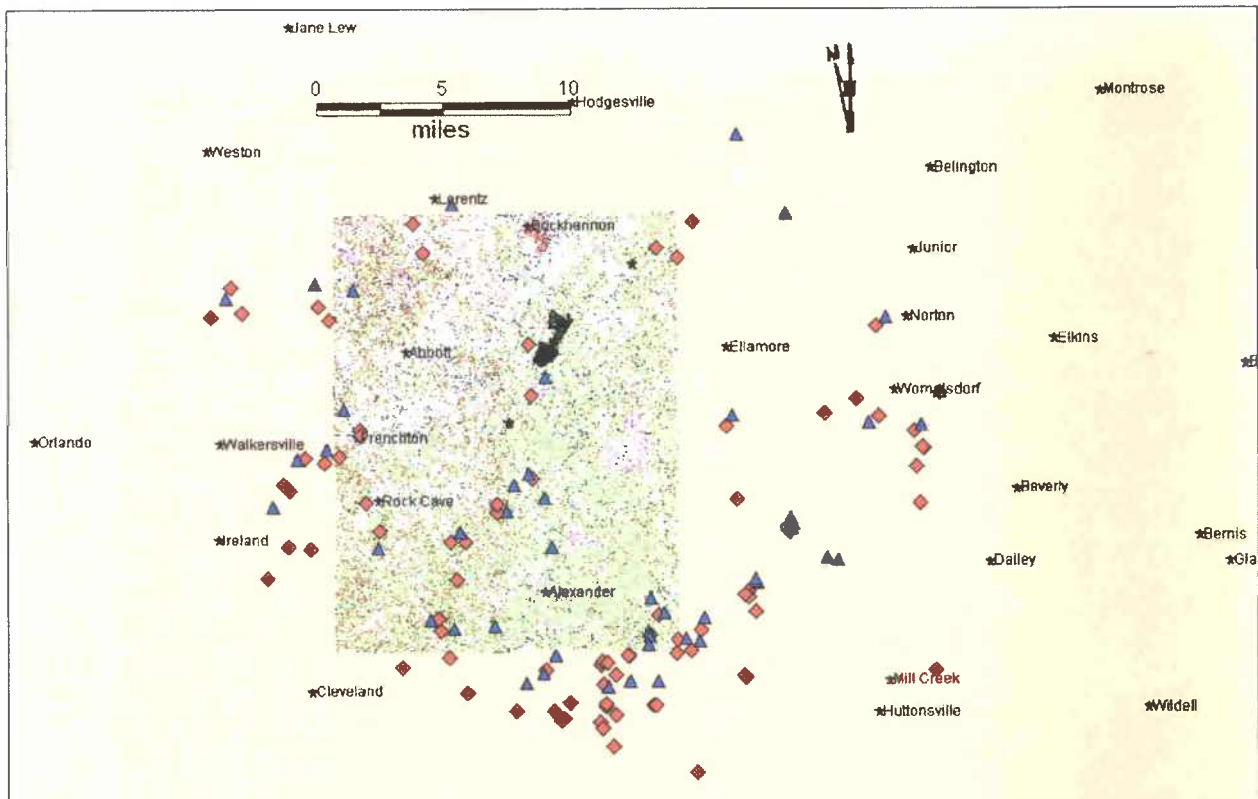


Figure 8. Locations of lightning strikes reported by NLDN (red diamonds) and USPLN (blue triangles) in relation to the Sago Mine between 4:00 a.m. and 7:15 a.m. on January 2, 2006.

Figure 9 represents a closer view of the Sago Mine with lightning strike locations by NLDN and USPLN displayed with their times of record. It appears that many NLDN strikes have a USPLN "mirror" that occurred at the same time, but are located a variable distance to the northeast. This "mirror" effect may be due to differences in detection methods between the two networks. For instance, NLDN records three strikes at 6:38:51 a.m. located approximately five miles northeast of the abandoned 2nd Left section, while the apparently corresponding USPLN strike is recorded approximately 4½ miles to the east-northeast of the three NLDN locations. The NLDN strike reported approximately 1.5 miles south of the Sago Mine portal, at 6:26:35 a.m. has a USPLN "mirror" located approximately one mile northeast of this location, in the bottom of the Buckhannon River valley. Despite the common association of offset locations at the same time, the USPLN system does not report a "mirror" for Vaisala's 6:26:35 a.m. strike located at -80.2331° E / 38.926° N, which is believed to have shattered the large poplar tree just west of the mine.

the recorded 101 kA 6:26:35 a.m. Vaisala strike (-80.2331° E/38.926° N). The time of this tree damage is unknown, though neither lightning detection network plots a strike at this location. The only other tree damage in the vicinity of the gas wells was represented by sycamore trees shedding bark, and this appears to be a natural occurrence.

Although neither lightning detection network indicates the presence of a strike near any of the gas wells visited northwest of the mine, or near the well adjacent to the abandoned 2nd Left section, it may be difficult to rule out the occurrence of an unrecorded strike of lightning. For the time frame and area evaluated, the data recorded by the respective networks do not appear to exhibit good overlapping of locations. For lightning strikes recorded at the same time, the USPLN appears to commonly plot locations a variable distance to the northeast of the same NLDN location. It is impossible to determine which location, if either, can be considered correct. It should be noted that the provided locations probably are not intended to provide precise ground strike locations, but can only provide the triangulated locations of the initiation of radio waves generated by lightning discharge several hundred feet above the ground. Due to the forking and branching commonly observed in lightning strikes, it would therefore be unreasonable to expect that the given locations would correspond to a precise coordinate on the ground. Data point locations indicate that both systems appear to have the capability to resolve separate strikes that occur at the same time to a resolution of within approximately ½ mile. Some strike locations recorded at the same time by Vaisala's NLDN suggest a resolution of 1/3 mile. However, examination of the data suggest that the two different networks have recorded different numbers of strikes, and that for strikes that apparently occurred at the same time, different peak currents and different locations were reported by the two systems. This is an indication that although the lightning detection systems are capable of providing a general location for lightning strikes, it may be unrealistic to assume that every lightning strike in a multiple discharge will be recorded, or that a location can be determined for every strike.

It is interesting to note that the USPLN system recorded a "mirror" for the NLDN strike that occurred approximately one mile south of the Sago Mine portal. Vaisala's NLDN system recorded this strike at 6:26:35 a.m., with a peak current of 38.8 kA at -80.2313° E / 38.8968° N. Weather Decision Technologies' USPLN system apparently recorded the same strike at 6:26:35 a.m., but with a slightly different peak current of 35 kA and in a location 4,900 feet to the northeast, at -80.2209°E / 38.9072° N. Similarly, the NLDN system recorded a strike at 5:57:48 a.m. with a peak current of 25.1 kA at -80.231° E / 38.8487° N, located approximately 4.5 miles south of the mine portal. The USPLN system apparently recorded the same strike at 5:57:48 a.m., but with a peak current of 24.6 kA at -80.2336° E / 38.8514° N, which is approximately 1,200 feet northwest of the NLDN location. These recorded positions are within approximately 2,800 feet of a power line that runs north past the Sago Mine. At 6:38:51 a.m., 12 minutes after the

inferred time of the explosion, the NLDN reported a cluster of three strikes with peak currents of 85.7, -86, and -12.6 kA between approximately 4.5-6.25 miles northeast of the abandoned 2nd Left section. The USPLN system appears to have recorded the same strikes as a single event, reported with a peak current of 93 kA, but located approximately 4.3 miles east-northeast of the NLDN cluster. In contrast, the NLDN strike that was recorded at 6:26:35 a.m. with a peak current of 101 kA at -80.2331° E / 38.926° N, which is within 200 feet of a shattered poplar tree just west of the Sago Mine, does not have a corresponding “mirror” reported by the USPLN system.

The apparent lack of precision or consistency in the lightning location data makes it difficult to exclude the possibility that an unrecorded lightning strike at 6:26:35 a.m. could have struck one of the gas wells north of Vaisala’s NLDN reported 101 kA strike location. No physical evidence of lightning damage was found in the vicinity of the gas wells and gas lines observed, and no lightning strikes were recorded by either lightning detection network in the immediate vicinity of any of the gas wells visited. A damaged tree was observed near a metal gas line in the evaluation area, but the time of damage is unknown.

If you should have any questions regarding this report, or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.



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August 29, 2006

VIA OVERNIGHT COURIER

Richard A. Gates
District Manager
U.S. Department of Labor
Mine Safety and Health Administration
135 Gemini Circle, Suite 213
Birmingham, AL 35209

Re: Sago Investigation

Dear Mr. Gates:

Enclosed for your information is the report of hydroGeophysics, Inc. on both phases of their work.

If you have any questions, please free to contact me.

Sincerely,



R. Henry Moore

RHM/dab
Enclosure

cc: Johnny Stemple
R. Nicholson, Esq
Laura E. Beverage, Esq.
Sam Kitts
Charles Dunbar
(all w/o encl.)

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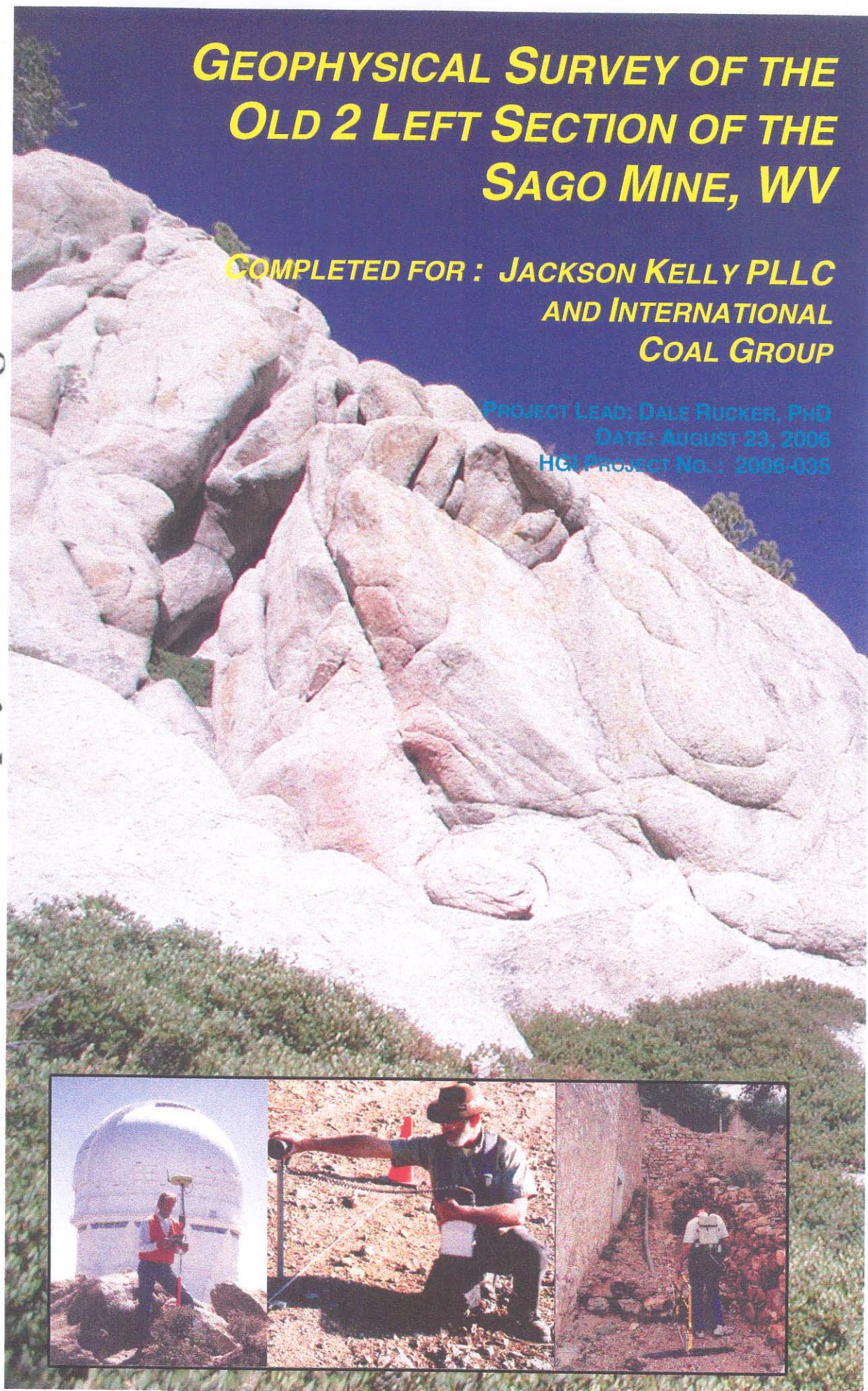
hydroGEOPHYSICS, Inc.

Geophysical Consulting and Services

GEOPHYSICAL SURVEY OF THE OLD 2 LEFT SECTION OF THE SAGO MINE, WV

**COMPLETED FOR : JACKSON KELLY PLLC
AND INTERNATIONAL
COAL GROUP**

**PROJECT LEAD: DALE RUCKER, PhD
DATE: AUGUST 23, 2006
HGI PROJECT No. : 2006-035**



Geophysical Survey for the Old 2 Left
Section of the Sago Mine,
Buckhannon, WV

Primary Investigator:
Dale Rucker, PhD

Contributing Investigators of Significant Importance:
Marc Levitt
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18 August 2006

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EXECUTIVE SUMMARY

hydroGEOPHYSICS, Inc. (HGI) was contracted with International Coal Group (ICG) and its representatives to conduct a geophysical investigation at the Old 2 Left section of the Sago Mine located near Buckhannon, West Virginia. The geophysical investigation was prompted following an explosion that occurred in a sealed area of the mine in January 2006. It is suspected that the explosion was caused by a lightning strike on the surface near the mine. However, a specific electrical path from the surface to the underground mine is unknown. The objective of the geophysical investigation was to characterize and map subsurface conditions in order to determine if a specific electrical pathway exists. The electrical path could have originated from anthropogenic or geologic features.

The anthropogenic features include metallic infrastructure from pipelines, wells, power lines, or other features that could have provided an ohmic conduction mechanism for electrical current to travel from the surface to the mine. Geologic features provide an electrolytic conduction mechanism for current travel. The electrolytic conduction relies on ionic movement within the pore space and along soil grain surfaces to transmit ions. More free ions in a pore space allows for greater current to flow, thereby reducing the electrical resistivity.

The investigation was conducted in two phases. The first phase (Phase I) included the mapping of anthropogenic features directly above the Old 2 Left section of the Sago Mine using magnetic gradiometry (MAG) and electromagnetic induction (EM). The MAG and EM mapping were carried out by either mounting the instruments on a cart, or by manually carrying the instruments in more topographically challenging areas.

Phase II consisted of completing a High Resolution Resistivity (HRR) survey to characterize the electrical properties specifically within the area of concern. The resistivity survey was completed by measuring the electric potential on a series of electrodes while injecting current on a nearby electrode. The survey was arranged such that a set of electrodes at the surface could be used in combination with electrodes on the roof of the mine. The connection of the two electrode sets was facilitated by an existing nearby borehole.

The main conclusions of the survey are:

- The total field magnetic results showed no unknown boreholes within the survey area that could have acted as a vertical conduit for current generated through a lightning strike to reach the mine elevation.
- The gradient magnetic results also showed no unknown boreholes within the surveyed areas.
- The EM conductivity results showed no vertical well casings in the surveyed areas.

- The EM in-phase results showed no unknown vertical well casings in the surveyed areas.
- The HRR results revealed no compelling vertically oriented conductive zone that could have acted as a conduit for current generated from a lightning strike to reach the mine.

1.0 Introduction

An explosion occurred in a sealed area of the Sago Mine in January 2006. It is postulated that the explosion originated from a spark generated by electrical current during a lightning strike at the surface and near the mine area where the explosion occurred. The electrical connectivity from the surface to the mine is unknown. A geophysical survey was conducted to map the subsurface electrical properties to determine an electrical path.

The electrical path could have originated from anthropogenic or naturally occurring geologic features. The anthropogenic features include metallic infrastructure such as pipelines, wells, buried power lines, or other cultural features that could have provided an ohmic conduction mechanism for electrical current to travel from the surface to the mine. A geophysical survey that relies on induced fields to map the magnetic and electrical properties of the near surface (top 20-30 feet) is capable of finding all major relevant conductors within the areas surveyed.

Geologic features provide an electrolytic conduction mechanism for current travel. The electrolytic conduction relies on ionic movement within the pore space and along soil grain surfaces to transmit ions. More free ions in a pore space allow for greater current to flow, thereby reducing the electrical resistivity. Factors affecting the resistivity include soil type (clay or shale vs. sand), moisture, and salt or metallic mineral content. Direct current resistivity is capable of mapping the subsurface to differentiate zones of low and high electrical resistivity.

1.1 Site Location

Located in north-central West Virginia, the current working mine portal (for the Sago Mine) is approximately 6 miles south of the town of Buckhannon. Plate 1, (Appendix A), shows the extent of the MAG and EM surveyed area. The area of concentrated interest for the geophysical survey was the Old 2 Left section, located at the northern end of the mine boundary.

1.2 Objective of Investigation

The objective of the geophysical investigation was to characterize and map subsurface properties to determine if an electrical path exists from the surface, above the Old 2 Left section of the Sago Mine, to the underground mine elevation.

1.3 Scope of Investigation

The investigation was conducted in two phases. The first phase (Phase I) included the mapping of anthropogenic features directly above the Old 2 Left section using MAG and EM. These instruments were cart-mounted for areas that were relatively flat with respect to the topography. Steeper topography or land that had high density vegetation required the instruments to be manually carried.

Phase II consisted of HRR data acquisition in order to map the subsurface electrical properties as related to geologic conditions. The HRR survey was completed by measuring the electric potential along a series of electrodes while a low voltage signal was injected at nearby electrodes. The survey was conducted such that a set of electrodes on the ground could be used in conjunction with roof bolts as subsurface electrodes along the mine's roof. The combination of the two electrode sets was facilitated by an access borehole.

The surface electrodes were placed at 15 foot intervals along a single transect. The roof bolts in the mine roof were used as the electrodes in the mine, and their spacing was variable depending on access and proximity to other infrastructure, such as wire meshing. A total of 112 electrodes were used on the surface and underground.

2.0 Methodology

2.1 Survey Area & Logistics

Data acquisition for this project was planned as a two-phase operation. During the Phase I portion, anthropogenic features in the area directly above the Old 2 Left section of the Sago Mine were mapped using MAG and EM instrumentation. Phase II of the project consisted of a HRR survey that was carried out in a focused area of concern within the MAG and EM areas.

Phase I mobilization commenced on June 12, 2006. Before field work was initiated, unrestricted access to all privately held areas was secured by ICG. The survey areas were located mostly in open grassy fields. Due to high traffic load, a road separating the northern portion of the survey from the southern portion was avoided.

A single-wheeled, fiberglass push cart was used to mount the MAG and EM instruments for simultaneous acquisition of both sets of data within areas of low topographic relief. Figure 1 shows the set up for the cart. Both instruments were connected to a common datalogger for time stamped, real-time data storage. A global positioning system (GPS) was used to geo-reference all the data, which was also attached to the datalogger.

Shortly after the Phase I surveys were started, technical difficulties that could not be resolved in the field necessitated HGI personnel to return to Tucson before all areas could be completely surveyed. Completion of the Phase I surveys was accomplished during the Phase II mobilization for the HRR surveys.

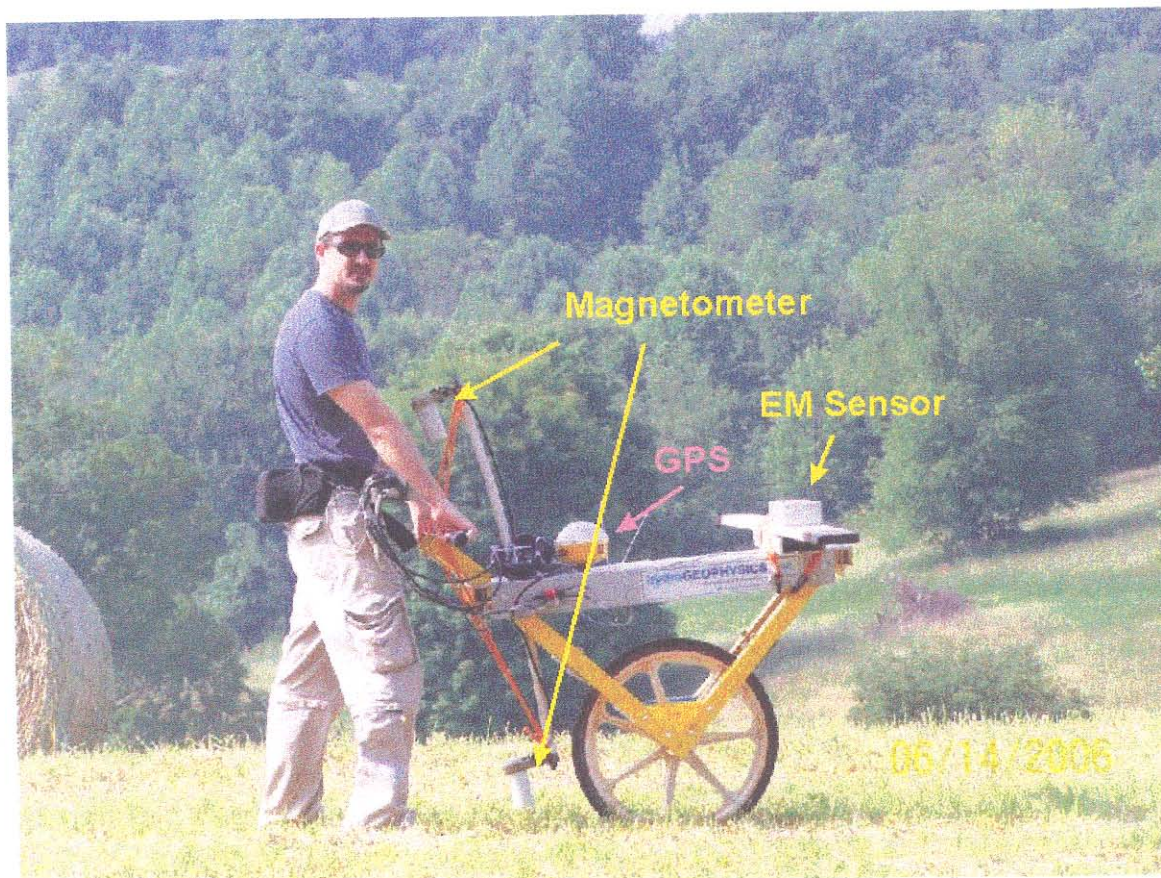


Figure 1. Push cart for simultaneous EM and MAG data acquisition. Dr. Dale Rucker

Phase II mobilization, to conduct the HRR surveys and the completion of MAG and EM data acquisition, commenced on July 17, 2006. To collect the HRR data, two sets of HRR electrodes were used: one set on the surface and one underground. The HRR survey was located in the vicinity of the suspected ignition site of the January 2006 methane explosion. The surface electrodes were installed at 15 foot intervals and the transmitter and receiver remote reference electrodes were deployed approximately 3,000 feet away. The underground HRR line used mine roof bolts for the same purpose. The spacing for the bolts varied. Figure 2 shows a schematic of the layout for the two sets of electrodes.

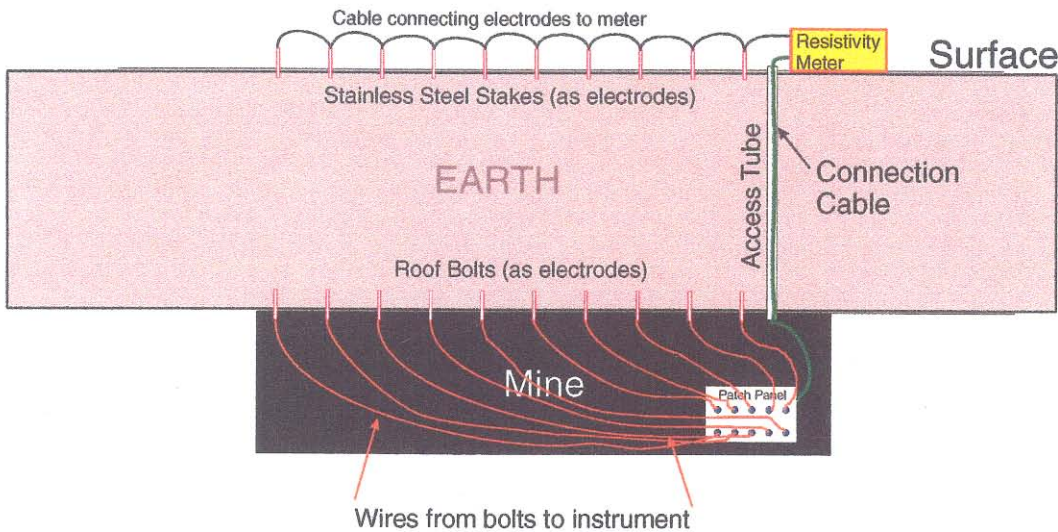


Figure 2. Schematic of the HRR line and equipment placement for the Sago resistivity survey.

Figure 3 shows the location of the surface array, overlain on an oblique photograph of the area. The surface line was approximately 825 feet long and consisted of 56 electrodes that were spaced at 15 foot intervals. The 4010 access borehole was used to connect the surface resistivity electrodes to the underground electrodes.



Figure 3. Photo of HRR survey line area. View is towards the east.

To conduct the subsurface HRR survey, entrance to the Sago Mine was required by HGI personnel to connect a multi-channel patch panel to the surface geophysical equipment, surface electrodes, and subsurface roof bolts. This necessitated HGI field engineer Shawn Calendine to complete mandatory underground coal mine hazard training. Certification of the completed ICG sponsored training was received on July 19, 2006. On the same day, the HGI field engineer was issued an ICG jumpsuit, steel toed boots, and a Self Contained Self Rescuer (SCSR) and escorted to the underground site by two MSHA officials and two ICG officials.

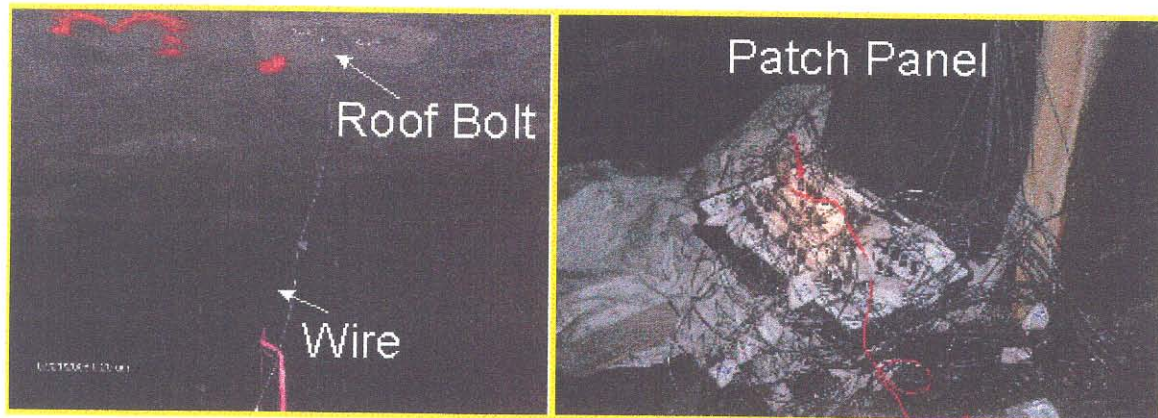


Figure 4. Photos of the underground roof bolts, wire leads, and patch panel equipment.

During Phase II, HRR data were acquired using an eight-channel, earth resistivity instrument. The resistivity instrument was connected to the subsurface HRR line via two, 150 meter long cables that were lowered through the 4010 access hole. The two cables were attached to a 56-channel patch panel (Model HRR-56PP, HGI, Tucson, AZ) that connected the roof bolt electrodes and their associated 56 wires. Figure 4 shows photographs of the underground setup. The HRR survey line end points and the electrode locations of each line were geographically surveyed by an ICG contractor. HRR data acquisition began on the morning of July 20, 2006 and was completed on the same day at approximately 8:00 pm.

On the morning of July 21, 2006, the 56 channel patch panel was retrieved from the mine by ICG employees, the two extension cables were pulled from the borehole using a crane, and all other cabling and electrodes were retrieved from the surface. Figure 5 shows the operations necessary to retrieve the cables, which weighed approximately 90 pounds each.

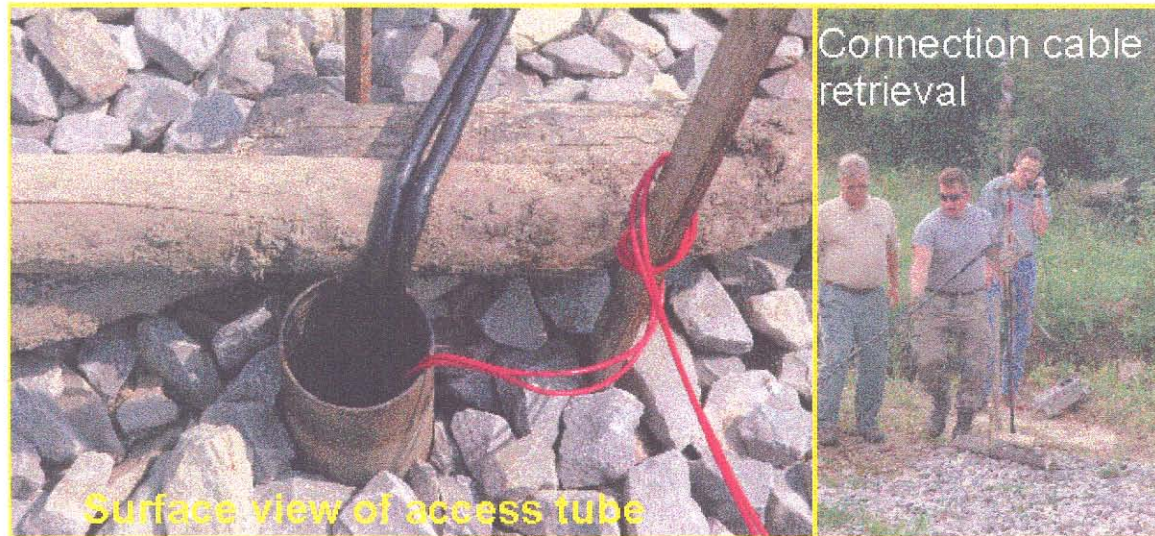


Figure 5. Photos of the cable retrieval operations.

Phase I MAG and EM surveys were reinitiated on July 25, 2006. Due to the highly uneven terrain at the site, the push-cart could not be used for most areas. Consequently, data for 12 of the 18 acres of the Phase I survey were acquired by individually walking with the equipment along pre-determined transects. To ensure the acquisition of high quality data, field personnel removed all metal from clothes and pockets, wore non-metallic personal protective equipment including non-metallic, composite-toed boots, leather gloves, and non-metallic protective eyewear. All Phase I MAG and EM surveys were completed by July 30, 2006.

2.2 Equipment

In order to fully maximize geophysical characterization efforts, HGI employed three different geophysical methods at the subject site, which required four different geophysical instruments.

2.2.1 Magnetometry and Electromagnetic Induction

Total Field Magnetometry

For the magnetic investigation, a proton procession magnetometer (Model G-856, Geometrics, Inc., San Jose, CA) was used for the base station to monitor diurnal variations within the ambient earth's magnetic field. The magnetometer consists of a kerosene-filled sensor, which is connected to a datalogger and 12V battery. Data were typically recorded at a sampling rate of 0.1 Hz (one data point every 10 seconds). At the end of each day, the data were downloaded to a laptop computer for processing and analysis.

A cesium-vapor magnetic gradiometer (Model G-858/G, Geometrics, Inc., San Jose, CA) was used to acquire the total magnetic field and magnetic gradient data across the site. The G-858/G was operated as a dual sensor gradiometer with the sensors oriented vertically with a static separation of one meter. The lower sensor was positioned approximately 30 centimeters from the ground surface. A data logger and control console were used to store the data and monitor data acquisition. Data were recorded at discrete time intervals, equating to a frequency of 5 Hz with an accuracy of 0.2 nanoteslas (nT). Time, date, and magnetic readings were recorded digitally and later downloaded to a laptop PC for processing.

Magnetic data were processed using specialized proprietary and commercial software, such as MAGMAPPER (Geometrics, Inc., San Jose, CA) and Surfer (Golden Software, Golden, CO). Processing included diurnal correction, drift removal, spike removal, data interpolation, and, where needed, filtering. A two-dimensional surface was derived that best fits long-wavelength components within the data. This crucial step (high-pass filtering) effectively removes the regional magnetic field and augments localized anomalies. The resulting map clearly delineates magnetic anomalies and may be compared with results of other geophysical methods (such as EM) to accurately locate specific subsurface objects.

Frequency-Domain Electromagnetics

Electromagnetic data were acquired using a co-planar, two-coil, vertical-axis frequency-domain, electromagnetic conductivity and susceptibility instrument (Model GEM-2, Geophex, Ltd., Raleigh, NC). The GEM-2 consists of a transmitter and a receiver coil separated 1.66 meters, a sensor housing (ski), and electronics console. During data collection the ski was oriented so that the transmitter and receiving coils were parallel to the direction of traverses (in-line). Both in-phase (real) and quadrature (imaginary) component data were acquired simultaneously at 5 frequencies ranging from 5kHz to 20 kHz. The electromagnetic data were converted to electrical conductivity using WinGEM software (Geophex, Ltd.).

Global Positioning System (GPS) Surveying

Geospatial control for the MAG and EM surveys was established using a real-time, differentially-corrected, single receiver, navigation system (Model AgGPS 132, Trimble Navigation, Ltd., Sunnyvale, CA). The GPS was connected directly to the G-858G console for data logging capabilities. The sampling rate of the GPS was fixed at one Hz. The AgGPS 132 provides sub-meter accuracy.

2.2.2 High Resolution Resistivity (HRR)

HRR data were acquired using an eight-channel resistivity instrument (Model SuperSting R-8 IP, Advanced Geosciences, Inc, Austin, TX). The SuperSting R-8 IP is a DC-

powered, battery operated, low voltage, low amperage, automatic, eight-channel, resistivity and induced polarization (IP) system. This system employs the SuperSting Swift general purpose cables that can be attached in series. Each cable segment contains four smart electrodes. Each electrode has the capability of acting as either a low-amperage current transmitter or as voltage potential measuring receiver.

The SuperSting R-8 IP has the capability of automatically switching between electrodes without physically changing the electrode connections after initial set-up. Automatic switching decreases physical labor, cuts down on human transcription and tracking errors, better allows the operator to control array logistics, and increases the rate and density of data acquired. HGI personnel took advantage of this capability and programmed the SuperSting R-8 IP to use a survey line spread of 112 smart electrodes with inter-electrode spacings ranging from 15 to 825 feet. All data were acquired using a pole-pole electrode configuration.

2.3 Data Processing

2.3.1 Magnetometry

Data processing for the total-field magnetic data began with geo-referencing with respect to the differential GPS data. The GPS data were recorded at a sampling rate of 1 Hz, whereas the G-858/G magnetic data were recorded at a rate of 5 Hz. Linear interpolation was used to geo-reference every magnetic data point based on the time stamp.

After geo-referencing, the total-field magnetic data were corrected for diurnal variations in the earth's magnetic field. The G-856 magnetic data were used for removing these variations by subtracting the base station data from the G-858 roving data. Before diurnal corrections, however, the G-856 base station data were de-spiked and filtered with a low-pass filter to remove high frequency noise.

The last step in time-series filtering of the total-field magnetic data involved the removal of the heading error. Heading errors result in the preferential alignment of the sensors in the earth's magnetic field, which will cause anomalous readings unrelated to any response from buried metallic debris. Heading error was calculated from magnetic data collected in eight distinct directions. A curve was fit for direction of travel versus field strength, which was subsequently subtracted from the data.

After correcting the G-858/G magnetic data for each of the time-series issues, the data were compiled spatially and passed through a low-pass one-dimensional (1-D) spatial filter to remove high frequency noise. Coincident data points (within 0.03 m) were removed to eliminate redundancy.

2.3.2 Electromagnetic Induction

The GEM-2 measures both in-phase and quadrature components of the electromagnetic signal. Typically, the in-phase is related to the magnetic susceptibility and the quadrature is related to the subsurface electrical conductivity, each of which are a function of signal frequency, vertical separation between the coils and the ground, coil orientation

(horizontal or vertical), and coil separation. EM measurements were made at five transmitter frequencies; 5, 7.5, 10, 15, and 20 kHz.

The first step in processing the EM data is geo-referencing of each data point with the differential GPS. The GPS data were recorded at a sampling rate of 1 Hz, whereas the GEM-2 EM data were recorded at a sampling rate of 3 Hz. Linear interpolation was used to geo-reference each data point based on the time stamp.

After geo-referencing, measured in-phase and quadrature data were transformed to in-phase susceptibility and conductivity using an inversion algorithm provided to HGI by Geophex, Ltd. The inversion produced in-phase susceptibility and electrical conductivity values as a function of each of the transmitter frequencies and a total average, frequency independent electrical conductivity. Additional corrections were made to compensate for instrumental drift associated with environmental factors and daily setup differences.

After inverting the data and correcting for drift, the data were compiled spatially and passed through a low-pass one-dimensional spatial filter to remove high frequency noise. Coincident data points (within 0.03 m) were removed to eliminate redundancy.

2.3.3 Tomographic Inversion of Electrical Resistivity

Inversion involves calculating the distribution of true electrical resistivities of the subsurface that give rise to the measured apparent resistivity distribution according to the governing equation:

$$\frac{\partial}{\partial x} \left(\frac{1}{\rho} \frac{\partial V}{\partial x} \right) + \frac{\partial}{\partial x} \left(\frac{1}{\rho} \frac{\partial V}{\partial x} \right) + I = 0.$$

The objective of the inversion is to obtain an electrical property section that lends itself to enhanced interpretability as it relates to the geological properties of the survey area. Several methods of inversion are presented in Oldenburg and Li (1994), Loke and Barker (1995), and LaBrecque et al. (1996).

The Sago Mine site provided a unique opportunity to conduct resistivity surveys to characterize the electrical properties of the study area using both surface and subsurface electrodes. Roof bolts within the mine workings were used as additional subsurface electrodes that would augment measurements made with surface electrodes. The motivation behind this approach was that the additional subsurface measurements would enhance resolution.

To investigate the utility and enhanced resolution afforded by subsurface electrodes, a modeling exercise was conducted. Using the same model geometry as illustrated in the following examples, a simulation was carried out to generate a set of synthetic field measurements that would be obtained using all possible combinations of 112 (56 surface and 56 subsurface) electrodes.

Figure 6 shows an example of tomographic inversion for an idealized horizontally oriented 10 ohm-m conductive unit in a more resistive 100 ohm-m homogeneous host rock. The top figure shows the schematic of the model. The middle figure shows the resulting measured field data that the earth would generate for the given geologic model. The data are plotted as a standard pseudosection showing contours of apparent resistivity (See Geophysical Theory explanation in Appendix A). The bottom figure shows the resulting inverted representative resistivity section. As can be seen in the inverted section, the conductive unit is clearly visible in the more electrically resistive host rock.

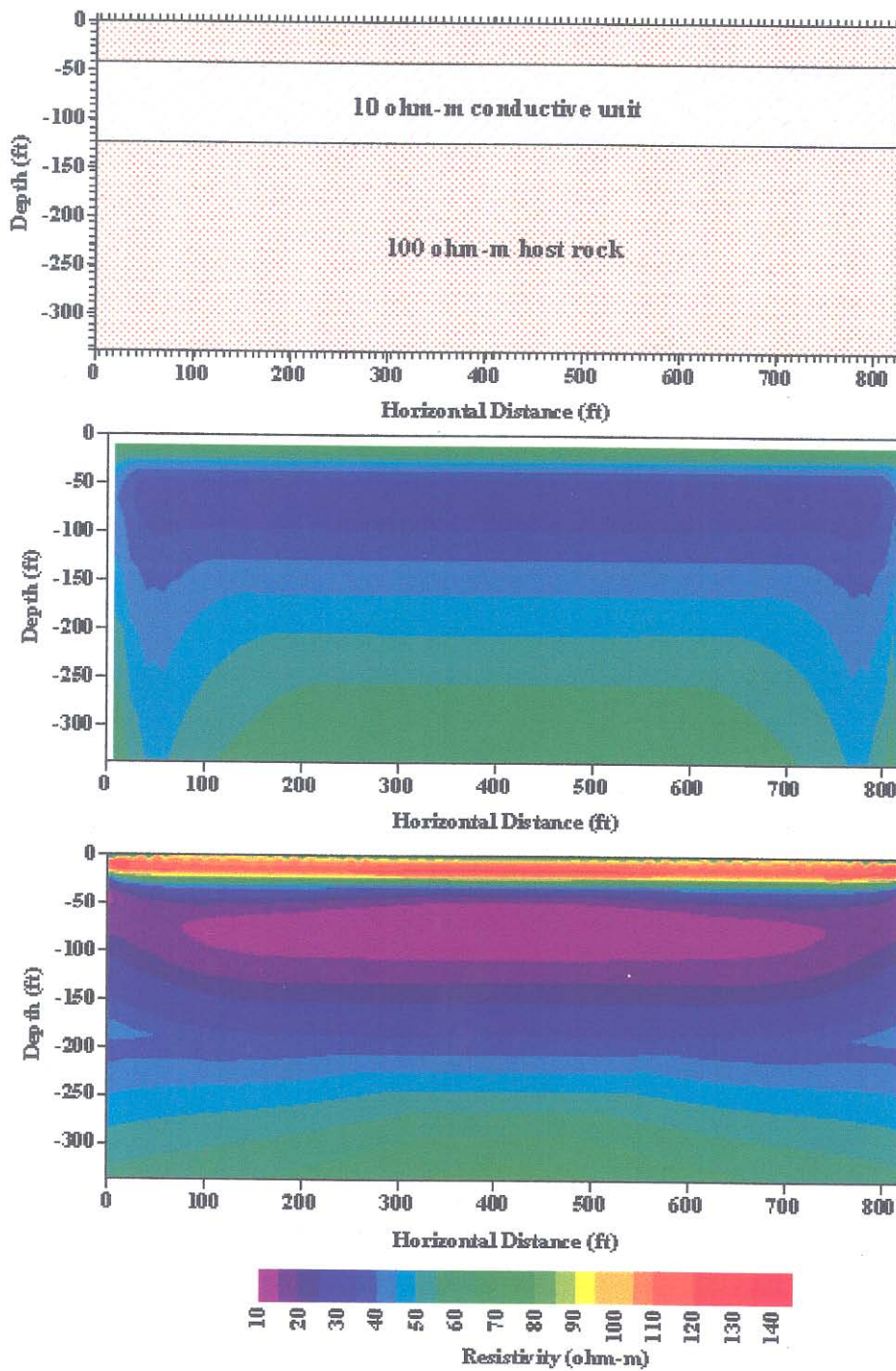


Figure 6. Tomographic inversion for a horizontally oriented conductive unit within a resistive host rock based on measurements made using surface electrodes. Top) Geologic representation of the subsurface, Middle) Measured apparent resistivity of the subsurface, Bottom) Tomographic inversion of the data to reconstruct the subsurface from the measurements.

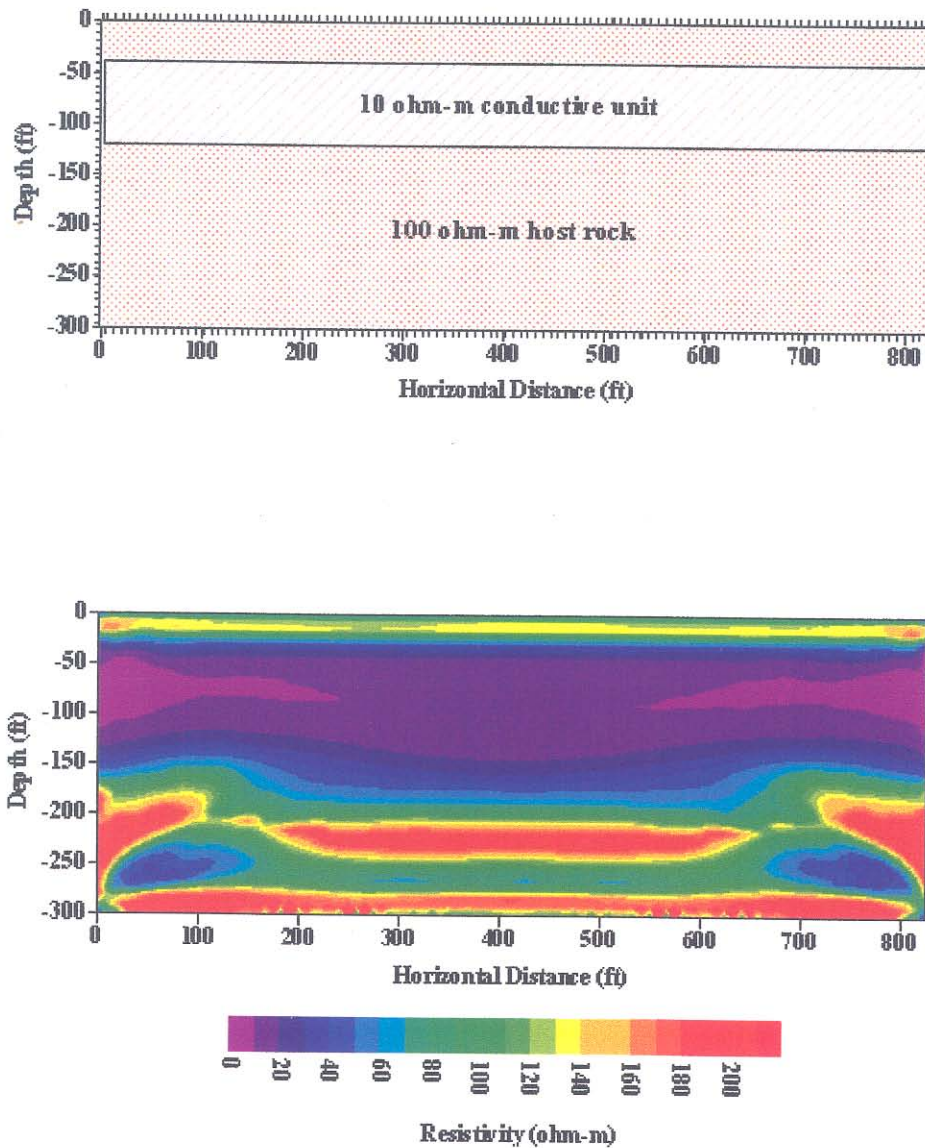


Figure 7. Tomographic inversion for a horizontally oriented conductive unit within a resistive host rock based on measurements made using both surface and subsurface electrodes.

Figure 7 above shows both the geologic model used and the inversion results using both surface and subsurface electrodes. In comparison with the results obtained using surface electrodes only (Fig. 6), the combined surface and subsurface measurement resistivity section shows enhanced resolution at greater depths. The resolution is manifested in the ability to discriminate the high resistivity host rock unit that exists below the conductive unit. This higher resistivity area is not as clearly characterized in the inversion obtained using surface measurements only.

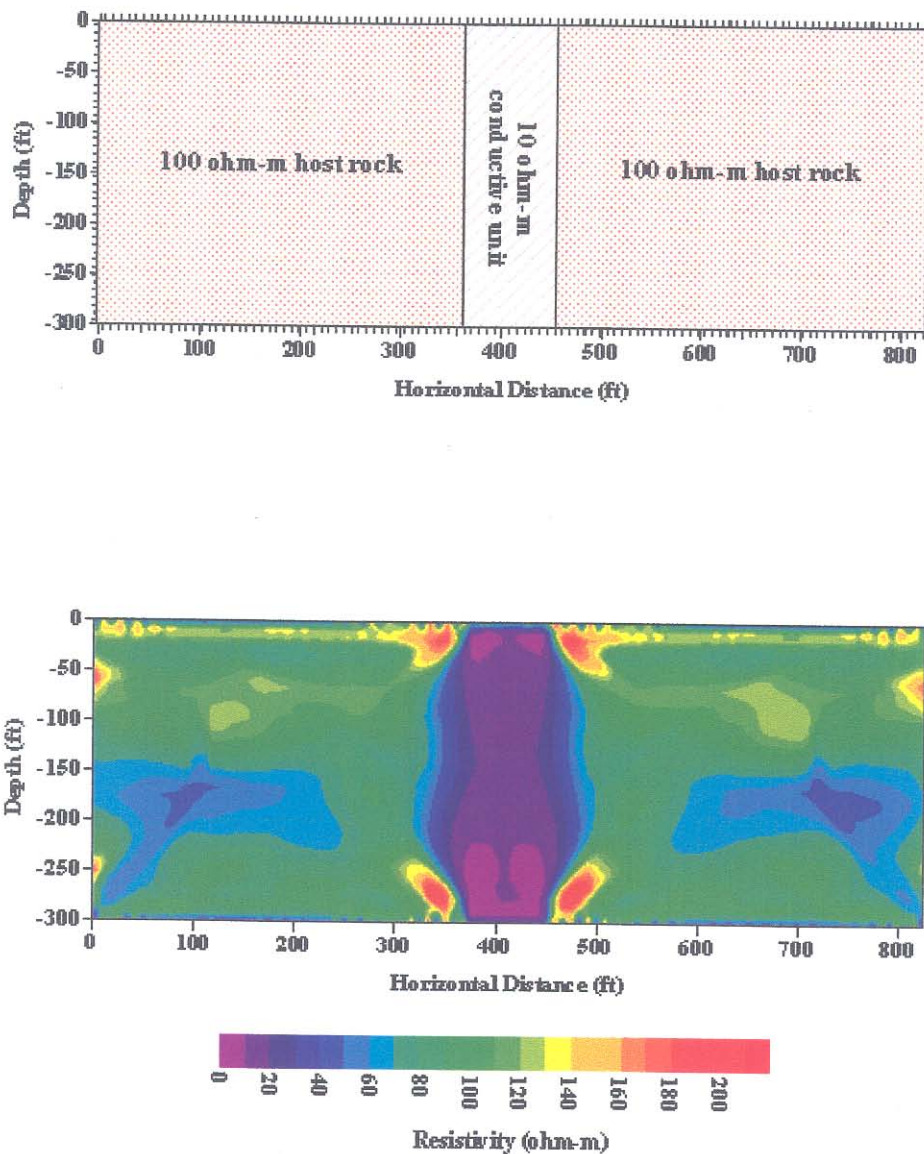


Figure 8. Tomographic inversion for a vertically oriented conductive unit within a resistive host rock based on measurements made using both surface and subsurface electrodes.

A similar modeling exercise was carried out with a vertically oriented 10 ohm-m conductive unit in a 100 ohm-m host rock. This geometry would be most conducive for electrical current flow from the surface to the underground. Figure 8 shows the model and inversion results for a set of synthetic pole-pole array configuration measurements using all possible combinations of 56 surface and 56 subsurface electrodes. Again, the inverted resistivity section clearly shows the conductive unit.

The results of these modeling exercises demonstrate that enhanced resolution is achieved when surface electrode resistivity measurements are augmented with subsurface measurements. Enhanced resolution increases the ability to resolve electrically conductive pathways that may exist within the study site.

3.0 Results & Interpretation

3.1 Electromagnetic Induction

In total, 6.39 line miles were traversed to cover the 18.1 acres of survey area for acquisition of the EM data. To facilitate efficiency in conducting the EM surveys, the study area was divided into 6 different survey zones (Plate 2). The results for each of the 6 zones are discussed separately. The recorded electromagnetic field response is divided into two sub-components; in-phase and conductivity (also referred to as quadrature). The in-phase component is most sensitive to metallic objects and is measured in parts per million (ppm). Under normal conditions, in the absence of any metallic objects, the expected nominal reading should be close to zero. The conductivity component is sensitive to variations in soil conditions and measurements are obtained in units of Siemens per meter (S/m). Conductivity measurements can also be strongly influenced by the presence of metal objects; as these objects are typically much better electrical conductors than the surrounding soil or geologic material. A color contoured plot of in-phase measurements using a transmitter frequency of 10 kHz is shown in Plate 3. Plate 4 shows the color contoured plot of electrical conductivity measurements obtained at 10 kHz. The other four frequencies (5kHz, 7.5 kHz, 15 kHz, and 20 kHz) showed similar responses.

3.1.1 Electromagnetic In-Phase

Zone 1 covered an area of 3.6 acres and consisted of a total of 10 survey lines. Within the southern portion of this survey zone there are several areas where the measured in-phase response exhibit anomalously low values. The majority of these areas coincide with structures or metal objects that were observed and noted during the survey. There is also an area in the central-eastern portion of the zone that exhibits anomalously high in-phase values. This area is associated with the foundation of a demolished structure. The remnants of the foundation were observed to contain rebar reinforcement.

Survey zone 2 covered an area of 2.5 acres and consisted of 10 survey lines. In the southern portion of the grid, two areas exhibit anomalous in-phase responses. These areas were identified during the survey and are associated with buildings and a parked vehicle. In the northwestern corner of the survey zone there are three localized anomalies that are associated with a driveway.

Survey zone 3 covered an area of 3.4 acres and consisted of 10 survey lines. Within this surveyed zone there are anomalously low responses caused by metallic-wire fencing.

Survey zone 4 covered an area of 1.3 acres and consisted of 10 survey lines. This zone contains an area having a rectangular geometry that yields anomalously low in-phase values. This response cannot be attributed to any observed features that may potentially

be associated with metallic objects. This feature is labeled as ‘unknown’ in Plate 3. The response may be caused by buried debris.

Survey zone 5 covered an area of 1.1 acres and consisted of 6 survey lines. Within this survey zone there are two areas where anomalously low in-phase values were measured. An anomaly in the approximate middle of the grid is attributed to metallic items near an observed spring.

Survey zone 6 covered an area of 6.2 acres and consisted of approximately 12 survey lines. Anomalously high in-phase values in areas of this survey zone are associated with known metallic objects. Three areas in particular show anomalously high values. The high responses in the northeastern area of zone 6 are attributed to infrastructure associated with an active gas well, metal fencing, and vehicles. The high response in the western portion of zone 6 is associated with a pipeline.

3.1.2 *Electromagnetic Conductivity*

The quadrature (conductivity) component survey results shown in Plate 4 indicate conductive areas associated with both surface and subsurface metal structures. In the northern portion of the survey site, (survey zone 6) anomalously high conductivity areas associated with a buried pipeline, an active gas well, and metal fencing are clearly visible. In addition, high conductivity areas are seen in survey zone 2. These conductive anomalies are associated with a building and a parked vehicle. Across the remainder of the survey area, there are no additional conductive anomalies that would indicate the presence of unknown objects in the subsurface.

3.2 *Magnetics*

In total, 6.39 line miles of MAG data were acquired to cover the 18.1 acres of survey area. To facilitate efficiency in conducting the MAG surveys, the study area was divided into 6 different survey zones. The size, number, and survey coverage within each zone is the same as that of the EM surveys. Plate 2 shows the MAG survey zones and the coverage. The results for each of the six zones are discussed independently.

3.2.1 *Total Field Magnetics*

Referring to Plate 5, the contoured total field data are overlain onto a geo-referenced aerial photo of the Old 2 Left Area.

Overall, anomalous responses can be attributed to surface or shallow subsurface anthropogenic features such as vehicles, fencing, buried pipelines, and old foundations. These features are plotted and identified directly on the plate. Within the surveyed areas, no unexplainable anomalies exist that can be interpreted as an unknown metallic casing providing a vertical pathway for electrical conduction to the mine.

In zone 1, localized responses are caused by an abandoned foundation and metal rubble. A small localized feature within the upper right portion of the zone is probably caused by buried ferrous rubble.

In zone 2, localized responses are caused by vehicles, building structures, fences, and features associated with the driveway. No other anomalous responses exist.

In zone 3, the area is totally void of anomalous responses.

In zone 4, fencing causes anomalous responses along the southeast and northwest edges of the area. No other anomalous responses exist.

In zone 5, two slight responses exist in the northern portion of the grid and may represent some type of ferrous buried pipe or utility. The responses appear to lead to the abandoned foundation.

In zone 6 (north of the road) a linear response is oriented roughly east-west and represents a known buried utility line. A gas well and associated infrastructure cause a large anomaly in the east-central portion of the grid. Vehicles and metal fencing cause a response located in the extreme northeast corner of the grid.

3.2.2 Magnetic Gradient

Referring to Plate 6, the vertical gradient results are overlain onto the geo-referenced aerial photo of the Old 2 Left Area. The individual zone sizes and number of lines are the same as the EM coverage.

Within zone 1, metal stakes and an abandoned foundation cause responses in the east-central and southern portions of the grid. A localized anomaly in the northeast portion of the grid exists and may be caused by ferrous debris.

Within zone 2, above-ground features such as vehicles and buildings are the cause of anomalous responses.

Within zone 3, a few minor and localized anomalous responses exist and are interpreted to represent ferrous scrap.

Within zone 4, two localized features exist along the northeastern grid boundary. These may represent buried metallic debris.

Within zone 5, two anomalies exist within the northern portion of the grid. They appear to be aligned with the abandoned foundation in zone 1 and may represent an old pipeline, although this is only a supposition. These anomalies may need to be ground-truthed by ICG personnel to identify the source.

In zone 6 (north of the road) a linear response is oriented roughly east-west and represents a known buried utility line. A gas well and associated infrastructure causes a large anomaly in the east-central portion of the grid. Vehicles and metal fencing cause a response located in the northeast corner of the grid.

None of the magnetic responses identified as debris, rubble, or any other specific metallic material have a magnetic signature characteristic of a long, vertical, steel well casing.

3.3 High Resolution Resistivity (HRR)

Plate 7 shows the location of the surface resistivity line and underground roof bolt electrode locations overlain on a geo-referenced aerial photo of the Site. The resistivity survey was located in the specific area of influence identified in the field by ICG project personnel. Surface electrode locations are indicated in yellow and roof bolt electrodes are indicated in blue.

In order to create the two-dimensional inverted section, where surface and roof bolt electrode data were integrated, it was necessary to project the actual roof bolt electrode locations to coincide with the surface electrode orientation. This was completed by iteratively determining a mathematical relationship that geometrically projected the roof bolt electrode locations to the surface line. The actual and projected roof bolt locations are shown in Figure 9.

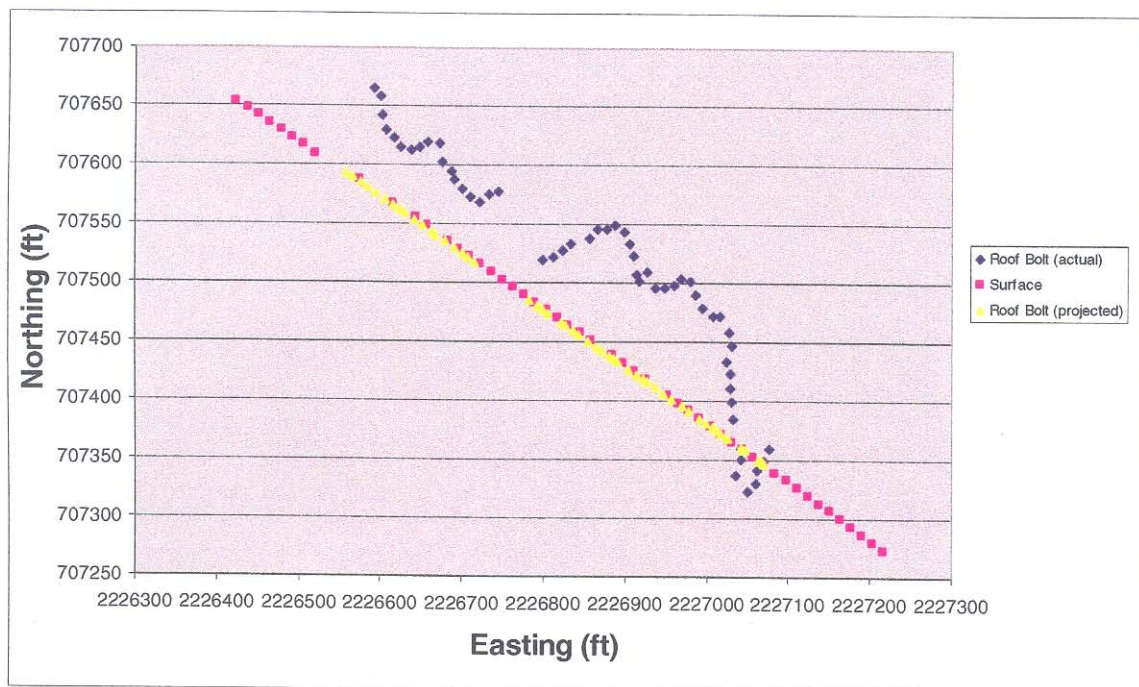


Figure 9: Graph showing projected placement of roof bolt electrodes to surface electrode orientation.

Plate 8 shows the inversion results for the HRR survey. Results are plotted as a function of station location versus elevation. The top image shows the results using surface data

only. The bottom image shows the results using data from both surface and roof bolt electrodes. The resistivity values range from 1 to over 1100 ohm-m. Higher resistivity values are indicated in red hues, while lower resistivity values are represented using blue to purple hues. In general, higher values are indicative of relatively low moisture content and/or coarse grained materials while lower values would be indicative of higher moisture content and/or finer-grained material.

To the immediate right of both images, a generalized lithologic log is shown that was constructed from data obtained from borehole 4010 (core log number SF 52-06) that is located approximately 200 feet north of the survey line. This borehole was used to route the resistivity cables down to the mine elevation. Solid brown represents topsoil, stippled brown represents sandstone units, and the green intervals represent clay and shale horizons.

The results using surface data only (top image) indicate that a relatively thin resistive zone exists at the surface that has a thickness ranging from 10 to 50 feet. This zone substantially thins from about station 700 to the eastern end of the line. The high resistivity values shown in this zone are interpreted to represent lithologies with low moisture content. The bottom of this near surface resistive zone correlates with the lithologic log, where sandstone layers transition into predominately shale and clay horizons.

The near surface resistive zone rapidly transitions downwards into a highly conductive zone that is moderately thick (approximately 150 feet). The top of this zone is represented by the sharp change from resistive to conductive values. However, the bottom of the conductive zone is poorly defined due to the increased volumetric averaging that occurs as the depth of investigation increases. The highly conductive values are interpreted as zones of high moisture content that may also be augmented by fine-grained lithologies. The beginning elevation of this conductive zone correlates with the interception of shale and clay layers within core SF 52-06. However, past this depth, little correlation exists between the surface electrode results and the borehole log.

Starting at the approximate elevation of 1500 to 1475 feet, the values gradually increase in resistivity to the end of the section. Again, this gradual increase is due to volumetric averaging. This deeper resistive zone is interpreted to represent moderately dry and more cemented strata.

Referring to the lower image shown on Plate 9, the different resistivity zones are more vertically confined with the incorporation of the roof bolt electrode data. Note however that there is a substantial amount of vertical “streaking” of the data. This is caused by the high density of horizontally dispersed electrodes relative to the large amount of vertical volume of earth that is being imaged. This in turn causes the data to be strongly vertically biased, which is an artifact of the inversion process.

Compared to the surface-only section, the near surface resistive sandstone layer appears to be more consistent in thickness; averaging approximately 40 feet. Some vertical breaks

are apparent within this layer (for example at stations 280 and 725), but these are considered to be questionable data at station 280 and a possible fault at 725.

The middle conductive layer appears to have the largest thickness of approximately 100 feet between stations 200 to 400. This conductive zone appears to thin towards the east. Beneath this conductive layer, the values become more resistive.

Good correlation exists between the first two electrically-defined zones and the lithologic log. Clay and shale layers were intercepted within the same general depths as the conductive horizon. Above the conductive layer, the highly resistive zone correlates with sandstone and topsoil. Below the conductive horizon poor correlation exists between the lithology encountered in core SF 52-06 and the resistivity section. A possible explanation is that the lower resistive zone represents more compacted media and thus lower moisture content.

In summary, the resistivity results geophysically indicate a three-layer geologic section; trending from resistive to conductive to resistive as depth increases to the mine level. HGI believes that the results represent naturally occurring geologic conditions. If the results would have had the appearance similar to the modeled results shown in Figure 8, Section 2.3.3, then it would have supported the idea of a vertically conductive pathway. The resistivity results are contrary to this model, and are more similar to the model results shown in Figure 7 of Section 2.3.3.

4.0 Conclusions

Within the limits of the areas surveyed and the resolution of the instruments used, no vertically oriented, metallic or low resistivity conductor was identified.

The results from the MAG and EM surveys provided responses associated with several electrically conductive features including known pipelines, wells, power lines, and other objects. No anomalous signatures were identified within the surveyed areas that are similar to the responses normally associated with a vertical steel well casing or any other vertically oriented, ferrous, or other metallic feature..

The total field magnetometry showed no steel-cased, boreholes within the surveyed area. The gradient magnetic results also showed no unknown boreholes within the surveyed areas.

The EM conductivity results showed no unknown, vertical, metallic well casings in the surveyed areas. The EM in-phase results showed no unknown, vertical, metallic well casings in the surveyed areas.

The results of the HRR survey indicate that natural geologic conditions exist within the subsurface and that no vertically oriented, low resistivity zone could be identified.

APPENDIX A : Geophysical Theory

A.1 Magnetic Gradiometry

Magnetometry is the study of the Earth's magnetic field and is the oldest branch of geophysics (Telford et al., 1990). The Earth's field is composed of three main parts: the main field which is internal, i.e., from a source from within the Earth that varies slowly in time and space; a secondary field which is external to the Earth and varies rapidly in time; and small internal fields constant in time and space which are caused by local magnetic anomalies in the near-surface crust.

Of interest to the geophysicist are the localized anomalies. These anomalies from contrasts in the magnetic susceptibility (k) and are caused by magnetic minerals (mainly magnetite or pyrrhotite) or buried steel. The average values for k are typically less than 1 for sedimentary formations and upwards to 20,000 for magnetic minerals.

The magnetic field is measured with a magnetometer. Magnetometers permit rapid, non-contact surveys to locate buried metallic objects and features. Portable (one person) field units can be used virtually anywhere that a person can walk, although, they may be sensitive to local interferences, such as fences and overhead wires. Airborne magnetometers are towed by aircraft and are used to measure regional anomalies. Field-portable magnetometers may be single- or dual-sensor. Dual-sensor magnetometers are called gradiometers; they measure gradient of the magnetic field; single-sensor magnetometers measure total field.

Magnetic surveys are typically run with two separate magnetometers. The first magnetometer is used as a base station to record the Earth's primary field and the diurnally changing secondary field. The second magnetometer is used as a rover to measure the spatial variation of the earth's field and may include various components (i.e. inclination, declination, and total intensity). By removing the temporal variation and, perhaps, the static value of the base station, from that of the rover, one is left with a residual magnetic field that is the result of local spatial variations only. The rover magnetometer is moved along a predetermined linear grid laid out at the site. Readings are virtually continuous and results can be monitored in the field as the survey proceeds.

The shortcoming with most magnetometers is that they only record the total magnetic field (F) and not the separate components of the vector field. This shortcoming can make the interpretation of magnetic anomalies difficult, especially since the strength of the field between the magnetometer and target is reduced as a function of the inverse of distance cubed. Additional complications can include the inclination and declination of the earth's field, the presence of any remnant magnetization associated with the target, and the shape of the target.

A.2 Electromagnetic Induction

Earth materials have the capacity to transmit electrical currents over a wide range, depending on the material property and electrical conductivity. Electrical conductivity is a function of soil type, porosity, saturation, and dissolved salts. Electromagnetic methods seek to identify various earth materials by measuring their electrical characteristics and interpreting results in terms of those characteristics.

Electromagnetic induction methods employ a transmitting (Tx) coil and a receiving (Rx) coil spaced at some given distance. The Tx coil induces eddy currents in the earth, which themselves generate magnetic fields that are influenced by the earth materials within the zone of excitation. Some parts of these fields are intercepted by Rx coil, resulting in an output voltage proportional to the electrical conductivity within the zone. By moving these coils laterally, variations in conductivity can be interpreted to find various buried features and-or objects. The Tx coil frequency and distance between Tx and Rx coils determine the depth of investigation, and the output permits construction of a stratigraphic profile of intervening depth.

A.3 High Resolution Resistivity

The resistivity method is based on the capacity of earth materials to pass electrical current. Earth resistivity is a function of soil type, porosity, moisture, and dissolved salts. The concept behind applying the resistivity method is to detect and map changes or distortions in an imposed electrical field due to heterogeneities in the subsurface.

Resistivity (ρ) is a volumetric property measured in ohm-meters that describes the resistance to current flow within a medium. The inverse, conductivity (σ) in units of Siemens/meter, describes the ease by which current will flow through a medium. Electric current can be propagated in rocks and minerals in one of three ways: electronic (ohmic), electrolytic, and dielectric conduction. Ohmic conductance occurs in metals, where free electrons give rise to direct conduction of current. Rocks and non-metallic minerals have extremely high resistivities (low conductivities) and direct current transmission through these materials is difficult. A porous media, on the other hand, can carry current through ions, which is the second type of current propagation (electrolytic). Electrolytic conduction relies on the molecules within a pore space to have excess or deficiency of electrons. Here, the conduction varies with the mobility, concentration, and degree of dissociation of ions. Electrolytic conduction is relatively slow with respect to ohmic conduction due to the reliance on a physical transport of material resulting in chemical transformation (Telford et al., 1990). The last type of propagation is dielectric conduction, which takes place in poor conductors or insulators. Dielectric conduction occurs under the influence of an externally applied alternating electric field, where atomic electrons are displaced slightly with respect to their nuclei.

In the field, the electric current may be generated by battery or motor-generator driven equipment, depending on the particular application and the amount of power required. Current is introduced into the ground through electrodes (metal rods). Earth-to-electrode

coupling is typically enhanced by pouring water around the electrodes. The electrodes are placed along linear transects and provide points for both current transmission and electric potential measurements.

Estimating resistivity is not a direct process. When current (I) is applied and voltage (V) measured, Ohm's law is assumed. Resistance (R) in units of ohms can be calculated:

$$R = \frac{V}{I}$$

Resistivity and resistance are then related through a geometric factor over which the measurement is made. The simplest example is a solid cylinder with a cross sectional area of A and length, L:

$$\rho = R \frac{A}{L}$$

Hence, resistivity can be calculated by knowing the voltage, current, and geometry over which the measurement is made. In the earth, a hemispherical geometry exists. The hemispherical geometry is referred to as a half-space, due to the fact that all current applied at the surface travels into the ground; above the ground, air has an infinite resistivity. Because the volume of earth involved in a resistivity measurement on a non-homogeneous earth is unknown, the concept of apparent resistivity has been introduced.

Field data are acquired using an electrode array. A four-electrode array employs electric current injected into the earth through one pair of electrodes (transmitting dipole) and the resultant electric potential is measured by the other pair (receiving dipole). The most common configurations are dipole-dipole, Wenner and Schlumberger arrays. Their use depends upon site conditions and the information desired. Figure 1 shows the dipole-dipole configuration, where C1 and C2 are connected to the current source and P1 and P2 are connected to the volt meter:

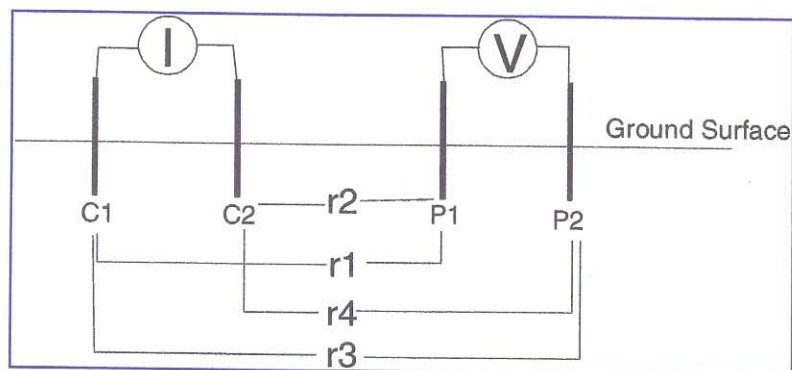


Figure A.1 Dipole-dipole array configuration.

For the four-electrode array, the geometric factor, K , is

$$K = 2\pi \frac{1}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)},$$

where r_1 through r_4 are defined in the schematic.

Since the earth property of resistivity is the desired product, an inverse calculation (or inverse model) is needed to convert the measured electric potential to resistivity. Inversion refers to the operation of estimating earth parameters, given the measured potential, input current, and boundary conditions. The inverse calculation assumes that each measurement of potential was a result of a homogeneous earth:

$$\rho_a = 2\pi \frac{V}{I} K$$

Other assumptions used in the above equation are isotropy (i.e., no directional dependence of resistivity), no displacement currents (using a DC or low frequency current application), and the resistivity is constant throughout such that Laplace's equation can be assumed. Since the degree of heterogeneity is not known *a priori*, a true resistivity is not calculated. To obtain a true resistivity, tomography is required, which generates a model of true resistivity given the measurements of apparent resistivity, electrode arrangement, and other boundary conditions.

hydroGEOPHYSICS, Inc. uses a pole-pole array for its high resolution resistivity (HRR) surveys. For the pole-pole array, one electrode from each of the current and potential pair is fixed effectively at infinity (remote reference), while the other current and potential electrodes act as "rover" electrodes. Practically, the remote reference electrodes are spaced approximately 2 to 10 times the distance of the furthest separation of the rover electrodes, which can be up to 200 meters apart. The pole-pole array provides higher data density, increased signal to noise ratio, and requires less transmitted energy. Roy and Apparao (1971) discuss the superiority of the pole-pole method when conducting shallow (near-surface) surveys.

The calculation of apparent resistivity is simplified in the pole-pole array:

$$\rho_a = 2\pi \frac{V}{I} (n \cdot a)$$

where a is the basic electrode spacing and n is the integer multiplier as the current and potential electrodes incrementally separate. The following schematic (Figure 2) demonstrates the idea of a linear transect of electrodes on the surface with the a -spacing being the separation between each electrode and the n spacing increasing as the potential

electrode moves away from the current electrode. The geophysical survey at the Sago Mine Site included a fixed a-spacing of 15 feet for measurements obtained at the surface and n increased from 1 to 56. For a complete survey, each electrode has one turn at transmission, while potential measurements are made using all other electrodes in the array sequentially.

The linear transect arrangement produces a two-dimensional data set of resistivity as a function of x and z , where z is the dimension into the earth and x is along the surface. Although resistivity is a function of the volume over which the measurement is made, its location is typically plotted as a point for ease of representation. The location of the point is a function of n and is referred to as the depth of investigation. Hallof (1957) demonstrated that the intersection of two 45° lines (with respect to the surface) extending downward from each of the transmission and receiving electrodes would produce a suitable pseudosection for interpretation. In this fashion, the pole-pole array has data vertically plotted at:

$$z = 0.5na$$

which is a linear plotting method. For HRR, the location of n is a function of the maximum sensitivity of signal, which decreases as a logarithmic function as n increases. Once z is determined, the two-dimensional data set can then be presented as a contour plot, where equivalent values are connected by a contour line or color.

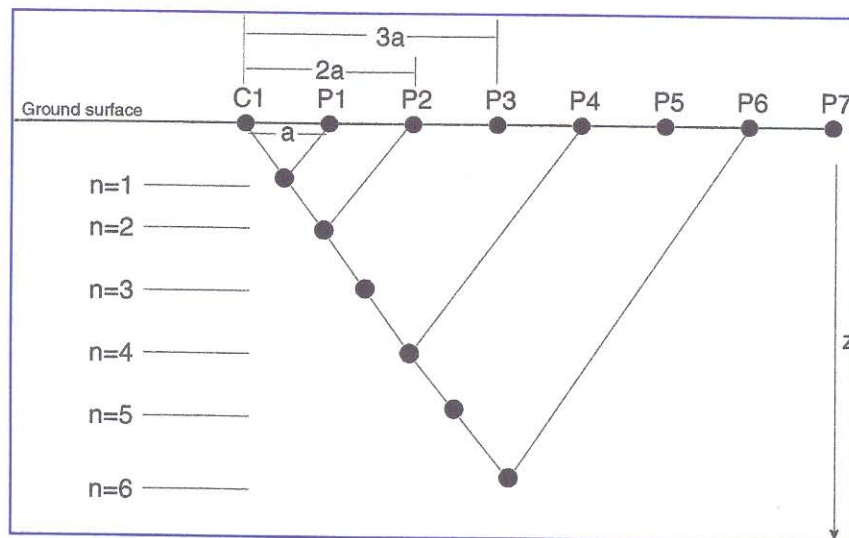


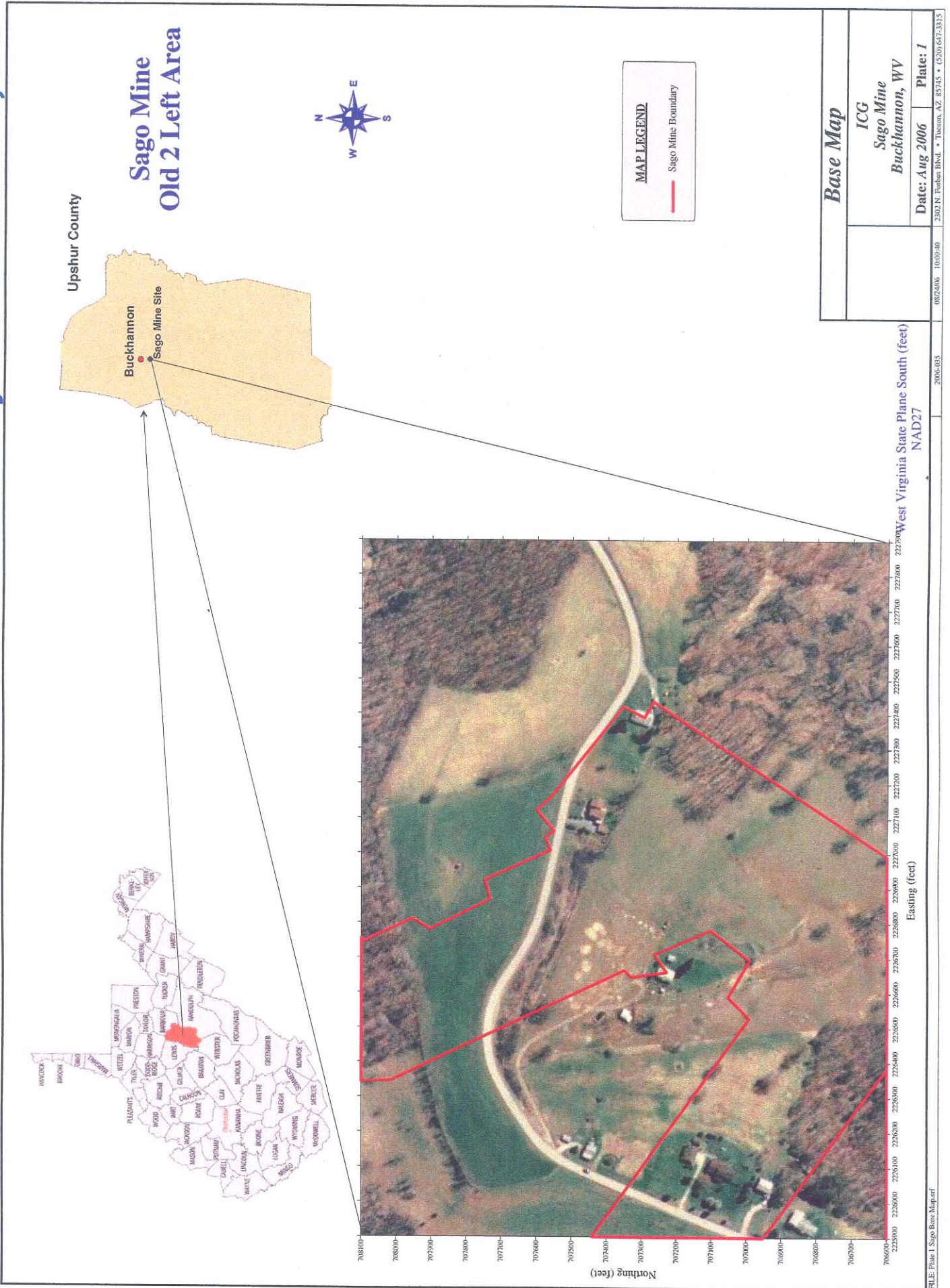
Figure A.2. Construction of two-dimensional apparent resistivity pseudosection.

A.3.1 Depth of Investigation

The depth of investigation stems from a need to relate a measurement made at the surface to some particular depth in order that survey parameters can be optimized for target

identification (Barker, 1989). Prior to tomographic inversion, apparent resistivity pseudosections were used primarily for interpretation of subsurface electrical anomalies. Field practitioners became quite efficient at locating the depth to specific targets, such as ore bodies. Therefore, the presentation of the pseudosection is important in these regards.

The traditional linear pseudosection of Hallof (1957) has limitations with respect to a physical meaning of the earth. Many researchers, therefore, have taken a closer examination of the plotting method to allow for a more reasonable geological interpretation. The most widely accepted depth of investigation studies are those presented by Roy and Apparao (1971), Roy (1972), and Koefoed (1972), who defined a depth of investigation characteristic (DIC) model for determining the depth of a measurement. The DIC was determined by finding the depth at which a thin horizontal layer within a homogeneous background makes the maximum contribution to the total measured signal at the surface. The depth of investigation is a logarithmic function of electrode spacing and places no emphasis on actual resistivity values. At its extreme, the logarithmic plotting methodology fails when an infinitely conductive layer is placed within the earth. A large electrode separation would still prevent signal from penetrating the layer.

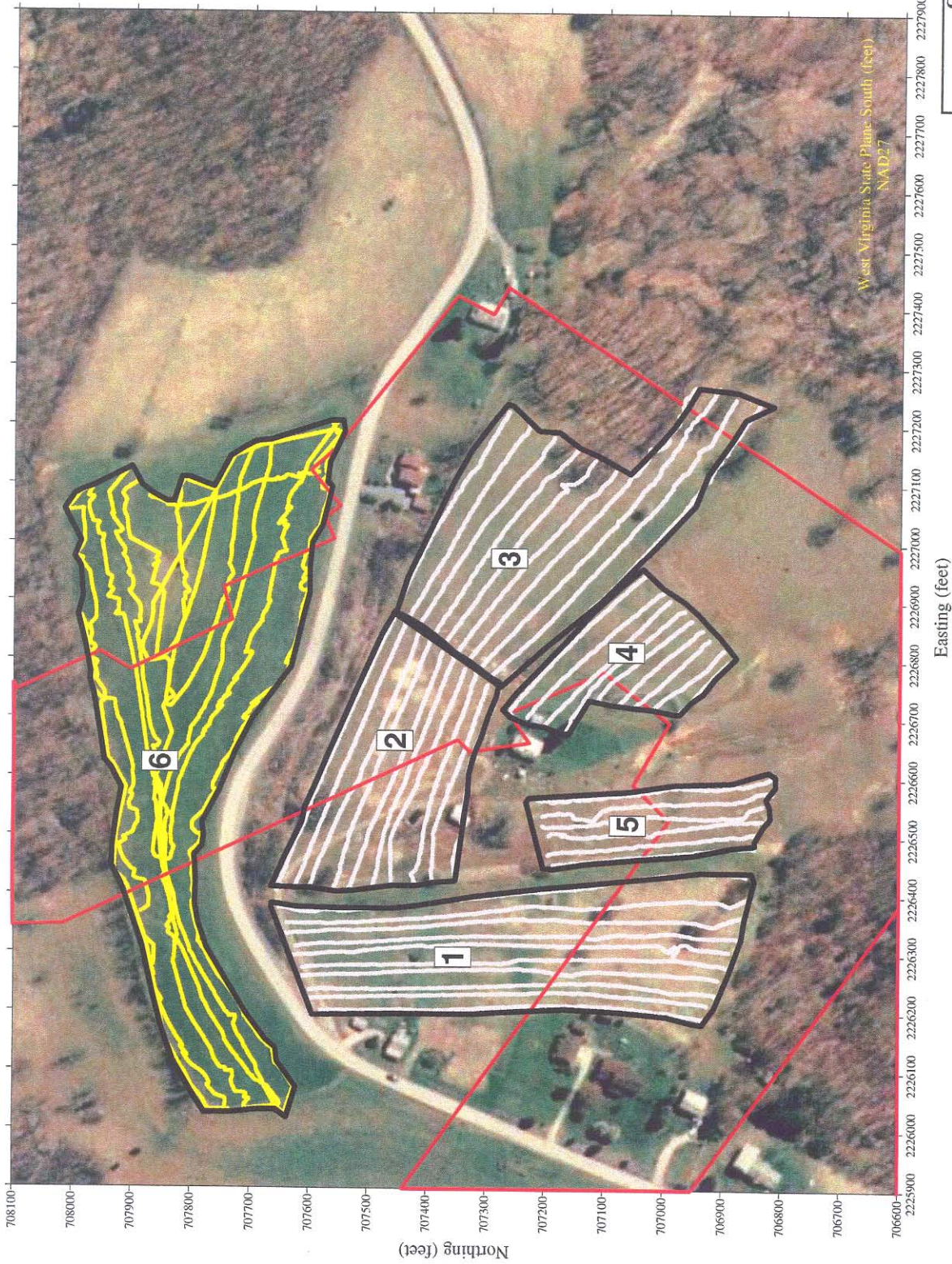


Sago Mine
Old 2 Left Area



MAP LEGEND

- Instruments mounted on G.O. Cart
- Instruments Carried by Hand
- Sago Mine Boundary
- GPS Data Point
- Survey Zone Boundary
- 1** Survey Zone Number



Survey Coverage

ICG Sago Mine Buckhannon, WV	
Date: August 2006	Plate: 2
2302 N. Forber Blvd. • Thomas, AZ 85745 • (520) 647-3315	

Survey Coverage - Magnetometry and Electromagnetics

Sago Mine
Old 2 Left Area



In-Phase
(ppm)



MAP LEGEND

- Sago Mine Boundary
- Physical Barrier



Easting (feet)

Northing (feet)

West Virginia State Plane South (feet)
NAD27

Geophysical Survey	
ICG	
Sago Mine	
Buckhannon, WV	
Date: Aug 2006	Plate: 3
082406 100956	2006-03 2302 N. Forbes Blvd. • Tussum, AZ 85715 • (520) 677-5315

Electromagnetic Induction: In-Phase 10kHz

Sago Mine
Old 2 Left Area

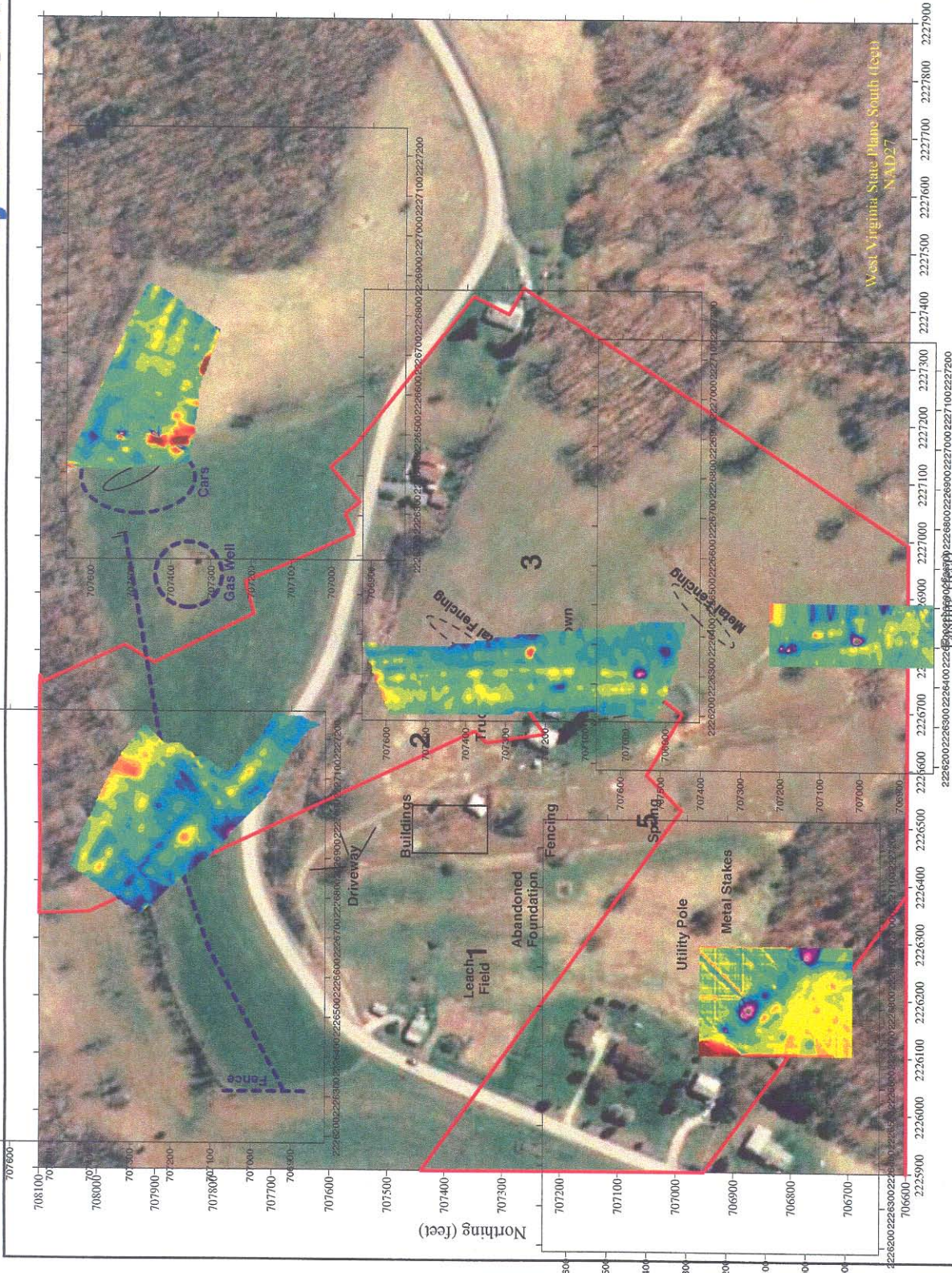


In-Phase
(ppm)



MAP LEGEND

- Sago Mine Boundary
- Physical Barrier



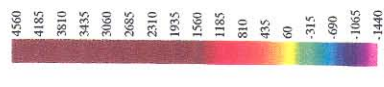
Geophysical Survey	
ICG Sago Mine Buckhannon, WV	
Date: Aug 2006	Plate: 3
08/24/06 10:15:47	2302 N. Forbes Blvd. • Tucson, AZ 85745 • (520) 647-3315

Electromagnetic Induction: In-Phase 10kHz

Sago Mine
Old 2 Left Area

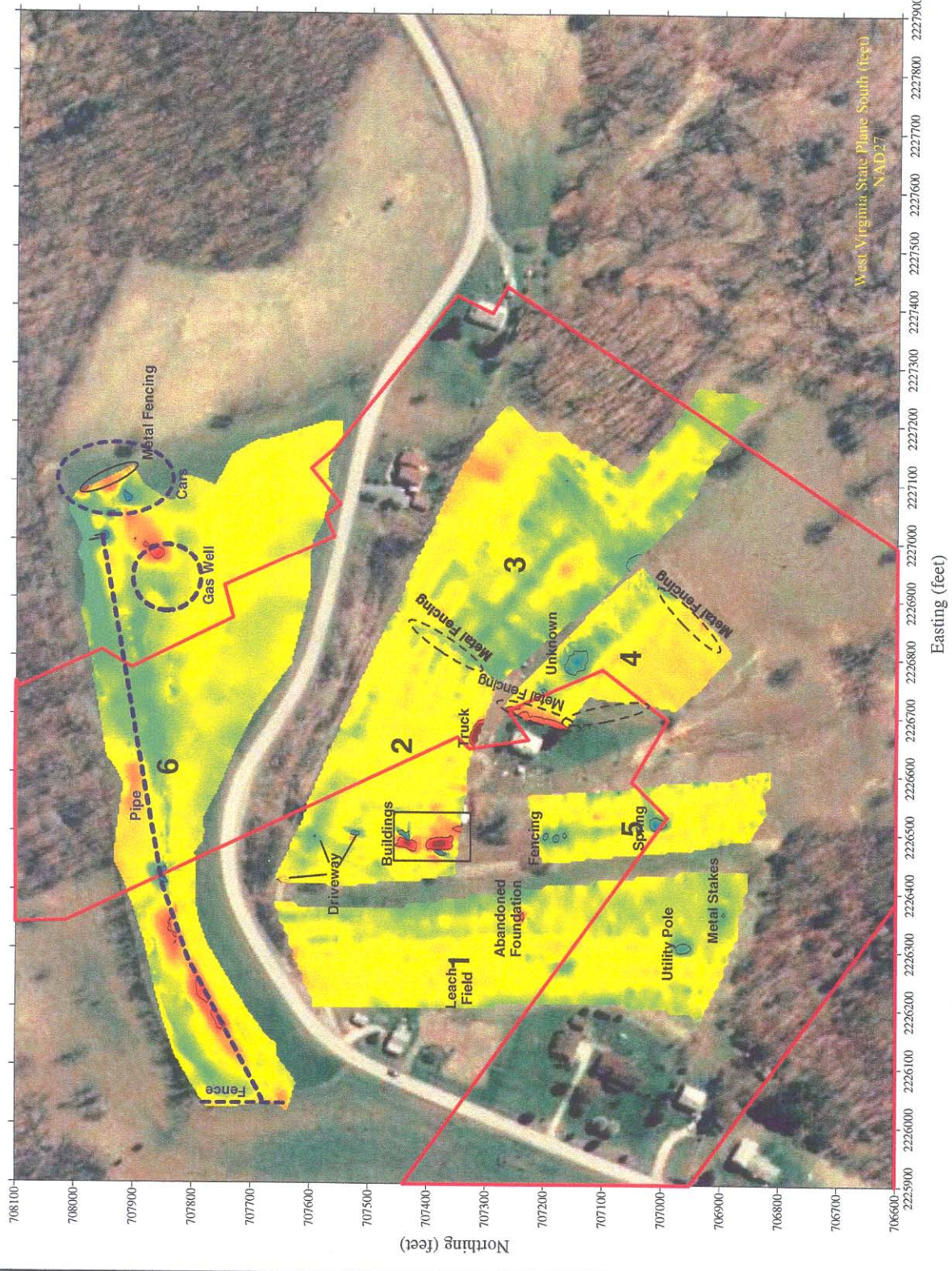


In-Phase
(ppm)



MAP LEGEND

- Sago Mine Boundary
- Physical Barrier



Geophysical Survey	
ICG	
Sago Mine	
Buckhannon, WV	
Date: Aug 2006	Plate: 3
2302 N. Perkins Blvd. • Tavon, AZ 85745 • (302) 647-5315	

Electromagnetic Induction: In-Phase 10kHz

**Sago Mine
Old 2 Left Area**



Electrical
Conductivity
(mS/m)



MAP LEGEND

- Sago Mine Boundary
- - - - Physical Barrier



Easting (feet)

Geophysical Survey

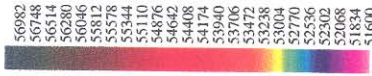
ICG Sago Mine Buckhannon, WV	
Date: Aug 2006	Plate: 4

Electromagnetic Induction: Conductivity 10kHz

Sago Mine
Old 2 Left Area



Total Magnetic Field (nT)



MAP LEGEND

- Sago Mine Boundary
- Physical Barrier



West Virginia State Plane South (feet)
NAD27

Easting (feet)

Total Magnetic Field (Top Sensor)

Geophysical Survey

ICG
Sago Mine
Buckhannon, WV

Date: Aug 2006 Plate: 5

**Sago Mine
Old 2 Left Area**



Magnetic Gradient (nT/m)



MAP LEGEND

- Sago Mine Boundary
- GPS Data Point
- Physical Barrier



West Virginia State Plane South (feet)
NAD27

Easting (feet)

Geophysical Survey

Vertical Magnetic Gradient (Top - Bottom Sensor)

ICG
Sago Mine
Buckhannon, WV

Date: Aug 2006 Plate: 6

Sago Mine
Old 2 Left Area



MAP LEGEND

- Sago Mine Boundary
- Surface Electrode Location
- Roof Bolt Location

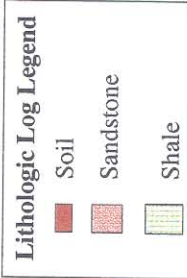
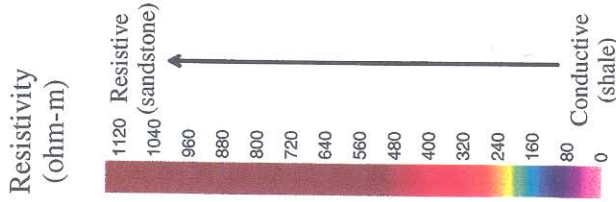
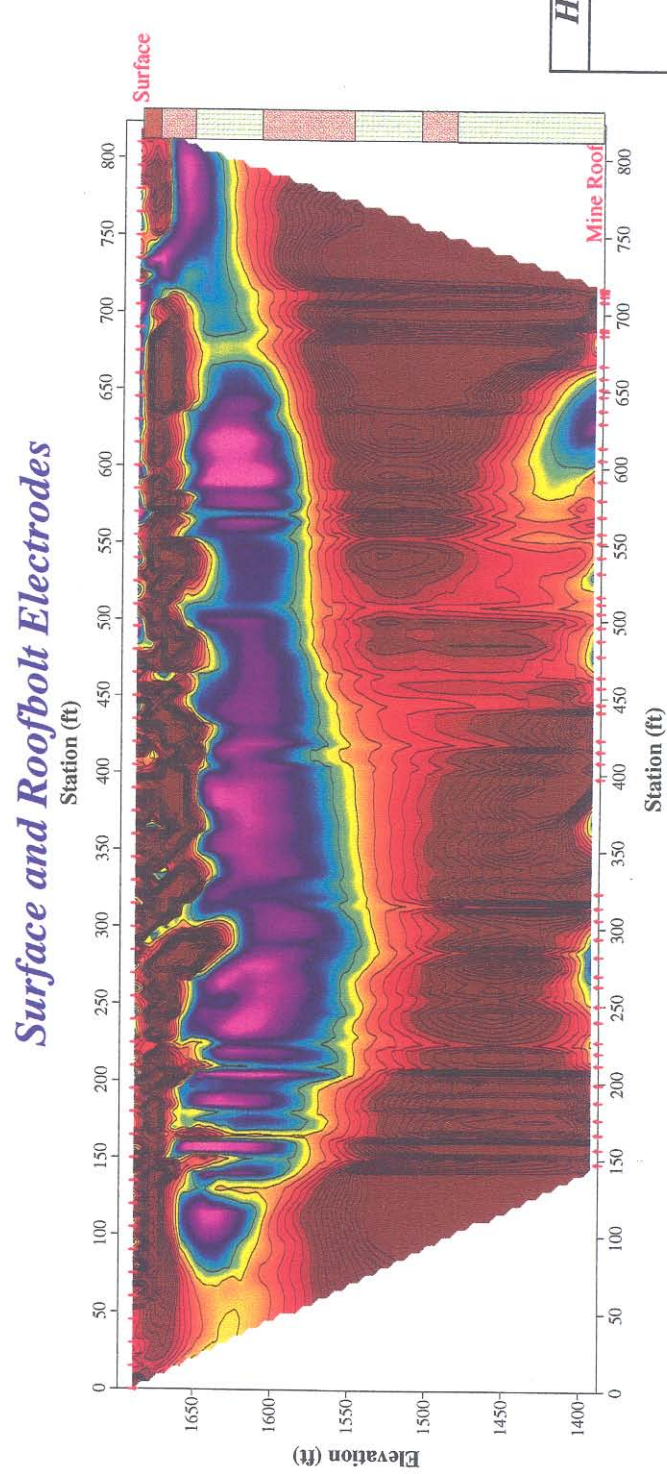
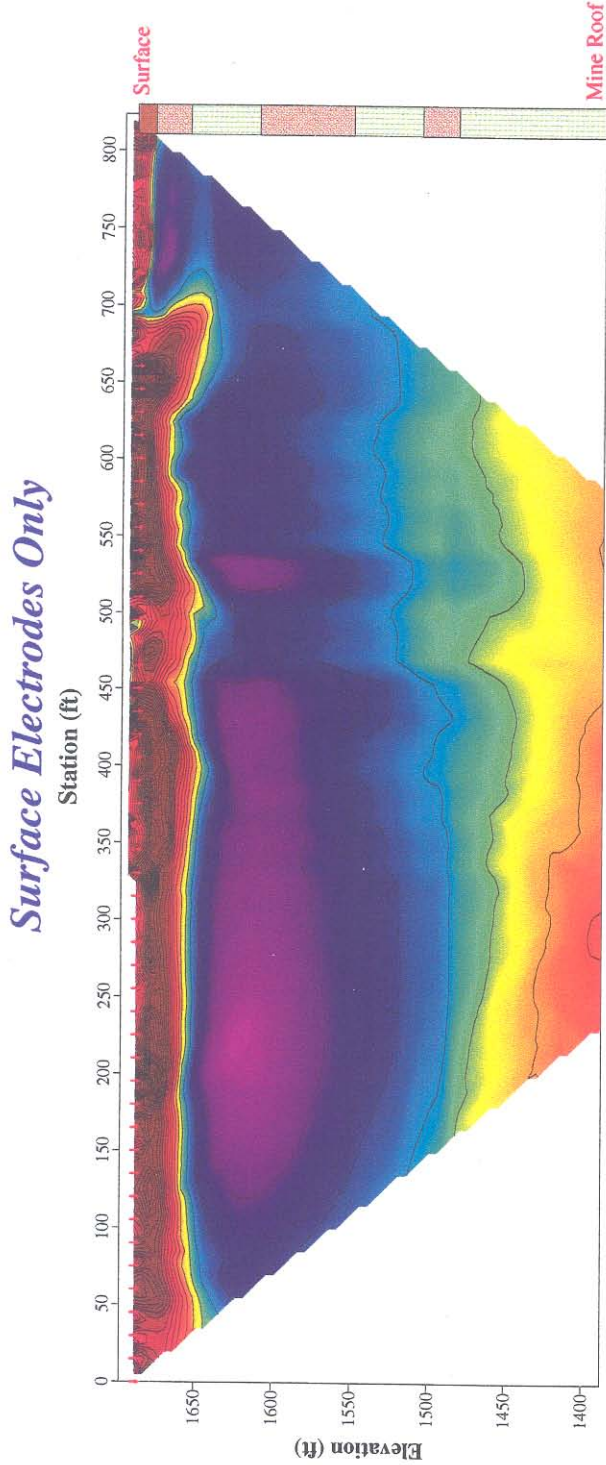


Geophysical Survey	
ICG Sago Mine Buckhannon, WV	
Date: Aug 2006	Plate: 7
0829406 1035:06	2006-055
3302 N. Fisher Blvd. • Tucson, AZ 85745 • (520) 647-3313	

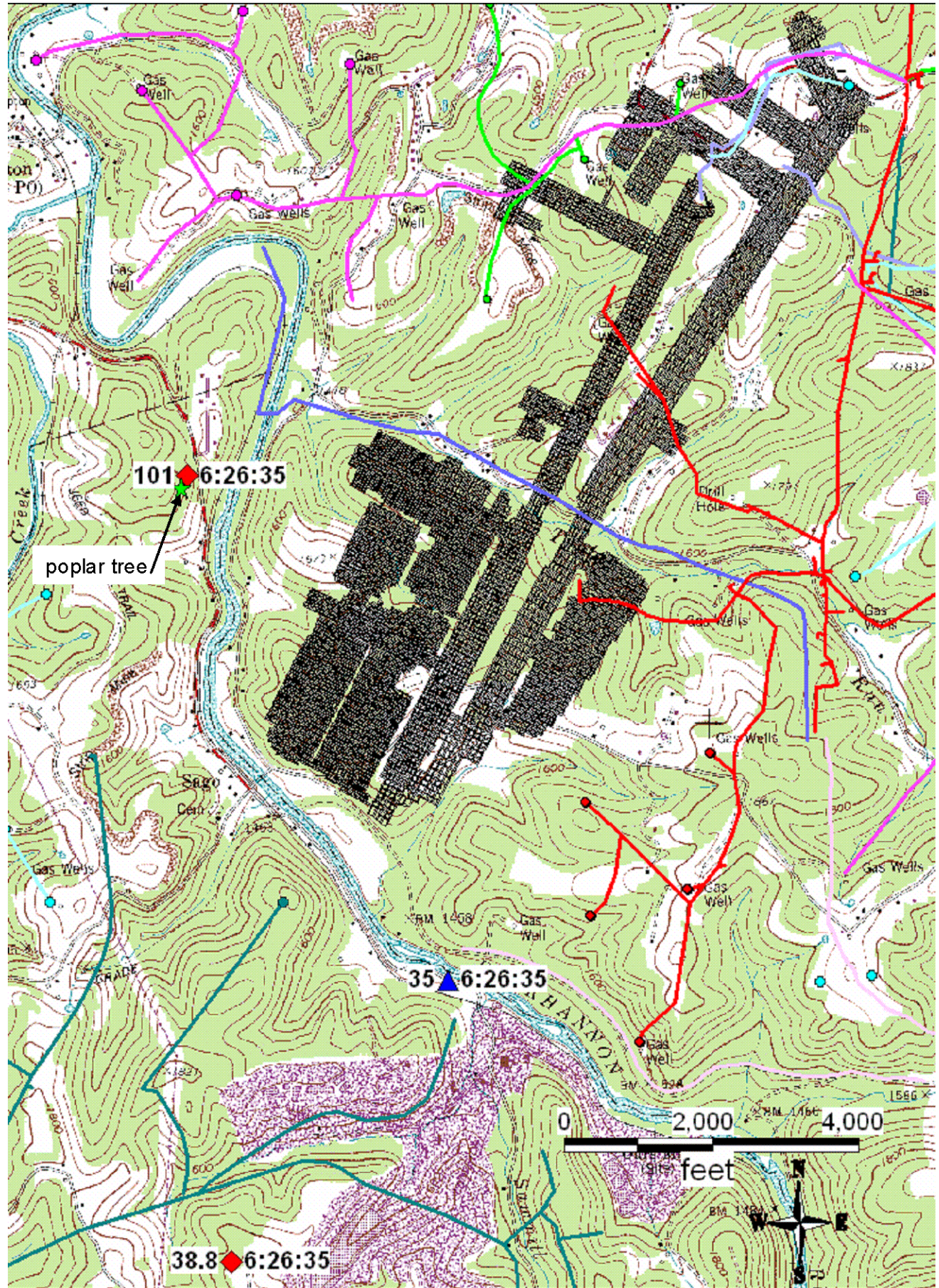
High Resolution Resistivity Line Location

FILE: Plate 7 - HRRL Line Locations.tif


**Sago Mine
Old 2 Left Area**




High Resolution Resistivity	
ICG	
Sago Mine	
Buckhannon, WV	
Date: Aug 2006	Plate: 8
082406 10-6010 2006-05	
2802 N. Forbes Blvd. • Tucson, AZ 85745 • (520) 647-3315	



Explanation

101  **6:26:35** Location of lightning strike reported by Vaisala's National Lightning Detection Network (NLDN). Number to left of symbol represents the peak current in kilo-amps; number to right of symbol represents the time that the peak current was recorded.

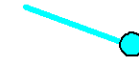
35  **6:26:35** Location of lightning strike reported by Weather Decision Technologies, Inc.'s U.S. Precision Lightning Network (USPLN). Number to left of symbol represents the peak current in kilo-amps; number to right of symbol represents the time that the peak current was recorded.



Sago Mine workings.



Keyspan gas lines and wells.



Great Oak gas lines and wells.



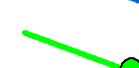
Dominion gas lines and wells.



Chesapeake gas lines and wells.



Trubie Run gas lines.



Mike Ross gas lines and wells.



Eastern American Office gas lines.



Eastern American Energy gas lines and wells.



Location of large poplar tree shattered by lightning.

Appendix GG

Sago Mine MSHA ID 46-08791

Wolf Run Mining Company

Sago Mine in relation to recorded locations of lightning strikes, gas wells, and gas lines.

Location of gas lines and gas wells courtesy of WVOMHS&T.

Appendix HH - Observation and Sampling Collection Methodology

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division



06AA23(b)

August 31, 2006

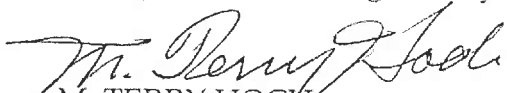
MEMORANDUM FOR RICHARD A. GATES

District Manager, CMS&H District 11

THROUGH:



KELVIN K. WU

Acting Chief, Pittsburgh Safety and Health Technology Center


M. TERRY HOCH

Chief, Roof Control Division

FROM:


SANDIN E. PHILLIPSON

Geologist, Roof Control Division

SUBJECT:

Observations and Sample Collection Methodology at Wolf Run Coal Company, Sago Mine, MSHA I. D. No. 46-08791, on March 20-21, 2006

Observations

As requested by the Accident Investigation Team, several rock and water samples were collected from the Sago Mine. Several water samples were collected from the Buckhannon River, Trubie Run, and an un-named tributary off Trubie Run. Additionally, observations of features were conducted in the vicinity of spad 4064.

March 20, 2006 Sample Collection

Sample collection began on the track entry of the Main between crosscuts 32 and 33, where arches were installed through difficult ground conditions beneath Trubie Run. Dripping water was collected in a small glass vial, and labeled "Trubie" (Figure 1).



Figure 1. Collection of dripping water in the track entry of the Main, between Crosscuts 32-33.

Observations resumed in by the former 2nd Left Seals. The underground sample collection effort was prompted by an interest to document the cause of the “blue haze” that has been observed throughout portions of the 2nd Left Mains. Figure 2 represents a map of the 2nd Left Mains showing the locations of water and rock samples collected on March 20, 2006. Observations proceeded in by along the #7 Entry of the Main, where “blue haze” was observed on several broken rock faces. This entry had been benched, and these locations were not accessible. “Blue haze” was observed in the vicinity of spad 3986, where the crosscut had not been benched. Two samples, one of rock that hosts the “blue haze” on its surface, as well as a water sample, were collected from the roof of the crosscut between spads 3986 and 3981. Water droplets were collected with a plastic eye dropper by drawing each individual droplet into the dropper, and then expelling the water into a glass vial (Figure 3). When all available water droplets that were in contact with the “blue haze” had been collected, the glass vial was approximately half full. The plastic eye dropper was used only at this collection site, and was labeled with the sample number “BH3986-28” before being separately stored to avoid cross contamination with other eye droppers, which were carried in a sealed plastic freezer bag. Mine personnel assisted in the collection of a slab of immediate roof rock that hosted “blue haze” on a fracture surface. When the slab was retrieved, it was broken in half, with one half retained by MSHA personnel and the other half provided to mine personnel, who were present. The MSHA sample was stored in a freezer bag and labeled “BH3986-28” whereas the sample provided to the mine was stored in a freezer bag labeled “BH3986-28 duplicate”. Photos were taken of the sample in place in the roof, after it had been split in half, and of each half in its respective bag (Figure 4).

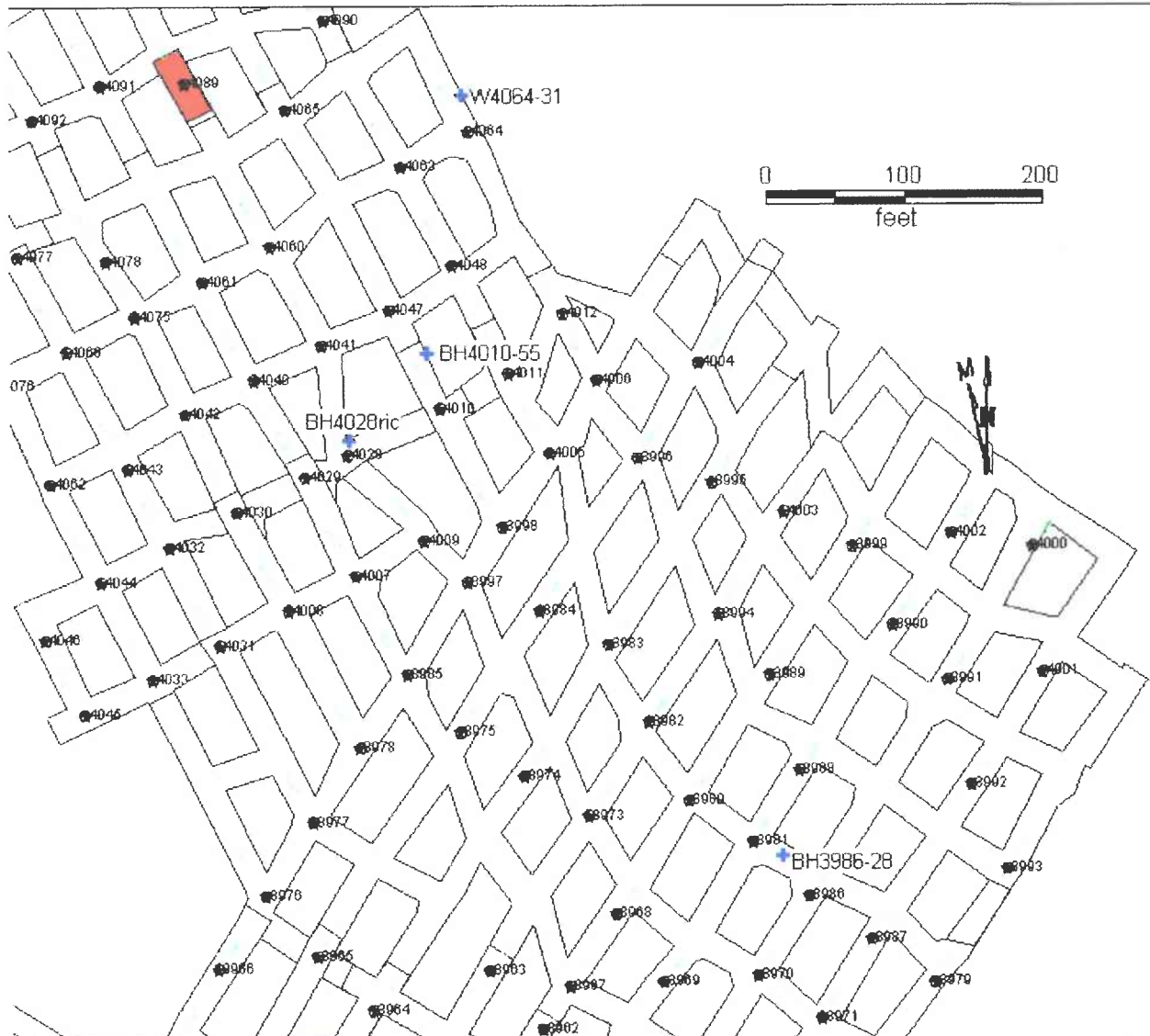


Figure 2. Map of the observed area of 2nd Left Mains in which rock and water samples were collected on March 20, 2006.



Figure 3. Collection of water droplets on the roof and fracture faces where "blue haze" was observed between spads 3986 and 3981.



Figure 4. Photo of Sample BH3986-28, with the mine's duplicate sample. The sample was collected from the roof approximately 28 feet into the left-hand crosscut from spad 3986. The distance was measured with a laser range finder.

Observations then proceeded along the #2 Entry of 2nd Left Mains, and across to the vicinity of spad 4028. "Blue haze" was observed on the rib of the right inby crosscut in the spad 4028 intersection. No water was present at this site, and so no water sample could be collected. However, a slab of rib that hosted the "blue haze" on the exposed face was collected, and split in half, with each half provided to the mine and MSHA personnel present (Figure 5). As the MSHA sample was being further split to obtain a suitably sized sample to place in a bag, the rock separated along a prominent bedding plane, exposing a fossil of a fern leaf attached to a very well developed central stalk, preserving the diamond-shaped, nearly serrated texture of the bark.



Figure 5. Samples collected from the right inby crosscut in the spad 4028 intersection. Half of the sample was retained by MSHA in a bag labeled "BH4028ric" and the other half was retained by mine personnel in a bag labeled "BH4028ric duplicate."

Observations continued across to the spad 4010 intersection, which had to be accessed by proceeding inby from spad 4028 to a more accessible crosscut due to benching. No water was observed in this sample collection locality, so no water sample was collected. A slab of "blue haze" coated rock was obtained from the right rib of the #6 Entry, where the floor ramped down to the beginning of the benched area (Figure 6).



Figure 6. Slab of “blue haze” coated rock retrieved from the right rib approximately 55 feet inby spad 4010. This slab was subsequently split in half, with each half retained by mine and MSHA personnel present.

Observations continued inby along #7 Entry, from the adjacent crosscut from spad 4010 to the crosscut inby spad 4063. This crosscut connects with terminated #8 Entry, where a barrier was left for a gas well. Observations were made of the intersection of the crosscut and the #8 Entry, the segment of the #8 Entry inby spad 4064, and the segment of the crosscut. A sample of water seeping from the right rib of the #8 Entry was collected with a plastic eye dropper, which was labeled with the sample number “W4064-31” to mark it distinctly from the eye dropper used previously for sample collection at the BH3986-28 site (Figure 7). The labeled eye dropper was photographed.



Figure 7. Water sample in glass vial collected from right rib of solid coal block in #8 Entry, 31 feet inby spad 4064. Plastic eye dropper is labeled with sample number to distinguish it from the separate dropper used in collection of sample BH3986-28.

The intersection is characterized by a series of wavy brown streaks, which extend into the adjacent #8 Entry and crosscut. Each wavy brown streak has a linear, although undulatory trend that was measured with a Brunton compass. The streaks in the outby side of the #8 Entry exhibit a trend of approximately N 13-15°E, such that they project into the right inby corner of the intersection (Figure 8 and 9). Traversing from the #8 Entry inby to the left-hand crosscut, the brown wavy streaks change their orientation, and continue to trend toward the right inby corner of the intersection. Thus, the brown wavy streaks define a radiating pattern with a center point about the right inby corner of the intersection. These long, roughly linear, but wavy brown streaks are developed in flat, planar portions of the exposed roof. Several brown wavy streaks were observed that are approximately perpendicular to those developed on the planar roof horizon. These perpendicular streaks were developed along protrusions or small brows from the roof, and represented the exposed ridges of bedding asperities, and are generally less than 4 feet long. Comparatively, the longer linear, but wavy streaks are generally 7-12 feet long. The brown wavy streaks do not represent surficial dust, and instead represent actual linear exposures of rock. The brown shale is masked by a very thin bedding parting of black, carboniferous shale, except where it has been removed to expose the brown wavy streaks. The removal mechanism gave the appearance of sand blasting or scouring, rather than gouging. There were no depressions associated with the streaks that would suggest a geologic origin such as scour marks or trace fossil imprints. Despite the straight rib profiles observed even in the benched portions of this

area, characterized by an absence of sloughing, several large (1 x 2 feet) blocks of coal had been removed from the face of the discontinued #8 Entry. This intersection, and the short segment of the crosscut and entry, had not been benched. While in the intersection, gas could be heard seeping from the right rib, and the sound of gurgling water was also apparent from the right rib. The sound was similar to that of water running down a drain, rather than pouring into a standing body. The intersection was characterized by standing water that ranged in depth from nominally 3 inches to at least 7 inches. Underground observations concluded in this intersection and the mine was exited.



Figure 8. Photo of linear, wavy brown streaks in the terminated #8 Entry, viewed looking inby along #8 Entry. Streaks are actually the exposed based of the brown shale that overlies the thin black carbonaceous shale bedding parting.

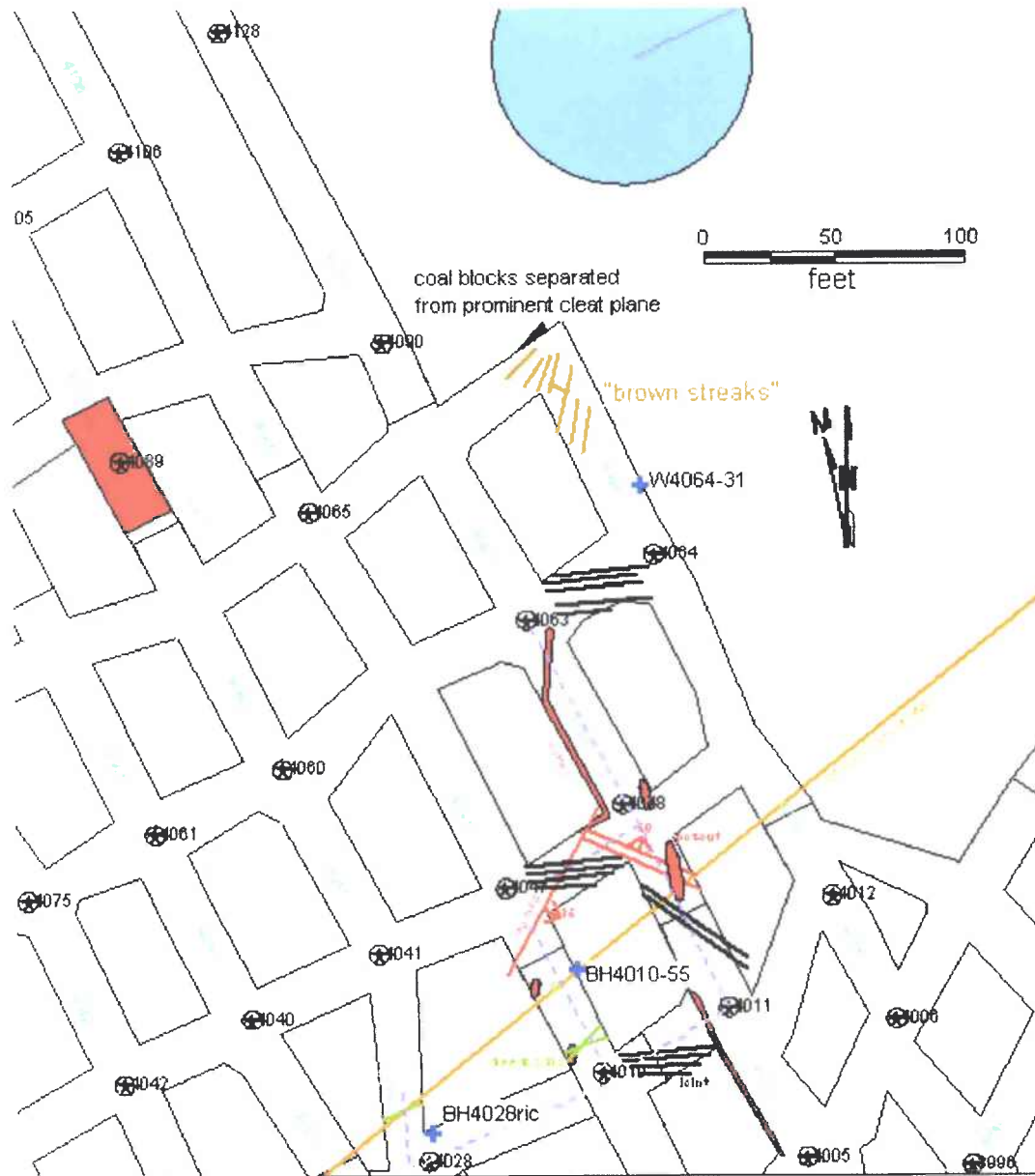


Figure 9. Detailed map of observations in the 2nd Left Mains, showing positions of "brown streaks" and sample collection sites with detailed geological observations from February 21, 2006.

March 21, 2006, Observations

Observations and sample collection continued on the surface the following day. Water samples were collected from a segment of the Buckhannon River, a segment of Trubie Run, a small tributary that drains into Trubie Run, and from Trubie Run at a position directly over the Main where sample "Trubie" was collected on the previous day (Figure 10).

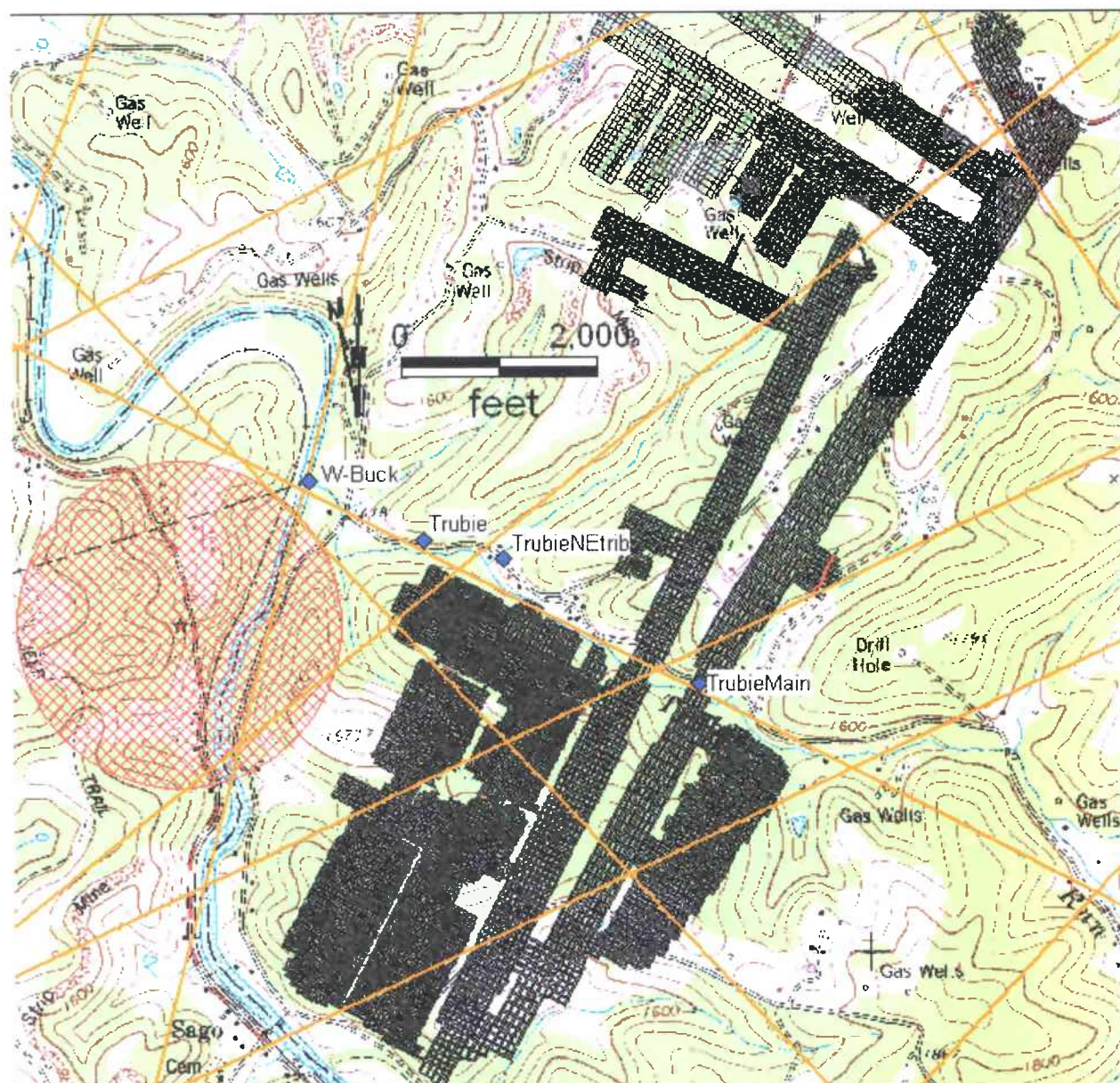


Figure 10. Map of surface water sample locations in relation to Sago Mine workings, RCD lineaments, and location of lightning strike.

The first sample was collected from the Buckhannon River along a segment north of the position of a reported lightning strike, and the point where Trubie Run enters the river. The sample, labeled "W-Buck," was collected from the edge of the stream bank, in slow moving water, with no visible organic material present. The location of the sample site was determined with a hand-held GPS unit, and recorded for display in the GIS from which Figure 10 was produced. The next sample was collected from Trubie Run between the Buckhannon River and the un-named, northeast trending tributary, and labeled "Trubie" (Figure 11). A sample with the same name was collected on March 20, 2006, from the underground workings on the track entry in the Main beneath Trubie Run. However, the two samples have different exhibit numbers. Sample

“TrubieNEtrib” was collected from the un-named tributary that trends northeast from Trubie Run. No other access could be found for this small stream, although the valley was paralleled by a county road to the head of the valley. Sample “TrubieMain” was collected from Trubie Run above the point where the Main passes beneath Trubie Run. This location was determined with a hand-held GPS based on coordinates provided by the mine. All locations were confirmed by MSHA personnel using their own hand-held GPS unit.



Figure 11. Photo of surface water sample collection at location “Trubie.” Not to be confused with the sample named “Trubie” collected from the track entry of the Main, underground.

Upon completion of the surface water sample collection, a prominent tree that was reportedly struck by lightning on the day of the Sago Mine explosion was visited. The position of the tree was determined using a hand-held GPS unit, and plotted on the RCD GIS maps (Figure 12). Using a powerful hand-held magnet, a small piece of magnetic material was found at the base of the tree. The material is interpreted to be magnetite, and exhibits surface oxidation. The genesis of the magnetite is not known. The magnetite could represent detrital material that was originally incorporated in eroded sedimentary rock, or if evidence of lightning striking the ground, would have to represent a change from original hematite (Fe_2O_3) to magnetite (Fe_3O_4).

oxides, are summarized in Table 1. The analysis results appear to be representative of sedimentary rocks, and even highlight the differences between roof shale (BH3986-28 and #8 brown streaks) with a higher percentage of silica and lower alumina in keeping with the abundant quartz grains distributed throughout the shale. In contrast, samples collected from the rib (BH4010-55 and BH4028ric) host significantly lower silica values and much higher alumina values, reflecting domination by clay with a lack of clastic sedimentary input. These differences are also reflected in marked differences in the magnesium, potassium, and phosphate contents in which MgO and K₂O are lowest in the paleo-soil horizon binder collected from the rib of BH4010-55, while phosphate is higher. Differences between the rib samples from BH4028ric and BH4010-55 may reflect that sample BH4028ric was collected from a fossiliferous portion of the coal seam, whereas samples from BH4010-55 were collected from a paleo-soil horizon that separates the upper and lower splits of the coal seam.

Element:	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ (T)	MnO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	LOI	Total
Units:	%	%	%	%	%	%	%	%	%	%	%	%
Detection Limit:	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01	0.01	0.01
Reference Method:	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP
# 8 brown streaks, Exhibit 7	55.85	24.33	3.52	0.02	1.42	0.25	0.37	3.98	1.141	0.1	9.27	100.2
BH3986-28, Exhibit 3	55.3	22.07	5.34	0.059	1.41	0.23	0.3	3.54	1.079	0.11	9.32	98.78
BH4010-55, Exhibit 5	45.52	31.04	2.28	0.003	0.18	0.46	0.36	1.75	1.259	0.87	13.51	98.22
BH4010-55B, Exhibit 5b	48.47	30.34	2.03	0.003	0.22	0.38	0.39	2	1.491	0.6	12.5	98.43
BH4028ric, Exhibit 4	48.87	26.13	3	0.012	1.04	0.14	0.35	2.62	1.269	0.09	16.97	100.5

Table 1. Results of Inductively Coupled Plasma analysis, reported as major oxides, for rock samples collected in 2nd Left Mains.

A sample of the “brown streaks” in the dropped #8 Entry was determined by X-ray diffraction to contain quartz, muscovite, kaolinite, siderite, and rutile. The presence of quartz, muscovite, and kaolinite are expected components of shale, and the results are supported by microscopic analysis conducted on other samples of the immediate roof that documented the presence of abundant quartz grains scattered throughout a matrix of muscovite mica. Siderite, an iron carbonate, is a sedimentary mineral found in clays, shales, and coal beds. Rutile, a titanium oxide, is a common accessory mineral in sedimentary rocks due to its resistance to weathering. The “brown streaks” are actually scour marks, exposing the overlying brown shale where the thin, black carbonaceous bedding parting of the immediate roof was scoured away. It is interesting to note that the “brown streak” scour marks form a radial pattern with respect to the northeast corner of the #8 Entry face, beyond which is located the cased gas well.

The purpose of the water samples collected from surface streams on March 21, 2006, and from the right rib of the #8 Entry on 2nd Left Main (W4064-31) and from the track entry of the Main (“Trubie”) was to assess the pH and electrical conductivity of water in the vicinity of the mine. A photo-lineament, referred to as “RCD Lineament 9NE” projects directly over the inby side of spad 4010, and appears to represent a steep, narrow drainage that trends northeast from Trubie Run. The water samples were

collected in segments that run from the area of the prominent lightning-damaged tree to the spad 4010 area to assess the potential that electrolytic solutions might occur in fracture zones between these two points. Results of pH and electrical conductivity tests are summarized in Table 2. The pH values of all samples, both surface and underground, are nearly neutral, ranging from 6.8 to 7.5. The pH of water samples collected from the surface, from the Buckhannon River and Trubie Run, are consistently 6.8. The pH of water samples collected underground is slightly more alkaline, at 7.1-7.5. Electrical conductivity values are reported in units of micro-Siemens per centimeter. A micro-Siemens is the same as a micro-mho, denoting that conductivity reported in "mho" units is the inverse of resistivity reported in "ohms." Samples collected from Trubie Run and the northeast-trending tributary of Trubie Run is very similar, ranging from 42.3-47.9 micro-Siemens/cm. These conductivity values are within a range comparable to that for "good city drinking water." Upon entering the Buckhannon River, the electrical conductivity values exhibit a marked increase and nearly double to 83.5 micro-Siemens/cm. This value is comparable to a range greater than that of ocean water. Water samples collected underground exhibit a much higher conductivity, with a sample collected from the fire tap at the junction with the new 2nd Left Main characterized by a value of 196 micro-Siemens/cm and the sample of dripping water collected from the track entry Main directly beneath Trubie Run (Figure 1), characterized by a value of 295 micro-Siemens/cm. The sample of dripping water collected from the right rib of the #8 Entry (W4064-31) is characterized by a much higher electrical conductivity of 708 micro-Siemens/cm. For example, this value is comparable to the electrical conductivity given by one reference as a 30% solution of nitric acid. It should be noted that Sample W4064-31 was collected from the rib of the #8 Entry near where the cased gas well is located.

	Conductivity	pH
Units:	$\mu\text{S/cm}$	pH
Detection Limit:	0.01	0.1
Reference Method:	ISE	pH
Fire tap - 2nd Left; Exhibit 1	196	7.1
Trubie; Exhibit 1	295	7.2
W4064-31; Exhibit 6	708	7.5
W-Buck; Exhibit 1	83.5	6.8
Trubie; Exhibit 2	47.9	6.8
Trubie NE trib; Exhibit 3	44.8	6.8
Trubie Main; Exhibit 4	42.3	6.8

Table 2. Electrical conductivity values (in micro-Siemens per centimeter) and pH values for water samples collected underground and from surface streams.

Chemical analyses were also conducted on samples W4064-31 and BH3986-28 by the Inductively Coupled Plasma-Mass Spectrometry method, to identify approximately 3-dozen trace elements. The most abundant material in both samples was sodium, which occurred in the water droplets collected at locality BH3986-28 at a concentration of 447 ppm, and at locality W4064-31 at a concentration of 135 ppm. The next most

respectively; silica at 12 and 9 ppm, respectively; potassium at 10.4 and 1.9 ppm, respectively; magnesium at 2.2 and 0.6 ppm, respectively; aluminum at 2.2 and 0.2 ppm, respectively; and less than 1 ppm of cobalt, zinc, arsenic, and bromine with even lower concentrations of remaining trace elements.

Based on the neutral pH values for the water samples, it would be difficult to consider water in the vicinity of the mine as "acid mine water." Based on the electrical conductivity values for the water samples, surface water appears to have little likelihood for representing a good conductor, although the sample from the Buckhannon River exhibited greater conductivity than that of ocean water. The water samples collected underground exhibit much greater values for electrical conductivity, with water dripping from the roof and rib exhibiting the highest conductivity values. The sample with the highest electrical conductivity value (W4064-31) was collected from the rib adjacent to the cased gas well (Figure 9). Based on a review of available literature, the value of 708 micro-Siemens/cm is comparable to the conductivity of a 30% solution of nitric acid. Because the pH of the sample is shown to be neutral, the high conductivity value suggests that some other ionic substance is present and has dissociated. Strong acids are considered good electrical conductors because they easily dissociate into charged ions in solution. The presence of high concentrations of sodium may be an indication of a strong ionic solution in this vicinity. That the sample with the very highest value of electrical conductivity is localized in the vicinity of the gas well may be significant, considering that the radial pattern of scour marks is located in the same entry within a few tens of feet, and radiate out from the entry corner beyond which is located the cased gas well (Figure 9). Of all the water samples collected, it appears that Sample W4064-31 would be the most likely to represent an electrolytic solution capable of conducting electricity. It should also be noted that during the sample collection effort, a significant amount of water was heard draining through the rib, which is an indication that this is not a solid, impermeable coal rib.

If you should have any questions or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.

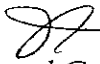
U.S. Department of Labor

Mine Safety and Health Administration
Industrial Park Road
RR1, Box 251
Triadelphia, West Virginia 26059



April 23, 2007

MEMORANDUM FOR: RICHARD A. GATES
District Manager, Coal Mine Safety and Health, District 11

FROM: JOHN P. FAINI 
Chief, Approval and Certification Center

SUBJECT: Executive Summary of Submersible Pump Parts Recovered
from the Sago Mine

The Approval and Certification Center (A&CC), as requested by Coal Mine Safety and Health and the West Virginia Office of Miner's Health, Safety, and Training, conducted a laboratory investigation of submersible pump parts recovered from the abandoned (sealed) area of the Sago Mine. This equipment included: 6 trailing cable pieces (3 pairs of cables); a pump control box with associated trailing cable and pump cable; and a coupler (cathead) with associated trailing cable. The purpose of this investigation was to inspect and test the parts from the submersible pump assembly to determine: the electrical continuity of the pump trailing cables; if the cable ends match together and the mechanism for breakage of the three pairs of cables; and, if there is any evidence of sparking, heating, melting, etc. of the cables, cathead, and control box. The laboratory examination and testing included visual examination of the cables with a magnifying glass and a low powered microscope. A digital multimeter was used to make continuity measurements of the cable conductors.

The laboratory examination and testing could not determine if a continuous cable ran from the cathead to the pump at the time of the explosion. A discrepancy in the markings present on the trailing cables associated with the cathead, six (6) cable pieces and the trailing cable on the pump control box suggests that two different trailing cables were used to provide power for the submersible pump. A splice or cable coupler joining these two different trailing cables was not recovered from the mine for this examination.

The mechanism for breakage of the cable pairs could not be specifically determined to be from moving equipment or from explosion-related tears. The laboratory investigation showed that the damage to all three pairs of cable was caused from being pulled apart rather than severed by mechanical means. All of the respective cable pairs appeared to match.

There was no evidence of arcing or sparking on any of the cable ends or the pump control box. Some heat damage appeared to be on the tape portions of one cable pair.

There was some evidence of water contamination inside of the pump control box. The pump control box did not house any energy storage devices such as capacitors or batteries.

cc: D. Chirdon
K. Porter
R. Boring
Files

MSHA:A&CC:RCBoring:klb:04-23-07

FILE COPY
SURNAME
<i>R. Boring</i>
<i>K. Porter</i>
<i>D. Chirdon</i>

U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236



Mine Electrical Systems Division

April 4, 2007

MEMORANDUM FOR RICHARD A. GATES

District Manager
CMS&H District 11

THROUGH:


M. TERRY HOCH

Chief, Pittsburgh Safety and Health Technology Center

FROM:


WILLIAM J. HELFRICH

Chief, Mine Electrical Systems Division

SUBJECT: Sago Mine Pump Cable Test

Attached is a copy of the subject report which details the testing that was conducted on a section of a pump cable removed from the sealed are of the Sago Mine (ID #46-08791), located in Upshur County, West Virginia.

If you have any questions, please contact William Helfrich at (412) 386-6959 or email at Helfrich.william@dol.gov.

Attachment

cc: R. Phillips, CMS&H District 2

bcc: M. Skiles, TS w/attach
L. Zeiler, TS w/attach
T. Hoch, PSHTC w/attach
R. Stoltz, VENT w/attach
W. Helfrich, MESD w/attach
D. Skorski, MESD w/attach
MESD Files w/attach

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UNITED STATES DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
PITTSBURGH SAFETY AND HEALTH TECHNOLOGY CENTER
MINE ELECTRICAL SYSTEMS DIVISION (MESD)

REPORT NO: L-04022007-1

INVESTIGATION DATE: January 31, 2007

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Pittsburgh Research Center

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SUBJECT: Inspection and Testing of Sago Mine Pump Cable

INTRODUCTION

On December 4, 2006, the Mine Electrical Systems Division (MESD) was requested to obtain a section of a pump cable from the sealed area of the Sago Mine. Arrangements were made with Coal Mine Safety and Health (CMS&H) District 3 and the mine operator to retrieve the cable on December 7, 2006. MESD took possession of the cable on that day and has securely maintained the section of cable. A water bath testing of the cable, which provides information on the dielectric strength of the conductor insulation and jacket, was conducted on January 31, 2007.

CABLE TESTING PROCEDURES

The following cable tests used the test procedures in NEMA WC-70/ICEA S-95-658-1999, titled "Ethylene-Propylene-Rubber Insulated Wire and Cable - Nonshielded 0-2kV Cables," Section 6.10.1 - "Voltage Tests" as a guideline.

General

These tests consisted of voltage tests on a Tiger Brand Cable, AWG #6, 3-conductor, type G-GC, 2000 volt cable. Each conductor was tested separately, and a voltage was applied between individual conductors and the grounded water tank.

The multiple conductor cable was immersed in water for at least 12 hours and tested while still immersed.

Resistance Test

After the cable has been immersed in water for the determined time, a resistance test was made between each conductor and the tank frame, as well as between each of the conductors. A continuity measurement was also made on each conductor in the cable.

Alternating Current Voltage Test

This test was made with an alternating potential from a transformer of ample capacity, which was in no case less than 3 kilo-volt-amperes. The frequency of the test voltage was nominally between 49 and 61 hertz, and had a wave shape approximating a sine wave as closely as possible.

Single-phase voltage was applied separately across each of the four (4) insulated cable conductors and the two (2) ground conductors, and tank frame. The order was red, white, black, yellow (ground check), ground 1, and ground 2. The tank frame was grounded to the power system ground.

The rate of increase from initial applied voltage of zero (or previous test voltage) to each following applied voltage for the specified test voltage was approximately uniform and was not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds.

The duration of the alternating-current test voltage to the immersed cable was as follows for each conductor:

<u>Voltage</u>		<u>Duration</u>
100 volts	-	5 minutes
200 volts	-	5 minutes
300 volts	-	5 minutes
400 volts	-	5 minutes
500 volts	-	5 minutes
600 volts	-	5 minutes
700 volts	-	5 minutes
800 volts	-	5 minutes
900 volts	-	5 minutes
1000 volts	-	5 minutes
1200 volts	-	5 minutes
1400 volts	-	5 minutes
1600 volts	-	5 minutes
1800 volts	-	5 minutes
2000 volts	-	5 minutes (maximum rating of cable)

End of Test

Measurements were made of voltage and current flow in the ground path for each of the voltage levels. If a current of a least 100 milli-amperes was detected at any voltage level, the test was terminated, and NO additional testing was conducted on that conductor.

It was possible that a catastrophic failure of the conductors in the cable could occur during this testing. The power supply was provided with ground fault tripping, which was not adjustable and was approximately 5.4 amperes.

If a current of a least 100 milli-amperes was not detected through the 2000-volt test level, NO additional testing was conducted on that conductor individually as it had passed this part of the test.

Test Setup (see Figure 1 below)

Electrical testing was conducted in a metal tank, with each side and depth of approximately 3 feet. The tank was grounded to the power system ground and filled with tap water. The test cable was immersed in tank water, which was maintained at room temperature for at least 12 hours, and the water level was kept constant.

The length of the test cable was approximately 190 feet. The cable was rolled onto a fabricated reel to permit the cable to fit into the tank in its entirety. The outer jacket of the first 6 inches of each end of the cable was stripped away. The three-phase conductors, ground check wire, and two ground wires were isolated from each other on each end. Approximately 1 inch of conductor insulation was removed from each insulated conductor (one end only) to facilitate connection of test leads.

A 1-foot portion (minimum) of each end of the cable was kept above water as leakage insulation.

A diagram of the test setup can be found at the end of this document (Figure 1).

Test Procedures

Resistance Test (No Power/Conducted with a Fluke Model 87 VOM)

1. Visual observation of the test cable.
2. Measure continuity of each conductor in cable (see results in Table 1 below).
3. Connect test leads to cable and tank.
4. Measure resistance of each conductor in the cable.
 - a. Each conductor to the grounded water tank (see results in Table 2 below).
 - b. Each conductor to all the other conductors (see results in Table 3 below).

Table 1. - Continuity Measurements of Each Conductor

Red	White	Black	Ground Check	Ground 1	Ground 2
0.1 ohms	0.1 ohms	0.1 ohms	0.2 ohms	0.5 ohms	0.5 ohms

**Table 2. - Resistance Measurements of Conductors in Cable
(measurements recorded in meg-ohms)**

Red	White	Black	Ground Check	Ground 1	Ground 2
1.351	6.4	1.304	1.889	1.014	1.014

Tests were conducted with one lead of ohm-meter connected to each conductor and the other lead connected to the metal tank.

Table 3. - Resistance Measurements between Conductors in Cable

	Red	White	Black	Ground Check	Ground 1	Ground 2
Red		3.45M	78K	0.945M	31.2K	31.8K
White			9.65M	12M	8.74M	8.8M
Black				0.968M	40K	40K
Ground Check					29.7K	30.5K
Ground 1						0.3K
Ground 2						

"M" designates Meg-ohms (millions)

"K" designates Kilo-ohms (thousands)

Alternating Current Test Procedures (results are shown in Table 4 below)

1. Visual observation of the test cable (no power).
2. Connect test leads to cable and tank in the order described earlier (red, white, black, ground check).
3. **Remove all observers from test area.**
4. Engage main power switch.
5. Switch power source on.
6. Increase voltage to 100 volts at predetermined rate.
7. Hold voltage constant for 5 minutes time.
8. If current flow was below 100 milli-amperes, increase voltage to 200 volts at predetermined rate.
9. Hold voltage constant for 5 minutes time.

10. If current flow was below 100 milli-amperes, increase voltage to 300 volts at predetermined rate.
11. Hold voltage constant for 5 minutes time.
12. If current flow was below 100 milli-amperes, continue increasing the voltage in 100-volt increments (or 200-volt increments, see table below) up to the 2000 volt limit.
NOTE: If current flow exceeded 100 milli-amperes at any voltage level, testing was over for that conductor.
13. Decrease test voltage to zero.
14. Switch power source off. Keep key on person.
15. Bleed off any static charge on water tank with shorting stick. Hang shorting stick on tank.
16. Connect test lead to different conductor.
17. Remove shorting stick.
18. Repeat from Step 5.

Table 4. - Cable Testing Results (individual conductor to grounded tank frame)						
Current Level Through Conductors (milli-amperes)						
Voltage Level (volts)	Red	White	Black	Ground Check	Ground 1	Ground 2
100	5	3	6	7	24V/107mA	24V/206mA
200	12	3	14	17		
300	16	4	22	20		
400	18	4	32	28		
500	19	5	37	29		
600	21	5	41	35		
700	25 ¹	6	43	35		
800	29 ²	6	43	34		
900	9 ³	7	42	33		
1000	9 ⁴	8	41	36		
1200	12 ⁵	9	78	41		
1400	11 ⁶	10	100	40		
1600	12 ⁷	12		43 ¹⁰		
1800	GFT	13		250 ¹¹		
2000		14				

Notes:

- 1 - ammeter briefly read over 100 milli-amps 3 times during test
- 2 - ammeter briefly fluctuated over 100 milli-amps 2 to 3 times
- 3 - ammeter read over 2 amps twice during test
- 4 - ammeter read over 2 amps twice during test
- 5 - ammeter read over 100 milli-amps numerous times during test

- 6 - ammeter fluctuated number times over 500 milli-amps and once over 1 amp
- 7 - ammeter read over 4 amps twice during test
- 8 - initially, ammeter read over 100 milli-amps
- 9 - ammeter averaged over 100 milli-amps for duration of test
- 10 - ammeter fluctuated over 100 milli-amps several times during test
- 11 - ammeter averaged over 250 milli-amps at beginning of test
- GFT - ground fault trip on power supply (current level at least 5.4 amps)

The white phase conductor passed the testing at the voltage rating of the cable (2000 volts). The investigators decided to test this cable further to determine the voltage level at which it would fail. The additional testing procedures followed the previous procedures with the exception of the duration at each voltage level. A 1-minute hold at each voltage level would be used to determine the level of voltage for the white conductor to meet the failure criteria. The following table illustrates the results of this additional testing (Table 5).

**Table 5. - Cable Testing Results
(voltages above the 2000-volt rating of the cable under test)**

Current level through white phase conductor (milli-amps)

Voltage Level (volts)	Red	White	Black	Ground Check	Ground 1	Ground 2
2500		18				
3000		21				
3500		24				
4000		27				
4500		30				
5000		36				
5500		GFT				

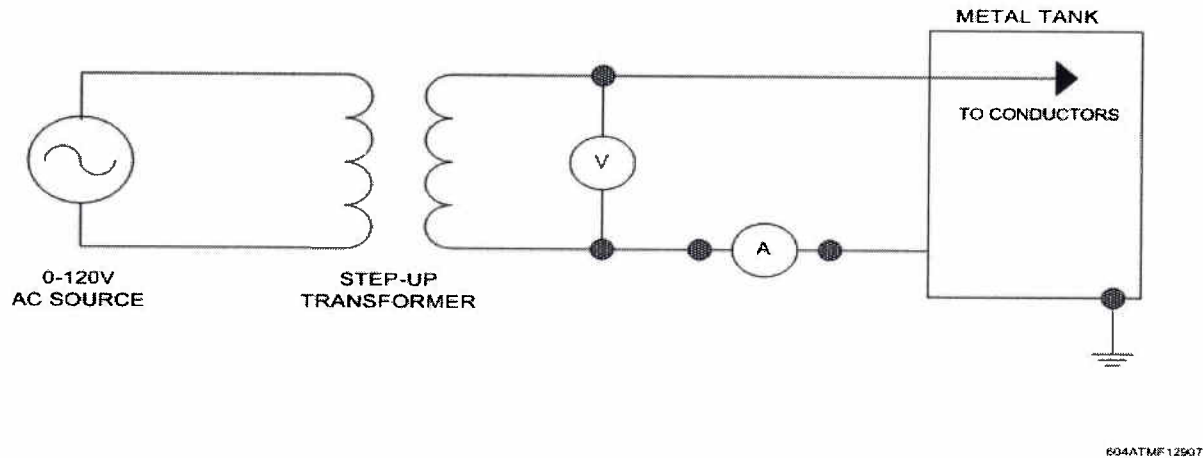


Figure 1. - Test Set-Up

VISUAL OBSERVATIONS

Following the removal of the cable from the water bath testing, the cable was allowed to dry. The cable was then removed from the cable reel and all damaged areas and splices were documented. The table below (Table 6) provides the locations of damaged areas and splices with respect to the coupler (cat head) end of the cable. The measured length of the cable was 192.5 feet.

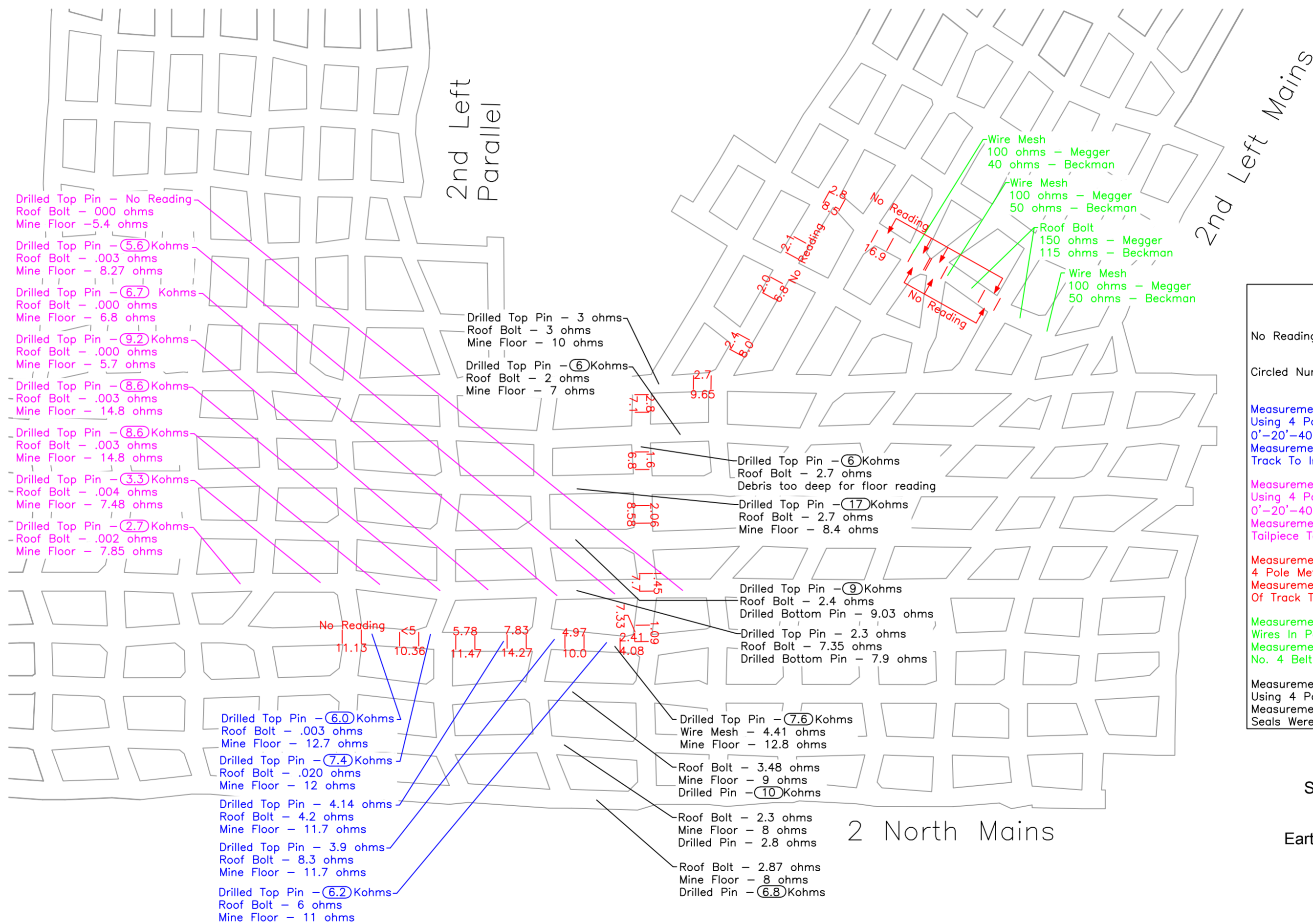
Table 6. - Visual Observations of Pump Cable
(all measurements (in feet) are from coupler end of cable)

Damaged Sections (includes nicks, slices, cracks, etc.)		Spliced Sections (included permanent and temporary splices) T: Temporary P: Permanent	Taped Sections
11.5	27	87.3 P	17.7
37.7	46	132.8 P	33.5
65.9	87.1	146.7 T	
93.4	94.7	182.9 P	
96.9	99		
100.3	105.4		
108.1	108.4		
110.9	111.7		
112.1	114.9		
120.4	121		
128.1	131.3		
132.1	135.2		
138.7	139.5		
141.7	144.6		
150.7	162.4		
168.8	171.9		
174.3	180.3		
185.7	186.5		
186.9	187.8		

SUMMARY

The water bath testing of the pump cable revealed that the insulation on three of the four insulated conductors in the cable (red, black, and ground check) failed prior to the test voltage reaching the rated voltage of the cable (2000 volts). The white conductor reached a voltage of approximately 5,500 volts before a failure of the insulation occurred. The design of the cable did not provide insulation for the 2 ground conductors. As expected, they both failed at a very low voltage.

There were numerous locations on the cable jacket where significant damage was apparent. There were three permanent splices and one temporary splice in the section of cable tested. Based on the overall condition of this relatively short section of cable, the test results confirmed the anticipated failure of the insulation surrounding the conductors.



Drilled Top Pin - No Reading
Roof Bolt - .000 ohms
Mine Floor - 5.4 ohms

Drilled Top Pin - (5.6) Kohms
Roof Bolt - .003 ohms
Mine Floor - 8.27 ohms

Drilled Top Pin - (6.7) Kohms
Roof Bolt - .000 ohms
Mine Floor - 6.8 ohms

Drilled Top Pin - (9.2) Kohms
Roof Bolt - .000 ohms
Mine Floor - 5.7 ohms

Drilled Top Pin - (8.6) Kohms
Roof Bolt - .003 ohms
Mine Floor - 14.8 ohms

Drilled Top Pin - (8.6) Kohms
Roof Bolt - .003 ohms
Mine Floor - 14.8 ohms

Drilled Top Pin - (3.3) Kohms
Roof Bolt - .004 ohms
Mine Floor - 7.48 ohms

Drilled Top Pin - (2.7) Kohms
Roof Bolt - .002 ohms
Mine Floor - 7.85 ohms

Drilled Top Pin - 3 ohms
Roof Bolt - 3 ohms
Mine Floor - 10 ohms

Drilled Top Pin - (6) Kohms
Roof Bolt - 2 ohms
Mine Floor - 7 ohms

Drilled Top Pin - (6) Kohms
Roof Bolt - 2.7 ohms
Debris too deep for floor reading

Drilled Top Pin - (17) Kohms
Roof Bolt - 2.7 ohms
Mine Floor - 8.4 ohms

Drilled Top Pin - (9) Kohms
Roof Bolt - 2.4 ohms
Drilled Bottom Pin - 9.03 ohms

Drilled Top Pin - 2.3 ohms
Roof Bolt - 7.35 ohms
Drilled Bottom Pin - 7.9 ohms

Drilled Top Pin - (6.0) Kohms
Roof Bolt - .003 ohms
Mine Floor - 12.7 ohms

Drilled Top Pin - (7.4) Kohms
Roof Bolt - .020 ohms
Mine Floor - 12 ohms

Drilled Top Pin - 4.14 ohms
Roof Bolt - 4.2 ohms
Mine Floor - 11.7 ohms

Drilled Top Pin - 3.9 ohms
Roof Bolt - 8.3 ohms
Mine Floor - 11.7 ohms

Drilled Top Pin - (6.2) Kohms
Roof Bolt - 6 ohms
Mine Floor - 11 ohms

Drilled Top Pin - (7.6) Kohms
Wire Mesh - 4.41 ohms
Mine Floor - 12.8 ohms

Roof Bolt - 3.48 ohms
Mine Floor - 9 ohms
Drilled Pin - (10) Kohms

Roof Bolt - 2.3 ohms
Mine Floor - 8 ohms
Drilled Pin - 2.8 ohms

Roof Bolt - 2.87 ohms
Mine Floor - 8 ohms
Drilled Pin - (6.8) Kohms

Wire Mesh
100 ohms - Megger
40 ohms - Beckman

Wire Mesh
100 ohms - Megger
50 ohms - Beckman

Roof Bolt
150 ohms - Megger
115 ohms - Beckman

Wire Mesh
100 ohms - Megger
50 ohms - Beckman

Legend

No Reading: Reading Beyond The Capability Of The Instrument

Circled Number: Test Equipment Indicated Reading Is Not Reliable

Measurements Taken With N.G.I. Resistance Tester Using 4 Pole Method With Pins Installed At 0'-20'-40'-60' Intervals
Measurements Taken From End of Track To Inby Seal Installed In That Area

Measurements Taken With N.G.I. Resistance Tester Using 4 Pole Method With Pins Installed At 0'-20'-40'-60' Intervals
Measurements Taken From No. 4 Belt Tailpiece To Inby Seal Installed In That Entry

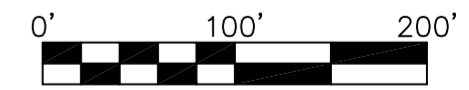
Measurements Taken With N.G.I. Resistance Tester 4 Pole Method - Readings Are In Ohms
Measurements Taken From End Of Track To SS4010: Top and Floor Readings.

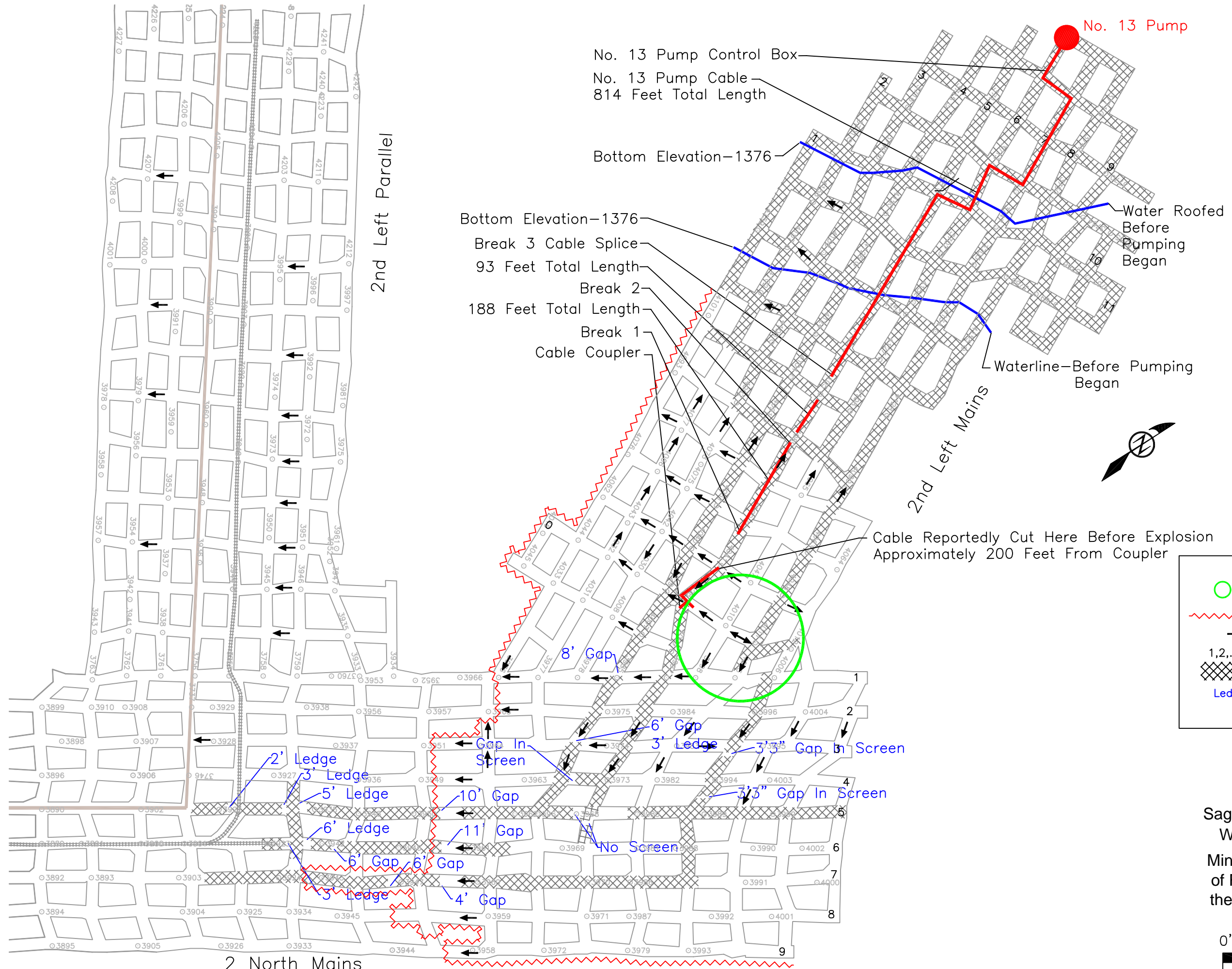
Measurements Taken With 2-No. 12 Solid Copper Wires In Parallel
Measurements Taken From No. 6 Belt Starter And No. 4 Belt Tailpiece

Measurements Taken With N.G.I. Resistance Tester Using 4 Pole Method
Measurements Taken From End Of Track To Where Seals Were Installed

Appendix KK

Sago Mine, MSHA ID 46-08791
Wolf Run Mining Company
Earth Resistance Measurement Values





Legend

- Origin
- ~ Extent Of Flame
- \rightarrow Primary Direction Of Forces
- 1,2,... Entry Number
- Wire Mesh
- Ledge Gap In Screen Where Extra Height Was Extracted

Appendix LL

Sago Mine, MSHA ID 46-08791
 Wolf Run Mining Company
 Mine Map Detailing the Extent of Flame and the Direction of the Primary Explosion Forces

