ENCE 667 Class Project
Pile Optimization

Presented by:

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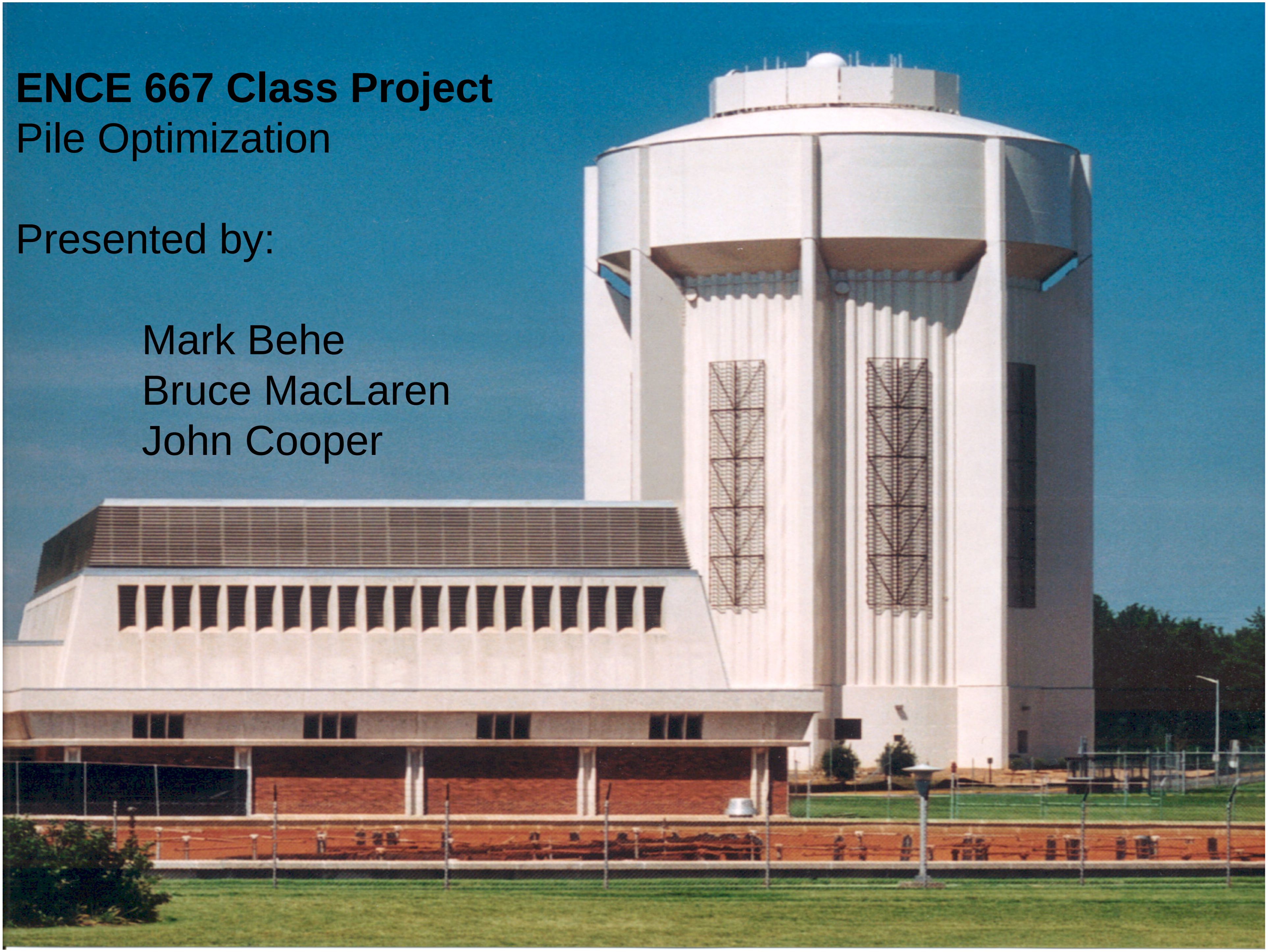


Background

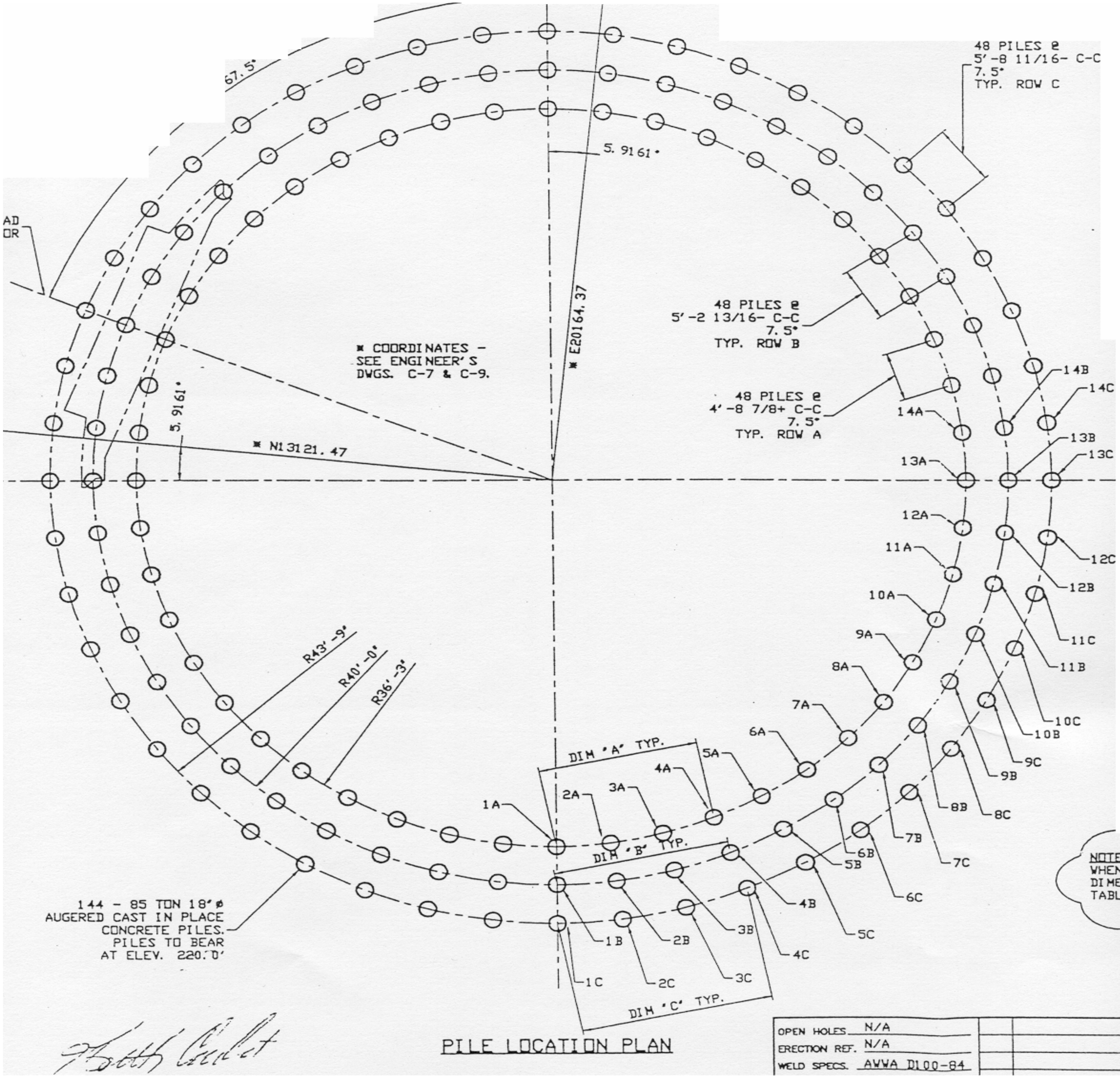
- Addressed a need for water storage
- Replaced two antiquated water tanks
- Design incorporated a communications facility and community room
- Key component of the project was a deep foundation system

Project Objectives

- Pile Optimization
  - Maximize number of pile placements per crane setup, to minimize setup time
- Create a probability distribution
  - Create mechanism for management type decisions, or “what-if” scenarios

Key Variables

- Foundation system consists of 144 - 18” diameter auger cast piles
- Installed in three concentric rings
- Will study the time effects of:
  - Crew and crane
  - Auger rig assembly
  - Grout pump



INS. PILE LAYOUT TABLE (36'-3 RAD.)

PILE #	DIM 'A'
1A TO 1A	0'-0
TO 2A	4'-8 7/8
TO 3A	9'-5 9/16
TO 4A	14'-1 3/4
TO 5A	18'-9 3/16
TO 6A	23'-3 5/8
TO 7A	27'-8 15/16
TO 8A	32'-0 13/16
TO 9A	36'-3
TO 10A	40'-3 3/8
TO 11A	44'-1 5/8
TO 12A	47'-9 5/8
TO 13A	51'-3 3/16
TO 14A	54'-6 1/8

CENTER PILE LAYOUT TABLE (40'-0 RAD.)

PILE #	DIM 'B'
1B TO 1B	0'-0
TO 2B	5'-2 13/16
TO 3B	10'-5 5/16
TO 4B	15'-7 5/16
TO 5B	20'-8 7/16
TO 6B	25'-8 9/16
TO 7B	30'-7 3/8
TO 8B	35'-4 5/8
TO 9B	40'-0
TO 10B	44'-5 3/8
TO 11B	48'-8 7/16
TO 12B	52'-9
TO 13B	56'-6 13/16
TO 14B	60'-1 3/4

OS. PILE LAYOUT TABLE (43'-9 RAD.)

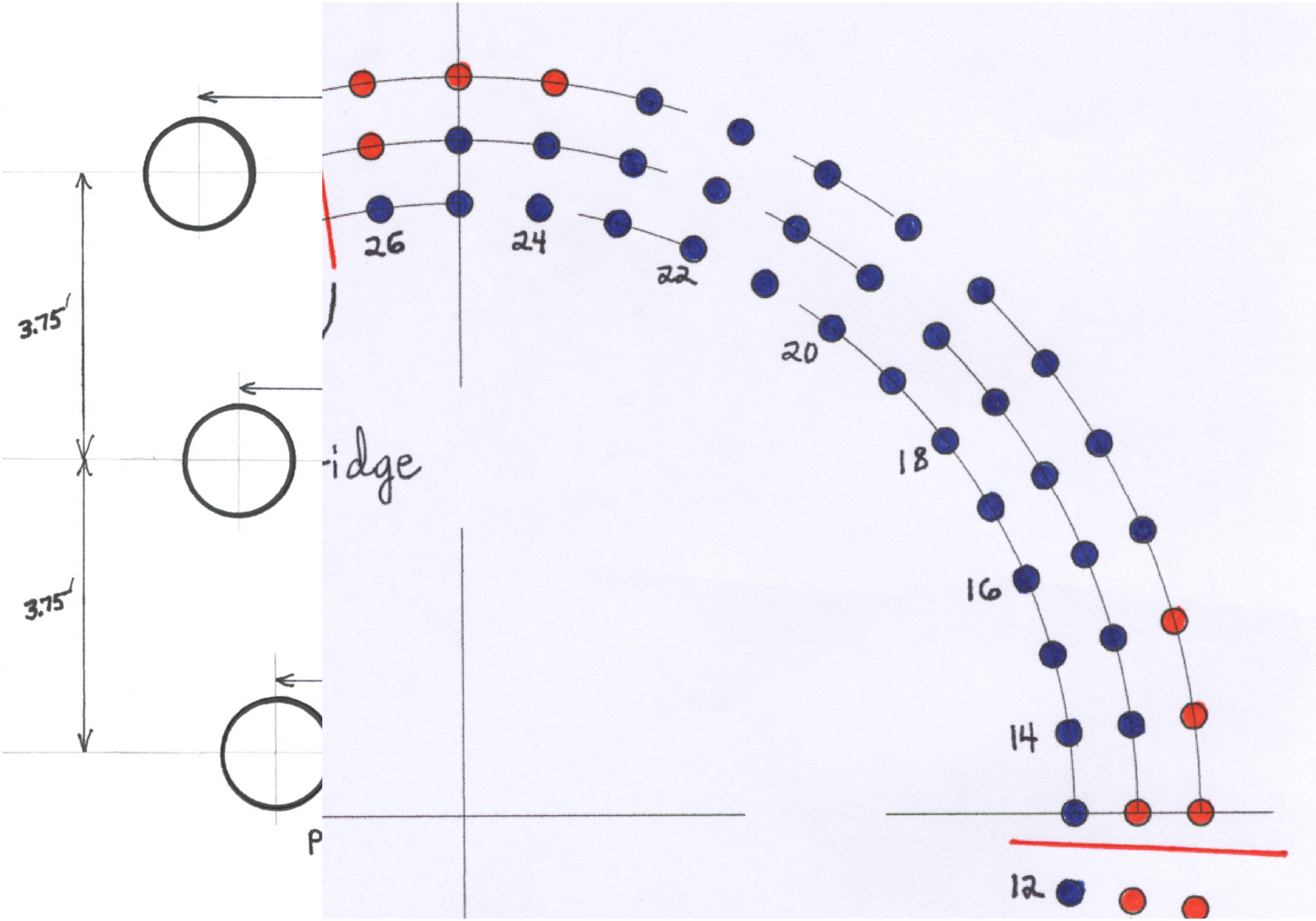
PILE #	DIM 'C'
1C TO 1C	0'-0
TO 2C	5'-8 11/16
TO 3C	11'-5 1/16
TO 4C	17'-0 7/8
TO 5C	22'-7 3/4
TO 6C	28'-1 1/2
TO 7C	33'-5 13/16
TO 8C	38'-8 3/8
TO 9C	43'-9
TO 10C	48'-7 3/8
TO 11C	53'-3 3/16
TO 12C	57'-8 5/16
TO 13C	61'-10 7/16
TO 14C	65'-9 7/16


Link-Belt


Link-Belt

Constraints

- Number of hours worked in a day
- Distances that must be maintained between adjacent piles during installation within a specific timeframe
- Distance maintained by crane to any given pile
- Geometry of the pile cap



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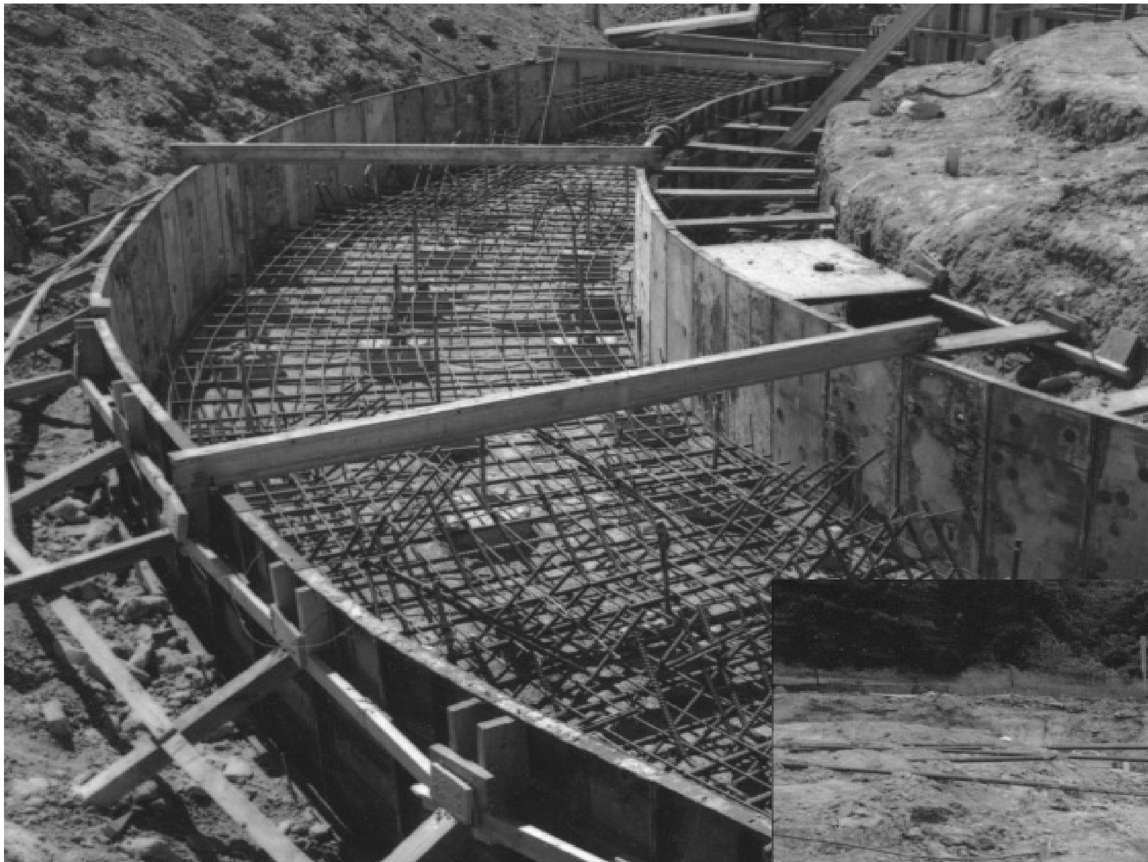


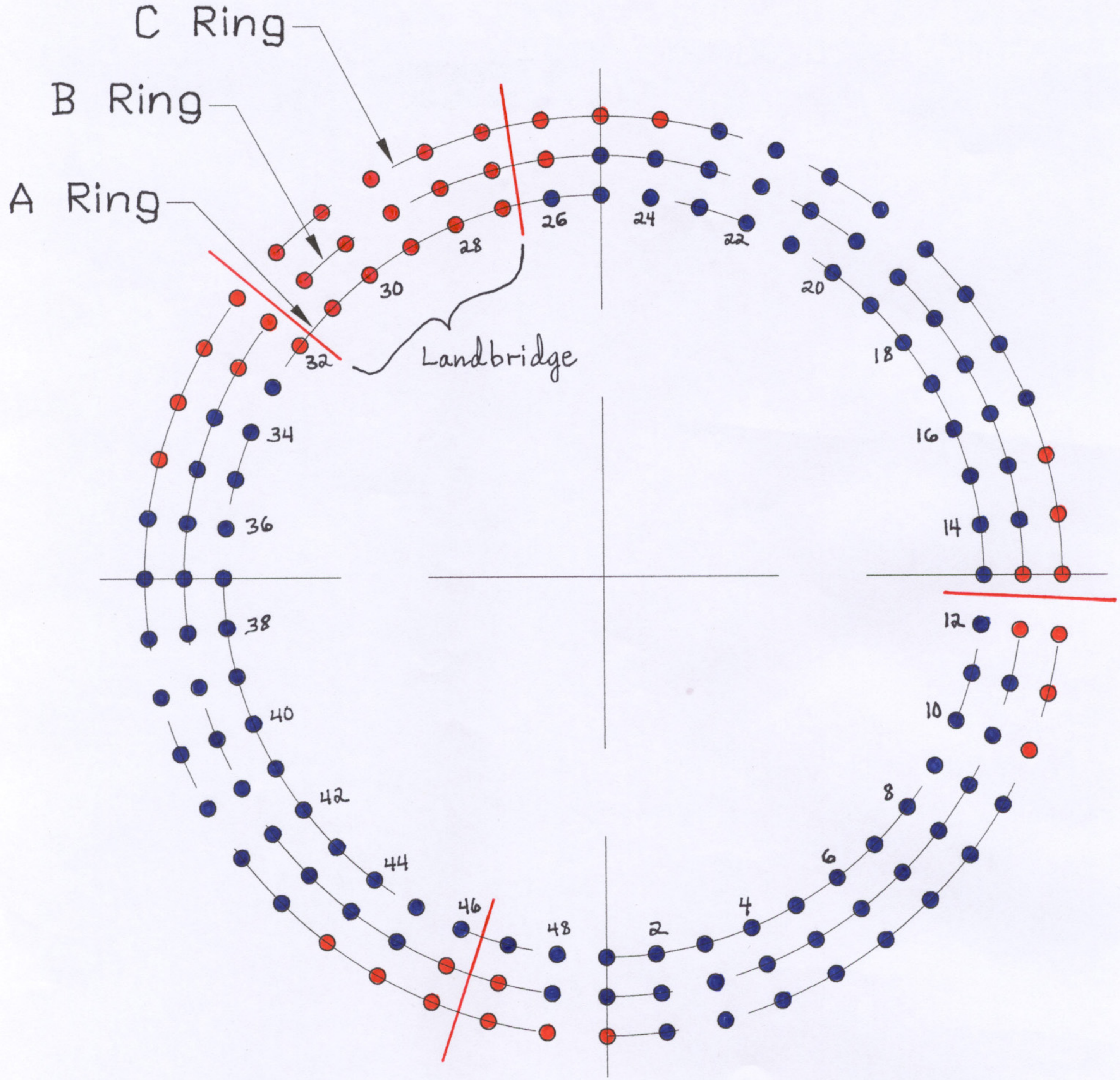

4 “What-If” Scenarios Shall Be Considered

- Scenario #1: Buy/Rent Faster Grout Pump
- Scenario #2a: Buy/Rent Faster Auger Rig Assembly (Reduce Drill Times By 2 Minutes)
- Scenario #2b: Buy/Rent Faster Auger Rig Assembly (Reduce Drill Times By 3 Minutes)
- Scenario #3: Buy/Rent Faster Grout Pump <u>AND</u> Buy/Rent Faster Auger Rig Assembly (Reduce Drill Times By 3 Minutes)

General Analytical Approach

- Feasible Pile Installation Regions Defined Based On Geometry Of Crane Placement With Respect To 3 Concentric Pile Rings

- Determine Most Efficient Pile Installation Sequence Over Feasible Pile Installation Region



C Ring
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Landbridge
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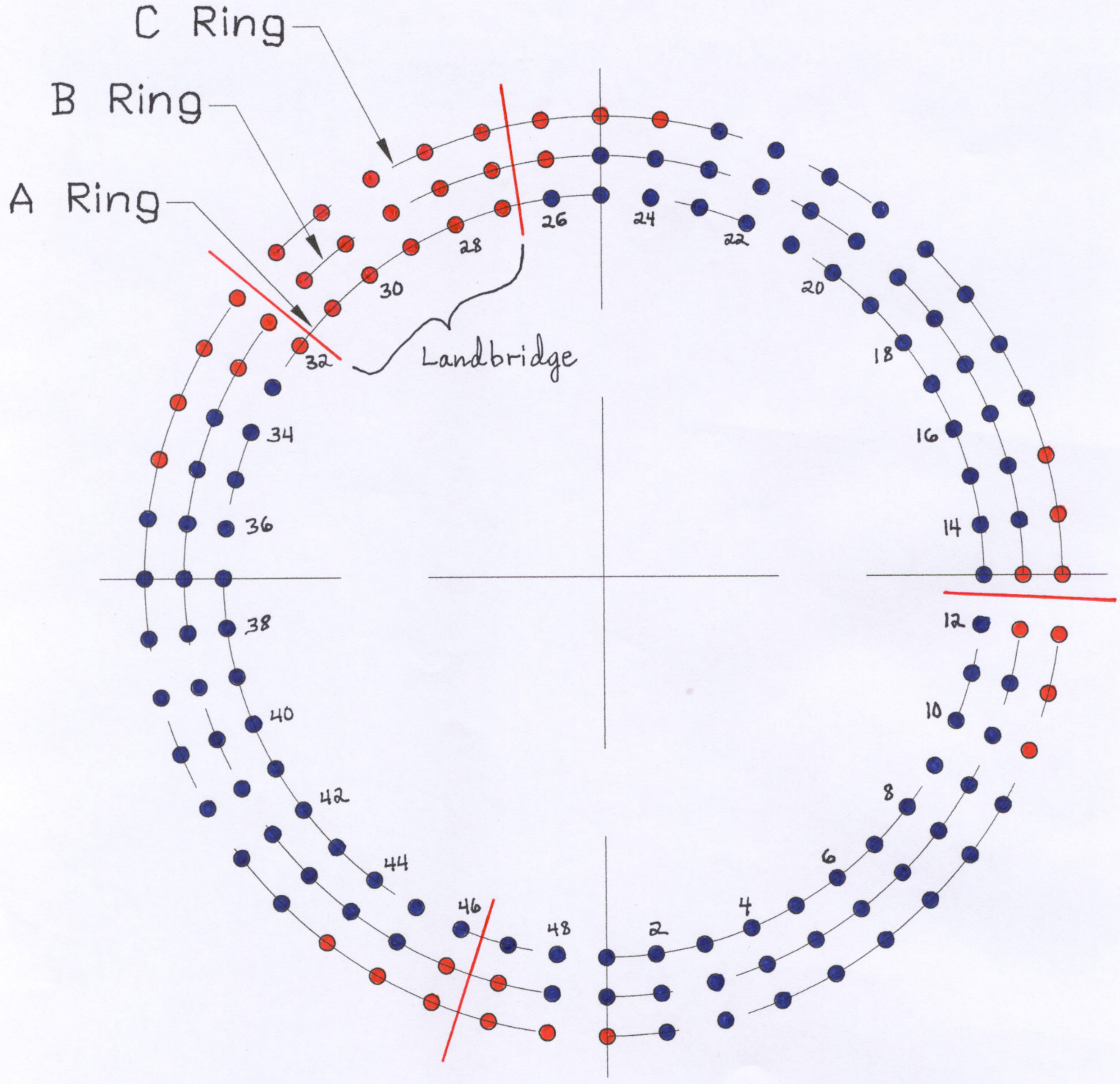
General Analytical Approach (cont.)

- **Create Spreadsheet of Pile Installation Time Components: Auger Set-Up Time, Drill Time, Grout Pump Time, and Total Installation Time**
- **Alter Times To Reflect Use Of Technologies To Improve (Decrease) Total Installation Times**
- **Perform Bin Analysis On Total Installation Times To Determine Type Of Distribution**
- **Determine σ, μ, and Minimum & Maximum Observed Total Installation Times And Use @Risk To Generate Probability Distribution**
- **Determine Probability of Encroaching On “Wet” Pile**

Scenario #1: Buy/Rent Faster Grout Pump

Pile #	Crane Setup Location (ft) (Interior)	Total # Of Piles Installed	Start Time	Avg. auger Setup time (min)	**Start Drill Time**	Drill Time (min)	**Start Pump Time**	Pump Time (min)	**End Pump Time**	Total Time To Install Pile (min)	Cumulative total time (min)
23C	25	1	8:30	0:10	8:40	0:08	8:48	0:05	8:53	0:23	0:23
21C	25	2	8:53	0:10	9:03	0:08	9:11	0:05	9:16	0:23	0:46
19C	25	3	9:16	0:10	9:26	0:08	9:34	0:05	9:39	0:23	1:09
17C	25	4	9:39	0:10	9:49	0:08	9:57	0:05	10:02	0:23	1:32
24B	25	5	10:02	0:10	10:12	0:08	10:20	0:05	10:25	0:23	1:55
22B	25	6	10:25	0:10	10:35	0:08	10:43	0:05	10:48	0:23	2:18
20B	25	7	10:48	0:10	10:58	0:08	11:06	0:05	11:11	0:23	2:41
18B	25	8	11:11	0:10	11:21	0:08	11:29	0:05	11:34	0:23	3:04
16B	25	9	11:34	0:10	11:44	0:08	11:52	0:05	11:57	0:23	3:27
14B	25	10	11:57	0:10	12:07	0:08	12:15	0:05	12:20	0:23	3:50
25A	25	11	12:20	0:10	12:30	0:08	12:38	0:05	12:43	0:23	4:13
23A	25	12	12:43	0:10	12:53	0:08	13:01	0:05	13:06	0:23	4:36
21A	25	13	13:06	0:10	13:16	0:08	13:24	0:05	13:29	0:23	4:59
19A	25	14	13:29	0:10	13:39	0:08	13:47	0:05	13:52	0:23	5:22
17A	25	15	13:52	0:10	14:02	0:08	14:10	0:05	14:15	0:23	5:45
15A	25	16	14:15	0:10	14:25	0:08	14:33	0:05	14:38	0:23	6:08
13A	25	17	14:38	0:10	14:48	0:08	14:56	0:05	15:01	0:23	6:31
22C	25	18	15:01	0:10	15:11	0:08	15:19	0:05	15:24	0:23	6:54
20C	25	19	15:24	0:10	15:34	0:08	15:42	0:05	15:47	0:23	7:17
18C	25	20	15:47	0:10	15:57	0:08	16:05	0:05	16:10	0:23	7:40
16C	25	**21**	16:10	0:10	16:20	0:08	16:28	0:05	16:33	0:23	8:03
25B	25	22	16:33	0:10	16:43	0:08	16:51	0:05	16:56	0:23	8:26



C Ring
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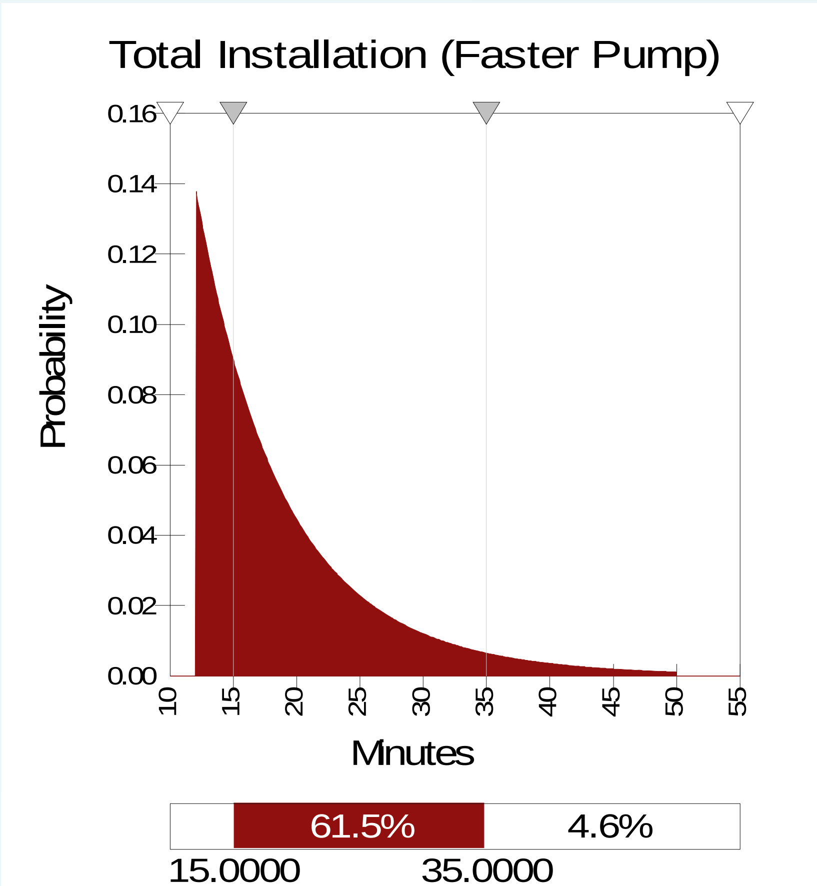
Probability Distribution For Scenario #1



- Note 15 Minute Threshold Time
- Probability Of Installing 1 Pile In Less Than or Equal To 15 minutes = 33.9%
- Probability Of Encroaching On "Wet" Pile = $(0.339)^{16}$ or 3.04×10^{-8} %

Results For Faster Grout Pump (Scenario #1)

- Pump Times Reduced By 5 Minutes, Effectively Reducing Total Installation Times By 5 Minutes
- Number of Piles Installed In 8 Hour-Day = 21 Piles
- Probability Of Encroaching On "Wet" Pile While Installing Adjacent Pile = $(0.339)^{16} = 3.04 \times 10^{-8}$ %

Cost Tradeoff

	Original Daily Costs	Scenario 1: Buy/Rent Faster Pump		Scenario 2a: Buy/Rent Faster Auger (Shaves 2 minutes off Drill Time)		Scenario 2b: Buy/Rent Faster Auger (Shaves 3 minutes off Drill Time)		Scenario 3: Rent/Buy Faster Pump Buy/Rent Faster Auger Rig		
Day 1	$35,800		$36,800		$37,300		$37,500		$38,500	
Day 2	$11,800		$12,800		$13,300		$17,500		$18,500	
Day 3	$11,800		$11,800		$14,300		$18,500		$18,500	
Day 4	$11,800		$11,800		$14,300		$18,500		$18,500	
Day 5	$11,800		$11,800		$14,300		$18,500		$18,500	
Day 6	$11,800		$11,800		$14,300		$18,500		$28,500	
Day 7	$11,800		$26,800		$14,300		$18,500			
Day 8	$11,800				$27,300		$27,500			
Day 9	$11,800									
Day 10	$25,800									
Cost per pile	$1,083		$858		$1,038		$1,215		$979	
Mobilization	$20,000	LS	$20,000	LS	$20,000	LS	$20,000	LS	$20,000	LS
Crane	$3,800	day	$3,800	day	$5,000	day	$5,000	day	$5,000	day
Auger Rig	$1,200	day	$1,200	day	$1,500	day	$1,700	day	$1,700	day
Grout Pump	$1,000	day	$2,000	day	$1,000	day	$1,000	day	$2,000	day
Back Hoe & Dump Truck	$1,800	day	$1,800	day	$1,800	day	$1,800	day	$1,800	day
5 Man Crew	$4,000	day	$4,000	day	$4,000	day	$4,000	day	$4,000	day
Assembly	$4,000	LS	$4,000	LS	$4,000	LS	$4,000	LS	$4,000	LS
Disassembly/Demobilize	$14,000	LS	$14,000	LS	$14,000	LS	$14,000	LS	$14,000	LS

Cost Trade-off

	Original	Scenario 1	Scenario 2a	Scenario 2b	Scenario 3
Cost per pile	$1,083	$858	$1,038	$1,215	$979
Total piles/8-hour	17	21	19	19	24
Probability of encountering a wet pile.	0	3.04×10^{-8}	0	5.19×10^{-15}	1.14×10^{-4}
Days to Install 144 Piles	9	7	8	8	6
Cost per day	$17,328	$ 17,650	$ 18,684	$ 21,870	$ 23,496
Total Cost for 144 Piles	$ 155,952	$123,552	$ 149,472	$ 174,960	$140,976

Recommendations

Scenario 1

- does not have the shortest duration, but it is the most cost effective
- has the lowest cost per pile
- has a reasonable production rate compared to the other scenarios

Future work

- Use a set of linear equations to model the pile installation process and the constraints that govern the installation and calculate the optimal pile installation path using LINDO or other linear programming method (Original Objective of this project)

- Compare the results of the heuristic approach studied in this paper against an optimization approach as listed above

- Attempt to model the minimization of worker downtime while optimizing pile installation productivity. This also holds true for monitoring equipment downtime

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- Study the scenario of working from the exterior of the pile rings, possibly with a second crew and auger rig assembly

Any Questions?