December 23, 2019

Mr. Jeffrey McCormick
Director
Town of Burrillville Department of Public Works
65 Union Avenue
Harrisville, RI 02830

RE: **Phase II Investigations and Evaluations**
Harrisville Pond Dam
Burrillville, Rhode Island
(Pare Project No. 19010.00)

Dear Mr. McCormick:

Pare Corporation (Pare) is pleased to provide the Town of Burrillville (Client) with the results of our Phase II Investigations and Evaluations regarding the leakage and developing sinkholes downstream of the abandoned outlet and downstream wall at the Harrisville Pond Dam. Figure No. 1: Exploration Locations and Proposed Work Plan, is attached to the back of this report as an illustrated reference for existing site conditions and proposed improvements.

The following report is a supplement to Pare's Preliminary Investigations and Evaluation Report, dated April 16, 2019, and is based on our Contract for Engineering Services, signed on January 10, 2019, amended on July 9, 2019, and is subject to the Terms and Conditions of the existing On Call Contract between Pare and the Client.

BACKGROUND

As part of the preliminary investigations and evaluations, Pare completed above-water inspections, below-water inspections, file reviews, and research to assess the stability of the embankment to the east/left of the primary spillway where developing gaps are occurring between the crest paver stones, and the area of the abandoned outlet and downstream wall where sinkholes have been developing.

The following conclusions and recommendations are paraphrased from Pare's Preliminary Investigations and Evaluation Report:

EMBANKMENT LEFT OF THE PRIMARY SPILLWAY

Conclusions

It is Pare's opinion that the majority of the upstream slope left of the primary spillway is undergoing a surficial slope failure along the riprap layer.

Recommendations

Pare recommends removing and replacing the existing rip rap with a new rip rap system designed to better-resist the long-term cyclic wave action and freeze/thaw effects.

SINKHOLES AND A CRACKED DOWNSTREAM WALL RIGHT OF THE PRIMARY SPILLWAY

Conclusions

Based on the presence of reoccurring sinkholes forming downstream of a leaking outlet, it is likely that the leakage is flowing uncontrollably through the embankment causing the erosion of fines from the embankment and below the downstream wall resulting in wall cracking and the formation of sinkholes.

Recommendations

A. *Water Control:* Before work can begin, the installation of a designed cofferdam around the abandoned outlet will be required to remove the hydrostatic pressure and to allow this area to be safely dewatered. Potential cofferdam types include super-sack stacked sandbags; a portable cofferdam, or driven steel sheet piling.
B. *Seal the Leak:* To limit further damage from occurring within the embankment, the leak at the gate must be addressed by either repairing the existing timber gate or installing a temporarily plug such as a steel plate.
C. *Assess internal Embankment Damage:* It is known that there are voids within the earthen embankment sections which have likely caused undo stress and cracking along the short downstream retaining wall; however, the extent of the internal damage is not known and should be investigated as part of a subsequent study.

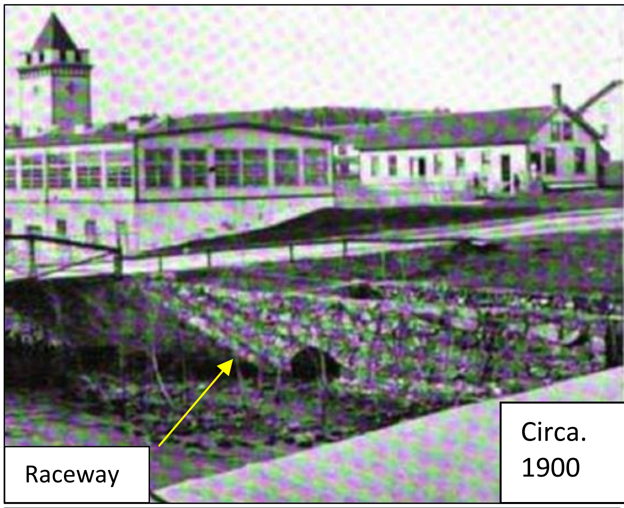
PHASE II INVESTIGATIONS

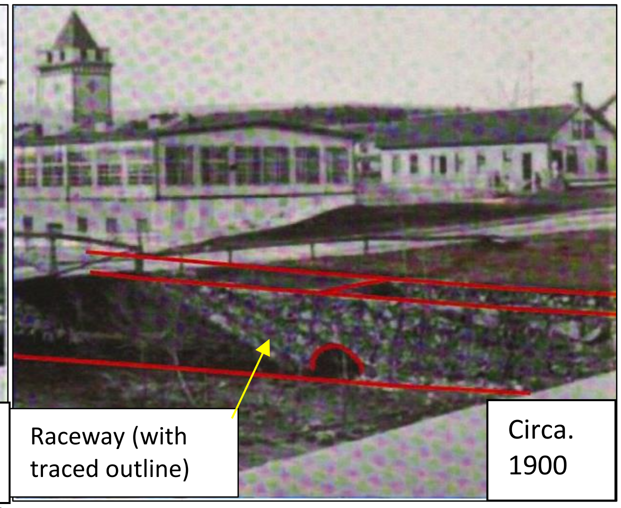
Based upon these recommendations, the Town of Burrillville engaged Pare Corporation (Pare) to complete a supplemental investigation which includes research and field studies, dye testing, a geophysical survey, and subsurface investigations.

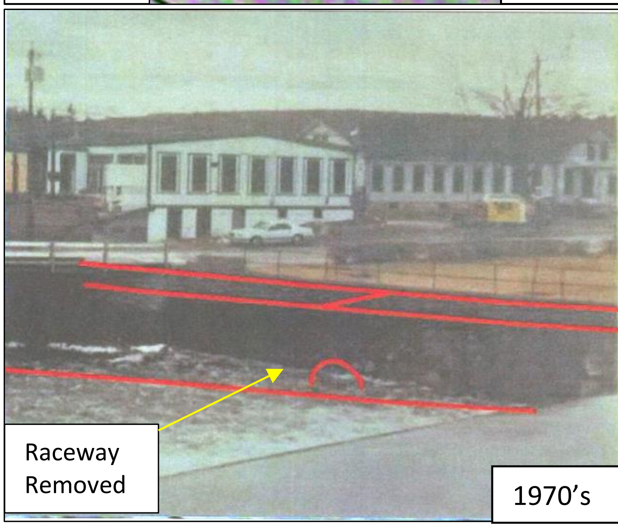
Additional Research and Field Studies:

For the purpose of locating possible leakage flow paths via abandoned channels and/or utilities, additional research was completed at the Jesse M. Smith Memorial Library, within RIDEM files, within Pare's project archives, and the internet. In conjunction with this research, additional field visits were completed to review site geometries and characteristics for the purpose of correlating with Pare's research.

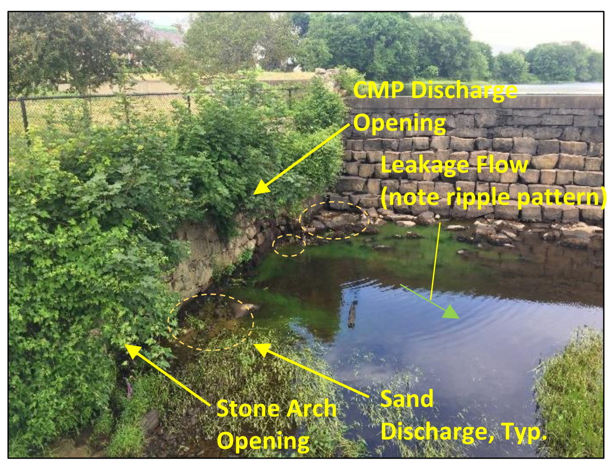
A. *Historic Raceway:* In Pare's previous report, a circa 1900 photo of the spillway discharge channel's right wall appeared to show a stone masonry raceway directly behind the existing right wall. Through additional research, an inspection photo taken in the 1970's from the same viewpoint reveals that the old raceway was built in front of the existing wall, so the wall shown today is actually the former raceway's right wall. There is also a stone arch opening on the right wall which is still seen today. It is likely that a pipe penetrated the raceway. Whether this assumed pipe functioned as a discharge for the former outlet or a pipeline crossing is unknown.







B. *Dye Testing:* On July 17th, 2019, a second dye test was completed at the abandoned outlet. At the time of the test, the impoundment levels were below the crest of the spillway and the low-level outlet gates were closed; therefore, eliminating turbulent conditions. The test involved releasing about 10 ounces of green dye near the hole in the abandoned gate. Within minutes the dye could be seen flowing from the base of the primary spillway right training wall from the base of the spillway steps to the stone arch opening about 40 feet downstream as shown in the attached photo. Higher concentrations of dye appeared to flow through wall areas upstream and downstream of the CMP with visible sand discharge fans at these locations.



Geophysical Survey

A nondestructive testing program was completed at the site on July 16 and 17, 2019 by Hager-Richter Geoscience, Inc. (HRGS) under contract with Pare. The program consisted of conducting a ground penetrating radar (GPR) survey and a multichannel analysis of surface waves (MASW) survey across the area of interest right of the primary spillway and downstream of the impoundment. The purpose of both surveys is to detect possible voids within the study area. The GPR method was used to detect and map interfaces of contrasting electrical properties while the MASW method was used to detect low shear wave velocity zones related to the possible presence of subsurface voids.

A. *Geophysical Survey Findings:* As paraphrased from the HRGS report, the following conclusions were determined from the Geophysical surveys:
   1. *GPR*
      a. Possible voids or loose soils up to 7 feet below the existing ground surface in the east portion of the area of interest adjacent to the 48-inch corrugated metal pipe (CMP).
      b. A zone of subsided soils above the 48-inch CMP across the area of interest, most notedly in the eastern portion.

   2. *MASW*
      a. Possible zone of voids or loose soils at depths from 4 to 15 feet in the east portion of the area of interest.
      b. Possible pipes or other utilities, including a possible former raceway, oriented north to south near the center of the area of interest.
      c. A zone of possible buried riprap or boulders along the north and northwest side of the concrete retaining wall in the area of interest.

   Further discussions on the GPR and MASW surveys including theories, limitations, procedures, and findings can be found in the attached report titled "Geophysical Survey Harrisville Pond Dam" prepared by Hager-Richter Geosciences, Inc, August 2019 (HRGS Report).

Subsurface Investigations:
A subsurface investigation program was performed at the site on September 6, 2019 to determine the condition and nature of the earthen embankment and foundation materials, and to confirm the findings of the Geophysical Survey. The program consisted of the drilling of one boring (B19-1(OW)) and the digging of two test pits (TP19-1 and TP19-2) at the following selected areas based on the results of the Geophysical Survey (See Figure 1; Subsurface Location Plan):

Boring/Test Pit ID	Offset from the Spillway Right Training Wall	Offset from Upstream Wall
B19-1(OW)	47 feet right	12 feet downstream
TP19-1	32 feet right	71 feet downstream
TP19-2	56 feet right	62 feet downstream

Soil Boring B19-1(OW) was advanced approximately 32 feet below the existing ground surface. Water levels were observed during the advancement of the boring. At the completion of the exploration, a groundwater observation well was installed to provide a means to monitor the phreatic water surface within the embankment.

Soil boring B19-1(OW) was completed by New Hampshire Boring of Glastonbury, Connecticut with a track-mounted drill rig utilizing 4 ¼ -inch diameter hollow stem augers. During the advancement of the boring, standard penetration tests (SPT) were performed continuously through the dam embankment soils and at maximum 5-foot intervals within the natural strata below the dam in accordance with ASTM D1586 to obtain an indication of the relative density and consistency of the underlying soils. The SPT value "N" represents the number of blows, from a 140-pound weight free falling 30-inches, required to drive the 2-inch split spoon sampler through the middle 12-inches of the 24-inch sampling interval. In this case, the driller used a safety hammer to advance the split spoon sampler. The boring was logged, and representative split spoon samples were visually classified and collected in jars by Pare personnel.

Both test pits were advanced approximately 7 feet below the existing ground surface. The onsite Pare representative observed excavation efforts, collected and identified soil samples, and developed a log for each test pit.

The test pits were completed by the Town with a standard rubber tire backhoe. Upon completion, test pits were backfilled with onsite excavated soil placed in maximum 6-inch lifts with each lift compacted with at least 6 passes of a plate compactor supplied and operated by the Town.

The logs for Boring B19-1(OW), and for Test Pits TP19-1 and TP19-2 are attached at the end of this report.

A. *Subsurface Investigation Findings:* During the explorations, subsurface soils were visually classified utilizing the Burmister Classification System. This system describes soil composition based upon the percentage of soil particle size present in the sample with the major soil particle size listed first following other soil components described as "and" indicating 35-50% by weight, "some" indicating 20-35% by weight, "little" indicating 10-20% by weight, or "trace" indicating 0-10% by weight.

   In general, the explorations indicate a soil profile consisting of the following:

   Stratum 1A: Embankment Fill – Topsoil

   In Boring B19-1(OW), and Test Pits TP19-1 and TP19-2, Topsoil was encountered at the ground surface to depths of 12, 6, and 14 inches, respectively. Stratum 1A is described as dark brown organic based silty sand mixture used to support grass growth.

   Stratum 1B: Embankment Fill – Subsoil

   In Boring B19-1(OW), and Test Pits TP19-1 and TP19-2, Subsoil was encountered directly below Stratum 1 at thicknesses of approximately 8, 18, and 15 inches, respectively. The Stratum 1B is described as tannish brown fine to coarse sand with little to some silt, trace to little fine gravel with trace amounts of roots.

   Stratum 1C: Embankment Fill – Sand with Gravel

   In Boring B19-1(OW) and Test Pits TP19-1 and TP19-2, Sand and Gravel Fill was encountered directly below Stratum 1B at thicknesses of approximately 16.5, 5, and 1 feet, respectively. Test Pit TP19-1 terminated within Stratum 1C at 7 feet below the existing ground surface while Test Pit TP19-2 and Boring B19-1(OW) fully penetrated Stratum 1C at depths of approximately 18 and 1.5 feet, respectively.

   Stratum 1C is described as poorly- to well-graded sand, trace to little gravel and urban fill (i.e., wood, brick, slate, roofing rubble), and trace amounts of silt. Based upon SPT values collected within B19-1(OW), the soils of Stratum 1C range from medium dense near the top 4 feet, to loose for the next 8 feet, to very loose or a possible void throughout the lower 4 feet of the stratum. In fact, only 2 blows of a 140-pound hammer were required to drive the sampler through the lower 4 feet, bottoming out at a depth of approximately 18 feet below the existing ground surface.

Stratum 2: Insitu Foundation Soils – Silty Sand with Gravel

In Boring B19-1(OW) and TP19-2, a naturally deposited Silty Sand with Gravel was encountered directly below the Embankment Fill to boring and test pit terminations at 32 and 7 feet below the existing ground surface, respectively. Stratum 2 is described as gray poorly- to well-graded sand, little to and amounts of gravel, and trace to little silt. Based upon SPT values collected within B19-1(OW), the soils of Stratum 2 are very dense.

Phreatic Surface

Water levels were measured during and after the advancement of Boring B19-1(OW). At the completion of drilling B19-1(OW), the depth to water was measured at approximately 8.2 feet (i.e., El. 329.5 feet). During the completion of the explorations, the pond elevation was near normal pool conditions (i.e., El. 333.3 feet). No water was encountered in the test pits.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the preliminary and current studies completed in the area right of the primary spillway, the following conclusions can be made:

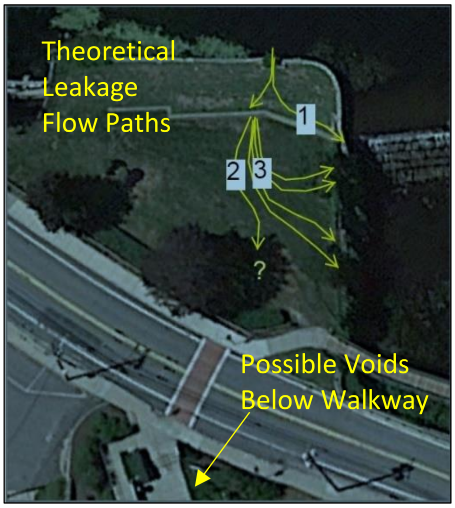
A. *Leakage Flow Paths:* The primary leakage is sourced through the hole in the timber gate of the abandoned outlet. Based on dye testing and the findings of the Geophysical Survey, Pare has gained a better understanding of the leakage through the dam which is believed to be divided into three general flow paths as follows:

   Flow Path #1

   Water enters the hole in the outlet gate, passes perpendicularly through the embankment to the zone of buried riprap or boulders upstream of the downstream wall and flows to the left through the stone and exits out the spillway's right training wall at the base of the stepped spillway blocks.

   Flow Path #2

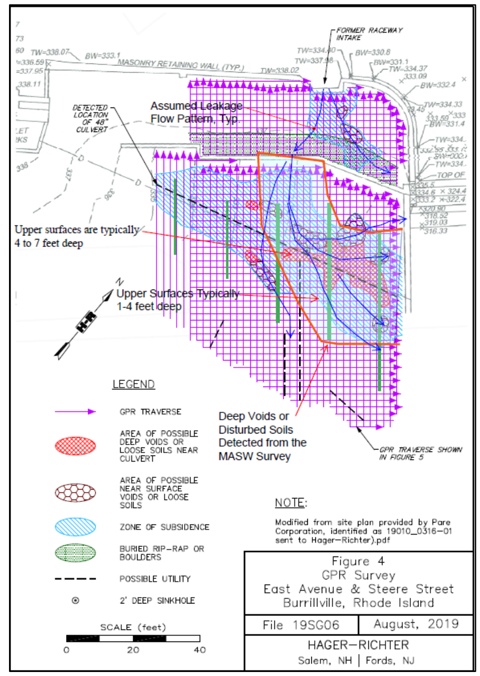
   Water enters the hole in the gate, passes perpendicularly through the embankment to the zone of buried riprap or boulders behind the downstream wall and flows to the right then passes through a possible opening at the base of the downstream wall. Once passing through the downstream wall, the majority of leakage flows in a leftward arch pattern and exits out the base of the spillway's right training wall in areas upstream and downstream of the 48-inch CMP discharge. It is believed that the leakage through the wall is reduced in the area of the CMP discharge because it flows into the CMP through an open joint about 30 feet upstream of the discharge. The open joint was found during Pare's previous investigation and is presented in the respective report.



Flow Path #3

The remainder of the leakage may be finding its way through a buried raceway which extends under East Avenue towards the former mill complex to an unknown location. Soundings completed on the concrete walkway on the northwest side of the library appear to indicate hollow zones as confirmed through probing adjacent to the northern edge of the walkway of at least 3 feet deep.

B. *Voids, Loose Zones, Sinkholes, and Zones of Soil Subsidence:* Based on data collected from the Geophysical Survey and field observations, areas of soil subsidence, sinkholes, numerous voids, and/or loose zones are present throughout the area of interest as illustrated on the attached annotated Figure from HRGS' Report.



Upstream of the downstream wall, near-surface voids or loose soils and zones of subsidence appear to concentrate in areas downstream of the abandoned outlet intake, shifting left towards the spillway channel when progressing downstream.

Downstream of the downstream wall, near-surface voids or loose soils, deep voids or loose soils, and zones of subsidence appear to concentrate from the center of the downstream wall arching left towards the spillway discharge channel spanning a distance of about 55 feet downstream.

The void or very loose zone encountered within Boring B19-1(OW) near the base of the embankment does not appear to be related to the leaking outlet due to its location with respect to the outlet. It may be related to the shifted upstream wall and the settlement occurring behind the wall.

As confirmed by the presence of accumulated areas of soil discharge piles at the leakage exit points within the discharge channel, piping (i.e., transport of soils) from the embankment via the leakage flow paths are likely causing the formation of these deficiencies and will continue until leakage control measures are taken.

Recommendations

In Pare's previous report, recommendations were presented to repair the embankment left of the primary spillway, providing water control, and sealing the leaking outlet. As part of this Phase II evaluation, the following are recommendations to repair the embankment right of the primary spillway.

Once water controls have been established and the leak at the outlet has been temporarily sealed, the following repairs can be completed.

1. Restore the abandoned outlet to function as a low-level outlet. Remove and dispose the old outlet components including the gate, frame, and conduit sections. Install a new gate, frame, operating components, and a new conduit through the embankment to discharge into the primary spillway channel.

2. Replace the 40-inch corrugated metal pipe (CMP) that serves the outlet at the right abutment. Remove and dispose the existing CMP in its entirety and install a new conduit with a similar flow opening.

3. Locate and seal the probable opening in the downstream wall. Complete test pits on the upstream side of the downstream wall to locate an opening in the wall that is allowing leakage to migrate from upstream to downstream. Take measures to provide excavation support and to balance excavation depths on either side of the wall to prevent an unstable condition. When found, seal up the opening and backfill the excavations with a compacted structural fill.

4. Repair/replace the upstream wall right of the primary spillway. Depending on the wall conditions that are encountered after dewatering and excavations, either repair and re-mortar the upstream wall and install a filtered stone buttress on the upstream side of the wall or replace the wall in its entirety. If the wall needs to be replaced, it is recommended to install a driven sheet pile cutoff wall to tie into the wall foundation.

5. Repoint/chink joints within the primary spillway right wall between the spillway and the pedestrian bridge.

6. Remove the loose soils within the embankment right of the primary spillway and replace with compacted structural fill. Concurrent with the above recommended work, the soils of the embankment right of the spillway are recommended to be excavated to firm ground and replaced with an appropriate compacted structural fill. This work should be staged with designed shoring utilized to protect existing structures.

ANTICIPATED OPINIONS OF PROBABLE COSTS FOR DESIGN, PERMITTING, & CONSTRUCTION

Attached to this report is an updated table presenting anticipated opinions of probable cost (OPC) for design, permitting, and construction.

We trust that this report meets your needs at this time. If you have any questions, please do not hesitate to call us at 508.543.1755.

Sincerely,

PARE CORPORATION

David M. Matheson, P.E.	J. Matthew Bellisle, P.E.
Senior Project Engineer	Senior Vice President

<u>Attachments:</u>
Figure No. 1: Exploration Locations and Proposed Work Plan
Logs of Soil Boring and Test Pits
Hager-Richter's Geophysical Survey Report
Harrisville Pond Dam Improvements-Opinion of Probable Cost for Design, Permitting, and Construction.

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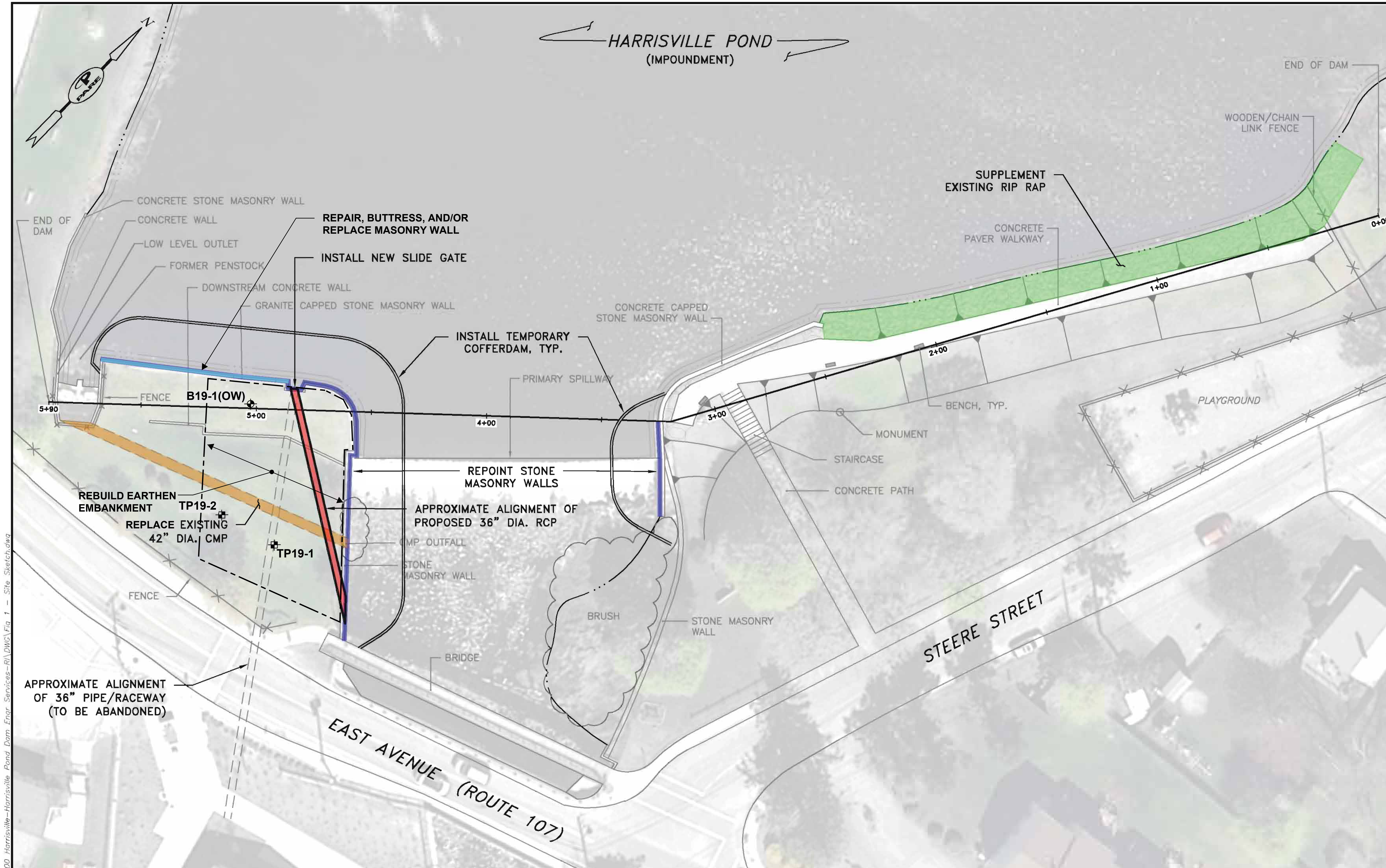


PROPOSED WORK PLAN

SCALE: 1"=40'±

NOTE:

1. PLAN DEVELOPED FROM NOTES TAKEN DURING THE INSPECTION AND AVAILABLE AERIAL IMAGERY FROM RIGIS. INFORMATION IS PROVIDED FOR REFERENCE PURPOSES ONLY.

LEGEND:

B19-1(OW) — SOIL BORING COMPLETED BY NEW ENGLAND BORING ON SEPTEMBER 6, 2019 AND OBSERVED BY PARE PERSONNEL.

TP19-1 — TEST PIT COMPLETED BY TOWN ON SEPTEMBER 6, 2019 AND OBSERVED BY PARE PERSONNEL.

Y:\JOBS\19 Jobs\19010.00 Harrisville-Harrisville Pond Dam Engr Services-RI\DWG\Fig 1 - Site Sketch.dwg

PARE CORPORATION
ENGINEERS • SCIENTISTS • PLANNERS
10 LINCOLN ROAD, SUITE 103
FOXBORO, MA 02035
508-543-1755

SCALE ADJUSTMENT GUIDE

0" 1"

BAR IS ONE INCH ON ORIGINAL DRAWING.

HARRISVILLE POND DAM

RI DAM No. 008

BURRILLVILLE, RHODE ISLAND

OWNER: TOWN OF BURRILLVILLE

REVISIONS:

PROJECT NO.:	19010.00
DATE:	DECEMBER 2019
SCALE:	AS NOTED
DESIGNED BY:	DMM
CHECKED BY:	DMM
DRAWN BY:	LMC
APPROVED BY:	DMM

EXPLORATION LOCATIONS & PROPOSED WORK PLAN

FIGURE NO.: 1

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
PARE CORPORATION T: 508-543-1755
F: 508-543-1881

BORING NUMBER B19-1

CLIENT Town of Burrillville DPW
PROJECT NAME Harrisville Pond Dam
PROJECT NUMBER 19010.00
PROJECT LOCATION Harrisville, RI
DATE STARTED 9/6/19 COMPLETED 9/6/19
GROUND ELEVATION 337.7 +/-
HOLE SIZE 3 in.
DRILLING CONTRACTOR New England Boring Contractors, Inc.
GROUND WATER LEVELS:
DRILLING METHOD Auger - ATV Mounted Rig
AT TIME OF DRILLING 8.20 ft
LOGGED BY RAL CHECKED BY DMM
AT END OF DRILLING ---
BORING LOCATION SEE EXPLORATION PLAN

DEPTH (ft)	CASING (bl/ft)	SAMPLE TYPE NUMBER	RECOVERY/PEN. (in)	DEPTH (FT)	BLOW COUNTS/6"	MIN/FT	GRAPHIC LOG	SAMPLE DESCRIPTION	STRATUM DESCRIPTION
0		S-1	15 / 24	0 - 2	4-11-14-13 (25)			Dry, medium dense, dark brown/brown, fine to medium SAND, little organic silt, trace fine gravel, trace organics (root, grass).	TOPSOIL / SUBSOIL
		S-2	15 / 24	2 - 4	10-7-4-4 (11)			Dry, medium dense, tan-brown, fine SAND, some medium to coarse sand, trace fine gravel, trace silt.	SAND (EMBANKMENT FILL)
5		S-3	9 / 24	4 - 6	12-8-6-7 (14)			Dry, medium dense, tan, fine to medium SAND, little fine to coarse GRAVEL, little coarse sand, trace silt.	
		S-4	20 / 24	6 - 8	8-6-2-2 (8)			Moist, loose, tan, fine to medium SAND, little fine to coarse gravel, little coarse sand, trace silt.	
10		S-5	10 / 24	8 - 10	10-5-4-3 (9)			Wet, loose, brown, fine to coarse SAND, little fine to coarse gravel, trace silt, trace wood.	
		S-6	7 / 24	10 - 12	5-4-3-7 (7)			Wet, loose, brown, fine to coarse SAND, trace fine to coarse gravel, trace silt.	
		S-7	12 / 24	12 - 14	3-3-3-3 (6)			Wet, loose, brown-gray, fine to coarse SAND, trace fine to coarse gravel, trace silt.	
15		S-8	3 / 24	14 - 16	5-0-0-0 (0)			Wet, very loose, brown, fine to coarse SAND, trace fine gravel, trace silt.	
		S-9	2 / 24	16 - 18	1-0-0-0 (0)			Wet, very loose, brown, fine to coarse SAND, trace coarse gravel.	
20		S-10	16 / 18	18 - 19.5	57-90-135 (225)			A: Upper 7" - Wet, very dense, tan-brown, fine to medium SAND, little silt, trace coarse sand. B: Lower 9" - Wet, very dense, gray, fine to coarse SAND and fine to coarse GRAVEL, little silt.	INSITU SAND & GRAVEL
		S-11	24 / 24	20 - 22	39-59-53-92 (112)			Wet, very dense, gray, fine to coarse SAND and fine to coarse GRAVEL, little silt.	
25		S-12	24 / 24	22 - 24	40-80-97-103 (177)			Wet, very dense, gray, fine to coarse SAND and fine to coarse GRAVEL, trace silt.	
		S-13	10 / 24	25 - 27	63-54-36-30 (90)			Wet, very dense, gray, fine to coarse SAND and fine to coarse GRAVEL, trace silt.	
30									

GRANULAR SOILS BLOWS/FT	DENSITY
0 - 4	V. LOOSE
4 -10	LOOSE
10 - 30	M. DENSE
30 - 50	DENSE
>50	V. DENSE

COHESIVE SOILS BLOWS/FT	DENSITY
<2	V. SOFT
2 - 4	SOFT
4 - 8	M. STIFF
8 - 15	STIFF
15 - 30	V. STIFF
>30	HARD

REMARKS:
1.S-4: Iron mottling observed throughout.
2.140-lb. safety hammor used.
3.Very loose soil/possible void from 14.5'-18'.
4.Refusal at 19.5'.
5.No sample from 19.5'-20'.
6.A groundwater monitoring woll was installed from 16'-4'. Bentonite filter packs were installed from 17'-16' and 4'-3'. Soil cuttings and gravel was installed from 3' to near groundsurface with a standpipe anchored with concrete.

BURMISTER CLASSIFICATION	
TRACE	0 -10%
LITTLE	10 - 20%
SOME	20 - 35%
AND	35 - 50%
PERCENT BY WEIGHT	

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES, TRANSITIONS MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

(Continued Next Page)

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
T: 508-543-1755
F: 508-543-1881

BORING NUMBER B19-1

CLIENT Town of Burrillville DPW
PROJECT NAME Harrisville Pond Dam
PROJECT NUMBER 19010.00
PROJECT LOCATION Harrisville, RI

DEPTH (ft)	CASING (bl/ft)	SAMPLE TYPE NUMBER	RECOVERY/PEN. (in)	DEPTH (FT)	BLOW COUNTS/6"	MIN/FT	GRAPHIC LOG	SAMPLE DESCRIPTION	STRATUM DESCRIPTION
30		S-14	8 / 24	30 - 32	93-48-44-63 (92)			Wet, very dense, gray, fine to coarse SAND and fine to coarse GRAVEL, little silt.	SAND & GRAVEL
35								Bottom of borehole at 32.0 feet.	
40									
45									
50									
55									
60									
65									

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
T: 508-543-1755
F: 508-543-1881

TEST PIT NUMBER TP19-1

CLIENT Town of Burrillville DPW
PROJECT NAME Harrisville Pond Dam
PROJECT NUMBER 19010.00
PROJECT LOCATION Harrisville, RI
DATE STARTED 9/6/19 COMPLETED 9/6/19
GROUND ELEVATION 332 ft NAVD 88
EXCAVATION CONTRACTOR Town of Burrillville DPW
EXCAVATION METHOD Backhoe
LOGGED BY RAL CHECKED BY DMM
BORING LOCATION SEE EXPLORATION PLAN

GROUNDWATER READINGS

DATE/TIME	WATER AT	NOTES
		No groundwater observed

DEPTH (in)	DEPTH (IN)	EXCAVATION EFFORT	BOULDERS CNT/CLASS	REMARKS	GROUNDWATER ELEVATION	GRAPHIC LOG	SAMPLE DESCRIPTION	PID READING
0	0	E	0				Moist, dry, black-brown, fine to medium SAND, little organics (roots, grass), little organic silt, trace coarse sand. (TOPSOIL)	N/A
	6	E	0				Moist, dry, brown, fine to coarse SAND, little silt and fine gravel, trace organics (roots). (SUBSOIL)	N/A
	26	E	0				Dry, tan, fine to medium SAND, little silt and fine gravel, little urban fill (slate, brick, roofing), trace organics (roots 2"± dia.). (FILL)	N/A

Bottom of test pit at 84.0 inches.

BOULDER CLASS		TEST PIT PLAN	EXCAVATION EFFORT		ABBREVIATIONS		BURMISTER CLASSIFICATION	
DESIGNATION	SIZE	3' × 8'	E	EASY	F	FINE	TRACE	0 -10%
A	6" TO 18"		M	MODERATE	M	MEDIUM	LITTLE	10 - 20%
B	18" TO 36"		D	DIFFICULT	C	COARSE	SOME	20 - 35%
C	36" & UP				V	VERY	AND	35 - 50%
					F-M	FINE TO MEDIUM	PERCENT BY WEIGHT	
					F-C	FINE TO COARSE		
		VOLUME = CU.YDS			NE	NOT ENCOUNTERED		

REMARKS:

TEST PIT LOG - GINT STD US LAB.GDT - 9/16/19 08:42 - Y:\JOBS\19 JOBS\19010.00 HARRISVILLE-HARRISVILLE POND DAM ENGR SERVICES-RI\TEST PITS\19010.00 TEST PITS.GPJ

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, MA 02035
T: 508-543-1755
F: 508-543-1881

TEST PIT NUMBER TP19-2

CLIENT Town of Burrillville DPW
PROJECT NAME Harrisville Pond Dam
PROJECT NUMBER 19010.00
PROJECT LOCATION Harrisville, RI
DATE STARTED 9/6/19 COMPLETED 9/6/19
GROUND ELEVATION 334 ft NAVD 88
EXCAVATION CONTRACTOR Town of Burrillville DPW
EXCAVATION METHOD Backhoe
LOGGED BY RAL CHECKED BY DMM
BORING LOCATION SEE EXPLORATION PLAN

GROUNDWATER READINGS		
DATE/TIME	WATER AT	NOTES
		No groundwater observed

DEPTH (IN)	EXCAVATION EFFORT	BOULDERS CNT/CLASS	REMARKS	GROUNDWATER ELEVATION	SAMPLE DESCRIPTION	PID READING
0	E	0			Moist, dry, black-brown, fine to medium SAND, little organics (roots, grass), little organic silt, trace coarse sand. (TOPSOIL)	N/A
14	E	0			Moist, dry, brown/tan, fine to medium SAND, some silt, trace fine gravel, trace roots. (SUBSOIL)	N/A
29	D	B, C			Moist, dry, dark gray, fine to coarse GRAVEL and urban FILL (brick, concrete), some fine to coarse sand, trace silt. (FILL)	N/A
41	E	0			Dry, tan, fine to coarse SAND, little fine gravel and silt. (FINE TO COARSE SAND)	N/A

Bottom of test pit at 80.0 inches.

BOULDER CLASS		
DESIGNATION	SIZE	
A	6" TO 18"	
B	18" TO 36"	
C	36" & UP	

TEST PIT PLAN: 4' × 8'
VOLUME = CU.YDS

EXCAVATION EFFORT	
E	EASY
M	MODERATE
D	DIFFICULT

ABBREVIATIONS	
F	FINE
M	MEDIUM
C	COARSE
V	VERY
F-M	FINE TO MEDIUM
F-C	FINE TO COARSE
NE	NOT ENCOUNTERED

BURMISTER CLASSIFICATION	
TRACE	0 -10%
LITTLE	10 - 20%
SOME	20 - 35%
AND	35 - 50%

PERCENT BY WEIGHT

REMARKS:

HAGER-RICHTER
GEOSCIENCE, INC.

GEOPHYSICAL SURVEY
HARRISVILLE POND DAM
EAST AVENUE AND STEERE STREET
BURRILLVILLE, RHODE ISLAND

Prepared for:

Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, Massachusetts 02035

Prepared by:

Hager-Richter Geoscience, Inc.
8 Industrial Way - D10
Salem, New Hampshire 03079

File 19SG19
August, 2019

August 9, 2019
File 19SG06

David M. Matheson, P.E.
Senior Project Engineer
Pare Corporation
10 Lincoln Road, Suite 210
Foxboro, Massachusetts 02035

Main: 508-543-1755x5206
Fax: 508-543-1881
Email: dmatheson@parecorp.com

RE: Geophysical Survey
Harrisville Pond Dam
East Avenue and Steere Street
Burrillville, Rhode Island

Dear Mr. Matheson:

In this report, we summarize the results of a geophysical survey conducted by Hager-Richter Geoscience, Inc. (HRGS) at the above referenced site in Burrillville, Rhode Island for Pare Corporation (Pare). The scope of the survey and the area of interest were specified by Pare.

INTRODUCTION

Pare is conducting a geotechnical investigation of an area located adjacent to the southwest side of the spillway for the Harrisville Pond Dam in Burrillville, Rhode Island. The general location of the site is shown in Figure 1. According to information provided by Pare, sinkholes have been forming in an area located about 40 to 60 feet southeast of the Mill Pond and within about 30 feet of the of the southwest side of the spillway. The area of sinkhole formation lies above a portion of a 48-inch diameter corrugated metal pipe that crosses from outlet works in the southwest corner of the pond to an outfall into the spillway below the dam. In addition, former raceways running roughly parallel to the spillway are reportedly in the grassy area about 20 feet southwest of the spillway. Pare requested a geophysical survey to detect, and if detected, to determine the positions of possible voids in the grassy area west of the spillway.

The area of interest (AOI) for the survey covers approximately 10,000 square feet, is mostly grassy, and includes a concrete retaining wall that crosses approximately west to east through the center of the AOI. An approximately 3-foot diameter, 2-foot deep sinkhole has opened up recently and was present at the time of the survey near the center of the AOI. Reportedly, sinkholes have formed and been repaired over the years in the vicinity of the current sinkhole. Figure 2 shows the locations of the area of interest and the sinkhole present at the time of the survey.

OBJECTIVE

The objective of the geophysical survey was to detect, and if detected, to determine the locations of voids or zones of loose soil in an approximately 10,000 sq. ft. area of interest located west of the spillway of the Harrisville Pond Dam.

THE SURVEY

Steven Grant, P.G., and Bryan Carnahan of HRGS conducted the field operations on July 16 and 17, 2019. The project was coordinated with Mr. David M. Matheson, P.E., of Pare who was present at the site and specified the area of interest. Mr. Jeffrey McCormick, the Director of the Department of Public Works of the Town of Burrillville (Burrillville DPW), assisted with noise control for the survey by controlling water flow over the dam and through the 48-inch culvert as needed. Photograph 1, below, shows typical conditions at the site.

Photograph 1. MASW line across the area of interest at Harrisville pond Dam, view to the northwest. The MASW geophones are the orange objects located along the yellow tape. The 3-ft diameter, 2-ft deep sinkhole is in the taller grass between the two people. The spillway is located to the right, on the other side of the chain-link fence, and the pond is behind the retaining wall and raised grassy area in the background.

The geophysical survey consisted of the ground penetrating radar (GPR) and multichannel analysis of surface waves (MASW) methods. Data analysis and interpretation were completed at the HRGS offices. Original data and field notes will be retained in the HRGS files for a minimum of three (3) years.

EQUIPMENT AND PROCEDURES

GPR. The GPR survey was conducted using a GSSI UtilityScan Dual Frequency digital subsurface imaging radar system. The system includes a survey wheel that triggers the recording of the data at fixed intervals, thereby ensuring the accuracy of the features detected along the survey lines. The system was used with 800 MHz and 300 MHz antennae. Data were recorded using 50 and 85 ns[1] time windows for the 800 MHz antenna and 300 MHz antenna, respectively.

The GPR survey was conducted in the accessible portions of the specified area of interest along a series of traverses spaced 2 feet apart oriented parallel and perpendicular to the edge of the spillway. Data from the GPR survey were processed using RADAN 7.4, commercially licensed GPR processing software from GSSI, and the profile images were interpreted. Interpretation of the records is based upon the nature and intensity of the reflected signals and on the resulting patterns.

GPR uses a high-frequency electromagnetic pulse (referred to herein as “radar signal”) transmitted from a radar antenna to probe the subsurface. The transmitted radar signals are reflected from subsurface interfaces of materials with contrasting electrical properties. Travel times of the radar signal can be converted to approximate depth below the surface by correlation with targets of known depths and by a curve matching routine. We monitor the acquisition of GPR data in the field and record the GPR data digitally for subsequent processing. Interpretation of the records is based on the nature and intensity of the reflected signals and on the resulting patterns.

The GPR signature for areas of possible voids or zones of subsidence is site specific and non-unique. Other structures, the ground surface, and/or subsurface soil and moisture conditions may produce GPR reflections that are similar to the GPR reflections caused by areas of possible voids or zones of subsidence. Whether areas of possible voids or zones of subsidence are actually present can only be determined by ground truth through boreholes or test excavations.

MASW. The shear wave survey was conducted using the multi-channel analysis of surface waves (MASW) method. MASW data were acquired along five (5) lines totaling 235 linear feet. The MASW survey was conducted using 4.5-Hz geophones and a geophone spacing of 1 foot. The energy source was a 4 lb sledgehammer striking a metal plate at each shot location on the ground.

[1] ns, abbreviation for nanosecond, 1/1,000,000,000 second. Light and the GPR signal require about 1 ns to travel 1 ft in air. The GPR signal requires about 3.5 ns to travel 1 ft in unsaturated sandy soil.

The multichannel analysis of surface waves (MASW) method is a seismic method that determines a shear-wave velocity (Vs) profile (i.e., Vs versus depth and horizontal distance) by analyzing a particular type of seismic wave on a multichannel record. The MASW method uses Rayleigh waves, which are elastic waves that travel in the subsurface near the earth's surface. The amplitude of such waves decreases with depth and the phase velocity of the waves is a function of frequency. The method uses multichannel recording and processing concepts widely used in reflection surveying by the oil and gas industry.

The MASW method requires multichannel records with at least 12 traces to produce reliable results. We use 48 channels (two 24-channel Geometrics Geode digital seismographs), coupled to 48 geophones to acquire 24-trace records. The data acquired for geophones numbered 1 - 24 are processed as discussed below to determine the shear wave velocity as a function of depth for discrete layers, and the velocity of each layer $V_s(x,n)$ is assigned to the midpoint of the line between Stations 1 and 24, i.e. x = 11.5 ft if the geophone spacing is 1 foot. The data acquired for geophones numbered 2 through 25 yield the vertical velocity profile at the midpoint of the line between stations 2 and 25, i.e. x = 12.5 ft if the geophone spacing is 1 foot. By processing the data for geophones m through m+24 and assigning the vertical profiles to the midpoints, the velocity of each layer is generated as a function of horizontal distance. The end point for the velocity determined with a 48-geophone spread using data acquired with 24 geophones is located at x = 36.5 ft from the start of the line if a 1-foot geophone spacing is used.

Figure 3 shows the data acquisition scheme and the way in which processing produces 24 vertical velocity profiles for a 48-geophone spread. As shown in Figure 3, a series of the first and last geophones do not yield velocities as function of depth at each of those 24 geophone locations. Due to the MASW array configuration for the current project, the first and last approximately 11.5 ft section of each MASW line does not exhibit results, as shown in the MASW plots in Figure 6.

The MASW survey is conducted using an active source, and the method using an active source is sometimes called an active MASW survey to distinguish it from a passive MASW survey in which ambient noise is used as the source. Levels of ambient noise are monitored in real time during data acquisition. Ambient noise is not utilized by the survey but is avoided by waiting for times when nearby traffic (the main source of ambient noise) is not adversely affecting the quality of the data. Only active source data were used for the subject survey and no passive source data were acquired. It is also important to use a low natural frequency geophone for most MASW surveys.

The surface waves used in MASW, considered noise in refraction and reflection surveys, are enhanced during data acquisition and processing for the MASW method. The seismic data are analyzed using *SurfSeis 6.0,* a commercially licensed software package developed by the Kansas Geological Survey. Briefly, *SurfSeis* provides a dispersion curve from which the interpreter selects the fundamental mode in detail, and the software then inverts the dispersion curve in terms of a model of shear wave velocity (Vs) as a function depth at the midpoint of the geophone spread (see Figure 4). Results can be presented as 2-D graphical plots of the shear wave velocity as a function of depth and distance along the line using contouring software such as *Surfer* or in tabular form showing shear wave velocity as a function of depth at a given station.

As discussed above, data are acquired for 24 channels at a time and the resulting 1-D shear wave distribution as a function of depth is assigned the horizontal position at the center of the 24-channel spread. The 1-D distributions are then combined to provide shear wave velocity distribution across the survey line and are presented as 2-D color plots. The variations in color correspond to apparent variations in subsurface shear wave velocity. Low shear wave velocities correlate with softer soils and higher shear wave velocities correlate with harder, more dense soil or bedrock.

LIMITATIONS OF THE METHODS

> HRGS MAKES NO GUARANTEE THAT ALL AREAS OF VOIDS OR LOOSE SOIL WERE DETECTED IN THIS SURVEY. HRGS IS NOT RESPONSIBLE FOR DETECTING VOIDS OR AREAS OF LOOSE SOIL THAT NORMALLY CANNOT BE DETECTED BY THE METHODS EMPLOYED OR THAT COULD NOT BE DETECTED BECAUSE OF SITE CONDITIONS.

GPR. GPR detects and maps interfaces of contrasting electrical properties, and air- or water-filled voids and disturbed soils have electrical properties very different from undisturbed soils and rock. The GPR method is useful for detecting voids and determining their footprint, but in general, GPR data cannot be used to determine the thickness of voids.

There are other limitations of the GPR technique: (1) surface conditions, (2) electrical conductivity and thickness of the subsurface layers, (3) electrical properties of the target(s), and (4) spacing of the traverses. Of these restrictions, only the last is controllable by us in most cases.

The condition of the survey surface can affect the quality of the GPR data and the depth of penetration of the GPR signal. For exterior sites, a surface covered with obstacles such as automobiles, dumpsters, thick leaf debris, materials piles, etc. limit the survey access. Similarly, for interior sites, a surface covered with obstacles such as desks, benches, laboratory equipment, etc. also limit access. Some floor coverings may limit the coupling of the GPR antenna with the subsurface.

The electrical conductivity of the subsurface determines the attenuation of the GPR signals, and thereby limits the maximum depth of exploration. The GPR signal does not penetrate clay-rich soils or soils contaminated with road salt. In some cases, the GPR signal may not penetrate below concrete pavement, and some asphalts are electrically conducting.

A strong contrast in the electrical conductivities of the ground and the target (for examples, UST, pipe, void, dry well, drum, contaminant plume) is required to obtain a reflection of the GPR signal. If the contrast is too small, then the reflection may be too weak to recognize, and the target can be missed.

Spacing of the traverses is limited by access at many sites, but where flexibility of traverse spacing is possible, the spacing is adjusted on the basis of the size of the target.

MASW. The MASW method, although theoretically sound, may not be applicable at all sites for the determination of shear wave velocity because of site limitations. Such limitations include adequate space, attenuation of the soils (especially for frequencies in the range 5 Hz to about 15 Hz), and the presence of structures with high velocity materials that extend to appreciable depth (such as thick concrete or asphalt slabs or basement walls of several below grade stories).
For sites where a high velocity layer overlies a significantly lower velocity layer, Lamb Waves may be generated rather than Rayleigh Waves. Because of their dispersive and multimodal nature, Lamb waves can be easily misidentified as Rayleigh-type surface waves during a MASW survey. The inversion algorithms used to interpret MASW data cannot be utilized to determine shear wave velocity structure when Lamb Waves dominate the data.

The depth of investigation for an MASW survey depends on the frequency spectrum of the seismic signal, and low frequency (long wavelength) signals are required to obtain data at large depths—the lower the frequency, the greater the depth of investigation. For sites where the soils or bedrock are highly attenuating for low frequencies, the depth of determination of the velocity of shear waves with the MASW method may be less than 100 feet.

As with all physical measurements, there is experimental error in the velocities that are determined using the MASW method. The uncertainty in velocity of shear waves is estimated to be approximately 10-15%.

RESULTS

General. The geophysical survey consisted of ground penetrating radar (GPR) and multi-channel analysis of surface waves (MASW) in the area of interest located on the southwest side of the spillway for the Harrisville Pond Dam, located in Burrillville, Rhode Island. Figure 2 shows the limits of the GPR survey area and the locations of the MASW lines. Figure 4 shows the interpreted location of features detected by the GPR survey. Figure 5 is an example GPR record acquired over the detected features. Figure 6 shows the results of the MASW survey in profile form.

GPR. GPR data were acquired in an approximately 70-foot by 100-foot area adjacent to the southwest side of the Harrisville Pond Dam spillway. Apparent GPR signal penetration was excellent, with two-way traveltime reflections received from approximately 75 to 85 ns of the 85 ns records acquired for the 300 MHz antenna and from approximately 40 to 50 ns of the 50ns records acquired for the 800 MHz antenna. Based upon site-specific velocity matching calibrations, the GPR signal penetration in the area of interest is estimated to have been 10 to 12 feet below ground surface for the 300 MHz antenna and 5 to 7 feet below ground surface for the 800 MHz antenna.

GPR reflections consistent with a large diameter pipe were detected at the record location of the 48-inch steel culvert that links the outlet works with the spillway outfall, and the detected location for the culvert is shown in Figure 4. The estimated depth of the top of the culvert ranges between about 3.5 feet to 5 feet. GPR reflections consistent with other pipes or other utilities were also evident in the GPR data for the area of interest, and their locations are shown as black dashed lines in Figure 3. The most prominent such feature is oriented northwest-southeast and is annotated as a possible raceway in Figure 4 based on its trajectory.

Detecting voids on the basis of GPR records is not always straightforward. The GPR signature for voids is non-unique, and this statement can be taken in two ways. Firstly, some GPR patterns that are typical of voids can also be produced by other subsurface features, and secondly, not all voids produce the same GPR reflection pattern. Below is a brief description of the types of GPR signatures of voids commonly encountered. Note that some voids exhibit more than one GPR signature.

Voids located below a hard, bridging layer, such as pavement or a layer of more densely packed materials, commonly produce a series of high amplitude GPR reflection multiples - a phenomenon commonly referred to as “ringing.” Other voids or zones of loose fill can be detected on the basis of localized zones of high amplitude, disturbed GPR signal diffractions from discontinuous soil layering or raveled material. Still other voids are characterized by zones of low GPR signal penetration, due to attenuation of the GPR signal by loose materials filling voids.

Based on the criteria described above, GPR reflections consistent with possible air-filled voids or zones of loose soils are present in records acquired in the area of interest at the site. We group possible voids or areas of loose soils into two broad categories: areas of possible deep voids or loose soils and areas of possible near-surface voids or loose soils. Areas of possible deep voids or loose soils are present in the east portion of the area of interest and their locations are shown as red cross-hatched areas in Figure 4. An example GPR record across an area of possible deep voids or loose soils is shown in Figure 5. GPR reflections for such features are characterized by strong reflections consistent with possible raveling or air-filled voids. Such areas of deep voids or loose soils are typically located near the 48-inch culvert and their upper surfaces are typically 4 to 7 feet deep. The association of possible voids or zones of loose soils with the 48-inch culvert and the area of possible historic raceways is consistent with such structures acting as conduits for water flow and resulting removal of materials.

Possible areas of near-surface voids or zones of loose soils were detected in the east portion of the area and their locations are shown as brown honey-combed areas in Figure 4. Such zones are typified by zones of low GPR signal strength, disturbed layering, or ringing. The tops of the areas of the near-surface voids or loose soils are typically 1 to 4 feet deep. Such zones of near surface voids or zones of loose soils are located near the 48-inch steel culvert and the former raceway intake. An example GPR record across an area of possible near-surface voids or loose soils is shown in Figure 5

GPR reflections consistent with areas of subsidence are present in the area of interest along the length of the 48-inch culvert. The location of the zone of subsidence is shown as blue hatching in Figure 4. The zone of subsidence is characterized by GPR reflectors dipping toward the center of the depressed area, such as would be expected for soil horizons draping toward a zone of soil removal. The zone of subsidence is more pronounced and extends deeper in the east portion of the area of interest. Multiple sets of such draped GPR reflectors may indicate a history of repeated infilling of sinkholes or depressed ground surface as they form. Interpreted possible deep and near-surface voids are located within the zone of possible subsidence. Figure 5 is an example GPR record showing possible draped soil horizons.

Detecting voids based on GPR records can be influenced by several factors. The GPR signature for voids is non-unique. Some GPR patterns that are typical of voids can also be produced by other subsurface features, and not all voids produce the same GPR reflection pattern. Whether voids are present at depths greater than the depth of GPR signal penetration (approximately 15 feet) or in areas inaccessible to the GPR equipment cannot be evaluated based on the GPR data alone and can only be determined by test borings or test excavations.

GPR reflections consistent with buried riprap or boulders were detected along the north and northwest sides of the concrete retaining wall that cuts through the area of interest. The zone of buried riprap or boulders is shown as a green stippled area in Figure 4.

MASW. The MASW method determines the spatial variation of shear wave velocity along the transects. In general, lower shear wave velocities indicate softer soils while higher shear wave velocities indicate more dense materials. Please note that due the acquisition parameters for the MASW arrays, as explained in the Equipment and Procedures section, results cannot be determined for the first and last approximately 11.5 feet of each MASW transect, as indicated in Figure 3.

The results of the MASW survey are shown in profile format in Figure 6. Based on the results of the MASW survey, we interpret that a thin (3 to 4 feet thick) near-surface layer of softer soil indicated by low (<500 ft/s) shear wave velocity (Vs) is present across the area surveyed. The near-surface low velocity strata is shown as a cross hatched area in Figure 6. The layer is relatively consistent across the area surveyed, and we infer that it is not necessarily associated with active sinkhole or void formation.

Zones of low velocity (<500 ft/s) materials interpreted to be possibly caused by voids or loose soils are present along the MASW lines in the east portion the area of interest and their locations are shown in Figure 6. Such zones are located below the near-surface low velocity strata discussed above, and were detected on MASW Lines 1, 2, and 3 at depths ranging between about 4 and 15 feet below ground surface. The velocity zone possible due to voids or loose soils extends under the majority of MASW Line 2, possibly reflecting the fact that Line 2 is located near the area of a former northwest-southeast oriented historic raceway.

CONCLUSIONS

Based upon the results of the geophysical survey conducted by HRGS in an area adjacent to the Harrisville Pond Dam in Burrillville, Rhode Island in July 2019, we conclude the following:

- Areas of possible deep (4 – 7 feet) and shallow (1 - 4 feet) voids or loose soils were detected based on the GPR data in the east portion of the area of interest adjacent to the 48-inch steel culvert.

- An area of subsidence above the 48-inch culvert was detected based on the GPR data across the area of interest and is most strongly manifested in the eastern portion of the area of interest.

- Low velocity zones possibly due to voids or loose soils were detected based on the MASW data at depths of 4 to 15 feet in the east portion of the area of interest

- The location of the 48-inch steel culvert connecting the inlet works to an outfall visible in the spillway channel was detected

- Possible pipes or other utilities, including a possible former raceway, were detected in the area of interest

- A zone of possible buried riprap or boulders was detected along the north and northwest side of a retaining wall in the area of interest.

LIMITATIONS ON USE OF THIS REPORT

This letter report was prepared for the exclusive use of Pare Corporation (Client). No other party shall be entitled to rely on this Report, or any information, documents, records, data, interpretations, advice or opinions given to Client by Hager-Richter Geoscience, Inc. (HRGS) in the performance of its work. The Report relates solely to the specific project for which HRGS has been retained and shall not be used or relied upon by Client or any third party for any variation or extension of this project, any other project or any other purpose without the express written permission of HRGS. Any unpermitted use by Client or any third party shall be at Client's or such third party's own risk and without any liability to HRGS.

HRGS has used reasonable care, skill, competence and judgment in the performance of' its services for this project consistent with professional standards for those providing similar services at the same time, in the same locale, and under like circumstances. Unless otherwise stated, the work performed by HRGS should be understood to be exploratory and interpretational in character and any results, findings or recommendations contained in this Report or resulting from the work proposed may include decisions which are judgmental in nature and not necessarily based solely on pure science or engineering. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, test pits, soil borings with collection of soil and water samples, and laboratory testing.

Except as expressly provided in this limitations section, HRGS makes no other representation or warranty of any kind whatsoever, oral or written, expressed or implied; and all implied warranties of merchantability and fitness for a particular purpose, are hereby disclaimed. If you have any questions or comments on this letter report, please contact us at your convenience. It has been a pleasure to work with Pare on this project. We look forward to working with you again in the future.

Sincerely,
HAGER-RICHTER GEOSCIENCE, INC.

Steven Grant, P.G.
Senior Geophysicist

Jeffrey Reid, P.G.
Owner / Principal Geophysicist

Attachments: Figures 1 - 6

N

APPROXIMATE SCALE (feet)

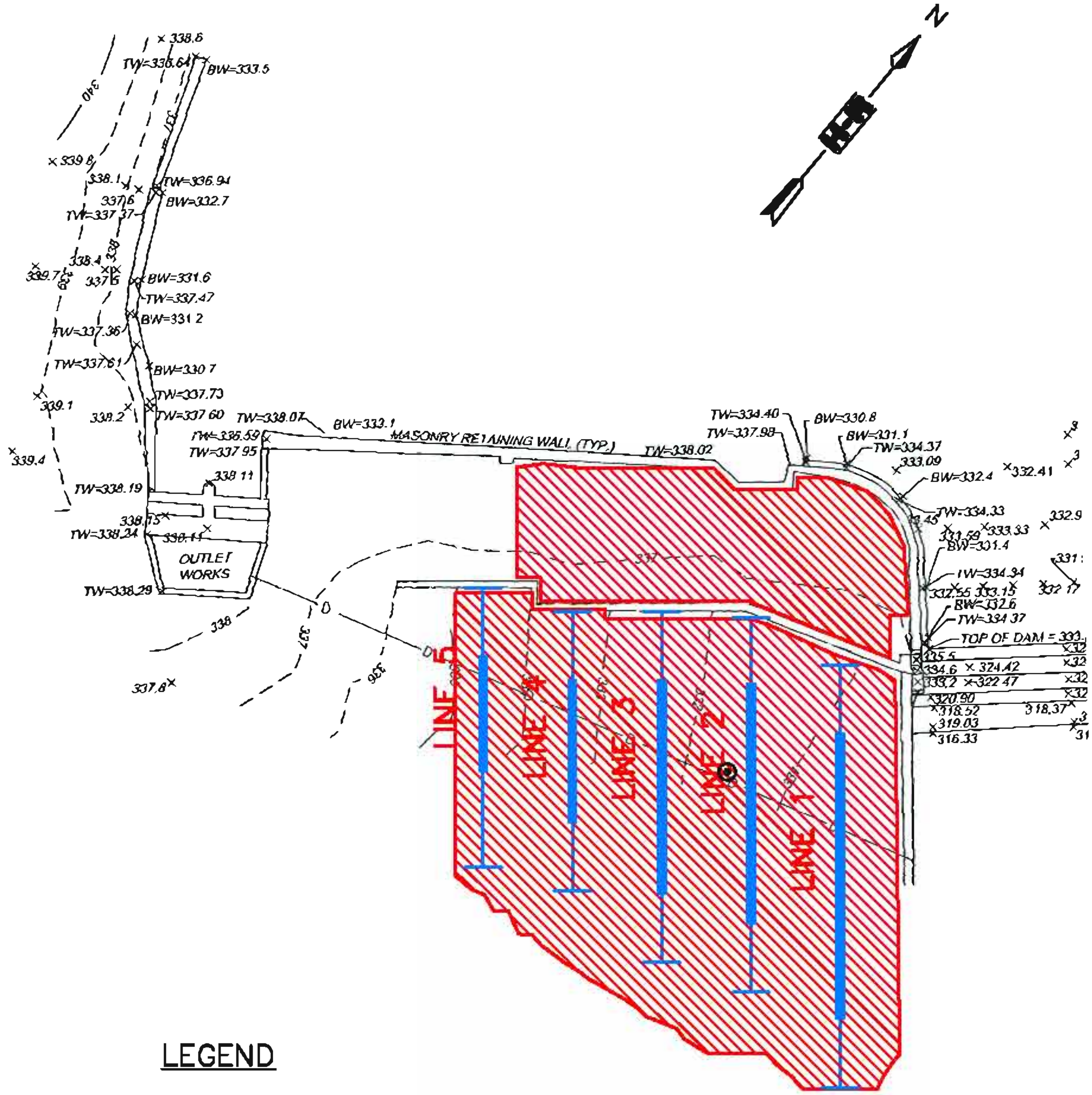
0 1000 2000

LOCATION

NOTE:

Modified from Google Earth Pro aerial photograph.

Figure 1 General Site Location East Avenue & Steere Street Burrillville, Rhode Island	
File 19SG06	August, 2019
HAGER–RICHTER Salem, NH | Fords, NJ	



LEGEND

APPROXIMATE LIMITS OF GPR SURVEY AREA

MASW SURVEY LINE WITH INDICATION OF THE EFFECTIVE DATA COVERAGE IN BOLD

2' DEEP SINKHOLE

SCALE (feet)

0 30 60

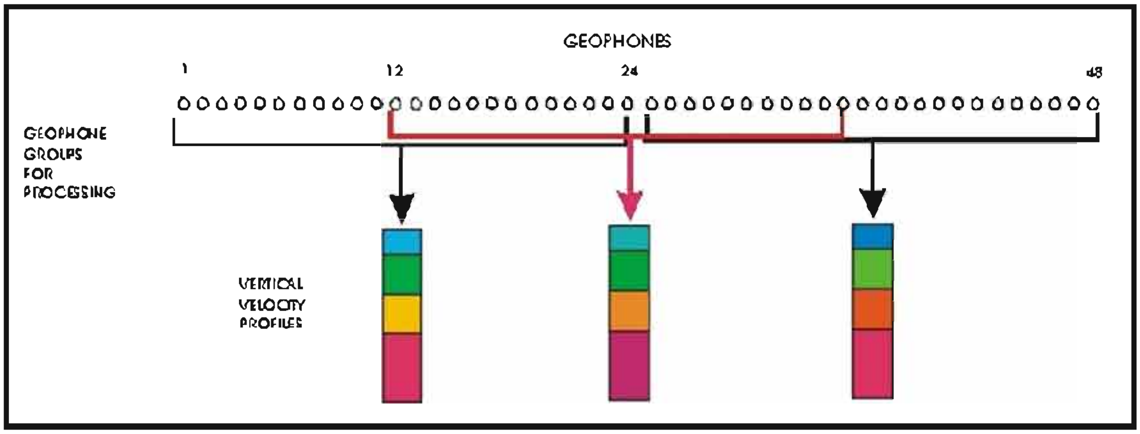
NOTE:

Modified from site plan provided by Pare Corporation, identified as 19010_0316-01 sent to Hager-Richter).pdf

Figure 2
Site Plan
East Avenue & Steere Street
Burrillville, Rhode Island

File 19SG06	August, 2019

HAGER-RICHTER
Salem, NH | Fords, NJ



Forty-eight geophones are connected to a seismograph. The seismic wave generator by a source located left of, and in line with, the geophones, is detected by geophone number 1 through 24 and recorded by the seismograph. The seismic wave recorded as a function of distance at geophones 1-24 is subsequently processed to provide the velocity of shear waves as a function of depth, and the vertical velocity profile is assigned to the location midway between geophones 1-24.

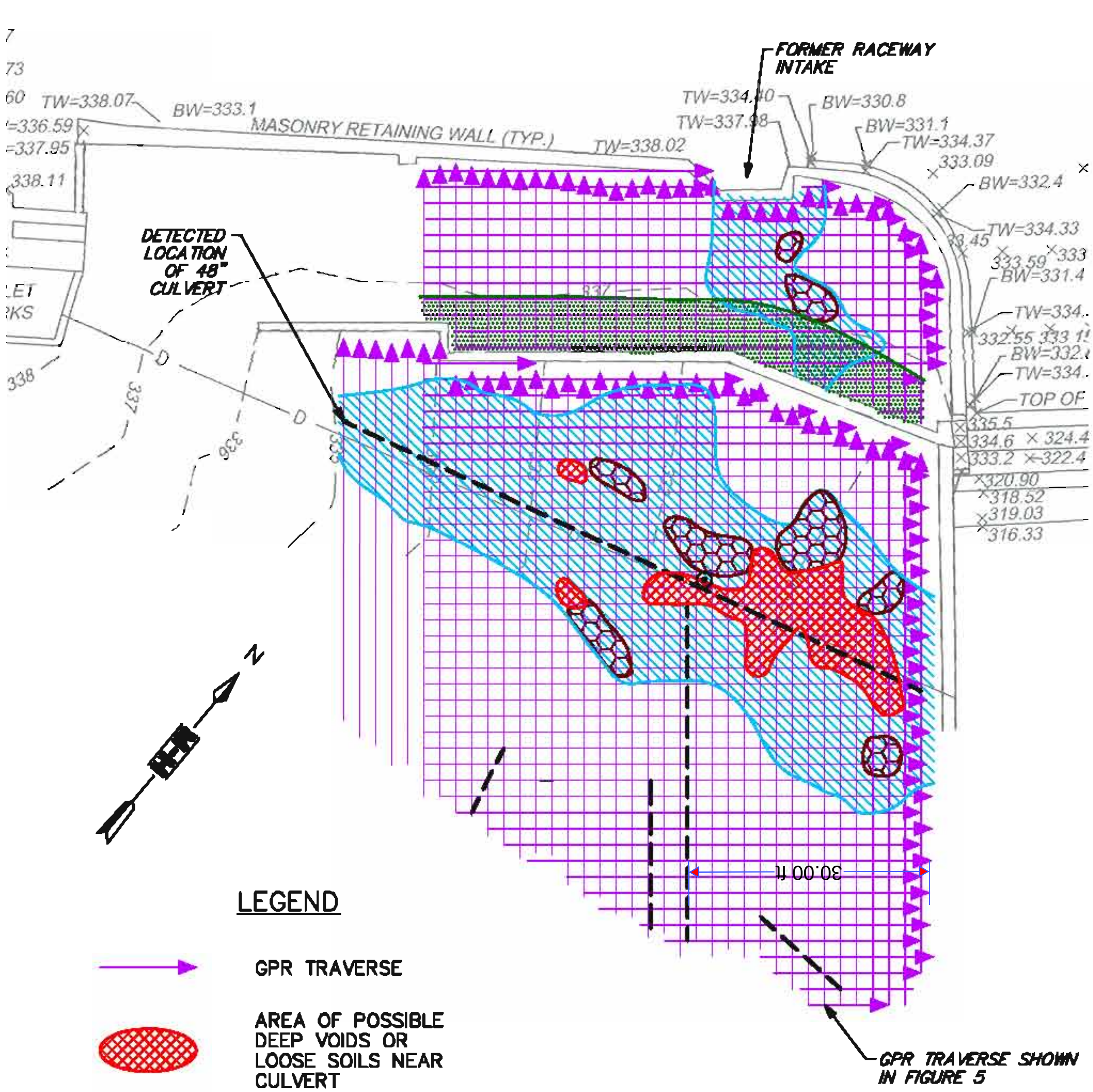
The data acquisition continues using geophones 2-25 with source located the same distance from geophone 2 as it was from geophone 1 for acquisition using geophones 1-24. This procedure continues using 24 geophones until the data for geophones 25-48 have been acquired. The figure shows the resulting vertical profiles for three sets of 24 geophones: 1-24 located midway between geophones 11 and 12, 12-35 located midway between geophones 23 and 24, 25-48 located midway between geophones 36 and 37.

These procedures produce vertical velocity profiles at 24 locations. The data can be presented in tables and as a cross section in which the values are contoured. On order to extend the coverage of the MASW line pre DDC we also processed the data for geophones 1 through 12 for the first 6 records. Due to the array configuration, the MASW results could not be extender further.

Figure 3
MASW Method
East Avenue & Steere Street
Burrillville, Rhode Island

File 19SG06	August, 2019

HAGER–RICHTER
Salem, NH | Fords, NJ



LEGEND

GPR TRAVERSE

AREA OF POSSIBLE DEEP VOIDS OR LOOSE SOILS NEAR CULVERT

AREA OF POSSIBLE NEAR SURFACE VOIDS OR LOOSE SOILS

ZONE OF SUBSIDENCE

BURIED RIP-RAP OR BOULDERS

POSSIBLE UTILITY

2' DEEP SINKHOLE

SCALE (feet)

0 20 40

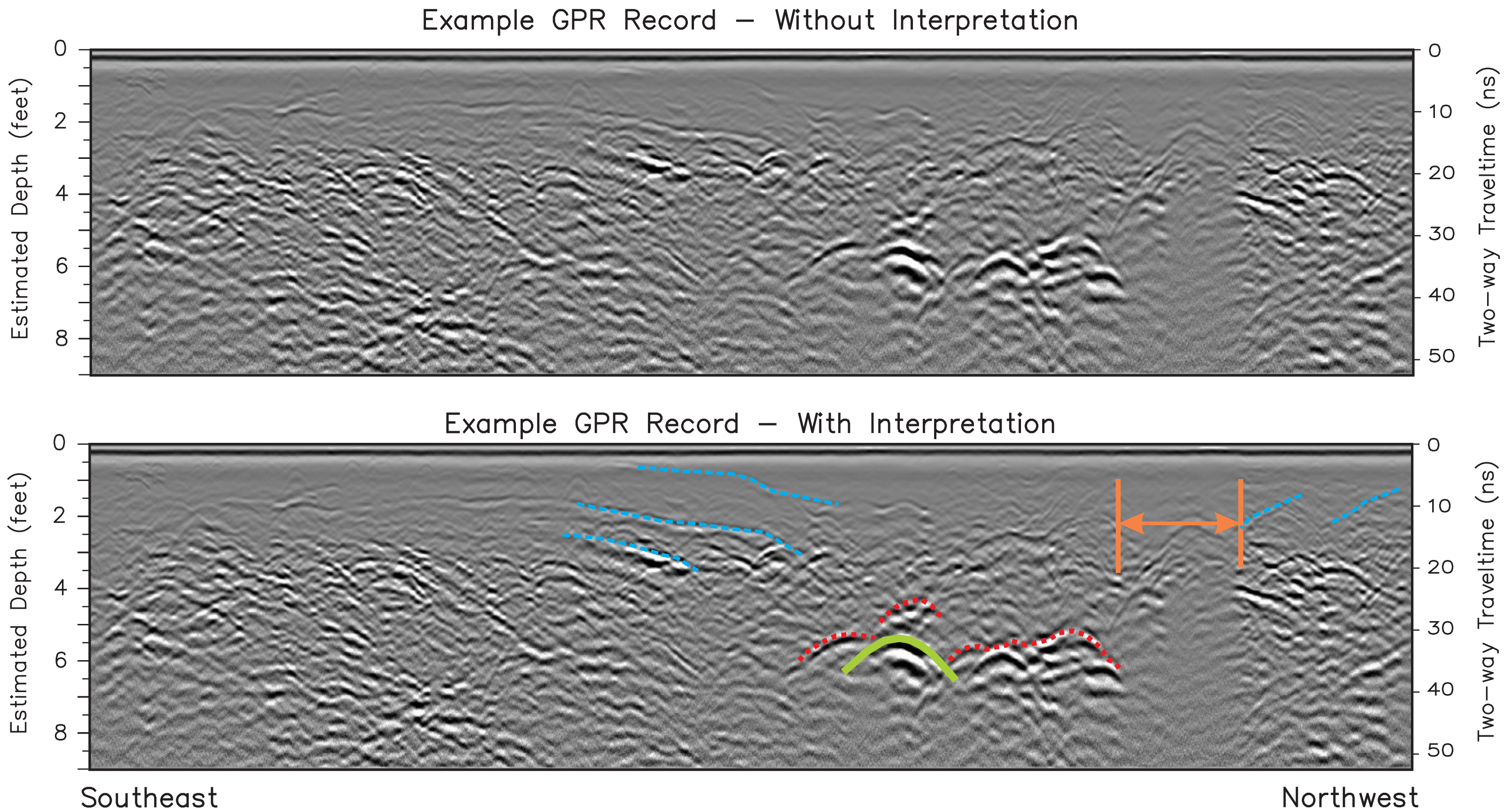
NOTE:

Modified from site plan provided by Pare Corporation, identified as 19010_0316-01 sent to Hager-Richter).pdf

Figure 4
GPR Survey
East Avenue & Steere Street
Burrillville, Rhode Island

File 19SG06	August, 2019

HAGER-RICHTER
Salem, NH | Fords, NJ



NOTES

1. GPR records shown was acquired using a GSSI UtilityScan Dual Frequency sub–surface imaging GPR System and a 800 MHZ antenna.

2. Estimated depths represent distance below round surface.

3. Estimated depth scale shown on the GPR records was calculated using a GPR signal propagation velocity of 0.348 ft/ns, as calibrated from analyses of hyperbolic reflections.

4. Location of example profiles shown on Figure 2.

LEGEND

TOP OF POSSIBLE DEEP VOID OR LOOSE SOILS

ZONE OF POSSIBLE NEAR–SURFACE VOID OR LOOSE SOILS

DRAPED SOIL HORIZONS INDICATIVE OF SUBSIDENCE

48–INCH STEEL CULVERT

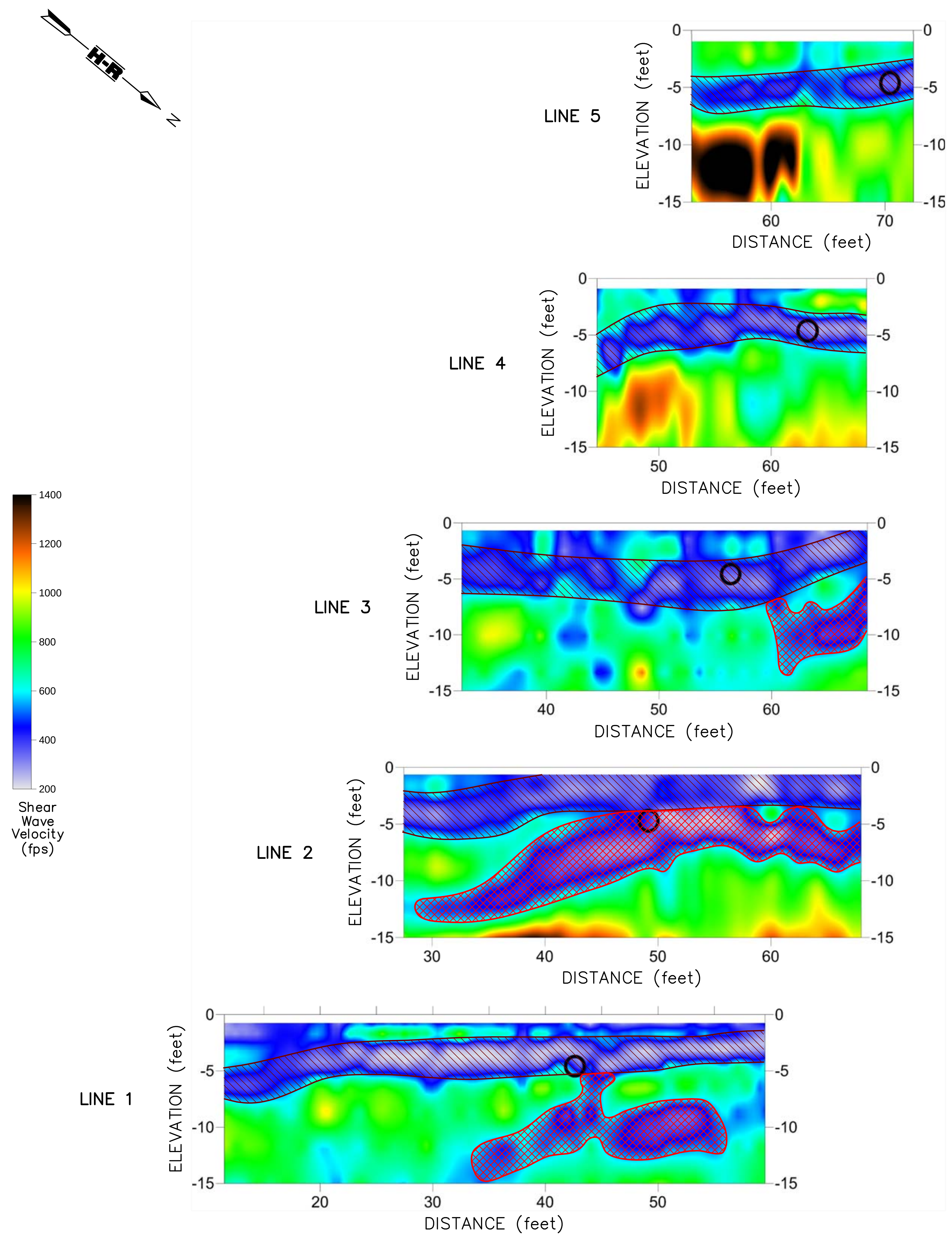
HORIZONTAL SCALE (feet)

0 10 20

Figure 5
Example GPR Sections
Harrisville Pond Dam
Burrillville, Rhode Island

FILE 19SG06	August, 2019

HAGER–RICHTER GEOSCIENCE, INC.
Salem, NH | Fords, NJ



LEGEND

LOW VELOCITY ZONE POSSIBLY DUE TO VOIDS/DISTURBED SOILS

NEAR-SURFACE LOW VELOCITY STRATA

SCALE (feet)

0 10 20

Figure 6
MASW Profiles
East Avenue & Steere Street
Burrillville, Rhode Island

File 19SG06	August, 2019

HAGER–RICHTER
Salem, NH | Fords, NJ

Item	Description	Low Range		High Range
	Harrisville Pond Dam Improvements			
Item	***Description***	***Low Range***		***High Range***
1	***General Requirements (Temp facilities, Project Superintendent, Submittals, Schedules, Meetings, Project Sign Onsite Testing, and Lab Testing)***			
2	***Riprap ($260 ft x 19.5 feet x 2.5 feet thick):***	$ 43,000.00	-	$ 50,000.00
3	***Water Control:***			
3a	Low Level Outlet & U/S Wall Work: Sheet Pile and Sand Bag Cofferdam (150lf)	$ 110,000.00	-	$ 130,000.00
3b	Sand Bag Cofferdams and Dewatering:	$ 15,000.00	-	$ 20,000.00
3c	Dewatering (Assume 30 days)	$ 3,000.00	-	$ 5,000.00
4	***Masonry Repointing***			
4a	Primary Spillway Left Training Wall:	$ 2,300.00	-	$ 3,300.00
4b	Primary Spillway Right Training Wall (770 sf):	$ 4,000.00	-	$ 5,000.00
5	***Repair and Buttress Upstream Wall Right of Abandonned Outlet***			
5a	Repointing and Chinking (1,800 sf):	$ 40,000.00	-	$ 60,000.00
5b	Buttressing, Goetextile Fabric (175 SY)	$ 1,400.00	-	$ 2,000.00
5c	Buttressing, Bedding and Armor Stone (200 Tons)	$ 11,000.00	-	$ 14,000.00
6	***Rehabilitate Outlet Right of Spillway:***			
6a	Excavate for new 36-inch Pipe (1,300 CY):	$ 25,000.00	-	$ 35,000.00
6b	Furnish & Install New Class 3 Concrete Pipe	$ 22,000.00	-	$ 30,000.00
6c	Furnish Imported Structural Fill (Assume 50% re-use)	$ 28,500.00	-	$ 30,000.00
6d	Place and Compact Structural Fill (1,300 CY):	$ 57,000.00	-	$ 65,000.00
6e	Furn. & Install Gate, hardware & Operator	$ 30,000.00	-	$ 40,000.00
6f	Regrade and protect approach & discharge areas	$ 7,000.00	-	$ 10,000.00
7	***Abandon former 36" outlet pipe and Raceway (100 LF)***	$ 15,000.00	-	$ 20,000.00
8	***Remove and Replace 42-inch CMP (120LF):***	$ 24,000.00	-	$ 30,000.00
8a	Excavate trench 880 CY 1,400 TONS (120ft long x 7.5 ft wide with 1.5H:1V slopes)	$ 21,000.00	-	$ 26,000.00
8b	Remove and Dispose 42-inch CMP (4 tons)	$ 1,000.00	-	$ 2,000.00
8c	Furnish new 42-inch concrete pipe 82,200 lb (685 lb/foot)	$ 18,000.00	-	$ 24,000.00
8d	Install Pipe (2 days)	$ 6,000.00	-	$ 8,000.00
8e	Furn. & Install Backfill (Assume 50% reuse) 440 CY = 775 tons	$ 35,000.00	-	$ 45,000.00
8f	Install on-site backfill (440 CY) 775 tons	$ 16,000.00	-	$ 21,000.00
8g	Misc. Work (i.e., Wall pennetrations, water stops)	$ 10,000.00	-	$ 15,000.00
9	***Overexcavate voids and Loose Soils from Embankment right of Spillway***			
9a	Excavation (Ave Depth: 15 ft, Width: 45 ft, Length: 60 ft) 2,200 CY	$ 45,000.00	-	$ 55,000.00
9b	Furnish, Install, Backfill, and Compact, Imported Fill (Assume 50% reuse)	$ 80,000.00	-	$ 90,000.00
9c	Install, Backfill, and Compact onsite Fill	$ 40,000.00	-	$ 50,000.00
10	***Underpinning and Repairing the Downstream Wall***			
10a	Underpinning (form and pour Concrete) 5 CY	$ 5,000.00	-	$ 7,000.00
	Subtotal	$ 715,200.00	-	$ 892,300.00
	Excavation and Backfill Credit from Overlaping Work	$ (100,000.00)	-	$ (120,000.00)
	Subtotal	$ 615,200.00	-	$ 772,300.00
	Permitting	$ 5,000.00	-	$ 10,000.00
	Contract Bonds	$ 18,456.00		$ 23,169.00
	Contingency (25%)	$ 153,800.00	-	$ 193,075.00
	15% Bidding Contingency	$ 92,280.00	-	$ 115,845.00
	Total Budgetary Construction Costs**	$ 884,736.00	-	$ 1,114,389.00
Alt1	***Replace the Upstrream Wall Right of the Abandonned Outlet***			
	Excavation 920 CY (80 feet long x 15-ft ave height, 5 ft U/S depth)	$ 18,000.00	-	$ 23,000.00
	Demolish and Remove Wall 350 CY	$ 87,500.00	-	$ 90,000.00
	Furnish and Install Cutoff Sheeting 800 sf (10 feet x 80 feet)	$ 36,000.00	-	$ 50,000.00
	Funish and Install new Concrete Wall (assume similar volume as existing) 350 CY	$ 175,000.00	-	$ 200,000.00
	Subtotal	$ 316,500.00	-	$ 363,000.00
	Contract Bonds	$ 9,495.00		$ 10,890.00
	Contingency (25%)	$ 79,125.00	-	$ 90,750.00
	Total Budgetary Construction Costs**	$ 405,120.00	-	$ 464,640.00
	** Budgetary Construction Costs Do not include Costs Associated with Engineering Design Services, Subsurface Explorations, and Engineering Support Services During Construction.			