Proactive by Design

GEOTECHNICAL
ENVIRONMENTAL
ECOLOGICAL
WATER
CONSTRUCTION MANAGEMENT

249 Vanderbilt Avenue
Norwood, MA 02062
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www.gza.com

October 5, 2015
File No. 02.0172505.00

Mr. Charlie Ezequelle
Renaugh Bros., Inc.
283 Fort Bridge Road #2
Vernon, Vermont 05354

Re: **Wave Equation Analyses**
Wardsboro BRF 013-1(15)
Wardsboro, Vermont

Dear Mr. Ezequelle:

At your request, GZA GeoEnvironmental, Inc. (GZA) has performed the following Wave Equation Analyses (WEAP) for the above referenced project. These analyses were performed in general accordance with the project specifications. A copy of the GRLWEAP output is attached and the WEAP input parameters are summarized below:

- Hammer – The APE D19-42 single acting diesel hammer with a ram weight of 4,189 lbs. and a maximum rated stroke of 11.25 feet, yielding a maximum rated energy of 47,132 foot-lbs. The APE D19-42 is equipped with a ratchet style fuel pump with four settings. The fuel pump setting are designed to limit the ram stroke to 5.6 feet, 7.4 feet, 9.3 feet, and 11.25 feet (open) yielding rated energies of 23,566 foot-lbs., 31,107 foot-lbs., 39,119 foot-lbs., and 47,132 foot-lbs., respectively. The APE D19-42 is modeled operating on fuel setting 3 (9.3 foot rated stroke) to develop the required nominal resistance at a reasonable penetration resistance without overstressing the pile section. The hammer cushioning material reportedly consists of 2 inches of Monocast MC904 blue nylon. No pile cushioning material is required for the pile type detailed below.

- Pile – 80-foot long, Grade 50 steel HP12x74 piles are modeled. The cross sectional steel area for this pile type is 21.8 square inches. The nominal resistance of 346 kips is based upon dividing the maximum factored load of 225 kips by a performance factor of 0.65. The maximum allowable driving stress for Grade 50 steel is 45 ksi (i.e., $0.9f_y$).

- Soil – Based on the subsurface information provided and the anticipated driving conditions, a shaft friction soil resistance profile and an end bearing resistance profile are modelled

  <u>Shaft Friction Profile</u>

  The friction resistance profile is modelled as 50% end bearing and 50% skin friction consisting of a 45-foot long triangular resistance distribution overlaying a larger 15-foot long rectangular distribution along the lower 60-feet of the installed pile.

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End Bearing Profile

The end bearing soil resistance profile is modelled as 90% end bearing and 10% skin friction consisting of a 45-foot long triangular resistance distribution overlaying a larger 15-foot long rectangular distribution along the lower 60-feet of the installed pile.

- Analysis – Two analyses model the above hammer-pile-soil system.

  1. Variable capacity analyses which develop a driving resistance based on the most efficient hammer stroke with the APE D19-42 operating on fuel setting 3.
  2. Constant capacity analyses which develop a driving resistance based on a varied hammer stroke.

- Results The preliminary recommended driving resistance is tabulated below.

PILE CAPACITY (kips)	RESISTANCE PROFILE	BLOW COUNT (bpi)	RAM STROKE (ft)	DRIVING STRESS (ksi)	TRANSFER ENERGY (kip-ft)
346 kips	Friction	4	7.2	24.1	19.8
	End-Bearing	5	7.6	31.9	21.0

Notes:

1. The maximum allowable driving stress is 45 ksi for Grade 50 steel.
2. The APE D19-42 is modeled operating on fuel setting 3.

The WEAP results tabulated above indicate that the APE D19-42 diesel hammer can develop the required ultimate load without overstressing the pile section based on assumed soil conditions. The preliminary driving criterion determined by the above WEAP analyses is 5 blows per inch with the APE D19-42 operating on fuel setting 3 and providing an approximate 7.5-foot ram stroke. Please note that the project documents require that the piles be driven to a pile penetration of 30.0 feet below the bottom of the pile cap. The specified dynamic pile test program will be performed to monitor the driving stresses, verify the above results and determine the final driving criterion for the production piles. Note that the driving criterion may be refined based on the results of the dynamic pile test program.

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If you have any questions or require additional information, please contact the undersigned.

Very truly yours,
GZA GEOENVIRONMENTAL, INC.

Michael Deery
Project Engineer

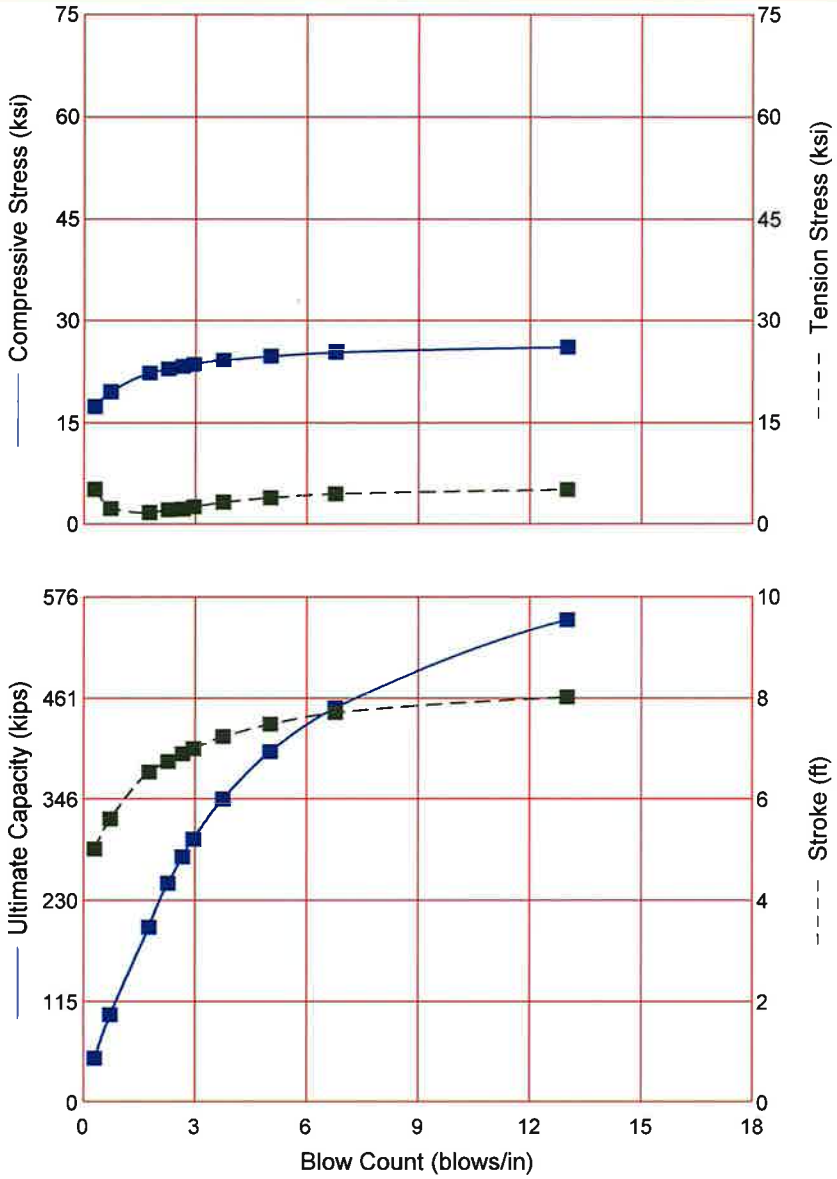
Bradford W. Roberts
Consultant/Reviewer

John E. Regan
Principal

Attachments: Wave Equation Analysis Results

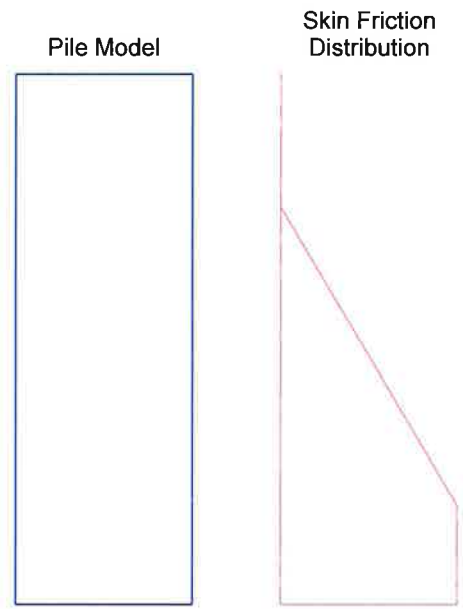
GZA GeoEnvironmental Inc.
BRF 013-1(15) APE D19F3 80'HP12x74 FR VC

01-Oct-2015
GRLWEAP Version 2010



APE D 19-42

Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1539 (90%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	75.00	ft
Pile Top Area	21.80	in2



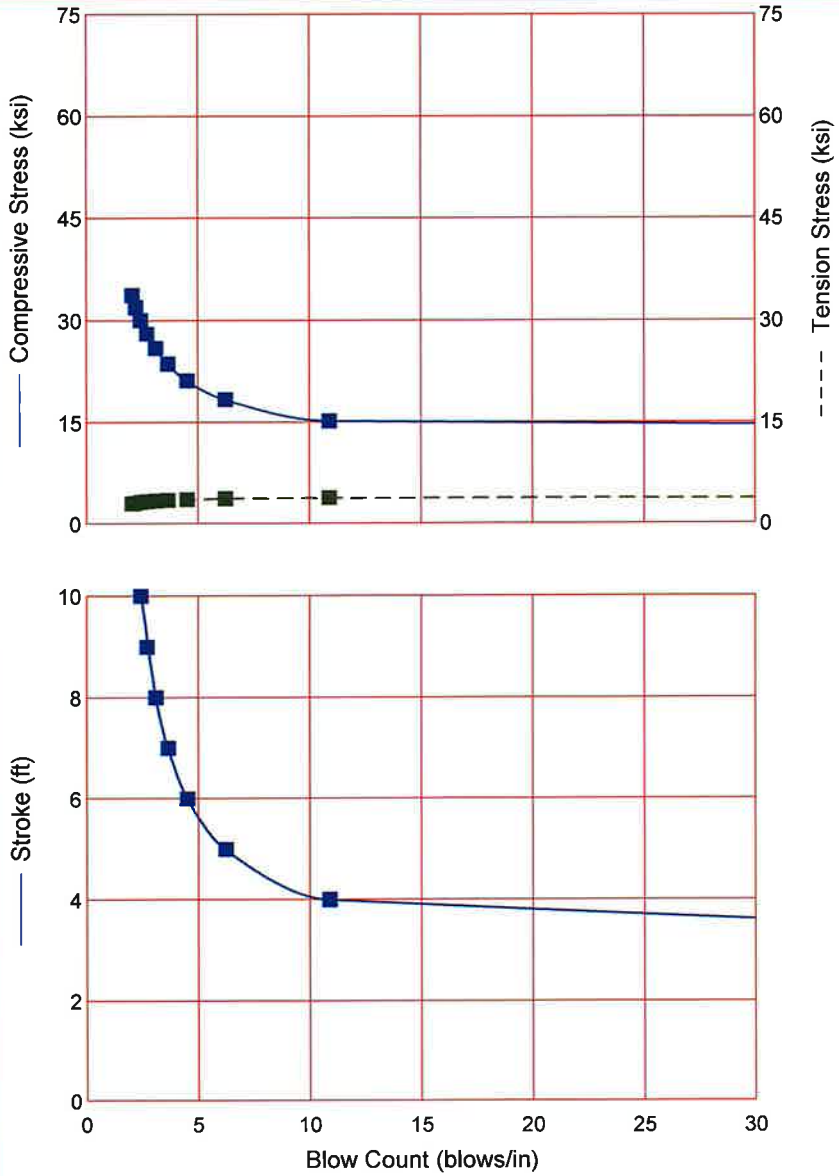
Res. Shaft = 50 %
(Proportional)

GZA GeoEnvironmental Inc. 01-Oct-2015
BRF 013-1(15) APE D19F3 80'HP12x74 FR VC GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
50.0	17.33	5.14	0.3	5.01	22.01
100.0	19.48	2.31	0.7	5.61	19.65
200.0	22.22	1.72	1.8	6.54	19.02
250.0	22.84	2.10	2.3	6.75	18.86
280.0	23.23	2.22	2.7	6.90	19.06
300.0	23.49	2.56	3.0	7.00	19.24
346.0	24.11	3.24	3.8	7.24	19.81
400.0	24.73	3.90	5.0	7.49	20.35
450.0	25.30	4.46	6.8	7.72	20.85
550.0	26.07	5.06	13.0	8.02	21.49

GZA GeoEnvironmental Inc.
BRF 013-1(15) APE D19 80'HP12x74 FR CC

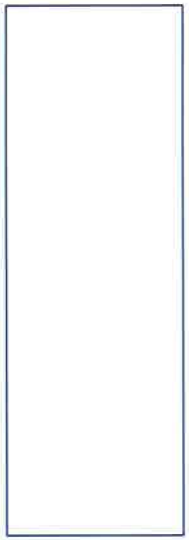
01-Oct-2015
GRLWEAP Version 2010



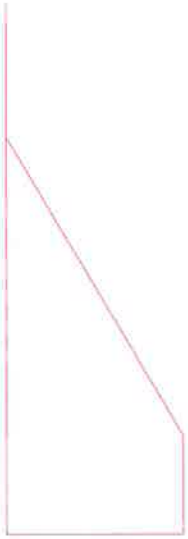
APE D 19-42

Capacity	346.0	kips
Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1710 (100%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	75.00	ft
Pile Top Area	21.80	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 50 %
(Proportional)

GZA GeoEnvironmental Inc. 01-Oct-2015
BRF 013-1(15) APE D19 80'HP12x74 FR CC GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
346.0	13.69	3.69	81.7	3.00	7.22
346.0	15.12	3.83	10.9	4.00	10.71
346.0	18.29	3.72	6.2	5.00	13.92
346.0	21.09	3.61	4.5	6.00	17.06
346.0	23.56	3.51	3.7	7.00	20.02
346.0	25.86	3.41	3.1	8.00	22.92
346.0	28.00	3.30	2.7	9.00	25.89
346.0	30.00	3.20	2.4	10.00	28.74
346.0	31.91	3.10	2.2	11.00	31.61
346.0	33.68	2.99	2.1	12.00	34.36

GZA GeoEnvironmental Inc. 01-Oct-2015
BRF 013-1(15) APE D19F3 80'HP12x74 EB VC GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
50.0	17.50	3.80	0.4	5.05	21.40
100.0	19.86	0.44	0.8	5.72	19.47
200.0	23.08	1.55	2.0	6.62	19.19
250.0	26.42	2.24	2.6	6.93	19.62
280.0	28.34	2.57	3.0	7.15	20.00
300.0	29.50	2.67	3.4	7.30	20.29
346.0	31.90	3.30	4.3	7.56	21.01
400.0	34.08	4.16	5.7	7.78	21.60
450.0	36.16	4.88	7.5	8.09	22.49
550.0	38.67	5.92	13.2	8.45	23.44

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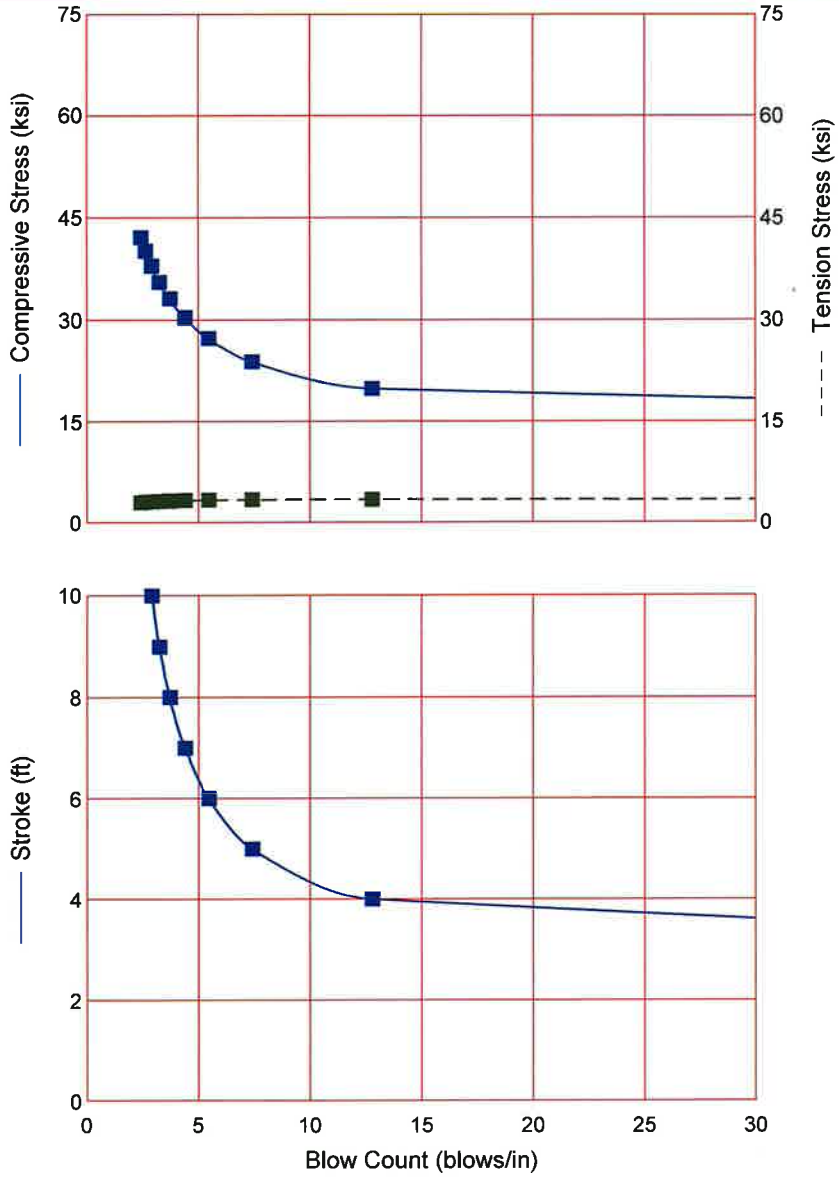
BRF 013-1(15) APE D19 80'HP12x74 EB CC

01-Oct-2015
GRLWEAP Version 2010

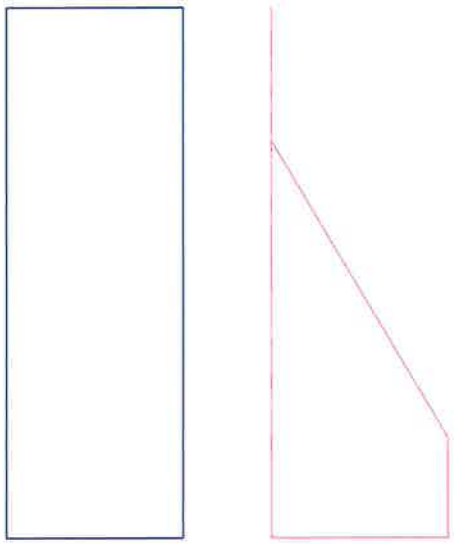


APE D 19-42

Capacity	346.0	kips
Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1710 (100%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	34825	kips/in
COR of H.C.	0.920	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.050	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	80.00	ft
Pile Penetration	75.00	ft
Pile Top Area	21.80	in2

Pile Model

Skin Friction Distribution



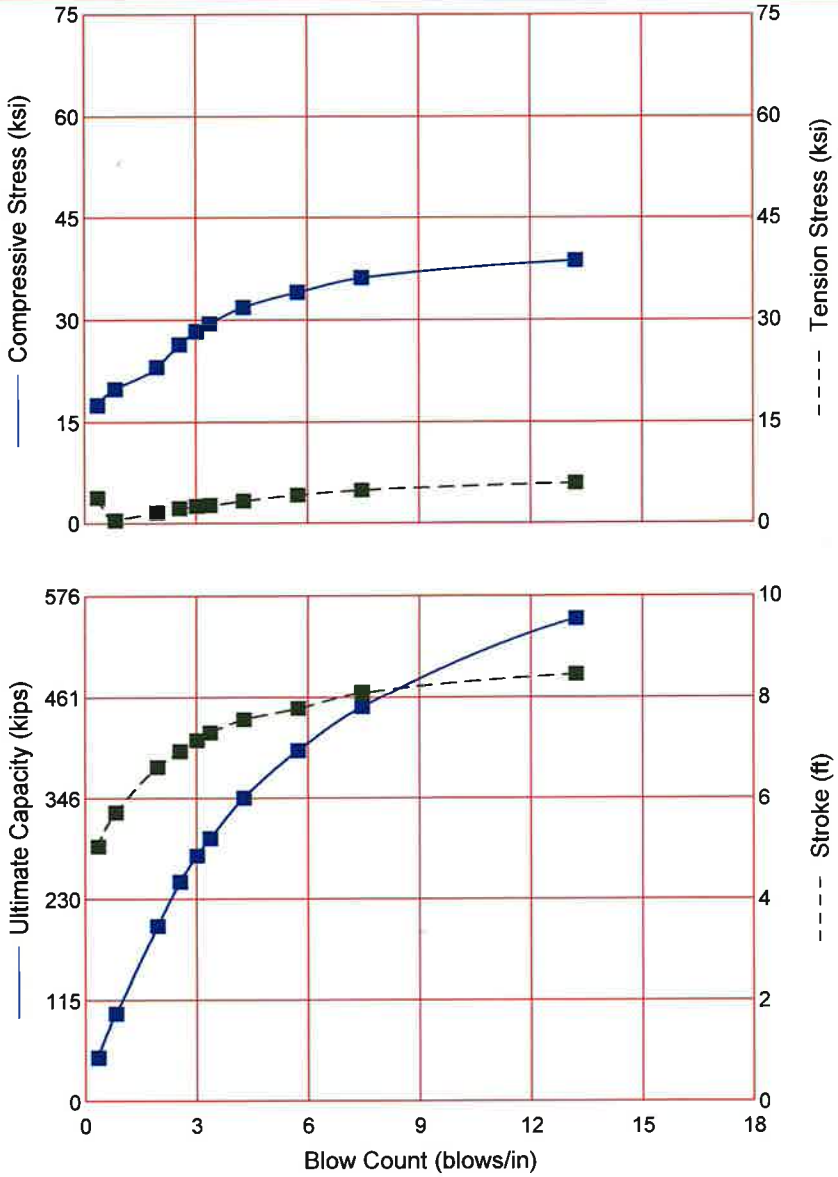
Res. Shaft = 10 %
(Proportional)

GZA GeoEnvironmental Inc. 01-Oct-2015
BRF 013-1(15) APE D19 80'HP12x74 EB CC GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
346.0	15.90	3.27	75.1	3.00	7.54
346.0	19.92	3.43	12.8	4.00	11.07
346.0	23.86	3.40	7.4	5.00	14.29
346.0	27.30	3.34	5.5	6.00	17.31
346.0	30.34	3.30	4.4	7.00	20.29
346.0	33.10	3.25	3.7	8.00	23.26
346.0	35.53	3.17	3.3	9.00	26.09
346.0	37.93	3.11	2.9	10.00	28.95
346.0	40.09	3.06	2.6	11.00	31.84
346.0	42.10	2.99	2.4	12.00	34.61

GZA GeoEnvironmental Inc.
BRF 013-1(15) APE D19F3 80'HP12x74 EB VC

01-Oct-2015
GRLWEAP Version 2010



APE D 19-42

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Pressure	1539 (90%)	psi
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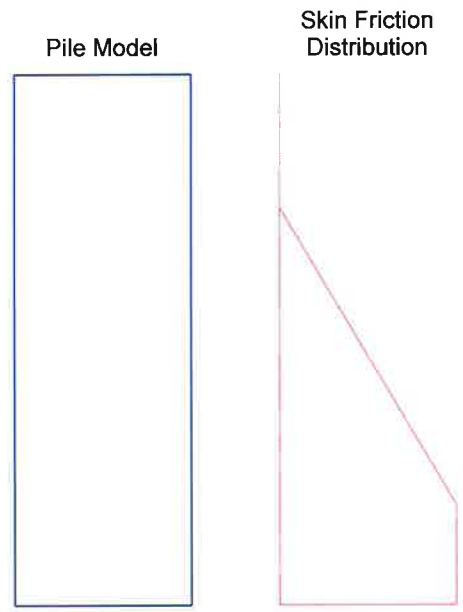
Pile Length	80.00	ft
Pile Penetration	75.00	ft
Pile Top Area	21.80	in2

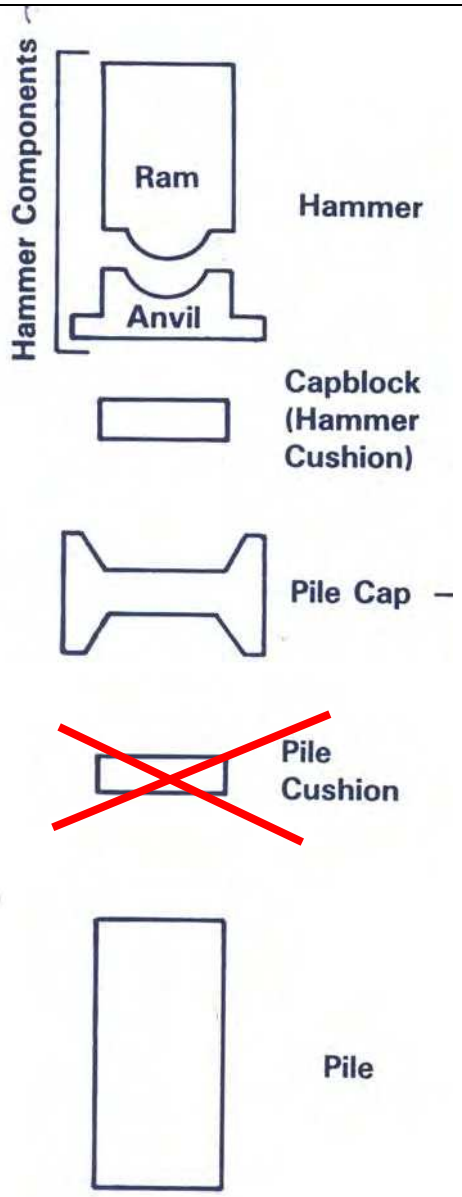


Res. Shaft = 10 %
(Proportional)

Pile and Driving Equipment Data Form

Project Name: Wardsboro 013-1 (15)
Project No.:
Route No.: 100

Structure Name: Route 100
Structure No: Bridge No: 68
Pile Driving Contractor: Valley Crane Services, Inc.
Foreperson: Scott Sargent



Manufacturer: APE
Type: Diesel Impact Hammer
Rated Energy (kip-ft): 52,362
Length of Stroke (ft): 12'-6"
Model: D19-42
Serial No: 0309222

Modifications:

Material: Monocast MC 904 P Blue Nylon
Thickness (in): 2 **Area (in^2):** 398
Modulus of Elasticity – E (ksi):
Coefficient of Restitution-e:

Also named:
Helmet
Bonnet
Anvil Block
Drivehead

Weight (lbs): 3000

Cushion material:
Thickness (in): **Area (in^2):**
Modulus of Elasticity – E (ksi):
Coefficient of restitution – e:

Pile Type & Size: HP 14X89
Length (in Leads) (ft): 40
Weight (lb/ft): 89
Wall thickness (in): N/A
Taper: N/A
Cross Sectional Area (in^2): 27
Ultimate Axial Pile Capacity (kips): 323
Steel Yield Strength (ksi): 50
Description of Splice:
Tip Treatment Description: POINT

Distribution- One copy each to:

- ☐ **State Structures Engineer**
- ☐ **State Soils & Foundations Engineer**
- ☐ **Resident Engineer:**

NOTE: If mandrel is used to drive the pile, please attach separate manufacturer's detail sheet(s), including weight and dimensions.

Submitted by: Charlie Ezequelle
Title: Project Manager - Valley Crane

Date: 09-28-2015