Appendix 5.13-A

Preliminary Assessment of the Electric and Magnetic Field Impacts Resulting from the Addition of the Cape Wind Park for the Preferred Alternative

PRELIMINARY ASSESSMENT

OF THE ELECTRIC AND MAGNETIC FIELD IMPACTS
ASSOCIATED WITH THE CAPE WIND PARK
FOR THE PREFERRED ALTERNATIVE

E·PRO

Engineering & Environmental Consulting

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CAPE WIND PROJECT
PRELIMINARY EMF ANALYSIS

SUMMARY:

This report summarizes the results of an assessment of the existing measured and predicted future electromagnetic fields (EMF) associated with the proposed Cape Wind Power Project. This assessment examines the proposed 115 kV transmission line interconnection route in the town of Yarmouth, the 115 kV submarine route across Nantucket Sound and the 33 kV collector cable system on Horseshoe Shoal. Measurements and calculations were performed at representative locations along the land route of the proposed transmission line and calculations were performed on the submarine cables.

On the mainland, magnetic field strengths at both the edge of pavement and edge of existing NSTAR Electric transmission line rights-of-way, as measured under existing conditions and as calculated with the future addition of the Cape Wind Power Project, are well within standards that apply in other states and the Massachusetts guideline applied by the Energy Facility Siting Board (EFSB). The estimated magnetic flux densities either within the roadway, at the edge of pavement, at landfall or at the edge of the transmission line right-of-way are less than the standards set forth by the states of Florida and New York,150 mG and 200 mG respectively; and the field strengths do not exceed the 85 mG level used as a benchmark by the Energy Facilities Siting Board (EFSB) of the Commonwealth of Massachusetts.

Since no existing sources of power frequency fields are present in the offshore Project Area, no baseline measurements were made in the marine environment. Calculations performed for the 115 kV and 33 kV submarine cables indicate that the resulting magnetic field strengths are low with the highest level being on the seabed directly over the cables, which are well below the field strength standards associated with the land based transmission rights-of-way. The highest fields associated with the with the 33 kV collector cables occur where they converge on the offshore electric service platform.

Due to their grounded metallic shields, the proposed submarine and land cables produce no external electric field. Also, since the Project will not change the operating voltages of the existing overhead transmission and distribution lines, the electric fields produced by the lines will not change. Thus, the Project will not produce or add to any electric field exposures either offshore or onshore.

ELECTRIC AND MAGNETIC FIELDS:

Electric power transmission lines create EMF because they carry electric currents at high voltages. The voltages and currents are produced by electric charges. Electric charges (electrons and protons) are present in all matter, and can give rise to electrical effects. Most objects are electrically neutral because positive and negative charges are present in equal numbers. When the balance of electric charges is altered, we experience electrical effects such as the attraction between a comb and our hair, the drawing of sparks after walking on a synthetic rug in the wintertime, or the presence of EMFs from power lines. The work put into separating electric charges is measured by *voltage*. The units of work-per-unit-charge are *volts* (V) or *kilovolts* (kV; 1 kV = 1000 V). Voltage is the "pressure" of electricity, and is analogous to the pressure of water in a plumbing system.

Electric charges push and pull on other charges and, therefore, each electric charge generates an *electric field* that exerts a force on nearby charges. Opposite charges (i.e., + and –) attract, and like charges (i.e., + and +) repel. Electric fields are equal to the "force per unit charge" and are measured in units of *volts/meter* (V/m) or *kilovolts/meter* (kV/m).

The movement of electric charges is called *electric current* and is measured in *amperes* (amps). Current measures the "flow" of electricity, which is analogous to the flow of water in a plumbing system. The moving charges in an electric current produce a *magnetic field* which exerts force on other moving charges. Wires carrying currents running in parallel attract, while wires carrying currents in opposite directions repel. This is the principle by which electric motors generate force.

Magnetic fields are measured in *gauss* (G) or *tesla* (T) (1 T = 10,000 G). Smaller fields are measured in *milligauss* (1 mG = 0.001 G) or *microtesla* (1 μT = one-millionth of a tesla). Milligauss is the unit most often used to measure the strength of magnetic fields in electric transmission lines. Permanent magnets contain electrical currents at the atomic level that can generate strong magnetic fields, approximately 100 to 500 G (i.e., 100,000 to 500,000 mG). Thus, magnetic fields from permanent magnets can exert forces on electric currents, or on other magnetic objects, as for example, when a compass needle orients toward a magnet.

EMFs decrease in size as the distance from the source (the electric charges or currents) increases. For an electric transmission line, EMF levels are highest next to the transmission lines (typically near the center of the right-of-way) and decrease as the distance from the transmission corridor increases. Electric fields are attenuated by objects such as trees and walls of structures, and are completely shielded by electrically conducting material such as metal, the earth, or the surface of the body. Magnetic fields, on the other hand, penetrate most materials.

Humans are exposed to a wide variety of natural and man-made electric and magnetic fields. The earth's atmosphere produces slowly-varying electric fields (about 0.1 to 10 kV/m) that occasionally manifest themselves as lightning. The earth's core produces a steady magnetic field, as can easily be demonstrated with a compass needle. The earth's magnetic field ranges in strength from about 470 mG to 590 mG over the United States, and is about 560 mG in the Northeast. Knowing the strength of the earth's fields provides a perspective on the size of the magnetic field measurements from an electric transmission line.

Man-made magnetic fields are common in everyday life. Many childhood toys contain magnets, and many of us use magnets to hold items on the metallic surface of refrigerators. These permanent magnets typically have fields in excess of 100,000 mG. An increasingly common diagnostic procedure, magnetic resonance imaging (MRI), uses fields of 20,000,000 mG on humans and is considered safer than X-rays. Magnets and steady electric currents, i.e., direct currents (DC), produce steady magnetic fields.

Electric transmission line currents are alternating currents (AC), because they change size and direction 60 times per second (60 cycles per second = 60 Hertz or 60 Hz). AC currents produce AC magnetic fields; however, aside from the variation in time (60 Hz) that characterizes electric transmission line fields, they are identical in nature to steady fields, such as those due to the earth's atmosphere, or geomagnetism. Moreover, as we move our bodies, the direction of the earth's magnetic field relative to us changes and our body experiences a time-varying magnetic field, as in the case of AC magnetic fields.

Electric power transmission lines, distribution lines, and the electric power lines that come into our homes and workplaces are sources of electric and magnetic fields that vary in time at a frequency of 60 Hz (in North America) or 50 Hz (abroad). Magnetic fields are proportional to the current, and electric fields are proportional to the voltage on the wires; both decrease as distance from the electrical wires increases. EMFs from different sources (e.g., adjacent wires) may partially cancel or may add to the EMF level at any location. For residences, typical baseline 60 Hz magnetic fields in the middle of rooms range from 0.5 to 2.0 mG. These fields are, to a large extent, produced by outdoor distribution wiring, indoor wiring, and electric currents in ground return pathways.

In the home, 60 Hz EMFs can also be found in the vicinity of electric appliances, including fans, electric ranges, microwave ovens, refrigerators, clothes washers and dryers, fluorescent lights, televisions, toasters, vacuum cleaners, etc. Appliances produce magnetic fields of 40 to 80 mG at distances of 1 foot, but the fields diminish quickly with distance. Personal electric appliances such as shavers, electric toothbrushes, hair dryers, massagers, electric toys, and electric blankets can produce fields measuring 100 mG or more in the vicinity of those using them.

Table 1 summarizes the strengths of magnetic fields associated with various devices and phenomena and several guidelines established by various organizations for certain occupations, individuals, and the general public.

Table 1: Magnetic Field Strengths

Device, Phenomenon, Location, or Standard	Magnetic Field Strength (mG)
Magnetic Resonance Imaging (MRI) scan	20,000,000 (1)
Permanent magnet	100,000 (1)
ACGIH* standard	10,000
ICNIRP** occupational guideline (1998)	4,167
ACGIH guideline for occupational exposures	10,000
ACGIH guideline for individuals with pacemakers	1,000
ICNIRP general public guideline (1998)	833
Earth's magnetic field	470 to 590 (1)
Hair dryers and electric blankets	100 to 500
Typical household appliance	40 to 80

*American Conference of Governmental Industrial Hygienists
**International Commission on Non-Ionizing Radiation Protection

Notes:
(1) These magnetic fields are steady fields (not time-varying) as opposed to the other fields listed which are low-frequency (60 Hz), time-varying fields.

BACKGROUND:

The Cape Wind Power Project involves the installation of multiple wind powered generating units in Nantucket Sound between Cape Cod and the Island of Nantucket. The individual wind powered generating units will interconnect to an offshore, platform-mounted substation via a 33 kV submarine cable collector system. At the substation, the 33 kV generator output will be stepped up to 115 kV and two pairs of submarine cables will run from the platform to the mainland. At the end of New Hampshire Avenue in Yarmouth, the 115 kV submarine cables will make landfall and transition from 4 - three conductor submarine cables to a 12 cable duct bank configuration and ultimately interconnect to NSTAR Electric's transmission facilities at Barnstable Switching Station. Illustrations of the submarine cable trench, the landfall transition vault, and the overland cable duct bank are provided in Appendix A.

The power frequency electromagnetic field (EMF) impact of the 33 kV submarine cable collector system, and of the 115 kV submarine and upland transmission route through Yarmouth to NSTAR Electric's Barnstable Switching Station is evaluated in this assessment. E/PRO Engineering and Environmental Consulting, LLC has been engaged to assess baseline magnetic field strengths and estimate anticipated changes to magnetic fields along the upland route resulting from the installation of the 115 kV Cape Wind Power cable.

As illustrated in Appendix B, the Yarmouth route has four (4) 115 kV submarine cables making landfall from Lewis Bay in the area of New Hampshire Avenue. The submarine cables will transition to a duct bank configuration containing 12 single-conductor cables and proceed up the west side of New Hampshire Avenue to Berry Avenue. The route will continue north up the east side of Berry Avenue across Route 28 on to Higgins Crowell Road. On Higgins Crowell Road, the route continues north on the east side of the road and crosses over Buck Island Road. Just north of Buck Island Road (near Horse Pond Road), the route shifts to the west side of the Higgins Crowell Road and continues north to a location south of Willow Street and north of where the 12 inch water main intersects Higgins Crowell Road. The route then shifts to the east side of Higgins Crowell Road and runs to the east side of Willow street. At Willow Street, the route turns north along the east side of Willow Street, pass Summer Street to the transmission right of way that accommodates 115 kV lines 118 and 119 and 23 kV line 92. At the transmission line right-of way, the cable trench will turn west and run within the right-of-way parallel with the 23 kV line and the 115 kV transmission lines to the Barnstable 115 kV Switching Station. An overhead, 23 kV distribution line located 6 to 10 feet off the edge of pavement exists along the entire street route; it is supplied by 23 kV line 92.

No existing sources of power frequency fields are present in the offshore Project Area. Therefore, no baseline measurements were made in the marine environment. E/PRO's task here has been to calculate anticipated magnetic fields generated by the 115 kV and 33 kV submarine cables.

The 115 kV Submarine Cable System will consist of four (4) 3-conductor, armored cables with solid dielectric insulation. The cables will be configured as two circuits of two cables each. Each circuit will carry half the electrical output of the wind farm at any given moment. Throughout the submarine route the cables will be laid 6 feet below the sea floor in two trenches: 2 cables per trench. The trenches will be spaced approximately 20 feet apart horizontally. The submarine cables will make the transition at the landfall to four separate cables each installed in an 18" conduit separated by approximately 10.5 feet at the seaward end.

The 33kV Cable Collector System will also consist of 3-conductor, armored, solid dielectric cables. The cables will be arranged in strings, each of which will connect approximately 7 - 10 wind turbine generators (WTG) radially to a 33 kV circuit breaker on the Offshore Substation. Some strings may be bifurcated. The electrical current in the cable segments within each string will vary depending on location within the string: cable segments closer to the substation will carry the output of more WTGs. Three different cable sizes will be used to accommodate this variation. Each cable will be buried approximately 6 feet below the sea floor, one cable per trench.

BASELINE MAGNETIC FIELD MEASUREMENTS:

On June 5 and 6, 2002, measurements of the magnetic flux density were conducted along the upland portion of theYarmouth route. Magnetic fields measured along the route are substantially the result of existing, roadside, 23 kV distribution lines. The loading on these distribution lines vary seasonally and at the time of measurement, the lines were considered to be lightly loaded. Measurements were additionally conducted across the NSTAR Electric 115 kV and 23 kV transmission line rights-of-way. All magnetic field measurements were taken with a Dexsil Fieldstar 1000 recording gaussmeter. All measurements were recorded at a point 1 meter above ground level.

In Yarmouth, magnetic flux density measurements as presented in Appendix C were conducted at the following locations along the proposed route:

1. East side of route at edge of pavement along Willow Street, Higgins Crowell Road, Berry Avenue and New Hampshire Avenue.

2. West side of route at edge of pavement along New Hampshire Avenue, Berry Avenue, Higgins Crowell Road and Willow Street.

3. Lateral Profiles were taken across the roadway at the following representative locations:

    a. L2 - Berry Avenue south of Route 28.
    b. L3 - Higgins Crowell Road north of Route 28.
    c. L4 - Higgins Crowell Road south of Buck Island Road.
    d. L5 - Higgins Crowell Road near Morse Pond Road.
    e. L6 - Higgins Crowell Road near Marguerite E. Small School.
    f. L7 - Higgins Crowell Road south of 23 kV right-of-way.

g. L8 - Higgins Crowell Road north of 23 kV right-of-way.
h. L9 - Willow Street near Summer Street.

These locations were selected as representative locations due to distribution line geometry, relative distribution line loading, or general proximity of a schoolyard.

4. Lateral Profile of 115 kV transmission Lines 118 and 119, and Line 92 (23 kV) on the east side of Willow Street. This profile is representative of NSTAR Electric's right-of-way between Barnstable Switching Station and Harwich Tap.

Table 2 provides a brief summary of the existing magnetic flux density measured at a point 1 meter above the road surface at the edge of pavement along the proposed route. A record of the entire route is provided in Appendix C.

Table 2 Summary of Longitudinal Measurements

Route	Maximum (mG)*	Minimum (mG)	Route Average (mG)
Yarmouth Route-North to South (east edge of pavement)	20.40	0.04	4.94
Yarmouth Route-South to North (west edge of pavement)	16.84	0.00	4.43

*The maximum value listed above is a normalized value and does not consider the slightly higher magnetic fields observed along the route directly beneath the 115 kV and 23 kV transmission lines.

Table 3 provides a brief summary of the existing magnetic flux density measured laterally across the roadway at representative locations along the two routes. The table presents the measured levels at a point 1 meter above the road surface at both sides of the pavement and the maximum value observed at that location. Records of these lateral measurements are provided in Appendix C

Table 3 Summary of Street Lateral Measurements

Lateral Location	Max (mG)	East Edge of Pavement (mG)	West Edge of Pavement (mG)
Yarmouth:			
L2 - Berry Avenue	3.00	1.16	2.92
L3 - Higgins Crowell Road	1.80	1.40	1.76
L4 - Higgins Crowell Road	3.00	2.36	2.20
L5 - Higgins Crowell Road	4.60	4.40	2.76
L6 - Higgins Crowell Road	4.64	4.56	2.68
L7 - Higgins Crowell Road	10.72	10.04	4.00
L8 - Higgins Crowell Road	19.00	18.16	9.20
L9 - Willow Street	14.52	6.84	13.64

Table 4 provides a summary of the existing magnetic flux density measured laterally across the transmission line right-of-way in Yarmouth. The table presents the measured levels at a point 1 meter above grade across the right-of-way. Measurements were taken at the lowest point of the line resulting in the highest field strengths. Records of these lateral measurements are provided in Appendix C

Table 4 Summary of Transmission Line Right-of-Way Lateral Measurements

Lateral Location	Max (mG)	North Edge of R-O-W (mG)	South Edge of R-O-W (mG)
Yarmouth:			
Line 118/119 & 92 - East of Willow Street	25.6	18.28	5.52

In addition to the magnetic fields created by the existing roadside 23 kV power lines running along the route, magnetic fields caused by overhead and underground low voltage service lines and magnetic fields from currents flowing on the underground water mains were also encountered. These currents are likely ground return currents that are the result of corroded service neutral connections in the vicinity of Berry Avenue and Higgins Crowell Road. The magnitude of these fields can be observed as the small hump near the west edge of pavement on the graphic summaries of the Yarmouth measurements provided in Appendix C.

ELECTRIC & MAGNETIC FIELD CALCULATIONS:

Electric & Magnetic field calculations were performed by the application of the "ENVIRO" computer program developed by the Electric Power Research Institute (EPRI).

UPLAND MAGNETIC FIELDS:

Initial calculations were bench marked against actual measurements by performing a series of calculations based upon line geometry and estimated operating conditions at the time measurements were taken. These models demonstrate how well the calculated values track the actual measurements. Models were developed for each of the following Yarmouth route locations to estimate the relative impact of the Cape Wind underground transmission line:

L2 - Berry Avenue south of Route 28.
L4 - Higgins Crowell Road south of Buck Island Road.
L6 - Higgins Crowell Road near Marguerite E. Small School.
L8 - Higgins Crowell Road north of 23 kV right-of-way.
Lateral Profile of transmission Lines 118, 119 and 92 on the east side of Willow Street

Comparisons of the modeled magnetic flux density and the actual measurements for the locations listed above are provided in Appendix D.

In addition to modeling the existing power line facilities, the magnetic flux density of the proposed transmission cable system duct bank is calculated based upon the Cape Wind generation running at a maximum output of 454 MW and annual average output of 168 MW. Based upon the 8 over 8 cable duct bank configuration described in Appendix A with 56 inches of cover (the minimum expected burial depth within the roadways), the maximum magnetic flux density created solely by the proposed underground transmission cable system at a point 1 meter above grade is estimated to be 7.1 mG at 168 MW and 19.6 mG at a peak of 454 MW. These values quickly decay by 30, 67 and 85 % at distances of 5, 10 and 15 feet respectively, from the centerline of the duct bank as illustrated in Appendix E.

To estimate the magnetic flux density impact of the Cape Wind Project, the characteristics of the cable duct bank were added to the route models identified above and calculations were performed to estimate the composite magnetic flux density from both existing and proposed facilities. Based upon information provided by NSTAR Electric, loadings on the existing power facilities were modified to reflect peak load conditions as these loadings were considered light at the time measurements were conducted.

Roadway Lateral Profile Calculations:

At the four (4) Yarmouth street locations identified above, calculations of the lateral magnetic flux density profiles were performed to determine the relative magnetic field impact associated with the Cape Wind transmission line. Three profiles were developed at each site. The first profile modeled the 23 kV distribution line at a peak load level without the Cape Wind Project. The peak load levels were estimated by applying the ratio of the current measured in line 92 during the historical system peak of August 9, 2001, to the current reported in line 92 at the time the magnetic field measurements were recorded on June 5, 2002. This ratio was then applied to the models developed to represent existing conditions for each lateral location. The second and third profiles modeled the 23 kV distribution line at peak load with Cape Wind at average output (168 MW) and maximum output (454 MW). The duct bank centerline is located in the roadway at 4.5 feet from the edge of pavement. The values listed below indicate the maximum flux density defined within the roadway and the levels estimated at the edge of pavement.

Magnetic Flux Density in Roadway

Lateral	Magnetic Flux Density (mG) at 1 meter above grade		
	Peak Load w/o CW	Peak Load w/CW @ 168 MW	Peak Load w/CW @ 454 MW
Yarmouth L2 Max	4.23	8.08	20.10
Yarmouth L2 East Edge	1.73	4.88	13.90
Yarmouth L2 West Edge	4.23	4.07	3.93
Yarmouth L4 Max	4.97	9.24	20.20
Yarmouth L4 East Edge	4.97	8.77	17.30
Yarmouth L4 West Edge	2.91	3.15	3.66
Yarmouth L6 Max	8.27	8.40	18.90
Yarmouth L6 East Edge	8.27	8.12	7.98
Yarmouth L6 West Edge	3.57	5.13	13.50
Yarmouth L8 Max	33.73*	31.80*	31.60*
Yarmouth L8 East Edge	33.73	31.80	31.60
Yarmouth L8 West Edge	14.49	12.70	15.40

*As indicated in Appendix E, the flux density at this location is slightly greater east of the edge of pavement directly beneath the 23 kV distribution line.

More detailed summaries of the calculated profiles are provided in Appendix E. Examination of profile L6 shows that with Cape Wind operating at either 168 MW or 454 MW the magnetic field on the east side of the road closest to Marguerite E. Small school is unchanged from that experienced under existing peak loading on the overhead distribution lines.

Transmission Line Profile Calculations:

In Yarmouth, a transmission line corridor crosses Willow Street just north of Summer Street. This transmission line corridor is 180 feet wide and presently accommodates Line 92 (23 kV line) and Lines 118 and 119 (115 kV Lines). Line 92 is constructed of single wood pole structures with crossarms and is located on south side of the corridor approximately 35 feet from the edge of right-of-way. Lines 118 and 119 are supported on a double circuit, single steel pole structure located on the north side of the corridor approximately 40 feet from the edge of right-of-way. Details of the right-of-way and the geometry of the lines are provided in Appendix F. The following line loadings were used for the magnetic field calculations. The overhead line loadings are maximums obtained from load flow forecast analyses performed by NSTAR Electric's System Planning Department for year 2005.

Operating Condition	Line 118	Line 119	C/W Cables
Peak Load w/o Cape Wind	643 A	311 A	0 A
Light Load w/o Cape Wind	216 A	105 A	0 A
Peak Load w/ Cape @ 168 MW	643 A	311 A	928 A
Peak Load w/ Cape @ 454 MW	643 A	311 A	2,524 A

Based upon load data provided by NSTAR, the Loading on Line 92 was assumed to be 350 Amps.

The proposed 115 kV cable duct bank is center-lined at 80 feet to the south of the line 118/119 centerline or 25 feet to the north of Line 92 centerline based on preliminary NSTAR Electric studies. The values listed below indicate the maximum magnetic flux density defined within the 180 foot wide right-of-way and the levels estimated at the edge of right-of-way at a point 1 meter above grade.

Lateral	Magnetic Flux Density (mG) at 1 meter above grade Peak Load w/o CW	Peak Load w/CW @ 168 MW	Peak Load w/CW @ 454 MW
Yarmouth R-O-W Max	127.0	127.0	127.0
Yarmouth R-O-W North Edge	55.9	55.9	55.9
Yarmouth R-O-W South Edge	12.2	12.2	12.2

The magnetic field impact to the Yarmouth transmission line corridor is negligible as the anticipated loads on the existing overhead lines over-shadow the fields created by the new underground transmission cables. Appendix G includes magnetic field profiles for the underground cables in isolation and for the composite of underground cables and overhead lines.

SUBMARINE CABLE SYSTEM MAGNETIC FIELDS:

115 kV Submarine Transmission Cables

Calculations were performed to predict the magnetic field strength over the 115 kV transmission cable trenches on the sea floor, and at varying water depths above the trenches. These calculations conservatively assumed least favorable phase orientation and took no credit for reduction in magnetic field strength due to the helical lay of the cables nor to the shielding effect of the cables' steel wire armor.

On the sea floor there are pronounced peaks in the field above each trench; but the intensity falls off considerably just 15 feet away (horizontally) from each trench. At elevations 10, 20 and 30 feet above the sea floor there are no pronounced peaks, just a gradual decrease with increasing horizontal distance. As illustrated in Appendix H, the calculated maximum magnetic flux density at the sea floor and corresponding field levels at three vertical distances above the cable trenches are as follows:

Elevation	Maximum Magnetic Flux Density (mG) 168 MW	454 MW
Sea Floor (0 ft)	22*	60*
+10 ft	4	10
+20 ft	2	5
+30 ft	1	3

* At the ocean floor, these values decline to 5 mG and 12 mG , respectively, 15 feet from each trench.

33 kV Submarine Collector Cables

Calculations were performed to predict the magnetic field strength over the collector system cables on the sea floor and at varying water depths above them. These calculations conservatively took no credit for reduction in magnetic field strength due to the helical lay of the cables or from the shielding effect of the cables' steel wire armor. The results of the calculations are similar to what was found for the 115 kV cables. Predicted peak magnetic field levels on the sea floor directly above the cable decrease rapidly with horizontal distance from the cable and with vertical distance above the sea floor. Magnetic field strength around a cable is proportional to its electrical current and therefore the field strength will vary widely depending on the location of the cable segment within a string of turbines and on the output of the turbines. To cover the range of current and field strengths, calculations were performed for the most lightly loaded cable segment located at the end of a string and carrying the output of only one WTG, and for a cable segment located between the closest turbine on a string and the substation and carrying the output of 10 WTGs, termed the homerun cable. As illustrated in Appendix I, the calculated magnetic flux density at the sea floor and field levels at three vertical distances above the cable trenches are as follows:

1. 150 mm^2 33 kV Cable

	Magnetic Flux Density (mG)	
Elevation	@ 28 Amps	@ 70 Amps
Sea Floor (0 ft)	1.06*	2.66*
+10 ft	0.16	0.39
+20 ft	0.06	0.15
+30 ft	0.03	0.08

* At the ocean floor, these values decline to 0.3 mG and 0.7 mG , respectively, 10 feet from the centerline.

2. 630 mm^2 33 kV Homerun Cable

	Magnetic Flux Density (mG)	
Elevation	@ 280 Amps	@ 700 Amps
Sea Floor (0 ft)	11.30	28.30
+10 ft	1.68	4.21
+20 ft	0.65	1.61
+30 ft	0.34	0.85

* At the ocean floor, these values decline to 3.2 mG and 8.0 mG , respectively, 10 feet from the centerline.

Calculations were also performed to predict the magnetic field strength generated by the 33 kV collector cables in the immediate vicinity of the Offshore Substation, where the cables converge. The calculations conservatively assumed five homerun cables, each carrying the maximum load of ten WTGs separated by one cable diameter with worst case phase orientation. Magnetic field levels were calculated at a distance of 2 feet from the cables, which would represent the maximum exposure to marine organisms on the surface of the scour protection. Magnetic field levels were also calculated at a distance of 10 feet from the cables, which would be the closest reasonable approach of a boater to the cables at the point where they rise vertically out of the water up to the platform mounted substation. The calculated peak values directly in line with the cables at the 2 foot and 10 foot distances and the calculated values a short distance to the side of the cables are as follows:

Distance from Cables		Maximum Magnetic Flux Density (mG) @ 280 Amps	@ 700 Amps
2 ft	directly over	189 mG*	473 mG*
10 ft	directly over	20 mG**	51 mG**

* At a 2 foot elevation, these values decline to 10 mG and 26 mG , respectively, 15 feet from the centerline.

* * At a 10 foot elevation, these values decline to 7 mG and 18 mG , respectively, 15 feet from the centerline.

More detailed summaries of the calculated profiles are provided in Appendix J.

SUBMARINE TO UPLAND CABLE TRANSITION:

The 115 kV submarine cable system will continue with the same configuration described for Nantucket Sound as it traverses Lewis Bay to the landfall transition location. Therefore, the predicted magnetic fields will continue to be the same as defined above for the 115 kV submarine cables. The transition to landfall will change the configuration so each of the four cables is routed in a separate 18” diameter HDPE conduit, installed by Horizontal Direction Drill (HDD). It is expected that the conduits will be spaced 10.5 feet apart at their seaward end; and magnetic field levels were calculated for this configuration and illustrated in Appendix K. For the specified pipe spacing, the calculated peak magnetic flux density directly above the cables at the sea floor, Mean Low Low Water (MLLW) and Mean High Water (MHW) are as follows:

Elevation	Maximum Magnetic Flux Density (mG) 168 MW	454 MW
Sea Floor (0 ft)	10.80	29.2
MLLW (2 ft)	6.91	18.8
MHW (5.5 ft)	4.23	11.5

At the transition vault located at the end of New Hampshire Avenue, the HDPE conduits will converge to a more compact configuration as detailed in Appendix A in order to facilitate the transition from submarine cable to duct type cable. Peak magnetic flux density was calculated at an elevation of one meter above grade at the vault as follows:

Elevation	Maximum Magnetic Flux Density (mG) 168 MW	454 MW
1 Meter above grade	11.3	30.8

More detailed summaries of the calculated profiles at the landfall transition are provided in Appendix K.

ELECTRIC FIELDS:

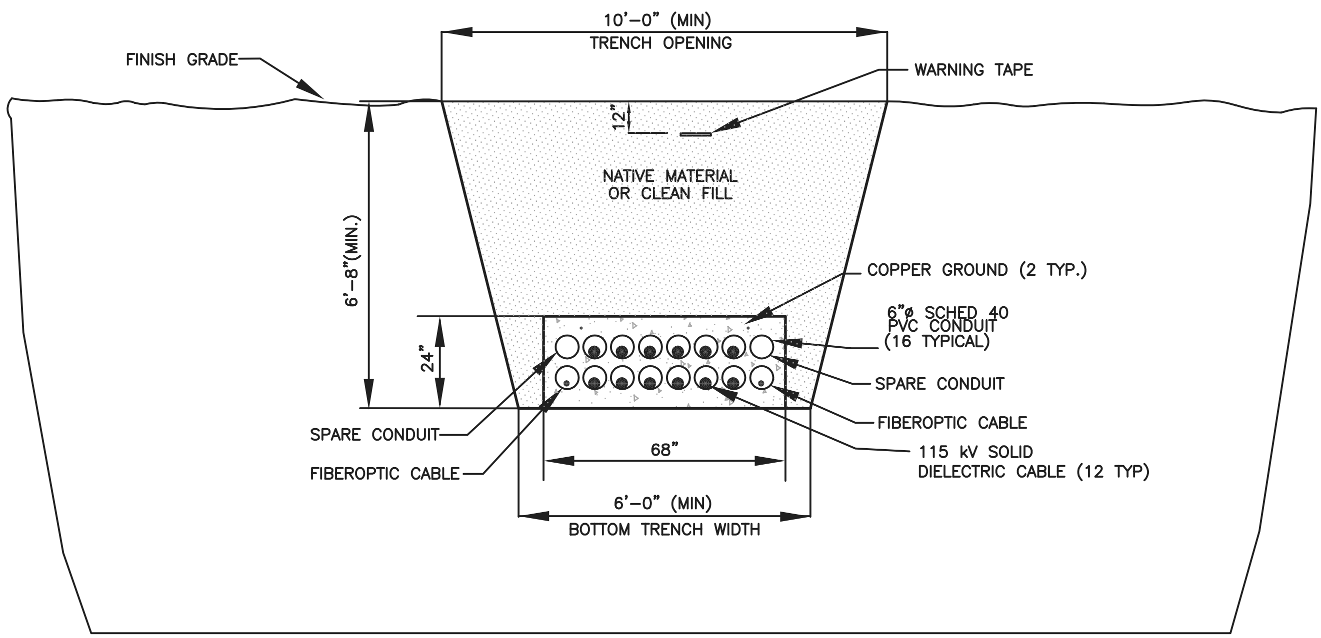
In the offshore environment the electric field of the proposed 115 kV and 33 kV submarine cables will be effectively contained within the body of each cable (i.e. shielded) by its grounded metallic shield. Likewise, because the electrical equipment at the WTG's and at the offshore substation will be effectively contained in grounded metal enclosures, all power frequency electric fields will be shielded and no measurable levels will be present.

On the mainland the electric fields created by the existing overhead power facilities will continue to exist at present levels. That is because electric field strength is a function of power line voltage and the operating voltages of those overhead lines will not be changed by addition of the Cape Wind facilities. Also, as with the submarine cables, the electric field of the proposed 115 kV underground cables will be contained by each cable's grounded metallic shield. Summaries of Electric Field Calculations for the existing overhead transmission and distribution lines are provided in Appendix L.

CONCLUSION

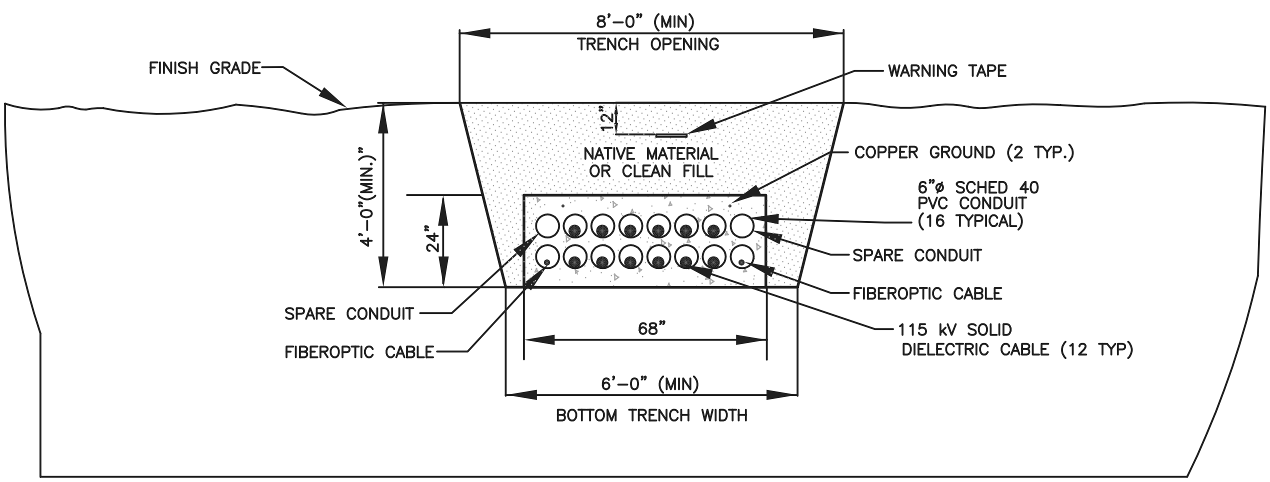
The calculated maximum field strength at the edge of NSTAR Electric's 115 kV transmission right-of-way with the Wind Park at maximum output of 454 MW is 55.9 mG for the Yarmouth route. Although there is no regulatory standard in Massachusetts for magnetic field levels on transmission line rights-of-way, the EFSB has applied an 85 mG guideline at the edge of the right-of-way in past proceedings. Other states such as New York and Florida have adopted edge of right of way standards of 200mG and 150mG respectively.

Appendix A



UPLAND CABLE TRENCH CROSS–SECTION (IN ROADWAYS)

CONCRETE ENCASED DUCTBANK



UPLAND CABLE TRENCH CROSS SECTION (IN R.O.W.)

CONCRETE ENCASED DUCTBANK

NOTE:

NATIVE MATERIAL TO BE USED ONLY IF DETERMINED TO HAVE APPROPRIATE THERMAL RESISTIVITY AND TO BE ACCEPTABLE IN ACCORDANCE WITH THE SOIL MANAGEMENT PLAN.

H:\E159\DEIS-DEIR\UPLAND-TRANSITION-VAULTS-111303\E159-DEIS-DETAILS-111303.DWG

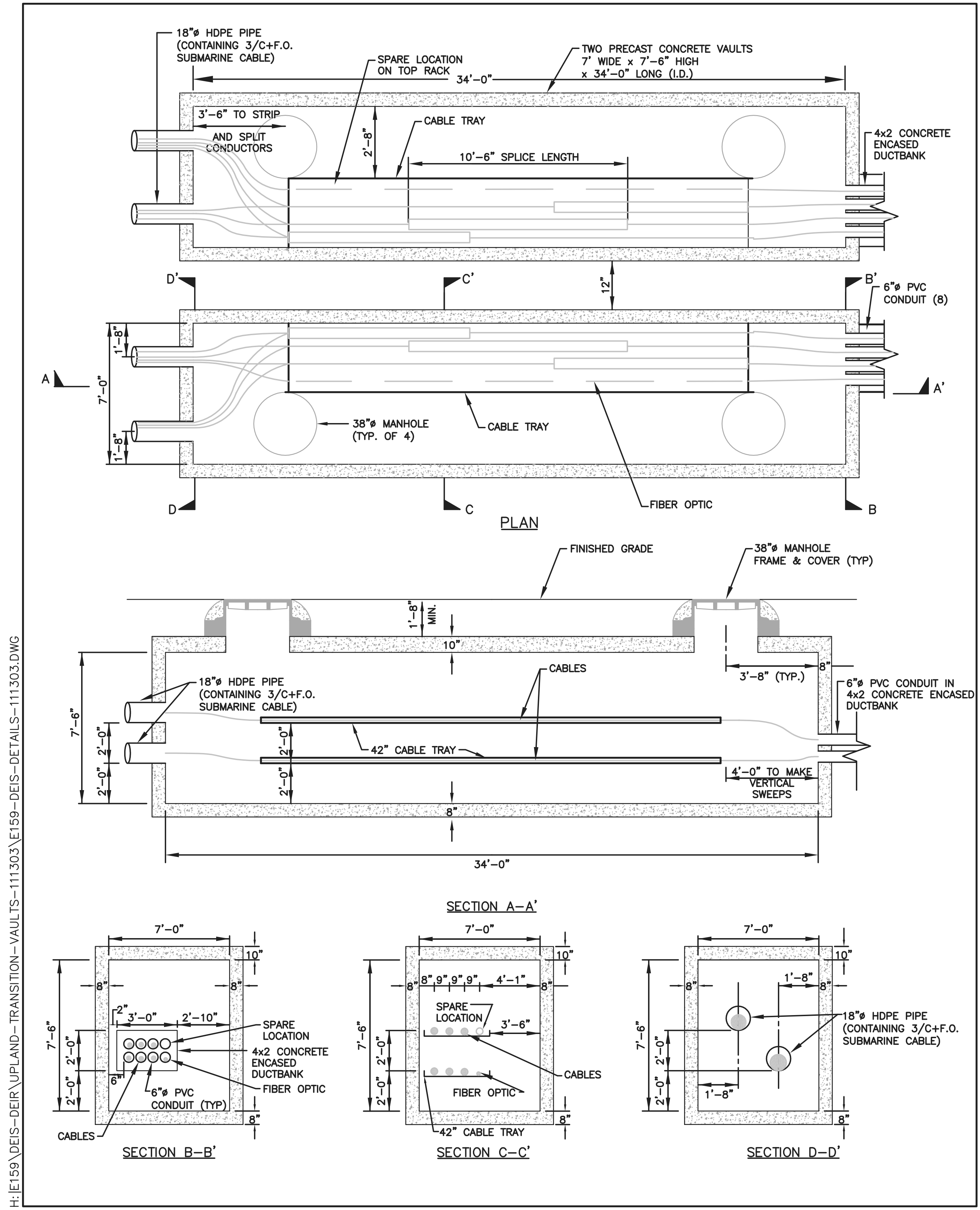
Cape Wind
Energy for Life.

ESS Group Inc.
Engineers
Scientists
Consultants

Cape Wind Associates, LLC
Cape Wind Project

Typical "8-over-8" Ductbank Cross-Section (Not To Scale)

Figure 4-13



Cape Wind Associates, LLC
Cape Wind Project

115 kV Landfall Transition Vault

(Not To Scale)

Figure 4-15

Engineers
Scientists
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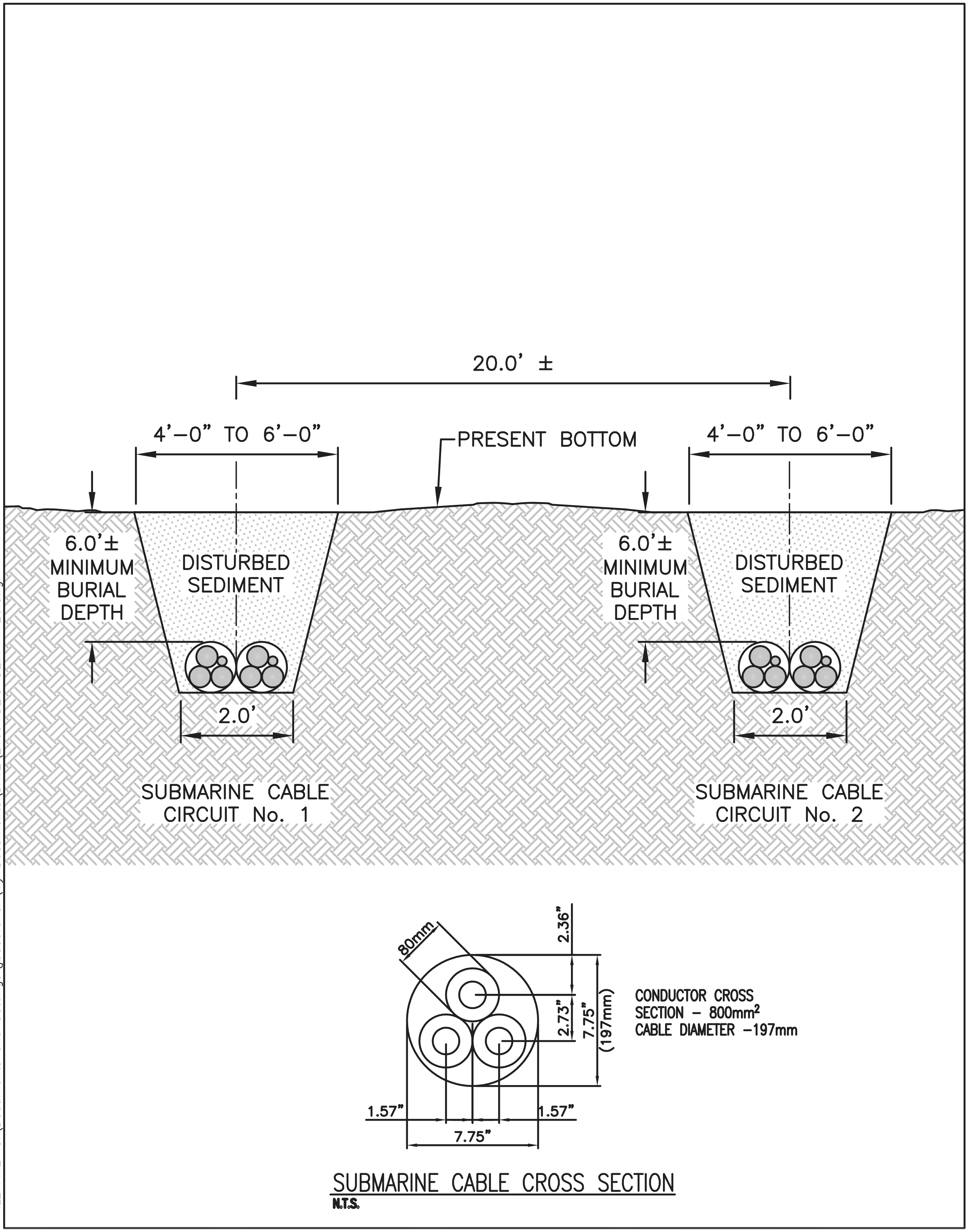

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ESS Group Inc.

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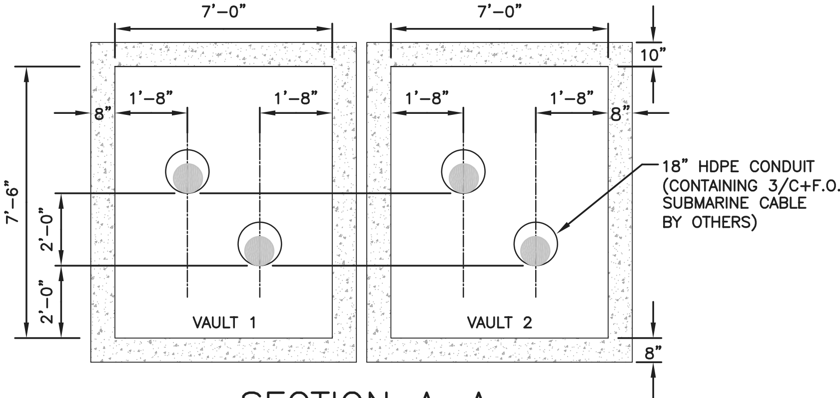
Scientists
Consultants

Cape Wind Associates, LLC
Cape Wind Project

Typical Cross Section of Submarine Cable Trench Using Jet Plow Embedment (Not To Scale)

Figure 4-20



SECTION A-A

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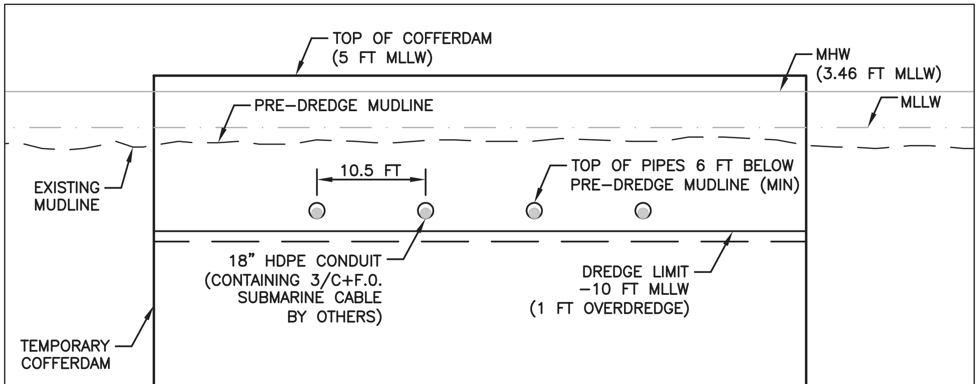

SECTION B-B

NOT TO SCALE

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Landfall Transition: Conceptual Design Sections

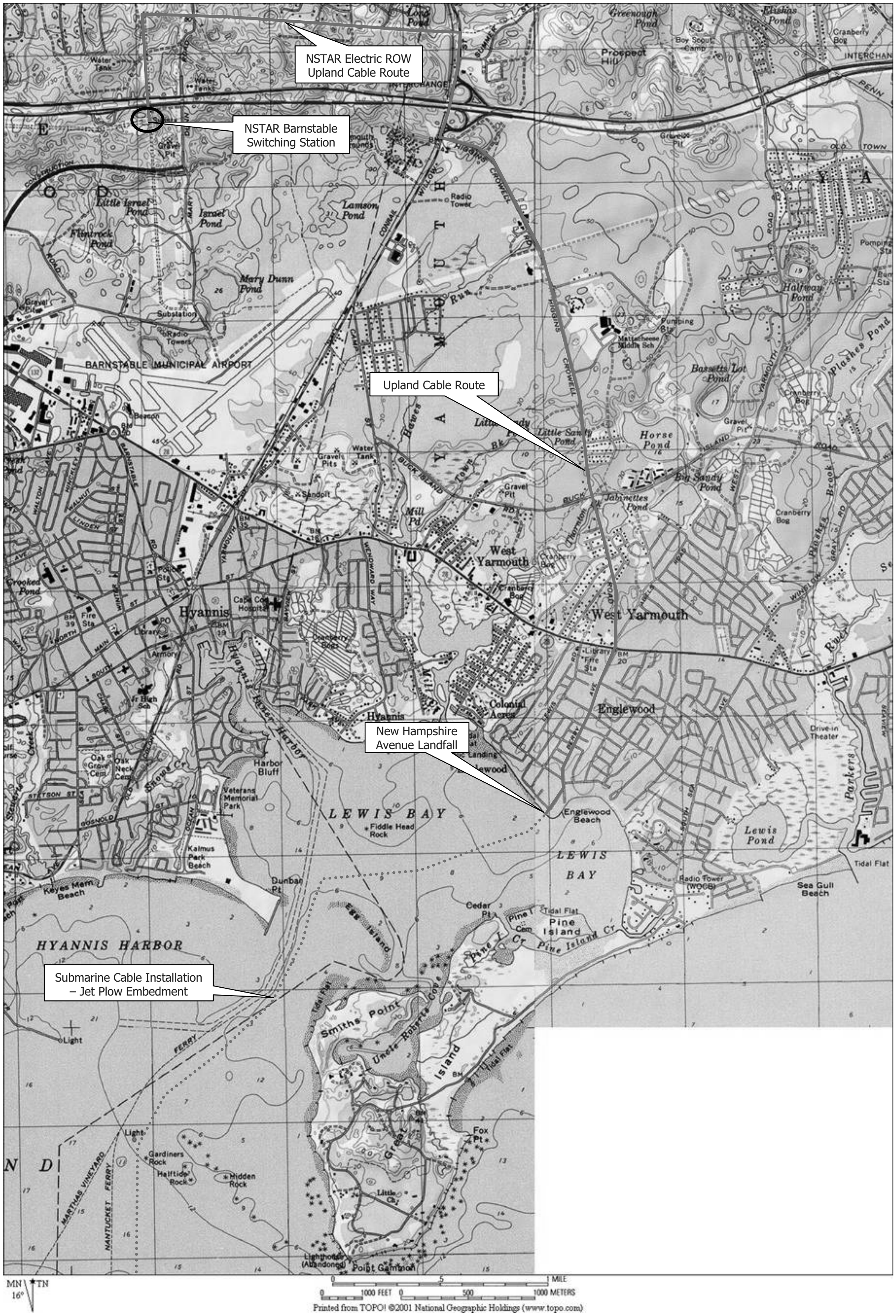
Figure 4-21
Sheet 3 of 3

Cape Wind Associates, LLC
Cape Wind Project

ESS Group, Inc.
Engineers
Scientists
Consultants

Cape Wind
Energy for Life.

Appendix B

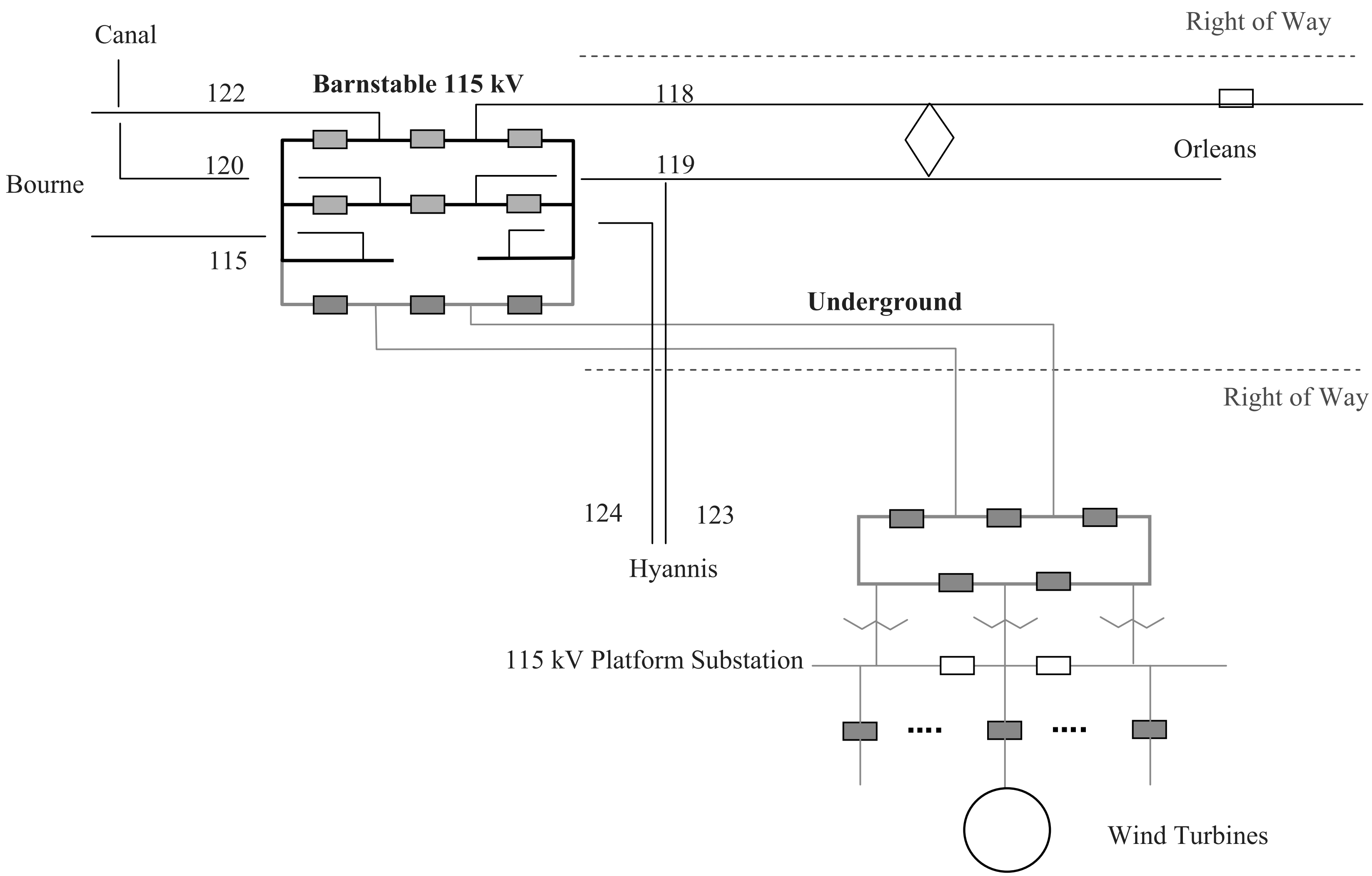


Cape Wind Project

Yarmouth – New Hampshire Avenue Landfall and Transmission Line Route

Source: USGS Topographic Maps on CD-ROM – Northeastern USA
Scale: As Shown

Figure 4-2



Cape Wind Project

Yarmouth Preferred Interconnection with Barnstable Switching Station

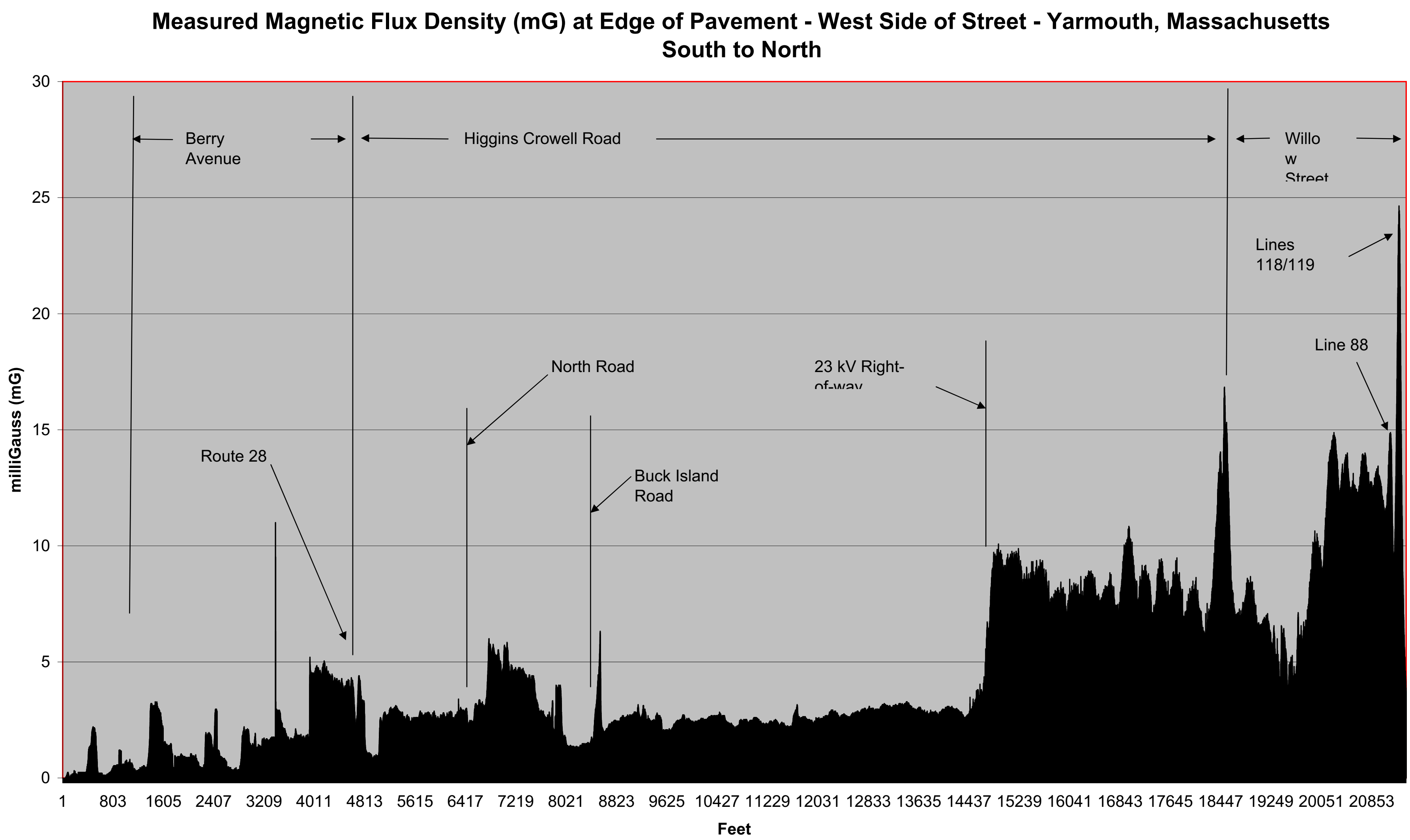
Figure 1-5

Engineers
Scientists
Consultants

Source: NSTAR Electric

Scale: not applicable

Appendix C



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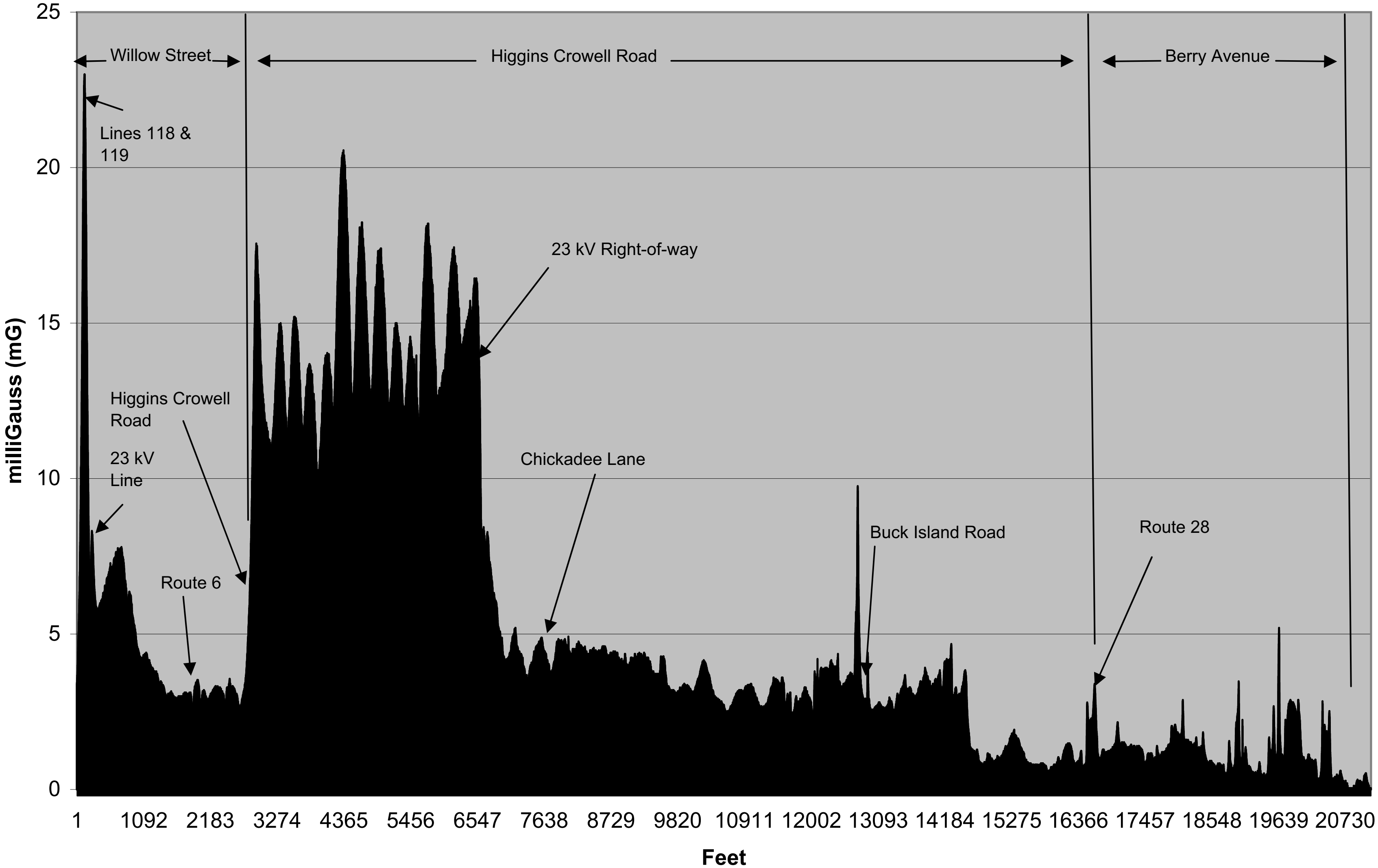
June 5, 2002

Measured Magnetic Flux Density (mG) at Edge of Pavement - East Side of Street - Yarmouth, Massachusetts
North to South



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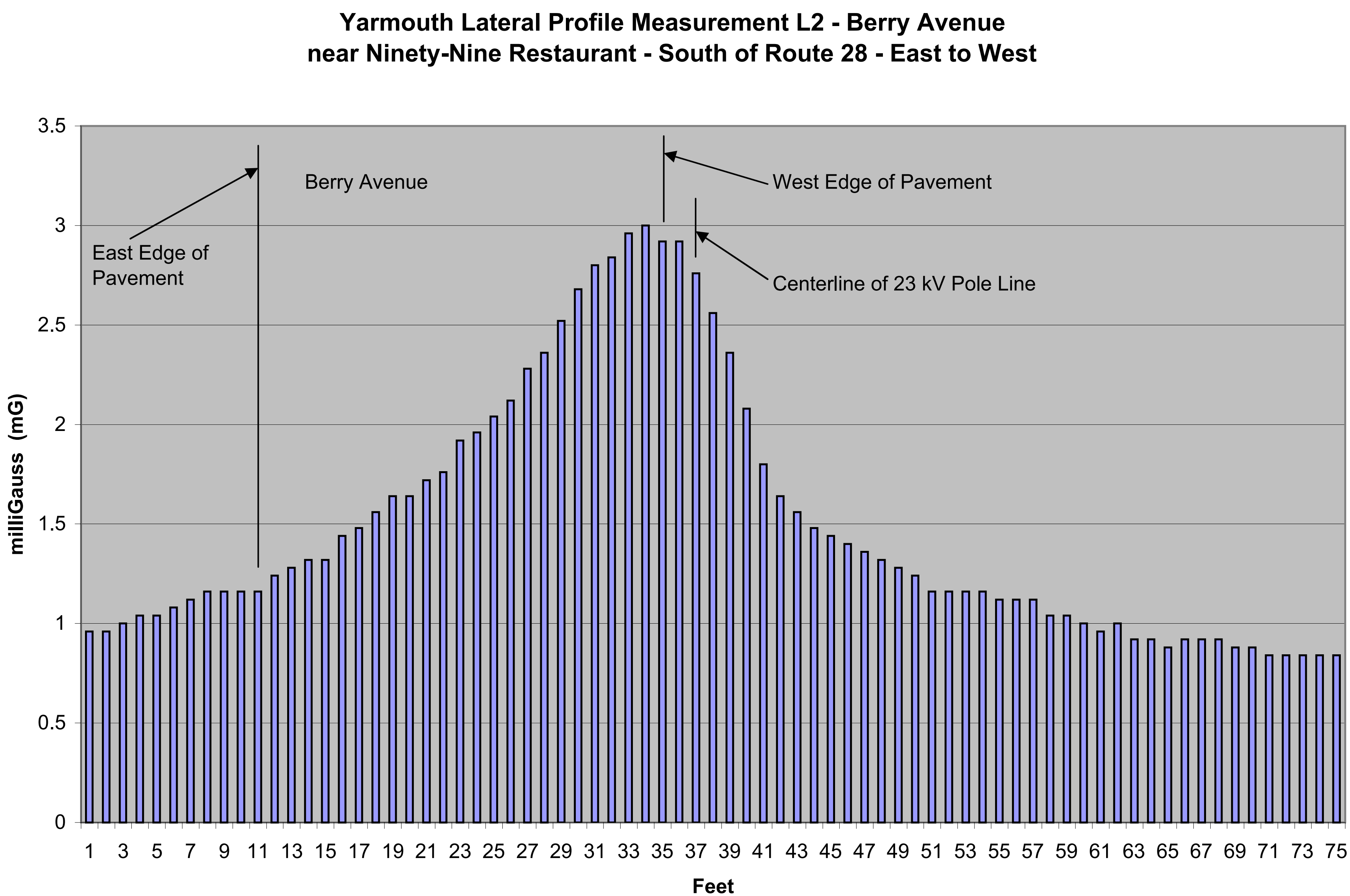
June 5, 2002

Magnetic Flux Density (mG)

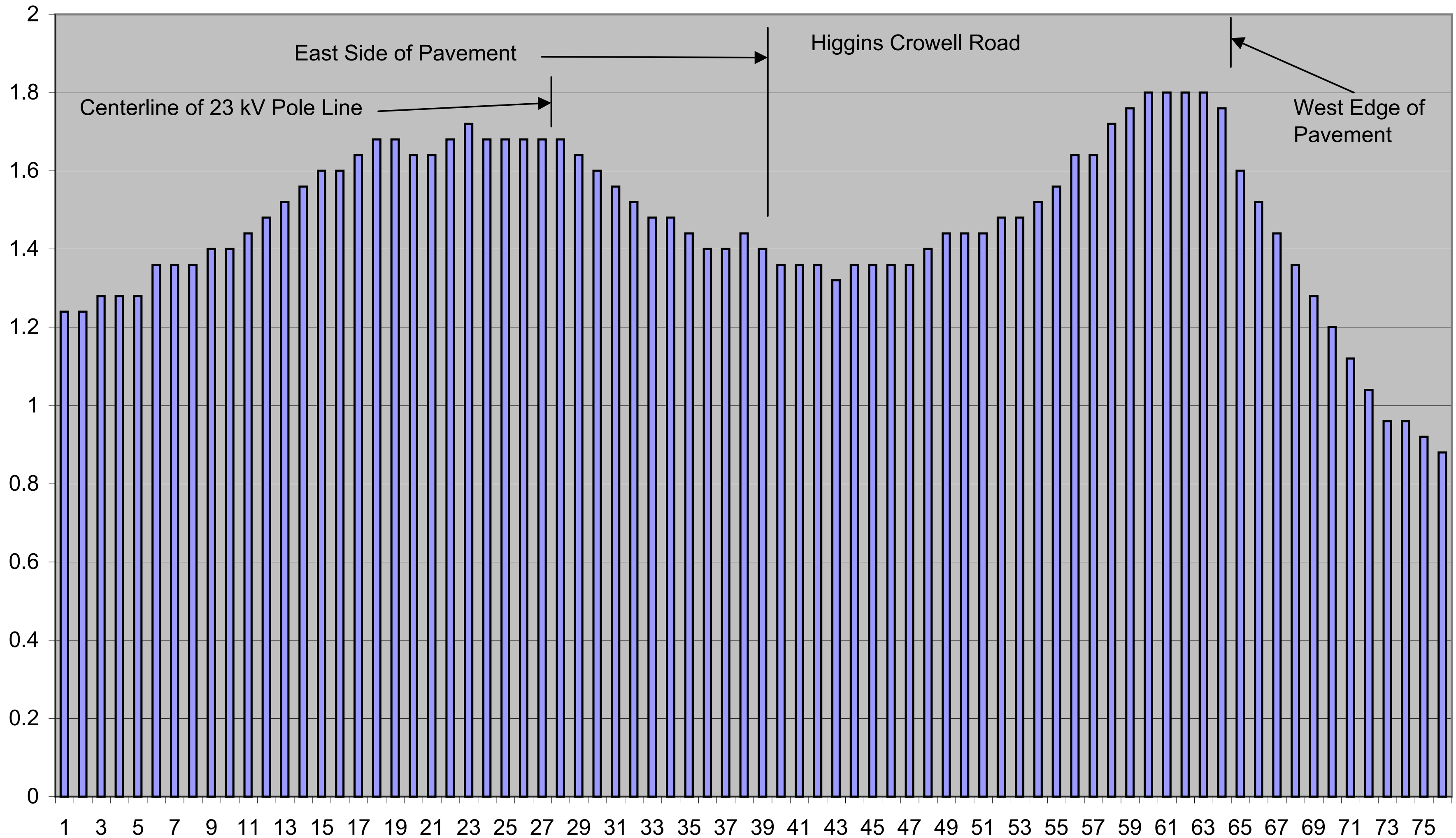


File:YarmouthLateral2A

June 6, 2002

Magnetic Flux Density (mG)

Yarmouth Lateral Profile Measurement L3 - Higgins Crowell Road North of Route 28
East to West



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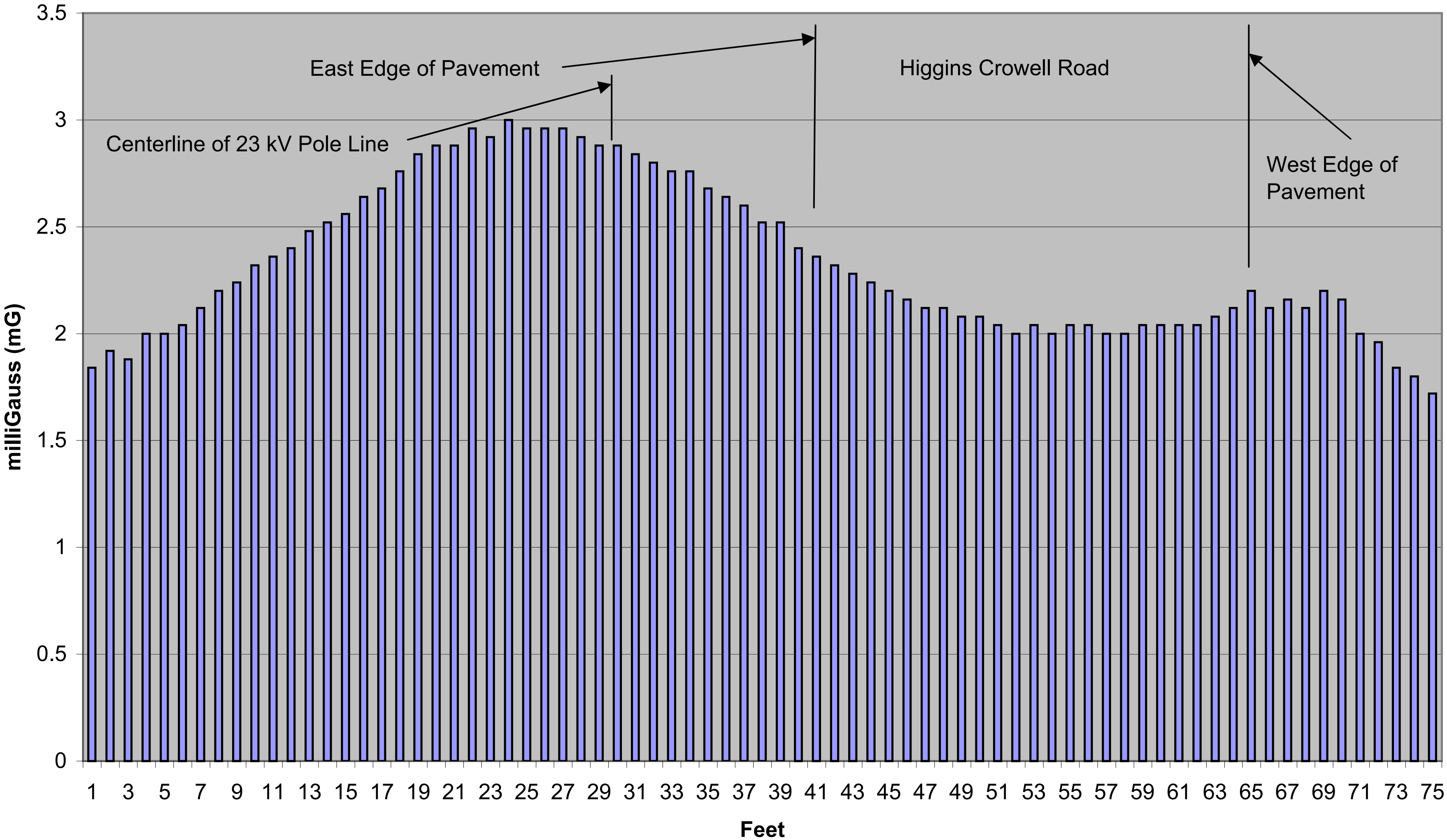
June 6, 2002

Magnetic Flux Density (mG)

Yarmouth Lateral Profile Measurement L4 - Higgins Crowell Road - South of Buck Island Rd
East to West



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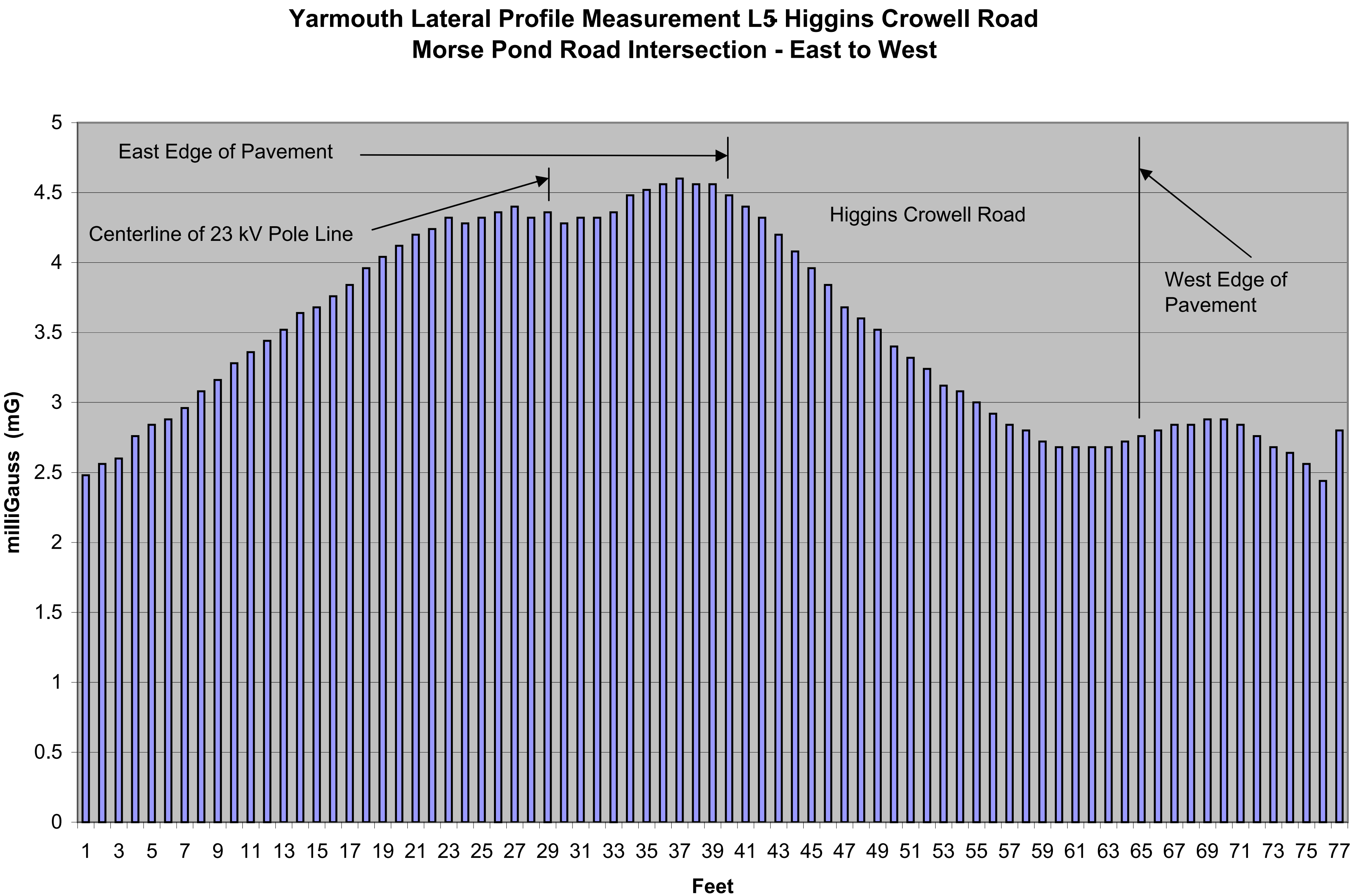
June 6, 2002

Magnetic Flux Density (mG)



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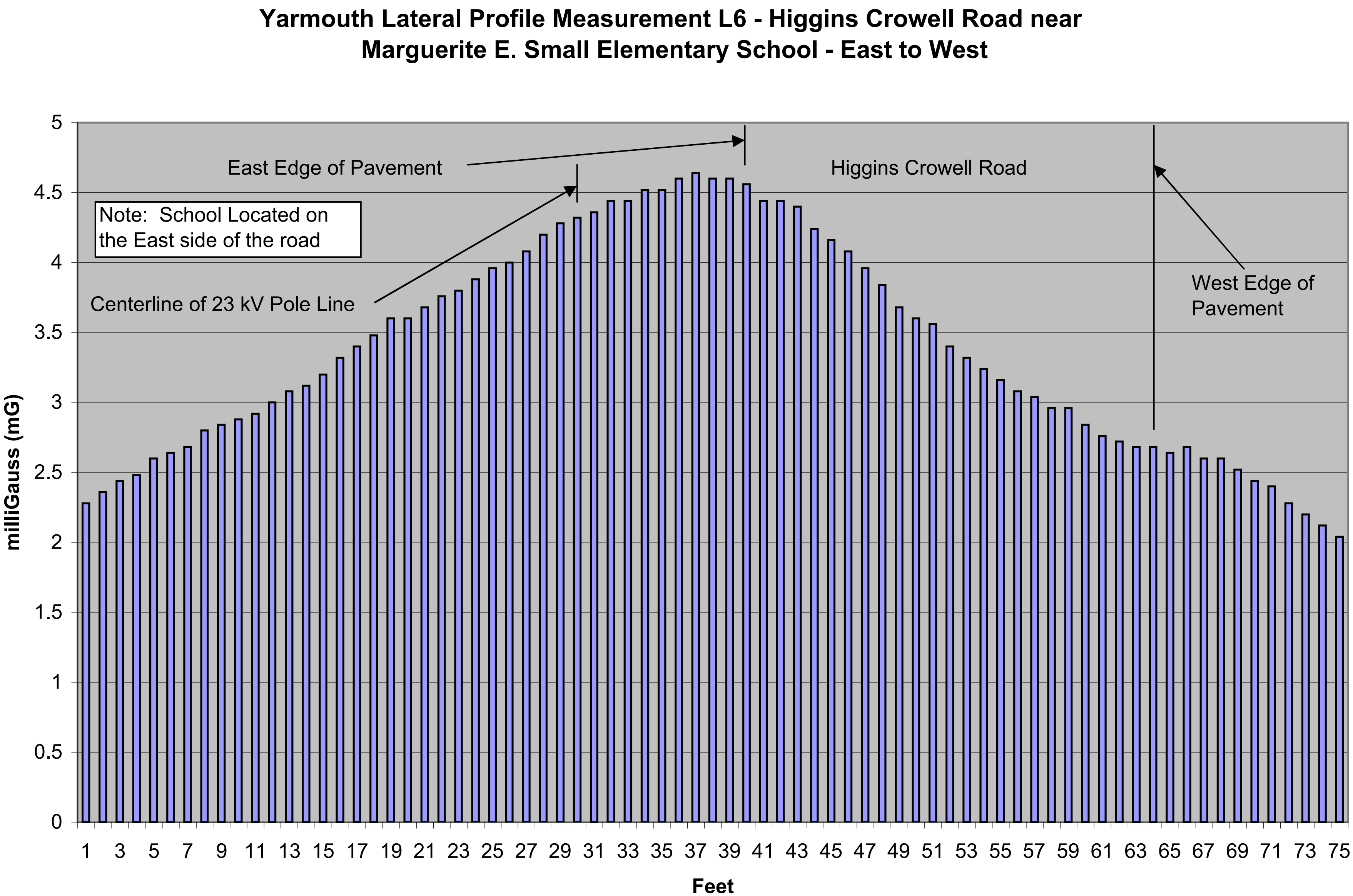
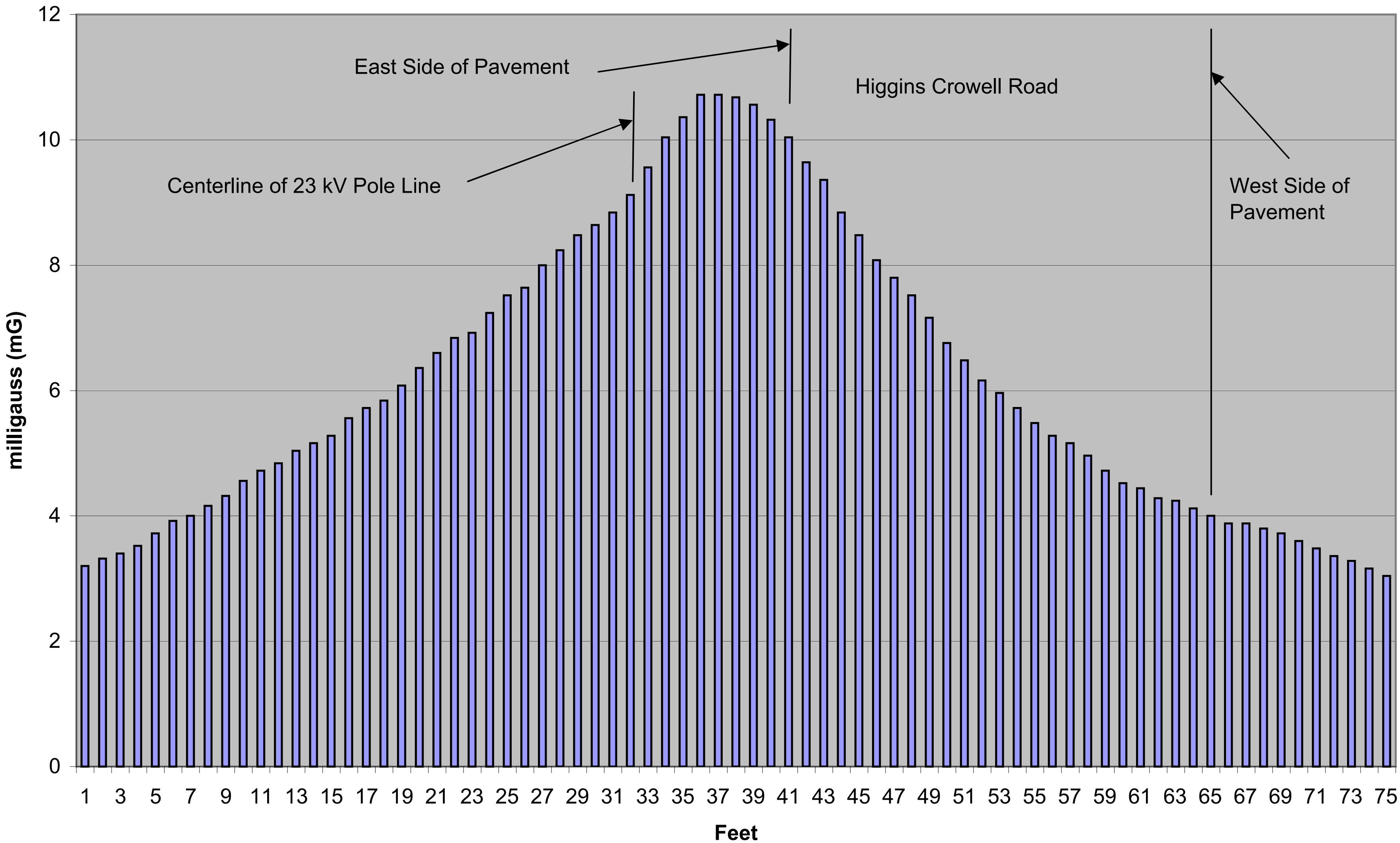
June 6, 2002


Yarmouth Lateral Profile Measurement L6 - Higgins Crowell Road near
Marguerite E. Small Elementary School - East to West
East Edge of Pavement
Higgins Crowell Road
Note: School Located on
the East side of the road
Centerline of 23 kV Pole Line
West Edge of
Pavement
milliGauss (mG)
Feet
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75

Magnetic Flux Density (mG)

Yarmouth Lateral Profile Measurement L7- Higgins Crowell Road South of 2kVR/W
East to West



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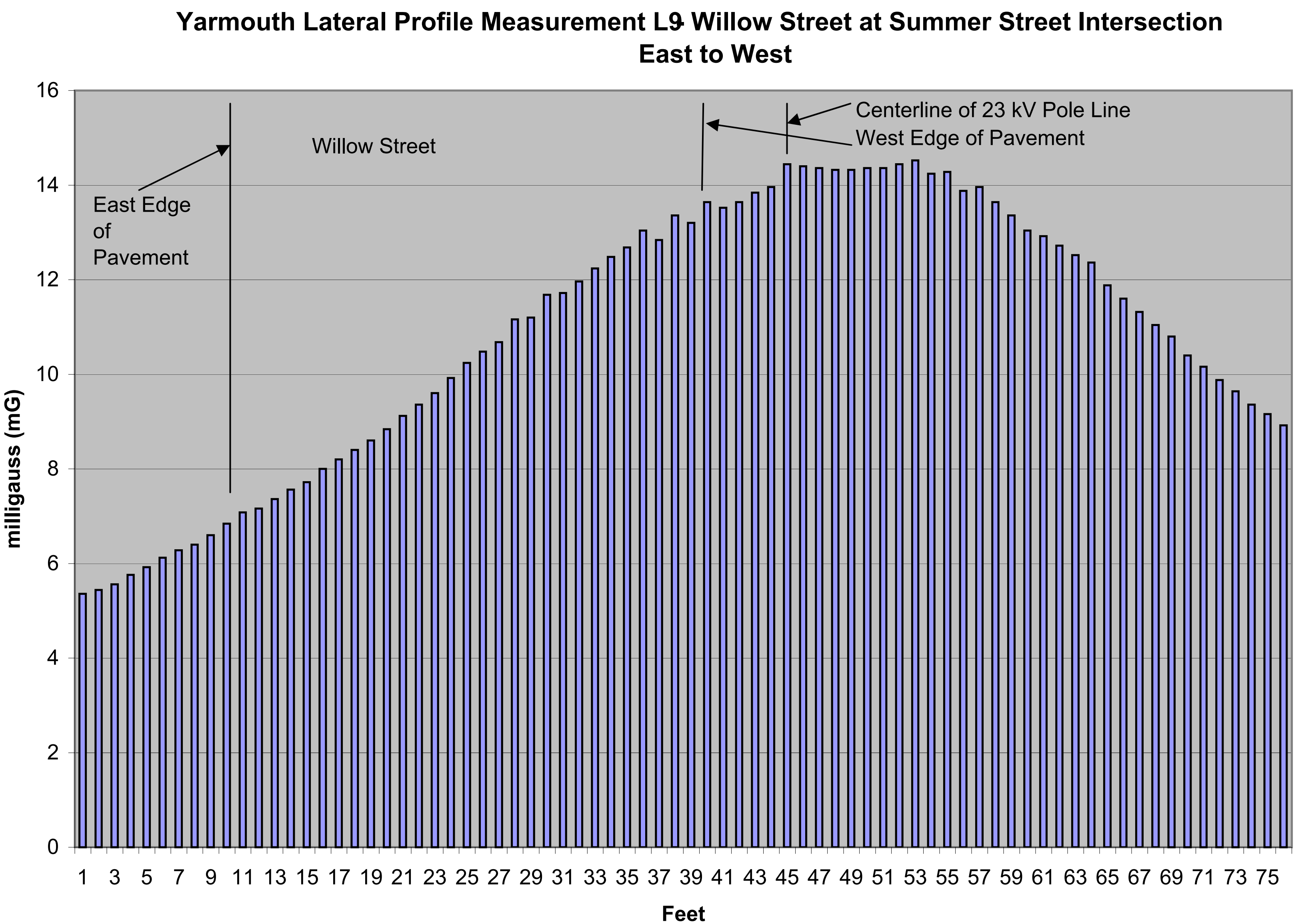
June 6, 2002

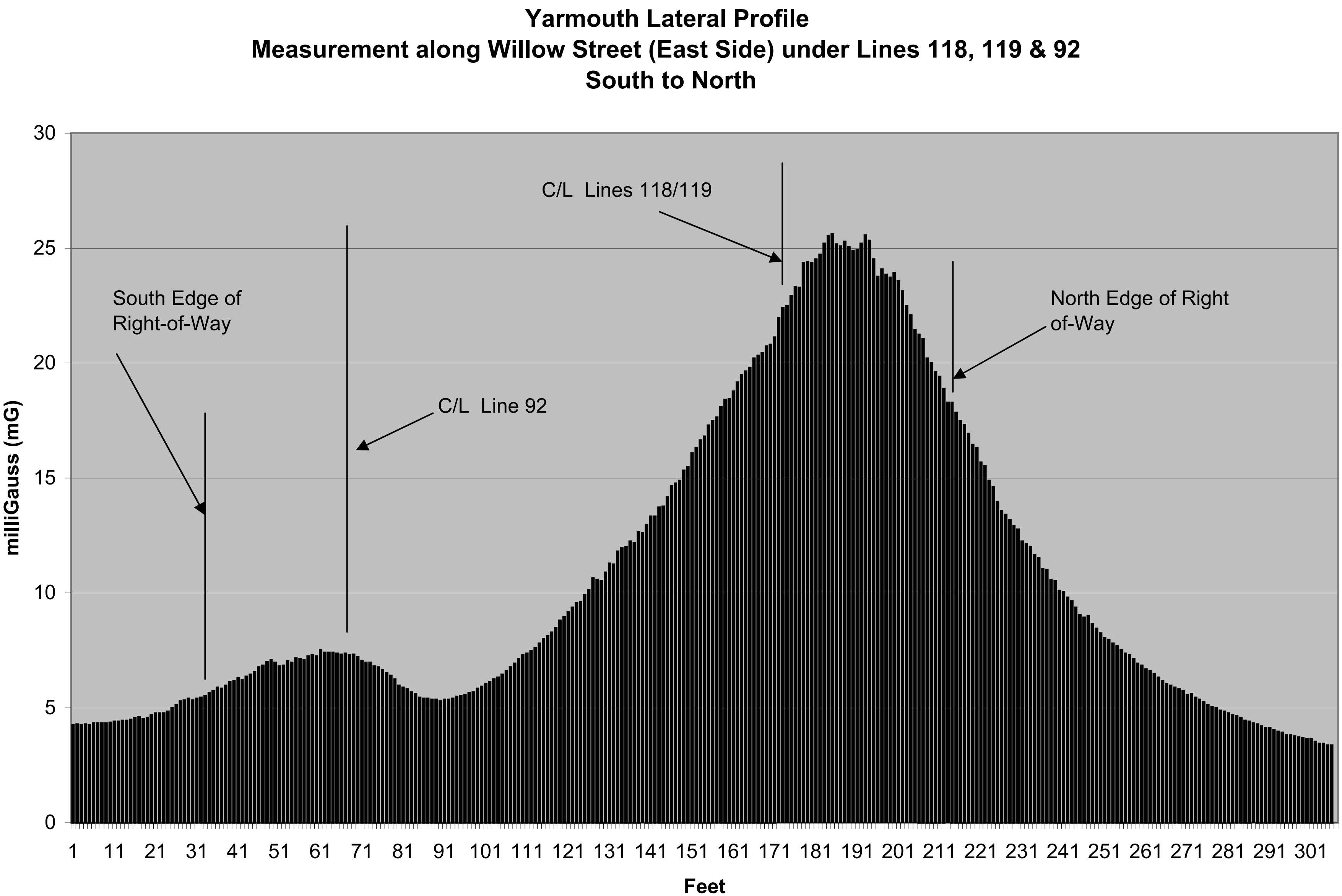
Magnetic Flux Density (mG)

File: YarmouthLateral8A

3/12/2004


Yarmouth Lateral Profile Measurement L9- Willow Street at Summer Street Intersection
East to West
Centerline of 23 kV Pole Line
West Edge of Pavement
Willow Street
East Edge
of
Pavement
milligauss (mG)
16
14
12
10
8
6
4
2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75
Feet

Magnetic Flux Density (mG)



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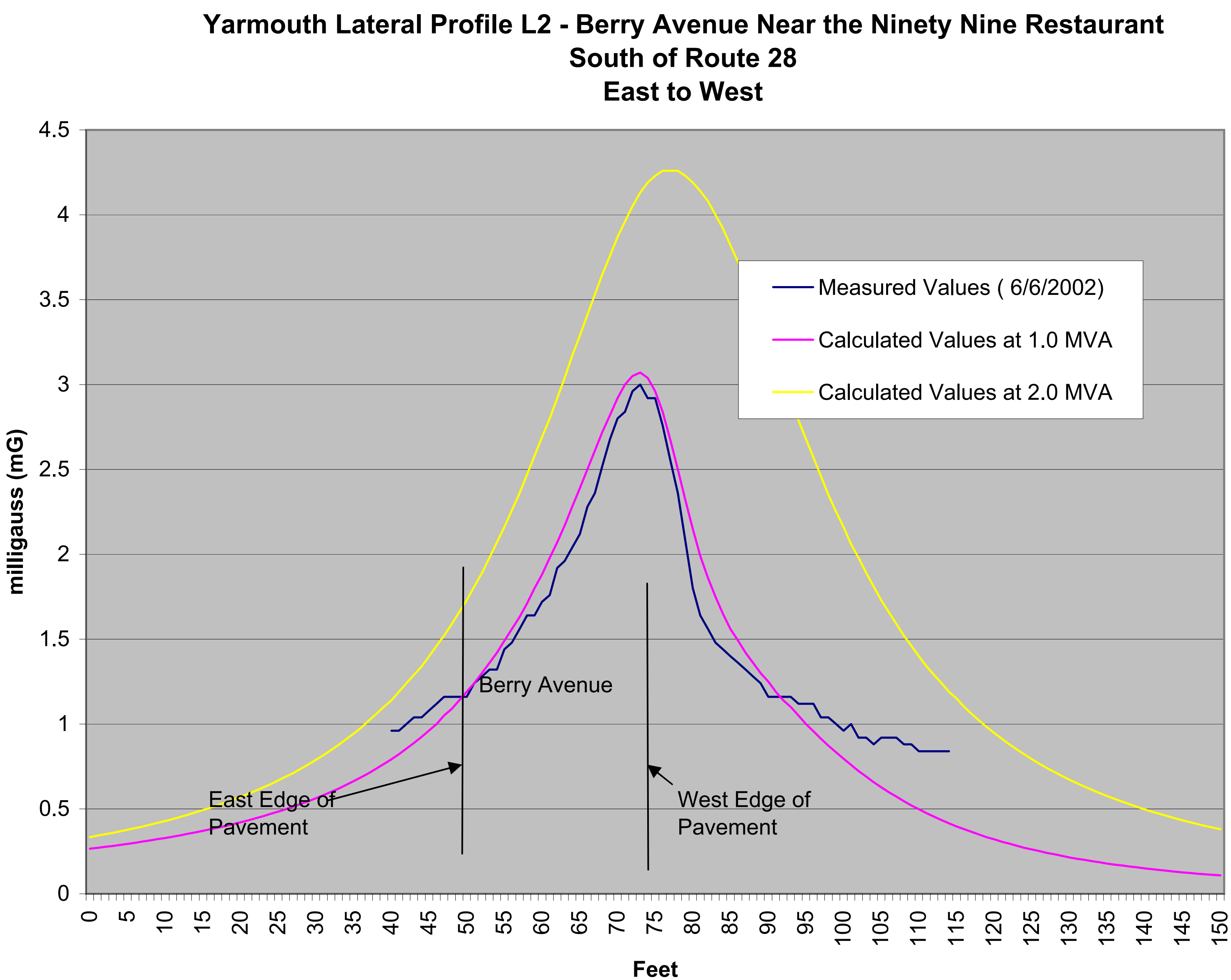
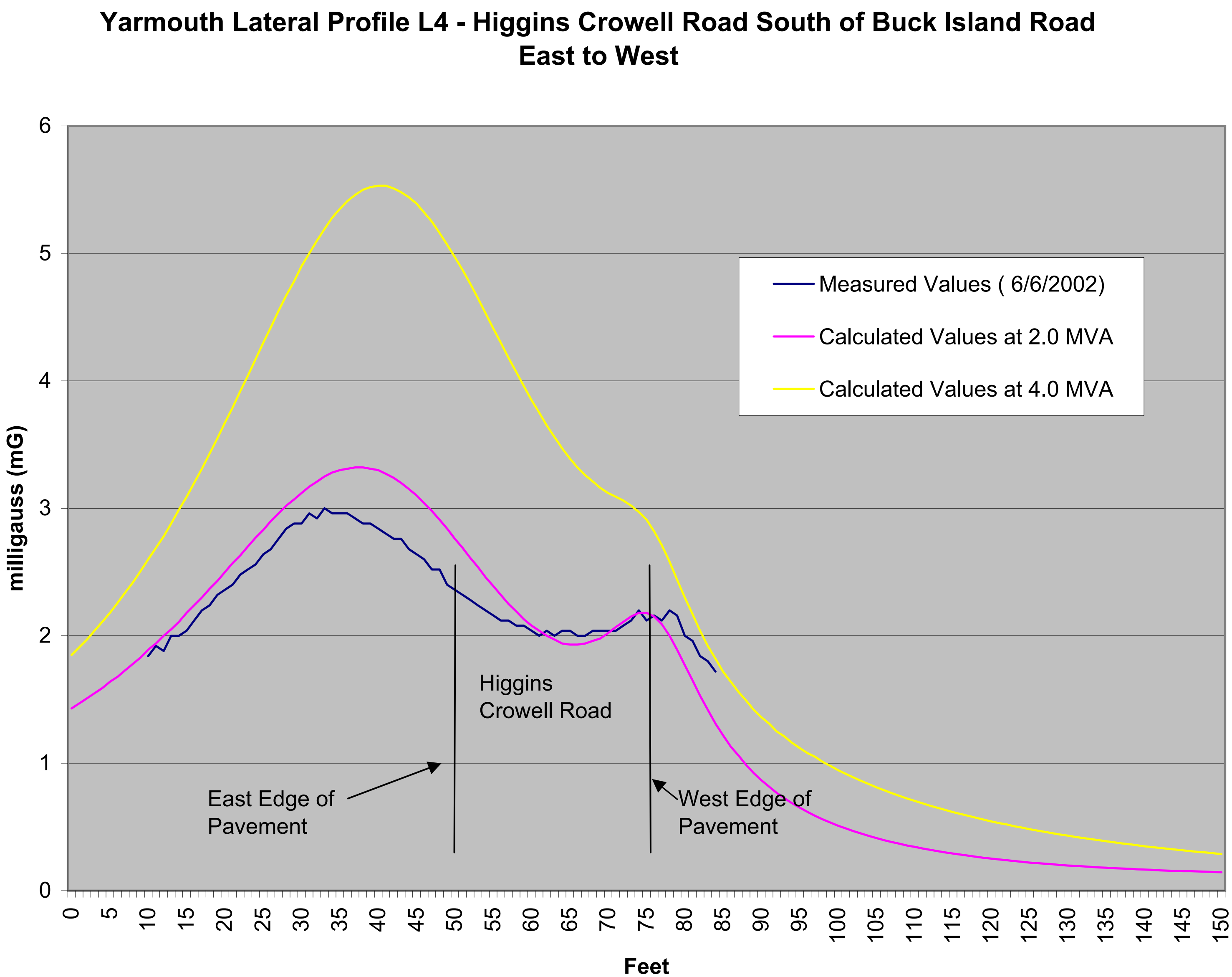
June 6, 2002

Appendix D

Magnetic Flux Density (mG) on 23 kV Distribution

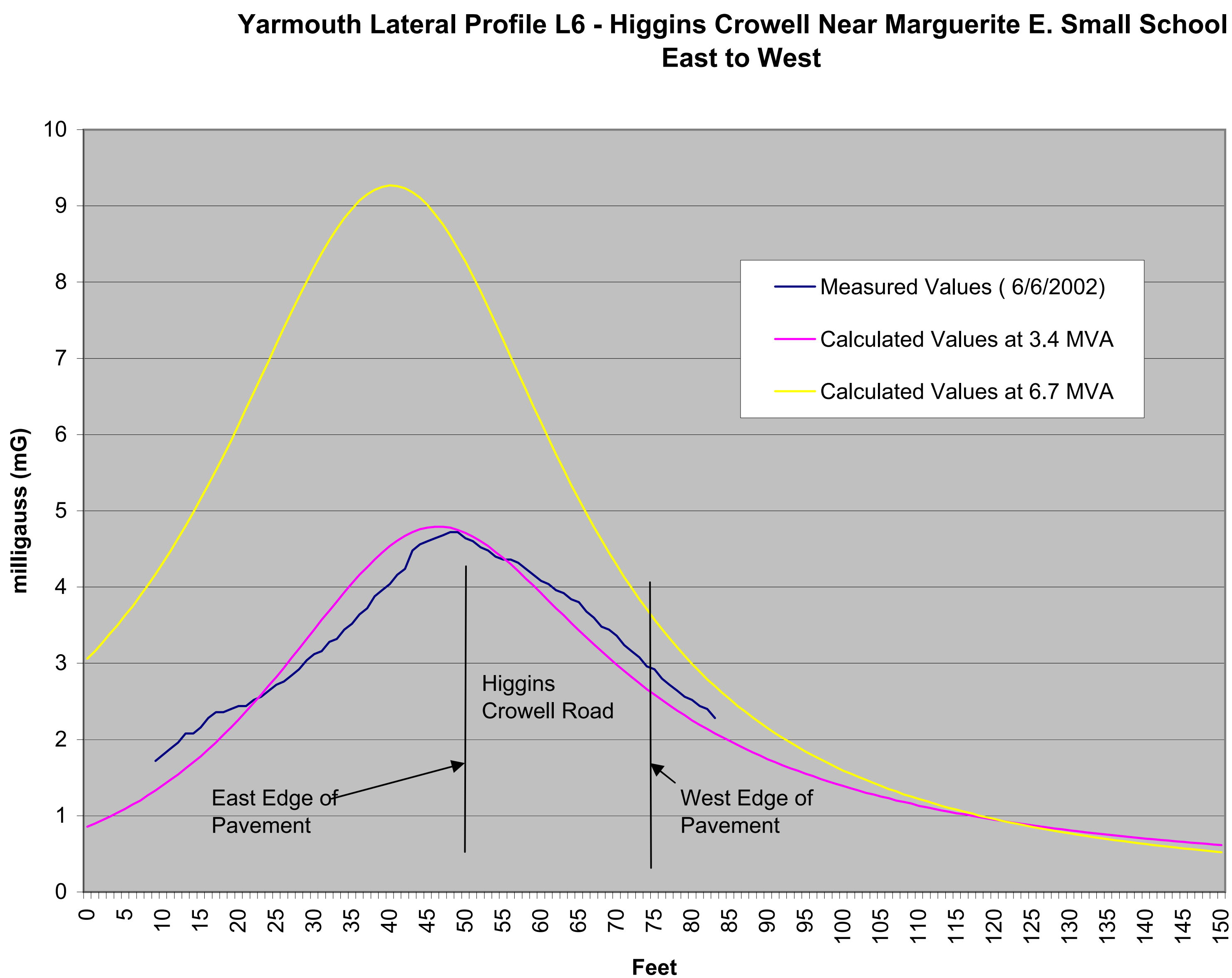


Magnetic Flux Density (mG) on 23 kV Distribution

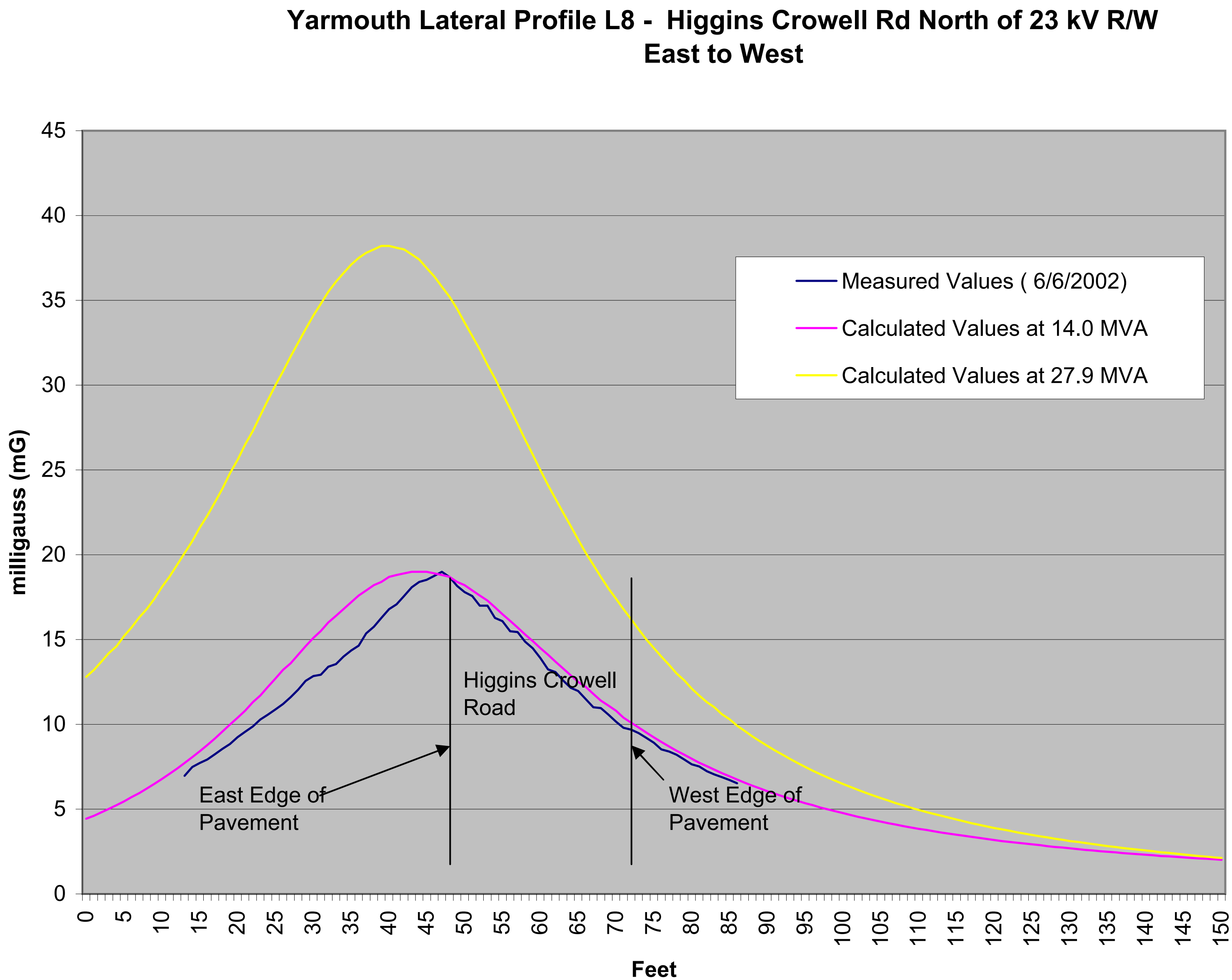


File: YarmLat4MeasCalc

9/10/2002


Yarmouth Lateral Profile L6 - Higgins Crowell Near Marguerite E. Small School
East to West
milligauss (mG)
0
1
2
3
4
5
6
7
8
9
10
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Feet
Measured Values (6/6/2002)
Calculated Values at 3.4 MVA
Calculated Values at 6.7 MVA
Higgins
Crowell Road
East Edge of
Pavement
West Edge of
Pavement

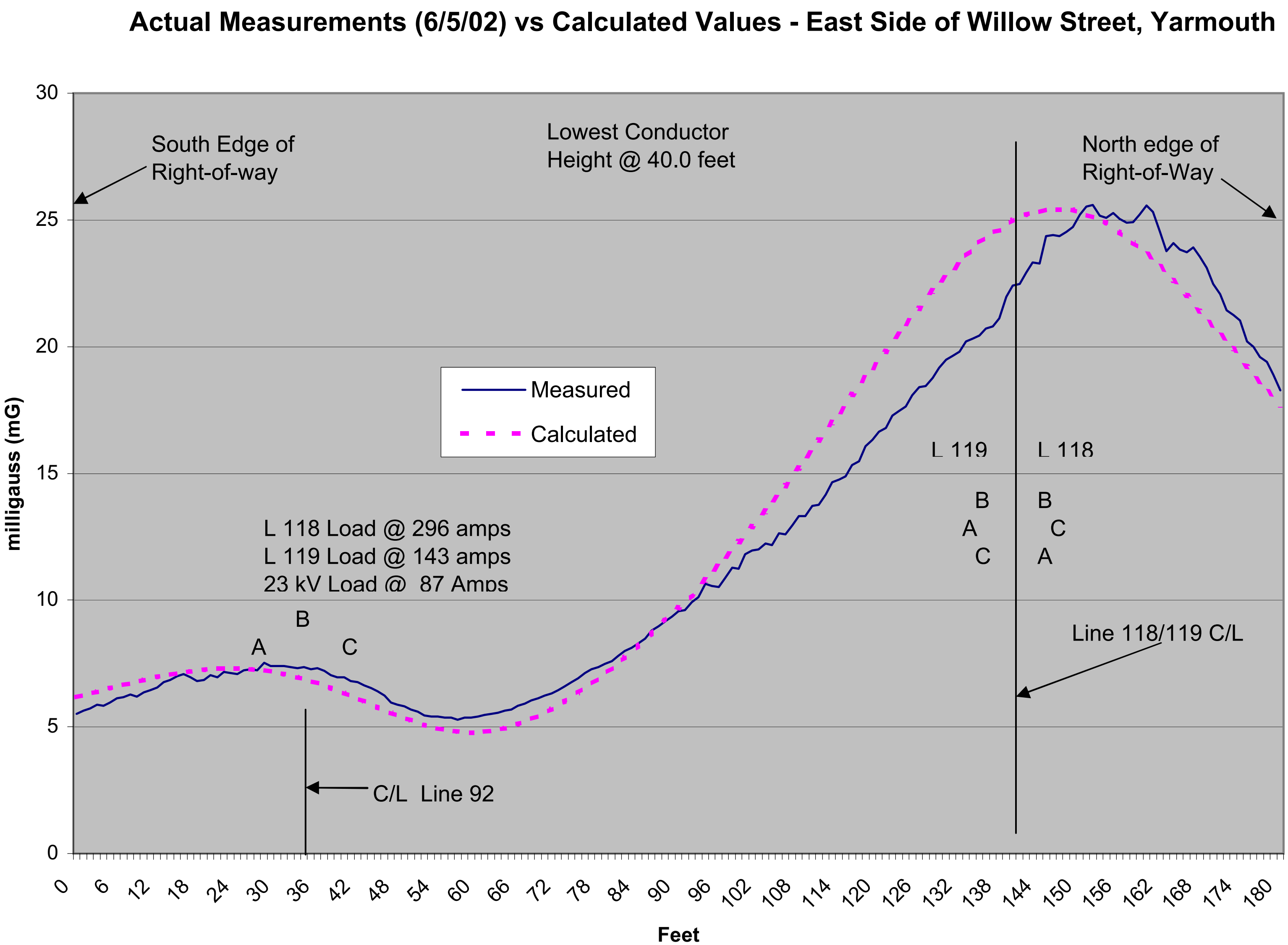
Magnetic Flux Density (mG) on 23 kV Distribution



File: YarmLat8MeasCalc

9/10/2002

Magnetic Flux Density (mG) on Line 118/119 Right-of-Way
Yarmouth, Massachusetts



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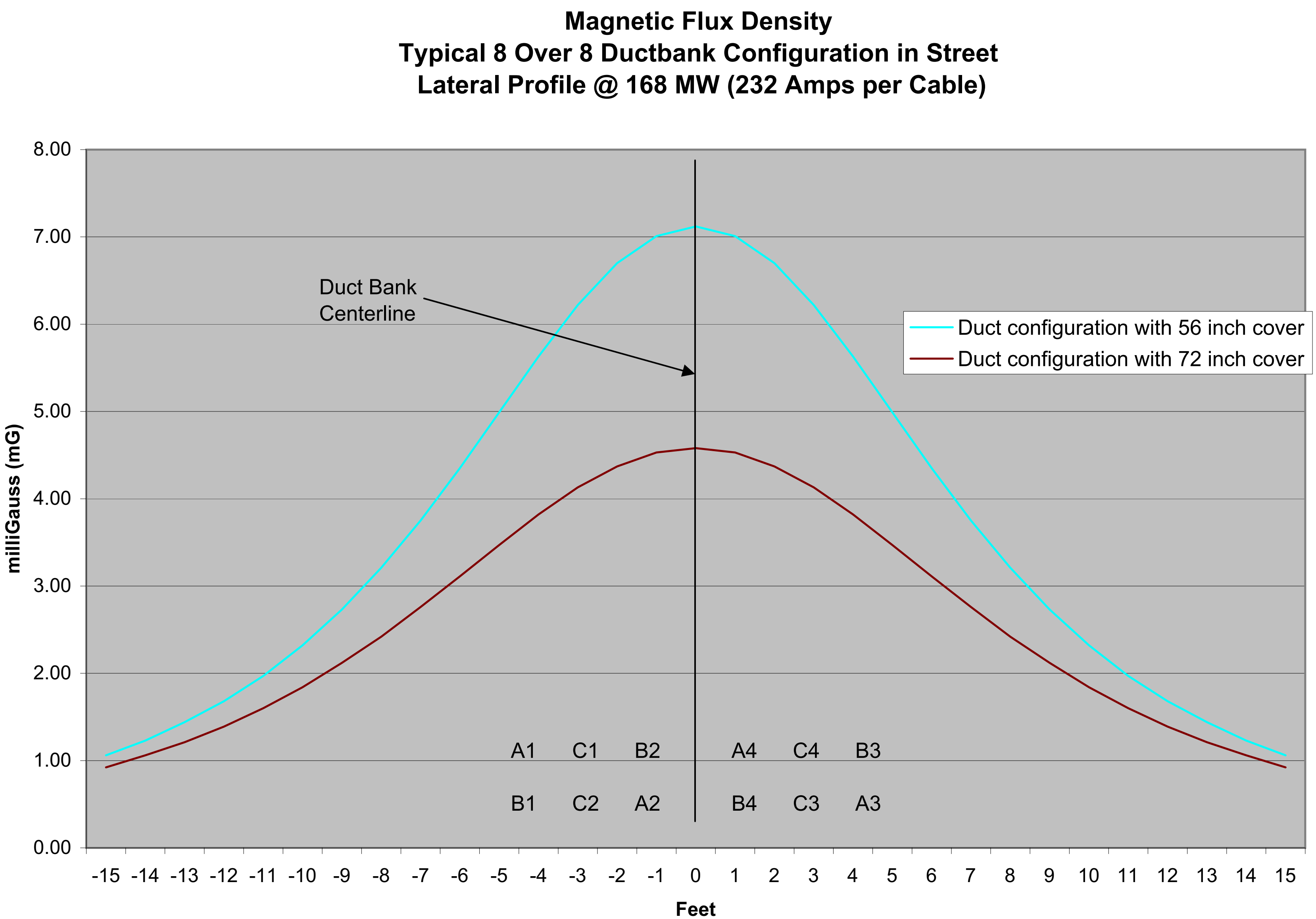
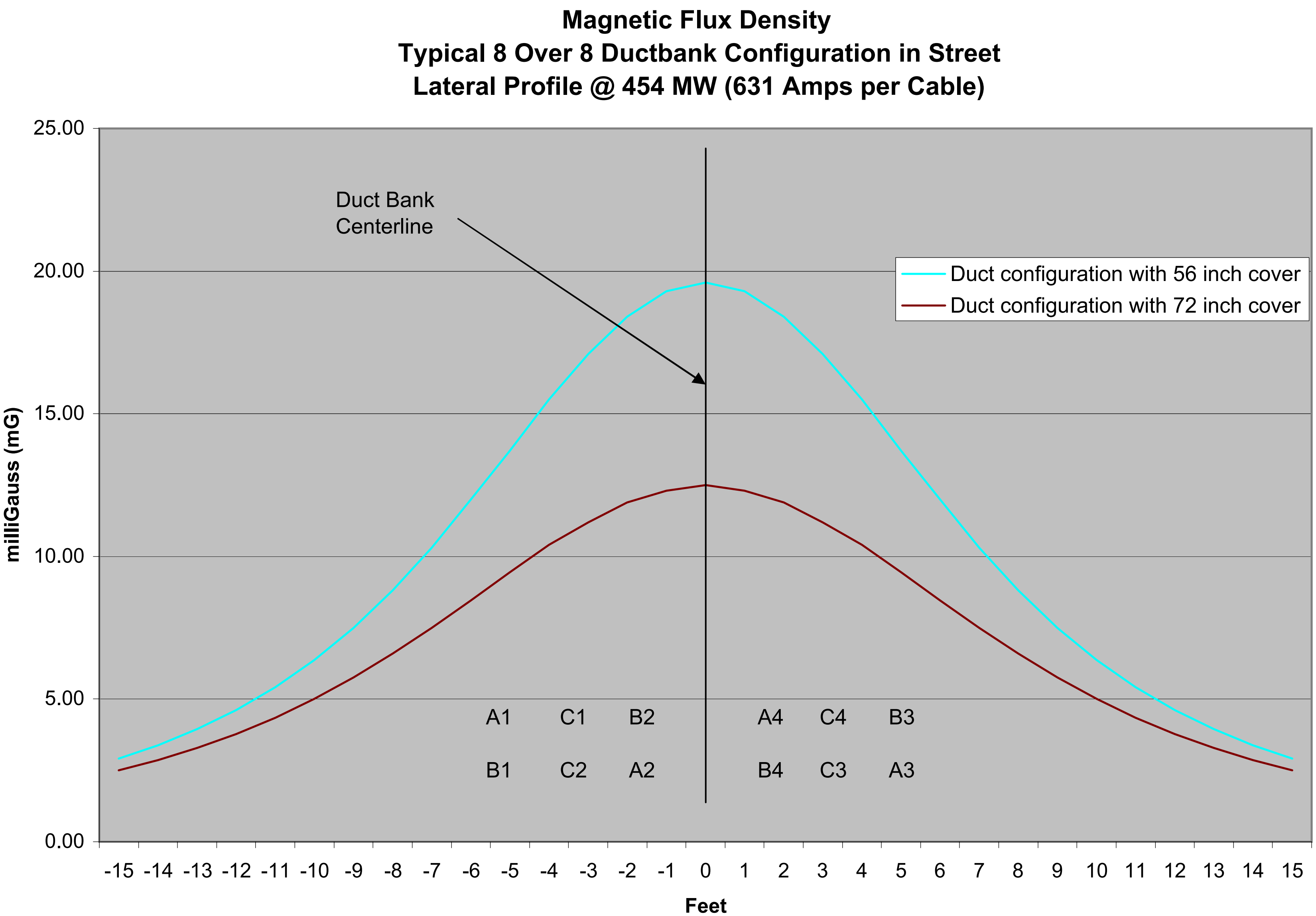
9/10/2002

Appendix E


Magnetic Flux Density
Typical 8 Over 8 Ductbank Configuration in Street
Lateral Profile @ 168 MW (232 Amps per Cable)
milliGauss (mG)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Duct Bank
Centerline
Duct configuration with 56 inch cover
Duct configuration with 72 inch cover
A1
C1
B2
A4
C4
B3
B1
C2
A2
B4
C3
A3
-15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Feet

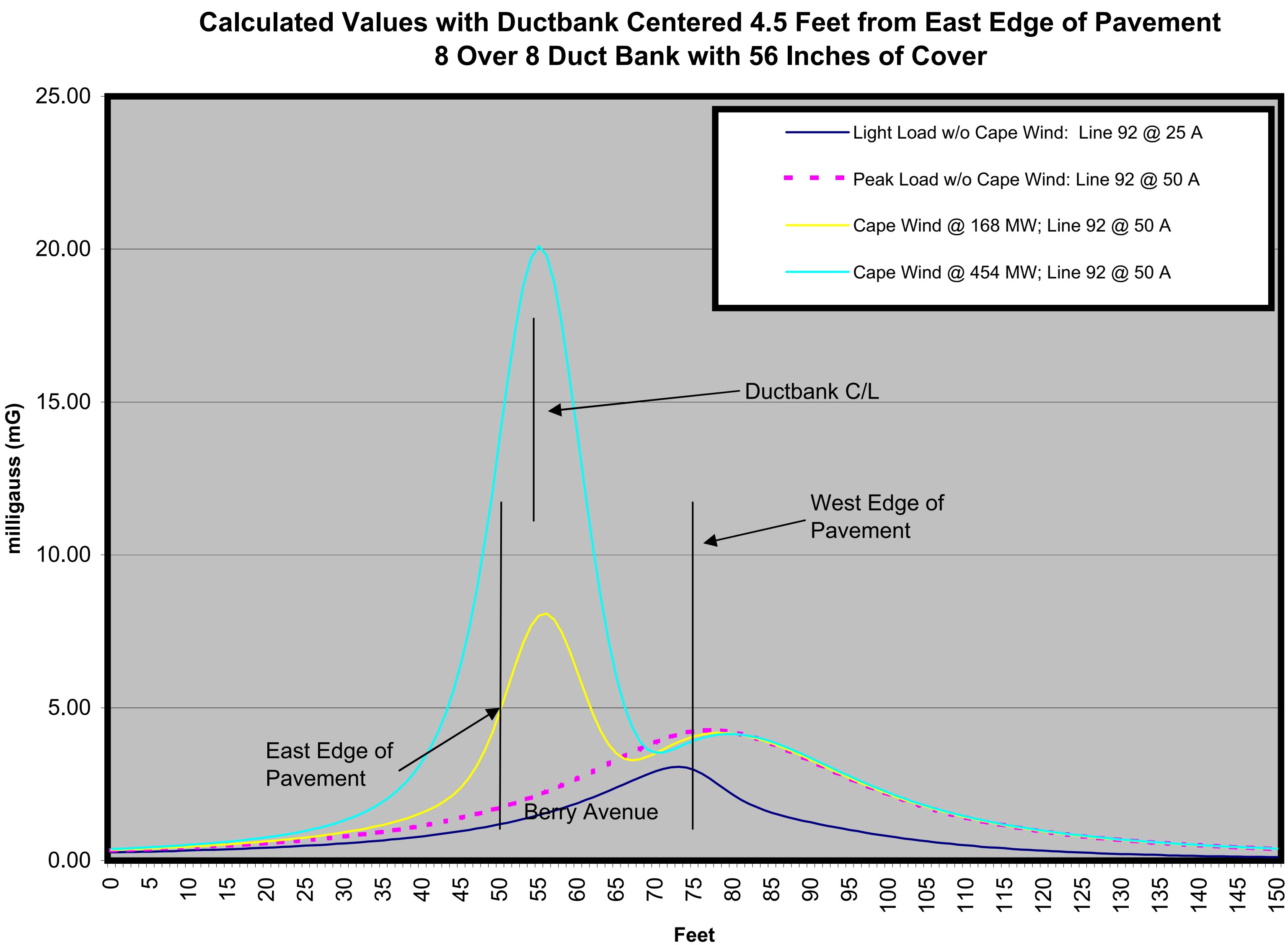
CAPE WIND PROJECT - CALCULATED EMF LEVELS ASSOCIATED WITH 115 kV DUCT BANK



File:CWDbnkMar904Pk

03/09/04

Magnetic Flux Density (mG) across Berry Avenue South of Route 28

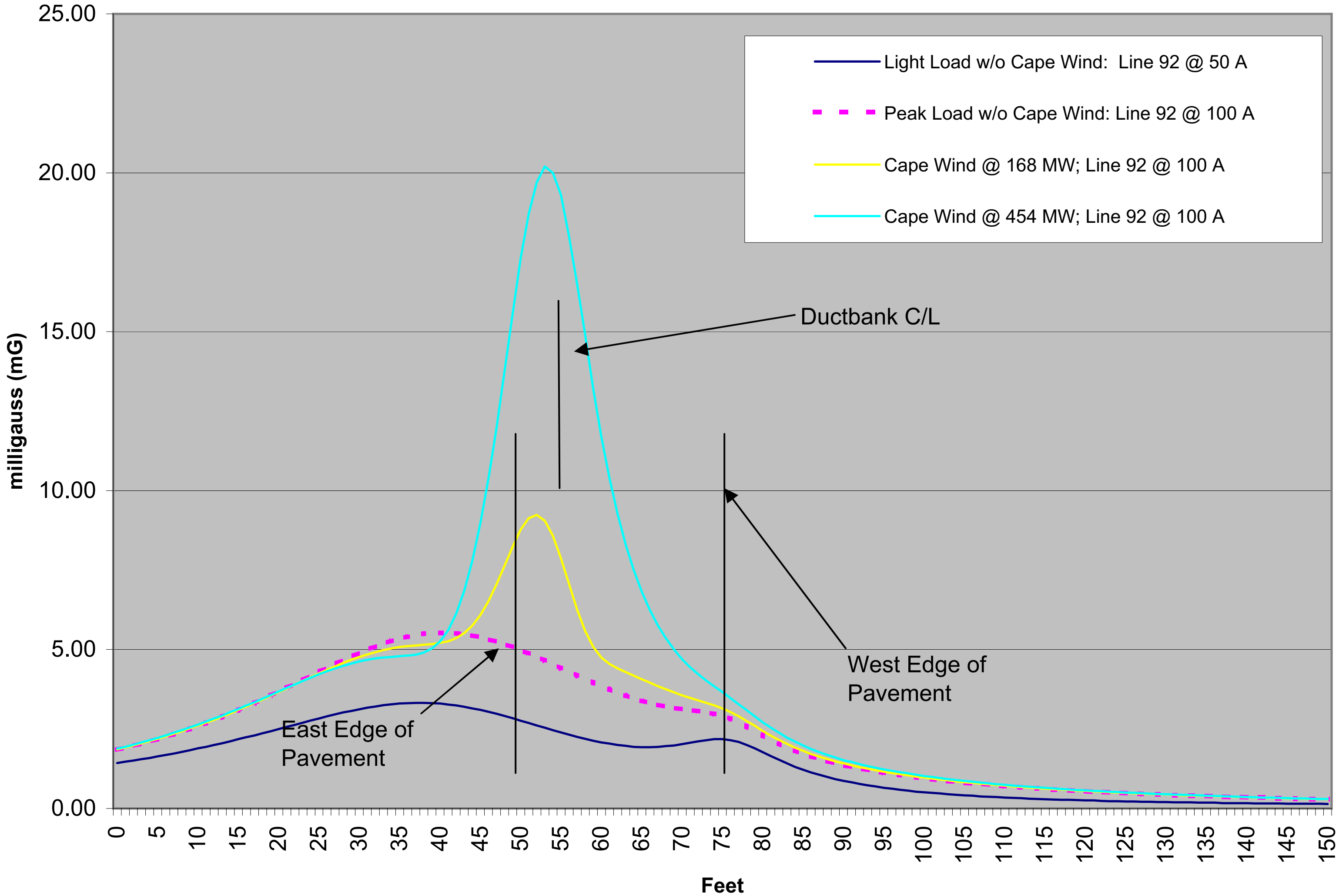


File: Lat2Calcs-Yarmouth

3/9/2004

Magnetic Flux Density (mG) across Higgins Crowell Road - South of Buck Island Road
Yarmouth, Massachusetts

Calculated Values with Ductbank Centered 4.5 Feet from East Edge of Pavement
8 Over 8 Duct Bank with 56 Inches of Cover

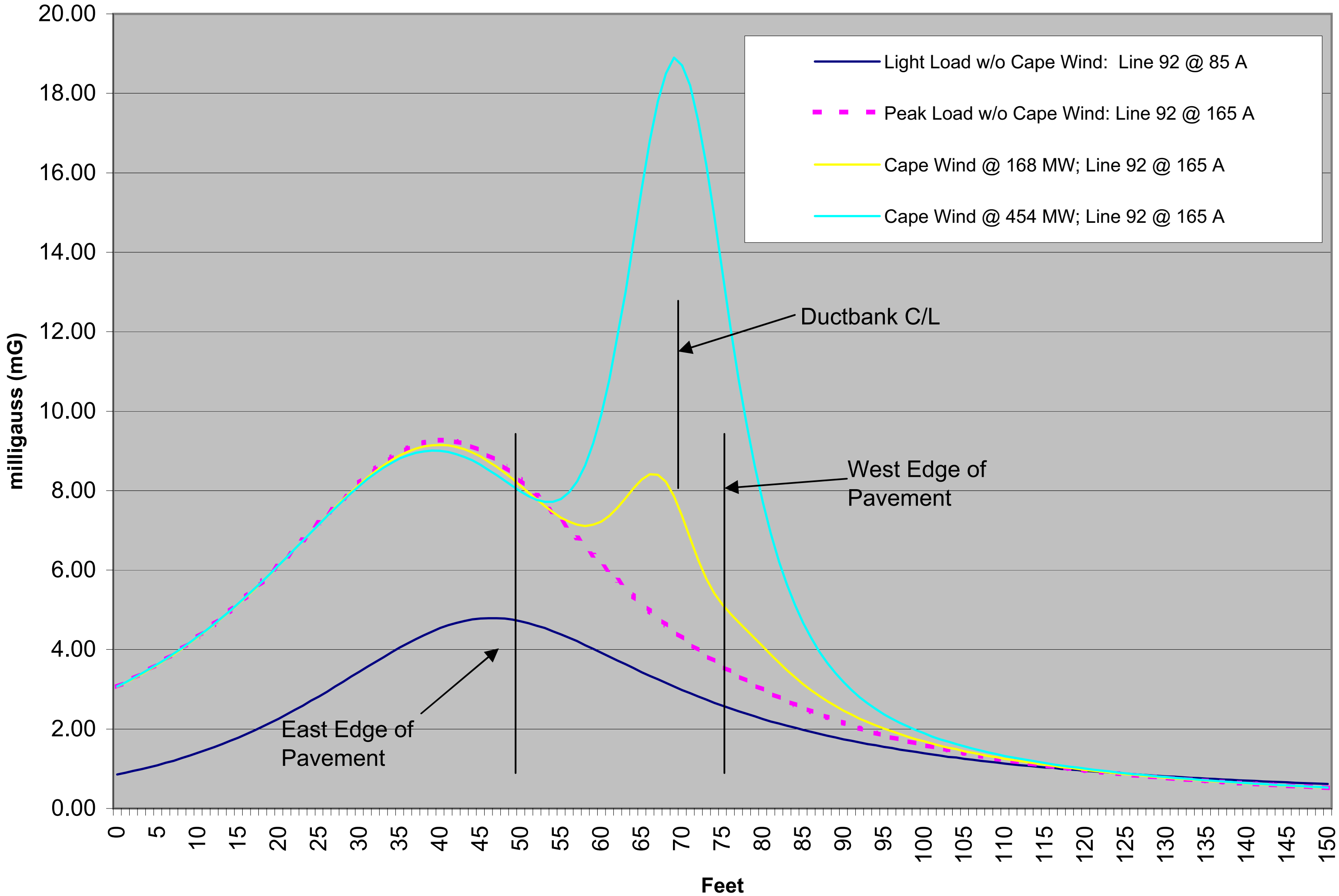


File: Lat4Calcs-Yarmouth

3/9/2004

Magnetic Flux Density (mG) across Higgins Crowell Road - Adjacent to Marguerite E. Small School
Yarmouth, Massachusetts

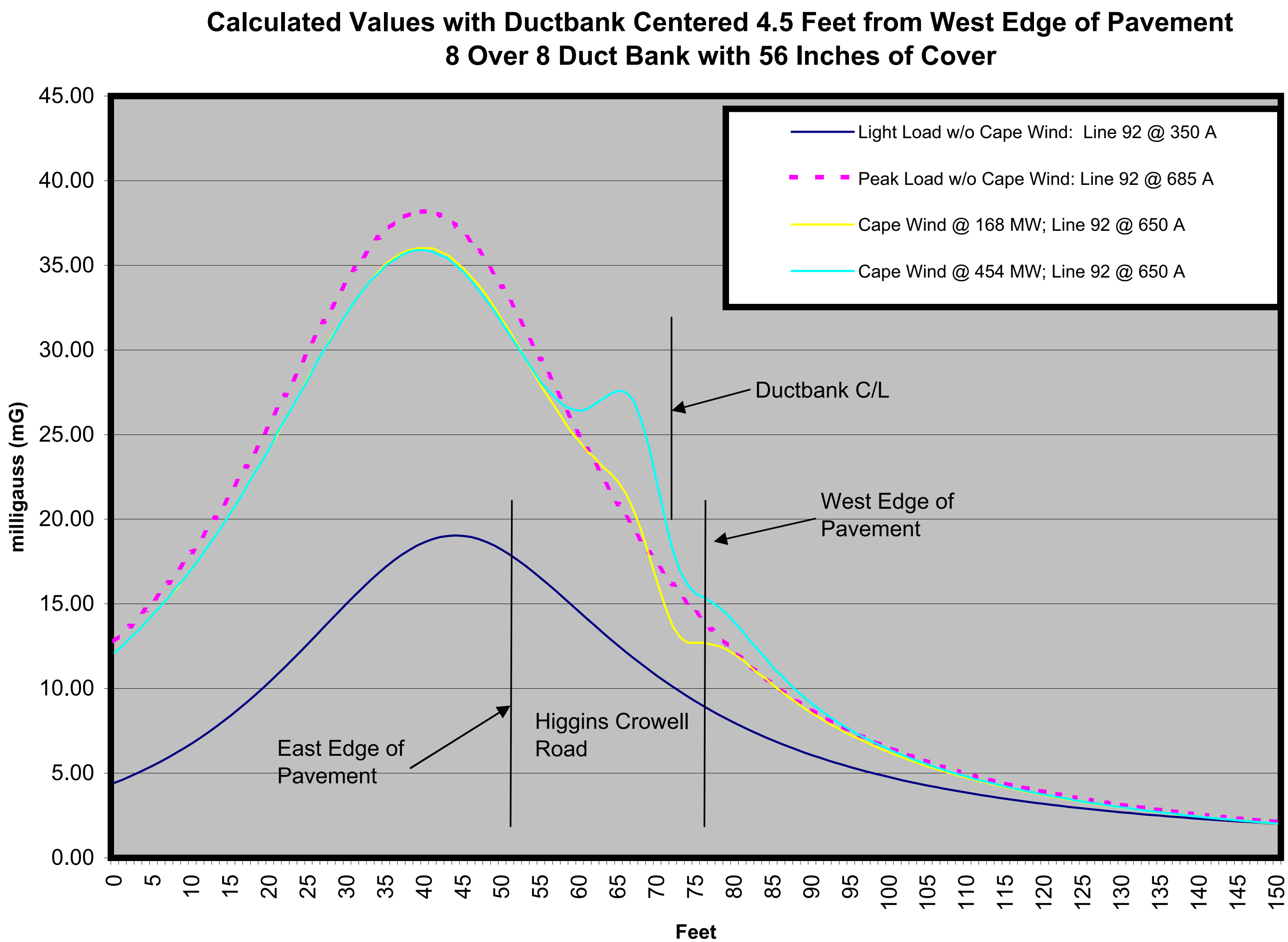
Calculated Values with Ductbank Centered 4.5 Feet from West Edge of Pavement
8 Over 8 Duct Bank with 56 Inches of Cover



File: Lat6Calcs-Yarmouth

3/9/2004

Magnetic Flux Density (mG) across Higgins Crowell Road North of 23 kV Right-of-Way
Yarmouth Massachusetts



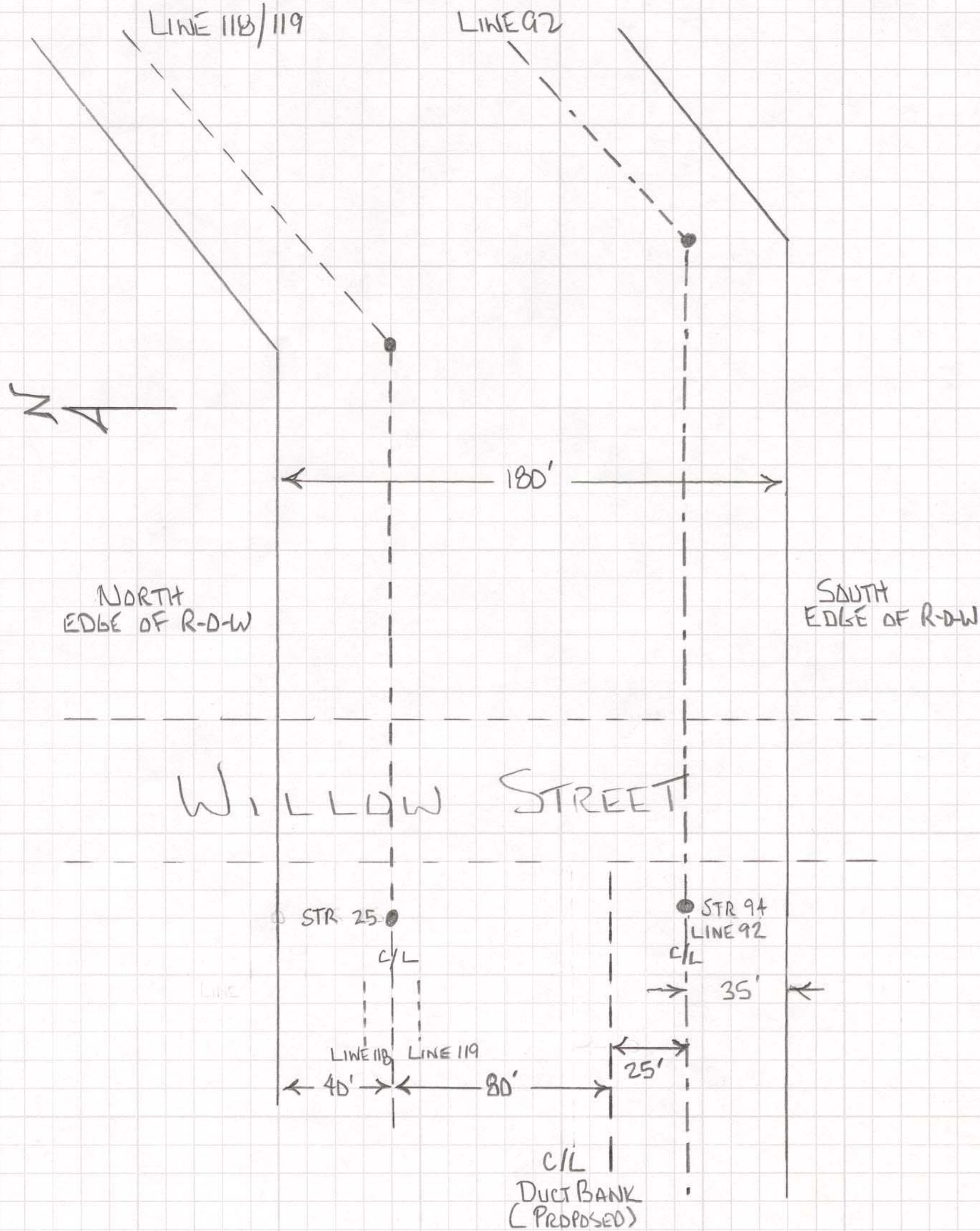
Appendix F

E·PRO

Engineering & Environmental Consulting, LLC

SUBJECT Yarmouth Right-of-Way (180 Feet) BOOK NO. PAGE NO. FILE NO. SHEET OF SHEETS

COMPUTED BY DATE CHECKED BY



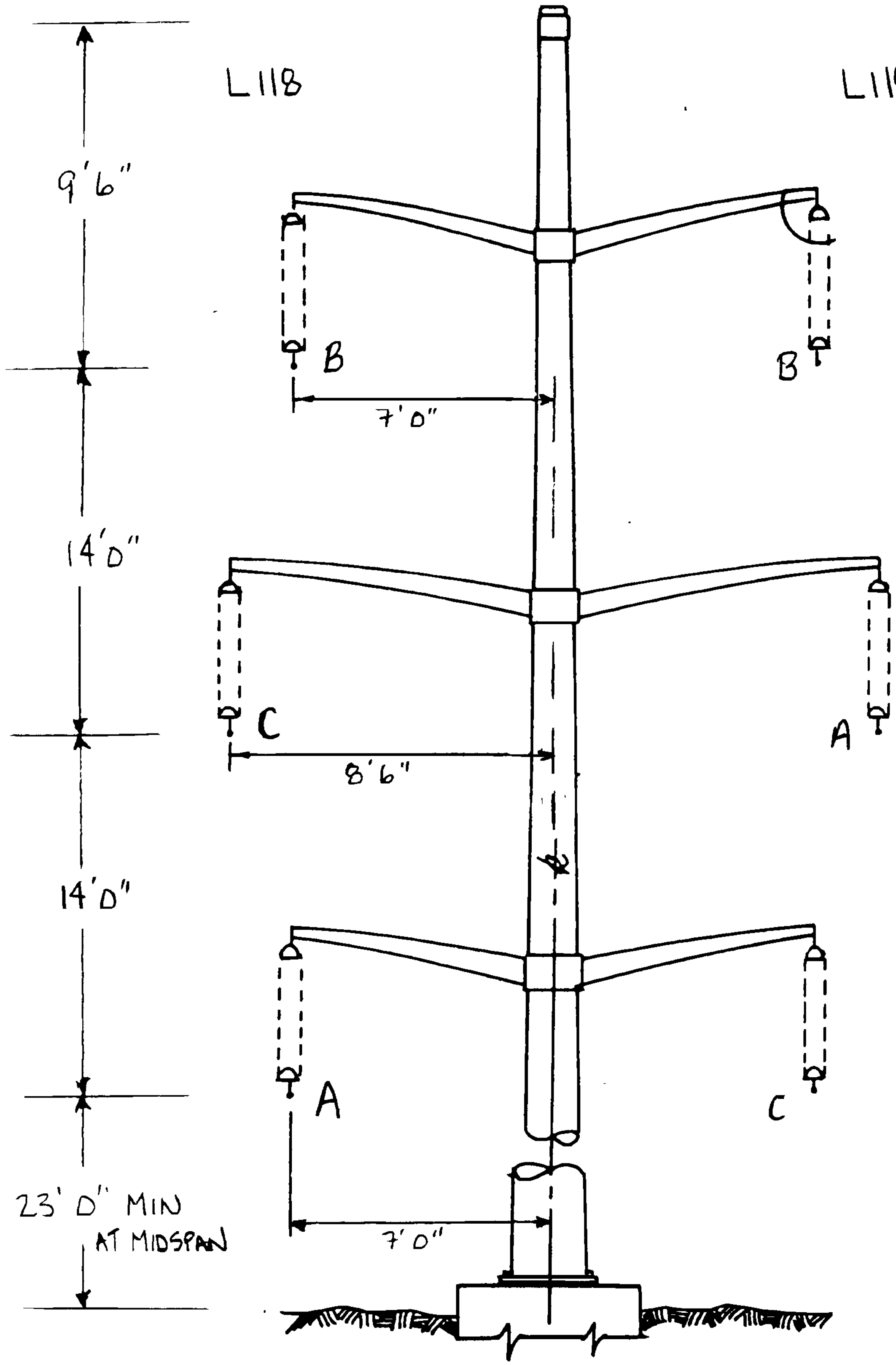
E·PRO

Engineering & Environmental Consulting, LLC

BOOK NO | PAGE NO
FILE NO

SUBJECT YARMOUTH LINE L118 & L119 SHEET OF SHEETS

COMPUTED BY DATE CHECKED BY



E·PRO

Engineering & Environmental Consulting, LLC

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	FILE NO.
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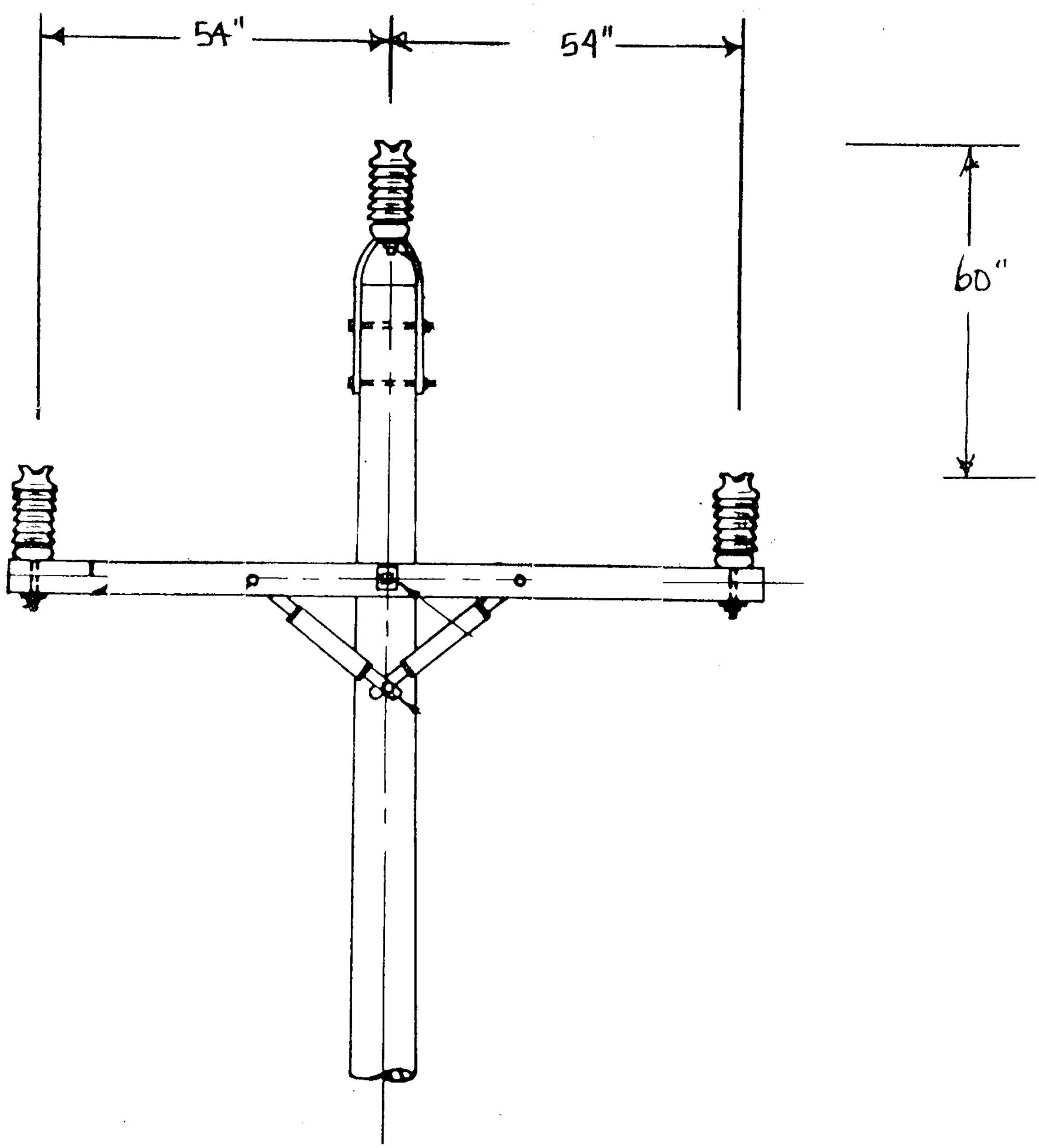
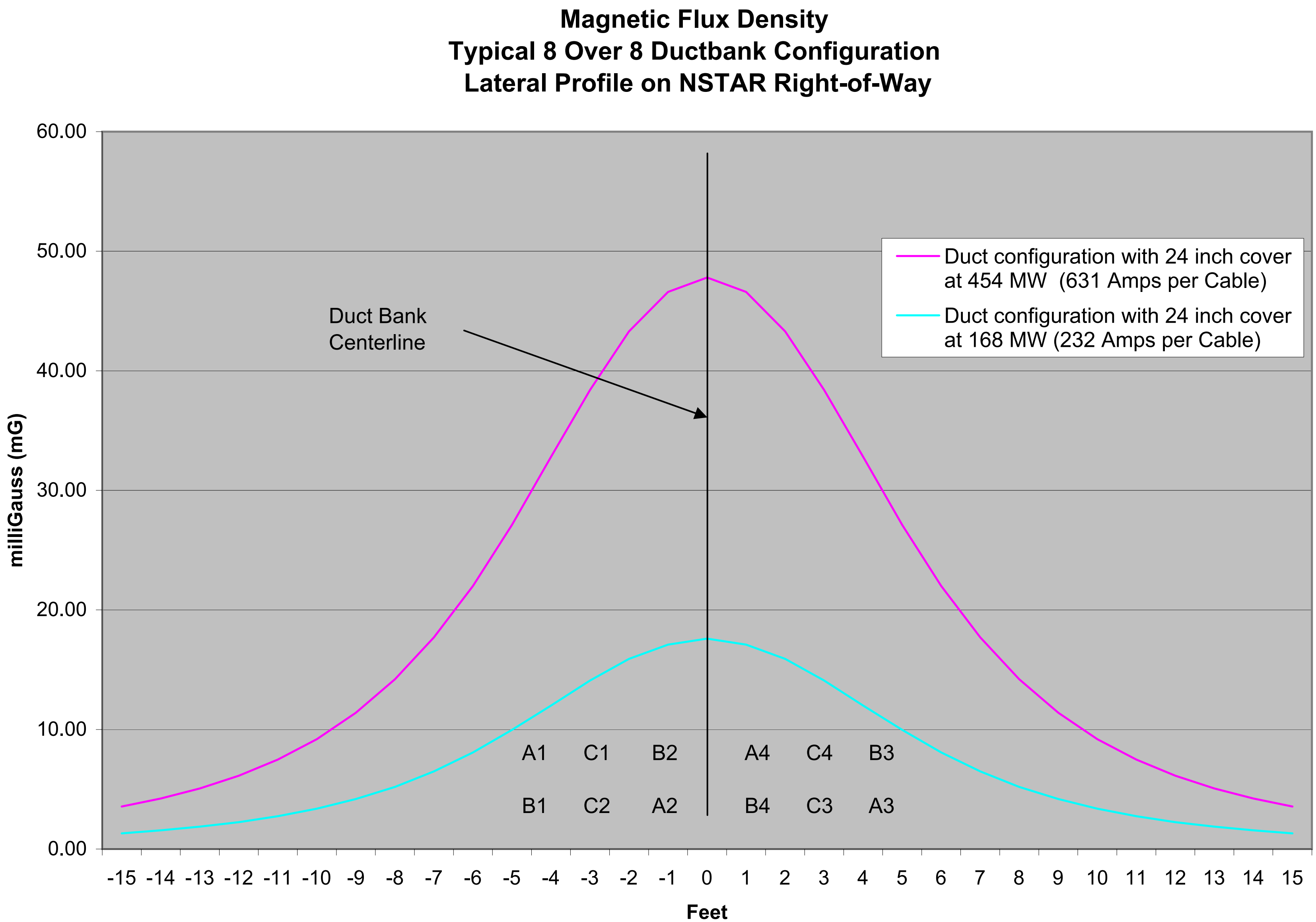


Appendix G

CAPE WIND PROJECT - CALCULATED EMF LEVELS ASSOCIATED WITH 115 kV DUCT BANK



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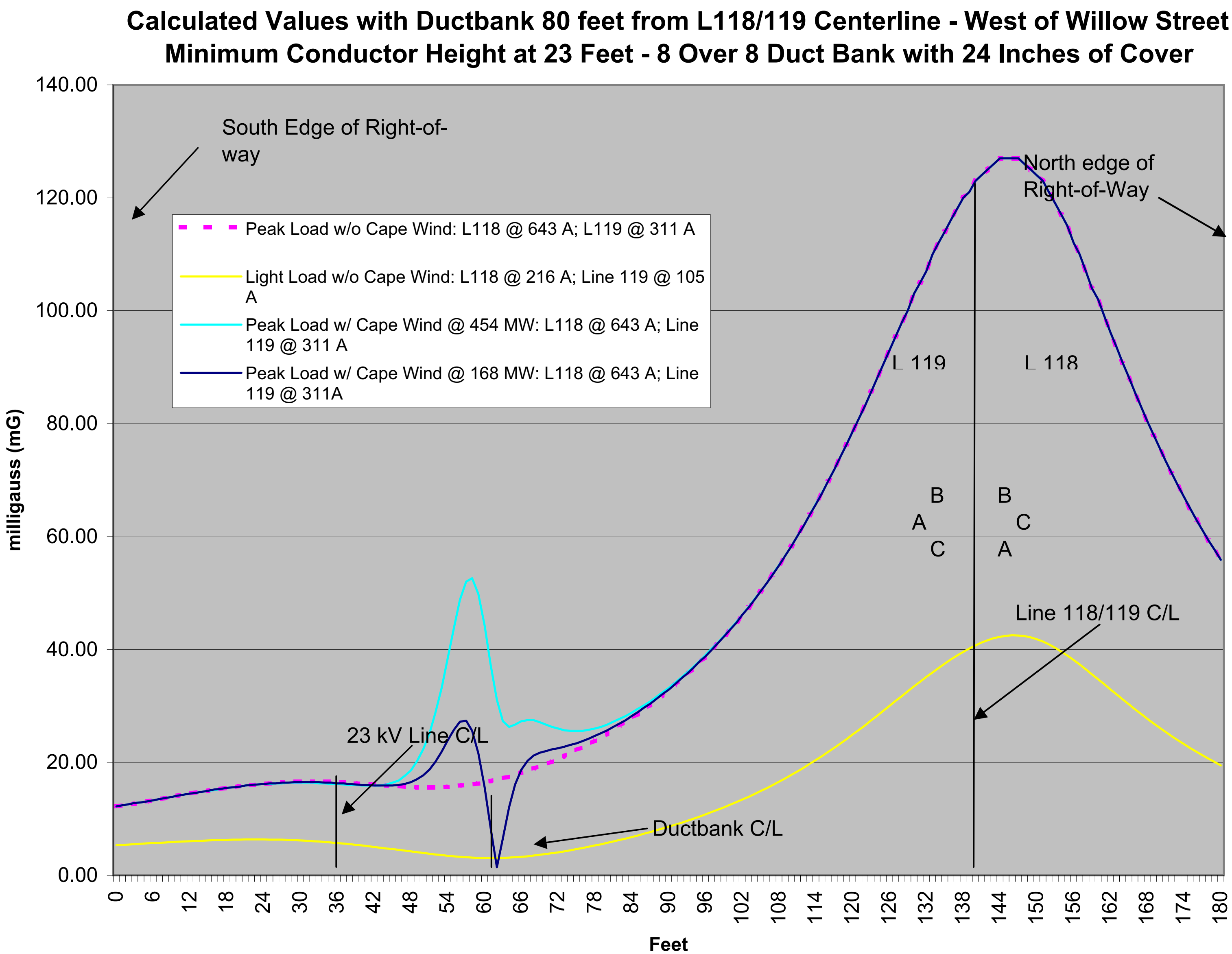
03/09/04

Magnetic Flux Density (mG) across Line 118/119 Right-of-Way
Yarmouth, Massachusetts



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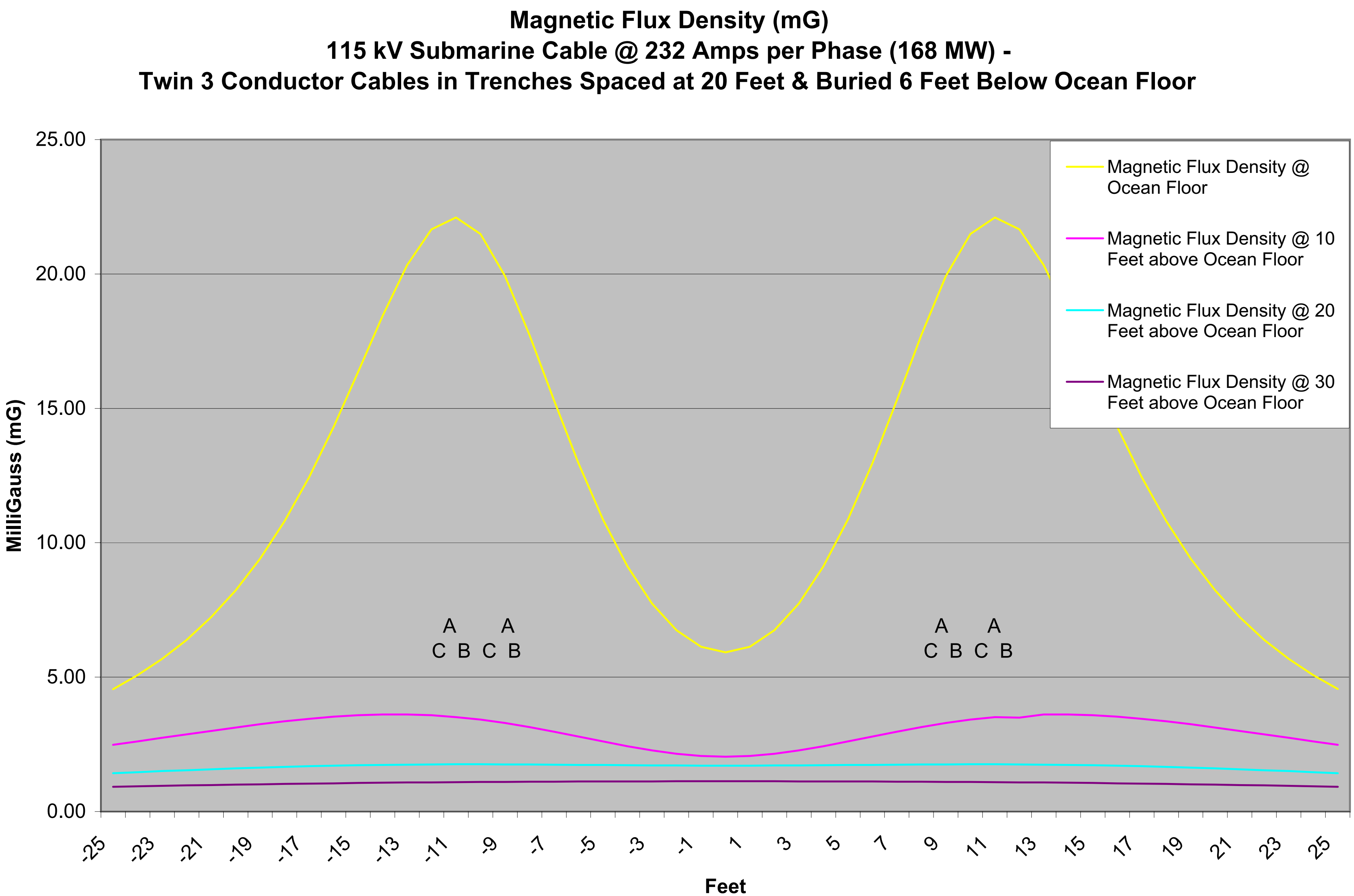
3/9/2004

Appendix H

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 115 kV SUBMARINE CABLES



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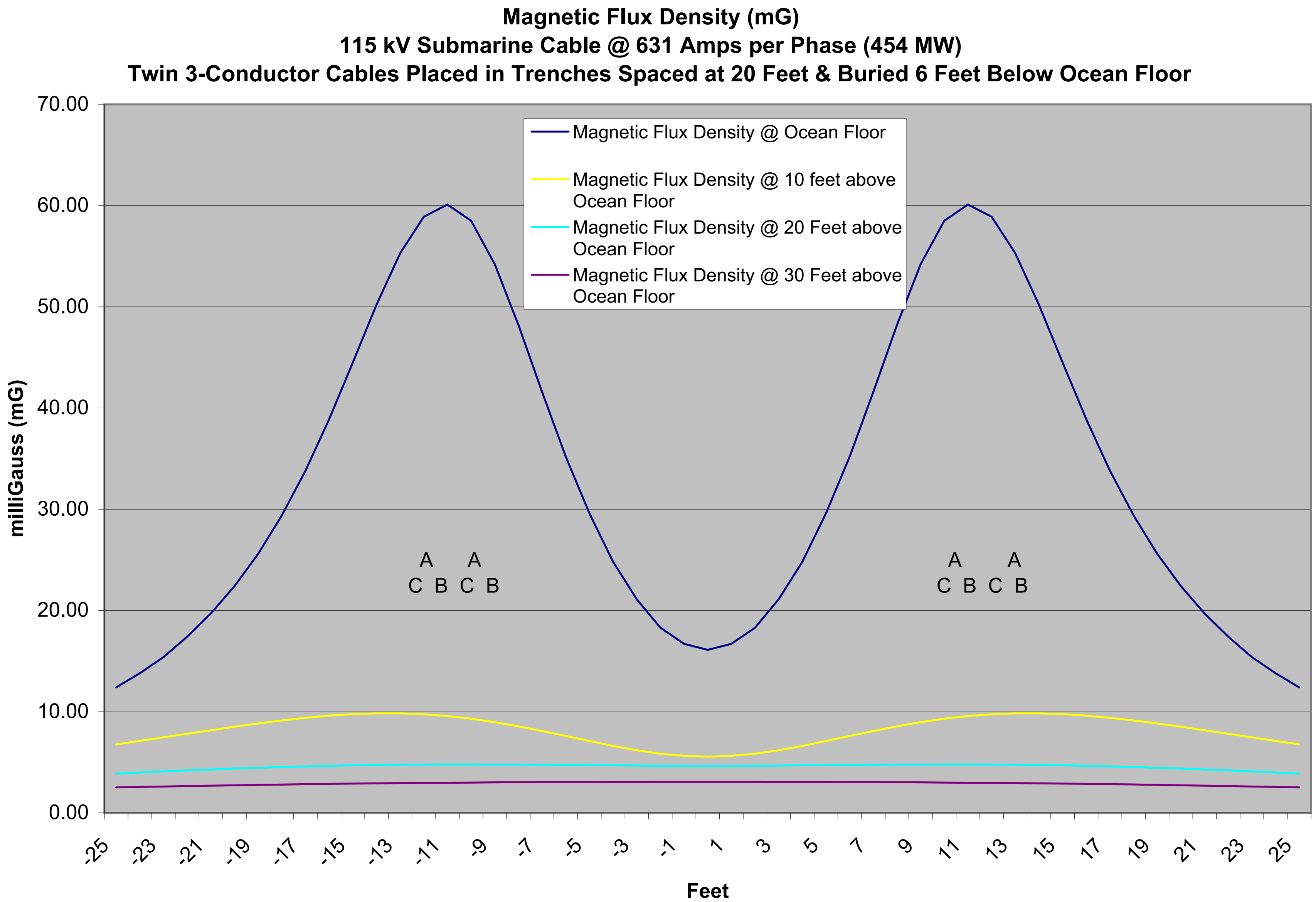
9/10/2003

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 115 kV SUBMARINE CABLES



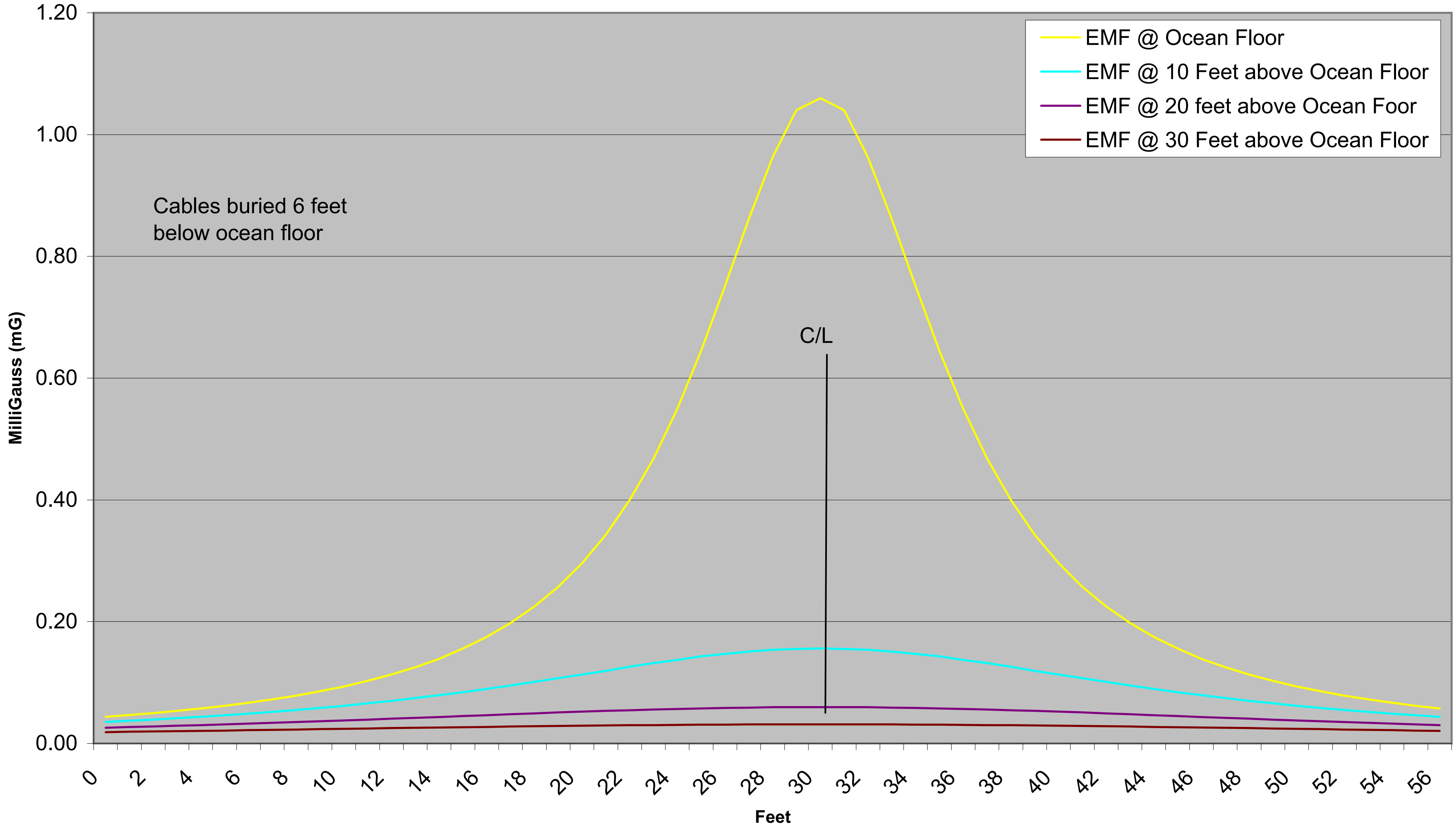
File:SubHV20PKREV1

08/28/03

Appendix I

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 33 kV SUBMARINE CABLES

Magnetic Flux Density (mG) @ 28 Amps per Phase - 33 kV-150 mm2 Submarine Cable



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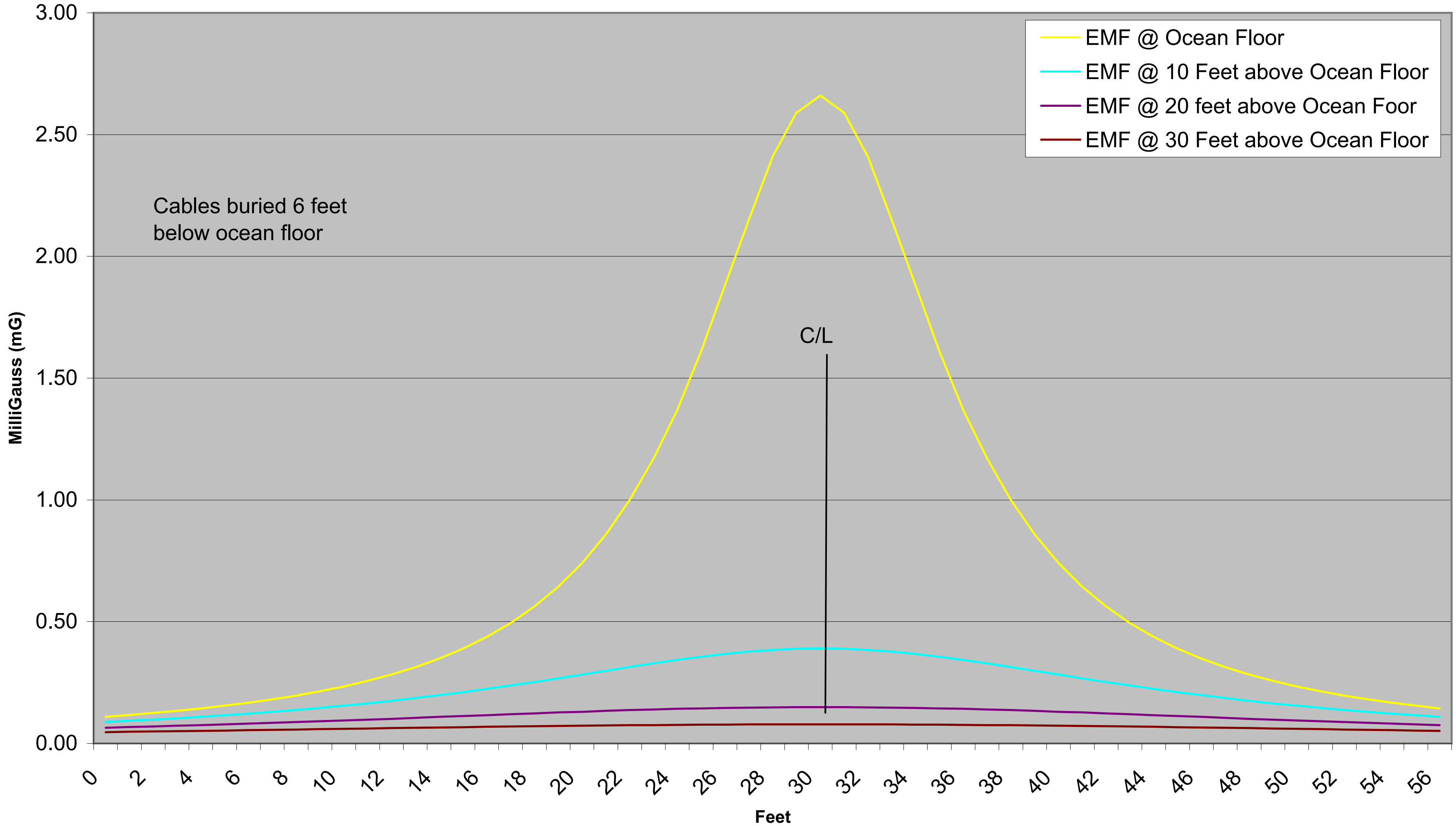
10/23/2002

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 33 kV SUBMARINE CABLES

Magnetic Flux Density (mG) @ 70 Amps per Phase - 33 kV-150 mm2 Submarine Cable



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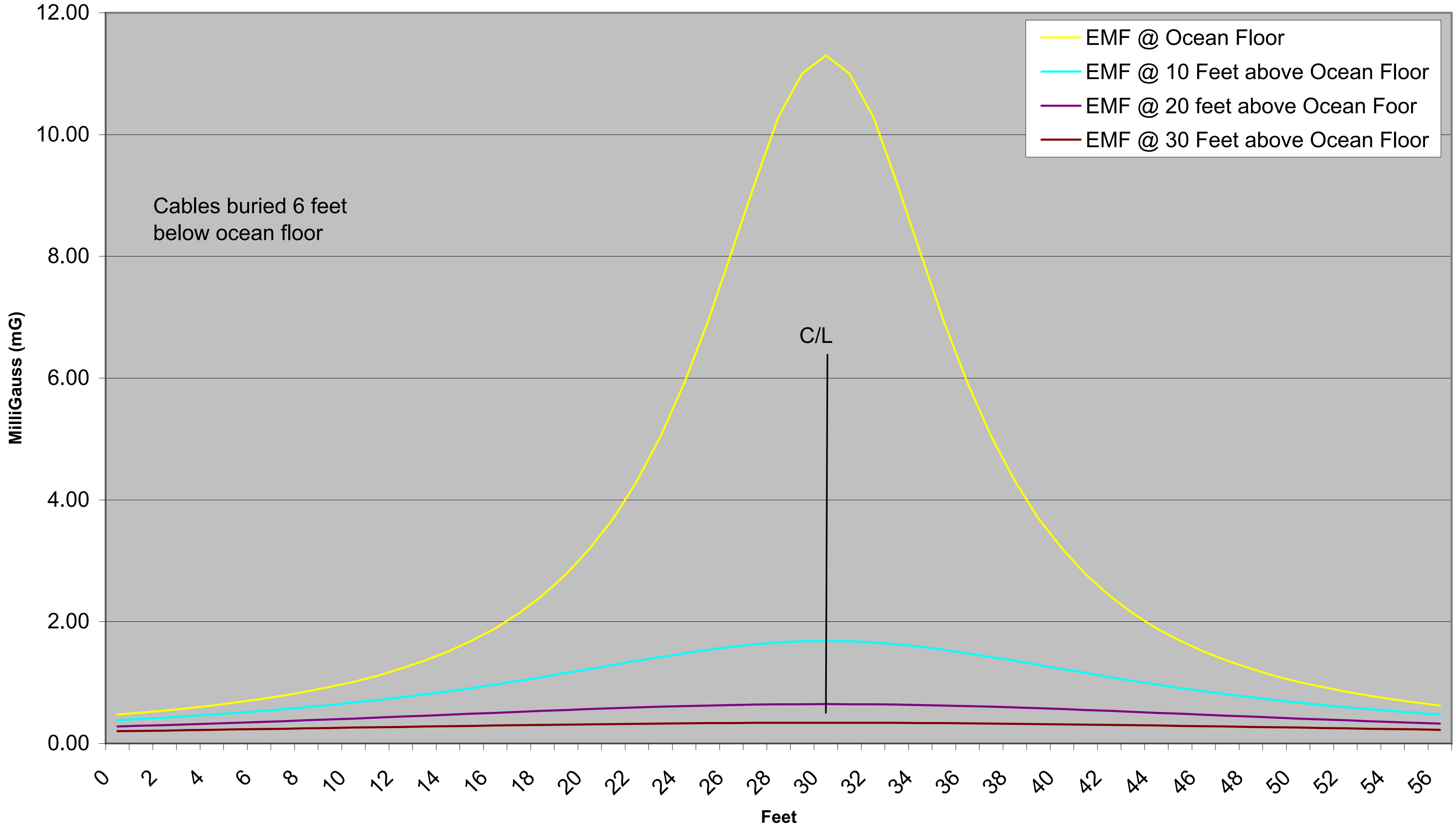
10/23/2002

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 33 kV SUBMARINE CABLES

Magnetic Flux Density (mG) @ 280 Amps per Phase - 33 kV- 630 mm2 Submarine Cable

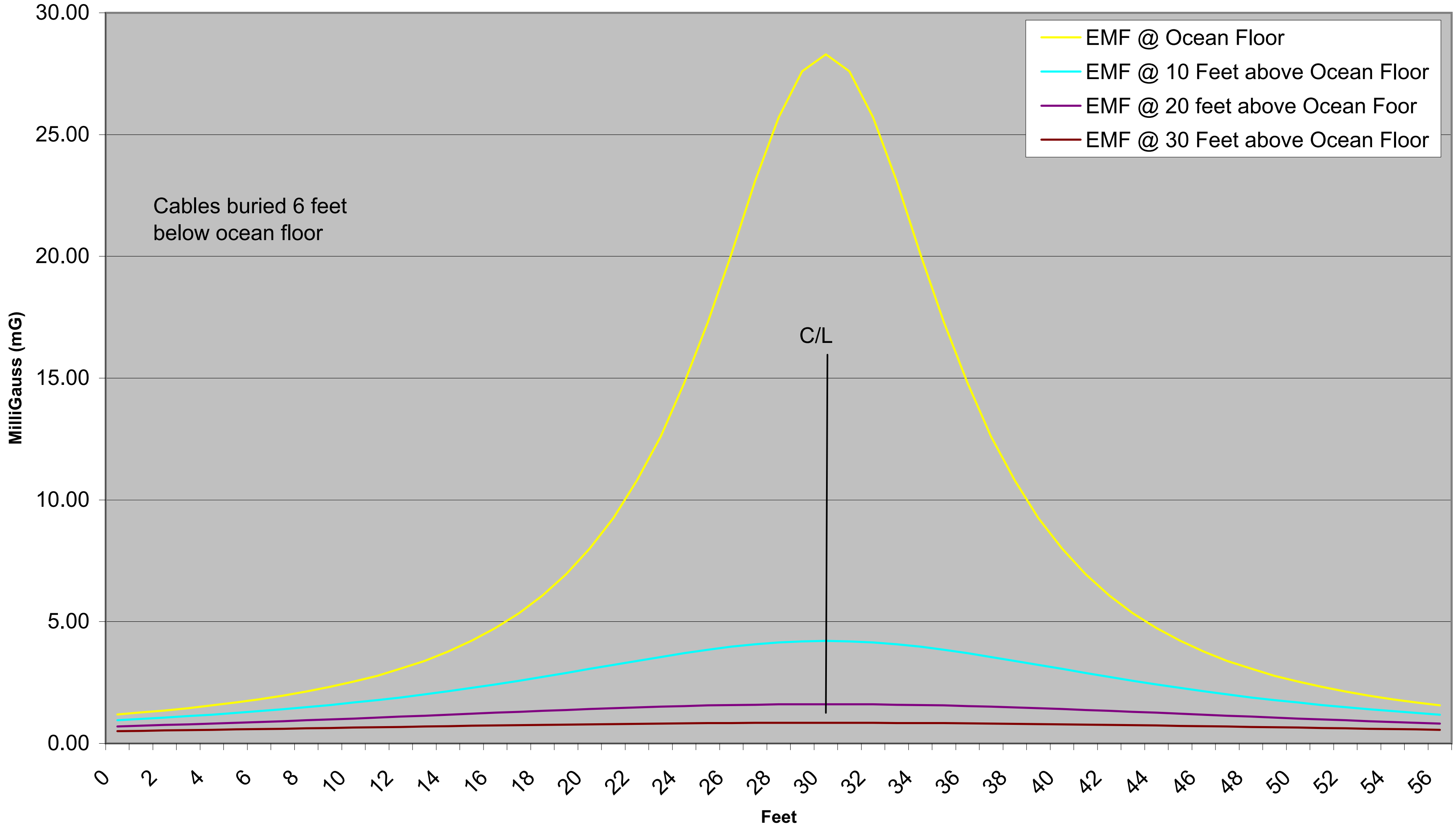


File:SubMV2AV

10/23/2002

CAPE WIND PROJECT CALCULATED EMF LEVELS ASSOCIATED WITH 33 kV SUBMARINE CABLES

Magnetic Flux Density (mG) @ 700 Amps per Phase - 33 kV- 630 mm2 Submarine Cable



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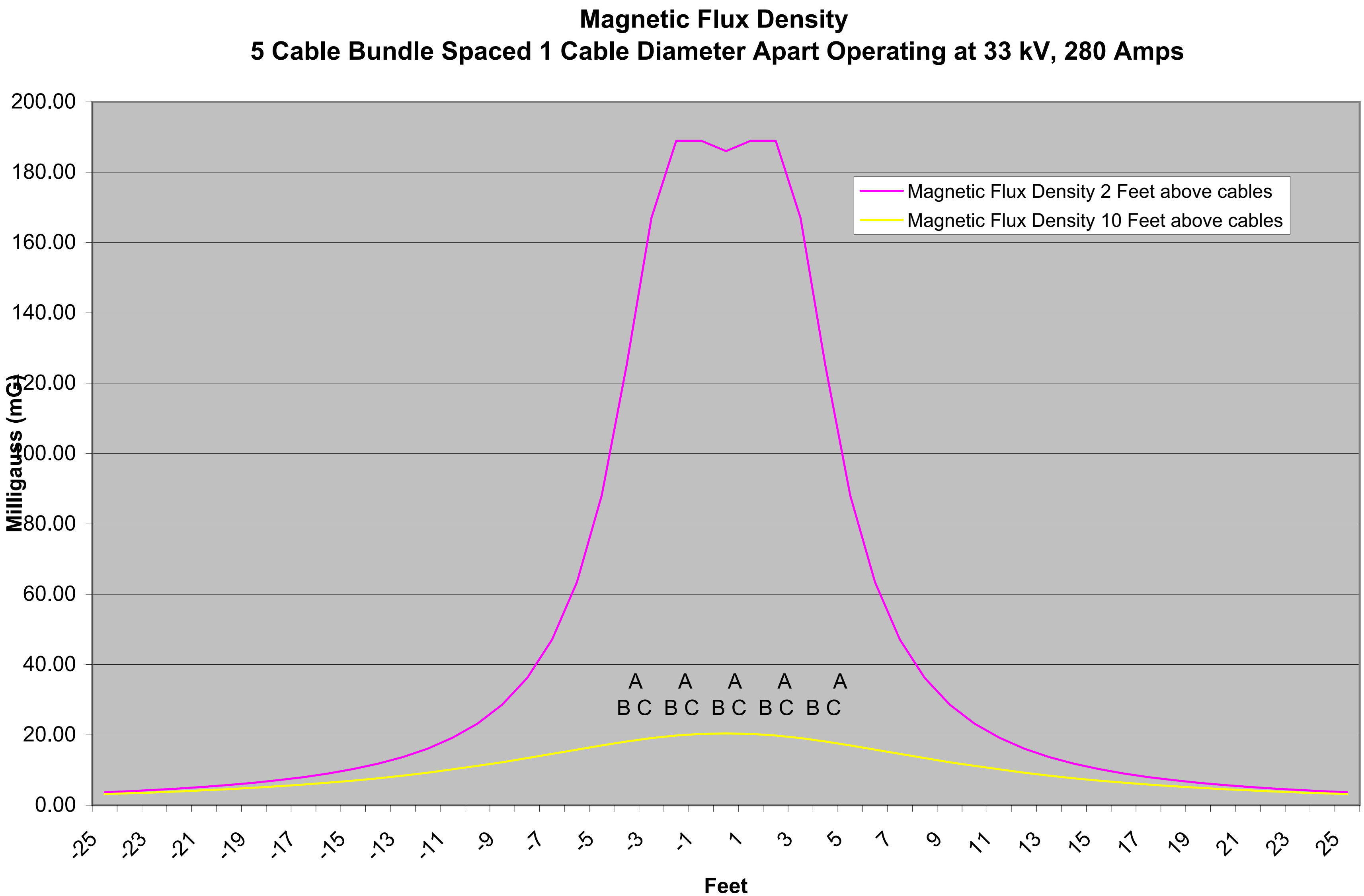
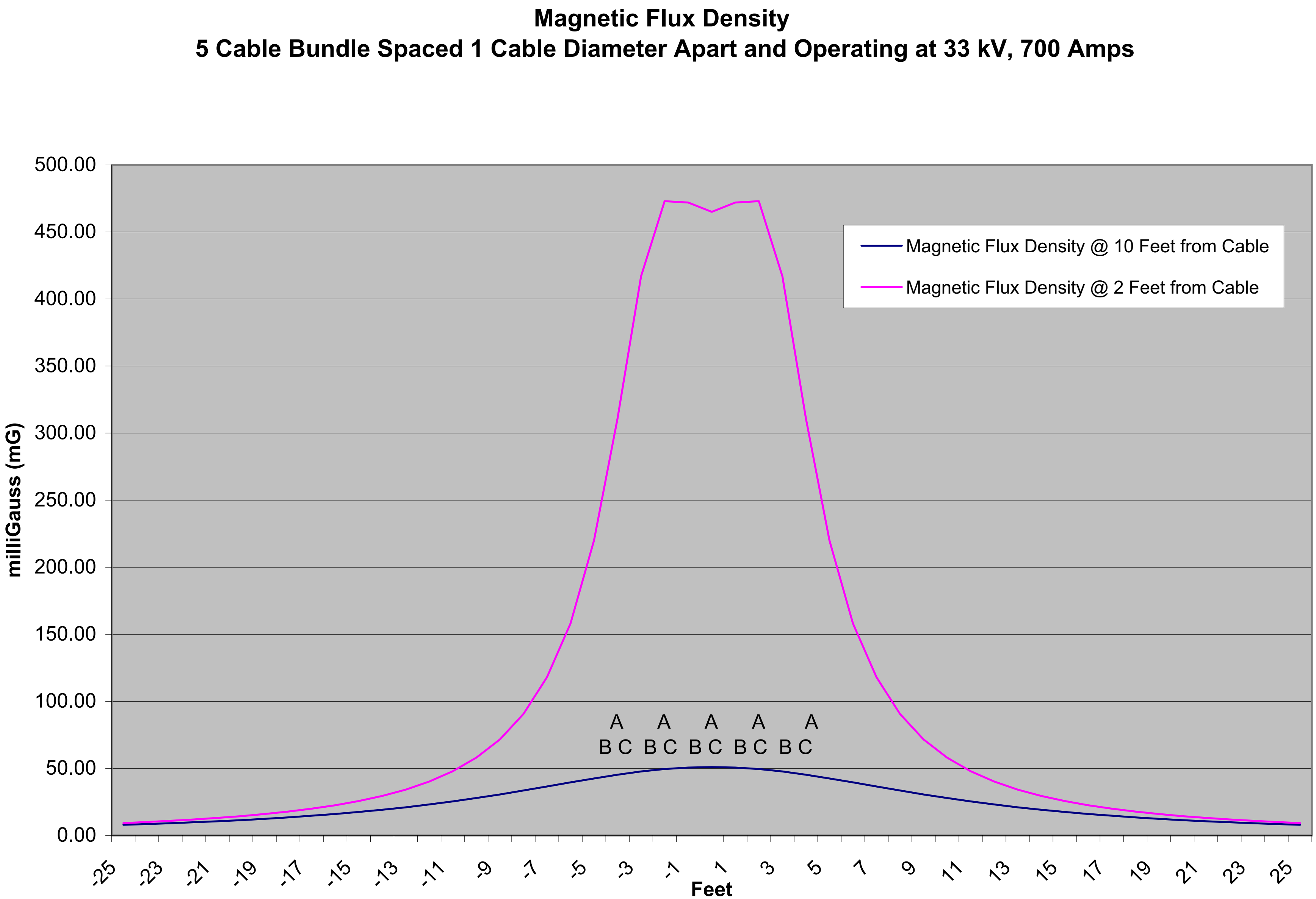
10/23/2002

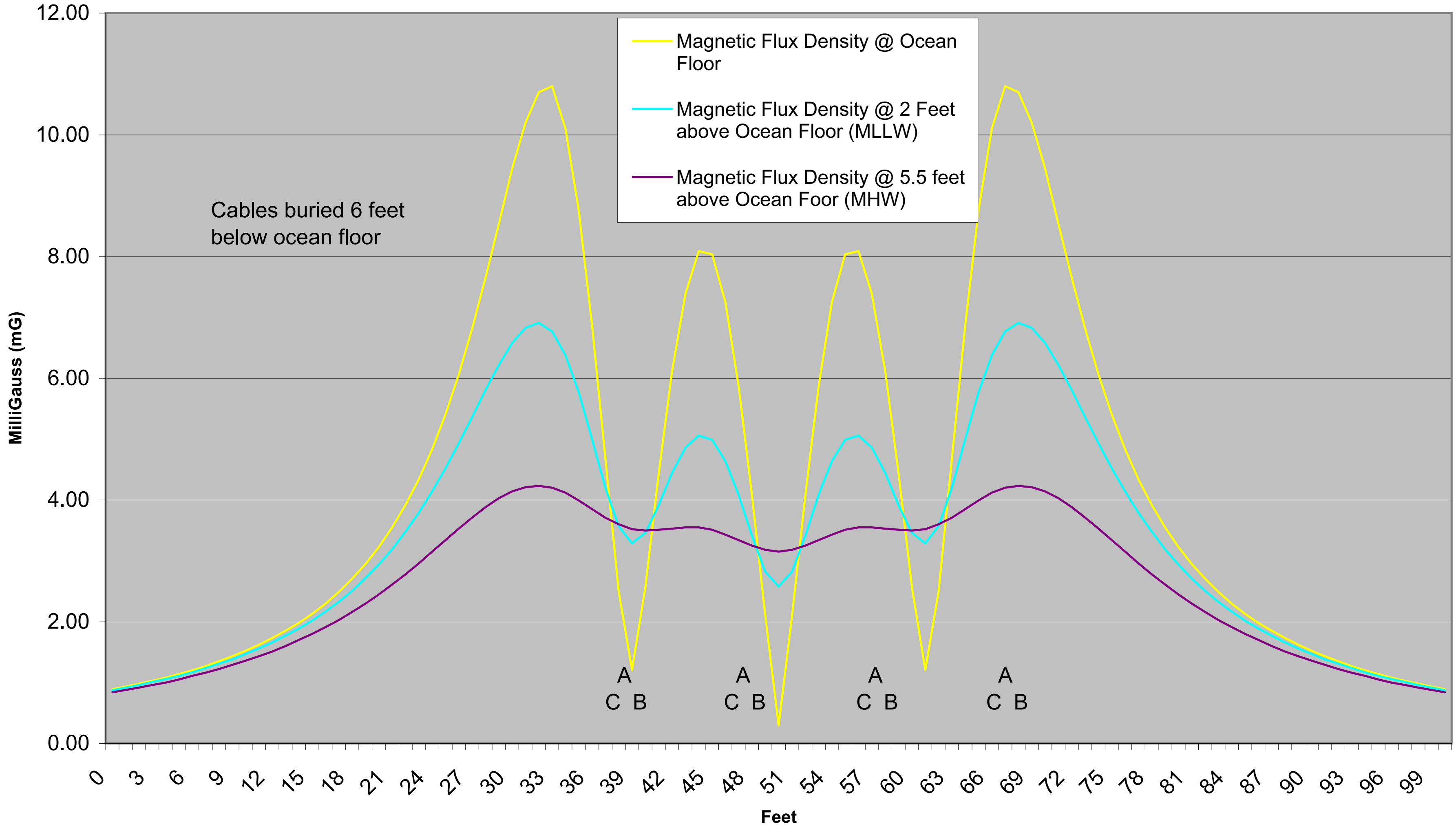
Appendix J


Magnetic Flux Density
5 Cable Bundle Spaced 1 Cable Diameter Apart Operating at 33 kV, 280 Amps
Milligauss (mG)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Magnetic Flux Density 2 Feet above cables
Magnetic Flux Density 10 Feet above cables
A A A A A
B C B C B C B C B C
-25 -23 -21 -19 -17 -15 -13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13 15 17 19 21 23 25
Feet

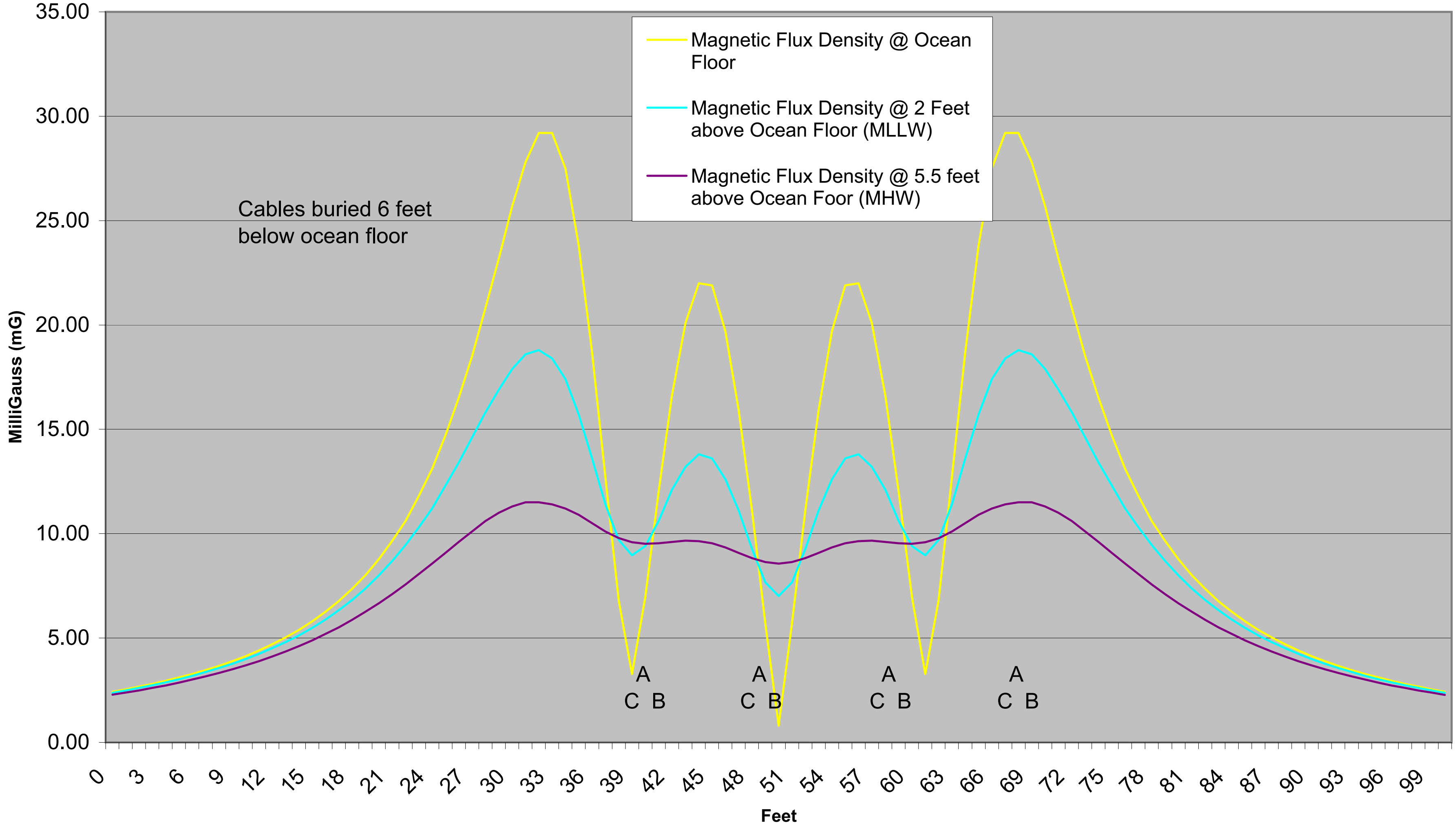

Magnetic Flux Density
5 Cable Bundle Spaced 1 Cable Diameter Apart and Operating at 33 kV, 700 Amps
milliGauss (mG)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-25 -23 -21 -19 -17 -15 -13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13 15 17 19 21 23 25
Feet
Magnetic Flux Density @ 10 Feet from Cable
Magnetic Flux Density @ 2 Feet from Cable
A A A A A
B C B C B C B C B C

Appendix K

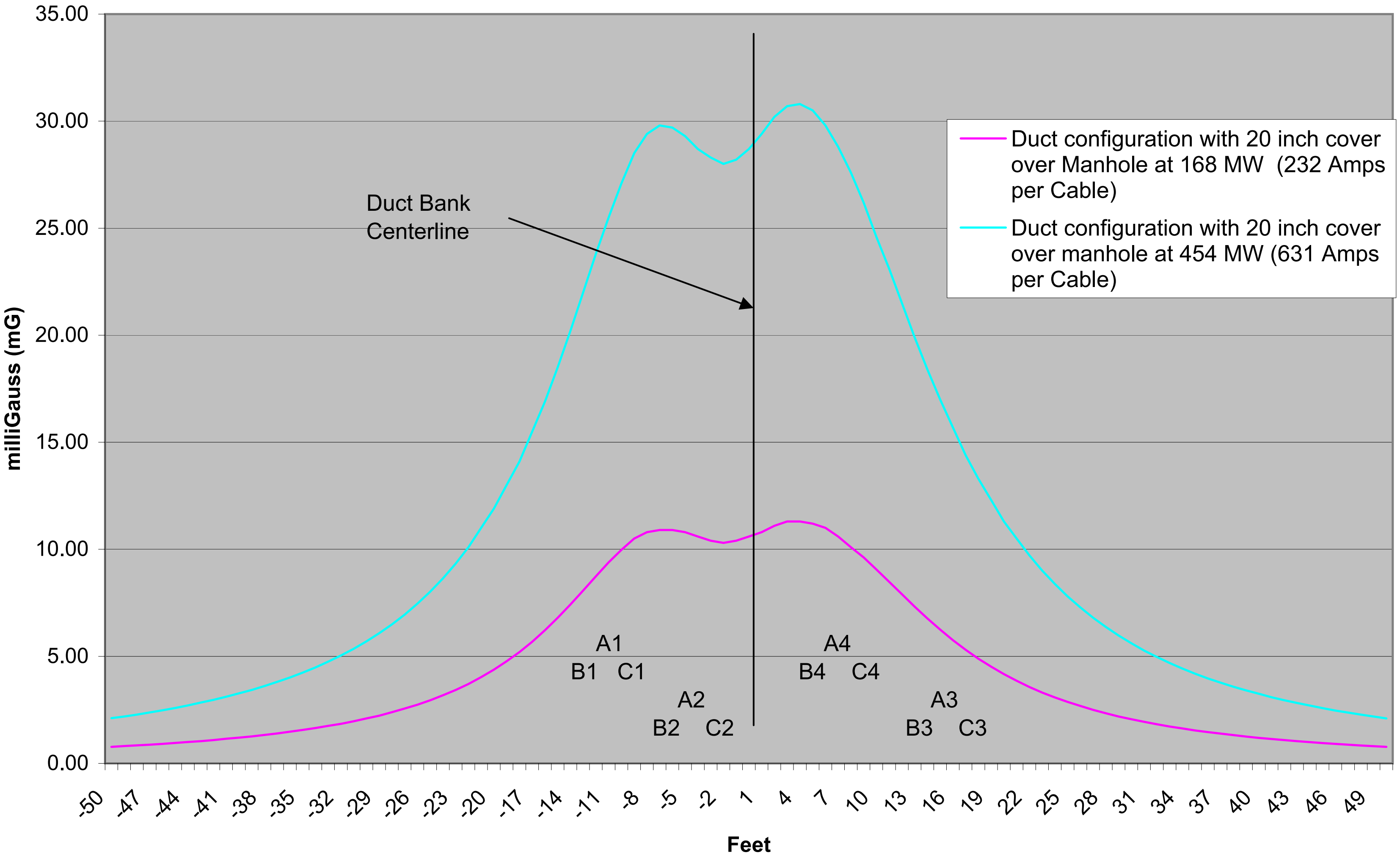
Magnetic Flux Density (mG) @ 232 Amps per Phase (168 MW) - 115 kV Submarine Cable Transition - Four Cables Placed in Separate Pipes 10.5 Feet Apart



Magnetic Flux Density (mG) @ 631 Amps per Phase (454 MW) - 115 kV Submarine Cable Transition - Four Cables Placed in Separate Pipes 10.5 Feet Apart



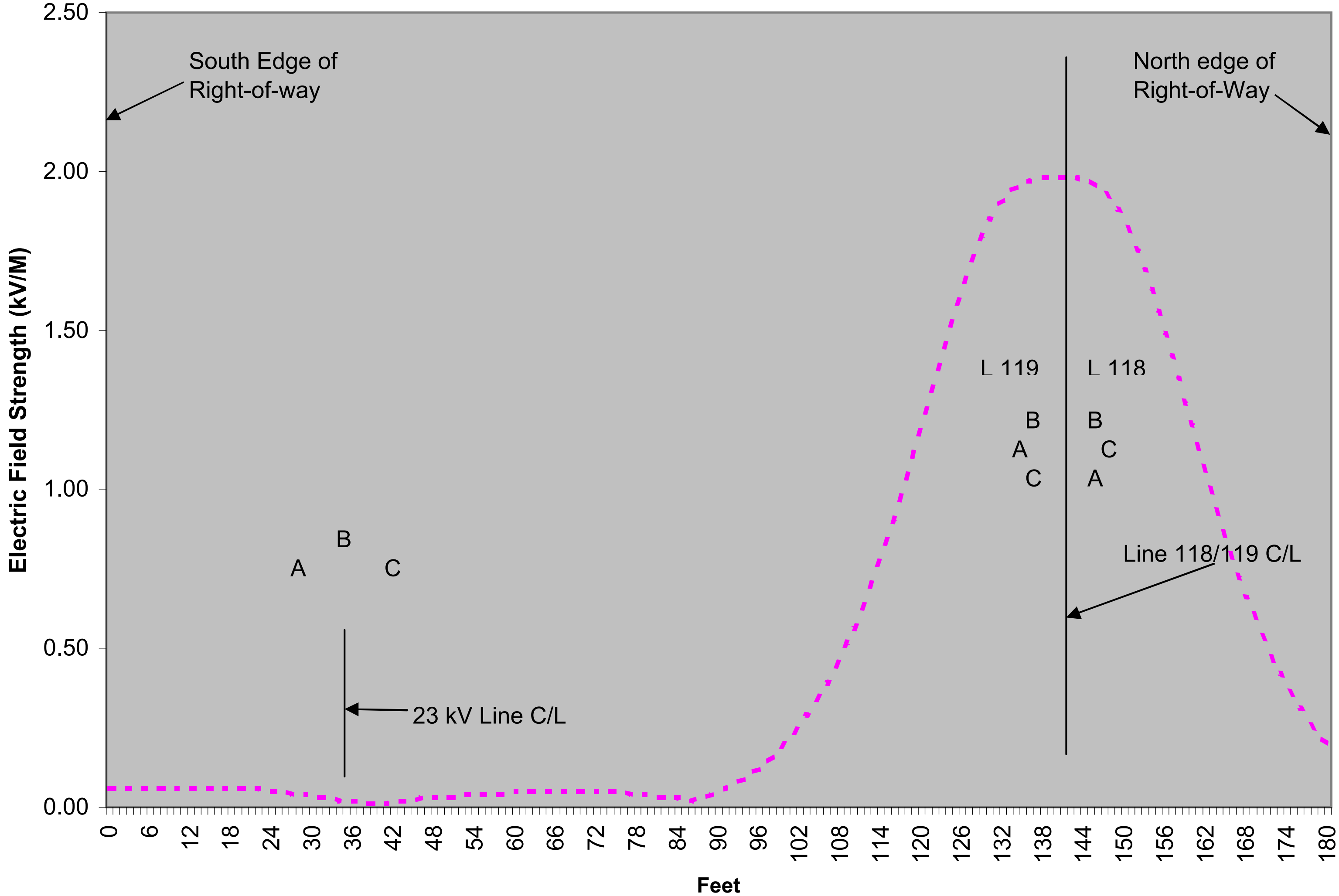
Magnetic Flux Density at One Meter above Grade
Submarine to Upland Cable Transition Manhole
Lateral Profile at Ocean Side of Transition Manhole



Appendix L

Electric Field Strength (kV/m) on Line 118/119 Right-of-Way
Yarmouth, Massachusetts

East Side of Willow Street, Yarmouth



File: YarmEfieldCalc115

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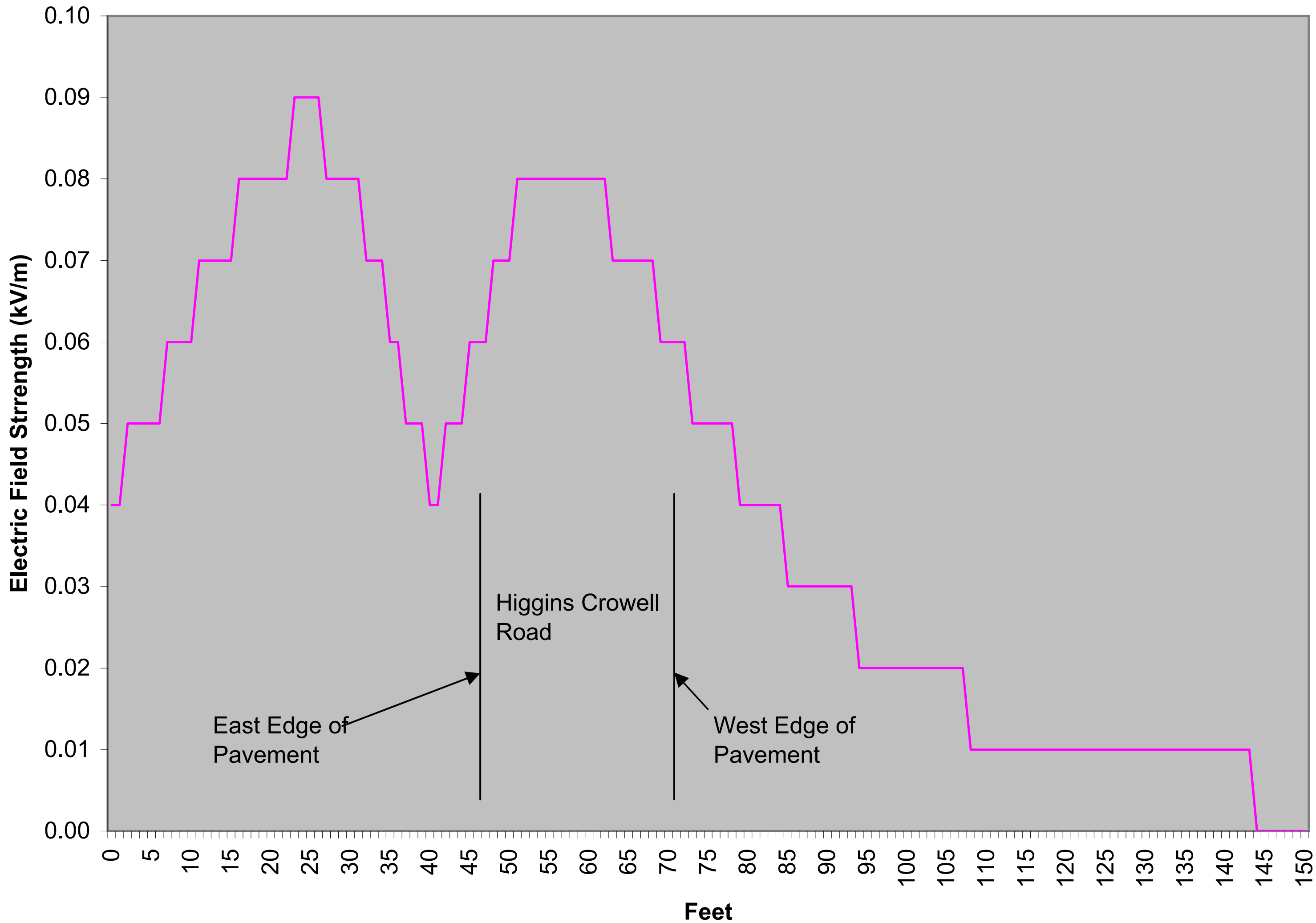
Electric Field Strength (kV/m) on 23 kV Distribution

Yarmouth Lateral Profile L8 - Higgins Crowell Rd North of 23 kV R/W
East to West



File: YarmLat8EfieldCalc

9/10/2002