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CLIENT:

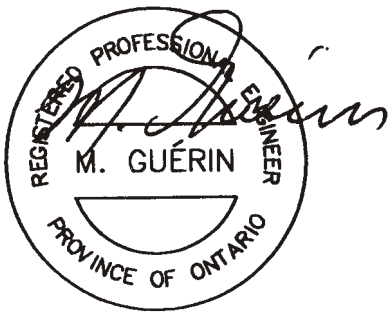
**NORR Ltd.**

55 Murray Street, Suite 600  
Ottawa, Ontario, K1N 5M3

PROJECT:

**CORRECTIONAL SERVICE OF CANADA  
PITTSBURGH INSTITUTION  
HIGHWAY 15, No. 3766, JOYCEVILLE, ONTARIO  
44,000-600V, 1500kVA PADMOUNT TRANSFORMER GROUNDING STUDY**

**JULY, 2012**



**Prepared By:  
Date:  
Ref. #:**

**Paul G. Nagy  
July 9, 2012  
NORR -12-01**

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- Drawing E-1: Substation Grounding

## **1.0 INTRODUCTION**

1.1 This report presents the Substation Grounding Study for the 44,000-600 Volt, 1500kVA outdoor padmount transformer at the Pittsburgh Institution site, Hwy 15, No. 3766, Joyceville, Ontario.

1.2 The study was based on the following information:

- Electrical Site Plan provided by KNORR Ltd.
- Soil resistivity and ground resistance measurement results by Carleton Electric, dated April 4 and May 31, 2012.
- Geotechnical Investigation report by DBA Engineering Ltd, dated September 11, 2011.
- Information provided by Hydro One regarding available fault levels.

## **2.0 SCOPE OF STUDY**

2.1 The scope of the study includes:

- (a) Calculation of the minimum required grounding system to:
  - Carry electric current into the earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affect continuity of service.
  - Ensure that a person in the vicinity of grounded facilities is not exposed to the danger of electric shock.
- (b) Recommendations of construction of the grounding system to implement the calculation results.



### **3.0 CALCULATIONS**

3.1 Calculations were carried out by using the EDSA Advanced Ground Mat Program based on the IEEE Std. 80-2000 Standard - "IEEE Guide for Safety in AC Substation Grounding".

3.2 Although based on the presently available line-to-ground fault current magnitude, the following factors in the calculations were selected to make the results conservative, allowing for possible future system growth:

- Parallel impedance representing any grounding resistance in the substation such as structures, station ground, buried piping, etc. was not considered.
- Effect of the proximity to the water table (approximately 1.6-2.4 m below surface) was not considered.

3.3 The calculations were carried out to design a grounding system with the smallest dimensions that would:

- Limit the potential rise of the substation ground mat to an acceptable value.
- Limit the resulting step, touch and transfer potentials in and around the substation to an acceptable value.

### 3.4 Calculation Results

EDSA Advanced Ground Mat Program v4.70.00

```
=====
Project No. : NORR-2012-01
Project Name: Pittsburgh Institute, Joyceville      Date   : July 8, 2012
Title       : 1500kVA Substation Grounding         Time   : 04:35:09 PM
Drawing No. : E-1                                  Company : Cadraw Corp.
Revision No.: 0                                     Engineer : Paul G. Nagy
Jobfile Name: Pittsburgh
```

#### System Information

```
=====
Substation Name      = 1500kVA
Unit System          = U.S. Standard
Fault Current        = 2000.00 (Amp)
Parallel Impedance   = 10000.00 (ohm)
Fault Current Division Factor,Sf= 0.50
Body Weight          = 110.00 (Lb)
Fault Duration       = 0.50 (second)
Surface Material Description = Crushed Rock
Thickness of Surface Material = 1.00 (ft)
Resistivity of Surface Material = 3000.00 (ohm-m)
Upper Layer Material Description= Soil, sand, gravel
Upper Layer Thickness = 25.65 (ft)
Resistivity of the Upper Layer = 29.25 (ohm-m)
Lower Layer Material Description= Bed rock
Resistivity of the Lower Layer = 10000.00 (ohm-m)
Allowable Touch Voltage = 808.226 (Volt)
Allowable Step Voltage  = 2740.758 (Volt)
```

#### Main Ground Grid

Axis #	X1	Y1	Z1	X2	Y2	Z2	Length	Diameter	Current
0001	0.0	0.0	2.0	0.0	30.0	2.0	30.00	0.4331	37.50
0002	5.0	0.0	2.0	5.0	30.0	2.0	30.00	0.4331	18.58
0003	10.0	0.0	2.0	10.0	30.0	2.0	30.00	0.4331	8.02
0004	15.0	0.0	2.0	15.0	30.0	2.0	30.00	0.4331	7.64
0005	20.0	0.0	2.0	20.0	30.0	2.0	30.00	0.4331	3.93
0006	25.0	0.0	2.0	25.0	30.0	2.0	30.00	0.4331	5.91
0007	30.0	0.0	2.0	30.0	30.0	2.0	30.00	0.4331	3.93
0008	35.0	0.0	2.0	35.0	30.0	2.0	30.00	0.4331	7.64
0009	40.0	0.0	2.0	40.0	30.0	2.0	30.00	0.4331	8.01
0010	45.0	0.0	2.0	45.0	30.0	2.0	30.00	0.4331	18.55
0011	50.0	0.0	2.0	50.0	30.0	2.0	30.00	0.4331	37.45
0012	0.0	0.0	2.0	50.0	0.0	2.0	50.00	0.4331	61.32
0013	0.0	5.0	2.0	50.0	5.0	2.0	50.00	0.4331	31.22
0014	0.0	10.0	2.0	50.0	10.0	2.0	50.00	0.4331	14.47
0015	0.0	15.0	2.0	50.0	15.0	2.0	50.00	0.4331	14.45
0016	0.0	20.0	2.0	50.0	20.0	2.0	50.00	0.4331	9.39
0017	0.0	25.0	2.0	50.0	25.0	2.0	50.00	0.4331	14.01
0018	0.0	30.0	2.0	50.0	30.0	2.0	50.00	0.4331	11.82
0019	0.0	30.0	2.0	0.0	40.0	2.0	10.00	0.4331	14.55
0020	5.0	30.0	2.0	5.0	40.0	2.0	10.00	0.4331	8.17
0021	10.0	30.0	2.0	10.0	40.0	2.0	10.00	0.4331	4.05
0022	15.0	30.0	2.0	15.0	40.0	2.0	10.00	0.4331	4.09

Axis #	X1	Y1	Z1	X2	Y2	Z2	Length	Diameter	Current
0023	20.0	30.0	2.0	20.0	40.0	2.0	10.00	0.4331	2.49
0024	25.0	30.0	2.0	25.0	40.0	2.0	10.00	0.4331	3.37
0025	30.0	30.0	2.0	30.0	40.0	2.0	10.00	0.4331	2.49
0026	35.0	30.0	2.0	35.0	40.0	2.0	10.00	0.4331	4.09
0027	40.0	30.0	2.0	40.0	40.0	2.0	10.00	0.4331	4.02
0028	45.0	30.0	2.0	45.0	40.0	2.0	10.00	0.4331	8.15
0029	50.0	30.0	2.0	50.0	40.0	2.0	10.00	0.4331	14.86
0030	0.0	35.0	2.0	50.0	35.0	2.0	50.00	0.4331	26.42
0031	0.0	40.0	2.0	50.0	40.0	2.0	50.00	0.4331	57.97
0032	0.0	0.0	2.0	0.0	0.0	12.0	10.00	0.7481	33.51
0033	0.0	10.0	2.0	0.0	10.0	12.0	10.00	0.7481	22.30
0034	0.0	20.0	2.0	0.0	20.0	12.0	10.00	0.7481	20.01
0035	0.0	30.0	2.0	0.0	30.0	12.0	10.00	0.7481	21.97
0036	10.0	0.0	2.0	10.0	0.0	12.0	10.00	0.7481	21.61
0037	10.0	10.0	2.0	10.0	10.0	12.0	10.00	0.7481	11.35
0038	10.0	20.0	2.0	10.0	20.0	12.0	10.00	0.7481	9.46
0039	10.0	30.0	2.0	10.0	30.0	12.0	10.00	0.7481	11.08
0040	20.0	0.0	2.0	20.0	0.0	12.0	10.00	0.7481	18.28
0041	20.0	10.0	2.0	20.0	10.0	12.0	10.00	0.7481	8.64
0042	20.0	20.0	2.0	20.0	20.0	12.0	10.00	0.7481	6.88
0043	20.0	30.0	2.0	20.0	30.0	12.0	10.00	0.7481	8.48
0044	30.0	0.0	2.0	30.0	0.0	12.0	10.00	0.7481	18.28
0045	30.0	10.0	2.0	30.0	10.0	12.0	10.00	0.7481	8.64
0046	30.0	20.0	2.0	30.0	20.0	12.0	10.00	0.7481	6.88
0047	30.0	30.0	2.0	30.0	30.0	12.0	10.00	0.7481	8.45
0048	40.0	0.0	2.0	40.0	0.0	12.0	10.00	0.7481	21.61
0049	40.0	10.0	2.0	40.0	10.0	12.0	10.00	0.7481	11.35
0050	40.0	20.0	2.0	40.0	20.0	12.0	10.00	0.7481	9.43
0051	40.0	30.0	2.0	40.0	30.0	12.0	10.00	0.7481	11.04
0052	50.0	0.0	2.0	50.0	0.0	12.0	10.00	0.7481	33.51
0053	50.0	10.0	2.0	50.0	10.0	12.0	10.00	0.7481	22.28
0054	50.0	20.0	2.0	50.0	20.0	12.0	10.00	0.7481	19.98
0055	50.0	30.0	2.0	50.0	30.0	12.0	10.00	0.7481	21.86
0056	0.0	40.0	1.6	0.0	40.0	11.6	10.00	0.7481	32.23
0057	10.0	40.0	2.0	10.0	40.0	12.0	10.00	0.7481	21.39
0058	20.0	40.0	2.0	20.0	40.0	12.0	10.00	0.7481	18.12
0059	30.0	40.0	2.0	30.0	40.0	12.0	10.00	0.7481	18.10
0060	40.0	40.0	2.0	40.0	40.0	12.0	10.00	0.7481	21.32
0061	50.0	40.0	2.0	50.0	40.0	12.0	10.00	0.7481	33.05

Total Conductor Length = 1190.1 ft

Ground Potential Rise = 3434.3 Volts

Grounding Grid & Rod Resistance = 3.4355 Ohms

Total Impedance of Installation = 3.4343 Ohms

Within the area: X: 0ft to 49.2126ft Y: 0ft to 39.3701ft  
Maximum Touch Voltage is at:( 0ft, 0ft) Voltage: 797.351(V)

PASS

## **4.0 RECOMMENDATIONS**

### **4.1 Construct a substation grounding system as follows:**

- Ground grid dimensions: 40' (12.192 m) wide x 50' (15.24 m) long
- Grid area: 2,000 square feet (185.8 square meters)
- Grid conductor spacing: 5' (1.524 m)
- Conductor length: 1,190' (362.7 m)
- Conductor material: #2/0 AWG, copper
- Ground rods: min. 24, 10' L x 0.75" dia (3 m L x 19 mm dia), copper clad

### **4.2 Installation details:**

- Ground grid conductor burial depth: 2.0' (0.6m)
- All connectors: compression type (Burndy Hi-ground)
- Surface material: minimum 1.0' (0.3m) layer of crushed stone, carried over extent of ground grid by 4' (1.2 m), install 2" x 6" osmose treated wood stops all around.
- Bond to all metal components by #2/0 stranded copper conductors, such as:
  - transformer enclosure
  - base reinforcing and bollards
  - overhead service dip pole grounding
  - all buried metal parts, pipes

#### 4.3 Bedrock conditions

According to the Geotechnical Investigation report, bedrock can be encountered at depths ranging between 1.75 and 8.73 m below the existing ground surface.

If rock conditions are experienced during ground rod installation, it is recommended to proceed as follows:

- Enclose ground rods in min. 6" (150mm) dia. well filled with Ground Enhancing Material (GEM) as manufactured by Erico or equivalent.
- Follow manufacturer's instructions for installation.

## **APPENDIX A**

### **SUBSTATION GROUNDING CALCULATION PLOTS**

- Soil Resistivity Graph
- Grid layout, GPR, Touch & Step Voltages
  - Absolute Potential 3D Graph
  - Step Potential Graph
  - Touch Potential Graph
  - Touch Potential 3D Graph



☐ Two layer Model
 ☐ Homogenous
 ☒ Compute from Measurements

Upper Layer Material Description: Soil, Sand, Gravel Lib Go to Next Window  
 Resistivity of the Upper Layer (ohm-m): 29.255  
 Upper Layer Thickness (ft): 25.653  
 Lower Layer Material Description: Bed rock Lib  
 Resistivity of the Lower Layer (ohm-m): 10000

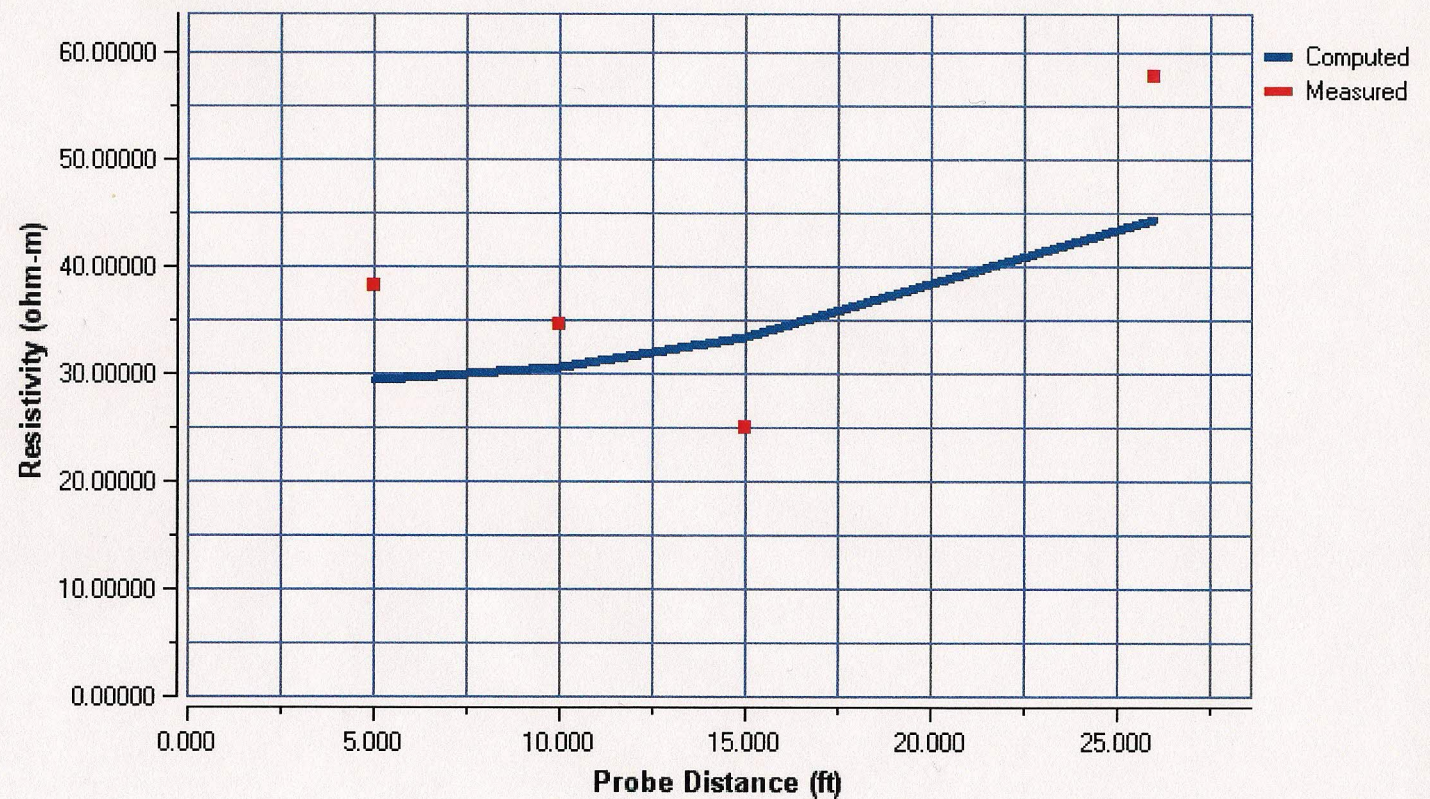
Probe Distance (ft)	Resistivity (ohm-m)
1	5.000
2	10.000
3	15.000
4	26.000
5	
6	
7	
8	
9	
10	

Previous Page
Next Page

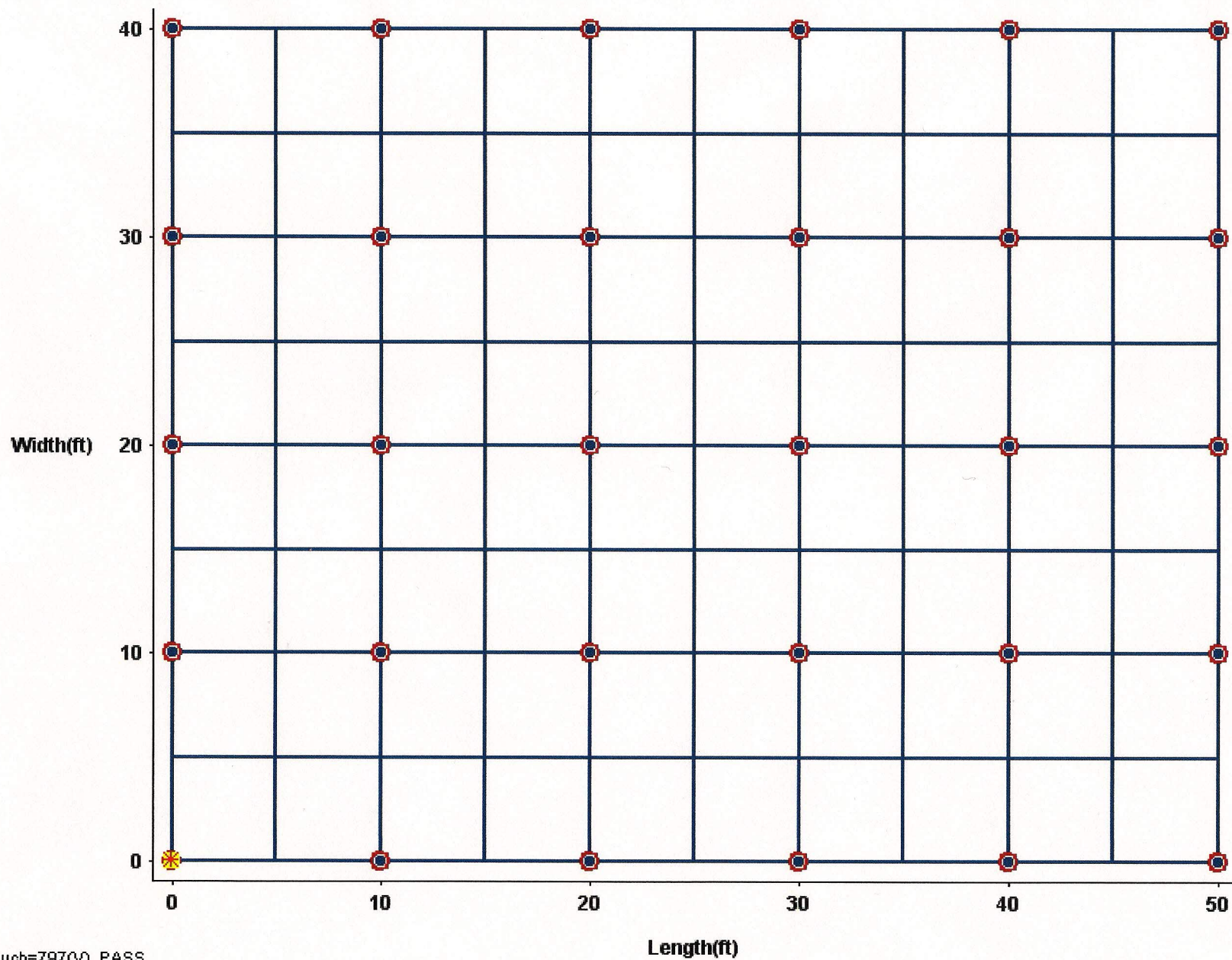
Calculate Two Layer Model



### Soil Resistivity Graph



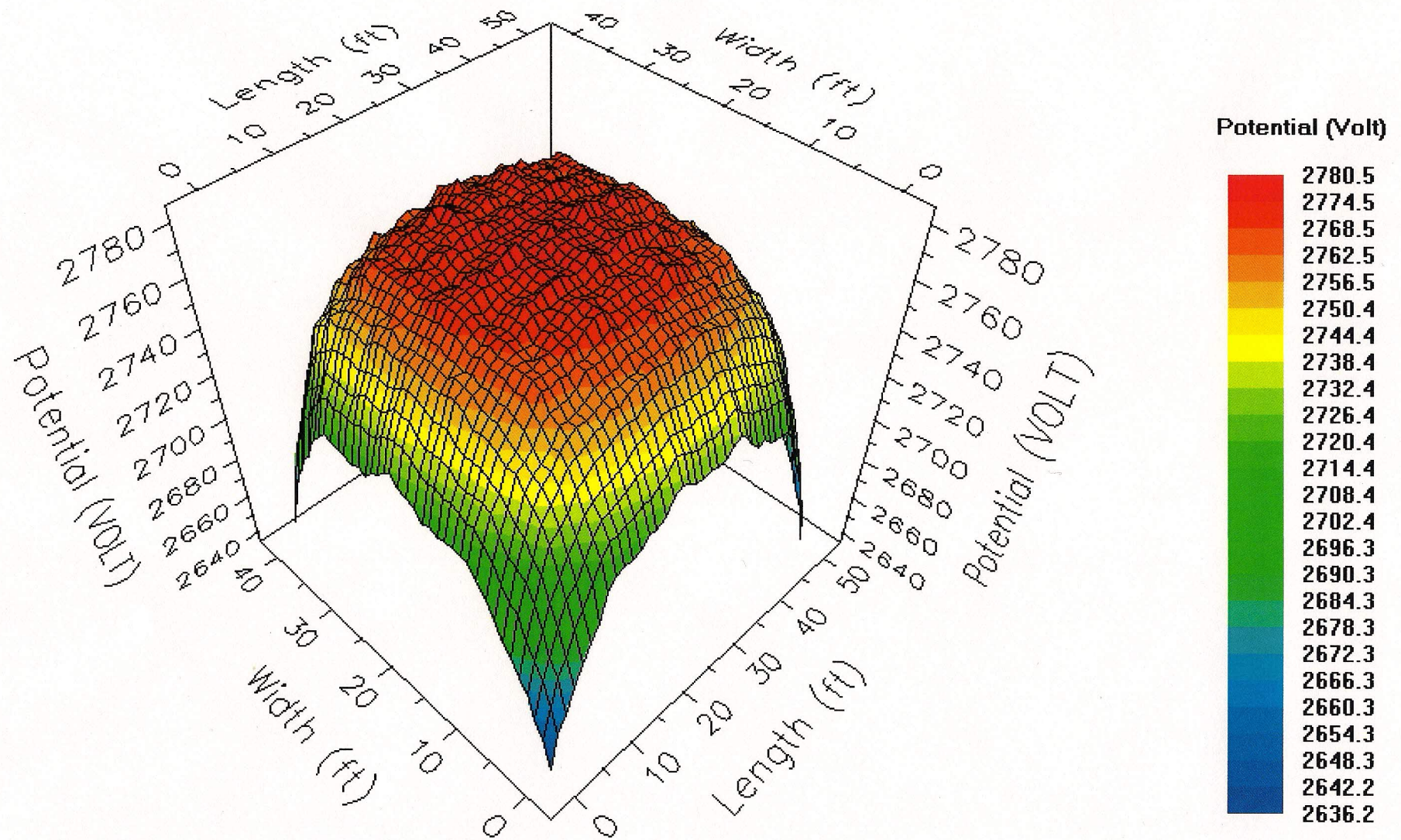




✱ Maximum Touch=797(V), PASS

GPR=3433.8(V) RG=3.43498(ohm) Et=808.226(V) Es=2740.76(V) H=25.653(ft) Rho1=29.255(ohm-m) Rho2=10000(ohm-m)

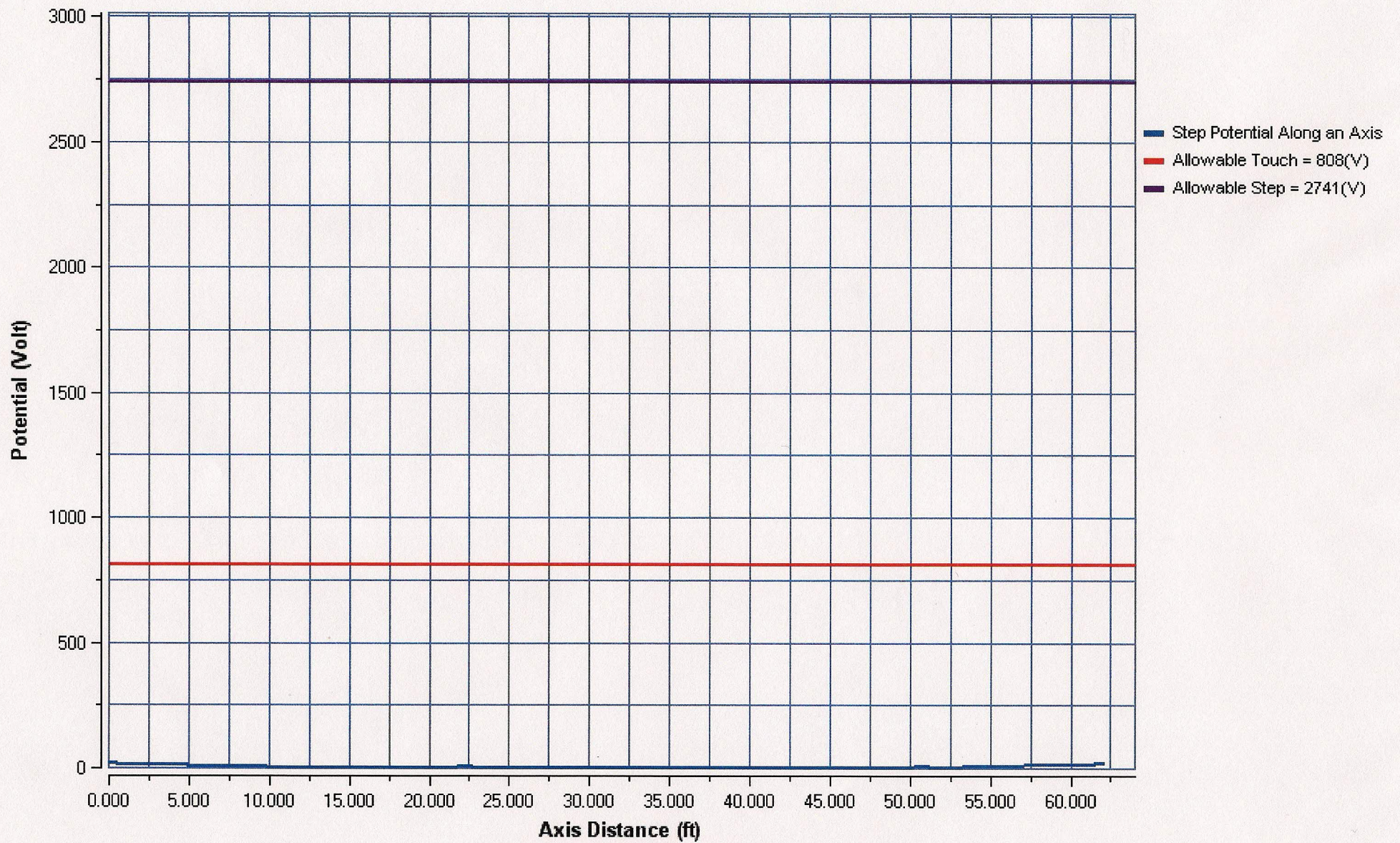




## Absolute Potential 3D Graph for 1500kVA

GPR=3434.27(V) RG=3.43545(ohm) Et=808.226(V) Es=2740.76(V) H=25.653(ft) Rho1=29.255(ohm-m) Rho2=10000(ohm-m)

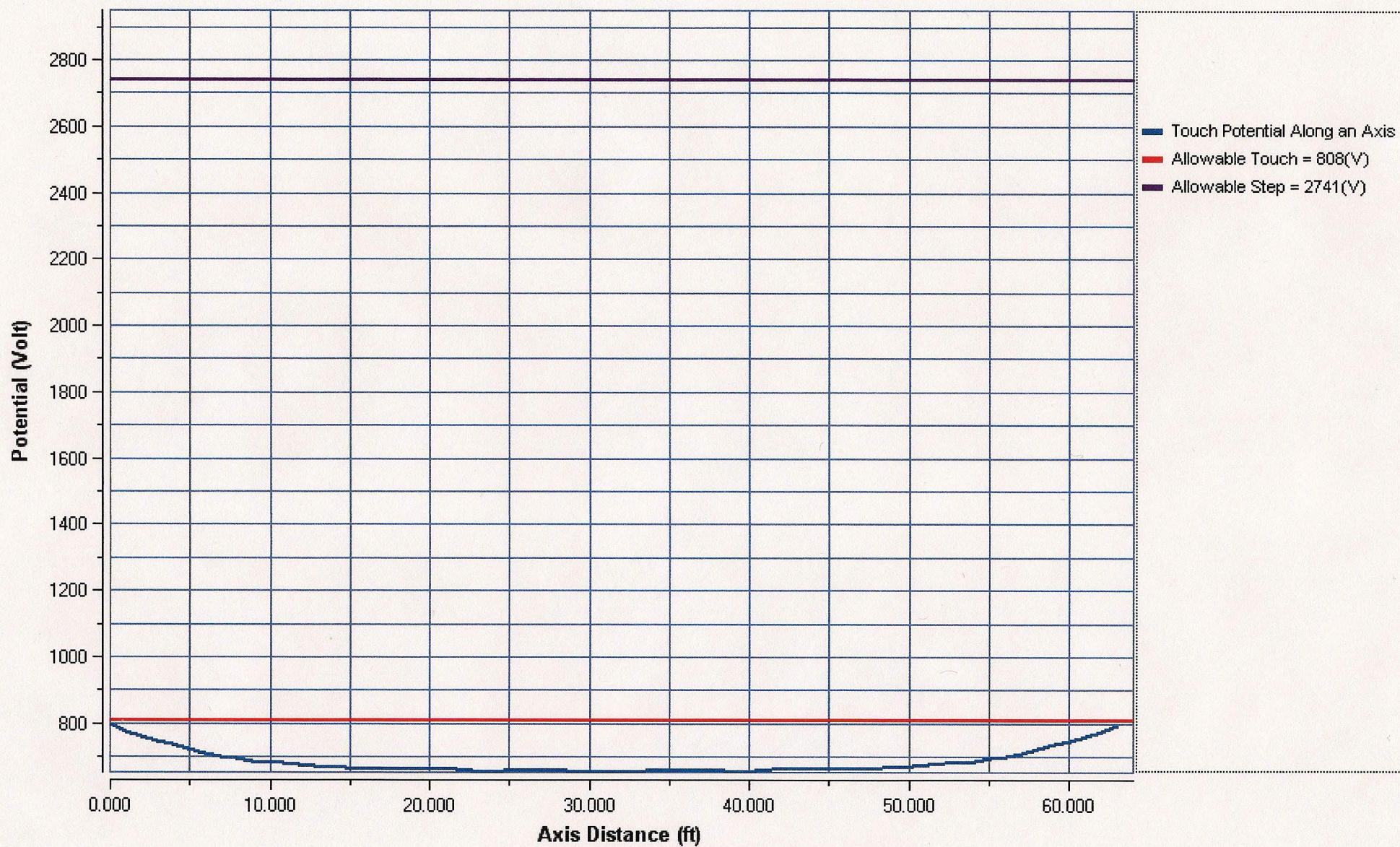




### Step Potential Along an Axis

GPR=3433.8(V) RG=3.43498(ohm) Et=808.226(V) Es=2740.76(V) H=25.653(ft) Rho1=29.255(ohm-m) Rho2=10000(ohm-m)

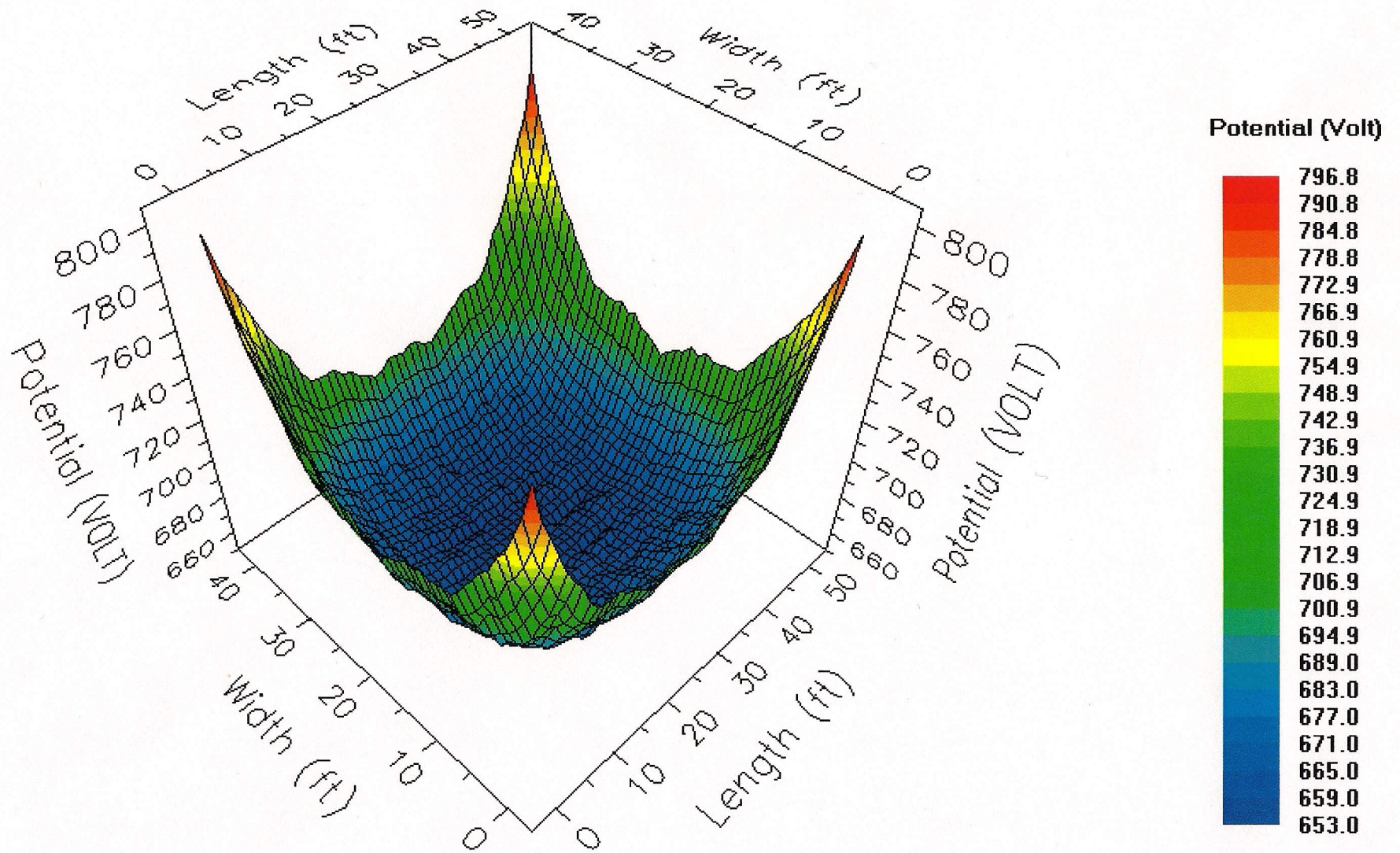




### Touch Potential Along an Axis

GPR=3433.8(V) RG=3.43498(ohm) Et=808.226(V) Es=2740.76(V) H=25.653(ft) Rho1=29.255(ohm-m) Rho2=10000(ohm-m)





## Touch Potential 3D Graph for 1500kVA

GPR=3433.8(V) RG=3.43498(ohm) Et=808.226(V) Es=2740.76(V) H=25.653(ft) Rho1=29.255(ohm-m) Rho2=10000(ohm-m)

**APPENDIX B**

**SOIL RESISTIVITY TEST REPORT FORMS**

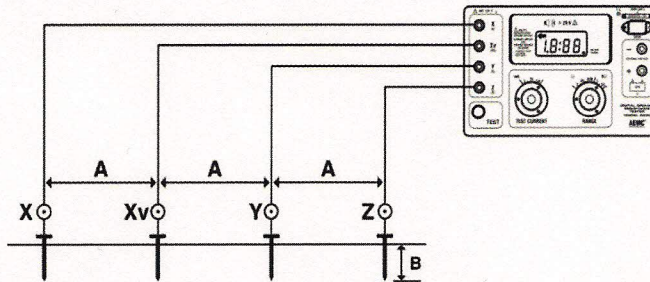


# Soil Resistivity Test

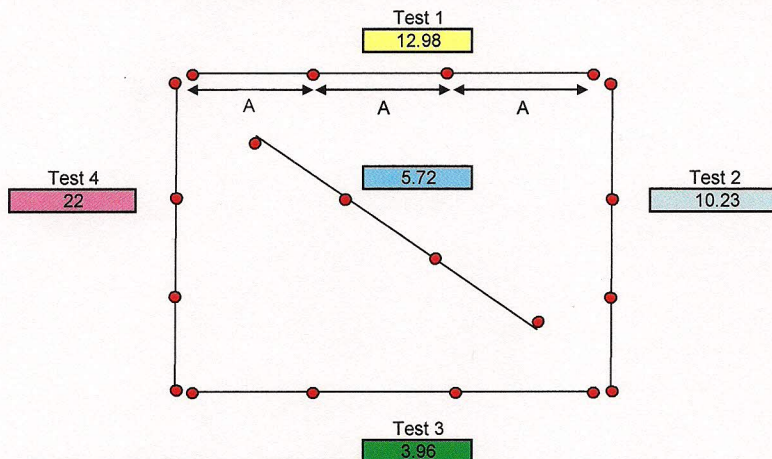
Test Date 5/31/2012

Instrument Mfg. AEMC Operator Name E. Malek  
 Model 4630 Test Location Pittsburgh Institution  
 Serial # 136419CF DV Address \_\_\_\_\_

Test Conditions		
Soil Condition:	<input type="checkbox"/> Moist <input checked="" type="checkbox"/> Dry	Temperature <u>26°C</u>
Soil Type:	<input type="checkbox"/> Clay <input type="checkbox"/> Limestone <input checked="" type="checkbox"/> Sand & Gravel	
	<input type="checkbox"/> Granite <input checked="" type="checkbox"/> Shale <input type="checkbox"/> Sandstone	
	<input type="checkbox"/> Loam <input type="checkbox"/> Slate <input type="checkbox"/> Other _____	



Electrode Spacing (A) 5 ft Electrode depth (B) 10 ft



rho calculation  $\rho = 191.5AR$

	Test Reading	Soil Resistivity
Test	R	$\rho$
1	12.98	12428.4
2	10.23	9795.23
3	3.96	3791.7
4	22	21065
5	5.72	5476.9

Effective soil resistivity: 10511.44  $\Omega$  - cm

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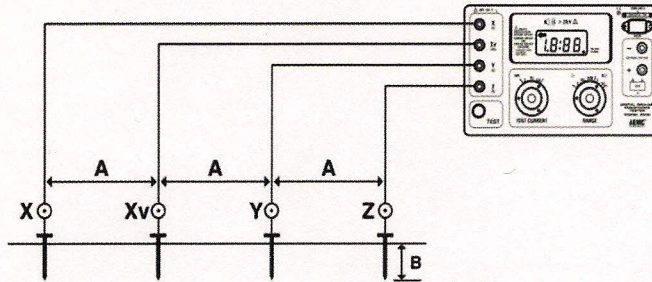


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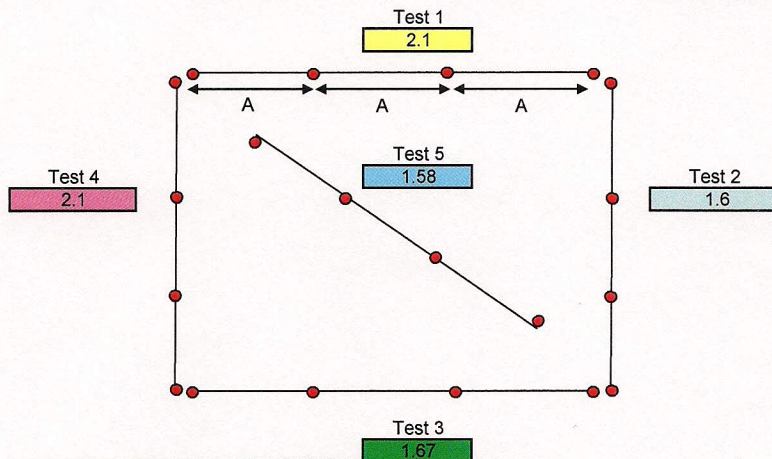
Test Date April 4, 2012

Instrument Mfg. AEMC Operator Name Ed Malek  
 Model 4630 Test Location Proposed site for new 44KV transformer  
 Serial # 136419CF DV Address Pittsburgh Institution, Joyceville

Test Conditions		
Soil Condition:	<input checked="" type="checkbox"/> Moist <input type="checkbox"/> Dry	Temperature <u>10°C</u>
Soil Type:	<input type="checkbox"/> Clay	<input type="checkbox"/> Limestone
	<input checked="" type="checkbox"/> Soil	<input checked="" type="checkbox"/> Sand & Gravel
	<input type="checkbox"/> Loam	<input type="checkbox"/> Shale
	<input type="checkbox"/> Slate	<input type="checkbox"/> Sandstone
		<input type="checkbox"/> Other



Electrode Spacing (A) 10 ft Electrode depth (B) 0.5 ft



rho calculation  $\rho = 191.5AR$

	Test Reading	Soil Resistivity
Test	R	$\rho$
1	2.1	4021.5
2	1.6	3064
3	1.67	3198.05
4	2.1	4021.5
5	1.58	3025.7

Effective soil resistivity: 3466.15  $\Omega$  - cm

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# Soil Resistivity Test

Test Date 5/31/2012

Instrument Mfg. AEMC

Operator Name E. Malek

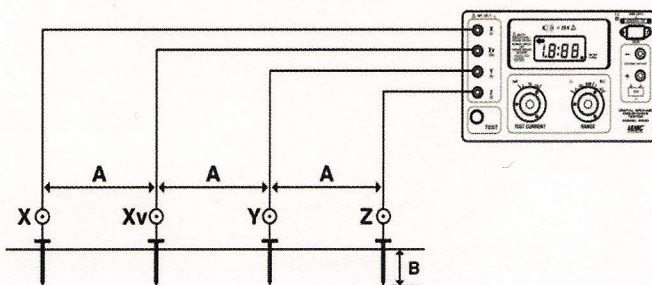
Model 4630

Test Location Pittsburgh Institution

Serial # 136419CF DV

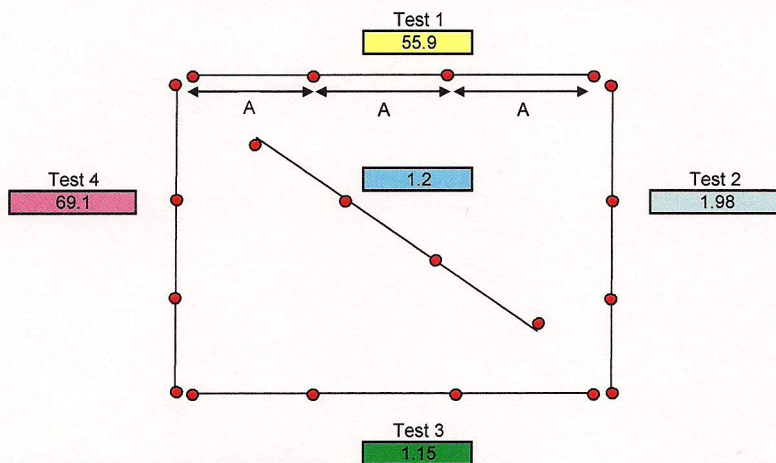
Address \_\_\_\_\_

Test Conditions		
Soil Condition:	<input type="checkbox"/> Moist <input checked="" type="checkbox"/> Dry	Temperature <u>26°C</u>
Soil Type:	<input type="checkbox"/> Clay	<input type="checkbox"/> Limestone
	<input type="checkbox"/> Granite	<input checked="" type="checkbox"/> Sand & Gravel
	<input type="checkbox"/> Loam	<input checked="" type="checkbox"/> Shale
	<input type="checkbox"/> Slate	<input type="checkbox"/> Sandstone
		<input type="checkbox"/> Other _____



Electrode Spacing (A) 15 ft

Electrode depth (B) 10 ft



rho calculation  $\rho = 191.5AR$

	Test Reading	Soil Resistivity
Test	R	$\rho$
1	55.9	160573
2	1.98	5687.55
3	1.15	3303.38
4	69.1	198490
5	1.2	3447

Effective soil resistivity: 74300.09  $\Omega$  - cm

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# Soil Resistivity Test

Test Date 5/31/2012

Instrument Mfg. AEMC

Operator Name E. Malek

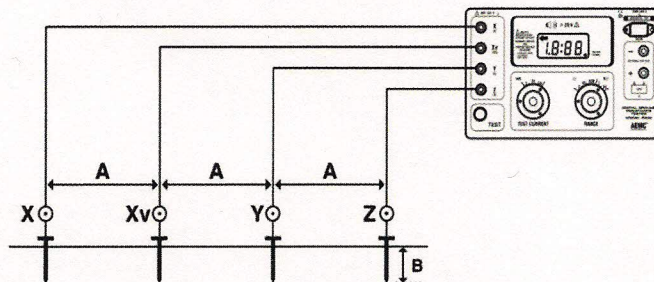
Model 4630

Test Location Pittsburgh Institution

Serial # 136419CF DV

Address \_\_\_\_\_

Test Conditions		
Soil Condition:	<input type="checkbox"/> Moist	<input checked="" type="checkbox"/> Dry
	Temperature <u>26°C</u>	
Soil Type:	<input type="checkbox"/> Clay	<input type="checkbox"/> Limestone
	<input type="checkbox"/> Granite	<input checked="" type="checkbox"/> Shale
	<input type="checkbox"/> Loam	<input type="checkbox"/> Slate
	<input checked="" type="checkbox"/> Sand & Gravel	<input type="checkbox"/> Sandstone
	<input type="checkbox"/> Other	_____

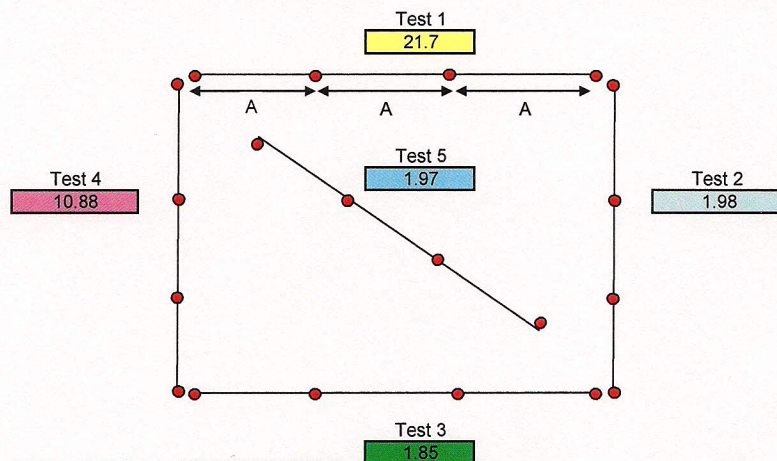


Electrode Spacing (A)

26 ft

Electrode depth (B)

10 ft



rho calculation  $\rho = 191.5AR$

Test	Test Reading R	Soil Resistivity $\rho$
1	21.7	108044
2	1.98	9858.42
3	1.85	9211.15
4	10.88	54171.5
5	1.97	9808.63

Effective soil resistivity:

38218.80  $\Omega$  - cm

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Tel: (613) 224-1588

## **APPENDIX C**

### **SUPPLY POINT SHORT CIRCUIT LEVEL & IMPEDANCE DATA**





## Hydro One Networks - Supply Point Short Circuit Level & Impedance Data

**Customer/Location :** Correctional Services - Pittsburgh Institution 3766 Hwy 15, Joyceville (new tap)

**Supply Station :** Frontenac TS

**Supply Circuit :** M1

**Supply Voltage (Nominal) :** 44 kV

### Existing Short Circuit Values

	<u>Maximum</u>	<u>Minimum</u>
3 Phase Amps :	1830 A	1542 A
L-L Amps :	1585 A	1336 A
L-G Amps :	1006 A	835 A
Z1 :	5.942 + j 13.3104	6.0059 + j 15.3374
Z0 :	9.8744 + j 49.8685	10.0448 + j 57.899
X1/R1 :	2.24	2.55
X0/R0 :	5.05	5.76

Notes: 1. Impedances are in  $\Omega$

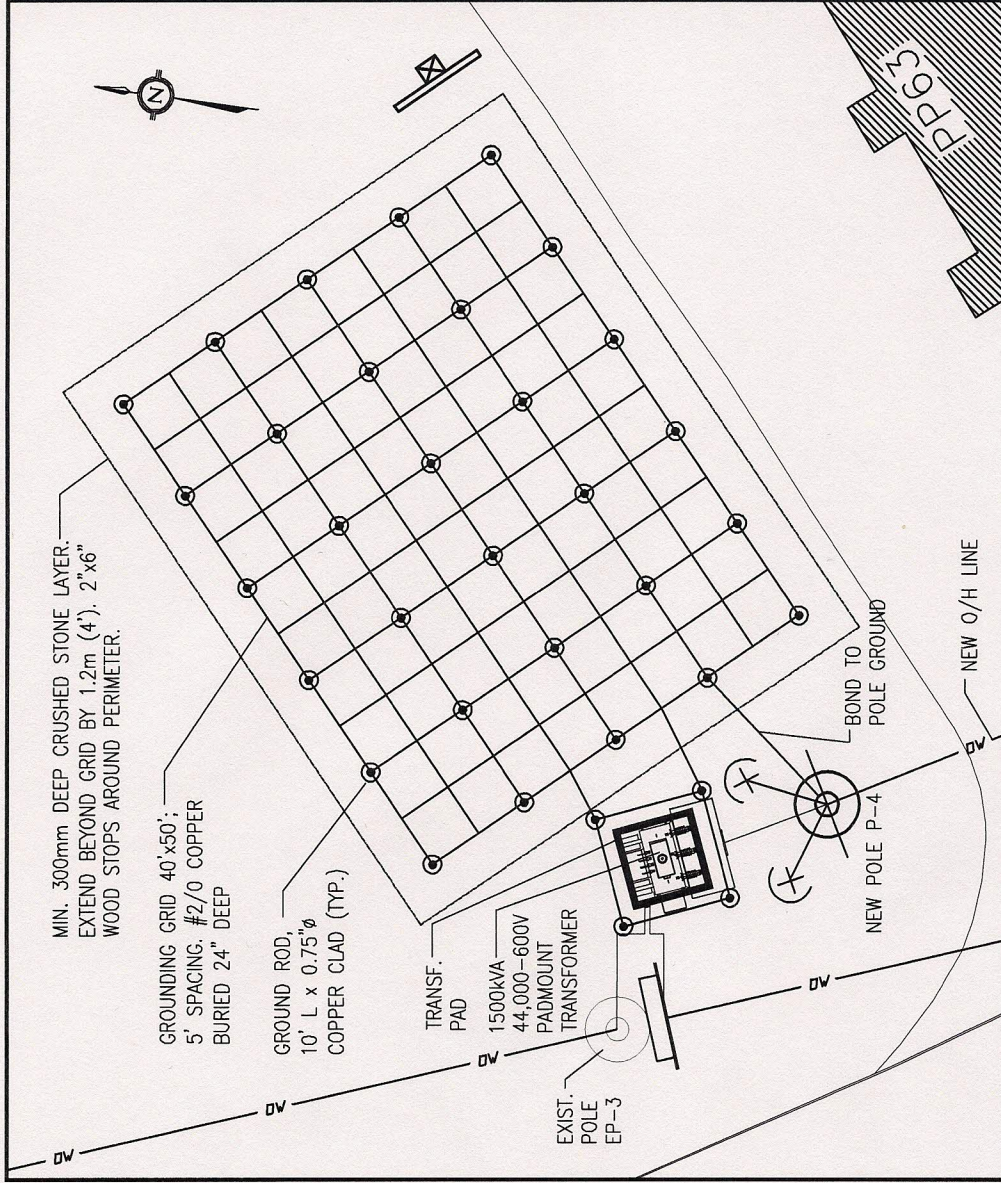
2. Short Circuit values and impedances represent system conditions at the time of the study, and are subject to change without notice.

3. Supply voltage set to 1.0 per unit for "Min" Source, 1.05 per unit for "Max" Source

Calculated by : Name: Antony Ivtiminov  
Position: DLT  
Date: June 27, 2012

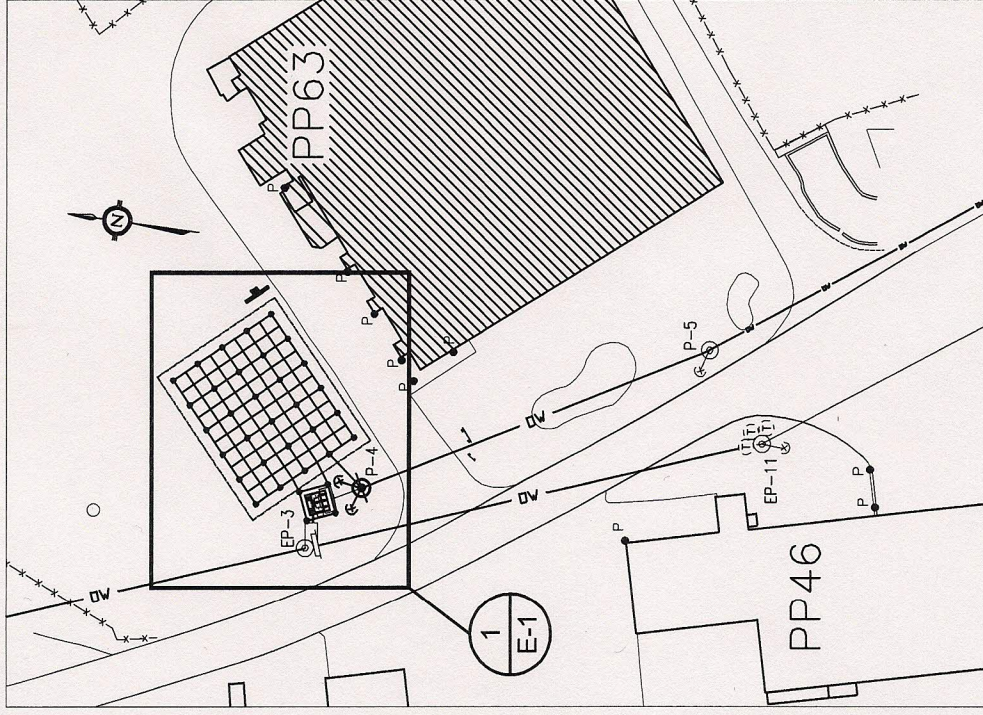
Rev: Sept 2008





1 GROUND GRID LAYOUT

E-1 SCALE 1:200



2 KEY PLAN

E-1 SCALE 1:750

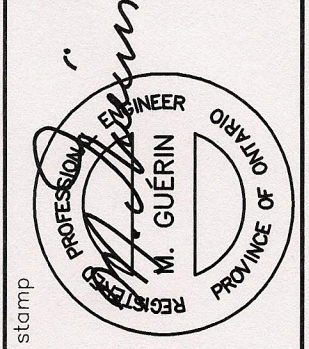
consultant

**ELECTRICAL ENGINEERING**

**CARRARA**

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project <b>PITTSBURGH INSTITUTION</b> JOYCEVILLE, ONTARIO	scale AS NOTED	designed P.G.N.	drawing <b>1500kVA SUBSTATION GROUNDING</b>
	drawn B.N.	checked M.G.	date JULY 09, 2012 project no. NORR-2012-01 drawing no. <b>E-1</b>