CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES

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Degree of Master of Science

By

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Declaration

The work submitted in this thesis is the result of my own investigations except where otherwise stated.

This subject has not been accepted for any degree, and is also not being concurrently submitted for any other degree by me or any other individual.

UOM Verified Signature

K.K. Shyamali

I endorse the declaration by the candidate.

UOM Verified Signature *UOM Verified Signature*

8/10/2010

Prof. J.R. Lucas Eng. W.D.A.S. Wijayapala

TABL E OF CONTENTS

Abstract

With the increasing demand for electricity supply and the country development,

Searching of Transmission Line corridor across populated areas is a major difficulty faced by the utility company. Further, most of the funding agents are very much concerned about the environmental impacts due to the constructions.

The width of Transmission Line corridor is proposed for two different Transmission Voltages and the sharing of single corridor for more lines and the required widths are proposed. Possibility of building construction and planting of trees within the Transmission Line corridor is decided and the maximum heights for constructions are also proposed.

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Also, I thank my colleagues in the Transmission Design branch of Ceylon Electricity Board very much for providing assistance in numerous ways to carry out the studies of the project.

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List of Figures

List of Tables

List of Annexes

Chapter - 1

Introduction and Scope

1.1 Introduction

Electricity is a basic need for the economic growth of any country. Therefore the electricity demand grows at a higher rate with the rapid development of the economy. To meet the increasing demand for electricity, addition of new generation capacity to the system is required. Similarly, transmission of electricity is also increased. Therefore, construction of new transmission lines is an increasing requirement. Searching of Transmission Line corridor is the major difficulty faced by the utility company, because of the crossings across forest reservations and populated area are very much considered at the initial environment approval. Further, most of the funding agents are very much concerned about the environmental impacts due to the constructions.

Similarly, at the initial stage of building constructions, the land owners are to get the approval from the relevant Pradeshiya Sabha to construct buildings in the close vicinity of Transmission Lines. Then the minimum clearance to buildings and other structures should be considered by the Pradeshiya Sabha.

1.2 Background

Horizontal clearance to buildings and other structures, right-of way width and sharing of same corridor are common concepts in other countries.

The design of Transmission Lines is done by the Transmission Design Branch in Ceylon Electricity Board (CEB) in Sri Lanka. Electrical clearance to objects vertically in the close vicinity of Transmission Line is taken into consideration at the design stage of Transmission Lines.

However, there are no defined values and ways to keep horizontal clearance to objects yet. When people construct buildings close to Transmission Lines, relevant Pradeshiya Sabha usually asks from CEB about the required minimum horizontal distance from Transmission Line to buildings before giving the approval for the construction of buildings. But currently in CEB, there are no defined and accepted values or methods of estimating this distance.

The horizontal clearance to buildings issue came into consideration of Transmission Design Branch at the implementing stage of Kerawalapitiya - Kotugoda 220kV Transmission Line.

Further, Asian Development Bank (ADB) asked for the required width of line corridor to have two adjacent tower lines of different voltages and width of single corridor at the evaluation stage of the scope of works to allocate funds for year 2008. But, CEB (Transmission Design Branch) did not give any specific answer since there was no specification and no detailed study had been done on the issue.

1.3 Goal

The horizontal clearance issue comes under several application areas. Horizontal clearance depends on the system voltage, type of conductor, objects like buildings, other supporting structures and other installations etc. Therefore, the objective of this project is to identify and study different application categories and introduce a method:

- To define horizontal clearances to buildings and other structures from Transmission Lines.

The right-of-way width is also have to be considered under several application areas like the system voltage, type of conductor, surroundings of the route such as one or more lines of structures on a single right-of-way etc. Therefore, under this project different application categories for right-of-way width are to be identified and studied on width of corridor accordingly. Ultimately introducing a method:

- To specify width of Transmission Line Corridor for new Transmission Lines

Chapter - 2

Problem Identification

2.1 Minimum Horizontal Clearance to Buildings and Other Structures

There should be a minimum separation distance, required to ensure safe operation of human beings and other objects together with Transmission Line in the close proximity of Transmission Lines.

The Horizontal clearances are to be applied for the displaced conductors from rest. To count the total safe distance from conductor attachment point, blowout of the conductor and the insulator string has to be taken in to consideration.

In order to provide an additional cushion of safety, higher values can be kept other than the minimum Electrical Clearance.

2.1.1 Minimum Horizontal Clearance to Buildings

The Technical Specification of Ceylon Electricity Board (CEB) for Transmission Lines does not specify horizontal clearance to buildings. Only the vertical clearances are specified. But, it is necessary to specify the horizontal clearance values for the implementation of Transmission Lines. The following figure simply gives the idea of minimum Horizontal Clearance.

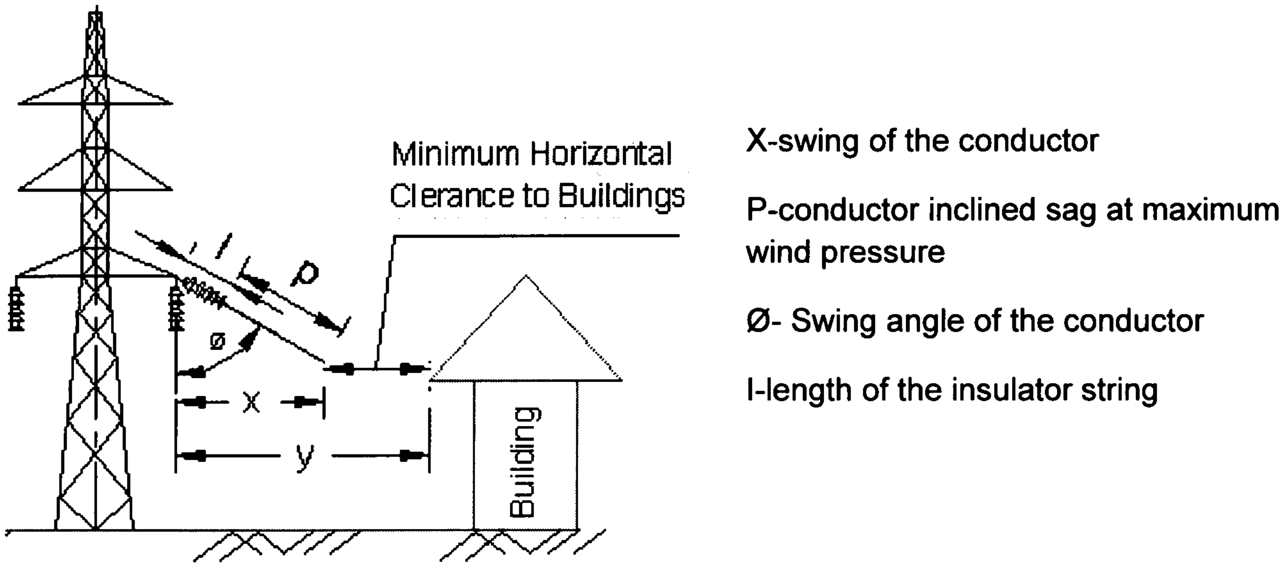


Figure 2-1: minimum horizontal clearance for buildings

When people are going to construct buildings in the close proximity of Transmission Lines, the relevant Pradeshiya Sabha asks CEB (Transmission Design Branch) about the required distance from the existing Transmission Lines. Currently, CEB specifies the required vertical clearance but no horizontal clearance is defined.

2.1.2 Minimum Horizontal Clearance to Other Structures

As was discussed under clause 2.1.1, Horizontal clearance to other structures is also necessary to be defined. For that, it is necessary to categorise the type of objects according to the requirement. The safety is the major consideration for Horizontal Clearance.

2.2 Right-of-Way (ROW) Width

For Transmission Lines, a right-of-way provides an environment, which allows the line to be operated and maintained safely and reliably. Determination of the right-of-way width is a task that requires the consideration of a variety of judgmental, technical, and economic factors.

Funding agencies who are more concerned about environmental impact is inquiring for these distances before allocating funds for the project. Recently this issue was raised before the fund allocation for 2008 projects by Asian Development Bank

(ADB). However Transmission Design Branch did not specify any value since there was no study had been done on this clearance.

2.3 Vegetation Management

Fires or electrical hazards and accidents can occur if vegetation is not controlled or cleared around overhead electricity power lines, resulting in serious risks to people and property and significant cost to CEB.

However, there is no vegetation management properly specified in CEB. Different project handlers are using different width of way leaves but there is no standard specification.

Further, it is necessary to manage proper maintenance of vegetation considering the safety of humans, maximum utilization of private lands and non-interruption of power supply.

2.4 Effects from Magnetic and Electric Fields

There are worldwide concerns to hazards caused due to the electro magnetic radiation from Transmission Lines. However, there are constructions under existing lines and no recommended limits for magnetic and electrical fields exist.

2.5 Objective

The objective of this project is to study the Horizontal Clearance to buildings and other objects, Right-of-Way Width for Transmission Lines, effects from Magnetic Field radiation considering the hazards due to field effect and the possibility of planting trees with different heights within ROW.

2.6 Sources of Data

In order to accomplish the goal, data was collected from following sources.

- Technical Specifications – Transmission Line, Ceylon Electricity Board
- www.windfinder.com
- Wind Energy Resource Atlas of Sri Lanka and the Maldives by D. Elliott, M. Schwartz, G. Scott, S. Haymes, D. Heimiller, R. George National Renewable Energy Laboratory
- Master Plan Study for Development of the Transmission System of Electricity Board, Nippon Koei Co., Ltd, Tokyo, Japan, Final Report, Appendix, January 1997.
- List of Towers, Mathugama – Ambalangoda 132kV Transmission line, Power Sector Development Transmission Project – Lot B

Chapter - 3

Methodology

3.1 Methodology of Calculation of Conductor Horizontal Displacement

The conductor horizontal displacement can be calculated using simple trigonometric theory. The following figure shows the simple idea of conductor horizontal displacement. According to the figure, the conductor horizontal displacement can be calculated by considering the inclined sag of the conductor and blowout length of insulator string at maximum wind pressure.

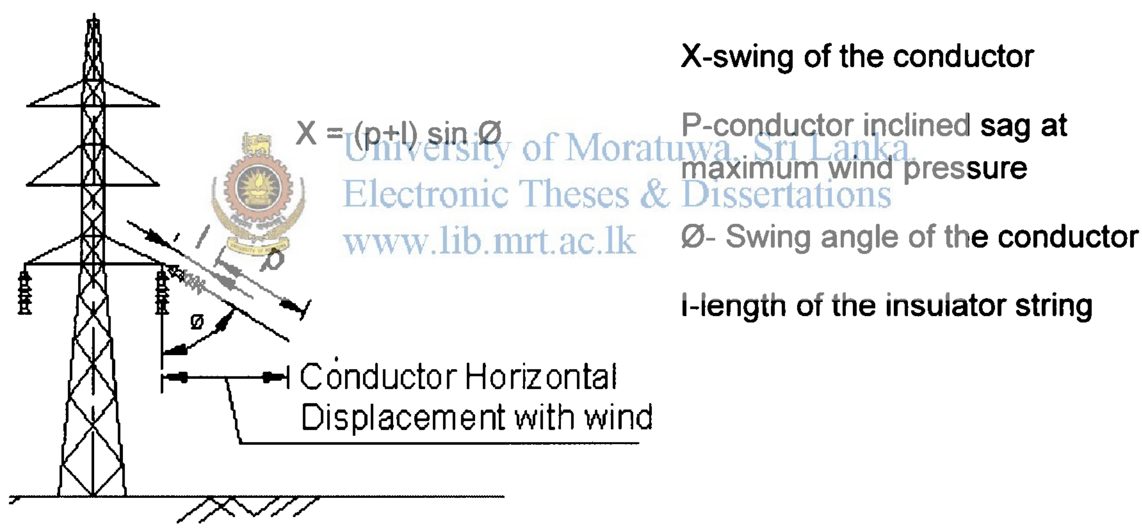
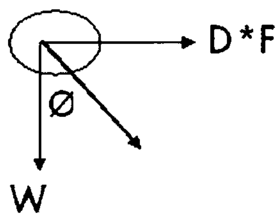


Figure 3-1: Conductor Horizontal Displacement

It is necessary to calculate the conductor swing angle to derive the horizontal displacement assuming that the conductor swing angle is same as the insulator swing angle.

3.1.1 Methodology of Calculation of Swing Angle

Simply, the swing angle can be calculated as shown below considering the horizontal and vertical forces on the conductor.



Swing Angle, $Ø = Tan^{-1}(d*F/w)$

Where:

D- Diameter of the conductor
F-Wind Pressure
W-Weight of the conductor

Figure 3-2: Conductor Swing Angle

3.1.2 Methodology of Calculation of Conductor Sag

The conductor sag is dependent on several factors which are listed below.

1. Equivalent span
2. Wind pressure
3. Operating temperature
4. Conductor properties
    - Diameter of conductor
    - Total cross sectional area
    - Modulus of elasticity
    - Linear coefficient of expansion
    - Ultimate breaking strength
    - Weight of the conductor per meter

➢ ***Equivalent span***

This is the weighted average or equivalent design span between two dead end supports. This span is useful when selecting appropriate template for a given section.

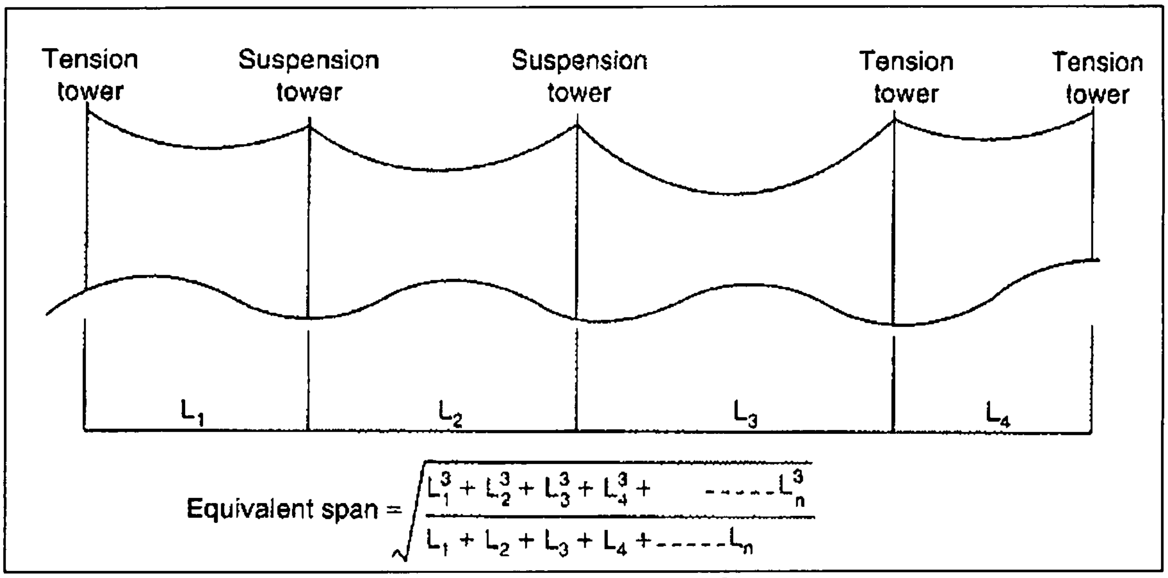


Figure 3-3: Equivalent Span

The Technical Specification of Transmission Line defines different equivalent span for different operating voltages of the line as shown below.

132kV		220kV	
Equivalent Span	***Applicable Range***	***Equivalent Span***	***Applicable Range***
200	176-275	150	126-225
300	276-375	250	226-325
400	376-475	350	326-425
500	476-575	450	426-525

Table 3-1: Defined Equivalent Span in CEB

The calculation of conductor vertical or inclined sag is necessary to be discussed in two steps, since the conductor maximum sag is calculated using the formula and the sag at any other point is determined from the coordinates of the catenary curve. Therefore, the following steps are to be taken into consideration. The horizontal displacement of the conductor is also necessary to be discussed accordingly.

I. The conductor sag at mid-span for specific equivalent span

II. Calculation of Conductor Sag at Spans other than mid-span for specific equivalent span

➢ *Wind pressure*

The Technical Specification for Transmission Line defines maximum wind pressure which is to be used for Transmission Line Design.

➢ *Temperature*

Technical Specification for Transmission Line defines the minimum, everyday and maximum operating temperatures. However, the temperatures and wind pressure are same for any operating voltage.

➢ *Conductor properties*

If we take one operating voltage say 132kV, the first three factors are same and the properties of the conductor can be different. If we take same type of conductor say ZEBRA, there can be minor difference based on the manufacturer. Therefore, the study was carried out to observe the sag difference for the change of parameters of same conductor type. The conductor properties of ZEBRA conductor which, used for Horana Grid Substation Project, Kerawalapitiya Kotugoda Transmission Project and Power Sector Development Project is used.

The properties of Zebra Conductor against operating Voltage are shown in the following table.

Operating Voltage	132kV		220kV
Project	PSDTP	HGSSP	KKTP
Diameter of conductor/ mm	28.62	28.62	28.62
Total cross sectional area/ mm^2	484.4	484.4	484.48
Modulus of elasticity/ N/mm^2	69000	69000	75001
Linear coefficient of expansion/ per °C	1.95E-05	1.95E-05	2.06E-05
Ultimate breaking strength/ N	130320	130320	14021
Weight of the conductor per meter/ kg/m	1.632	1.631	1.564

Table 3-2: Conductor Properties

However, the calculations showed that the minor difference in parameter doesn't make a major difference in conductor sag and that difference is in the range of 10-20mm range. When the sign value of that difference is taken for the calculation of horizontal displacement, then the effect is further reduced. Therefore, the effect from the minor difference of conductor parameters of same conductor type for the same operating voltage is considered as negligible. But if the operating voltage is different there is a considerable difference in following parameters of the conductor and it makes considerable difference in conductor sag.

- Modulus of elasticity
- Linear coefficient of expansion
- Ultimate breaking strength
- Weight of the conductor per meter

Therefore, it is understood that it is necessary to develop drawings for different equivalent spans at same operating voltage and different conductor types like Lynx, Zebra and Goat. Also the same has to be repeated for different operating voltages. However, currently CEB uses Zebra conductor for new construction due to the higher current carrying capacity of the conductor. But most of the existing lines are Lynx or Goat conductor. Therefore, it is necessary to study the same for Lynx, and Goat conductor since it is required to specify the clearance from existing lines to new constructions. However, as we discussed above, some of the conductor properties vary from manufacture to manufacture. Therefore, for the calculations, the properties of the existing conductors are required, but the required data is not available at most of the time. Further, different line have been designed for different maximum operating voltages like 54°C and 75°C.Therefore, it is not going to be addressed about the clearance for Lynx and Goat conductors. However, we can keep the same clearance as Zebra conductor even for Goat and Lynx conductors since the conductor sag for lynx or Goat conductor is lower than Zebra conductor.

3.1.2.1 Methodology of Calculation of Conductor Sag (at Mid-Span)

The calculation of conductor sag is based on several steps. Here, it is necessary to calculate conductor sag at maximum operating temperature without wind pressure and inclined sag at maximum wind pressure and 15°C (the derivation of this temperature is discussed later in this Chapter). A sample calculation is shown below.

Conductor Data (ZEBRA)

Diameter of conductor	*d*	=	28.62	mm
Total cross sectional area	*A*	=	484.4	mm²
Modulus of elasticity	*E*	=	69000	N/mm²
Linear coefficient of expansion	*α*	=	1.95E-05	per °C
Ultimate breaking strength	*UBS*	=	130320	N
Weight of the conductor per meter	*w*	=	1.632	kg/m

Condition Data

Minimum Temperature	=	7	*deg C*
Dynamic wind pressure	=	970	N/m²
Equivalent Span	=	300	m
Final Temperature	=	75	*deg C*
Initial factor of safety	=	2.5	
Final Factor of safety	=	4.5	

Wind Force on Conductor, P_f = $970*28.62*10^{-3}$ N/m

= 27.76 N/m

Loading factor with wind at given Temperature, = (P2+w2)1/2/w

= 2.0

Loading factor without wind at max temp = $(P^2+w^2)^{1/2}/w$

= 1.0

Max Allowable working Tension of the conductor = UTS/2.5

= 52128 N

Max Allowable stress on conductor, *f1* = $\frac{52128}{484.4}$

= 107.61 N/mm²

Weight of the conductor with grease, δ = 0.033 N/m/mm^2

Then working stress, *f2* can be determined by following formula

$$f_2^2\left[f_2-\left(f_1-\frac{a^2.\delta^2.Q_1^2.E}{24.f_1^2}-\alpha.t.E\right)\right]=\frac{a^2\delta^2.Q_2^2.E}{24}$$

where:

f_1 - Max Allowable stress on conductor

E - Modulus of Elasticity

a - Equivalent Span

t - Temperature Difference

α- Linear coefficient of expansion

Case 1: sag at 75°C without wind load

t = (75-7) °C

= 68 °C

$$f_2^2\left[f_2-\left(f_1-\frac{a^2.\delta^2.Q_1^2.E}{24.f_1^2}-\alpha.t.E\right)\right]=\frac{a^2\delta^2.Q_2^2.E}{24}$$

Substituting for parameters in above equation, it can be concluded with following expression.

$f_2^3 + 81.609*f_2^2 = 2.82*10^5$

Solving by Newton Raphsan method

f_2 = 46.88852 N/mm²

T = 46.88852*484.4 N

	=	22711.252	N
Sag, D	=	$\frac{300^2*0.033*1}{8*46.88852}$	m
	=	7.9299	m

Case 2: sag at 15°C with wind load

t = (15-7) °C

= 8 °C

$$f_2^2\left[f_2-\left(f_1-\frac{a^2.\delta^2.Q_1^2.E}{24.f_1^2}-\alpha.t.E\right)\right]=\frac{a^2\delta^2.Q_2^2.E}{24}$$

Substituting for parameters in above equation, it can be concluded with following expression.

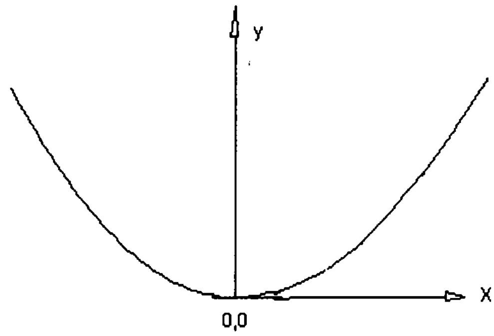
$f_2^3 + 0.94*f_2^2 = 11.32525*10^5$

Solving by Newton Raphsan method

f_2	=	103.92	N/mm²
T	=	103.92*484.4	N
	=	50339.61	N
Sag, D	=	$\frac{300^2*0.033*1}{8*103.92}$	m
	=	7.16	m

3.1.2.2 Methodology of Calculation of Conductor Sag at Spans Other than Mid-Span

The conductor sag along the span is necessary to be taken from the coordinates of the catenary curve. The coordinates of the curve can be calculated by following equation.



$Y=D^*x^2/a^2$
Where:
D-Maximum Sag
X-Distance from maximum sag point
a-Equivalent span

Figure 3-4: Catenary Curve

Here, the maximum conductor sag at mid span is substituted for D. then the coordinates of the curve are taken as the conductor sag at instant points along the span. However, it is important to select the correct equivalent span for the instant span consideration.

The catenary curve coordinates for Zebra conductor were calculated for all the equivalent spans discussed above (Refer Annex 3-1 to Annex 3-4).

3.1.3 Methodology of Calculation of Conductor Horizontal Displacement at Mid-Span

The conductor horizontal displacement can be calculated by considering the inclined sag at maximum wind pressure and coincident temperature taking into account the length of insulator string. Here, the sag is equal to the maximum conductor sag at mid-span for the relevant equivalent span.

3.1.4 Methodology of Calculation of Conductor Horizontal Displacement at Spans Other than Mid-Span

The conductor horizontal displacement can be calculated by considering the inclined sag which is taken from the coordinates of the catenary curve at maximum wind pressure and coincident temperature, taking into account the length of insulator string. However, it is important to discuss this case under following two steps.

- Instant Span is lesser than the equivalent span

- Instant Span is higher than the equivalent span

When the instant spans are shorter than the ruling span, there is no considerable issue of design matters. Therefore, the coordinates of the catenary curve can be taken as the sag of the conductor at any point along the span.

However, when the instant spans are longer than ruling span (say 300m template is used for 310m span), we should consider the same template coordinates for the actual shape of the conductor and we should not consider the template for 310 ruling span.

If we consider the equivalent 300m span, the maximum instant span that can cause to the calculation of equivalent span can be more than 375m (maximum allowable range of span). However, it is too difficult to have that much of span too since the design conditions of the towers are exceeded the allowable limits. Further, study was done on the actual spans of Mathugama – Ambalangoda 132kV Transmission line for the verification of practically possible maximum spans (Refer Annex 3-11).

Finally, maximum instant span of 400m for 300m equivalent span (equal to the basic span of 132kV Voltage) and 450m for 350m equivalent span (equal to the basic span of 220kV voltage) respectively is considered for the calculation of Right-Of-Way width.

Following table gives the easy reference to the calculation of conductor horizontal displacement.

Conductor Horizontal Displacement at 15°C and Maximum wind condition for 132kV ZEBRA Conductor Vs Equivalent Span					
	Length of Insulator String		=	2.289m	
Equivalent Span					
Span		200 m	300 m	400	500 m
x	x/2	Horizontal Displacement	Horizontal Displacement	Horizontal Displacement	Horizontal Displacement
0	0	1.9823	1.9823	1.9823	1.9823
25	12.5	2.0263	2.0254	2.0249	2.0246
50	25	2.1581	2.1546	2.1526	2.1514
75	37.5	2.3778	2.3699	2.3655	2.3628
100	50	2.6853	2.6714	2.6635	2.6588
125	62.5	3.0808	3.0590	3.0467	3.0393
150	75	3.5641	3.5327	3.5150	3.5044
175	87.5	4.1353	4.0926	4.0685	4.0540
200	100	4.7943	4.7386	4.7071	4.6882
225	112.5	5.5413	5.4707	5.4308	5.4070
250	125	6.3761	6.2890	6.2397	6.2103
275	137.5	7.2987	7.1934	7.1338	7.0981
300	150	8.3093	8.1839	8.1130	8.0706
325	162.5	9.4077	9.2606	9.1773	9.1275
350	175	10.5940	10.4234	10.3268	10.2691
375	187.5	11.8682	11.6723	11.5615	11.4952
400	200	13.2303	13.0074	12.8813	12.8058
425	212.5	14.6802	14.4286	14.2862	14.2011
450	225	16.2180	15.9359	15.7763	15.6808
475	237.5	17.8437	17.5294	17.3515	17.2452
500	250	19.5572	19.2090	19.0119	18.8941
525	262.5	21.3587	20.9748	20.7574	20.6275
550	275	23.2480	22.8266	22.5881	22.4455
575	287.5	25.2251	24.7646	24.5039	24.3481
600	300	27.2902	26.7888	26.5049	26.3352
625	312.5	29.4431	28.8990	28.5910	28.4069
650	325	31.6839	31.0954	30.7623	30.5632
675	337.5	34.0126	33.3780	33.0187	32.8040
700	350	36.4291	35.7466	35.3603	35.1294
725	362.5	38.9336	38.2014	37.7870	37.5393
750	375	41.5259	40.7424	40.2989	40.0338
775	387.5	44.2060	43.3695	42.8959	42.6128
800	400	46.9741	46.0827	45.5781	45.2764
Note: the correct equivalent span and the column of x/2 to read the distance from one tower location should be selected because x means the total span between the two towers					

Table 3-3: Conductor Horizontal Displacement Vs Equivalent Span for 132kV

Cordinates of catenary curve at 15°C and Maximum wind condition for 220kV ZEBRA Conductor					
	Length of Insulator String		=	3m	
Equivalent Span					
Span		150 m	250 m	350	450m
x	x/2	Horizontal Displacement	Horizontal Displacement	Horizontal Displacement	Horizontal Displacement
0	0	2.5981	2.5981	2.5981	2.5981
25	12.5	2.6402	2.6390	2.6384	2.6380
50	25	2.7665	2.7619	2.7593	2.7577
75	37.5	2.9770	2.9667	2.9607	2.9572
100	50	3.2717	3.2535	3.2428	3.2366
125	62.5	3.6505	3.6222	3.6055	3.5957
150	75	4.1136	4.0727	4.0488	4.0347
175	87.5	4.6609	4.6053	4.5726	4.5535
200	100	5.2924	5.2197	5.1771	5.1521
225	112.5	6.0081	5.9161	5.8621	5.8305
250	125	6.8079	6.6944	6.6277	6.5887
275	137.5	7.6920	7.5546	7.4740	7.4268
300	150	8.6603	8.4967	8.4008	8.3446
325	162.5	9.7127	9.5208	9.4082	9.3423
350	175	10.8494	10.6268	10.4962	10.4198
375	187.5	12.0702	11.8148	11.6648	11.5771
400	200	13.3753	13.0846	12.9140	12.8142
425	212.5	14.7645	14.4364	14.2438	14.1311
450	225	16.2380	15.8701	15.6542	15.5278
475	237.5	17.7956	17.3857	17.1452	17.0044
500	250	19.4375	18.9833	18.7168	18.5607
525	262.5	21.1635	20.6628	20.3689	20.1969
550	275	22.9737	22.4242	22.1017	21.9129
575	287.5	24.8682	24.2675	23.9150	23.7087
600	300	26.8468	26.1928	25.8090	25.5843
625	312.5	28.9096	28.2000	27.7835	27.5397
650	325	31.0566	30.2891	29.8386	29.5750
675	337.5	33.2879	32.4601	31.9744	31.6900
700	350	35.6033	34.7131	34.1907	33.8849
725	362.5	38.0029	37.0480	36.4876	36.1596
750	375	40.4867	39.4648	38.8651	38.5141
775	387.5	43.0547	41.9635	41.3232	40.9484
800	400	45.7069	44.5442	43.8619	43.4625
Note: the correct equivalent span and the column of x/2 to read the distance from one tower location should be selected because x means the total span between the two towers					

Table 3-4: Conductor Horizontal Displacement Vs Equivalent Span for 220kV

3.2 Minimum Horizontal Clearance

3.2.1 National Electrical Safety Code (NESC) Basic Electrical Clearance

NESC has defined basic clearances which are applicable under some design conditions. There is a defined maximum wind pressure and coincident temperature for the application of horizontal clearance. Therefore, the study on possibility of taking the same clearances at CEB design conditions was carried out.

NESC has defined maximum wind pressure of 290N/m^2 and the temperature of 15°C. However, in CEB the defined maximum wind pressure is 970N/m^2 and there is no temperature defined. However, these two factors are governed by IEC 60826. Therefore, a detail study was carried out based on the IEC 60826.

3.2.1.1 Maximum Wind Pressure

Design wind for the line design, referring to IEC 60826, should be 10 minutes mean wind velocity measured at 10m above ground level as close as to the line. However in Sri Lanka, the Department of Meteorology does not record the wind speed in 10 minutes of time period. Further, they have done recording for a period of 3 Hours and only for few districts; Hambantota, Puttalam and Potuvill. As an alternative we can take maximum yearly wind velocity and corrected to the 10 minutes mean wind velocity and finally, we need to consider unit-action of wind on conductors as per the IEC. Currently defined wind velocity for conductors might be taken in this way.

However, for the verification of the relevant wind velocity, defined wind pressure was calculated as shown below following the IEC.

$½*1.225*V^2$ =970N/m^2 (IEC 60826)

V =40m/s

Then it is nearly equal to 40 m/s.

Further, some wind data with available information in the web links was searched to verify the necessity of such a higher wind speed against practical wind pressure. Then, some data from the link www.windfinder.com/windreports/windreports_online_lk.htm was taken. The data is available for Hambantota, Puttalam, Potuvill and Negambo for the period of 11/2007

- 5/2009 daily from 7am to 7pm local time. According to the data the maximum average wind velocity is about 24m/s in Pottuvill (Refer Annex 3-5). However, the maximum yearly wind velocity can be higher than 24m/s.

The classification of wind speed which is categorized in www.windfinder.com is shown in the following table.

m/s	km/h	Label	Effect on sea	Effects on land
0 - 0.2	1	Calm	Sea like a mirror	Calm. Smoke rises vertically.
0.3-1.5	1.0-5.0	Light Air	Ripples with the appearance of scales are formed, but without foam crests	Wind motion visible in smoke.
1.6-3.3	6.0-11.0	Light Breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break	Wind felt on exposed skin. Leaves rustle.
3.4-5.4	12.0-19	Gentle Breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses	Leaves and smaller twigs in constant motion.
5.5-7.9	20-28	Moderate Breeze	Small waves, becoming larger; fairly frequent white horses	Dust and loose paper raised. Small branches begin to move.
8.0-10.7	29-38	Fresh Breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray	Branches of a moderate size move. Small trees begin to sway.
10.8-13.8	39-49	strong Breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.
13.9-17.1	50-61	Near Gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	Whole trees in motion. Effort needed to walk against the wind. Swaying of skyscrapers may be felt, especially by people on upper floors.
17.2-20.7	62-74	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind	Twigs broken from trees. Cars veer on road.
20.8-24.4	75-88	Severe Gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility	Larger branches break off trees, and some small trees blow over. Construction/temporary signs and barricades blow over. Damage to circus tents and canopies.
24.5-28.4	89-102	Storm	Very high waves with long over-hanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The 'tumbling' of the sea becomes heavy and shock-like. Visibility affected	Trees are broken off or uprooted, saplings bent and deformed, poorly attached asphalt shingles and shingles in poor condition peel off roofs.
28.5-32.6	103-117	Violent Storm	Exceptionally high waves (small and medium-size ships might disappear behind the waves). The sea is completely covered with long white patches of foam flying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected	Widespread vegetation damage. More damage to most roofing surfaces, asphalt tiles that have curled up and/or fractured due to age may break away completely.
32.7-36.9	118-133	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected	Considerable and widespread damage to vegetation, a few windows broken, structural damage to mobile homes and poorly constructed sheds and barns. Debris may be hurled about.

Table 3-5: Classification of Wind Speed in www.windfinder.com

According to the classification, even for Hurricane the wind speed is below 40m/s.

In addition to that the Wind Energy Resource Atlas of Sri Lanka and the Maldives by D. Elliott, M. Schwartz, G. Scott, S. Haymes, D. Heimiller, R. George National Renewable Energy Laboratory was studied. Here the wind speed is classified as shown in following table.

Class	Resource Potential (Utility-Scale)	Wind Power Density (W/m2) @ 50 m agl	Wind Speed (a) (m/s) @ 50 m agl
1	Poor	0 – 200	0.0 – 5.6
2	Marginal	200 – 300	5.6 – 6.4
3	Moderate	300 – 400	6.4 – 7.0
4	Good	400 – 500	7.0 – 7.5
5	Excellent	500 – 600	7.5 – 8.0
6	Excellent	600 – 800	8.0 – 8.8
7	Excellent	> 800	> 8.8

Table 3-6: Classification of Wind Speed in Wind Energy Resource Atlas of Sri Lanka

Wind resource areas of Class 4 and higher are considered suitable for utility-scale wind power development. Therefore, it is understood that CEB has considered wind speed for the line design consideration maintaining some safety factor.

Further, the defined insulator swing angle for the specification of tower body clearance is 40°C as shown in the following figure. The corresponding wind pressure for that swing angle is 470N/m^2 and the wind speed is 28m/s.

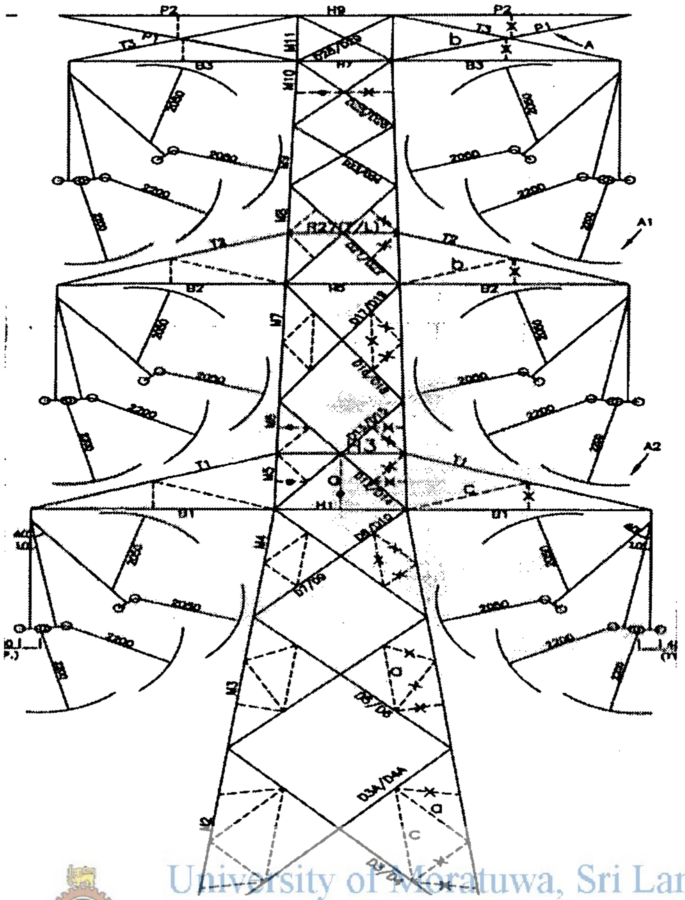


Figure 3-5: Design of Insulator Swing Angle of Tower

However, that is for the safety of CEB property (tower) but if the maximum wind pressure of 970N/m^2 occurred and conductor swing more than the 40°C, public property can be damaged since the towers have been designed for the maximum wind pressure. Therefore, the decision was taken to proceed with the same wind pressure which is currently used for line design in CEB.

However, the wind pressure used in NESC is 290N/m^2. Then, the problem was raised that the possibility of using same basic clearances for 970N/m^2. It was understood that the effect of wind pressure comes for the calculation of conductor horizontal displacement. The probability of occurring maximum wind pressure and maximum swing of the conductor are the factors which affects the object safety. Therefore, there is no issue of using same basic clearance.

3.2.1.2 Coincident Temperature

The wind velocity discussed above shall be considered as occurring at an air temperature equal to the average of the minimum daily temperatures peculiar to the site as per the IEC. The average minimum daily temperature may be obtained by means of analysis of the recordings over a certain number of years in a meteorological department as close as possible to the location of the line.

As an alternative it would be possible to take as a coincident air temperature which is minimum temperature increased by 15°C as per the IEC 60826 recommendation since we have used the alternative method for the calculation of maximum wind pressure. Minimum temperature should be considered as being equal to the minimum yearly value having a probability of occurrence of 2% or return period of 50 years. If the minimum possible temperature is accepted as 0°C the coincident temperature for maximum wind Pressure is 0°C+15°C (=15°C). The NESC also might use minimum temperature as 0°C and then the Coincident Temperature is as 15°C.

3.2.2 Additional Clearances based on Maximum Operating Voltage

NESC has defined the clearances for the voltages up to phase voltage of 22kV. The additional clearances based on maximum operating voltage are necessary to be added to the basic clearance values according to the guidelines given by the NESC. The following sample calculation shows how we can calculate the additional clearance.

Nominal system voltage between phases	=	132kV
Maximum Operating Voltage	=	145kV
Additional Clearance	=	$(145/\sqrt{3}-22)*10mm$
	=	0.6m

3.2.3 NESC Type Of Objects

Basic clearances for different object are defined in NESC. Therefore, required categories for Sri Lanka were selected. As an example NESC has defined clearances for Grain bins, but the requirement of those clearances for Sri Lanka is not necessary. The selected types of objects are as follows.

- Buildings, walls, balconies and areas which are accessible to pedestrians
- Other Installations not classified as buildings like TV antennas, Tanks etc
- Swimming Pools
- Rail Tracks
- Conductors and wires from other supporting structures
- Bridges

Following table shows the adapted basic clearances for objects at different voltages.

Horizontal Clearance to objects from 132kV Lines

Object	Condition	NESC basic clearance for V_p=22kV/(m)
Buildings, walls, balconies and areas which are accessible to pedestrians	at Rest, max Temp	2.3
	With wind	1.4
Other Installations not classified as buildings like TV antennas, Tanks etc	at Rest, max Temp	2.3
	With wind	1.4
Unguarded accessible parts of Bridges	at Rest, max Temp	2.3
	With wind	1.4
Unguarded inaccessible parts of Bridges	at Rest, max Temp	2.0
	With wind	1.4
Conductors and wires from other supporting structures	at Rest, max Temp	1.5
	With wind	1.4

Table 3-7: National Electrical Safety Code Basic Clearance

Horizontal Clearance to Rail Cars and Swimming pools from 132kV Lines

Object		NESC basic clearance for V_p=22kV/(m)
Swimming Pools	Any direction from water level	7.6
	Any direction from fixed pool related structures	5.2
Rail Cars	Nearest Rail	3.5

Table 3-8: National Electrical Safety Code Basic Clearance

Horizontal Clearance to objects from 220kV Lines

Object	Condition	NESC basic clearance for V_p=22kV/(m)
Buildings, walls, balconies and areas which are accessible to pedestrians	at Rest, max Temp	2.3
	With wind	1.4
Other Installations not classified as buildings like TV antennas, Tanks etc	at Rest, max Temp	2.3
	With wind	1.4
Unguarded accessible parts of Bridges	at Rest, max Temp	2.3
	With wind	1.4
Unguarded inaccessible parts of Bridges	at Rest, max Temp	2.0
	With wind	1.4
Conductors and wires from other supporting structures	at Rest, max Temp	1.5
	With wind	1.4

Table 3-9: National Electrical Safety Code Basic Clearance

Horizontal Clearance to Rail Cars and Swimming pools from 220kV Lines

Object		NESC basic clearance for V_p=22kV/(m)
Swimming Pools	Any direction from water level	7.6
	Any direction from fixed pool related structures	5.2
Rail Cars	Nearest Rail	3.5

Table 3-10: National Electrical Safety Code Basic Clearance

3.2.4 Clearance Adder

In some countries they use some country defined clearance adder too for higher safety. Therefore, the way that CEB has defined vertical clearances against the NESC was studied. In the case of vertical clearance, CEB defined values are directly related to the NESC clearances. Further, in some cases CEB have not added the additional clearance too. Therefore, it is not sure that CEB followed NESC or some other country defined values. In addition to that, CEB has added 0.3m of additional clearance for survey error. Therefore, the decision was taken not to use clearance adder except the survey error. This can be considered as some sort of clearance adder.

3.2.5 Recommended Total Horizontal Clearance

The total horizontal clearance to object is equals to the addition of NESC basic clearance and calculated additional clearance. Total clearance is taken by following Equation as we discussed earlier.

Total Clearance = NESC Clearance for V_p =22kV + NESC Additional Clearance

0.3m of survey error is necessary to be added for all the clearance values obtained from above equation.

According to clause 3.2.3, it can be seen that in some cases we have to keep different clearances based on different objects. The following tables shows the relevant clearances based on different type of conductors, spans, voltage level and type of objects etc.

Horizontal Clearance to objects from 132kV Lines

Object	Condition	NESC basic clearance for V_p=22kV/(m)	Additional Clearance V_{LL}=132kV/(m)	Clearance Adder/m	Total Clearance/m
Buildings, walls, balconies and areas which are accessible to pedestrians	at Rest, max Temp	2.3	0.6	0.3	3.2
	With wind	1.4	0.6	0.3	2.3
Other Installations not classified as buildings like TV antennas, Tanks etc	at Rest, max Temp	2.3	0.6	0.3	3.2
	With wind	1.4	0.6	0.3	2.3
Unguarded accessible parts of Bridges	at Rest, max Temp	2.3	0.6	0.3	3.2
	With wind	1.4	0.6	0.3	2.3
Unguarded inaccessible parts of Bridges	at Rest, max Temp	2.0	0.6	0.3	2.9
	With wind	1.4	0.6	0.3	2.3
Conductors and wires from other supporting structures	at Rest, max Temp	1.5	0.6	0.3	2.4
	With wind	1.4	0.6	0.3	2.3

Table 3-11: Minimum Horizontal Clearance to objects 132 KV

Horizontal Clearance to Rail Cars and Swimming pools from 132kV Lines

Object		NESC basic clearance for V_p=22kV/(m)	Additional Clearance V_{LL}=132kV/(m)	Clearance Adder/m	Total Clearance/m
Swimming Pools	Any direction from water level	7.6	0.3	0.3	8.5
	Any direction from fixed pool related structures	5.2	0.6	0.3	6.1
Rail Cars	Nearest Rail	3.5	0.6	0.3	4.4

Table 3-12: Minimum Horizontal Clearance to Rail Cars- 132 KV

Horizontal Clearance to objects from 220kV Lines

Object	Condition	NESC basic clearance for V_p=22kV/(m)	Additional Clearance V_{LL}=220kV/(m)	Clearance Adder/m	Total Clearance/m
Buildings, walls, balconies and areas which are accessible to pedestrians	at Rest, max Temp	2.3	1.2	0.3	3.8
	With wind	1.4	1.2	0.3	2.9
Other Installations not classified as buildings like TV antennas, Tanks etc	at Rest, max Temp	2.3	1.2	0.3	3.8
	With wind	1.4	1.2	0.3	2.9
Unguarded accessible parts of Bridges	at Rest, max Temp	2.3	1.2	0.3	3.8
	With wind	1.4	1.2	0.3	2.9
Unguarded inaccessible parts of Bridges	at Rest, max Temp	2.0	1.2	0.3	3.5
	With wind	1.4	1.2	0.3	2.9
Conductors and wires from other supporting structures	at Rest, max Temp	1.5	1.2	0.3	3.0
	With wind	1.4	1.2	0.3	2.9

Table 3-13: Minimum Horizontal Clearance to objects-220 KV

Horizontal Clearance to Rail Cars and Swimming pools from 220kV Lines

Object		NESC basic clearance for V_p=22kV/(m)	Additional Clearance V_{LL}=220kV/(m)	Clearance Adder/m	Total Clearance/m
Swimming Pools	Any direction from water level	7.6	1.2	0.3	9.1
	Any direction from fixed pool related structures	5.2	1.2	0.3	6.7
Rail Cars	Nearest Rail	3.5	1.2	0.3	5.0

Table 3-14: Minimum Horizontal Clearance to Rail Cars-220 KV

3.3 Methodology of Calculation of Total Horizontal Separation

The total horizontal displacement from centre line of a transmission line to any object depends on three factors. They are;

- The conductor horizontal displacement at maximum wind pressure
- Minimum horizontal clearance
- The length of the cross arm

The first two factors were discussed under clause 3.1 and 3.2 above and the length of the cross arm also depend on the manufacturer. However, each and every manufacturer tries to manufacture the tower at minimum cost. That is, for a selected maximum operating voltage most of the time the towers have the same length of cross arms. However, it is very much fair if we specify the total horizontal separation from the conductor attachment point to the object. Total horizontal separation between conductors and any other objects can be directly taken from the addition of conductor horizontal displacement and horizontal clearance.

The following tables provide the easy reference for total Horizontal separation from conductor attachment point to objects.

The Horizontal Separation between 132kV ZEBRA Conductor Attachment Point and The following Objects

Buildings, walls, balconies and areas which are accessible to pedestrians
Other Installations not classified as buildings like TV antennas, Tanks etc
Unguarded accessible parts of Bridges
Unguarded inaccessible parts of Bridges
Conductors and wires from other supporting structures

Minimum Horizontal Clearance = 2.3m

Equivalent Span									
Span		200 m		300		400 m		500m	
x	x/2	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m
0	0	1.9823	4.2823	1.9823	4.2823	1.9823	4.2823	1.9823	6.5823
25	12.5	2.0263	4.3263	2.0254	4.3254	2.0249	4.3249	2.0246	6.6249
50	25	2.1581	4.4581	2.1546	4.4546	2.1526	4.4526	2.1514	6.7526
75	37.5	2.3778	4.6778	2.3699	4.6699	2.3655	4.6655	2.3628	6.9655
100	50	2.6853	4.9853	2.6714	4.9714	2.6635	4.9635	2.6588	7.2635
125	62.5	3.0808	5.3808	3.0590	5.3590	3.0467	5.3467	3.0393	7.6467
150	75	3.5641	5.8641	3.5327	5.8327	3.5150	5.8150	3.5044	8.1150
175	87.5	4.1353	6.4353	4.0926	6.3926	4.0685	6.3685	4.0540	8.6685
200	100	4.7943	7.0943	4.7386	7.0386	4.7071	7.0071	4.6882	9.3071
225	112.5	5.5413	7.8413	5.4707	7.7707	5.4308	7.7308	5.4070	10.0308
250	125	6.3761	8.6761	6.2890	8.5890	6.2397	8.5397	6.2103	10.8397
275	137.5	7.2987	9.5987	7.1934	9.4934	7.1338	9.4338	7.0981	11.7338
300	150	8.3093	10.6093	8.1839	10.4839	8.1130	10.4130	8.0706	12.7130
325	162.5	9.4077	11.7077	9.2606	11.5606	9.1773	11.4773	9.1275	13.7773
350	175	10.5940	12.8940	10.4234	12.7234	10.3268	12.6268	10.2691	14.9268
375	187.5	11.8682	14.1682	11.6723	13.9723	11.5615	13.8615	11.4952	16.1615
400	200	13.2303	15.5303	13.0074	15.3074	12.8813	15.1813	12.8058	17.4813
425	212.5	14.6802	16.9802	14.4286	16.7286	14.2862	16.5862	14.2011	18.8862
450	225	16.2180	18.5180	15.9359	18.2359	15.7763	18.0763	15.6808	20.3763
475	237.5	17.8437	20.1437	17.5294	19.8294	17.3515	19.6515	17.2452	21.9515
500	250	19.5572	21.8572	19.2090	21.5090	19.0119	21.3119	18.8941	23.6119
525	262.5	21.3587	23.6587	20.9748	23.2748	20.7574	23.0574	20.6275	25.3574
550	275	23.2480	25.5480	22.8266	25.1266	22.5881	24.8881	22.4455	27.1881
575	287.5	25.2251	27.5251	24.7646	27.0646	24.5039	26.8039	24.3481	29.1039
600	300	27.2902	29.5902	26.7888	29.0888	26.5049	28.8049	26.3352	31.1049
625	312.5	29.4431	31.7431	28.8990	31.1990	28.5910	30.8910	28.4069	33.1910
650	325	31.6839	33.9839	31.0954	33.3954	30.7623	33.0623	30.5632	35.3623
675	337.5	34.0126	36.3126	33.3780	35.6780	33.0187	35.3187	32.8040	37.6187
700	350	36.4291	38.7291	35.7466	38.0466	35.3603	37.6603	35.1294	39.9603
725	362.5	38.9336	41.2336	38.2014	40.5014	37.7870	40.0870	37.5393	42.3870
750	375	41.5259	43.8259	40.7424	43.0424	40.2989	42.5989	40.0338	44.8989
775	387.5	44.2060	46.5060	43.3695	45.6695	42.8959	45.1959	42.6128	47.4959
800	400	46.9741	49.2741	46.0827	48.3827	45.5781	47.8781	45.2764	50.1781

Note: you should select the correct equivalent span and the column of x/2 to read the distance from one tower location because x means the total span between the two towers

Table 3-15: Minimum Horizontal Separation between 132kV conductor attachment point and the other objects

The Horizontal Separation between 220kV ZEBRA Conductor Attachment Point and The following Objects

Buildings, walls, balconies and areas which are accessible to pedestrians
Other Installations not classified as buildings like TV antennas, Tanks etc
Unguarded accessible parts of Bridges
Unguarded inaccessible parts of Bridges
Conductors and wires from other supporting structures

Minimum Horizontal Clearance = 2.9m

Equivalent Span									
Span		150 m		250		350m		450m	
x	x/2	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m	Horizontal Displacement	Total Horizontal Separation Between Conductors and objects/m
0	0	2.5981	5.4981	2.5981	5.4981	2.5981	5.4981	2.5981	8.3981
25	12.5	2.6402	5.5402	2.6390	5.5390	2.6384	5.5384	2.6380	8.4384
50	25	2.7665	5.6665	2.7619	5.6619	2.7593	5.6593	2.7577	8.5593
75	37.5	2.9770	5.8770	2.9667	5.8667	2.9607	5.8607	2.9572	8.7607
100	50	3.2717	6.1717	3.2535	6.1535	3.2428	6.1428	3.2366	9.0428
125	62.5	3.6505	6.5505	3.6222	6.5222	3.6055	6.5055	3.5957	9.4055
150	75	4.1136	7.0136	4.0727	6.9727	4.0488	6.9488	4.0347	9.8488
175	87.5	4.6609	7.5609	4.6053	7.5053	4.5726	7.4726	4.5535	10.3726
200	100	5.2924	8.1924	5.2197	8.1197	5.1771	8.0771	5.1521	10.9771
225	112.5	6.0081	8.9081	5.9161	8.8161	5.8621	8.7621	5.8305	11.6621
250	125	6.8079	9.7079	6.6944	9.5944	6.6277	9.5277	6.5887	12.4277
275	137.5	7.6920	10.5920	7.5546	10.4546	7.4740	10.3740	7.4268	13.2740
300	150	8.6603	11.5603	8.4967	11.3967	8.4008	11.3008	8.3446	14.2008
325	162.5	9.7127	12.6127	9.5208	12.4208	9.4082	12.3082	9.3423	15.2082
350	175	10.8494	13.7494	10.6268	13.5268	10.4962	13.3962	10.4198	16.2962
375	187.5	12.0702	14.9702	11.8148	14.7148	11.6648	14.5648	11.5771	17.4648
400	200	13.3753	16.2753	13.0846	15.9846	12.9140	15.8140	12.8142	18.7140
425	212.5	14.7645	17.6645	14.4364	17.3364	14.2438	17.1438	14.1311	20.0438
450	225	16.2380	19.1380	15.8701	18.7701	15.6542	18.5542	15.5278	21.4542
475	237.5	17.7956	20.6956	17.3857	20.2857	17.1452	20.0452	17.0044	22.9452
500	250	19.4375	22.3375	18.9833	21.8833	18.7168	21.6168	18.5607	24.5168
525	262.5	21.1635	24.0635	20.6628	23.5628	20.3689	23.2689	20.1969	26.1689
550	275	22.9737	25.8737	22.4242	25.3242	22.1017	25.0017	21.9129	27.9017
575	287.5	24.8682	27.7682	24.2675	27.1675	23.9150	26.8150	23.7087	29.7150
600	300	26.8468	29.7468	26.1928	29.0928	25.8090	28.7090	25.5843	31.6090
625	312.5	28.9096	31.8096	28.2000	31.1000	27.7835	30.6835	27.5397	33.5835
650	325	31.0566	33.9566	30.2891	33.1891	29.8386	32.7386	29.5750	35.6386
675	337.5	33.2879	36.1879	32.4601	35.3601	31.9744	34.8744	31.6900	37.7744
700	350	35.6033	38.5033	34.7131	37.6131	34.1907	37.0907	33.8849	39.9907
725	362.5	38.0029	40.9029	37.0480	39.9480	36.4876	39.3876	36.1596	42.2876
750	375	40.4867	43.3867	39.4648	42.3648	38.8651	41.7651	38.5141	44.6651
775	387.5	43.0547	45.9547	41.9635	44.8635	41.3232	44.2232	40.9484	47.1232
800	400	45.7069	48.6069	44.5442	47.4442	43.8619	46.7619	43.4625	49.6619

Note: you should select the correct equivalent span and the column of x/2 to read the distance from one tower location because x means the total span between the two towers

Table 3-16: Minimum Horizontal Separation between 220kV conductor attachment point and the other objects

3.4 Methodology of Calculation of Right-Of-Way (ROW) Width

3.4.1 Right of Way Width for Single Line

Following figure shows the simple idea of the Right-Of-Way.

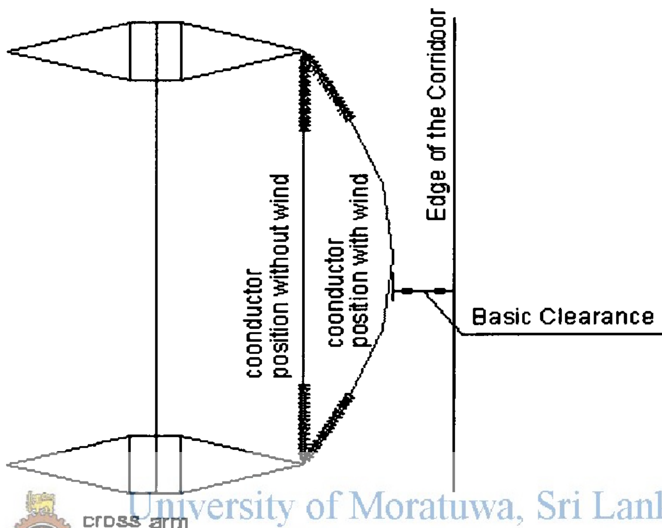


Figure 3-6: Top View of Right-of-Way

In the case of ROW, the mid-span sag at basic design span is considered for the calculation of total width. As per the technical specification, the basic design spans for 132kV and 220kV are 300m and 350m respectively. However, if the concept of equivalent span is considered, there is a range of using the same basic span between two section towers. Therefore, maximum range for the ROW is defined by considering the possible maximum instant span without violating the design conditions of tower as discussed above.

According to the minimum horizontal clearance, objects as we discussed above, the required minimum clearance to different objects are different. However, most of the objects have the same clearance except for Swimming Pools and Rail Cars. Therefore, it is decided to specify the ROW for the most common value and the availability of swimming pools near transmission lines is very much rear. Therefore, the availability of those two objects is decided to consider as special conditions and keep the clearance accordingly without considering the typical ROW.

The developed drawings for ROW show the basic steps of calculating ROW. Therefore, wherever additional clearance is necessary, total width can be derived accordingly. Typical right-of-way width is shown by the drawings attached in Annex 3- 6.

3.4.2 Single Right of Way Width for More Lines

Transmission line ROW can be shared with town or county roads, highways, railroads, etc. However, this covers the sharing of line corridor with other Transmission Line. Corridor sharing with existing facilities is usually encouraged because it minimizes impacts by:

- Reducing the amount of new ROW required
- Concentrating linear land uses and reducing the number of new corridors
- Creating an incremental, rather than a new impact

When there are two or more lines in the same corridor, three conditions shown in following figure should be taken in to consideration.

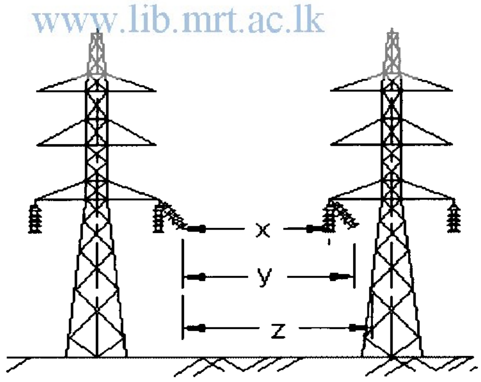


Figure 3-7: shared Corridor

The following assumptions are considered for different situations.

- For z, Tower of One Line is located next to the mid-span point of the line that has maximum sag
- For x & y, Mid-span of both lines is in lined with each other

Out of above three values, the critical value should be taken into consideration.

In this case there are two Transmission voltages. Further, 33kV distribution lines also strings over tower Lines. Therefore, sharing of the same corridor is necessary to be studied for two Transmission voltages and 33kV distribution voltage. The drawings were developed for following voltage combination.

- ROW for two 220kV and 220kV lines
- ROW for two 220kV and 132kV lines
- ROW for two 220kV and 33kV lines
- ROW for two 132kV and 132kV lines
- ROW for two 132kV and 33kV lines

The developed scaled drawings for different voltages are shown in Annex 3-7

However, as per the previous explanation, the width of shared corridor is depends on the cross arms length of both towers .therefore, the distance between two adjacent conductors of two lines is important.

3.5 Building Construction Within Right-Of-Way(ROW)

The power companies in most of the countries do not allow living within ROW. However, in Sri Lanka there is no such policy imposed by CEB. Therefore, the construction of buildings within Right-Of-Way can be allowed keeping basic vertical and horizontal clearances to buildings. However there is a risk if the conductor is fallen down on the buildings and any protection is not operated automatically to de-energize the conductor before the conductor released from their permanent position. Therefore, new construction exactly under the existing Transmission line is not recommended. Therefore, the study was carried out to observe the possibility of allowing building construction away from the conductor attachment point within ROW.

The usage of land can be optimized within ROW, and can be taken into two steps. That is along the span and perpendicular to the span. This study was done for the basic span separately for 132kV and 220kV voltages. Because, people can argue that there can be construction under the line away from the maximum sag point since the sag along the span is not unique. Similarly, the argument can be raised about the possibility of construction perpendicular to the span at different distance from the centre line of the Transmission Line. This study covered both these sections.

The developed scaled drawings for two voltages are annexed in Annex 3-8 which shows the maximum height of buildings which can be allowed to construct within ROW.

3.6 Methodology of Vegetation Management Within Right-Of-Way(ROW)

Trees and shrubs play an important role in our lives, whether we live in the city or country. There are many benefits from properly planted trees and shrubs, including:

- They consume carbon dioxide and produce oxygen.
- They can help us conserve energy, and money, in both summer and winter.
- They provide shelter for birds and small animals.
- They help control soil erosion.
- They serve as privacy screens and noise barriers.
- They add character and value to property.
- They add to our aesthetic quality of life.

When vegetation is located too closely to transmission lines, they create hazardous conditions. In fact, contact with an energized power line or arcing (flow of electricity through the air) of one will cause property damage.

The suggestions for selecting and locating trees and shrubs within ROW are provided by this study.

In compliance with the mature height of trees and vegetation, it can be allowed to plant on the Rights-of-way (ROW).

According to the National Electrical Safety Code, minimum clearance requirement is not specific for trees. Therefore, trees are decided to keep in the category of other Installations not classified as buildings like TV antennas, Tanks etc.

The minimum horizontal clearance to trees when they are falling was concerned for the derivation of mature height of trees within ROW.

The developed scaled drawings for two voltages are annexed in Annex 3-9 which shows the mature height of trees which can be allowed to plant within ROW at different distance from the centre line of the line.

3.7 Electric and Magnetic Fields

Health concerns over exposure to EMF (Electric and Magnetic Fields) are often raised when a new transmission line is proposed. Exposure to electric and magnetic fields caused by transmission lines has been studied since the late 1970s. These fields occur whenever electricity is used. The magnetic field is created when electric current flows through any device.

There is a concern to childhood leukemia and Chronic Lymphocyte Leukemia mostly for adults due to field exposure from transmission lines. However, the research to date has uncovered only weak and inconsistent associations between exposures and human health. Up to date, research has not been able to establish a cause and effect relationship between exposure to magnetic fields and human diseases.

3.7.1 Allowable Exposure Limits

Electric and magnetic field limitation has been defined by International Commission on Non-Ionization of Radiation Protection (ICNIRP). The recommended limits for the frequency of 50Hz is as shown in the following table.

	Electrical Field kV/m)	Magnetic Field (μT)
General Public	5	100
Occupational	10	500

Table 3-17: field exposure limits

According to the ICNIRP guide lines, the occupationally exposed population is consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. The general public comprises individuals of all ages and of varying health status.

The better solution for the field effect is to reduce the field strength by design techniques as discussed above.

3.7.2 Reducing EMF Levels of Transmission Lines

Magnetic fields can be measured with a gauss meter. The size of the magnetic field cannot be predicted from the line voltage but is related to the current flow. A 33 kV line can have a higher magnetic field than a 132 kV line. Magnetic fields quickly dissipate with distance from the transmission line.

In general there are four techniques which may be available to reduce magnetic field strength from electric transmission lines. They are,

- Increase distance from conductors
- Reduce conductor spacing
- Minimize current
- optimize phase configuration

A common method to reduce EMF is to bring the lines closer together. This causes the fields created by each of the three conductors to interfere with each other and produce a reduced total magnetic field. Magnetic fields generated by double-circuit lines are less than those generated by single-circuit lines because the magnetic fields interact and produce a lower total magnetic field.

Chapter - 4

Conclusion

4.1 Right-of-Way (ROW) Width

The minimum horizontal clearance to buildings and other structures can be taken from table 3-11 to table 3-14, according to the object category and the operating voltage. However, according to the tables, it is obvious that the clearances to any object except swimming pools and rail tracks are same for the same operating voltage. Therefore, the Right-of-Way (ROW) width is defined without considering swimming pools and rail tracks but wherever they are available it is necessary to widen the ROW keeping the additional clearance for those objects.

Typical ROW for 132kV and 220kV voltages can be defined as a range of 30-40m and 40-50m respectively.

The typical ROW which are specified in some reference documents are shown in Annex 3-10.

4.2 Building Construction within ROW

According to the phenomenon of clearances, there is a possibility of building construction within ROW with limited height compiling the required vertical and electrical clearances. According to the drawings discussed above, typical values for maximum building height can be specified.

However, it is required to get the verification that the recommended field exposure limits are complied with the locations. However, the manual calculation of field is difficult. But, measuring can be practiced to get verification of field under the Transmission line.

However, the most suitable solution for effects from the field is to reduce field with design techniques as discussed above.

4.3 Vegetation Management within ROW

The allowable mature height of trees is varying from different locations within ROW. According to the drawings discussed above, typical values for mature height of trees can be specified.

Reference

[1] Technical Specification for Transmission Lines, Ceylon Electricity Board.

[2] C2-2007, National Electrical Safety Code, the Institute of Electrical and Electronics Engineers, Copyright © 2006.

[3] Design Manual for High Voltage Transmission Lines, Electric Staff Division, Rural Utilities Service, U.S. Department of Agriculture.

[4] Typical Transmission Line Design as Result of the Guidance through the Design of Transmission Lines, [Report of Ceylon Electricity Board], Nikola Vucinic, 1997.

[5] C. Baylis, B. Hardy, Transmission and Distribution Electrical Engineering.

[6] Overhead Conductor Manual, 1st ed., Southwire Company.

[7] IEC 60826, International Electrotechnical Commission Standard, 2nd ed., 1991.

[8] Transmission Line EMF Guide Lines, Pacific Gas and Electric Company, May 1994.

[9] Guidelines For Limiting Exposure To Time-Varying Electric, Magnetic, And Electromagnetic Fields (Up To 300 GHz), health physics, volume 74, number 4, April 1998.

[10] Electric and Magnetic Fields from Overhead Power Lines, Empetus Close Corporation, Final Report, August 2006.

[11] NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields, National Institute of Environmental Health Sciences, National Institute of Health, May 1999.

[12] Guide Lines on Limits of Exposure to Static Magnetic Fields, International Commission on Non-Ionizing Radiation Protection, Health Physics Society, Copyright © 1994.

Properties of the conductor

Diameter of conductor	*D*	28.62	mm
Total cross sectional area	*A*	484.4	mm^2
Modulus of elasticity	E	69000	N/mm^2
Linear coefficient of expansion	A	1.95E-05	per °C
Ultimate breaking strength	*UBS*	130320	N
Weight of the conductor per meter	*W*	1.632	kg/m

Data for Catenary Curve (Template) Plotting for 132kV ZEBRA Conductor

Equivalent Span	200	300	400	500
Sag (D)	3.895	7.93	13.417	20.4

$$y=D*x^2/a^2$$

Coordinates of catenary curve at 75°C and No wind condition

		Equivalent Span			
		200 m	300 m	400	500 m
x	x/2	Y	y	y	y
0	0	0.0000000	0.0000000	0.0000000	0.0000000
25	12.5	0.0608594	0.0550694	0.0524102	0.0510000
50	25	0.2434375	0.2202778	0.2096406	0.2040000
75	37.5	0.5477344	0.4956250	0.4716914	0.4590000
100	50	0.9737500	0.8811111	0.8385625	0.8160000
125	62.5	1.5214844	1.3767361	1.3102539	1.2750000
150	75	2.1909375	1.9825000	1.8867656	1.8360000
175	87.5	2.9821094	2.6984028	2.5680977	2.4990000
200	100	3.8950000	3.5244444	3.3542500	3.2640000
225	112.5	4.9296094	4.4606250	4.2452227	4.1310000
250	125	6.0859375	5.5069444	5.2410156	5.1000000
275	137.5	7.3639844	6.6634028	6.3416289	6.1710000
300	150	8.7637500	7.9300000	7.5470625	7.3440000
325	162.5	10.2852344	9.3067361	8.8573164	8.6190000
350	175	11.9284375	10.7936111	10.2723906	9.9960000
375	187.5	13.6933594	12.3906250	11.7922852	11.4750000
400	200	15.5800000	14.0977778	13.4170000	13.0560000
425	212.5	17.5883594	15.9150694	15.1465352	14.7390000
450	225	19.7184375	17.8425000	16.9808906	16.5240000
475	237.5	21.9702344	19.8800694	18.9200664	18.4110000
500	250	24.3437500	22.0277778	20.9640625	20.4000000
525	262.5	26.8389844	24.2856250	23.1128789	22.4910000
550	275	29.4559375	26.6536111	25.3665156	24.6840000
575	287.5	32.1946094	29.1317361	27.7249727	26.9790000
600	300	35.0550000	31.7200000	30.1882500	29.3760000
625	312.5	38.0371094	34.4184028	32.7563477	31.8750000
650	325	41.1409375	37.2269444	35.4292656	34.4760000
675	337.5	44.3664844	40.1456250	38.2070039	37.1790000
700	350	47.7137500	43.1744444	41.0895625	39.9840000
725	362.5	51.1827344	46.3134028	44.0769414	42.8910000
750	375	54.7734375	49.5625000	47.1691406	45.9000000
775	387.5	58.4858594	52.9217361	50.3661602	49.0110000
800	400	62.3200000	56.3911111	53.6680000	52.2240000
825	412.5	66.2758594	59.9706250	57.0746602	55.5390000
850	425	70.3534375	63.6602778	60.5861406	58.9560000
875	437.5	74.5527344	67.4600694	64.2024414	62.4750000
900	450	78.8737500	71.3700000	67.9235625	66.0960000
925	462.5	83.3164844	75.3900694	71.7495039	69.8190000
950	475	87.8809375	79.5202778	75.6802656	73.6440000
975	487.5	92.5671094	83.7606250	79.7158477	77.5710000
1000	500	97.3750000	88.1111111	83.8562500	81.6000000

Properties of the conductor

Diameter of conductor	*D*	28.62	mm
Total cross sectional area	*A*	484.4	mm²
Modulus of elasticity	*E*	69000	N/mm²
Linear coefficient of expansion	A	1.95E-05	per °C
Ultimate breaking strength	*UBS*	130320	N
Weight of the conductor per meter	*W*	1.632	kg/m

Data for Catenary Curve (Template) Plotting

Equivalent Span	200	300	400	500
Sag (D)	3.402	7.161	12.837	19.803

$$y = D*x^2/a^2$$

Coordinates of catenary curve at 15°C and Maximum wind condition

		Equivalent Span			
		200 m	300 m	400	500 m
x	x/2	Y	y	y	y
0	0	0.0000000	0.0000000	0.0000000	0.0000000
25	12.5	0.0531563	0.0497292	0.0501445	0.0495075
50	25	0.2126250	0.1989167	0.2005781	0.1980300
75	37.5	0.4784063	0.4475625	0.4513008	0.4455675
100	50	0.8505000	0.7956667	0.8023125	0.7921200
125	62.5	1.3289063	1.2432292	1.2536133	1.2376875
150	75	1.9136250	1.7902500	1.8052031	1.7822700
175	87.5	2.6046563	2.4367292	2.4570820	2.4258675
200	100	3.4020000	3.1826667	3.2092500	3.1684800
225	112.5	4.3056563	4.0280625	4.0617070	4.0101075
250	125	5.3156250	4.9729167	5.0144531	4.9507500
275	137.5	6.4319063	6.0172292	6.0674883	5.9904075
300	150	7.6545000	7.1610000	7.2208125	7.1290800
325	162.5	8.9834063	8.4042292	8.4744258	8.3667675
350	175	10.4186250	9.7469167	9.8283281	9.7034700
375	187.5	11.9601563	11.1890625	11.2825195	11.1391875
400	200	13.6080000	12.7306667	12.8370000	12.6739200
425	212.5	15.3621563	14.3717292	14.4917695	14.3076675
450	225	17.2226250	16.1122500	16.2468281	16.0404300
475	237.5	19.1894063	17.9522292	18.1021758	17.8722075
500	250	21.2625000	19.8916667	20.0578125	19.8030000
525	262.5	23.4419063	21.9305625	22.1137383	21.8328075
550	275	25.7276250	24.0689167	24.2699531	23.9616300
575	287.5	28.1196563	26.3067292	26.5264570	26.1894675
600	300	30.6180000	28.6440000	28.8832500	28.5163200
625	312.5	33.2226563	31.0807292	31.3403320	30.9421875
650	325	35.9336250	33.6169167	33.8977031	33.4670700
675	337.5	38.7509063	36.2525625	36.5553633	36.0909675
700	350	41.6745000	38.9876667	39.3133125	38.8138800
725	362.5	44.7044063	41.8222292	42.1715508	41.6358075
750	375	47.8406250	44.7562500	45.1300781	44.5567500
775	387.5	51.0831563	47.7897292	48.1888945	47.5767075
800	400	54.4320000	50.9226667	51.3480000	50.6956800
825	412.5	57.8871563	54.1550625	54.6073945	53.9136675
850	425	61.4486250	57.4869167	57.9670781	57.2306700
875	437.5	65.1164063	60.9182292	61.4270508	60.6466875
900	450	68.8905000	64.4490000	64.9873125	64.1617200
925	462.5	72.7709063	68.0792292	68.6478633	67.7757675
950	475	76.7576250	71.8089167	72.4087031	71.4888300
975	487.5	80.8506563	75.6380625	76.2698320	75.3009075
1000	500	85.0500000	79.5666667	80.2312500	79.2120000

Properties of the conductor

Diameter of conductor	*D*	28.62	mm
Total cross sectional area	*A*	484.48	mm^2
Modulus of elasticity	*E*	75001	N/mm^2
Linear coefficient of expansion	A	2.06E-05	per °C
Ultimate breaking strength	*UBS*	137546	N
Weight of the conductor per meter	*W*	1.564	kg/m

Data for Catenary Curve (Template) Plotting for 220kV ZEBRA Conductor

Equivalent Span	150	250	350	450
Sag (D)	2.41	5.61	10.11	15.97

$$y = D*x^2/a^2$$

Coordinates of catenary curve at 75°C and No wind condition

Equivalent Span					
		150 m	250 m	350 m	450 m
x	x/2	Y	y	y	y
0	0	0.0000000	0.0000000	0.0000000	0.0000000
25	12.5	0.0669444	0.0561000	0.0515816	0.0492901
50	25	0.2677778	0.2244000	0.2063265	0.1971605
75	37.5	0.6025000	0.5049000	0.4642347	0.4436111
100	50	1.0711111	0.8976000	0.8253061	0.7886420
125	62.5	1.6736111	1.4025000	1.2895408	1.2322531
150	75	2.4100000	2.0196000	1.8569388	1.7744444
175	87.5	3.2802778	2.7489000	2.5275000	2.4152160
200	100	4.2844444	3.5904000	3.3012245	3.1545679
225	112.5	5.4225000	4.5441000	4.1781122	3.9925000
250	125	6.6944444	5.6100000	5.1581633	4.9290123
275	137.5	8.1002778	6.7881000	6.2413776	5.9641049
300	150	9.6400000	8.0784000	7.4277551	7.0977778
325	162.5	11.3136111	9.4809000	8.7172959	8.3300309
350	175	13.1211111	10.9956000	10.1100000	9.6608642
375	187.5	15.0625000	12.6225000	11.6058673	11.0902778
400	200	17.1377778	14.3616000	13.2048980	12.6182716
425	212.5	19.3469444	16.2129000	14.9070918	14.2448457
450	225	21.6900000	18.1764000	16.7124490	15.9700000
475	237.5	24.1669444	20.2521000	18.6209694	17.7937346
500	250	26.7777778	22.4400000	20.6326531	19.7160494
525	262.5	29.5225000	24.7401000	22.7475000	21.7369444
550	275	32.4011111	27.1524000	24.9655102	23.8564198
575	287.5	35.4136111	29.6769000	27.2866837	26.0744753
600	300	38.5600000	32.3136000	29.7110204	28.3911111
625	312.5	41.8402778	35.0625000	32.2385204	30.8063272
650	325	45.2544444	37.9236000	34.8691837	33.3201235
675	337.5	48.8025000	40.8969000	37.6030102	35.9325000
700	350	52.4844444	43.9824000	40.4400000	38.6434568
725	362.5	56.3002778	47.1801000	43.3801531	41.4529938
750	375	60.2500000	50.4900000	46.4234694	44.3611111
775	387.5	64.3336111	53.9121000	49.5699490	47.3678086
800	400	68.5511111	57.4464000	52.8195918	50.4730864
825	412.5	72.9025000	61.0929000	56.1723980	53.6769444
850	425	77.3877778	64.8516000	59.6283673	56.9793827
875	437.5	82.0069444	68.7225000	63.1875000	60.3804012
900	450	86.7600000	72.7056000	66.8497959	63.8800000
925	462.5	91.6469444	76.8009000	70.6152551	67.4781790
950	475	96.6677778	81.0084000	74.4838776	71.1749383
975	487.5	101.8225000	85.3281000	78.4556633	74.9702778
1000	500	107.1111111	89.7600000	82.5306122	78.8641975

Properties of the conductor

Diameter of conductor	*D*	28.62	mm
Total cross sectional area	*A*	484.48	mm^2
Modulus of elasticity	*E*	75001	N/mm^2
Linear coefficient of expansion	A	2.06E-05	per °C
Ultimate breaking strength	*UBS*	137546	N
Weight of the conductor per meter	*W*	1.564	kg/m

Data for Catenary Curve (Template) Plotting for 220kV ZEBRA Conductor

Equivalent Span	150	250	350	450
Sag (D)	1.75	4.73	9.12	14.93

$$y=D*x^2/a^2$$

Coordinates of catenary curve at 15°C and Maximum wind condition

		Equivalent Span			
		150 m	250 m	350	450m
x	x/2	Y	y	y	y
0	0	0.0000000	0.0000000	0.0000000	0.0000000
25	12.5	0.0486111	0.0473000	0.0465306	0.0460802
50	25	0.1944444	0.1892000	0.1861224	0.1843210
75	37.5	0.4375000	0.4257000	0.4187755	0.4147222
100	50	0.7777778	0.7568000	0.7444898	0.7372840
125	62.5	1.2152778	1.1825000	1.1632653	1.1520062
150	75	1.7500000	1.7028000	1.6751020	1.6588889
175	87.5	2.3819444	2.3177000	2.2800000	2.2579321
200	100	3.1111111	3.0272000	2.9779592	2.9491358
225	112.5	3.9375000	3.8313000	3.7689796	3.7325000
250	125	4.8611111	4.7300000	4.6530612	4.6080247
275	137.5	5.8819444	5.7233000	5.6302041	5.5757099
300	150	7.0000000	6.8112000	6.7004082	6.6355556
325	162.5	8.2152778	7.9937000	7.8636735	7.7875617
350	175	9.5277778	9.2708000	9.1200000	9.0317284
375	187.5	10.9375000	10.6425000	10.4693878	10.3680556
400	200	12.4444444	12.1088000	11.9118367	11.7965432
425	212.5	14.0486111	13.6697000	13.4473469	13.3171914
450	225	15.7500000	15.3252000	15.0759184	14.9300000
475	237.5	17.5486111	17.0753000	16.7975510	16.6349691
500	250	19.4444444	18.9200000	18.6122449	18.4320988
525	262.5	21.4375000	20.8593000	20.5200000	20.3213889
550	275	23.5277778	22.8932000	22.5208163	22.3028395
575	287.5	25.7152778	25.0217000	24.6146939	24.3764506
600	300	28.0000000	27.2448000	26.8016327	26.5422222
625	312.5	30.3819444	29.5625000	29.0816327	28.8001543
650	325	32.8611111	31.9748000	31.4546939	31.1502469
675	337.5	35.4375000	34.4817000	33.9208163	33.5925000
700	350	38.1111111	37.0832000	36.4800000	36.1269136
725	362.5	40.8819444	39.7793000	39.1322449	38.7534877
750	375	43.7500000	42.5700000	41.8775510	41.4722222
775	387.5	46.7152778	45.4553000	44.7159184	44.2831173
800	400	49.7777778	48.4352000	47.6473469	47.1861728
825	412.5	52.9375000	51.5097000	50.6718367	50.1813889
850	425	56.1944444	54.6788000	53.7893878	53.2687654
875	437.5	59.5486111	57.9425000	57.0000000	56.4483025
900	450	63.0000000	61.3008000	60.3036735	59.7200000
925	462.5	66.5486111	64.7537000	63.7004082	63.0838580
950	475	70.1944444	68.3012000	67.1902041	66.5398765
975	487.5	73.9375000	71.9433000	70.7730612	70.0880556
1000	500	77.7777778	75.6800000	74.4489796	73.7283951

Annex 3-5

Kalpitiya/Puttalam (KALPITYA)

Stats based on observations taken between 11/2007 - 10/2009 daily from 7am to 7pm local time.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	SUM 1-12
Wind probability > = 4 Beaufort (%)	1	0	0	3	6	14	12	5	12	1	4	0	**4**
Average Wind Speed (m/s)	2	2	2	2	3	4	4	3	4	2	2	2	**3**
Select Month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Negombo/Katunayake (NEGOMBO)

Stats based on observations taken between 11/2007 - 10/2009 daily from 7am to 7pm local time.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	SUM 1-12
Wind probability > = 4 Beaufort (%)	30	8	7	9	41	24	24	29	22	8	18	27	**20**
Average Wind Speed (m/s)	5	4	4	4	5	5	5	5	5	4	4	5	**4**
Select Month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Hambantota (HMBNTOTA)

Stats based on observations taken between 11/2007 - 10/2009 daily from 7am to 7pm local time.

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Wind probability > = 4 Beaufort (%)	34	25	21	47	71	51	54	44	67	26	36	30	**42**
Average Wind Speed (m/s)	5	5	4	6	8	6	6	6	7	5	5	5	**5**
Select Month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

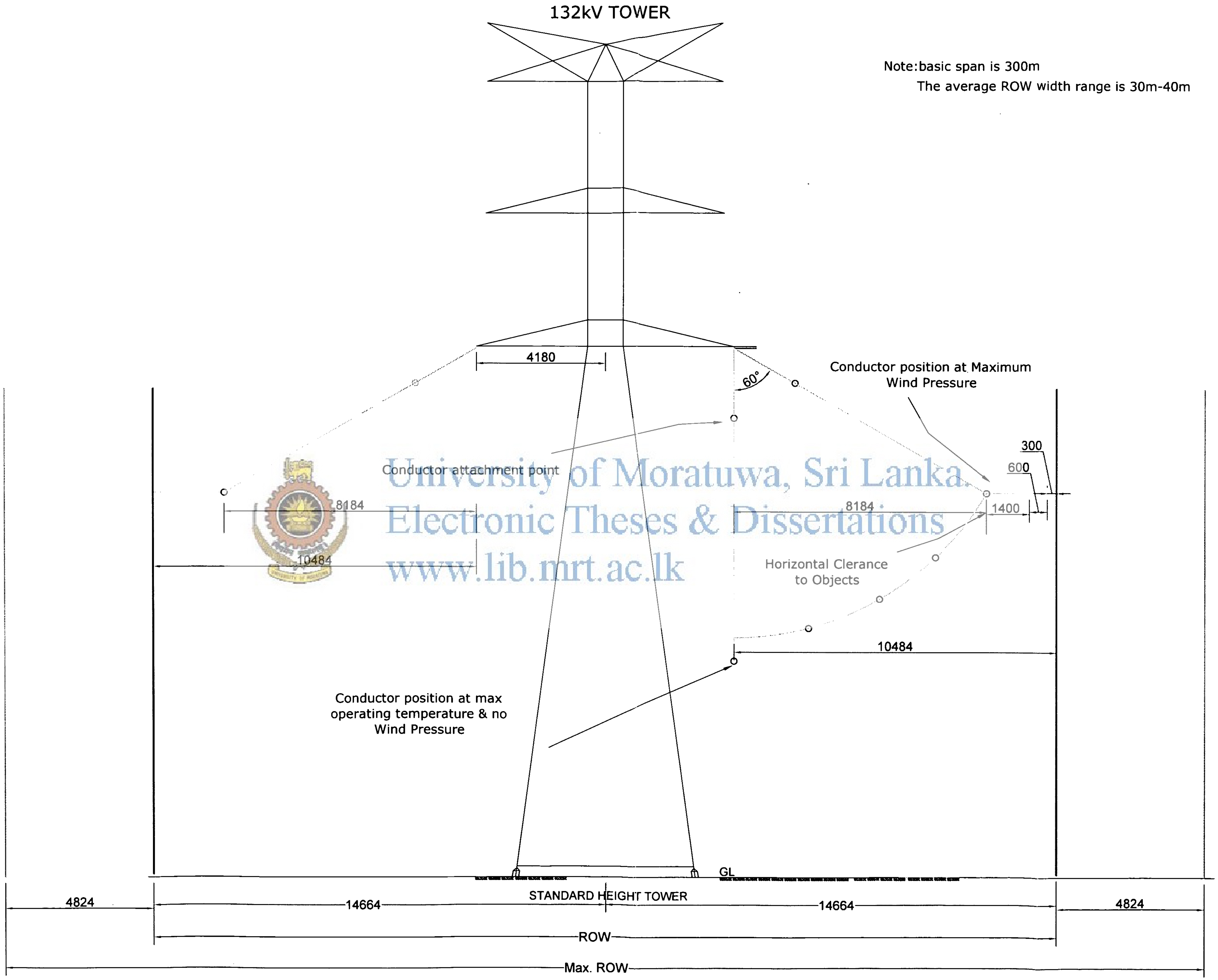
Arugam Bay/Pottuvil (POTTUVIL)

Stats based on observations taken between 11/2007 - 10/2009 daily from 7am to 7pm local time.

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Wind probability > = 4 Beaufort (%)	0	0	0	2	0	2	0	0	0	0	50	0	**4**
Average Wind Speed (m/s)	2	2	2	2	2	2	2	2	2	2	24	2	**4**
Select Month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

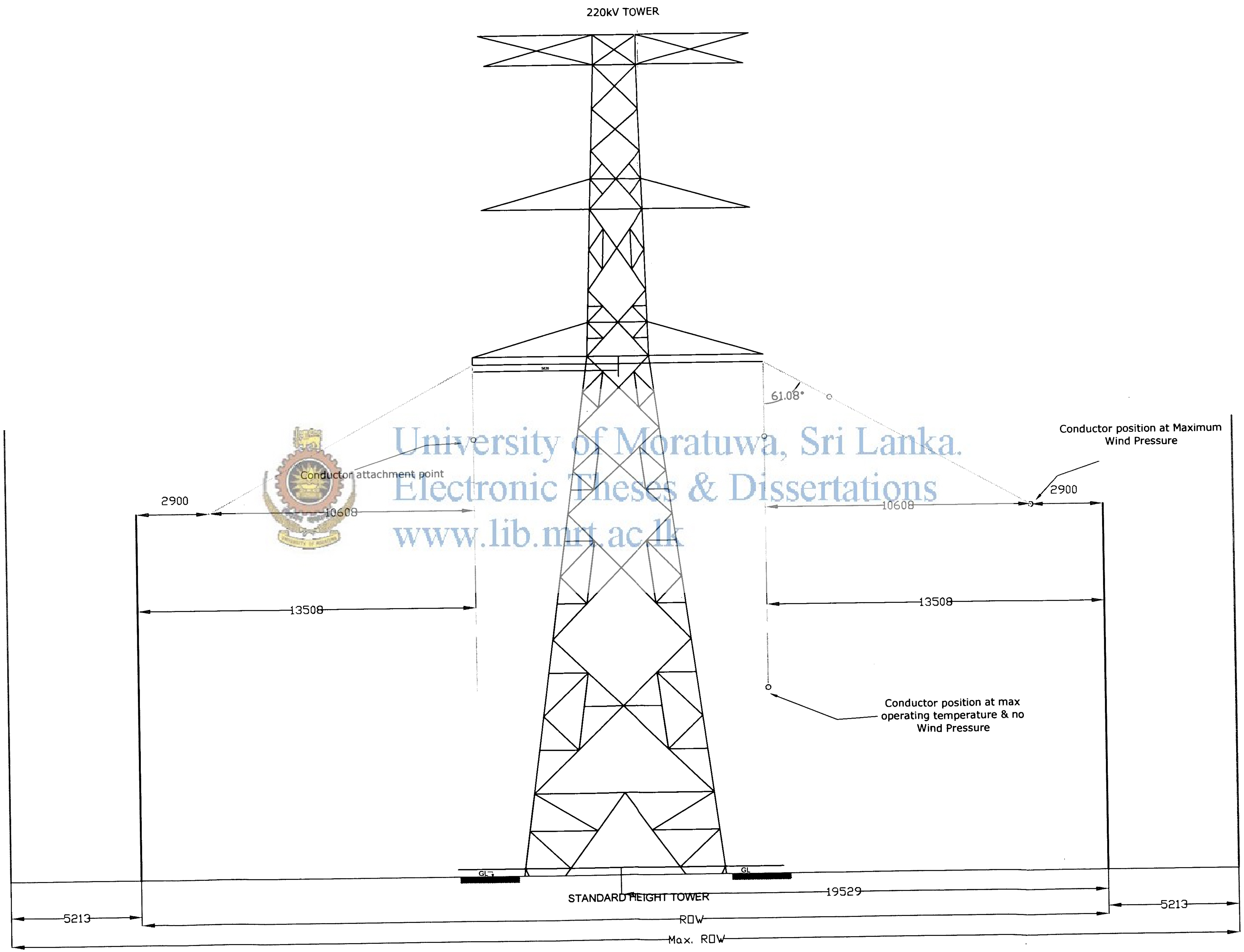
RIGHT-OF-WAY (ROW) WIDTH FOR SINGLE 132KV(ZEBRA) LINE

Note: basic span is 300m
The average ROW width range is 30m-40m



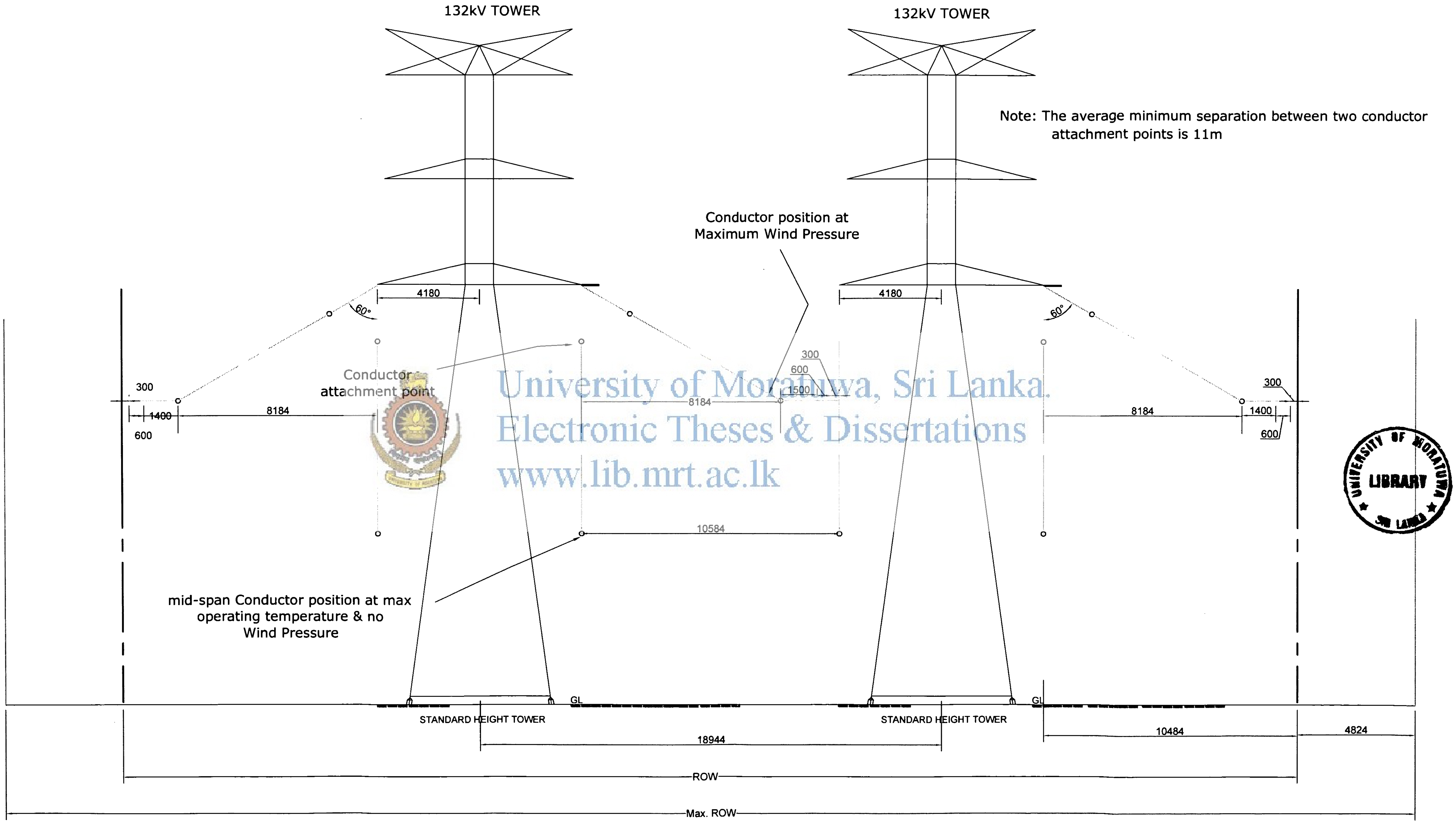
Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:125	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

RIGHT-OF-WAY (ROW) WIDTH FOR SINGLE 220KV (ZEBRA) LINE



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

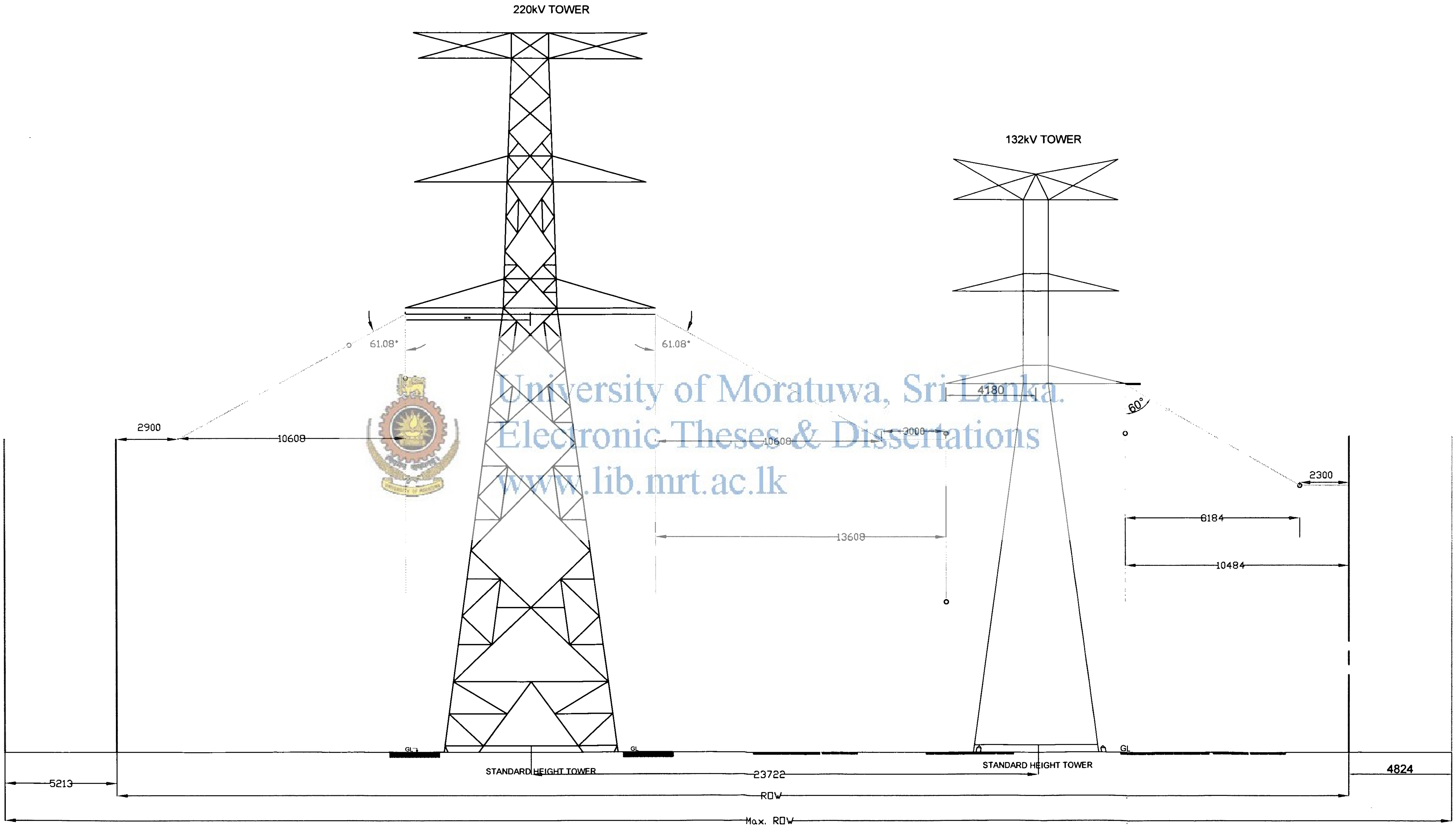
RIGHT-OF-WAY (ROW) WIDTH FOR TWO 132KV (ZEBRA) LINES



Note: The average minimum separation between two conductor attachment points is 11m

Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

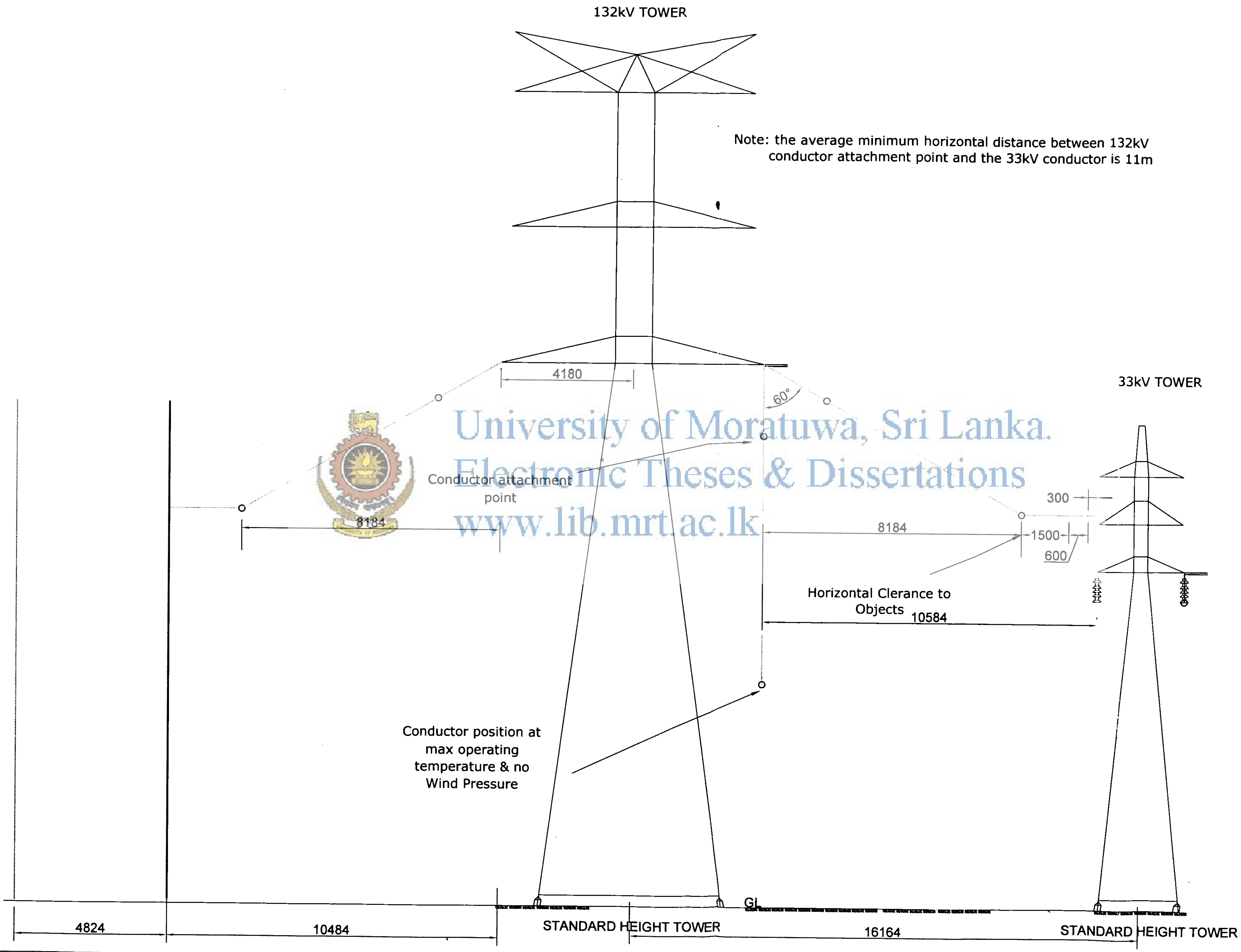
RIGHT-OF-WAY (ROW) WIDTH FOR 132KV (ZEBRA) & 220KV (ZEBRA) LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:175	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	Master of Science Dissertation Department of Electrical Engineering University of Moratuwa	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-7.3

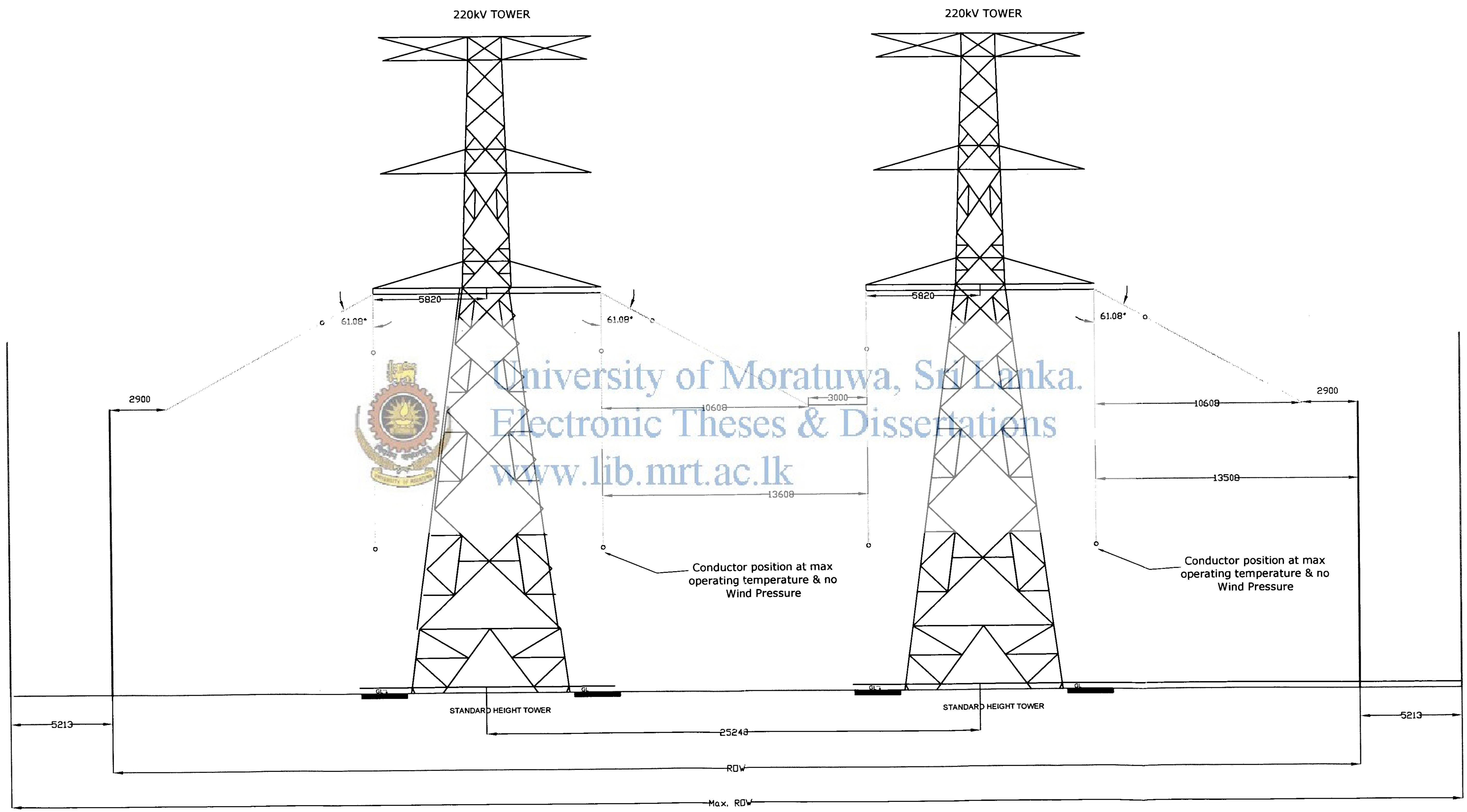
RIGHT-OF-WAY(ROW) WIDTH FOR 132KV(ZEBRA) & 33KV LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:125	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-7.4

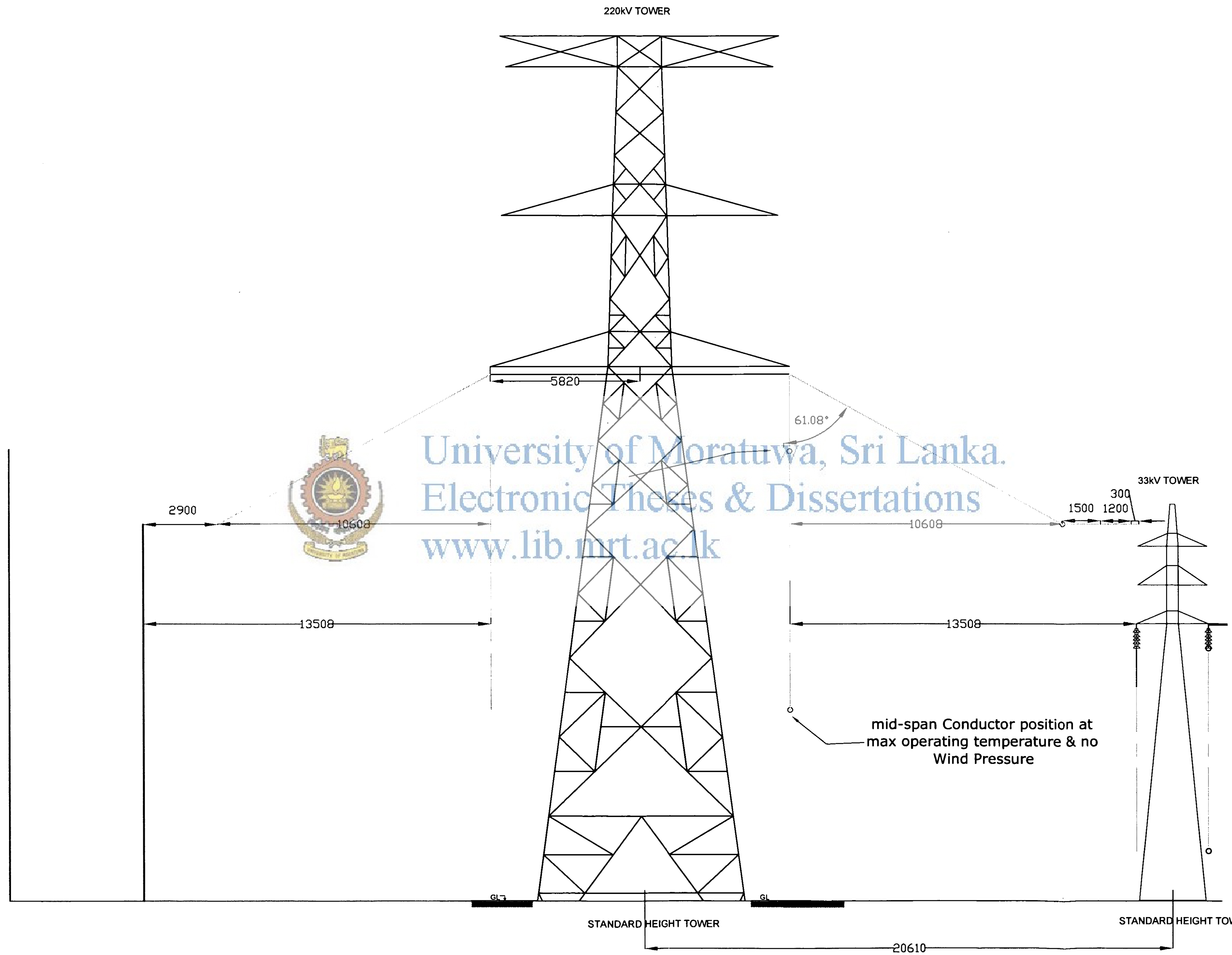
RIGHT-OF-WAY(ROW) WIDTH FOR TWO 220KV (ZEBRA) LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:200	CLEARANCE TO BUILDINGS AND FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-7.5

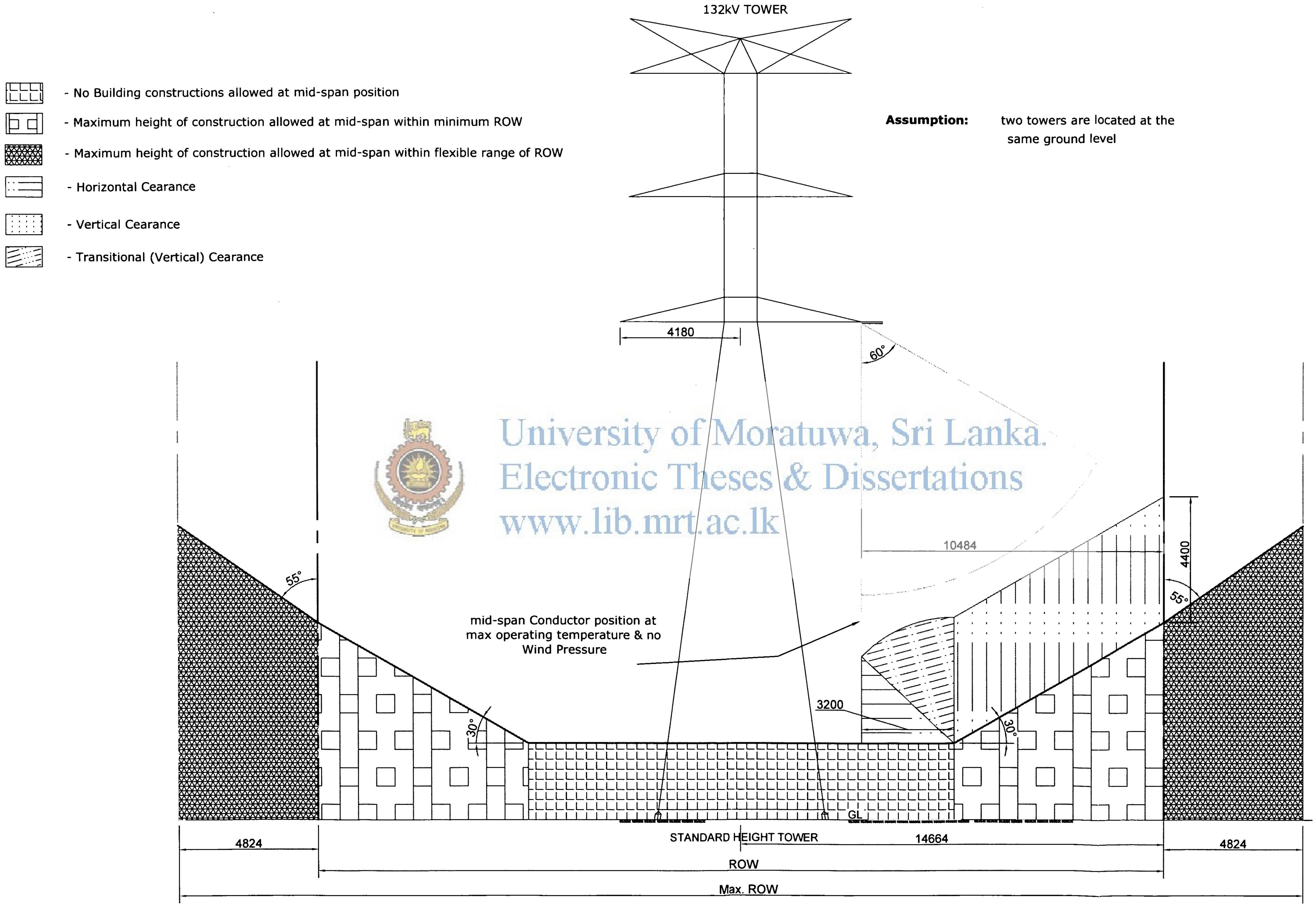
MATURE HEIGHT OF TREE WITHIN RIGHT-OF WAY (ROW) WIDTH FOR 220KV (ZEBRA) & 33KV LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

MAXIMUM HEIGHT OF BUIDING AT MID-SPAN WITHIN RIGHT-OF-WAY (ROW) WIDTH OF 132KV(ZEBRA) LINE

Annex 3.8.1



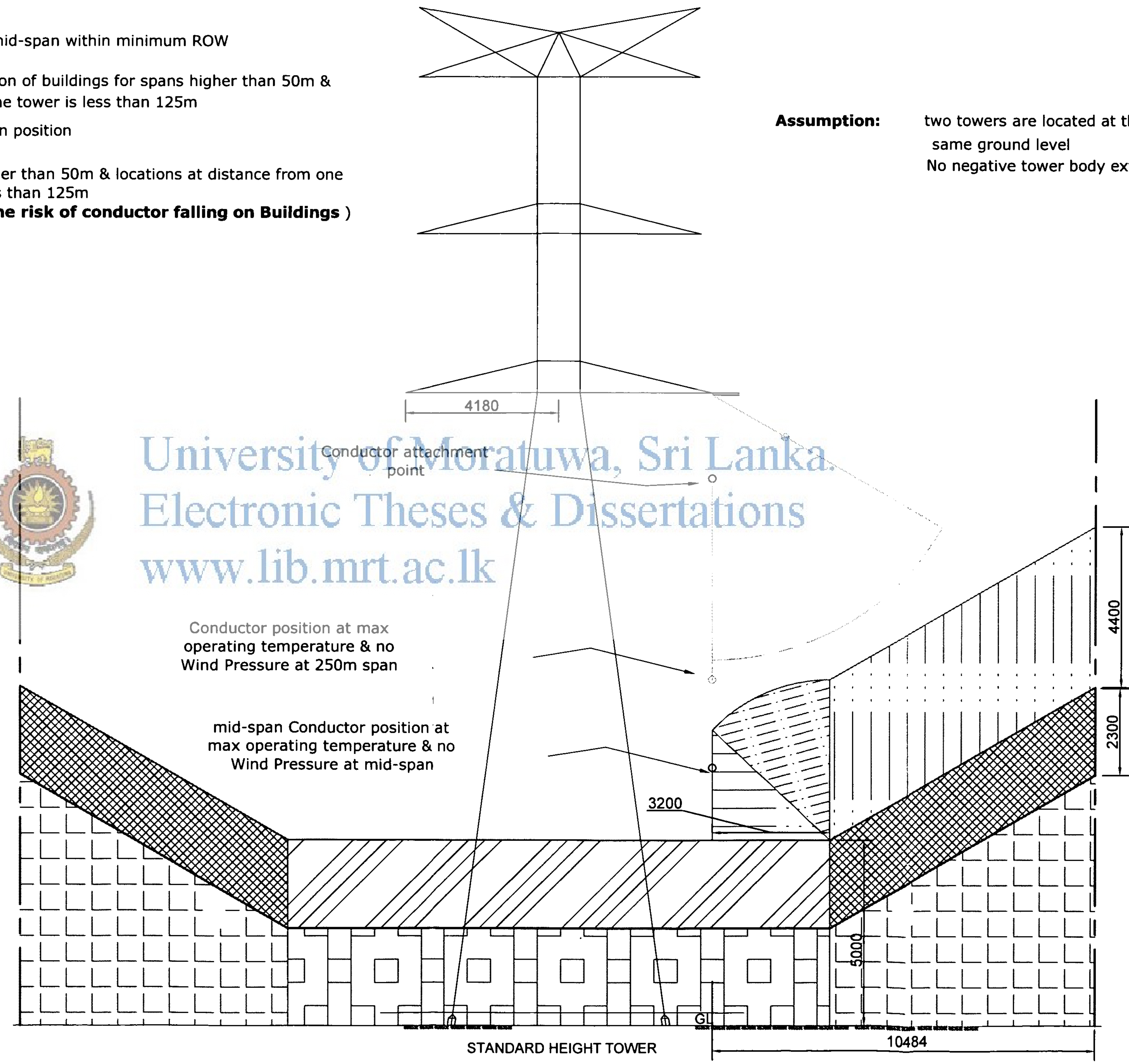
Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:125	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES		**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-8.2

MAXIMUM HEIGHT OF BUIDING ALONG THE SPAN WITHIN RIGHT-OF-WAY (ROW) OF 132KV (ZEBRA) LINE

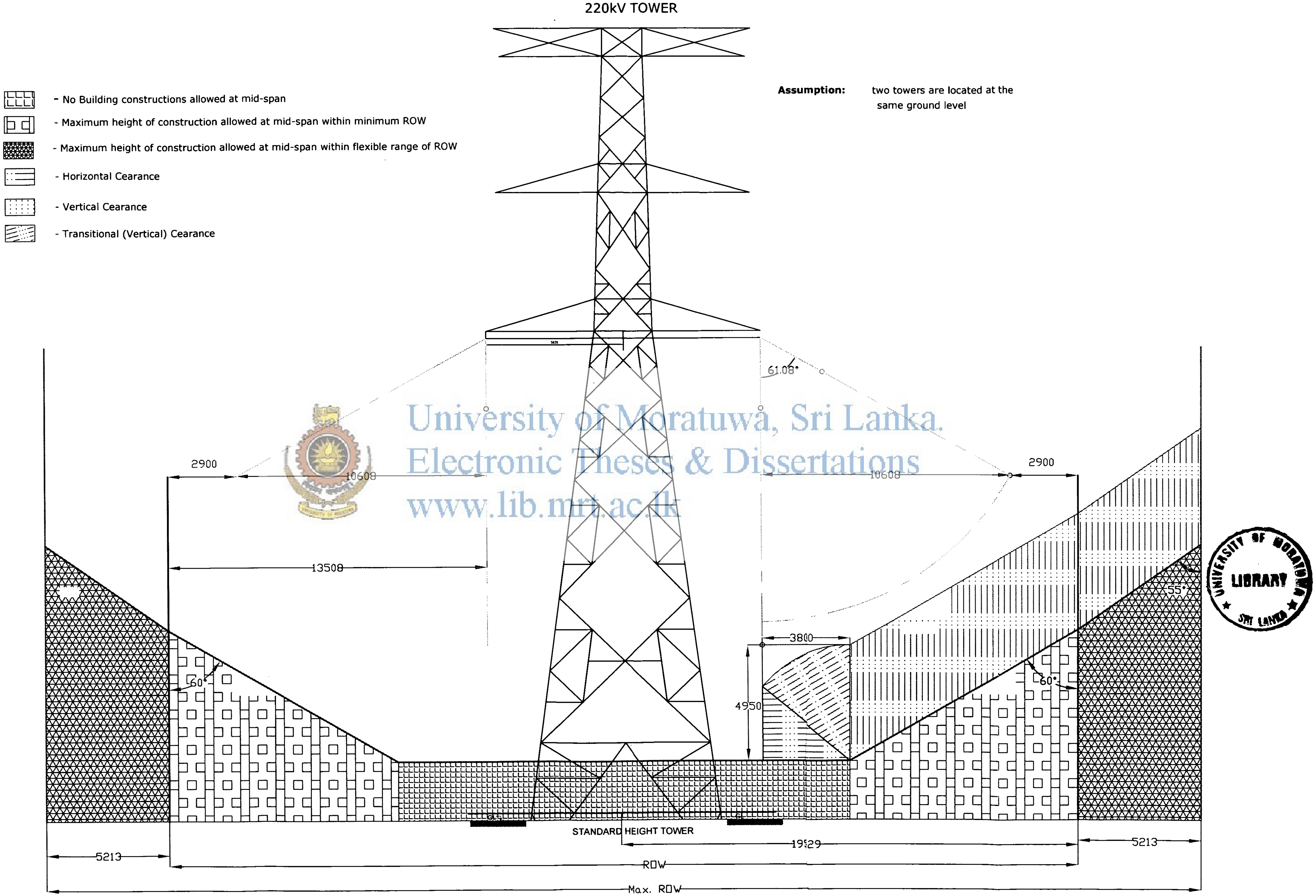
- Maximum height of construction allowed at mid-span within minimum ROW
- Increased height of safe region for construction of buildings for spans higher than 50m & locations at distance from one tower is less than 125m
- No Building constructions allowed at mid-span position
- Inceased Height of safe region for spans higher than 50m & locations at distance from one tower is less than 125m **(But Constructions not allowed due to the risk of conductor falling on Buildings)**
- Horizontal Cearance
- Vertical Cearance
- Transitional (Vertical) Cearance

Assumption: two towers are located at the same ground level
No negative tower body extensions used



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:125	CLEARANCE TO BUILDINGS AND FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

MAXIMUM HEIGHT OF BUIDING AT MID-SPAN WITHIN RIGHT-OF-WAY (ROW) WIDTH OF 220KV (ZEBRA) LINE



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

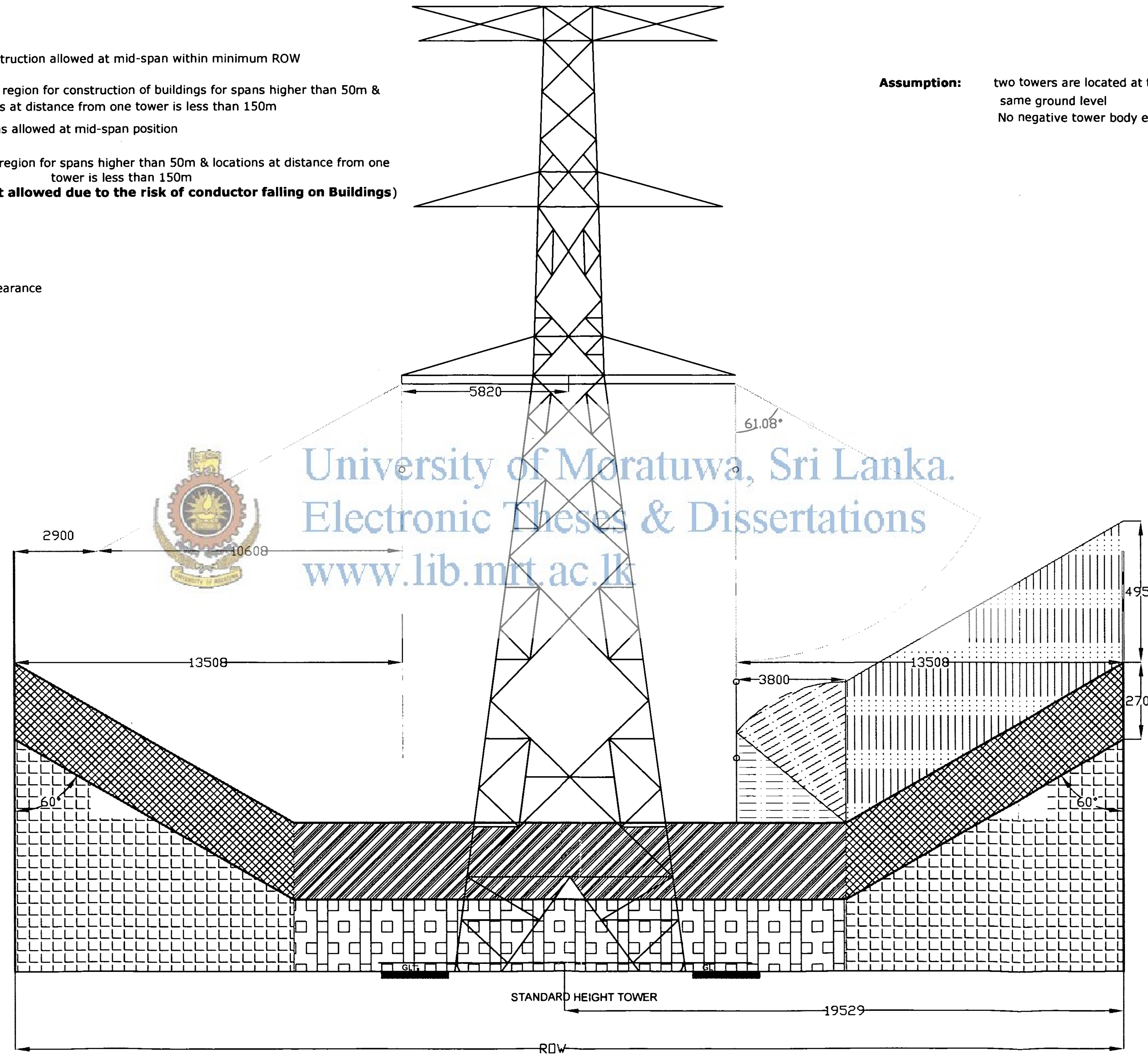
MAXIMUM HEIGHT OF BUIDING ALONG THE SPAN WITHIN RIGHT-OF-WAY (ROW) WIDTH OF 220KV (ZEBRA) LINE

Annex 3-8.4

220kV TOWER

- Maximum height of construction allowed at mid-span within minimum ROW
- Increased height of safe region for construction of buildings for spans higher than 50m & locations at distance from one tower is less than 150m
- No Building constructions allowed at mid-span position
- Inceased Height of safe region for spans higher than 50m & locations at distance from one tower is less than 150m
(**But Constructions not allowed due to the risk of conductor falling on Buildings**)
- Horizontal Cearance
- Vertical Cearance
- Transitional (Vertical) Cearance

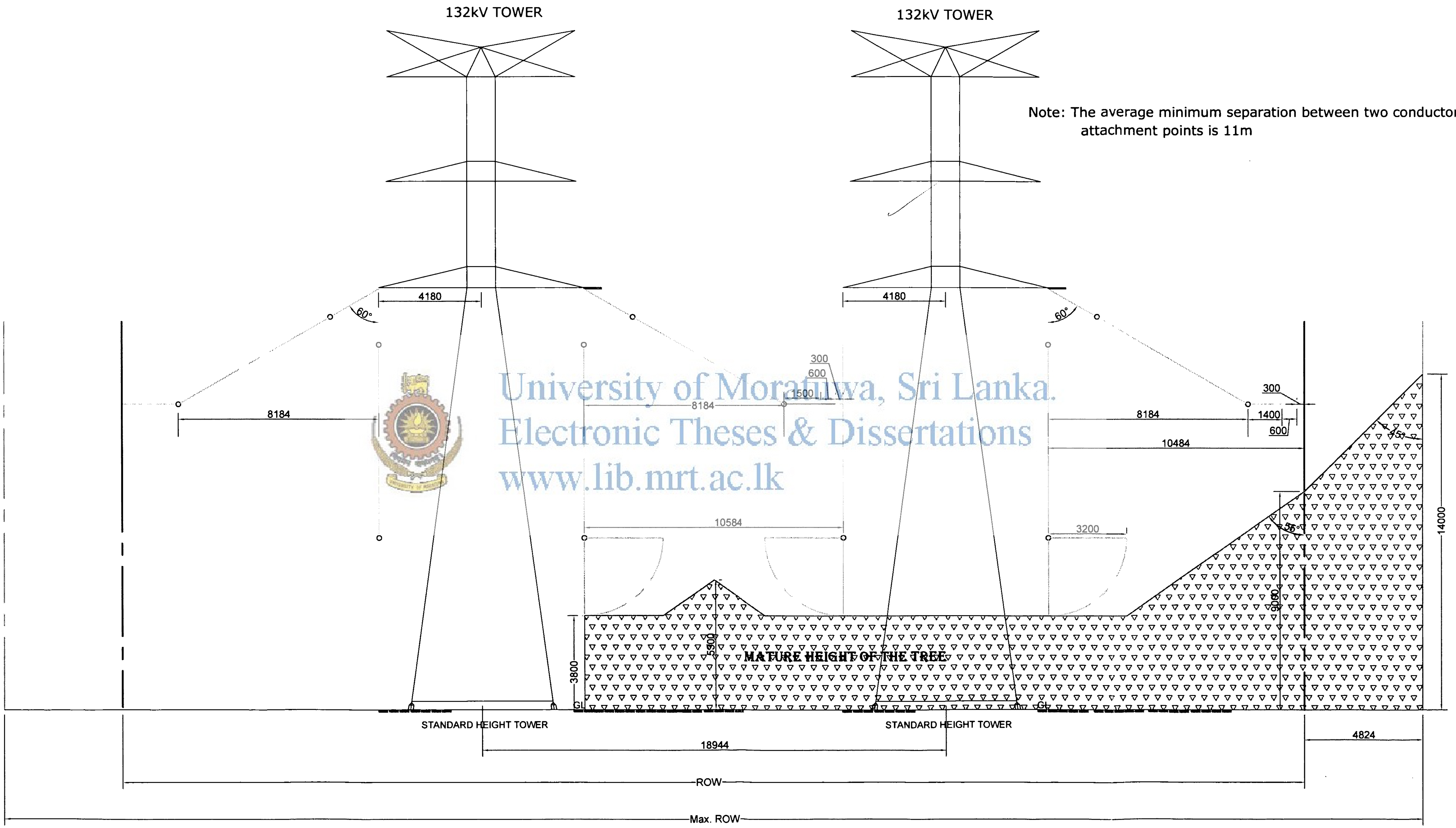
Assumption: two towers are located at the same ground level
No negative tower body extensions used



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-9.1

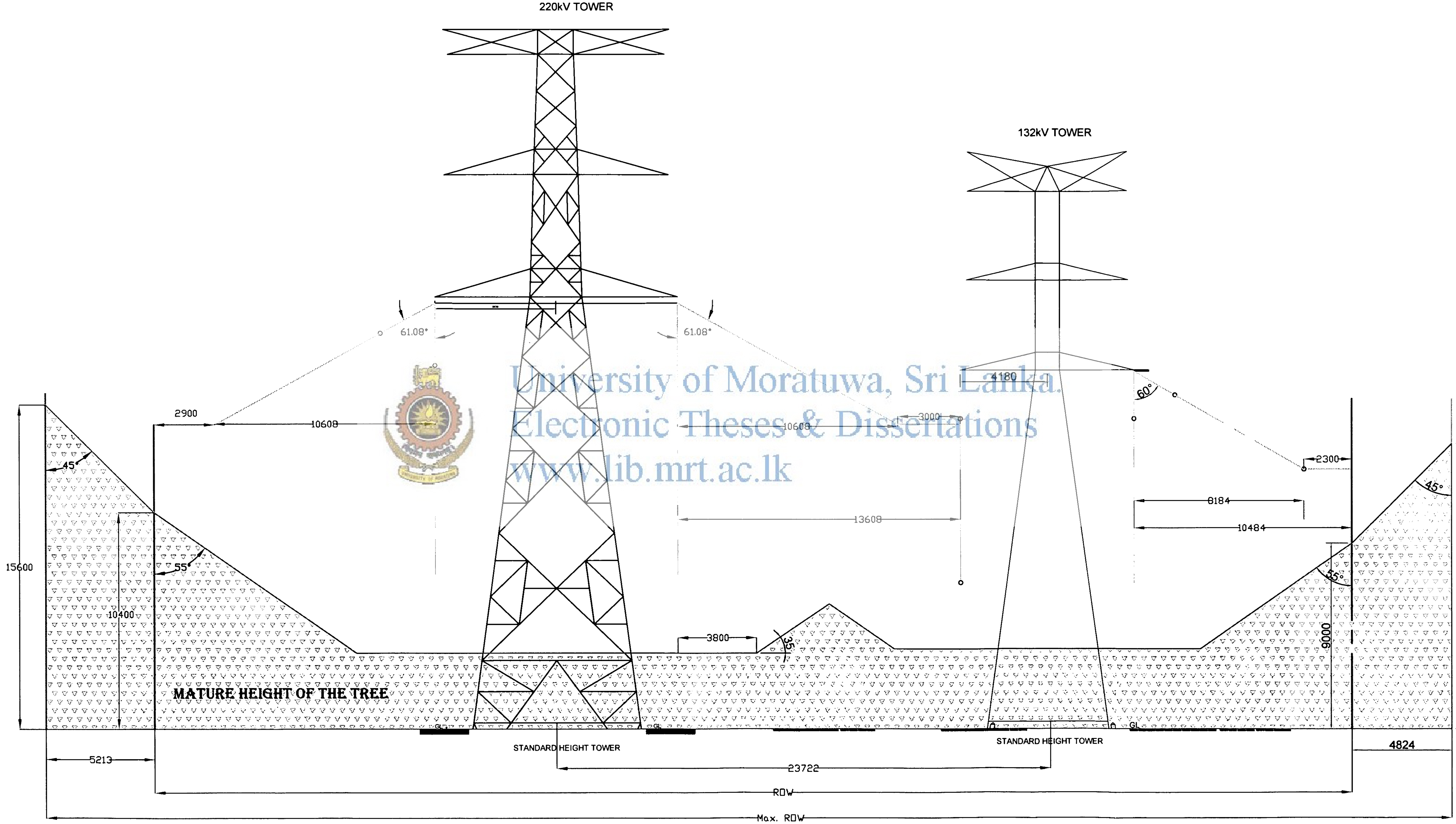
MATURE HEIGHT OF TREE WITHIN RIGHT-OF-WAY(ROW) OF TWO 132KV (ZEBRA) LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

Annex 3-9.2

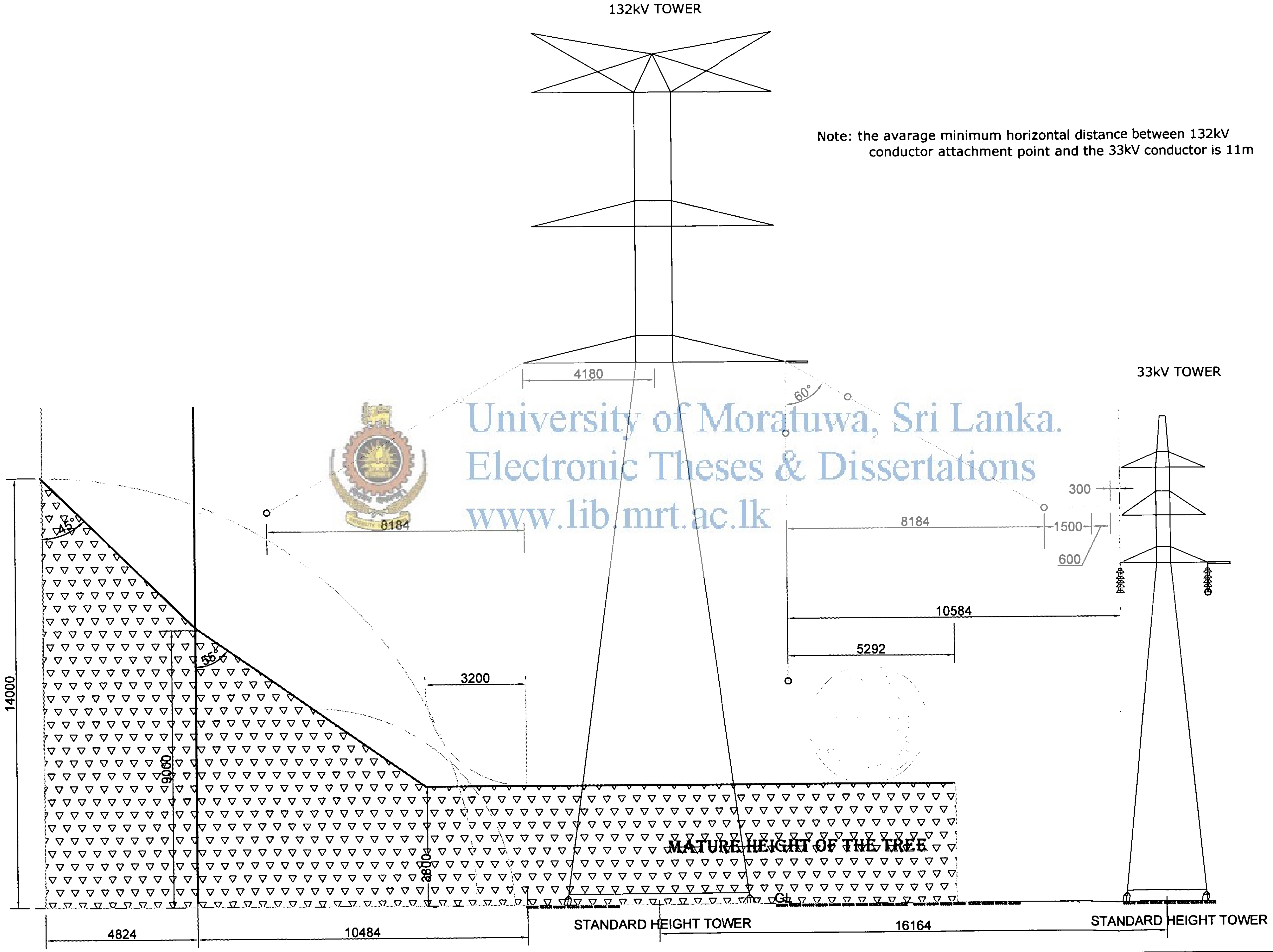
MATURE HEIGHT OF TREE WITHIN RIGHT-OF WAY (ROW) WIDTH OF 132KV (ZEBRA) & 220KV (ZEBRA) LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:175	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	Master of Science Dissertation Department of Electrical Engineering University of Moratuwa	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

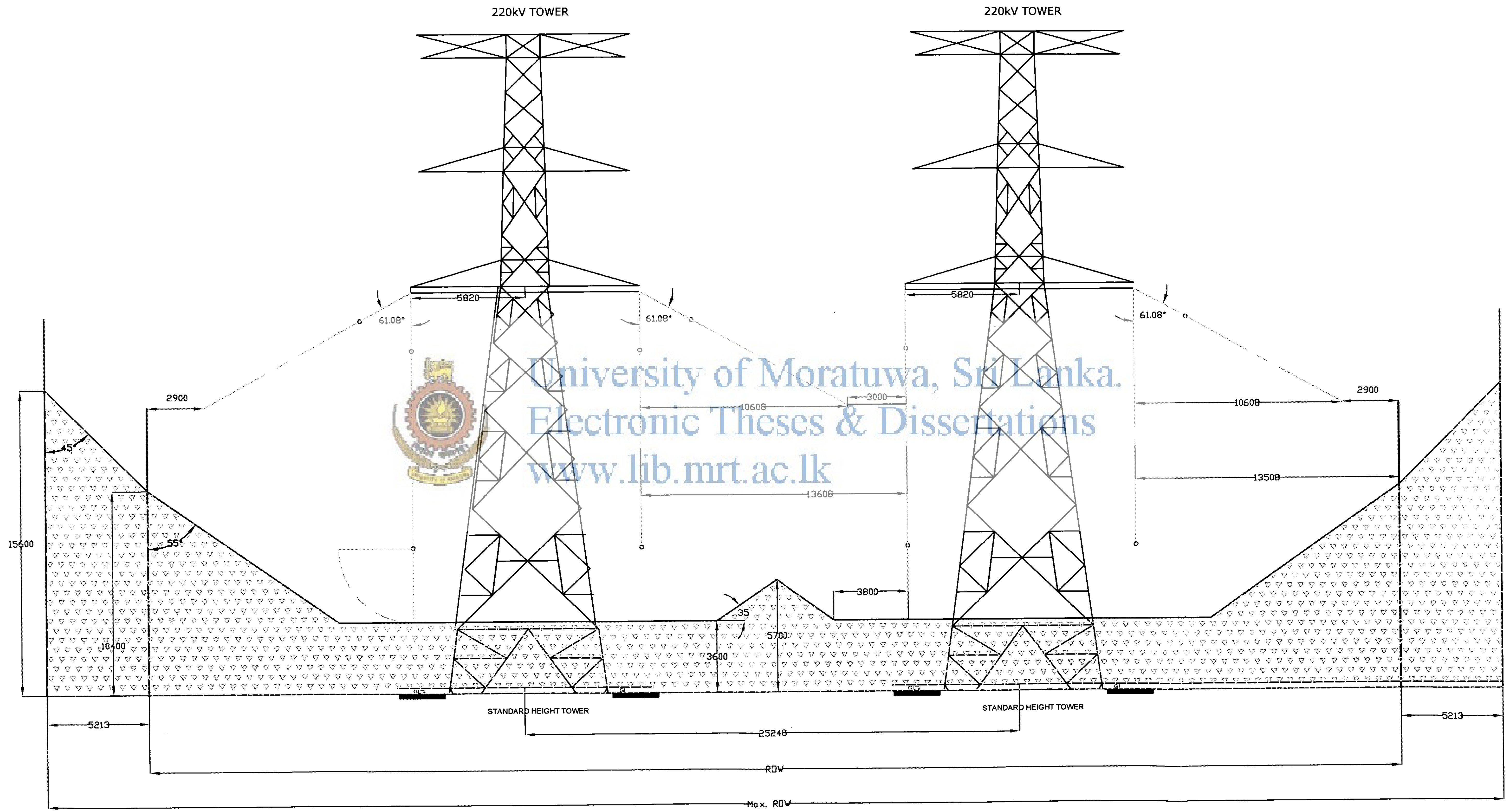
MATURE HEIGHT OF TREE WITHIN RIGHT-OF-WAY(ROW) OF 132KV(ZEBRA) & 33KV LINES

Note: the avarage minimum horizontal distance between 132kV conductor attachment point and the 33kV conductor is 11m



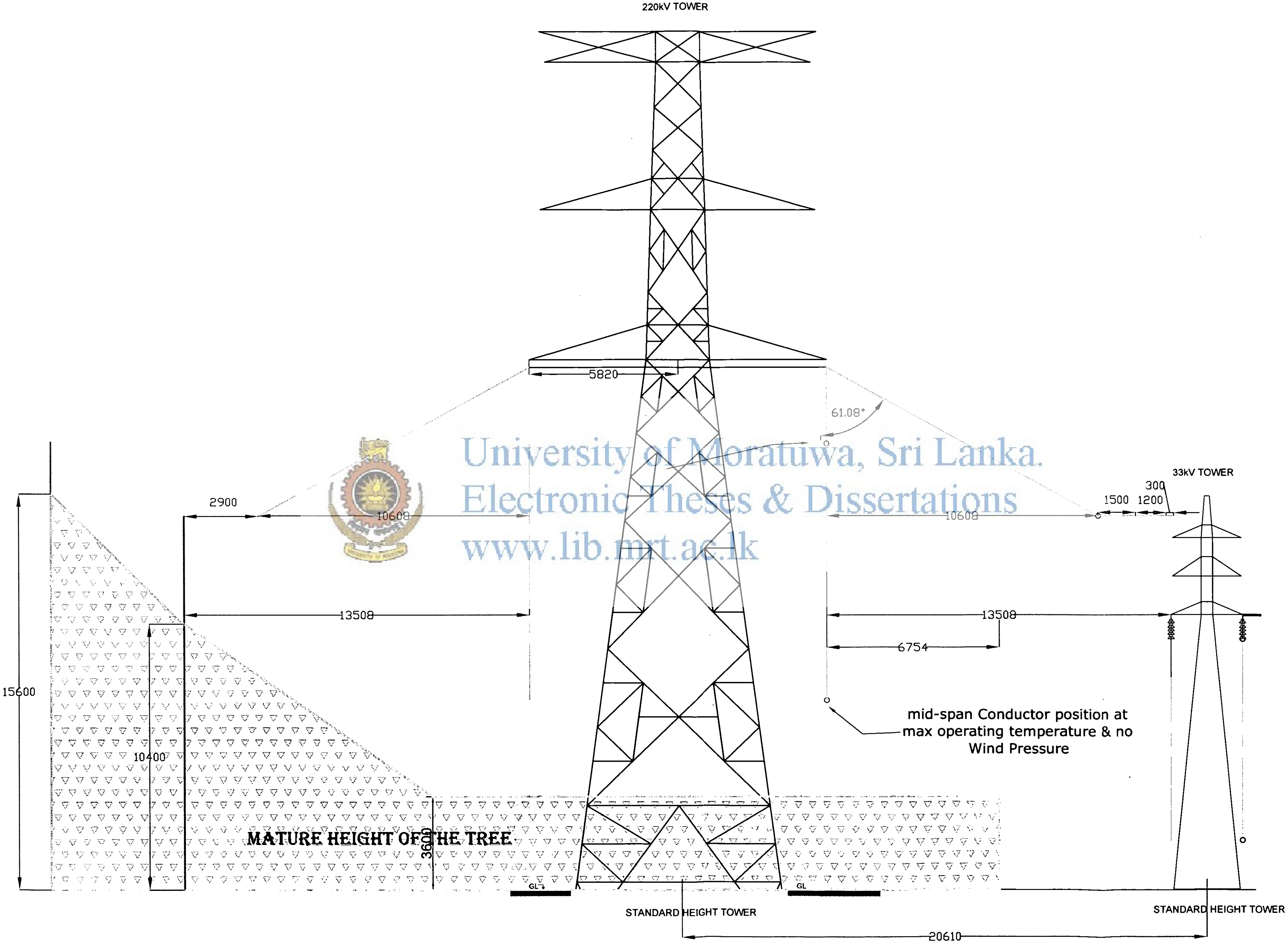
Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:125	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	Master of Science Dissertation Department of Electrical Engineering University of Moratuwa	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

MATURE HEIGHT OF TREE WITHIN RIGHT-OF-WAY(ROW) OF 220KV (ZEBRA) LINES



Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:200	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

MATURE HEIGHT OF TREE WITHIN RIGHT-OF WAY (ROW) WIDTH OF 220KV (ZEBRA) & 33KV LINES

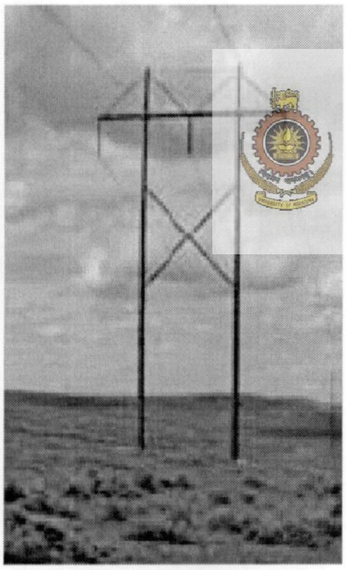


Drawn By: K.K.Shyamali Date: February 2010	All dimensions in millimeters Scale: 1:150	CLEARANCE TO BUILDINGS FROM OVERHEAD TRANSMISSION LINES	**Master of Science Dissertation** **Department of Electrical Engineering** **University of Moratuwa**	Supervised By: Prof. J. R. Lucas Eng. W.D.A.S. Wijayapala

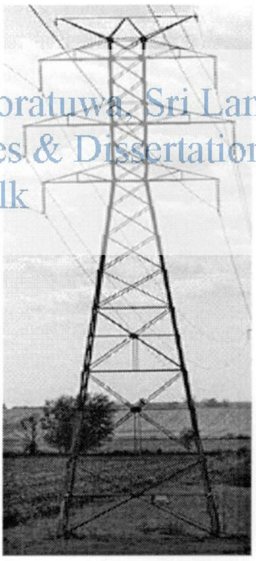
Typical Right-Of-Way (ROW) width defined in "Design Manual for High Voltage Transmission Lines" is shown in following table. The width of a right-of-way depends on the voltage of the line and the height of the structures. Please note that this is based on H-Frame Towers. Therefore, the length of cross arm can be different than the Lattice-style transmission structures which are used in CEB.

TABLE 5-2
TYPICAL RIGHT-OF-WAY WIDTHS

	Nominal Line-to-Line Voltage in kV				
	69	115	138	161	230
ROW Width, ft.	75-100	100	100-150	100-150	125-200

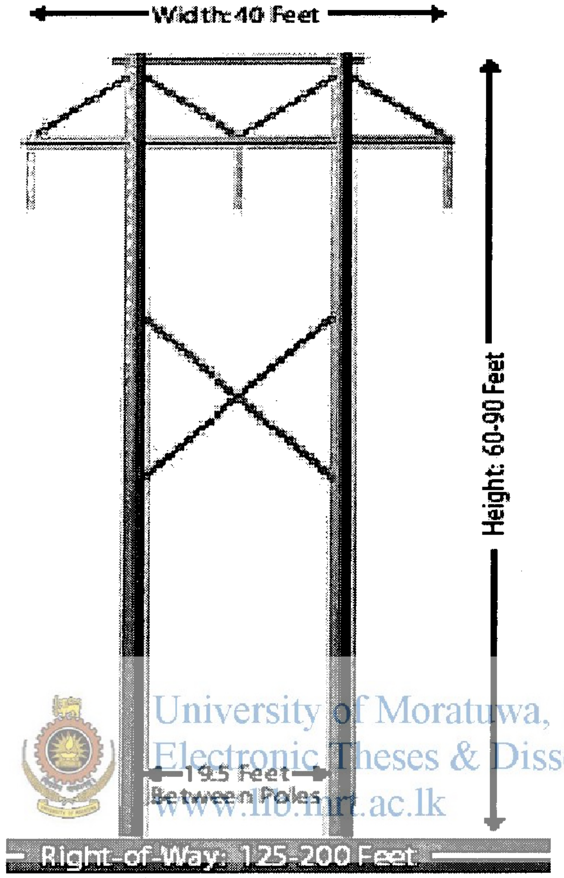


Typical H-frame Structure



Typical Lattice-style transmission structures

The following figure show that another H-frame tower which the specified ROW is 125-200ft.



Power Sector Development Transmission Project - Lot B
Mathugama - Ambalangoda 132kV Transmission Line
List of Towers

RECOMMENDED FOR APPROVAL
WITH COMMENTS
Transmission Design Branch
Ceylon Electricity Board
Date 27/07/06 Sign.

Drawing No. L069-MA-RTE-10

TOWER NO	SECTION NO	TOWER TYPE	BODY EXTN m	FORMATION LEVEL m	BACK SPAN m	ANGLE OF DEVIATION Deg.	LENGTH OF SECTION m	EQUIVALENT SPAN m	TENSION OF CONDUCTOR (BACK SPAN) - Actual AT 7°C+W daN	AT 7°C daN	AT 32°C daN	AT 75°C daN	WIND SPAN m	WEIGHT SPAN at 7°C TOTAL m	WEIGHT SPAN at 32°C TOTAL m	WEIGHT SPAN at 75°C TOTAL m
1		TDT	0	16.91					5055.00	3803.78	2893.03	1989.74	69.25	139.61	122.76	106.05
2	1	TD3	6	6.81	138.49	22° 30' 54" RT	138.49	138.49	5055.00	3803.78	2893.03	1989.74	219.76	160.30	175.49	190.35
3	2	TD6	6	5.24	301.03	44° 34' 04" LT	301.03	301.03	5212.80	3346.16	2837.34	2271.12	284.44	324.73	314.13	303.82
4	3	TD6	0	5.47	267.84	43° 43' 17" LT	267.84	267.84	5055.00	3803.78	2893.03	1989.74	273.53	204.95	219.85	234.95
5	4	TDL	3	4.79	279.21				5212.80	3346.16	2837.34	2271.12	304.73	325.52	322.35	318.84
6	4	TDL	3	4.25	330.24				5212.80	3346.16	2837.34	2271.12	326.86	328.48	328.24	327.96
7	4	TDL	3	3.47	323.48				5212.80	3346.16	2837.34	2271.12	325.38	322.76	323.16	323.60
8	4	TDL	3	3.09	327.27	0			5212.80	3346.16	2837.34	2271.12	337.20	338.63	338.41	338.17
9	5	TDL	3	2.45	347.13				5212.80	3346.16	2837.34	2271.12	359.71	308.34	316.16	324.85
10	5	TDL	12	1.91	372.29				5212.80	3346.16	2837.34	2271.12	324.00	395.93	384.99	372.82
11	5	TDL	9	1.69	275.71				5212.80	3346.16	2837.34	2271.12	315.98	346.85	342.15	336.93
12	5	TD1	0	1.27	356.25	11° 39' 46" LT	2611.58	331.09	5212.80	3346.16	2837.34	2271.12	299.17	236.63	246.14	256.72
13	6	TDL	0	2.11	242.08				5212.80	3346.16	2837.34	2271.12	281.81	276.57	277.37	278.26
14	6	TDL	3	1.03	321.53				5212.80	3346.16	2837.34	2271.12	309.70	323.30	321.23	318.93
15	6	TDL	3	0.87	297.86				5212.80	3346.16	2837.34	2271.12	313.84	275.06	280.96	287.52
16	6	TD1	9	0.81	329.82	0	1191.29	303.50	5212.80	3346.16	2837.34	2271.12	372.00	425.20	417.11	408.11
17	7	TDL	6	0.73	414.18				5212.80	3346.16	2837.34	2271.12	359.19	384.95	381.03	376.67
18	7	TDL	0	0.72	304.2				5212.80	3346.16	2837.34	2271.12	314.24	190.34	209.18	230.15
19	7	TD3	3	10.53	324.28	30° 04' 47" RT	1042.66	357.56	5212.80	3346.16	2837.34	2271.12	345.27	467.42	448.85	428.18
20	8	TDL	6	0.6	366.26				5212.80	3346.16	2837.34	2271.12	359.61	300.79	309.74	319.69
21	8	TDL	9	0.85	352.95				5212.80	3346.16	2837.34	2271.12	353.27	389.66	384.13	377.97
22	8	TDL	6	0.95	353.58				5212.80	3346.16	2837.34	2271.12	359.37	343.31	345.75	348.47
23	8	TDL	6	0.76	365.16				5212.80	3346.16	2837.34	2271.12	355.08	336.36	339.20	342.37
24	8	TDL	9	0.67	345				5212.80	3346.16	2837.34	2271.12	354.03	406.21	398.28	389.45
25	8	TDL	3	0.67	363.05				5212.80	3346.16	2837.34	2271.12	355.62	302.87	310.89	319.82

Annex 3-11

Power Sector Development Transmission Project - Lot B
Mathugama - Ambalangoda 132kV Transmission Line
List of Towers

REC... APPROVAL
Transmi...
Ceylon El...
Date

Drawing No. L069-MA-RTE-10

TOWER TOWER NO	SECTION NO	TOWER TYPE	BODY EXTN m	FORMATION LEVEL m	BACK SPAN m	ANGLE OF DEVIATION Deg.	LENGTH OF SECTION m	EQUIVALENT SPAN m	TENSION OF CONDUCTOR (BACK SPAN) - Actual AT 7°C+W daN	AT 7°C daN	AT 32°C daN	AT 75°C daN	WIND SPAN m	WEIGHT SPAN at 7°C TOTAL m	WEIGHT SPAN at 32°C TOTAL m	WEIGHT SPAN at 75°C TOTAL m
26	8	TDL	6	0.7	348.19				5212.80	3346.16	2837.34	2271.12	328.37	365.33	359.71	353.45
27	8	TD6	0	3.93	308.54	37° 36' 16" LT	2802.73	351.61	5212.80	3346.16	2837.34	2271.12	332.67	298.25	303.48	309.31
28	9	TDL	6	0.6	356.79				5212.8	3346.16	2837.34	2271.12	346.98	382.77	377.33	371.27
29	9	TDL	3	0.35	337.16				5212.8	3346.16	2837.34	2271.12	287.02	241.88	248.75	256.38
30	9	TDL	3	3.18	236.87				5212.8	3346.16	2837.34	2271.12	245.00	315.41	304.70	292.79
31	9	TDL	0	0.68	253.13				5212.8	3346.16	2837.34	2271.12	285.96	202.22	214.96	229.13
32	9	TD1	6	0.52	318.78	12° 32' 55" LT	1502.73	311.33	5212.8	3346.16	2837.34	2271.12	317.87	355.38	349.67	343.32
33	10	TDL	6	0.64	316.95				5212.80	3346.16	2837.34	2271.12	320.41	359.67	353.70	347.06
34	10	TDL	0	0.68	323.86				5212.80	3346.16	2837.34	2271.12	273.10	206.41	216.55	227.83
35	10	TDL	3	0.68	222.33				5212.80	3346.16	2837.34	2271.12	278.30	305.51	301.37	296.77
36	10	TDL	3	0.84	334.27				5212.80	3346.16	2837.34	2271.12	335.30	334.93	334.99	335.05
37	10	TDL	3	1.06	336.33				5212.80	3346.16	2837.34	2271.12	348.43	338.37	339.90	341.60
38	10	TDL	3	3.03	360.52				5212.80	3346.16	2837.34	2271.12	319.61	361.49	355.12	348.04
39	10	TD6	0	1.97	278.7	57° 58' 37" RT	2172.96	318.69	5212.80	3346.16	2837.34	2271.12	275.73	158.19	176.06	195.95
40	11	TDL	3	10.33	272.75				5212.80	3346.16	2837.34	2271.12	245.22	336.62	322.72	307.26
41	11	TDL	6	6.88	217.69				5212.80	3346.16	2837.34	2271.12	283.56	329.68	322.66	314.86
42	11	TD3	3	1.45	349.43	27° 03' 43" LT	839.87	295.37	5212.80	3346.16	2837.34	2271.12	350.72	283.94	294.10	305.39
43	12	TDL	6	1.2	352				5212.80	3346.16	2837.34	2271.12	336.06	311.70	315.41	319.53
44	12	TD3	9	4.43	320.12	28° 50' 24" RT	672.12	337.19	5212.80	3346.16	2837.34	2271.12	309.13	372.40	362.77	352.07
45	13	TDL	9	1.21	298.13				5212.80	3346.16	2837.34	2271.12	327.00	342.14	339.83	337.27
46	13	TDL	3	0.79	355.87				5212.80	3346.16	2837.34	2271.12	354.94	299.26	307.73	317.15
47	13	TDL	6	0.83	354				5212.80	3346.16	2837.34	2271.12	329.00	346.06	343.47	340.58
48	13	TDL	6	0.96	304				5212.80	3346.16	2837.34	2271.12	352.44	337.53	339.79	342.32
49	13	TDL	9	0.99	400.87				5212.80	3346.16	2837.34	2271.12	355.00	410.30	401.89	392.53
50	13	TDL	3	1.15	309.13				5212.80	3346.16	2837.34	2271.12	327.45	235.53	249.51	265.06
51	13	TDL	9	3.82	345.77				5212.80	3346.16	2837.34	2271.12	315.20	430.79	413.22	393.65
52	13	TD1	3	1.22	284.62	09° 58' 07" LT	2652.39	337.64	5212.80	3346.16	2837.34	2271.12	304.74	198.06	214.28	232.33

Power Sector Development Transmission Project - Lot B
Mathugama - Ambalangoda 132kV Transmission Line
List of Towers

APPROVAL
Date

Drawing No. L069-MA-RTE-10

TOWER NO	SECTION NO	TOWER TYPE	BODY EXTN m	FORMATION LEVEL m	BACK SPAN m	ANGLE OF DEVIATION Deg.	LENGTH OF SECTION m	EQUIVALENT SPAN m	TENSION OF CONDUCTOR (BACK SPAN) - Actual AT 7°C+W daN	AT 7°C daN	AT 32°C daN	AT 75°C daN	WIND SPAN m	WEIGHT SPAN at 7°C TOTAL m	WEIGHT SPAN at 32°C TOTAL m	WEIGHT SPAN at 75°C TOTAL m
53	14	TDL	3 +6	7.98	324.86				5212.80	3346.16	2837.34	2271.12	272.19	346.17	334.92	322.40
54	14	TD6	6	1.78	219.52	52° 08' 31" RT	544.38	287.07	5212.80	3346.16	2837.34	2271.12	246.58	200.98	209.24	217.98
55	15	TDL	6	3.52	273.63				5055.00	3803.78	2893.03	1989.74	209.86	184.46	190.54	196.58
56	15	TD6	9	3.01	146.09	34° 03' 58" LT	419.72	237.15	5055.00	3803.78	2893.03	1989.74	225.42	179.83	183.22	188.17
57	16	TDL	12	12.56	304.75				5212.80	3346.16	2837.34	2271.12	349.92	504.86	481.30	455.08
58	16	TD3	9	2.55	395.08	24° 34' 22" LT	699.83	358.55	5212.80	3346.16	2837.34	2271.12	397.07	342.16	350.51	359.80
59	17	TDL	6	2.89	399.06				5212.80	3346.16	2837.34	2271.12	359.53	361.67	361.34	360.98
60	17	TDL	3	3.43	320				5212.80	3346.16	2837.34	2271.12	345.50	305.14	311.28	318.11
61	17	TDL	6	4.74	371				5212.80	3346.16	2837.34	2271.12	357.50	392.85	387.48	381.49
62	17	TDL	3	5.92	344				5212.80	3346.16	2837.34	2271.12	353.64	320.54	325.57	331.17
63	17	TDL	3	9.75	363.28				5212.80	3346.16	2837.34	2271.12	313.12	384.06	373.27	361.27
64	17	TD3	0	6.6	262.95	25° 24' 15" LT	2060.29	351.27	5212.80	3346.16	2837.34	2271.12	264.31	156.77	173.12	191.32
65	18	TDL	9	5.05	265.66				5212.80	3346.16	2837.34	2271.12	278.21	383.80	367.74	349.87
66	18	TD6	3	4.52	290.76	59° 26' 36" RT	556.42	279.06	5212.80	3346.16	2837.34	2271.12	316.41	261.39	269.75	279.06
67	19	TDL	3	5.84	342.06				5212.80	3346.16	2837.34	2271.12	337.08	329.72	330.84	332.08
68	19	TDL	3	8.29	332.09				5212.80	3346.16	2837.34	2271.12	322.51	293.10	297.58	302.55
69	19	TD3	0	18	312.93	23° 52' 59" RT	987.08	329.69	5212.80	3346.16	2837.34	2271.12	347.47	360.44	358.47	356.27
70	20	TDL	3	20.82	382				5212.80	3346.16	2837.34	2271.12	348.00	450.57	434.97	417.61
71	20	TDL	6 3	7.2	314				5212.80	3346.16	2837.34	2271.12	293.00	248.65	255.40	262.90
72	20	TDL	3	6.77	272				5212.80	3346.16	2837.34	2271.12	278.76	282.85	282.23	281.54
73	20	TD3	3	2.61	285.51	14° 58' 12' LT	1253.51	322.16	5212.80	3346.16	2837.34	2271.12	315.26	244.31	255.10	267.10
74	21	TDL	9	3.29	345				5212.80	3346.16	2837.34	2271.12	359.50	412.45	404.40	395.44
75	21	TDL	9	1.06	374				5212.80	3346.16	2837.34	2271.12	343.50	280.07	289.71	300.45
76	21	TDL	12	5.69	313				5212.80	3346.16	2837.34	2271.12	359.66	409.13	401.61	393.23
77	21	TDL	12	5.98	406.31				5212.80	3346.16	2837.34	2271.12	342.96	313.27	317.79	322.81
78	21	TDL	12	10.15	279.61				5212.80	3346.16	2837.34	2271.12	349.21	422.52	411.37	398.97
79	21	TDL	3	10.71	418.8				5212.80	3346.16	2837.34	2271.12	329.94	307.49	310.90	314.70

RECOMMENDED FOR APPROVAL
WITH COMMENTS
Transmission Design Branch
Ceylon Electricity Board
Date 21/07/06 Sign.

Power Sector Development Transmission Project - Lot B
Mathugama - Ambalangoda 132kV Transmission Line
List of Towers

Drawing No. L069-MA-RTE-10

TOWER NO	SECTION NO	TOWER TYPE	BODY EXTN m	FORMATION LEVEL m	BACK SPAN m	ANGLE OF DEVIATION Deg.	LENGTH OF SECTION m	EQUIVALENT SPAN m	TENSION OF CONDUCTOR (BACK SPAN) - Actual AT 7°C+W daN	AT 7°C daN	AT 32°C daN	AT 75°C daN	WIND SPAN m	WEIGHT SPAN at 7°C TOTAL m	WEIGHT SPAN at 32°C TOTAL m	WEIGHT SPAN at 75°C TOTAL m
80	21	TD3	3	8.44	241.07	23° 04' 14" LT	2377.79	355.46	5212.80	3346.16	2837.34	2271.12	250.54	183.56	193.75	205.08
81	22	TDL	9	8.32	260.00				5212.80	3346.16	2837.34	2271.12	331.50	369.91	364.07	357.57
82	22	TDL	6	13.03	403.00				5212.80	3346.16	2837.34	2271.12	356.00	443.56	430.25	415.43
83	22	TDL	0	7.40	309.00				5212.80	3346.16	2837.34	2271.12	354.50	208.02	230.29	255.08
84	22	TDL	9	11.37	400				5212.80	3346.16	2837.34	2271.12	359.00	418.57	409.52	399.43
85	22	TDL	6	15.62	318				5212.80	3346.16	2837.34	2271.12	314.00	440.92	421.62	400.14
86	22	TDL	-3	7.02	310				5212.80	3346.16	2837.34	2271.12	321.04	205.73	223.27	242.78
87	22	TDI	0	3.48	332.07	06° 04' 28" RT	2332.07	343.46	5212.80	3346.16	2837.34	2271.12	293.00	190.75	214.94	239.04
88	23	TDL	9	5.04	253.92				5055.00	3803.78	2893.03	1987.74	220.49	340.68	311.90	283.30
89	23	TDI	6	6.36	187.06	11° 50' 32" RT	440.98	227.97	5055.00	3803.78	2893.03	1987.74	164.38	150.24	153.63	156.99
90	24	TDT	3	8.93	141.69		141.69	141.69	5055.00	3803.78	2893.03	1987.74	70.85	63.63	65.36	67.08
					28009.45											