ANALYSIS OF MOBILE RADIO PROPAGATION MEASUREMENTS

by

Richard Matsunaga

Contractor

Ottawa, October 1995
CRC Report No. CRC-CR-95-009

Communications Research Centre
Centre de recherches sur les communications

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ANALYSIS OF MOBILE RADIO PROPAGATION MEASUREMENTS

1. INTRODUCTION

1.1 BACKGROUND

This report is an extension of research which began with the analysis of Trois Rivières propagation measurements culminating in CRC Report No. CRC-CR-95-001 (1).

1.2 OBJECT

This report details the results of analysis of VHF/UHF measurement runs in southern Ontario, Montreal, Vancouver and Trois Rivières. In particular, the sets of data were compared with predictions computed with CRC PREDICT, while some location variability data were also analyzed. The end result of this analysis was to provide information which could lead to improving field strength predictions made by PREDICT.

2. THEORY

2.1 REGRESSION ANALYSIS

A simple, effective technique to determine the accuracy of predictions is to perform a simple linear regression analysis. This involves plotting the measured data against the predictions and fitting a least squares straight line to the data. The ideal situation will produce a line with a slope of unity and a y-intercept of zero. Non correlated data results in a line with a slope approaching zero.

3. DATA ANALYSIS

3.1 DATA ACQUISITION

The transmitter location and transmission frequencies of all the measurement runs are given in Table 1 Measurements were taken by several different groups: Industry Canada personnel performed the Montreal and Trois Rivières (2) measurements; the Vancouver data was taken by CRC personnel in the Radio Broadcast Transmission group; and all southern Ontario data was taken by Imagineering Limited (3,4) using equipment supplied by CRC's Radio Propagation group.

Data was sampled at different rates: Ontario measurements at FM-band and at 856 MHz were sampled every metre, while at 1.81 GHz, the sample rate was every half metre; Montreal and Trois Rivières data was sampled every 10 milliseconds; and Vancouver measurements were taken every centimetre.

Table 1: Transmission Properties

Location	Frequency (MHz)	Tx Latitude (°N)	Tx Longitude (°W)
First Canadian Place, Toronto (CFMX-FM)	96.3	43° 38' 56"	79° 22' 55"
CN Tower, Toronto (CKFM-FM)	99.9	43° 38' 33"	79° 23' 15"
Fort Erie (CKEY-FM)	101.1	42° 53' 52"	78° 57 27
Cobourg (CFMX-FM)	103.1	44° 04' 14"	78° 08' 36"
King City	856	43° 57' 58"	79° 33' 49"
Barrie	856	44° 24' 10"	79° 42' 38"
Fonthill	856	43° 02' 53"	79° 18' 09"
Kitchener	856	43° 27' 14"	80° 29' 09"
Montreal 11/94 (Lac Echo)	1462.75	45° 51' 48"	74° 1' 20"
Montreal 11/94 (Rigaud)	1465.75	45° 27' 4"	74° 17' 42"
Montreal 11/94 (Mont Royal)	1468.75	45° 30' 20"	73° 35' 32"
Montreal 05/94 (Mont Royal)	1468.75	45° 30' 20"	73° 35' 32"
Trois Rivières (100m tower)	1468.75	46° 29' 27"	72° 39' 00"
Trois Rivières (200m tower)	1468.75	46° 29' 27"	72° 39' 00"
Vancouver	1468.75	49° 21' 12"	122° 57' 18"
Edgar	1810	44° 31' 52"	79° 39' 33"
St. Catherines	1810	43° 08' 30"	79° 14' 12"

For the data collected in the Montreal area in April 1994, there were three transmitter sites operating at different frequencies. The measurements were taken simultaneously, covering mostly the northern half of the Montreal area. In May 1994, Montreal was again the site of propagation

measurements, this time with a single transmitter on Mont Royal. A full 360° was covered out to a distance of approximately 40 kilometres.

As noted by Imagineering, the Fonthill transmitting site suffered from possible antenna pattern distortion; therefore, the absolute value of the field strengths may be wrong. At the St. Catherines site, a 15-storey building obstructed the line of sight at two kilometres distance for one of the azimuths measured. This could have affected the results.

3.2 DATA PROCESSING

3.2a Raw Data

The raw data files came in different formats depending on the group who took the measurements. This data was converted to a simple form consisting of three columns: distance from transmitter, azimuth in degrees from north, and the path loss in dB. In the Montreal and Trois Rivières data files, some measurements were adjusted for noise and others were well into the noise. This type of data was deemed unreliable and was not used in the analysis. Any measurements beyond 100 kilometres are of little interest for this study and were rejected.

All analysis was performed with free space path loss removed from the data because it was of greater interest to examine effects of the local environment on the signal, without contending with the well known free space loss.

3.2b Small Sector and Cell Processing

The small sector length for each data set was selected to provide a sufficient number of samples for each sector while remaining within the limits suggested by Lee (5). For example, the Vancouver measurements, with a high sample rate, a sector length of 4 metres (20 wavelengths) was chosen. This gives 400 data points for each sector, which should give statistically accurate results. A small sector length at the upper end of the range suggested by Lee (40 wavelengths) was chosen for data sets with smaller sample rates.

The small sector medians were grouped into larger cells. Each cell was defined as an area with polar coordinates with the transmitting site as the origin. The cell size chosen was one kilometre along the radial by one or two degrees of azimuth. The angular width of the cell was chosen to be one degree for data sets which extended to greater than 60 km from the transmitter. For smaller data sets, the larger cell angle was selected.

4. RESULTS

4.1 PREDICTION ERROR ANALYSIS

4.1a Overall Error

The final cell statistics for all data sets were compared against predictions made using the computer program CRC PREDICT. Detailed results for Trois Rivières data can be found in CRC

Report No. CRC-CR-95-001. The results for the rest of the data are found in Table 2. A positive

Table 2: PREDICT error

Location	Frequency (MHz)	field strength difference (dB)
First Canadian Place, Toronto (CFMX-FM)	96.3	4.63
CN Tower, Toronto (CKFM-FM)	99.9	3.76
Fort Erie (CKEY-FM)	101.1	6.03
Cobourg (CFMX-FM)	103.1	0.77
King City	856	11.40
Barrie	856	11.38
Fonthill	856	22.27
Kitchener	856	6.70
Montreal (Lac Echo)	1462.75	12.26
Montreal (Rigaud)	1465.75	26.51
Montreal (Mont Royal)	1468.75	14.26
Montreal (May 1994)	1468.75	20.14
Vancouver	1468.75	16.65
Edgar	1810	14.02
St. Catherines	1810	8.04

field strength difference value indicates an optimistic prediction. Two things can be concluded immediately: PREDICT gives optimistic predictions in all cases; and the error in prediction increases with frequency (see Figure 1). In addition, it appears that the Fonthill data is, in fact, unreliable, since it does not seem to fit in with the rest of the measurements. This analysis gives no indication of bad data in St. Catherines.

4.1b Error by Surface Type

Further characterization of the data has been achieved by grouping cells with the same surface code as defined by the CRC Terrain Database (6). The overall mean differences by surface type are shown in Table 3. As in Table 2, a positive field strength error indicates an optimistic prediction. The values marked by asterisks (**) indicate cells which contained fewer than five small

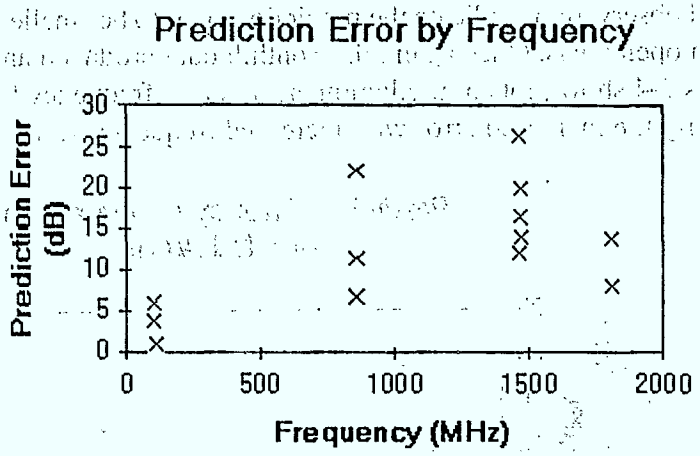


Figure 1: PREDICT error by frequency

Table 3: Mean field strength prediction error by surface type

Location	Frequency (MHz)	tree cover	open ground	suburban
First Canadian Place, Toronto (CFMX-FM)	96.3	-0.95**	4.52	6.26
CN Tower, Toronto (CKFM-FM)	99.9	3.40	2.82	5.59
Fort Erie (CKEY-FM)	101.1	2.82	6.75	8.87
Cobourg (CFMX-FM)	103.1	0.93	0.92	----
King City	856	6.61	12.08	----
Barrie	856	7.75	13.14	----
Fonthill	856	20.90	24.58	13.86
Kitchener	856	0.91	7.57	16.16**
Montreal (Lac Echo)	1462.75	10.96	12.96	15.82
Montreal (Rigaud)	1465.75	23.12	27.52	11.86
Montreal (Mt Royal)	1468.75	8.55	14.34	17.48
Montreal (May 1994)	1468.75	11.6	21.53	17.81
Vancouver	1468.75	11.8	----	17.8
Edgar	1810	7.93	16.81	----
St. Catherines	1810	3.32	9.02	6.68

sector medians. They do not provide a reliable median statistic. Only data from the three most

common terrain types as defined by the CRC Terrain Database, forested, open and suburban, were included. Initial observations indicate the prediction error to be smallest in forested areas, with the largest errors in open areas. Once again, the Fonthill data produced anomalous data, as seen in Table 3. Figures 2-4 show plots of prediction error versus frequency for different terrain types. These plots verify the increased error with increased frequency seen in Figure 1.

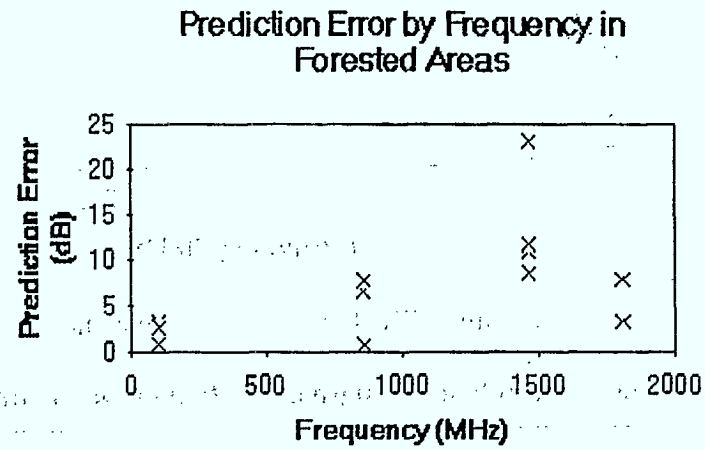


Figure 2: PREDICT error by frequency in forested areas

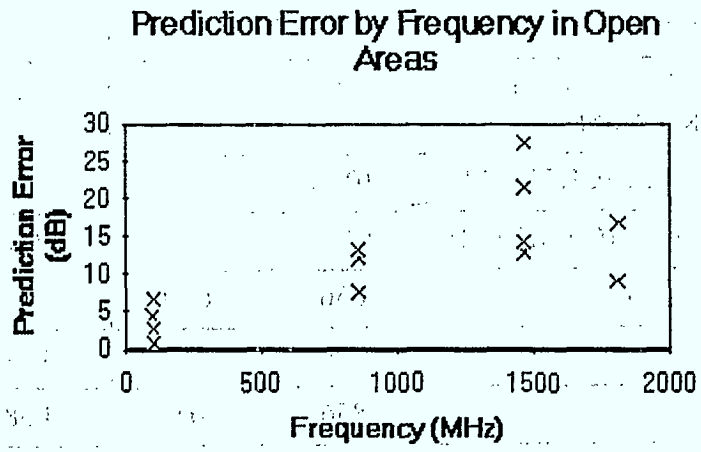


Figure 3: PREDICT error by frequency in open areas

4.1c Regression analysis of predictions

The least squares fit routine used for this analysis was a Numerical Recipes in C function called fitexy.c (7). This function uses the errors in both coordinates in its calculation of the best fit line. The variability in both the measured and the predicted data were used for these errors. Plots for all data sets are included in Appendix A. Table 4 contains the slope and intercept of the least squares line fit for the data broken down into different surface types. Only the three most common terrain types are included: forest, open, and suburban. The overall regression does include regions defined by the database as fresh water and marsh areas. Trois Rivières data is also included because regression analysis was not included in the previous report. The best predictions overall

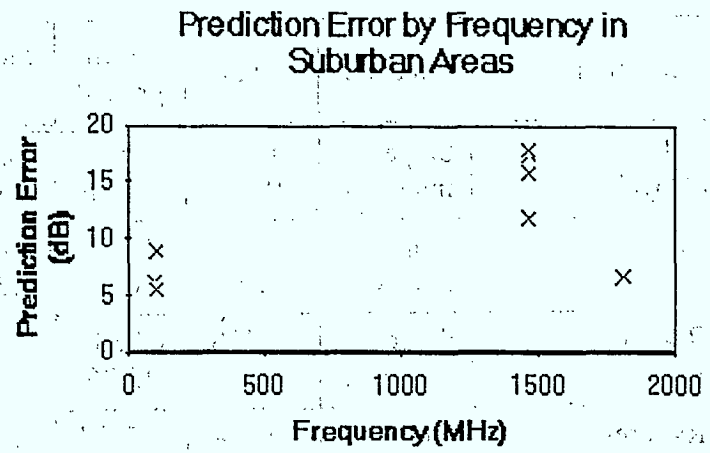


Figure 4: PREDICT error by frequency in suburban areas

Table 4: Regression Analysis Results

Location	Statistic	Forest	Open ground	Suburban	Overall
First Canadian Place, Toronto (CFMX-FM)	Slope Intercept	----	0.8040 10.30	0.8503 9.420	0.8074 9.960
CN Tower, Toronto (CKFM-FM)	Slope Intercept	----	1.020 2.280	0.8374 8.395	0.9345 5.288
Fort Erie (CKEY-FM)	Slope Intercept	0.9555 4.898	0.7696 15.53	0.9804 9.654	0.8993 10.14
Cobourg (CFMX-FM)	Slope Intercept	0.6168 11.91	0.6409 10.52	----	0.6993 8.900
King City	Slope Intercept	1.359 -4.762	0.8528 13.92	----	0.9284 12.51
Barrie	Slope Intercept	0.6618 21.32	0.7762 18.55	----	0.7534 18.94
Fonthill	Slope Intercept	0.9351 19.73	0.4331 29.50	----	0.6802 26.58
Kitchener	Slope Intercept	0.9302 2.447	1.034 6.413	----	0.9100 8.800
Montreal (Lac Echo)	Slope Intercept	1.441 1.893	-0.504 31.85	0.0351 32.61	0.145 25.15
Montreal (Rigaud)	Slope Intercept	0.751 28.30	0.893 28.50	-0.272 46.66	0.7402 29.49

Table 4: Regression Analysis Results

Location	Statistic	Forest	Open ground	Suburban	Overall
Montreal (Mont Royal)	Slope Intercept	0.506 18.84	0.529 18.91	0.696 21.50	0.562 19.50
Montreal (May 1994)	Slope Intercept	0.937 12.84	1.131 20.47	0.6032 23.87	0.749 22.54
Trois Rivières (100m tower)	Slope Intercept	0.8128 8.641	0.7383 12.26	1.421 -7.364	0.7570 11.72
Trois Rivières (200m tower)	Slope Intercept	0.6824 15.17	0.7427 14.04	2.102 -17.56	0.7356 14.29
Vancouver	Slope Intercept	0.8717 14.33	----	0.4945 26.53	0.6760 22.40
Edgar	Slope Intercept	0.9802 9.128	0.8744 19.61	----	0.7888 20.43
St. Catherines	Slope Intercept	2.565 -36.21	1.496 -5.020	0.2854 18.23	1.882 -13.18

appear to have occurred in areas defined as forested by the terrain database. Any sections which had inadequate sample sizes were not included in the table or the plot in Appendix A.

The St. Catherines measurements exhibit bad fit to predictions in all areas covered by the run. Since Imagineering singled out only one of four radials (358°) as being suspect, further regression analysis (for each individual radial) showed that the results for St. Catherines are wildly variable both for different terrain types and for different radials. In fact, the suburban regions of radial 358° were the only regions which were comparable to predictions (regression slope = 0.93; avg prediction error = 6.93 dB).

4.2 VARIABILITY ANALYSIS

For meaningful variability analysis, a large amount of data must be collected to provide the good sample sizes essential for statistical accuracy. In the previous report, the Trois Rivières data provided good variability data with coverage of more than 4000 cells of 1 kilometre by 1 degree. Both sets of Montreal data provided similar density, with full 360 degree coverage, out to a distance of approximately 40 kilometres. The remaining data sets only covered certain radials or small areas. For this reason, only variability data from the Montreal measurements have been included in this report.

To characterize the signal variability at 1.5 GHz, there are many ways to group the data in an attempt to find patterns. The groupings that have been implemented for this analysis are: surface type of the cell; rolling, hilly terrain; surface type of the preceding cell; and distance from the

transmitter.

4.2a Surface Type of Cell

The variability of the signal by surface type comparison is shown in Table 5. The Trois

Table 5: Effect of Surface Type on Variability

Surface Type	Location	# of cells	Mean Variability (dB)
Tree Cover	Montreal (Lac Echo)	251	2.93
	Montreal (Rigaud)	154	2.65
	Montreal (Mont Royal)	275	3.22
	Montreal (May 1994)	105	3.31
Bare Ground	Montreal (Lac Echo)	771	3.75
	Montreal (Rigaud)	688	3.21
	Montreal (Mont Royal)	1210	3.59
	Montreal (May 1994)	1010	3.87
Suburban	Montreal (Lac Echo)	34	3.28
	Montreal (Rigaud)	17	1.90
	Montreal (Mont Royal)	315	2.69
	Montreal (May 1994)	362	3.48

Rivières data showed little difference in the variability between forested and open areas. All the Montreal area data indicate that there is indeed a significant difference in variability between forested and open areas. In every case, the variability in forested cells was smaller than that found in open areas, with percentage differences ranging from 10% to 22%. Suburban cells also exhibited

lower variability than open areas, ranging from 10% to 41% lower. It must also be noted that the sample sizes for suburban areas were quite small for the Lac Echo and Rigaud transmitters.

4.2b Rolling, Hilly Terrain

Okumura (8) defines terrain undulations as the difference between the 10% and 90% terrain elevation levels within a distance of 10 km from the receiving point to the transmitting point. For this analysis, rolling, hilly terrain was defined as any region with an undulation height (Δh) of greater than 20 metres. In addition, for terrain to have been considered rough, more than one peak occurring in the 10 km section was necessary. In other words, multiple diffraction must have been taking place.

For the Montreal area, very few cells were characterized as being in hilly terrain. For the Lac Echo, Rigaud and the two Mont Royal transmitters, the percentage of cells that qualified as rolling, hilly terrain were 4%, 1%, 1.5% and 0.8%, respectively. The results of this analysis are given in Table 6. While it seems that hilly terrain has no clear effect on the variability, the sample

Table 6: Effect of Hilly Terrain on Variability

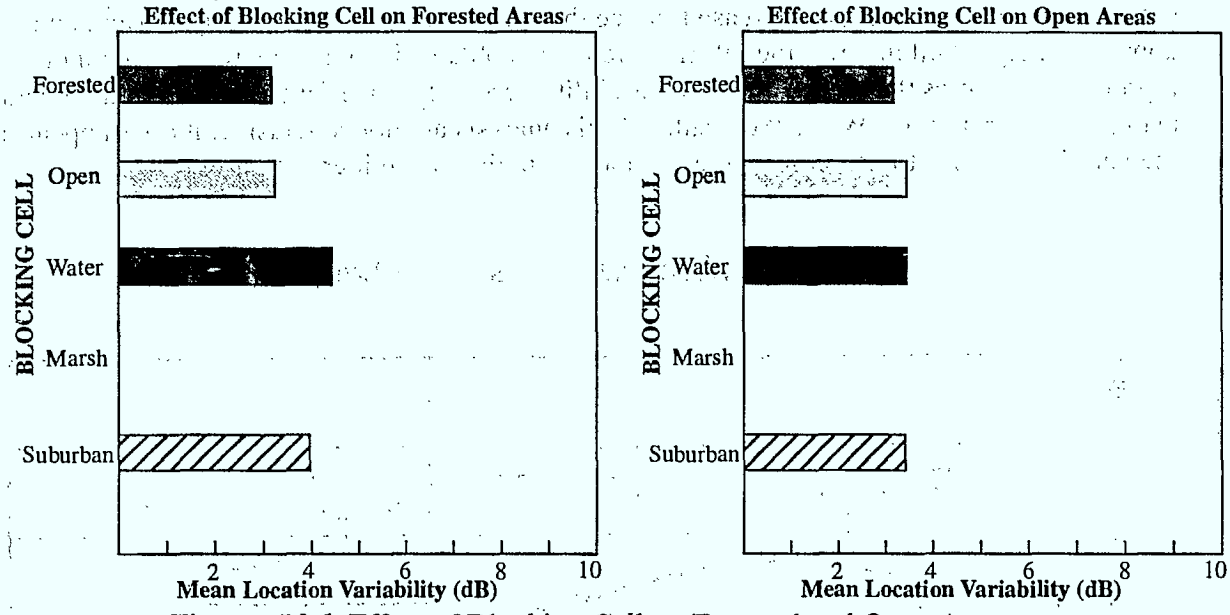
Terrain Type	Transmitter Location	Loc. Var. in non-hilly terrain (dB)	Loc. Var. in hilly terrain (dB)
Forested	Montreal (Lac Echo)	2.94	2.57
	Montreal (Mont Royal)	3.22	4.00
	Montreal (May 1994)	3.22	6.57
Open ground	Montreal (Lac Echo)	3.77	3.39
	Montreal (Rigaud)	3.22	2.64
	Montreal (Mont Royal)	3.59	3.69
	Montreal (May 1994)	3.87	4.43

sizes for hilly terrain were very small, and no conclusions can be drawn from this data. It has been included only to complete the data presented.

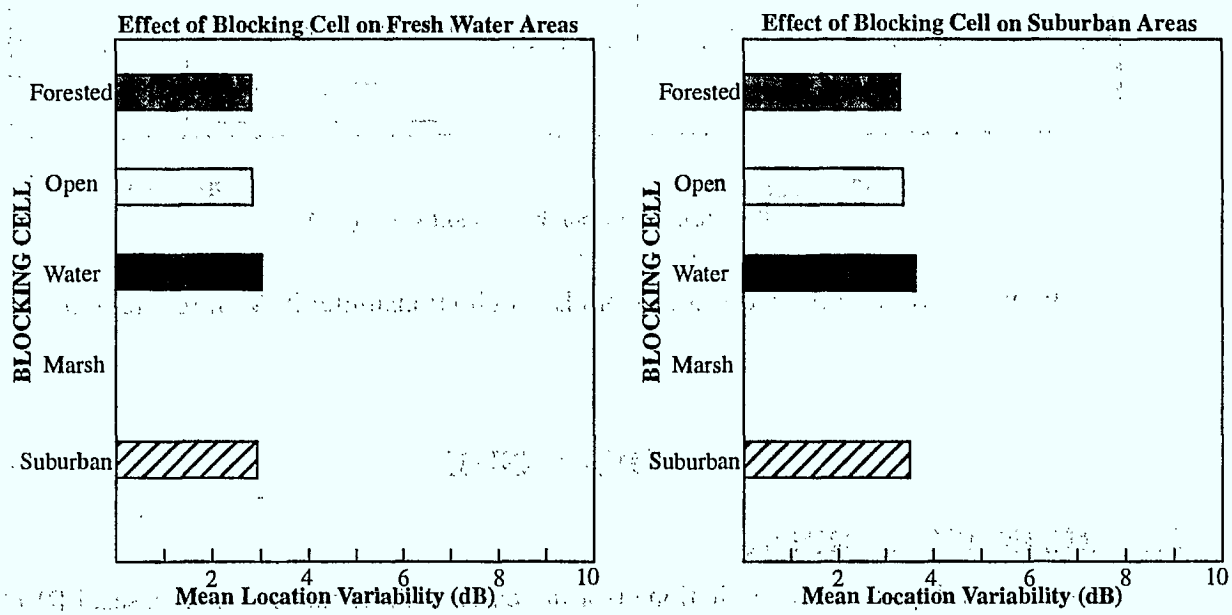
4.2c Preceding Cell Surface Type

In the analysis of Trois Rivières data, it was found that the variability did not appear to depend on the surface type of the blocking cell. The same analysis for the Montreal measurements

taken in May 1994 is shown in Figures 5-8. A slightly larger variability occurred in cells which were preceded by relatively open areas. Overall, however, there were no clear patterns to be



Figures 5&6: Effect of Blocking Cell on Forested and Open Areas



Figures 7&8: Effect of Blocking Cell on Fresh Water and Suburban Areas

found. Similar analysis on the remaining Montreal area data showed similar ambiguous results.

For the Trois Rivières data, the variability did seem to decrease as the distance from the transmitter increased. In an effort to further characterize the variability, the analysis of the blocking cell's surface type was subgrouped by its distance from the transmitter. Unfortunately, this analysis proved to be fruitless, and thus, the data was not included in this report.

4.2d Distance From the Transmitter

The measurements from Trois Rivières clearly showed the variability decreasing as the distance from the transmitter increased. Since the Montreal measurements only extended to approximately 40 kilometres, the informative results obtained from Trois Rivières cannot be reproduced. Figures 9-12 show plots of variability versus distance for the Montreal area data using 10 km groupings. While the results of this analysis are not conclusive, it does appear that the variability tends to decrease as the distance from the transmitter increases.

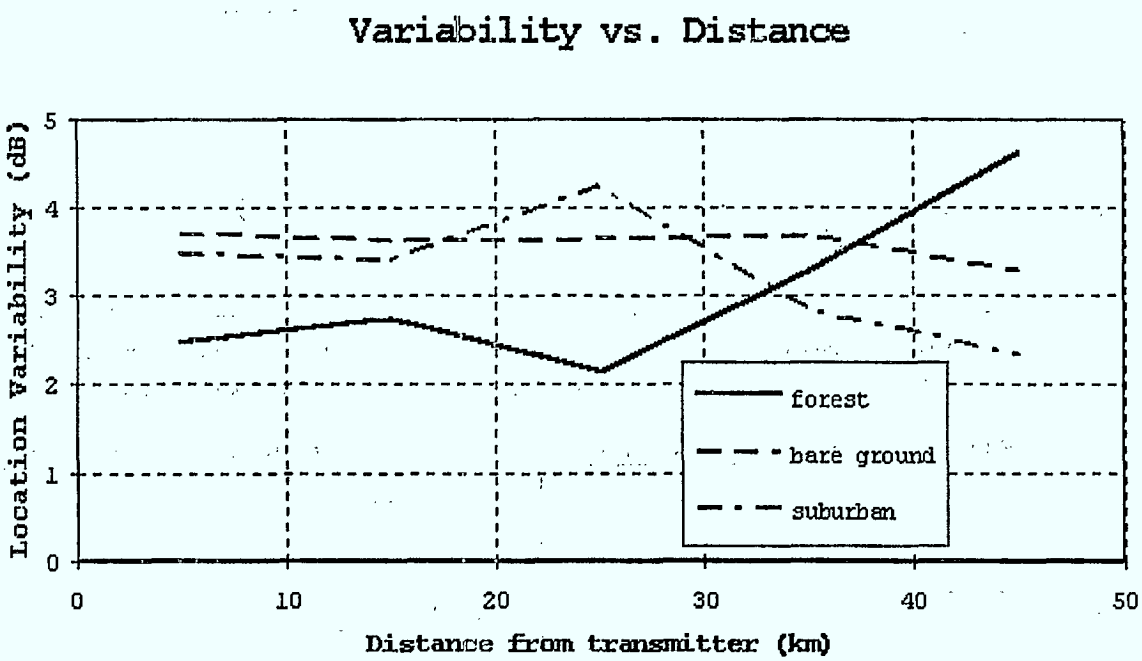


Figure 9: Variability by distance from Lac Echo transmitter in Montreal region

5. DISCUSSION

5.1 PREDICTION ERROR

As seen in Figure 1, the prediction error increases with frequency. In all cases, PREDICT gives optimistic field strength predictions. The worst error occurred for the Montreal region, for all the different transmitters. At the same frequency of transmission, the overall error for Trois Rivières was only 6.7 dB.

Since the May 1994 Mont Royal measurements were acquired as raw, binary data, and the exact transmission parameters and conversions were unknown, the results for this data set could be flawed at a fundamental level. The error is nearly 6 dB greater than measurements taken from the same transmitter in November 1994.

The error was smallest in areas defined as forested by the terrain database. A significant

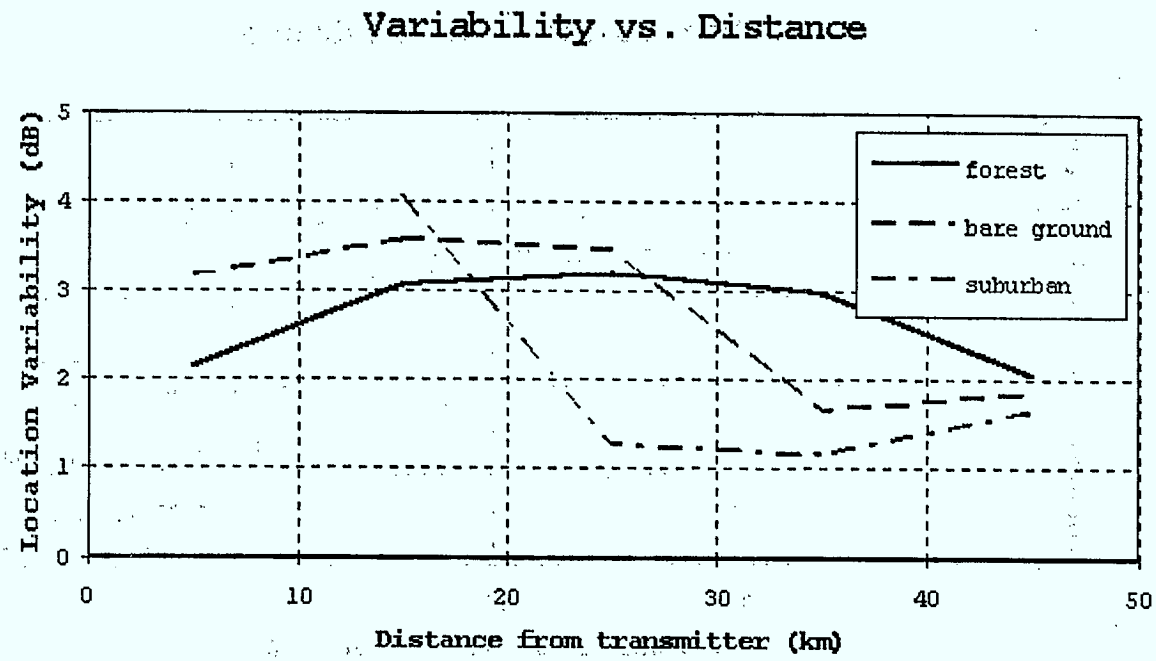


Figure 10: Variability by distance from Rigaud transmitter in Montreal region

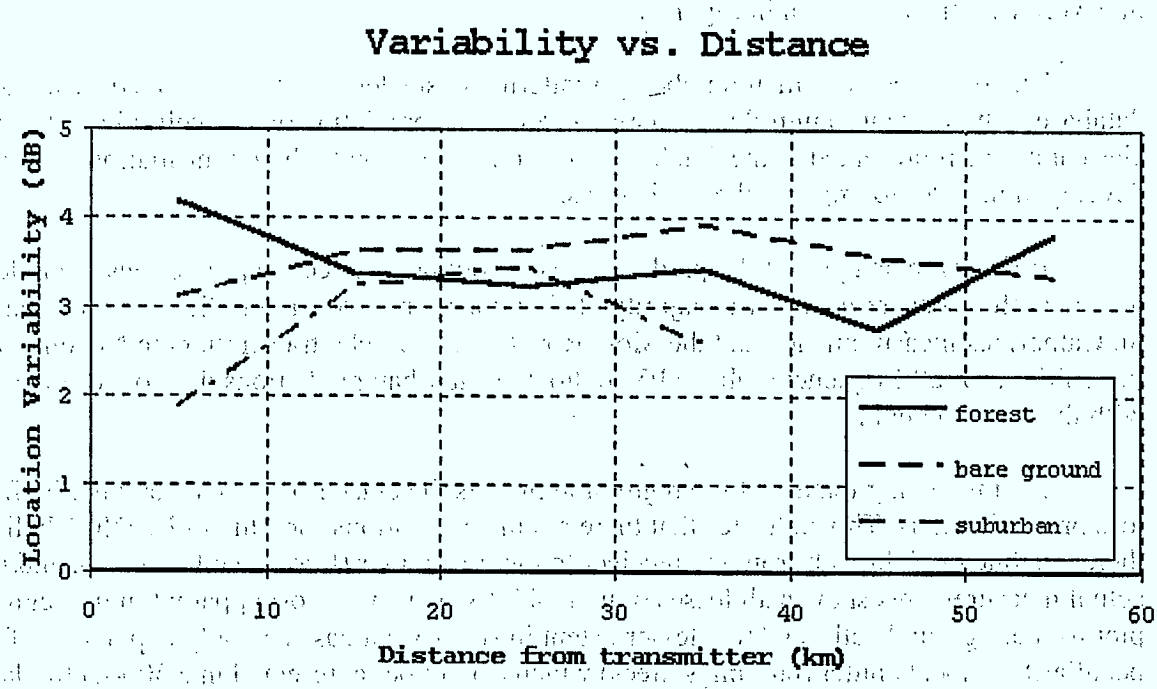


Figure 11: Variability by distance from Mont Royal transmitter in Montreal region

increase in the error was observed for open areas, while suburban areas fell somewhere in-

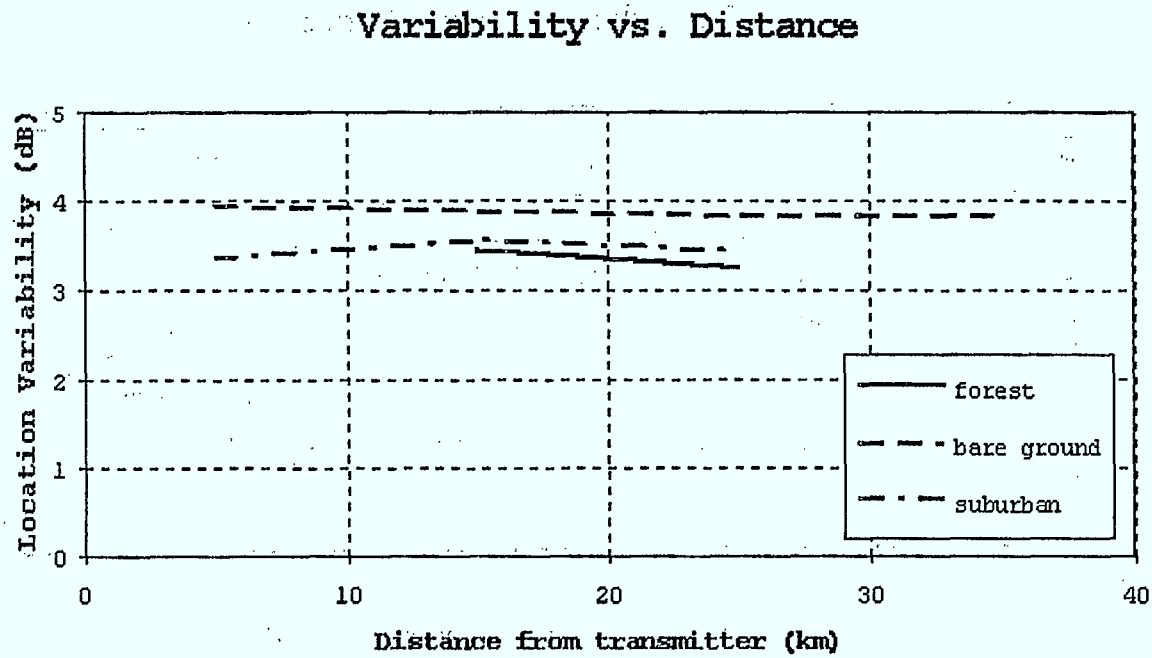


Figure 12: Variability by distance from Mont Royal transmitter in Montreal region (May 1994)

between. The prediction error by surface type was still increasing with frequency (Figures 2-4), thus verifying the trend seen in Figure 1.

The presence of a small number of scattering obstacles (in an area defined by the terrain database as bare ground) introduces a larger error in the prediction of that cell. Since these obstacles cannot be represented in the database, some other solution to their contribution must be developed in order to improve the predictions.

Regression analysis of the predictions is encouraging since the predictions are indeed correlated to the measurements for a majority of situations. The worst fit predictions occurred for the St. Catherines measurements, and the Mont Royal and Lac Echo transmitters in November 1994. In addition, for all frequencies above FM radio, the suburban predictions did not correlate well with the experimental.

An interesting feature of the regression plots is the cluster of points along the 0 dB path loss prediction axis. This indicates that there are many locations for which PREDICT believes there is a line of sight path from the receiver to the transmitter (free-space loss only), and the actual measurements show path losses of up to 45 dB. This was most apparent in the regression plot for bare ground cells, and to a lesser extent in suburban areas. The only explanation for this peculiarity is local clutter (buildings, trees) which cannot be represented in a 500-metre database. In other words, line of sight transmission is rarely achievable at vehicle height, and the effects of local clutter are widely varied and very difficult to predict.

In summary, the PREDICT accurately determined the trends of the field strength variations, but there was a varying optimistic error in all cases.

5.2 VARIABILITY

In the Trois Rivières report, second order models based on the distance from the transmitter were recommended for predicting the location variability of a signal at 1.5 GHz. This analysis suggests that the variability may be dependent on many different factors unique to each transmitting situation.

At 1.5 GHz, in the Montreal region, the average variability was much lower than that found for Trois Rivières. Unlike Trois Rivières, there were appreciable differences in the variability for cells of different surface type. For each transmitter, the variability in forested areas and suburban areas were smaller than in open cells with differences of 10% to 41%.

Hilly terrain was again represented by few cells. Data collected in the Montreal region exhibited no trends. More controlled research would be required to develop a practical definition of hilly terrain and its effect on the variability.

Once again, extensive analysis of the effect of the preceding cell's surface type did not yield any results. Increasing the scope of the analysis to include grouping by distance from the transmitter also yielded no information. It must be concluded that the preceding cell's surface type has no effect on the location variability.

Finally, the variability and the distance from the transmitter was analyzed. The Trois Rivières data showed strong correlation between the distance and the variability. The same results could not be reproduced with the Montreal region data. While it is difficult to make any conclusions, the variability does seem to decrease with distance. Since the Montreal area measurements only extend to approximately 50 km, these results would need to be verified with further measurements to confirm this relationship.

6.0 REFERENCES

[1] Matsunaga, Richard, "Analysis of Trois Rivières Propagation Measurements," CRC Report

No. CRC-CR-95-001, February 1995.

[2] Tyrie, Don, "1.5 GHz Propagation Tests: Trois Rivières Measurements," Indutry Canada Report, March 1994.

[3] Imagineering Limited, "Report on VHF and UHF Path Loss Measurements," CRC Report No. CRC-CR-94-, February 1994.

[4] Imagineering Limited, "Report on Path Loss Measurements at 1810 MHz," CRC Report No. CRC-CR-95-006, March 1995.

[5] Lee, William C.Y., "Estimate of Local Average Power of a Mobile Radio Signal, " IEEE Transactions on Vehicular Technology, Vol. VT-34, No. 1, February 1985. pp.22-27.

[6] Whitteker, J. H., "Storage Specifications for 500-metre-grid terrain data," CRC Report No. CRC-RP-92-002, Ottawa, August 1992.

[7] Press, William H., Saul A. Teukolsky, William T. Vetterling, Brian P. Flamey, "Numerical Recipes in C, The Art of Scientific Computing," Cambridge University Press, Cambridge, 1992. 994 pages.

[8] Okumura, Yoshihisa, Eiji Ohmori, Tomihiko Kawano, and Kaneharu Fukuda, "Field Strength and it's Variability in VHF and UHF Land-Mobile Radio Service," Review of the Electrical Communication Laboratory, Volume 16, Numbers 9-10, Sept.-Oct. 1968.

APPENDIX A

Prediction Error Regression Plots

First Canadian Place (CFMX-FM), Toronto

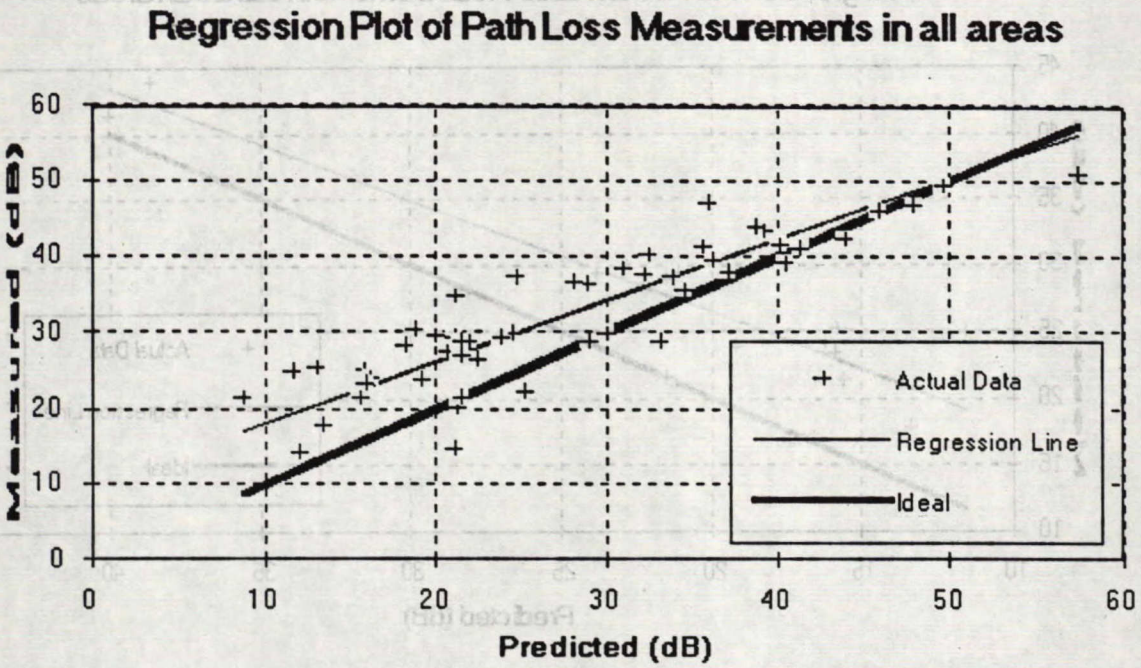


Figure A-1: Regression plot of prediction error for FCP in all areas

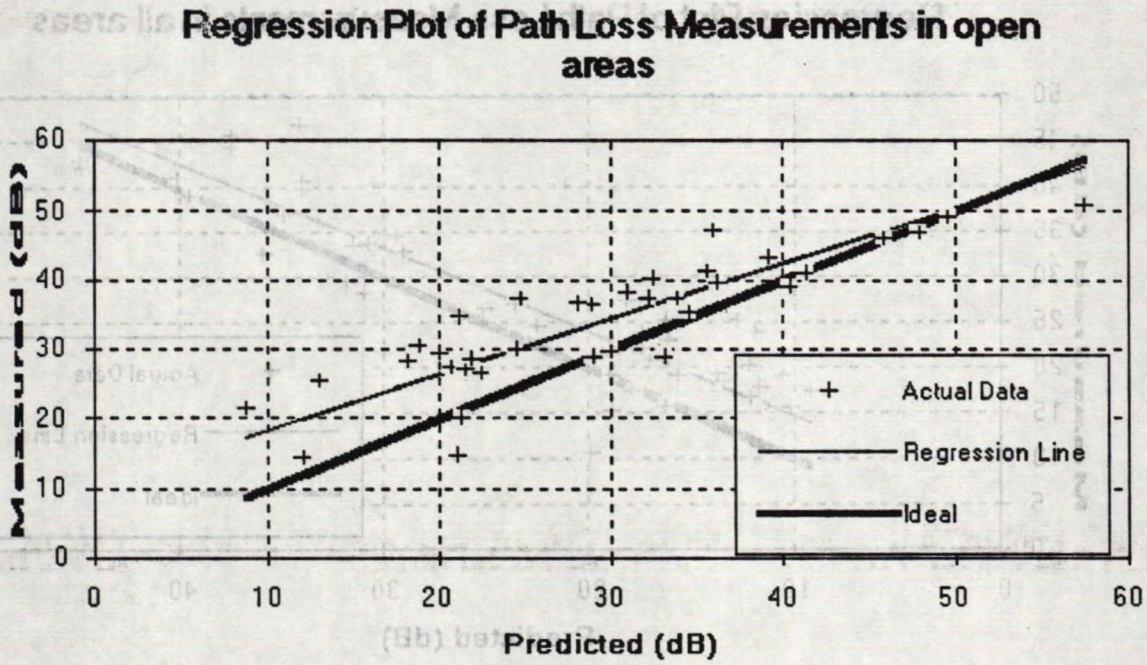


Figure A-2: Regression plot of prediction error for FCP in open areas

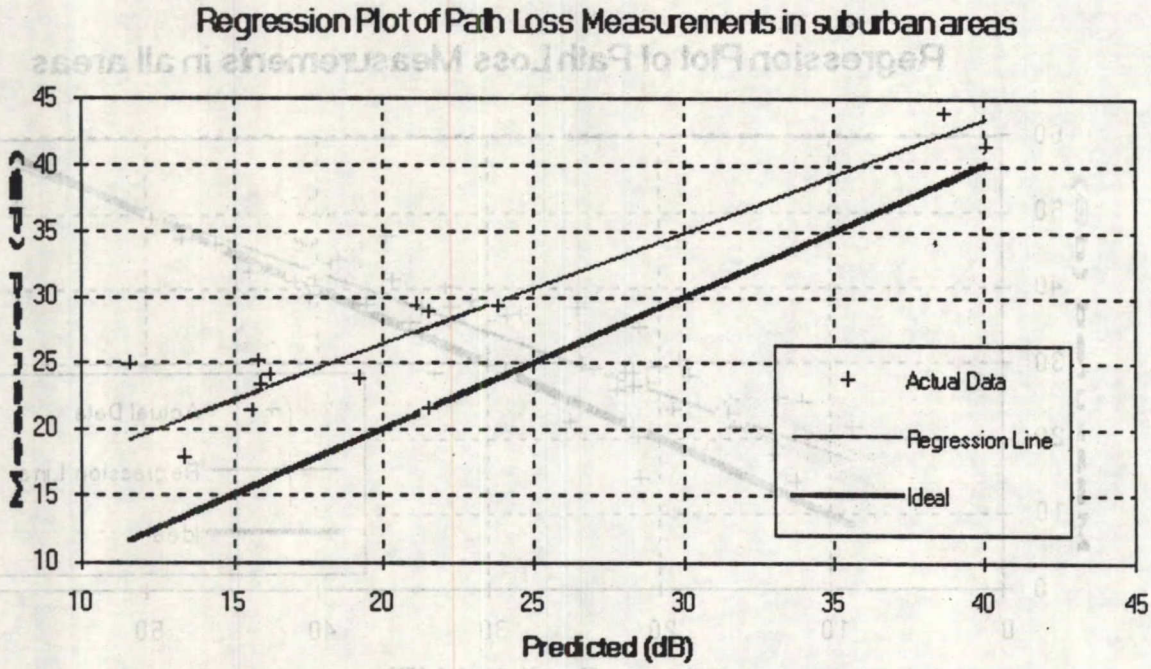


Figure A-3: Regression plot of prediction error for FCP in suburban areas

CN Tower (CKFM-FM), Toronto

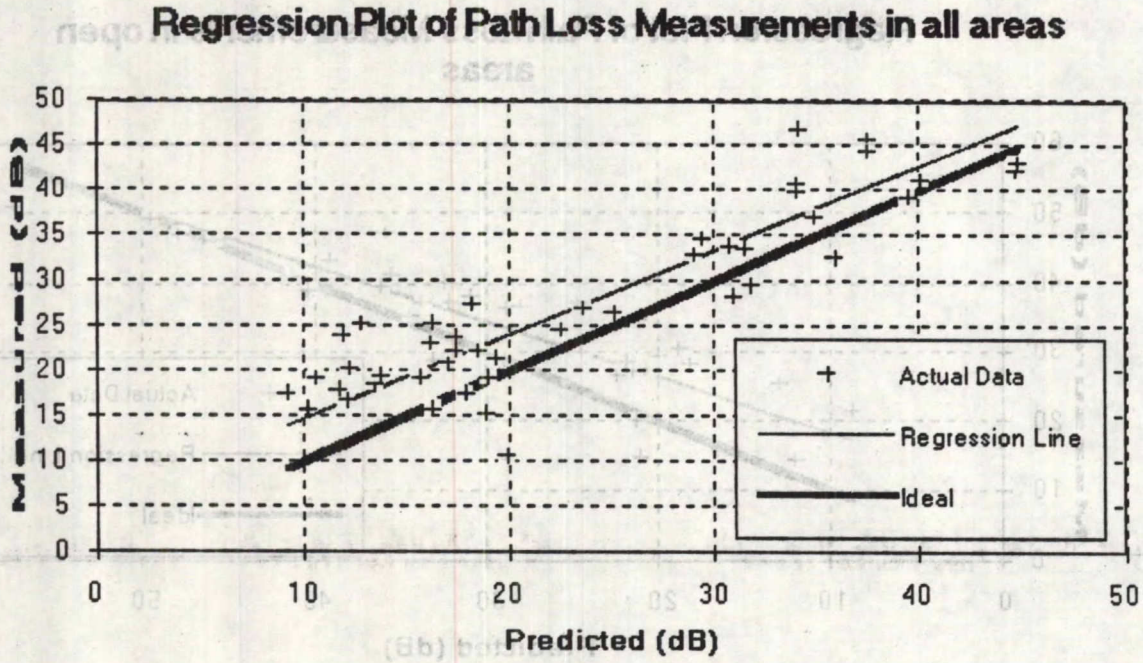


Figure A-4: Regression plot of prediction error for CNT in all areas

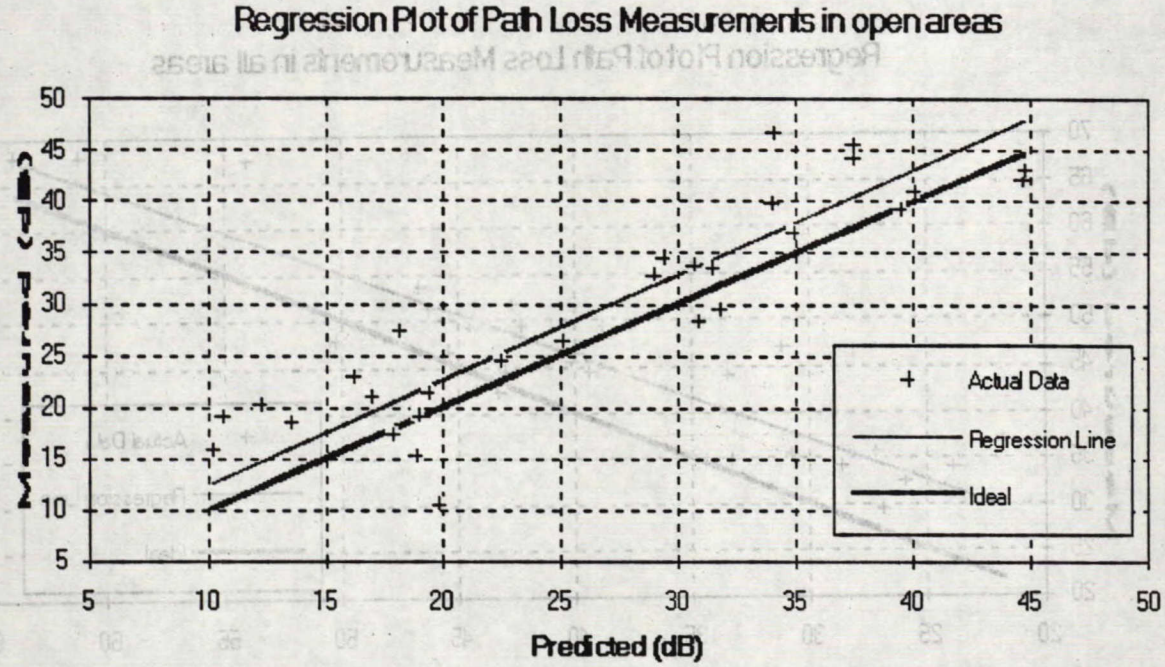


Figure A-5: Regression plot of prediction error for CNT in open areas

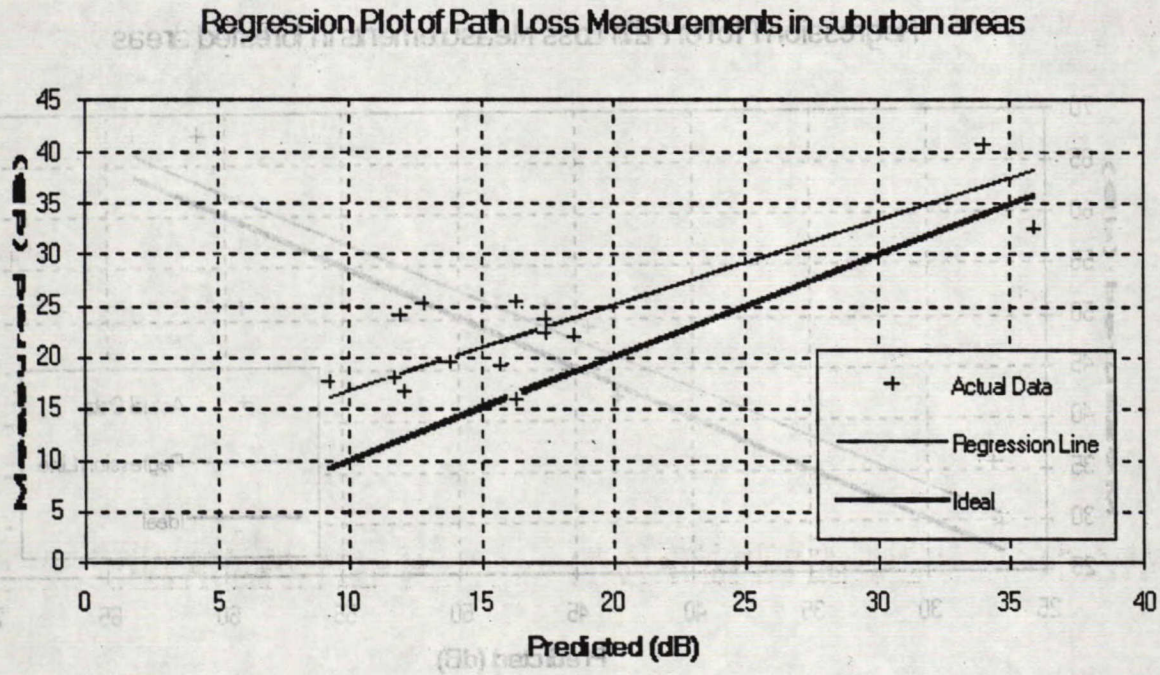


Figure A-6: Regression plot of prediction error for CNT in suburban areas

Fort Erie (CKEY-FM)

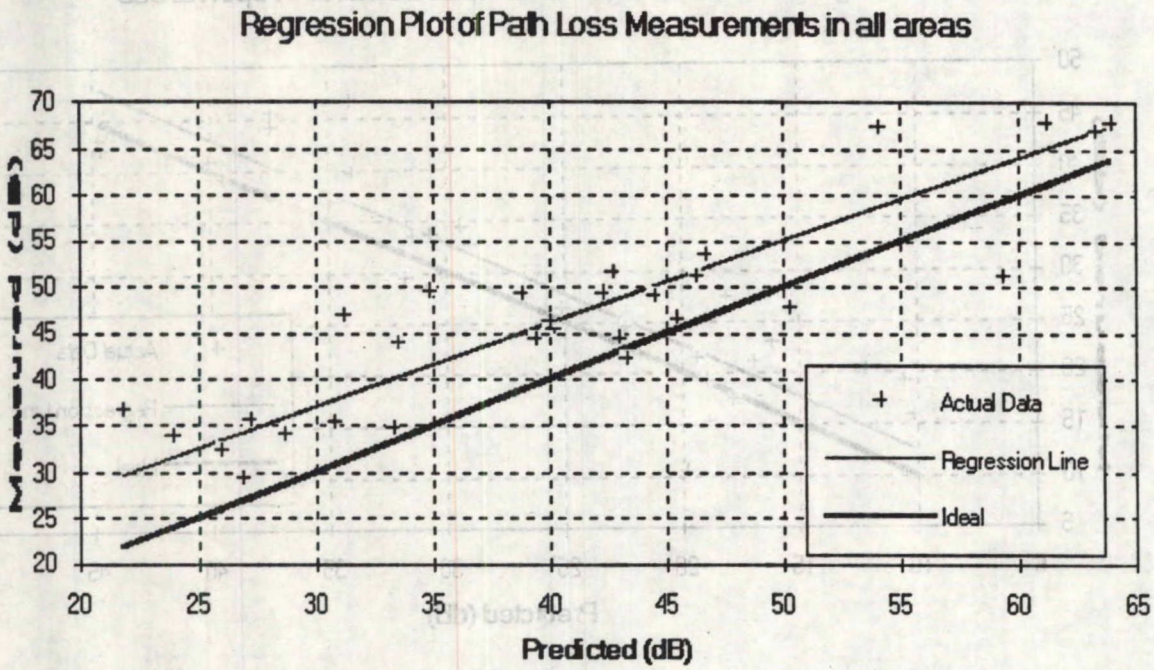


Figure A-7: Regression plot of prediction error for Fort Erie in all areas

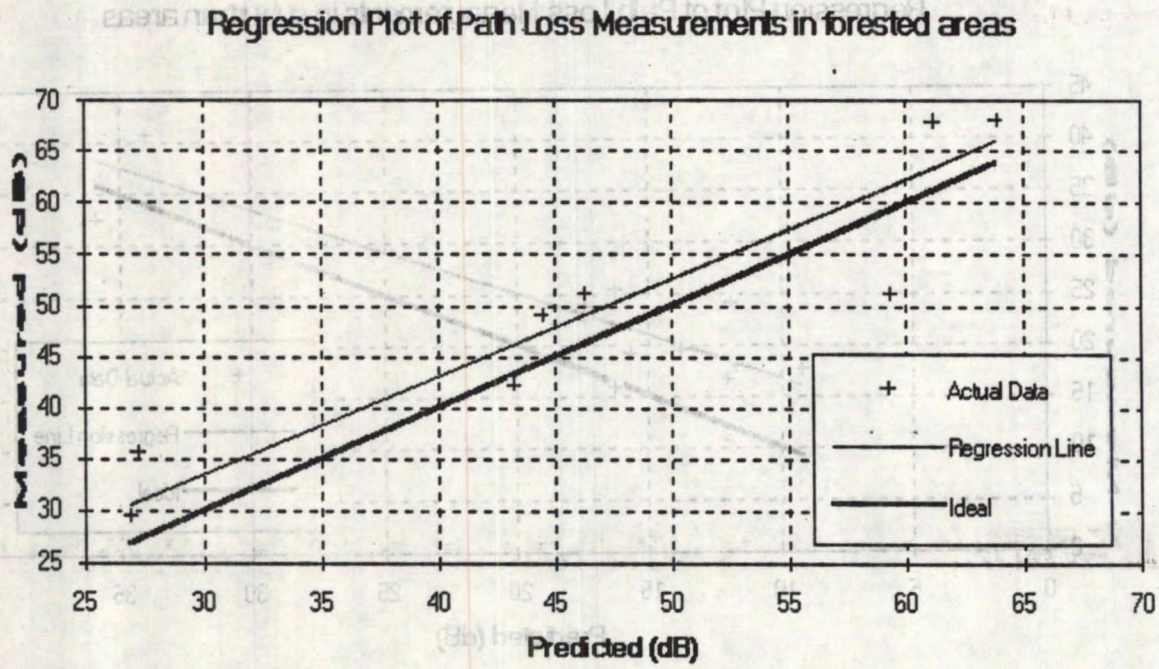


Figure A-8: Regression plot of prediction error for Fort Erie in forested areas

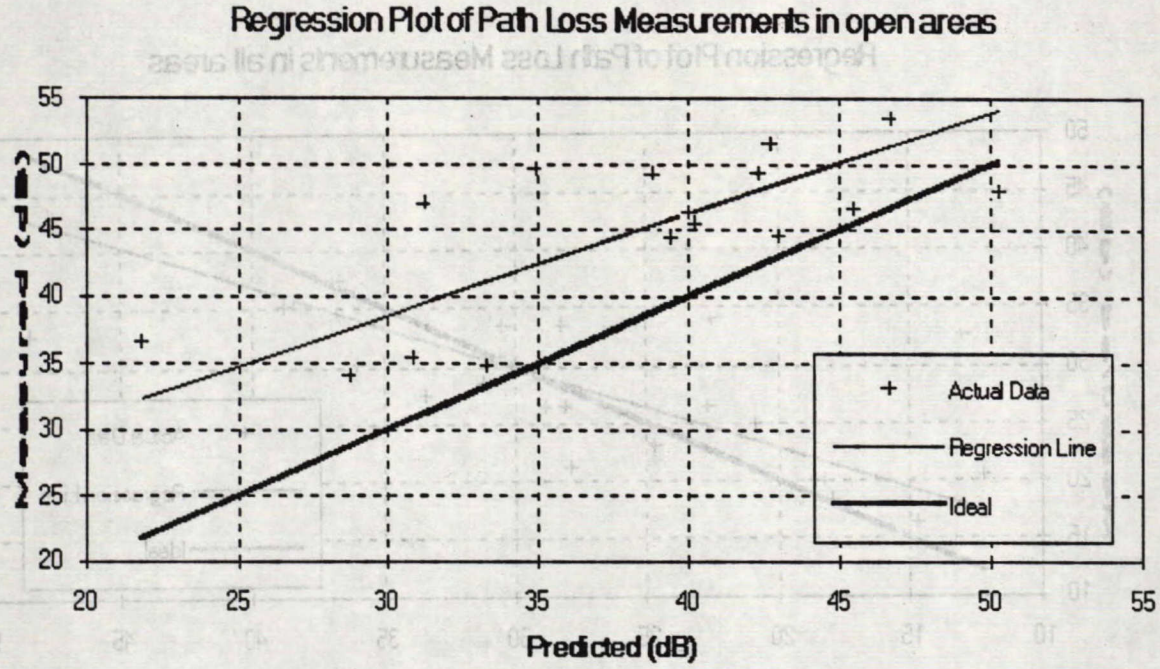


Figure A-9: Regression plot of prediction error for Fort Erie in open areas

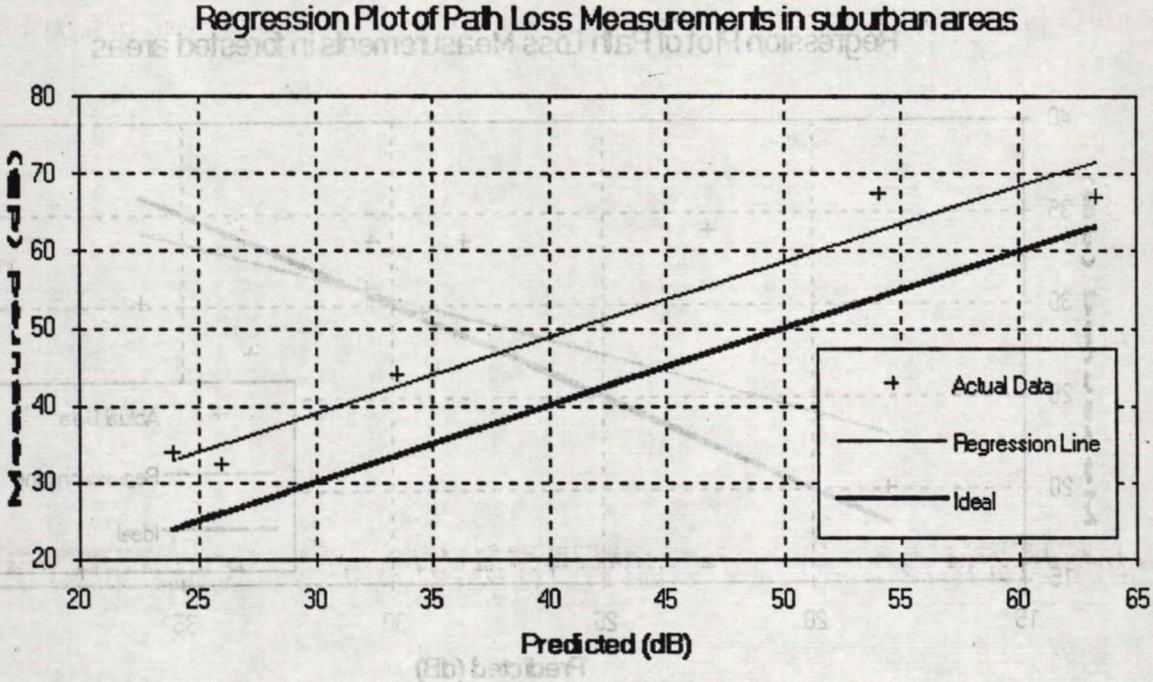


Figure A-10: Regression plot of prediction error for Fort Erie in suburban areas

Cobourg (CKEY-FM)

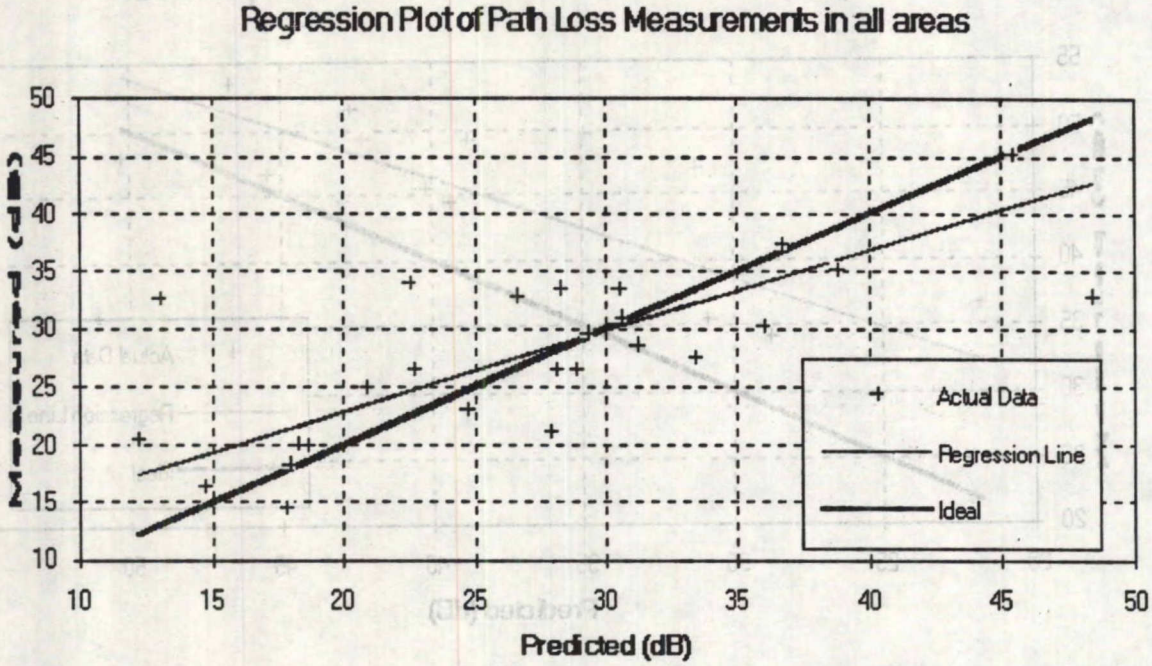


Figure A-11: Regression plot of prediction error for Cobourg in all areas

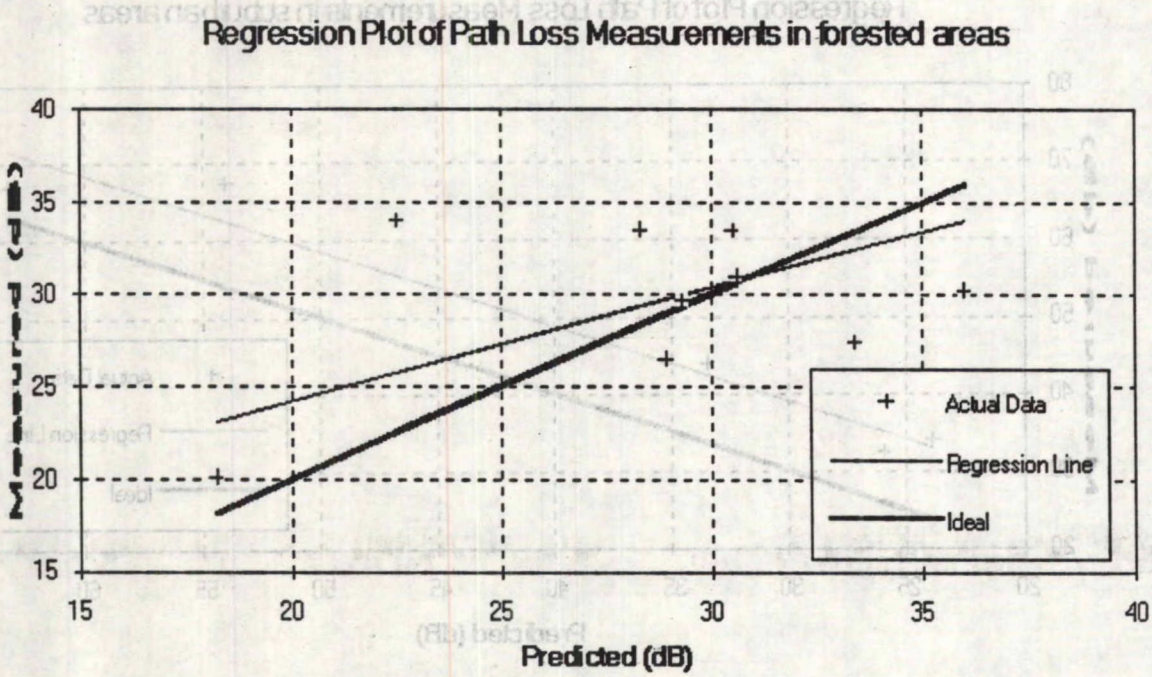


Figure A-12: Regression plot of prediction error for Cobourg in forested areas

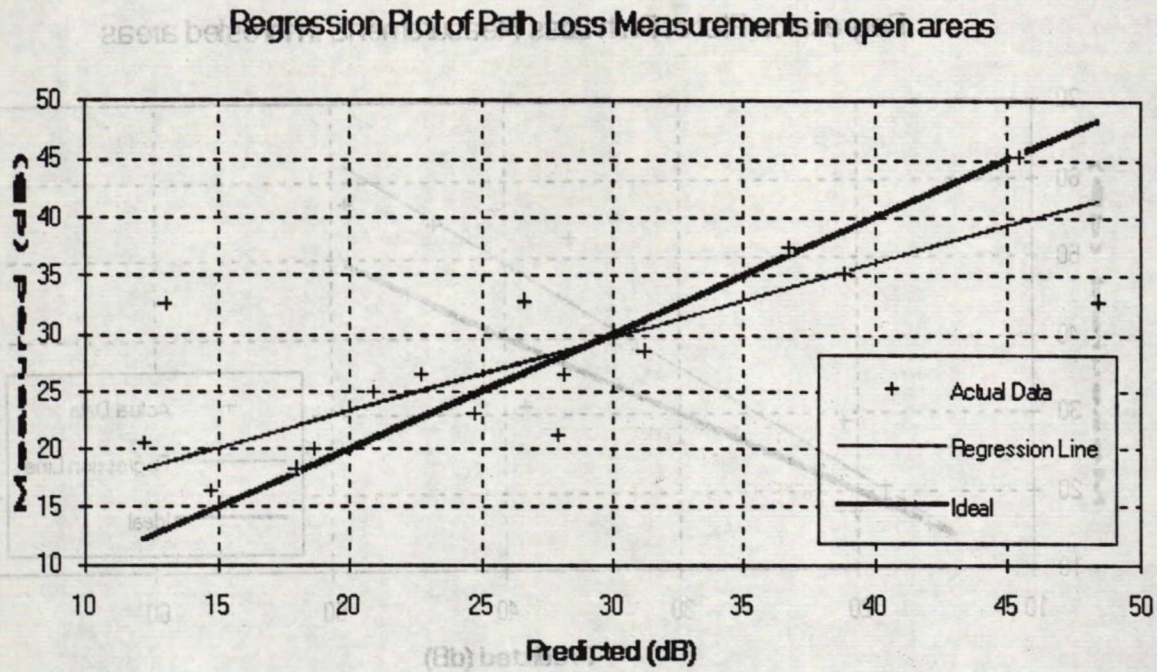


Figure A-13: Regression plot of prediction error for Cobourg in open areas

King City

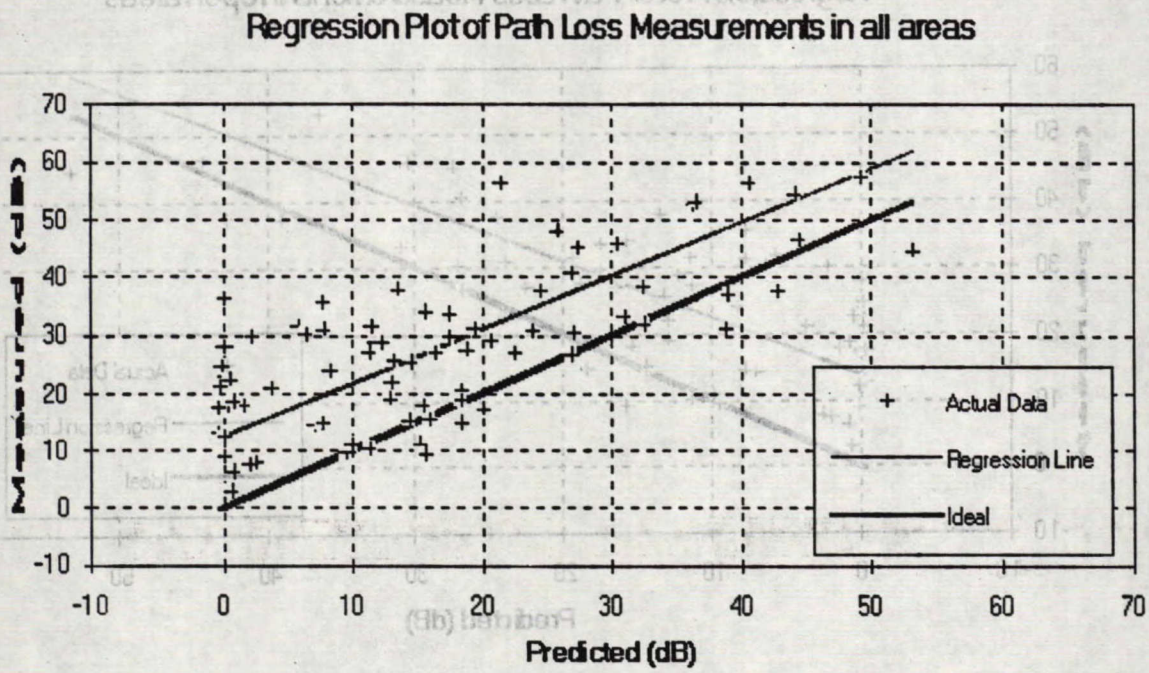


Figure A-14: Regression plot of prediction error for King City in all areas

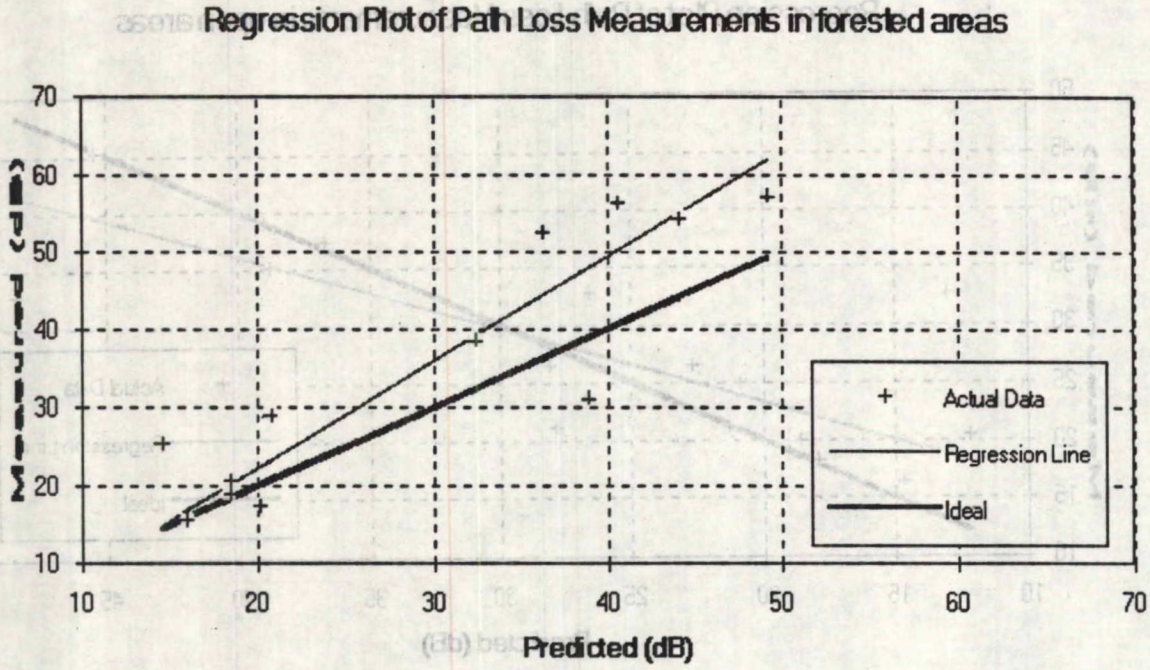


Figure A-15: Regression plot of prediction error for King City in forested areas

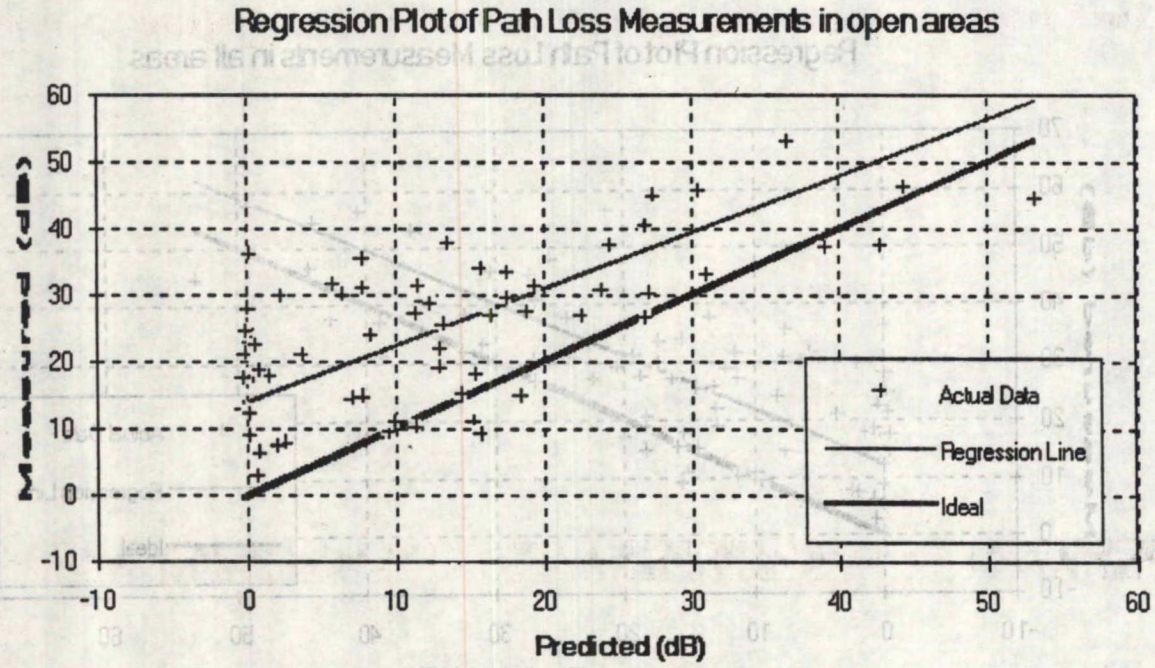


Figure A-16: Regression plot of prediction error for King City in open areas

Barrie

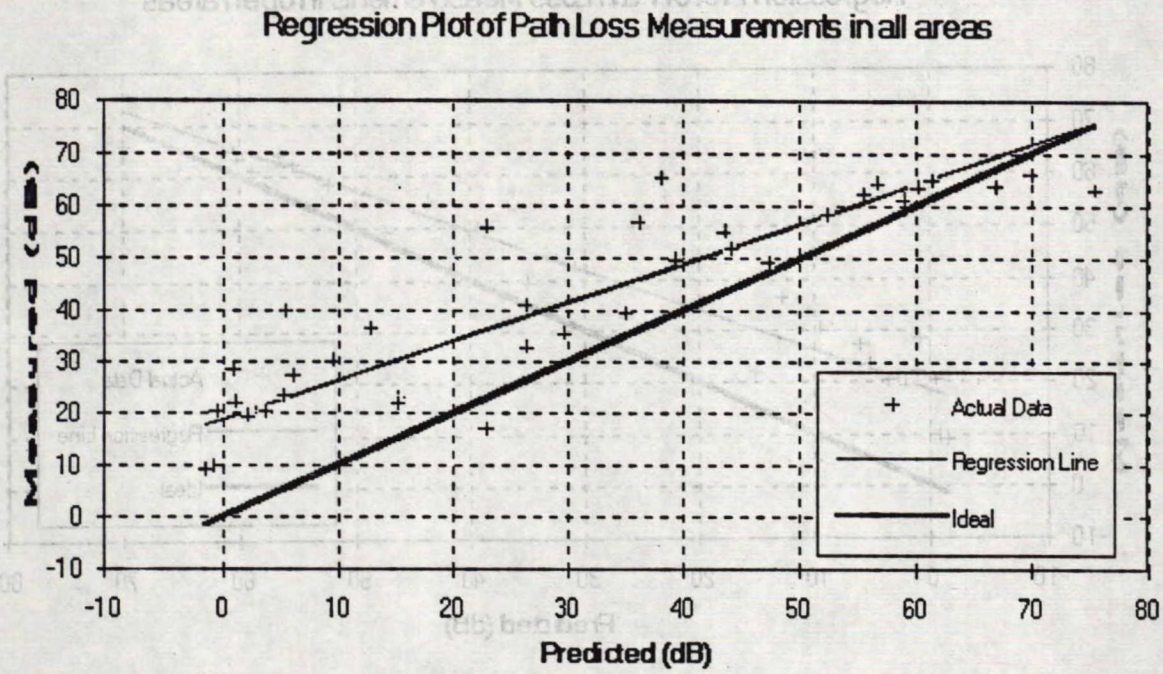


Figure A-17: Regression plot of prediction error for Barrie in all areas

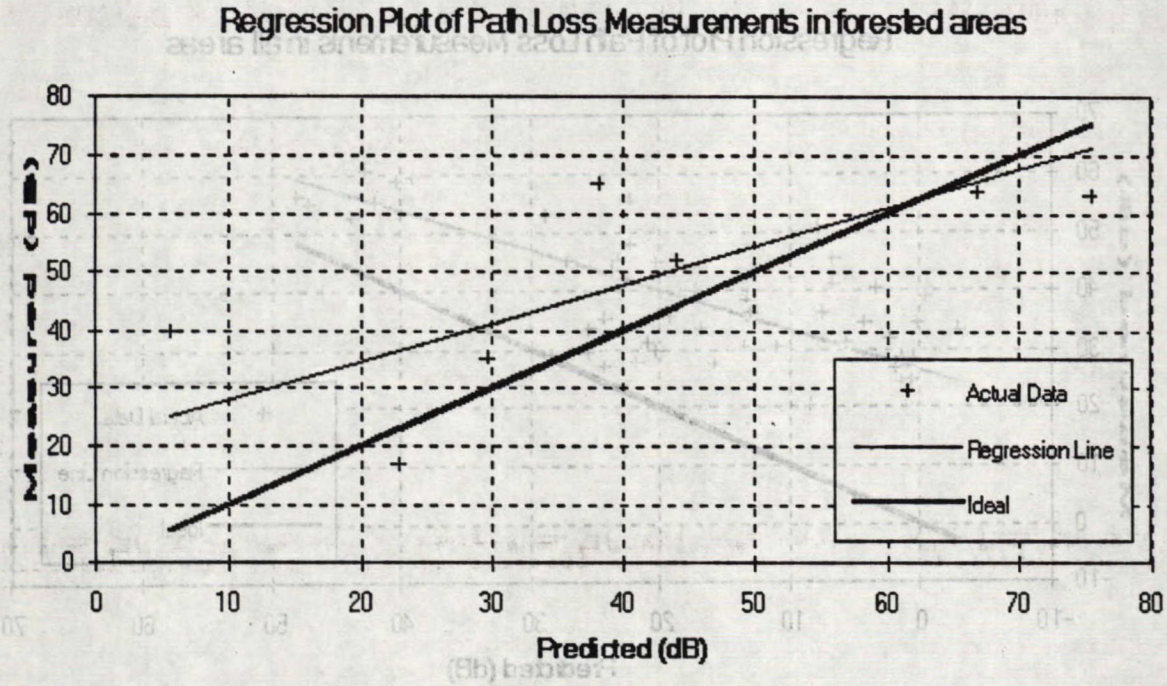


Figure A-18: Regression plot of prediction error for Barrie in forested areas

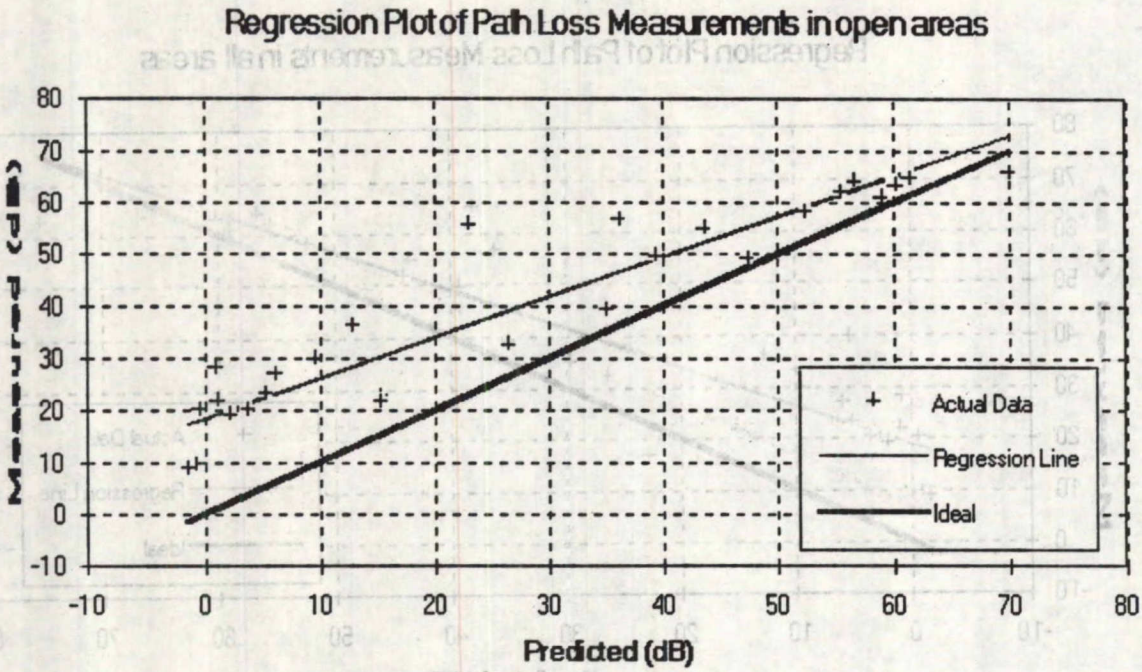


Figure A-19: Regression plot of prediction error for Barrie in open areas

Fonthill

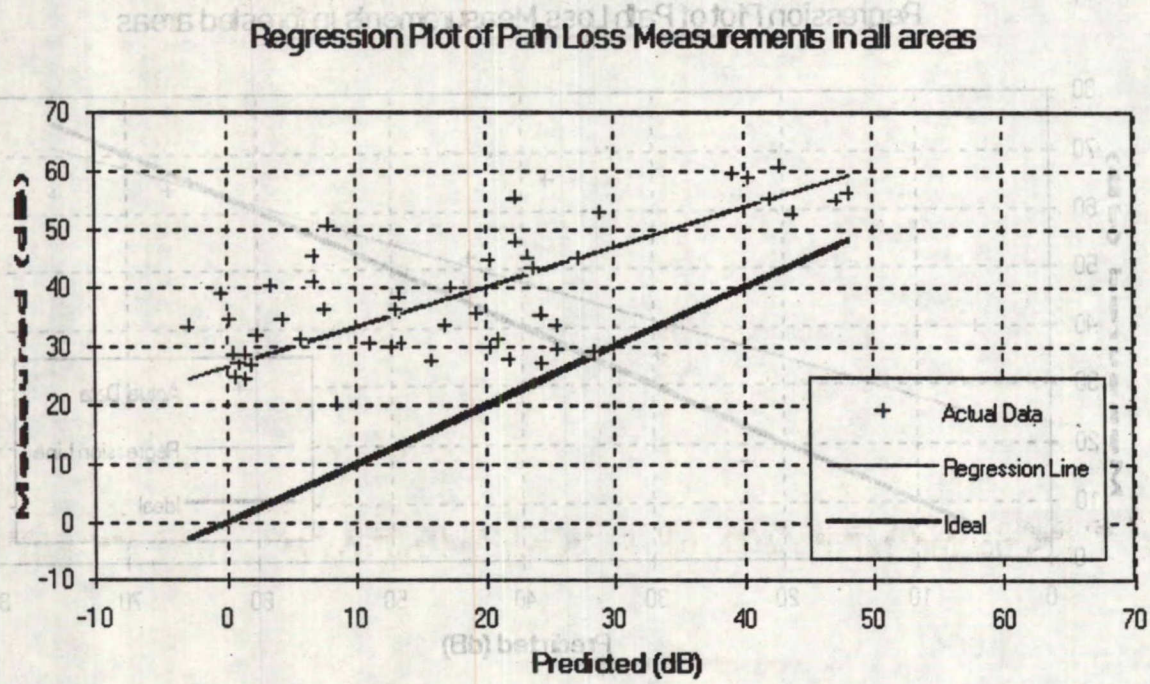


Figure A-20: Regression plot of prediction error for Fonthill in all areas

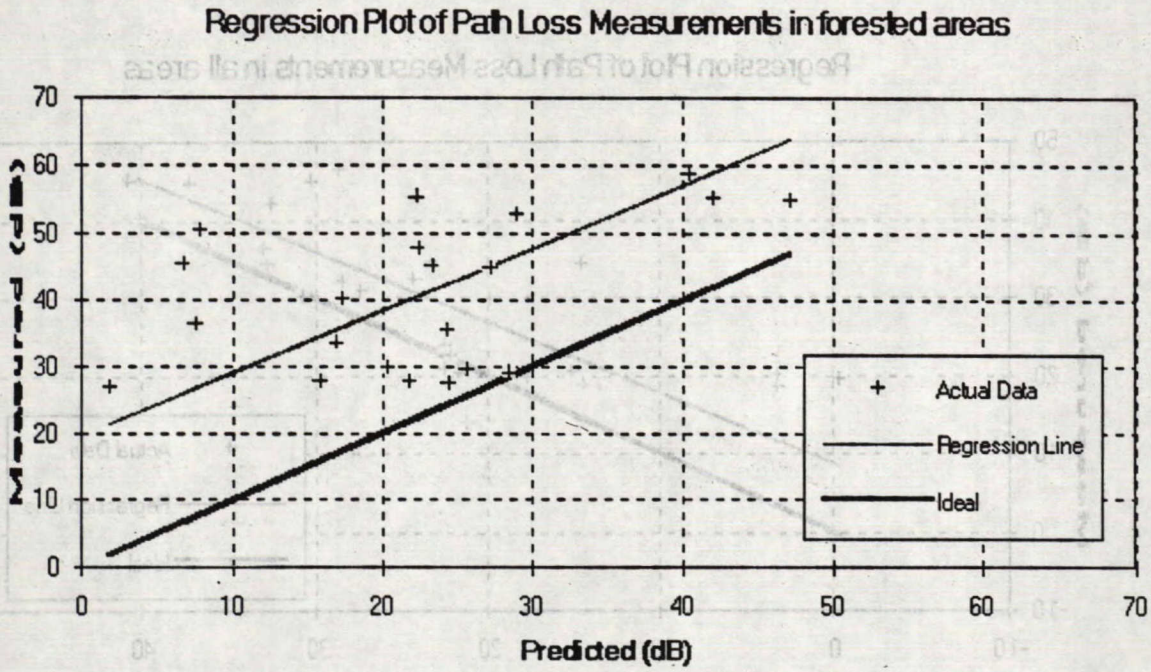


Figure A-21: Regression plot of prediction error for Fonthill in forested areas

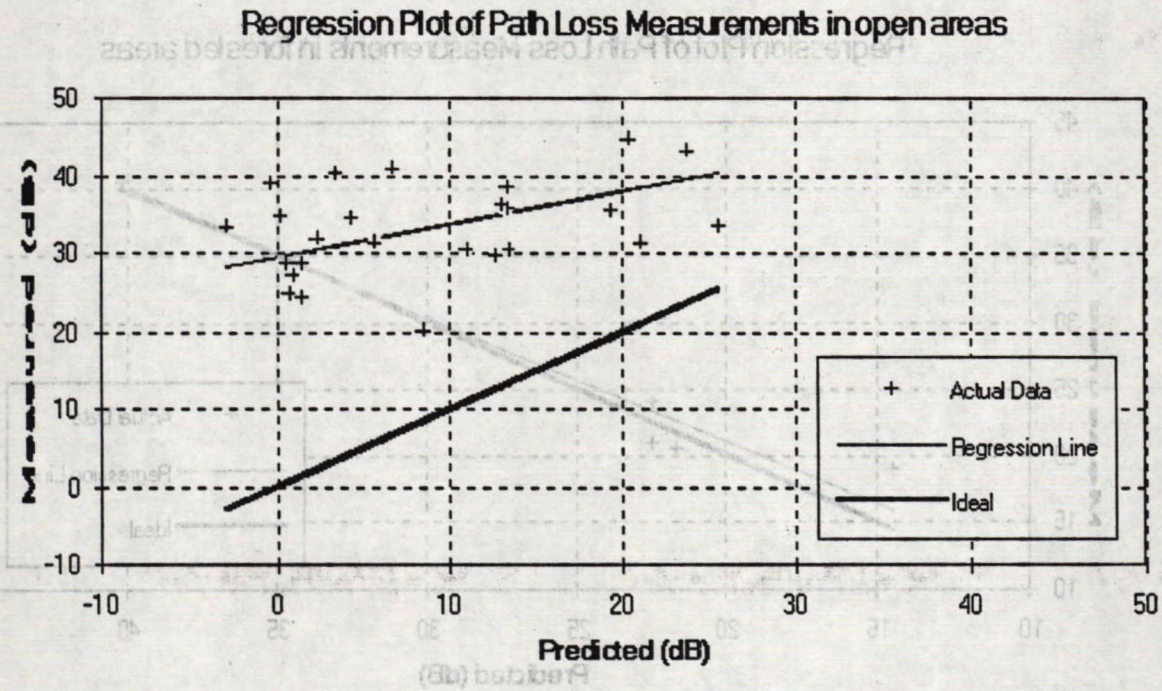


Figure A-22: Regression plot of prediction error for Fonthill in open areas

Kitchener

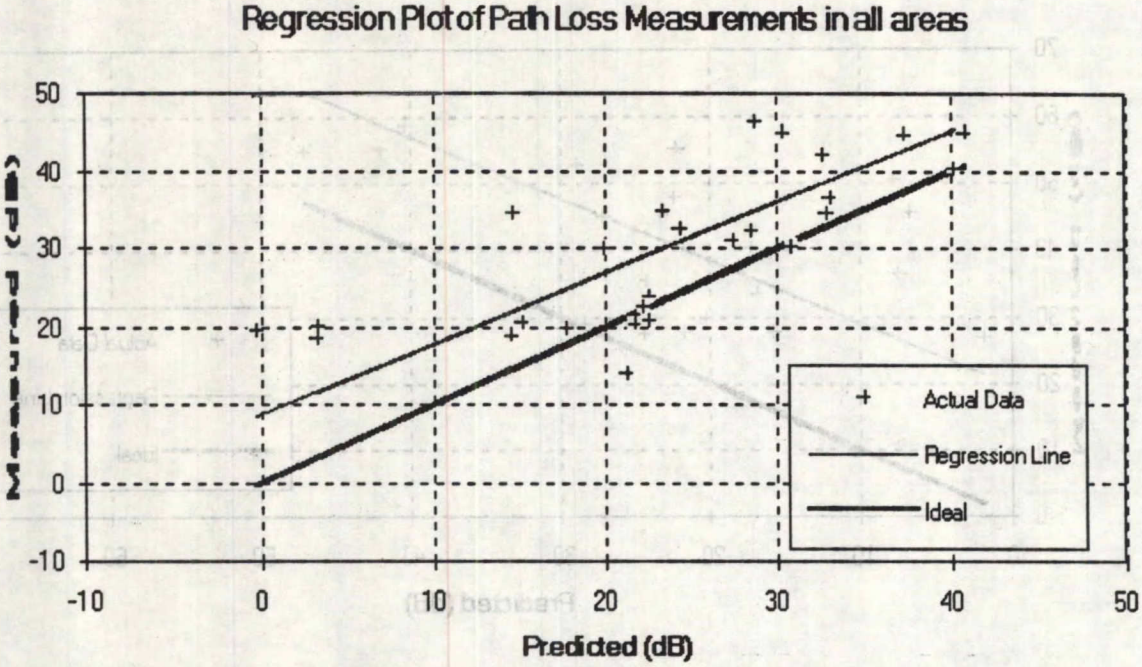


Figure A-23: Regression plot of prediction error for Kitchener in all areas

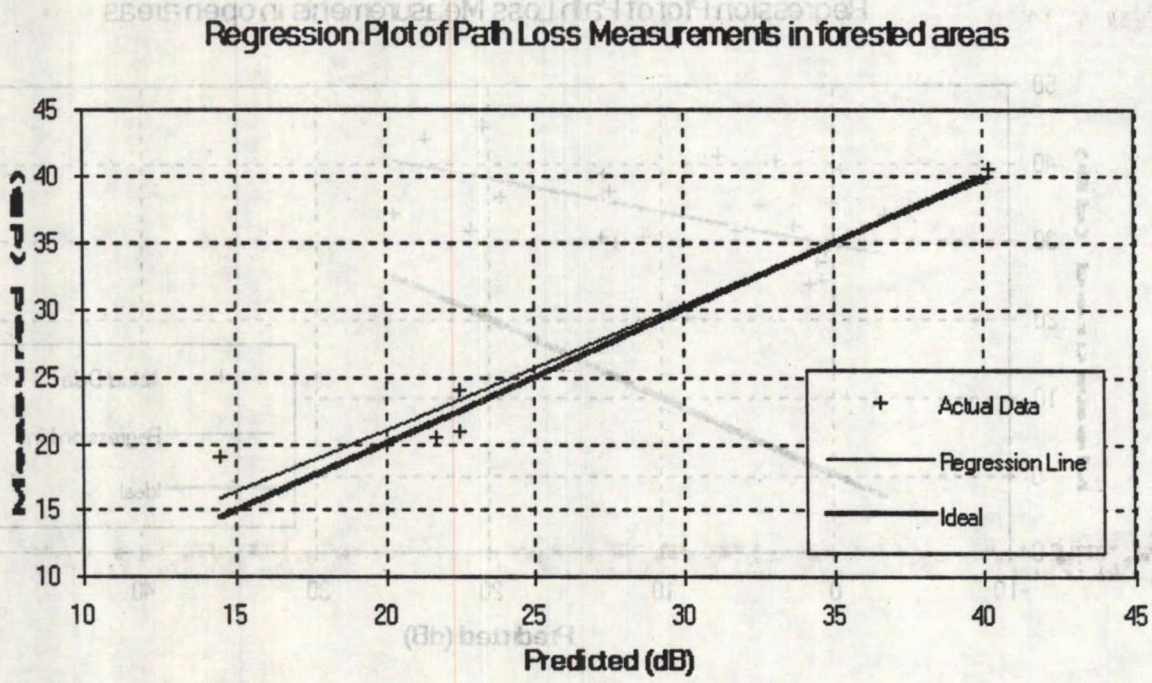


Figure A-24: Regression plot of prediction error for Kitchener in forested areas

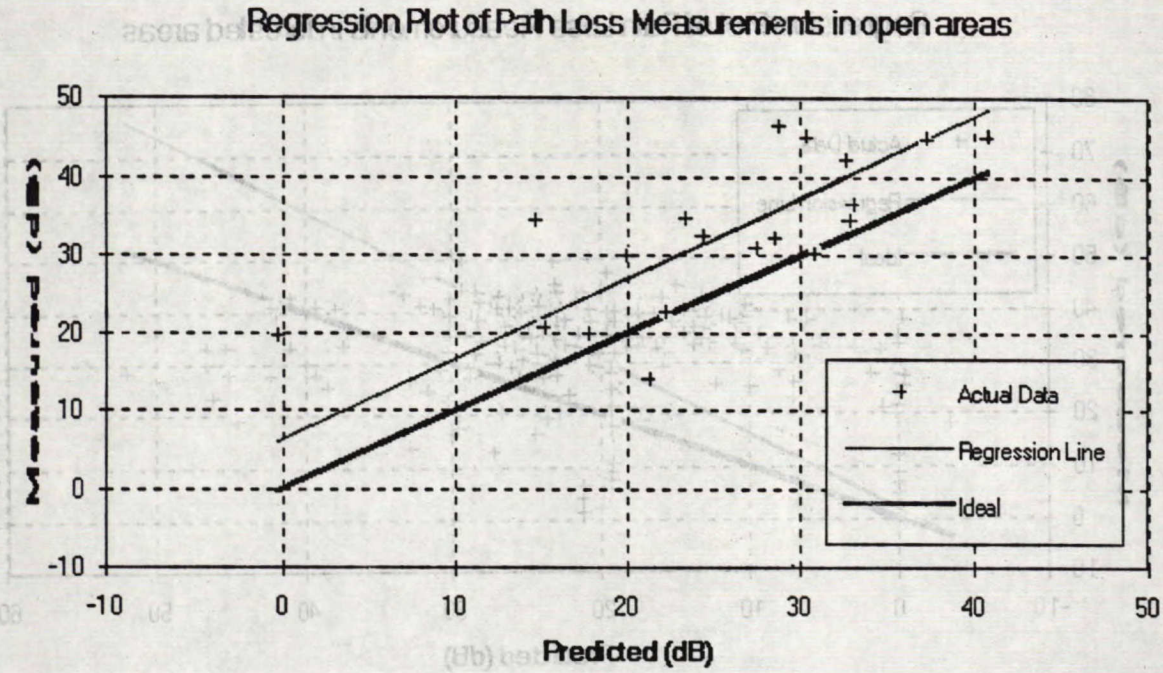


Figure A-25: Regression plot of prediction error for Kitchener in open areas

Montreal (Lac Echo)

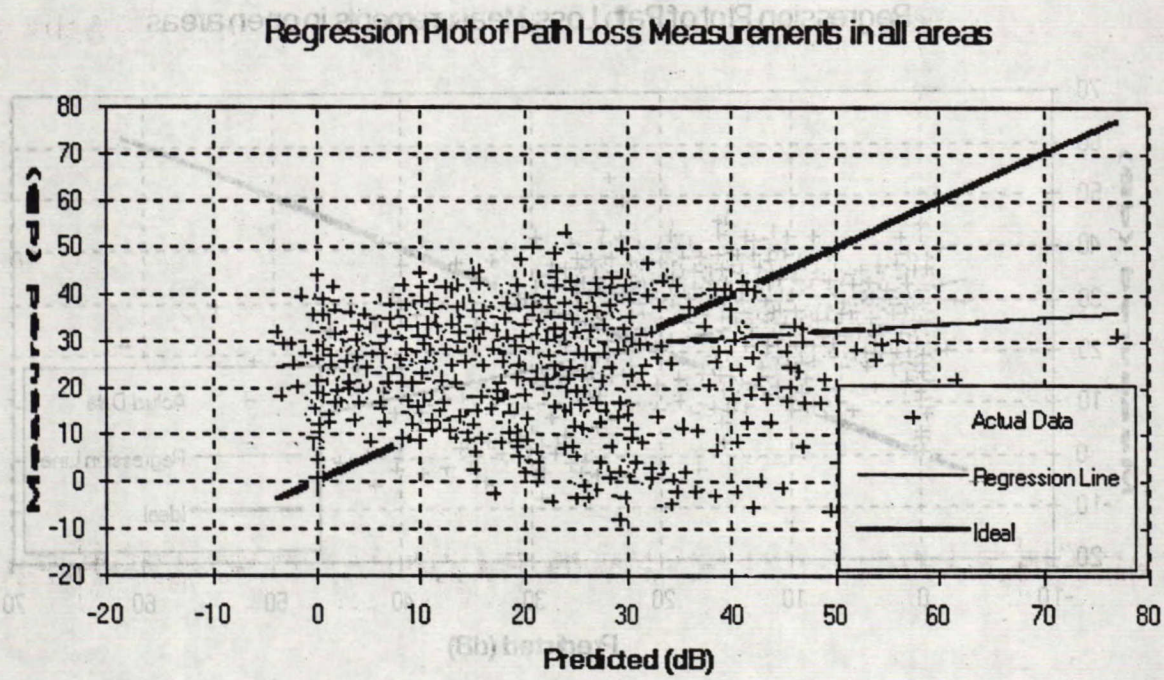


Figure A-26: Regression plot of prediction error for Montreal (Lac Echo) in all areas

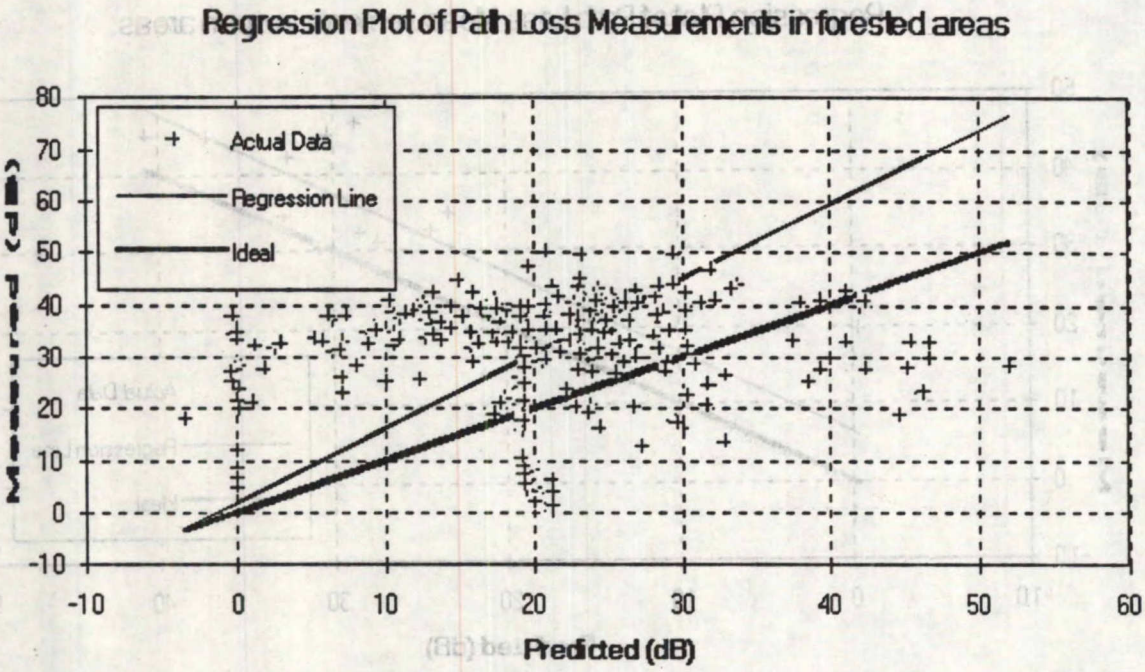


Figure A-27: Regression plot of prediction error for Montreal (Lac Echo) in forested areas

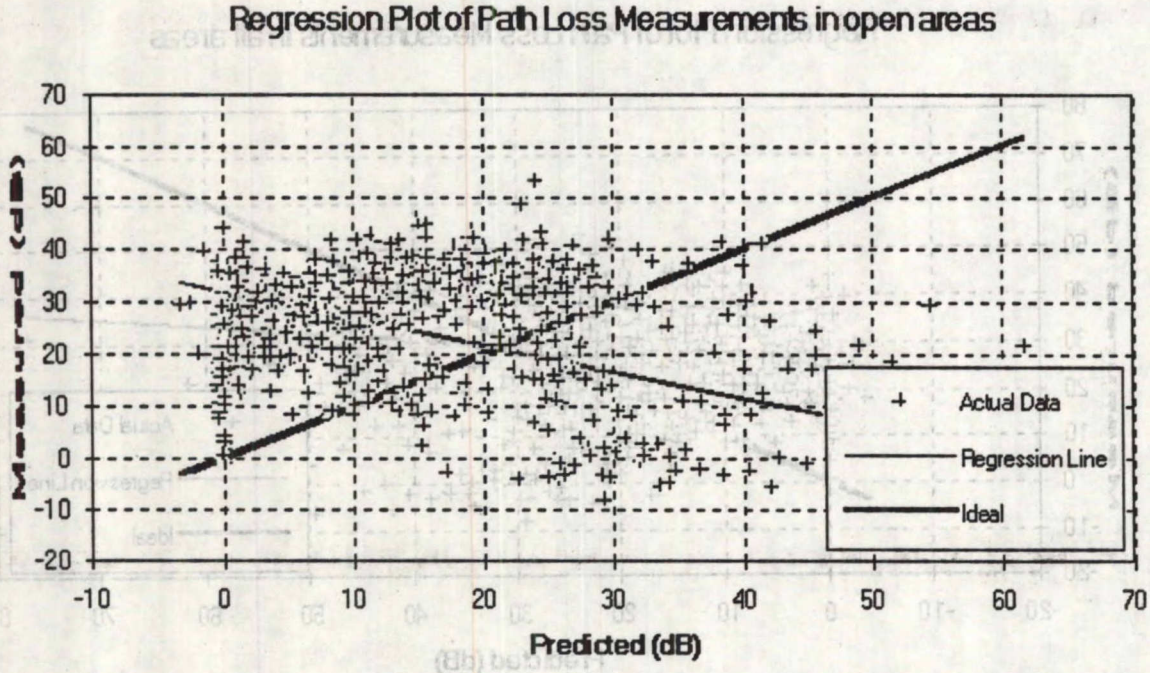


Figure A-28: Regression plot of prediction error for Montreal (Lac Echo) in open areas

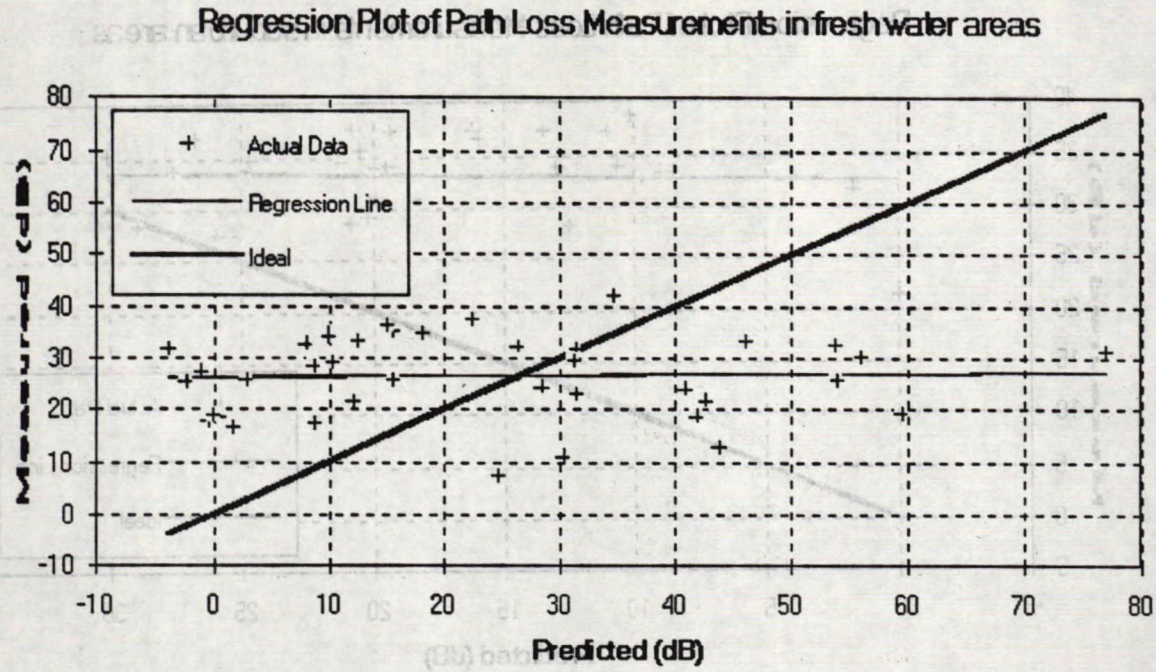


Figure A-29: Regression plot of prediction error for Montreal (Lac Echo) in fresh water areas

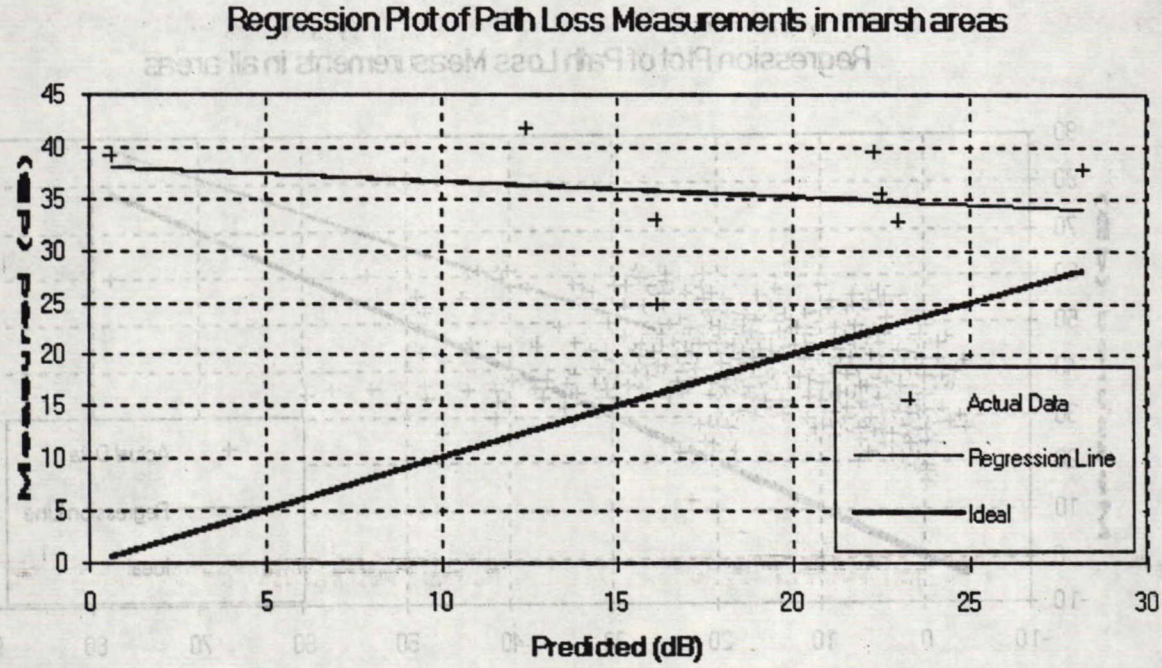


Figure A-30: Regression plot of prediction error for Montreal (Lac Echo) in marsh areas

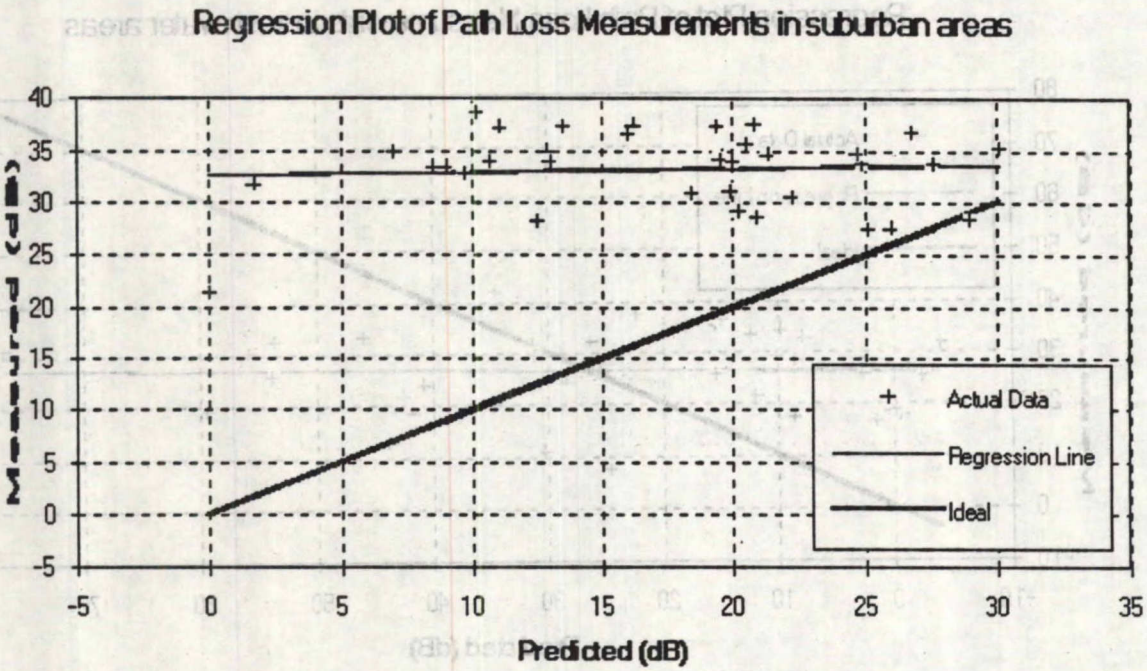


Figure A-31: Regression plot of prediction error for Montreal (Lac Echo) in suburban areas

Montreal (Rigaud)

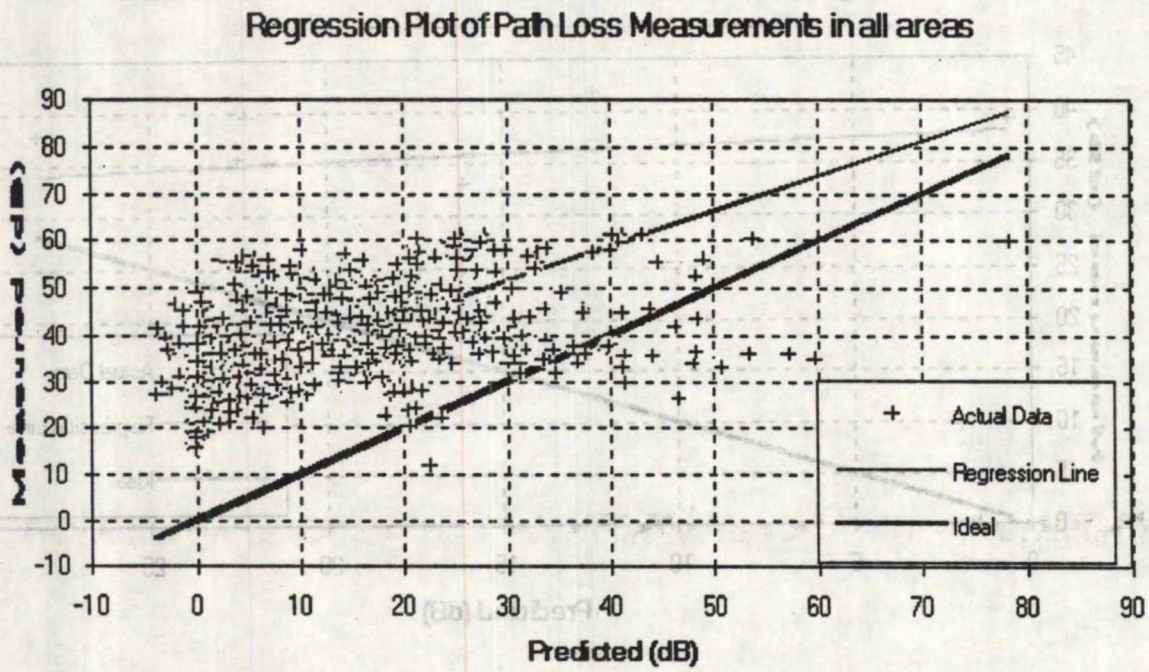


Figure A-32: Regression plot of prediction error for Montreal (Rigaud) in all areas

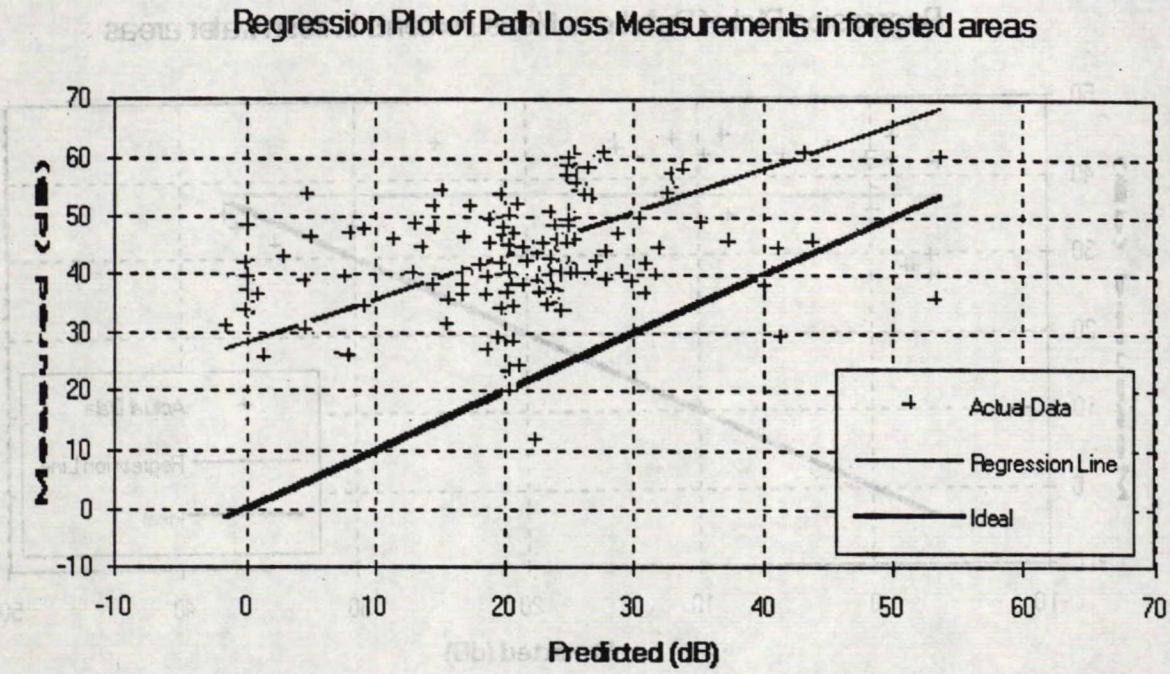


Figure A-33: Regression plot of prediction error for Montreal (Rigaud) in forested areas

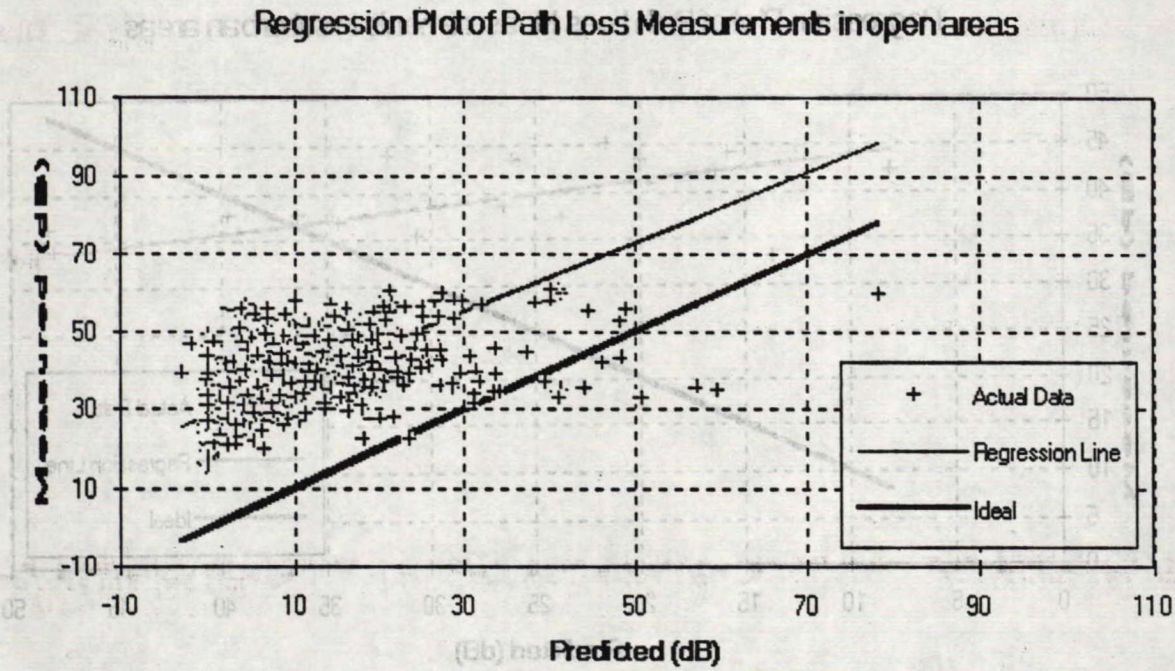


Figure A-34: Regression plot of prediction error for Montreal (Rigaud) in open areas

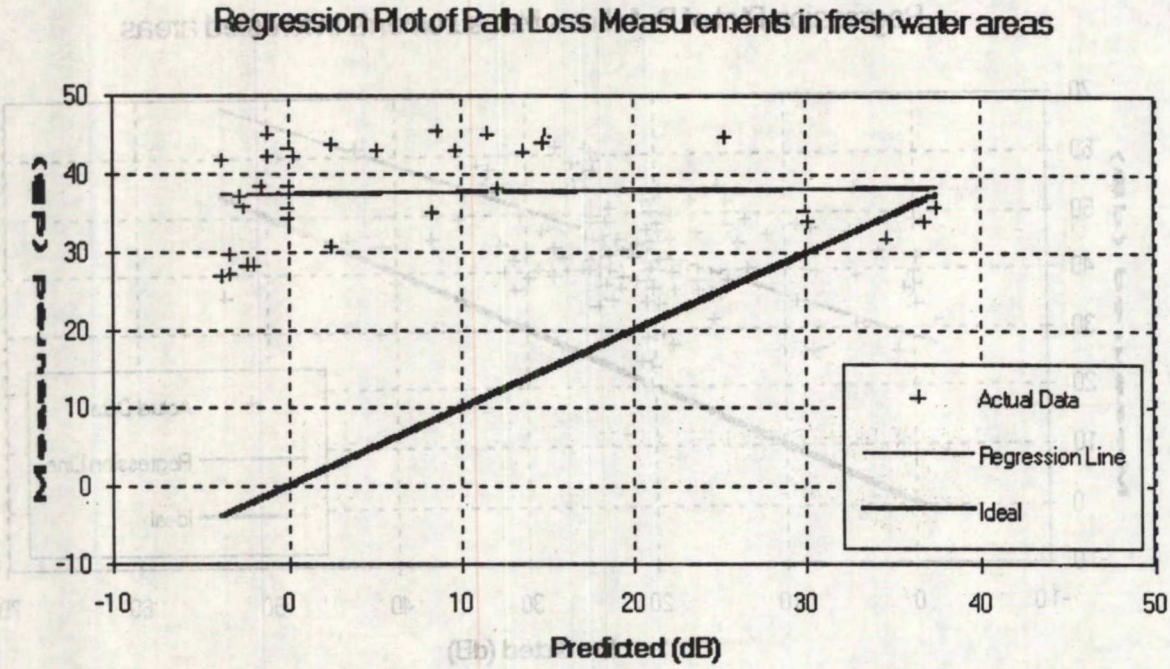


Figure A-35: Regression plot of prediction error for Montreal (Rigaud) in fresh water areas

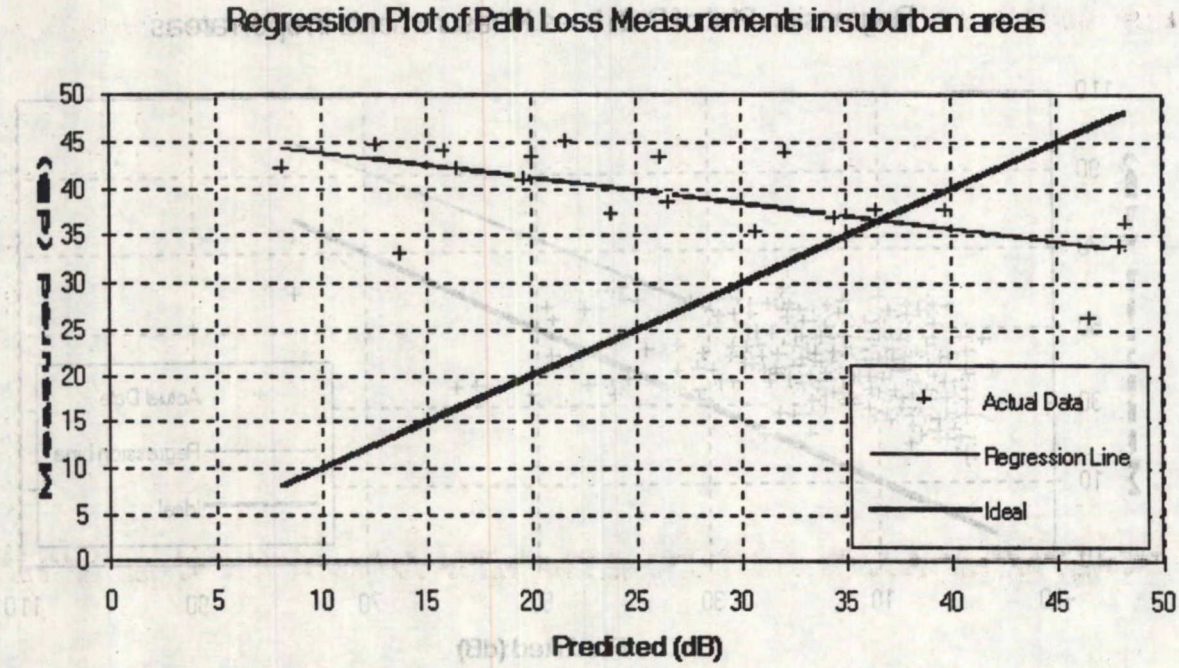


Figure A-36: Regression plot of prediction error for Montreal (Rigaud) in suburban areas

Montreal (Mont Royal) Nov. 1994

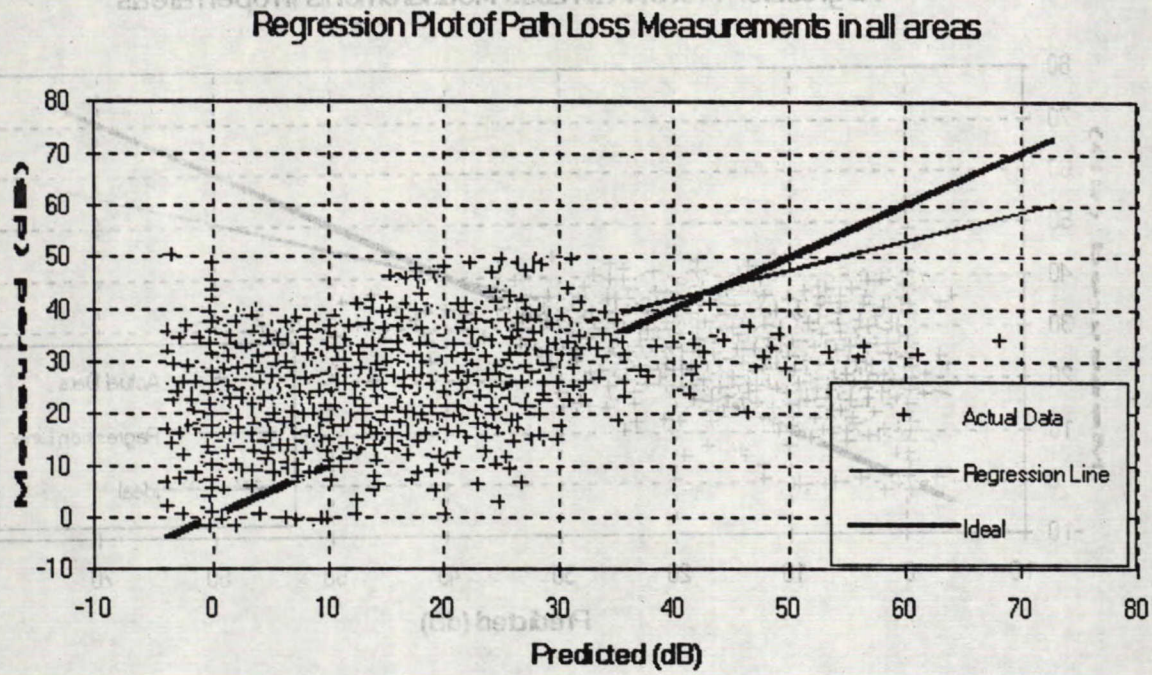


Figure A-37: Regression plot of prediction error for Montreal (Mt. Royal) in all areas

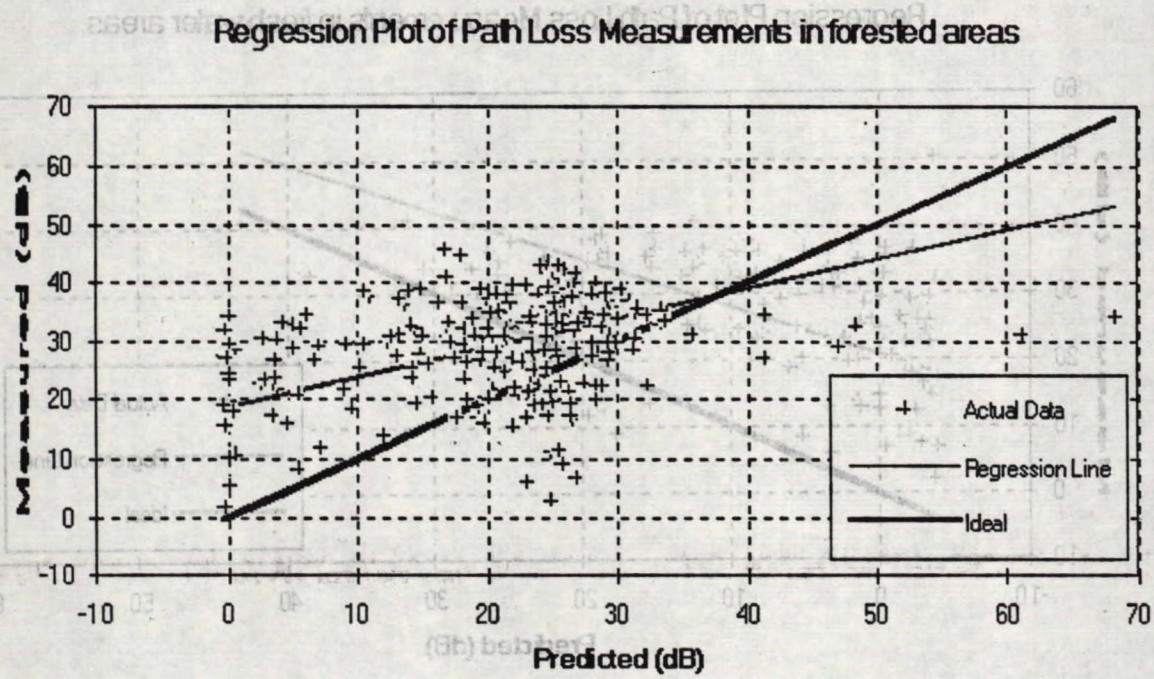


Figure A-38: Regression plot of prediction error for Montreal (Mt. Royal) in forested areas

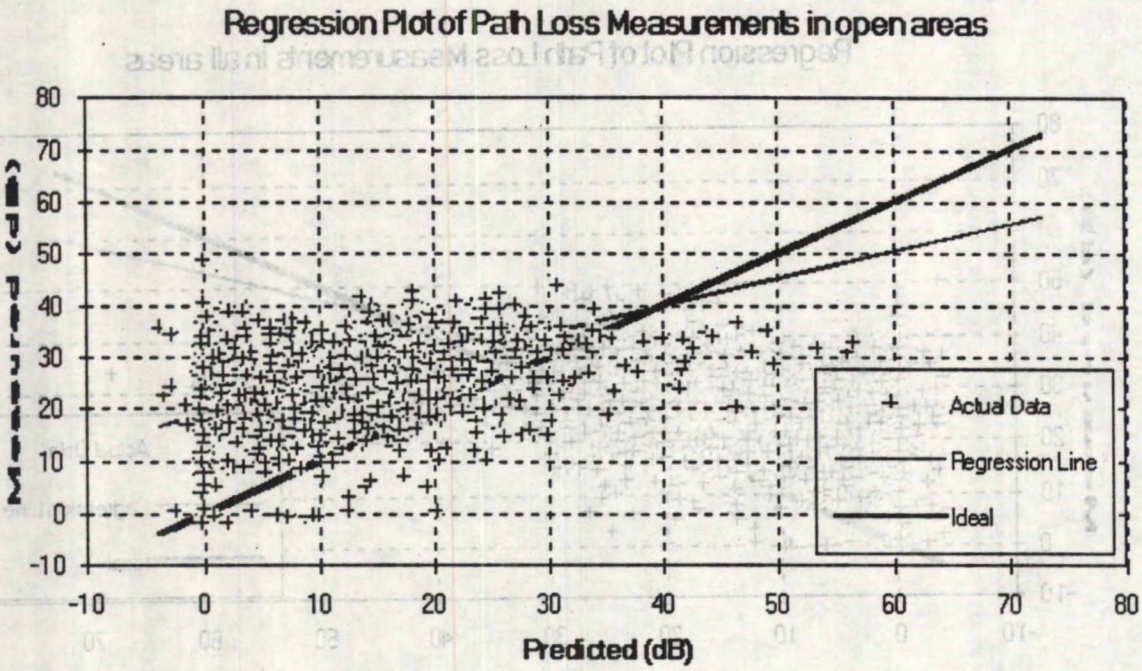


Figure A-39: Regression plot of prediction error for Montreal (Mt. Royal) in open areas

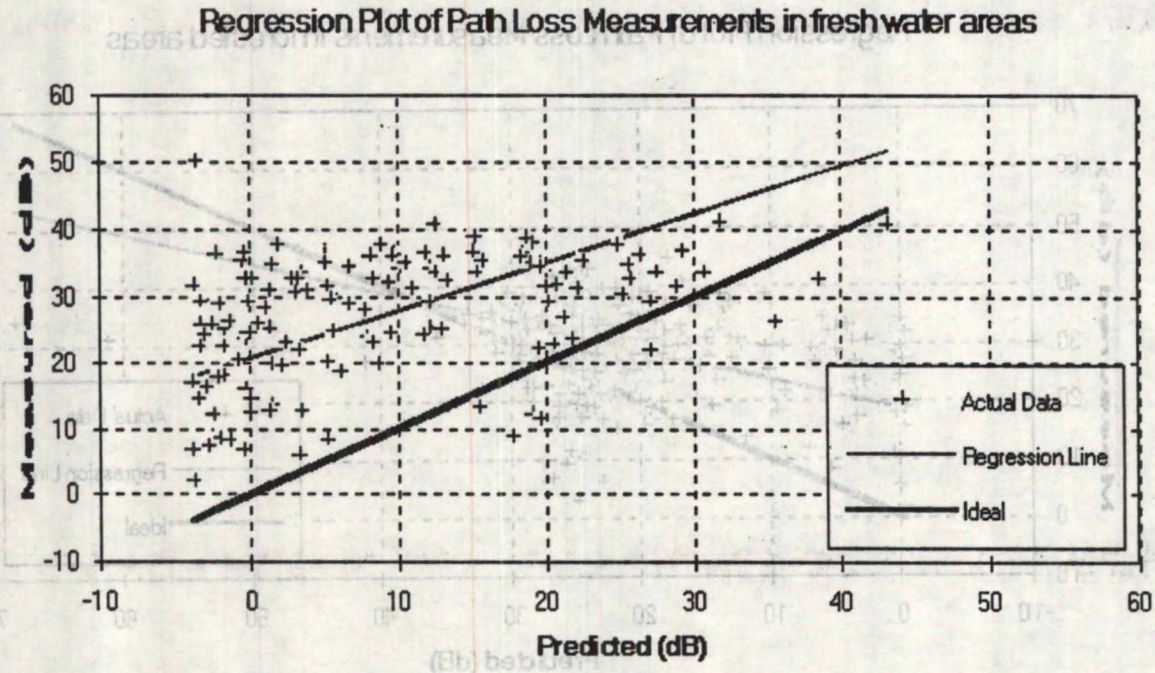


Figure A-40: Regression plot of prediction error for Montreal (Mt. Royal) in fresh water areas

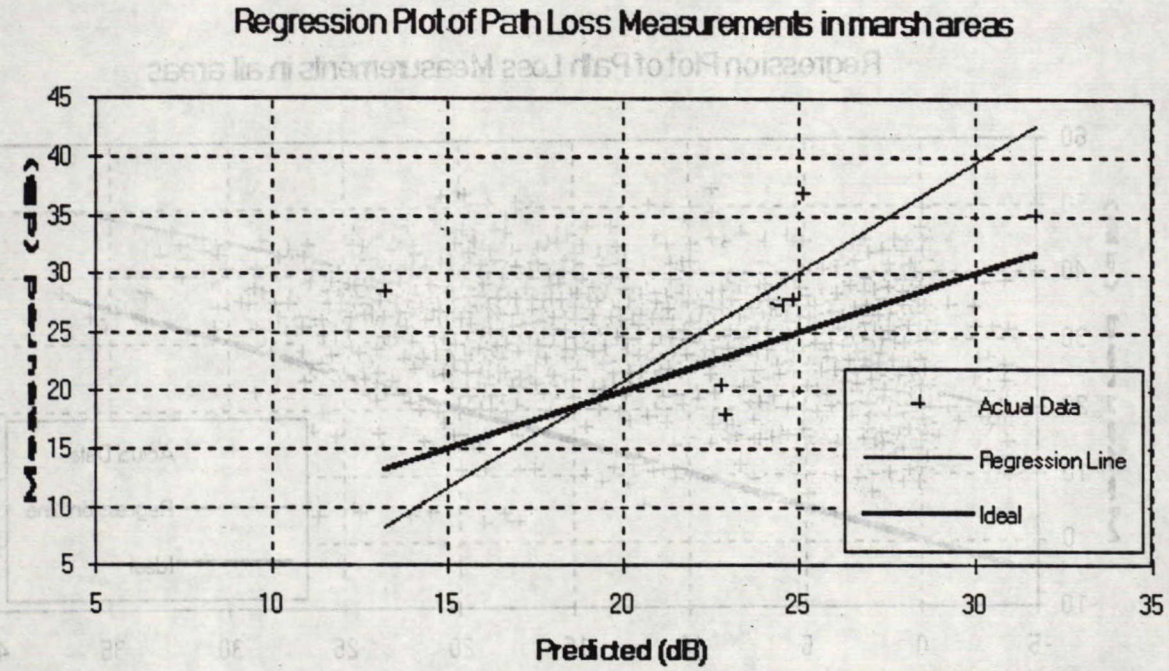


Figure A-41: Regression plot of prediction error for Montreal (Mt. Royal) in marsh areas

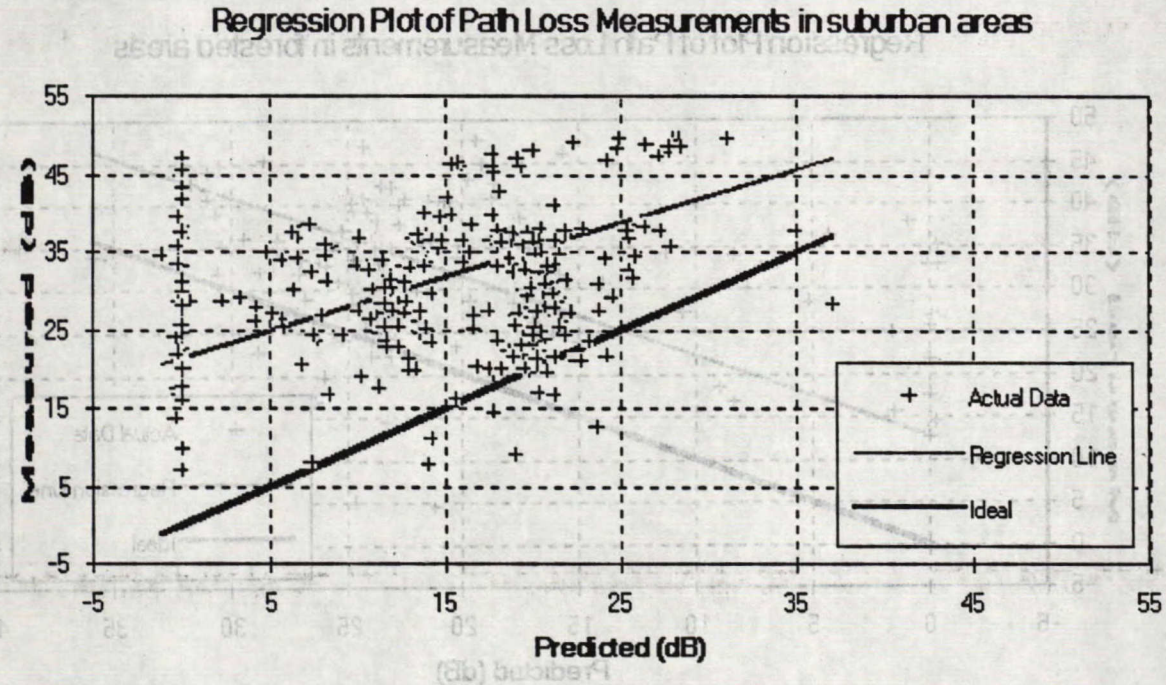


Figure A-42: Regression plot of prediction error for Montreal (Mt. Royal) in suburban areas

Montreal 05/94

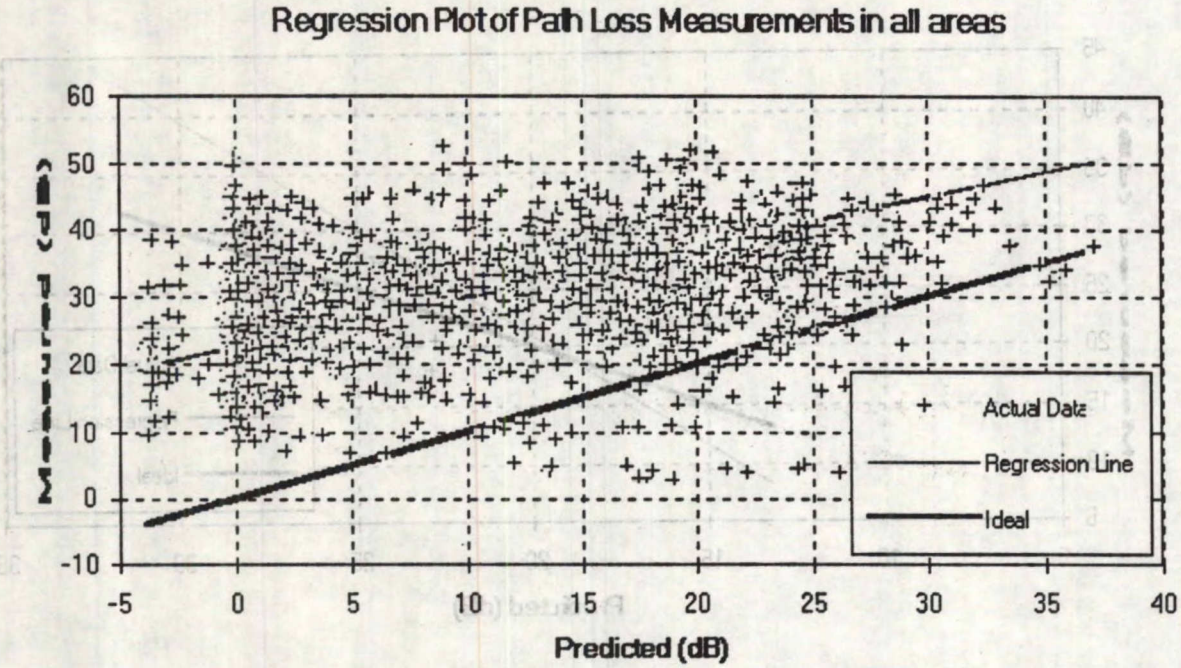


Figure A-43: Regression plot of prediction error for Montreal 05/94 in all areas

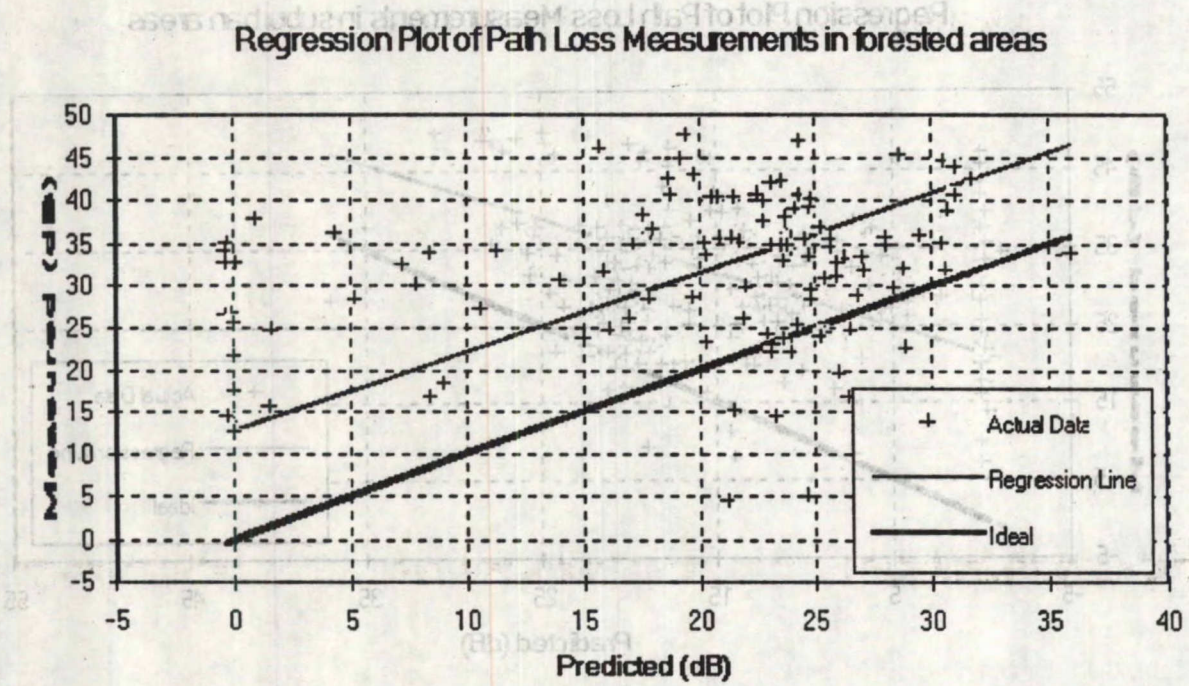


Figure A-44: Regression plot of prediction error for Montreal 05/94 in forested areas

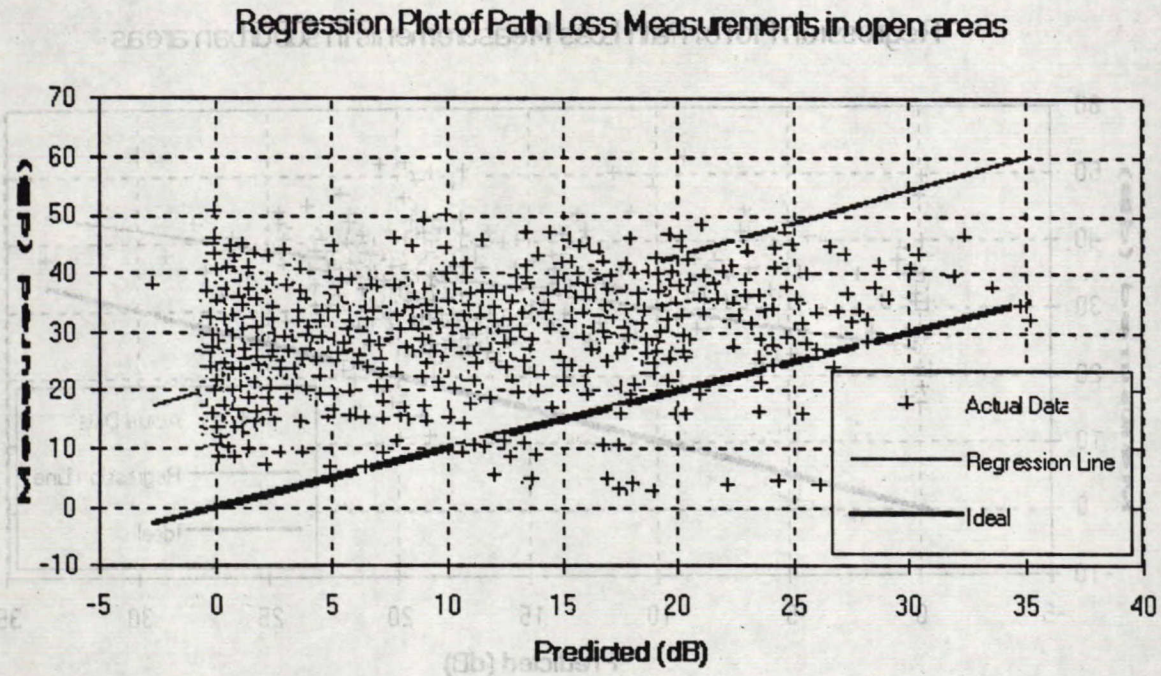


Figure A-45: Regression plot of prediction error for Montreal 05/94 in open areas

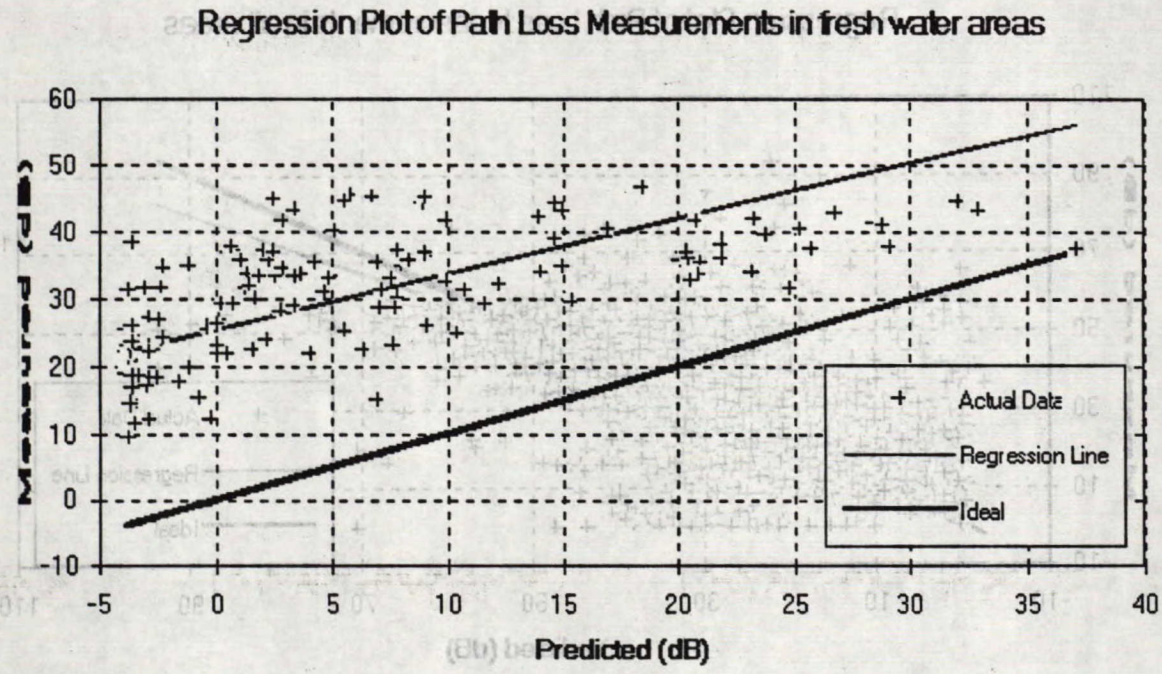


Figure A-46: Regression plot of prediction error for Montreal 05/94 in fresh water areas

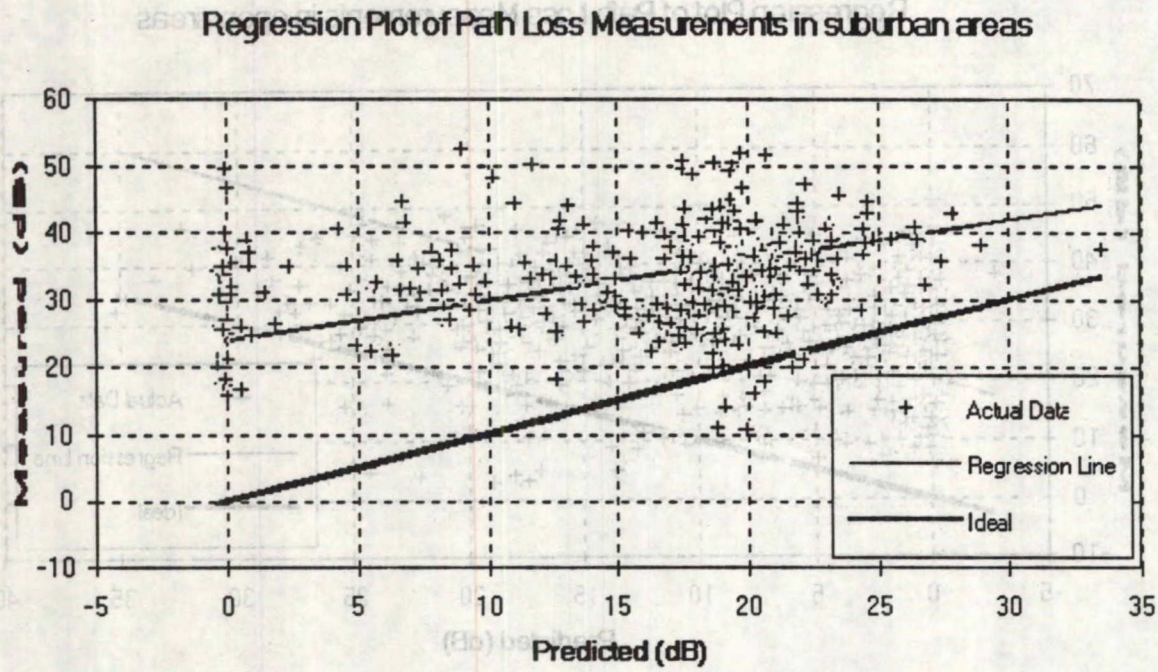


Figure A-47: Regression plot of prediction error for Montreal 05/94 in suburban areas

Trois Rivières - 100m tower

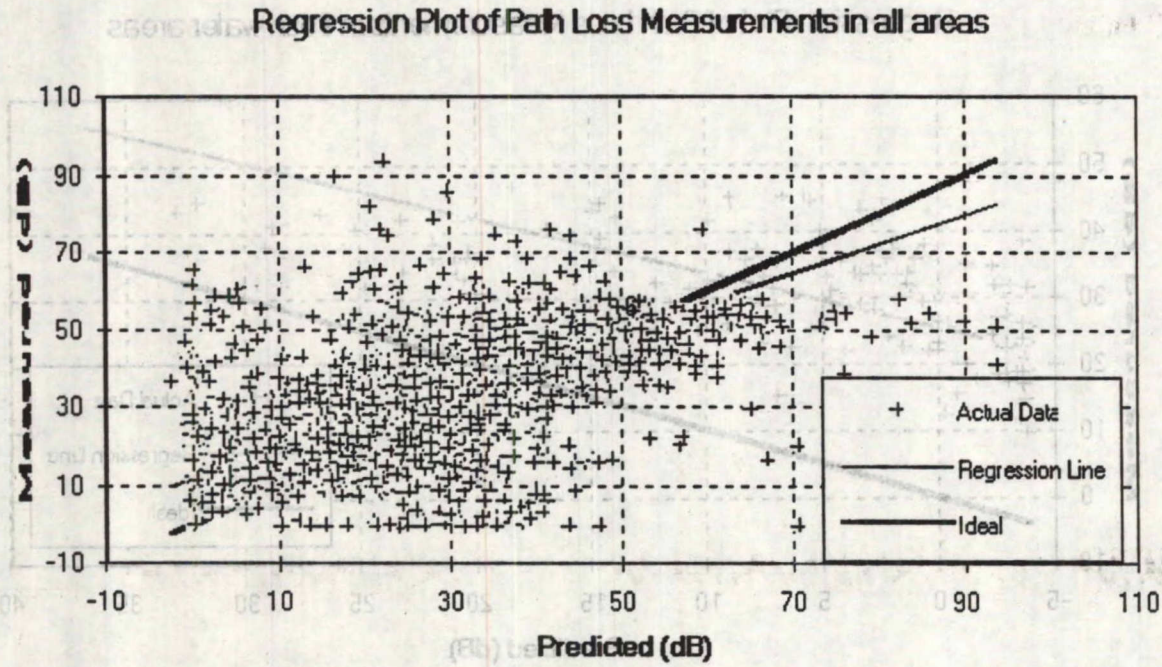


Figure A-48: Regression plot of prediction error for Trois Rivières (100m) in all areas

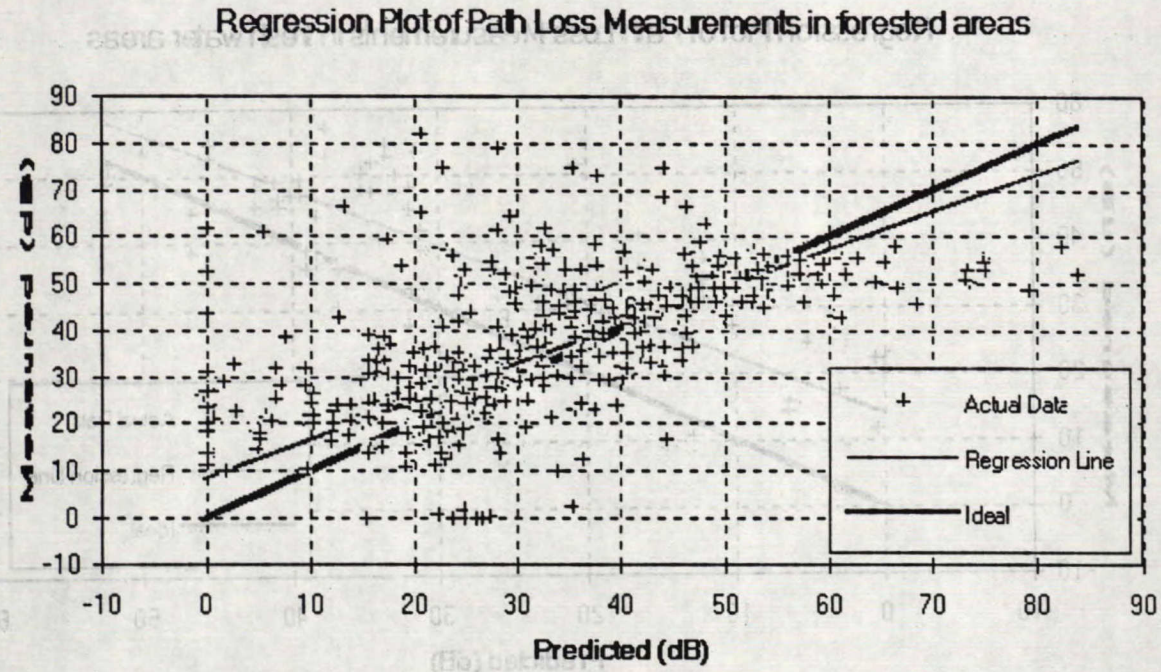


Figure A-49: Regression plot of prediction error for Trois Rivières (100m) in forested areas

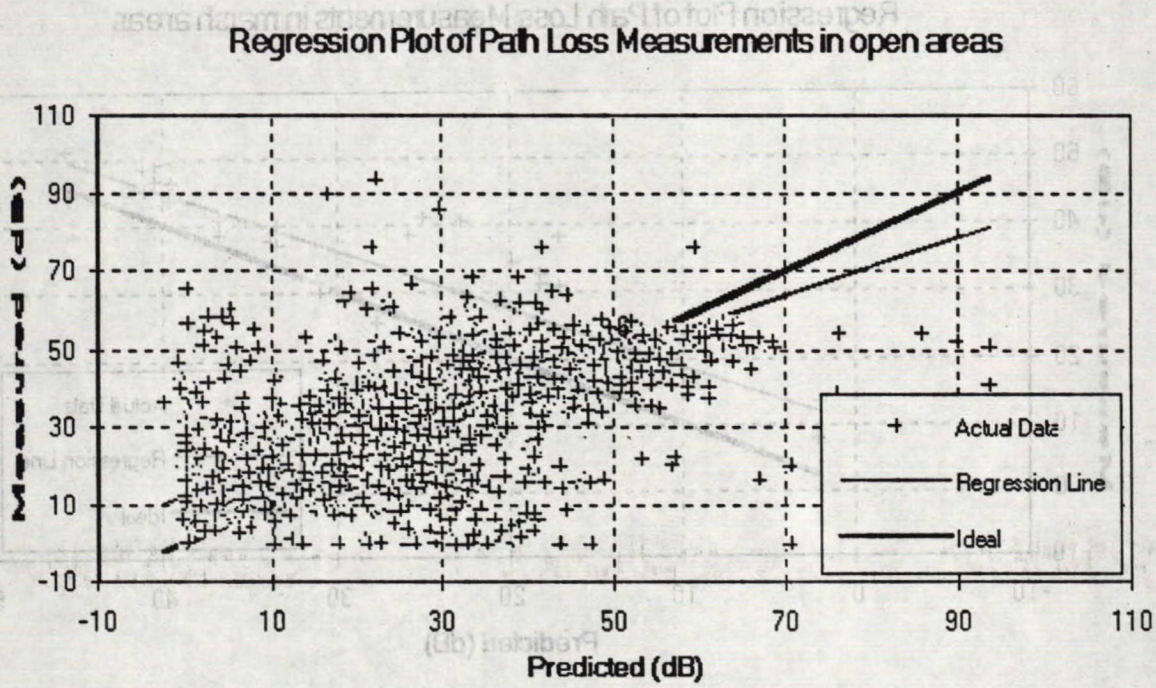


Figure A-50: Regression plot of prediction error for Trois Rivières (100m) in open areas

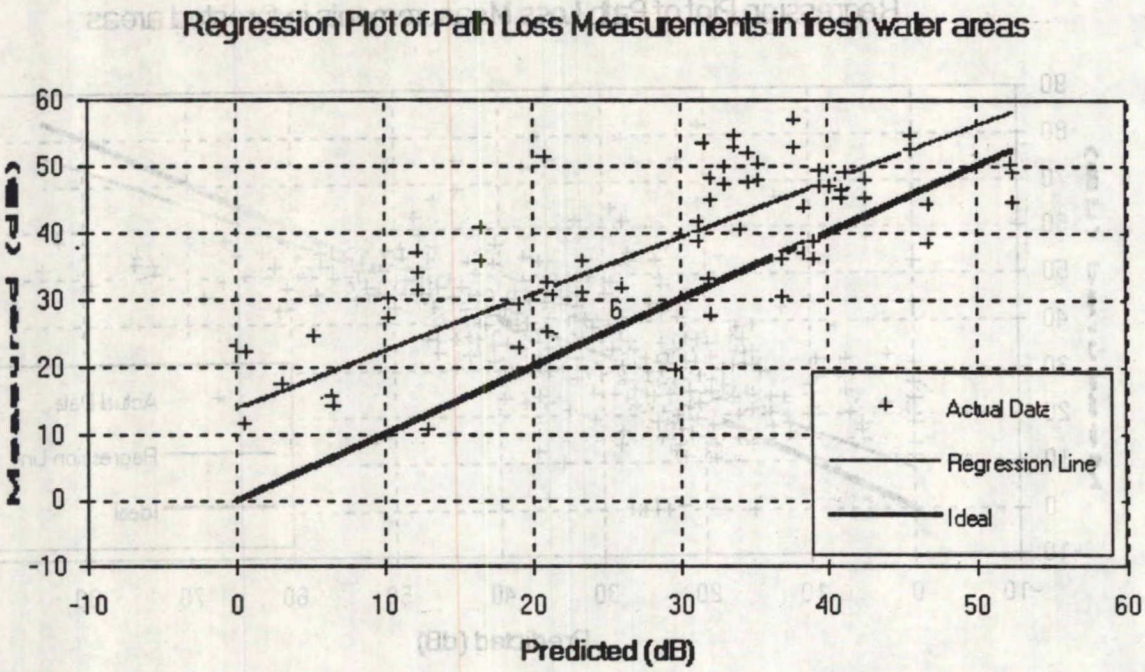


Figure A-51: Regression plot of prediction error for Trois Rivières (100m) in fresh water areas

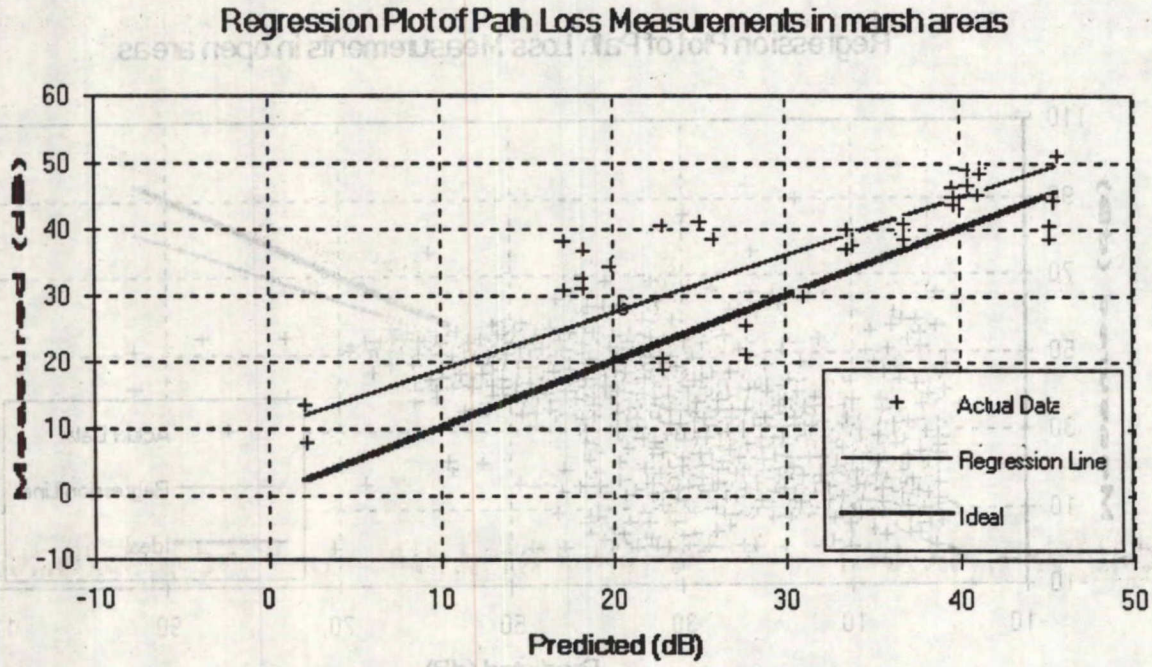


Figure A-52: Regression plot of prediction error for Trois Rivières (100m) in marsh areas

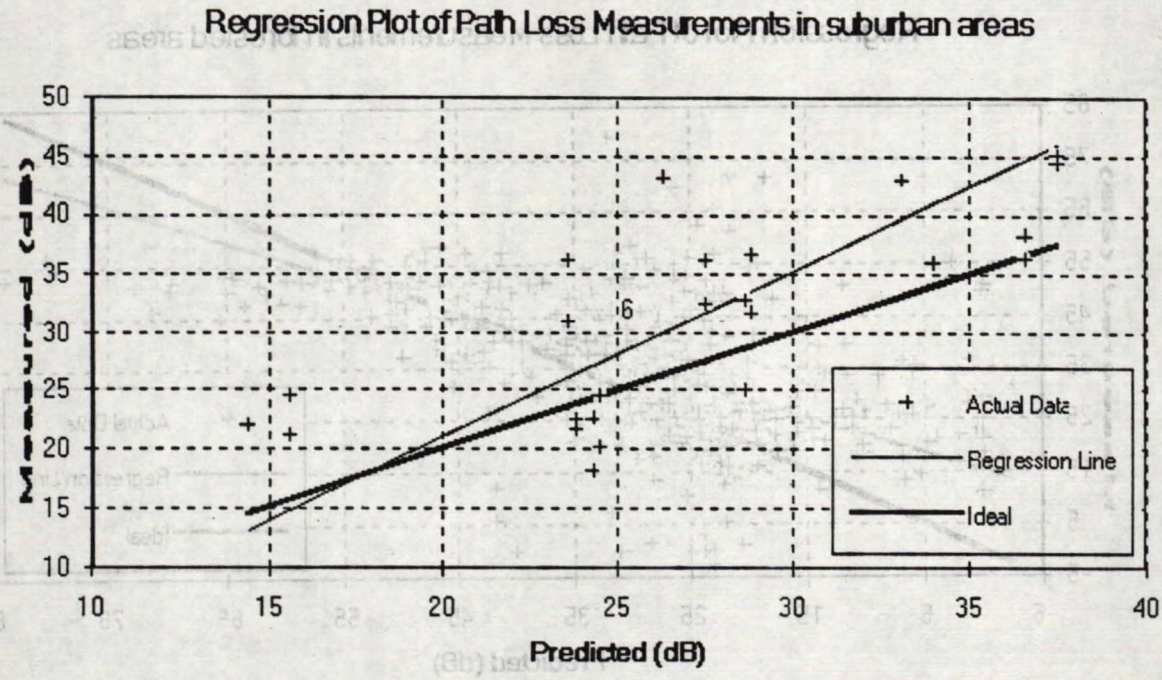


Figure A-53: Regression plot of prediction error for Trois Rivières (100m) in suburban areas

Trois Rivières - 200m tower

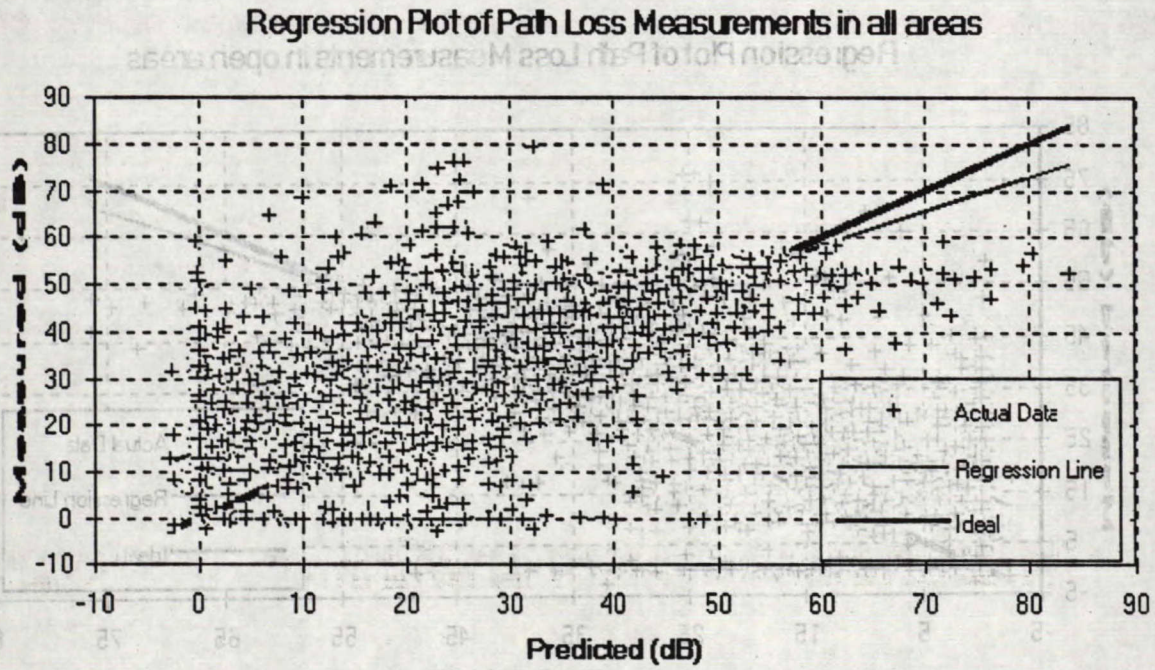


Figure A-54: Regression plot of prediction error for Trois Rivières (200m) in all areas

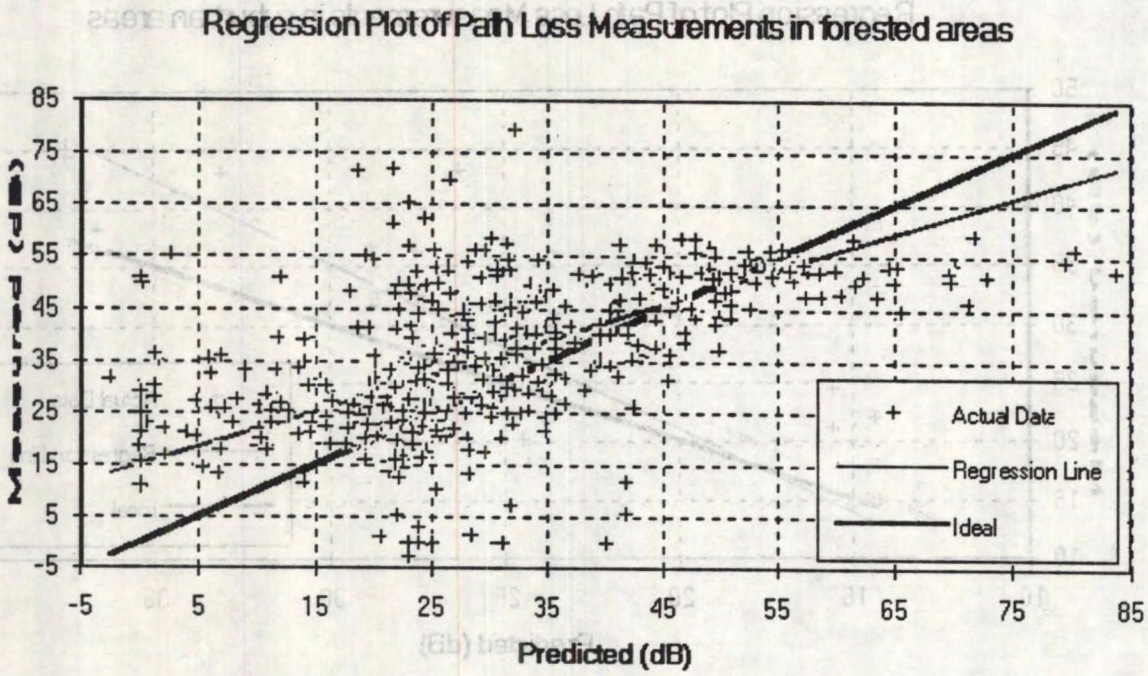


Figure A-55: Regression plot of prediction error for Trois Rivières (200m) in forested areas

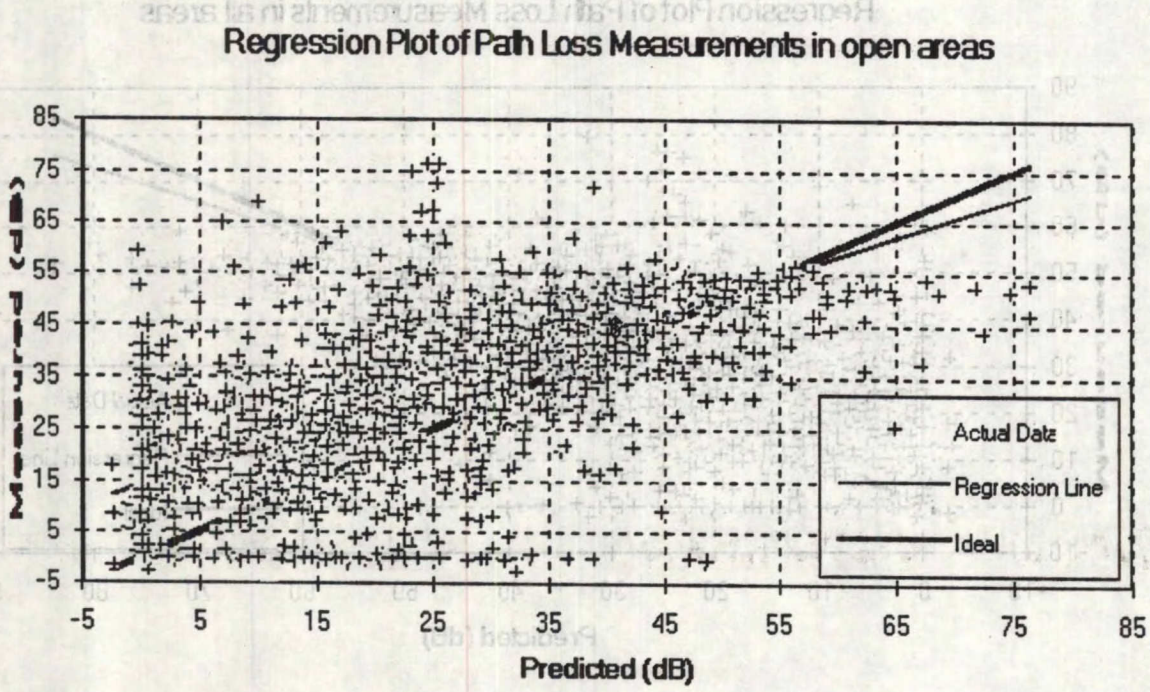


Figure A-56: Regression plot of prediction error for Trois Rivières (200m) in open areas

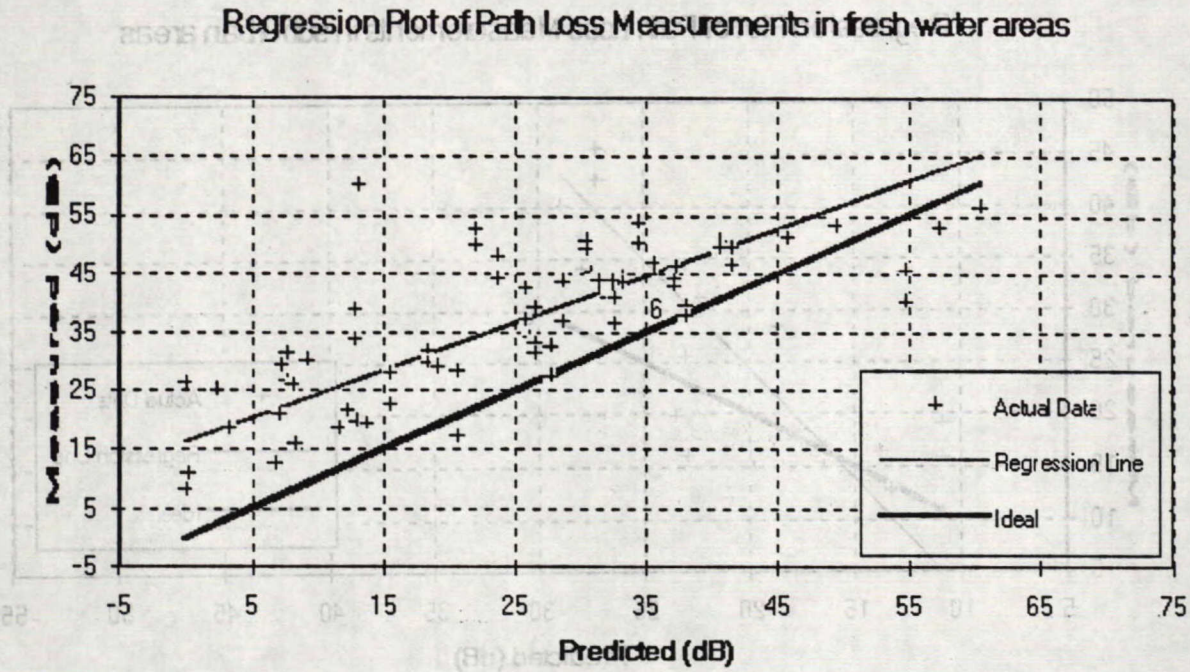


Figure A-57: Regression plot of prediction error for Trois Rivières (200m) in fresh water areas

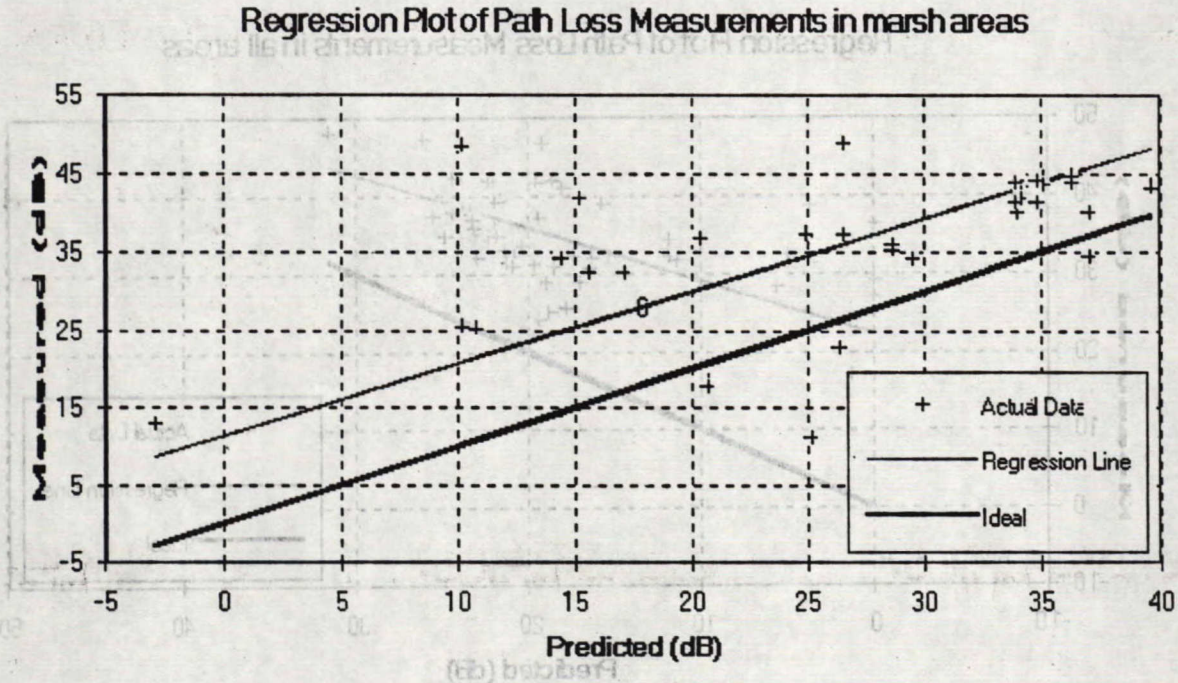


Figure A-58: Regression plot of prediction error for Trois Rivières (200m) in marsh areas

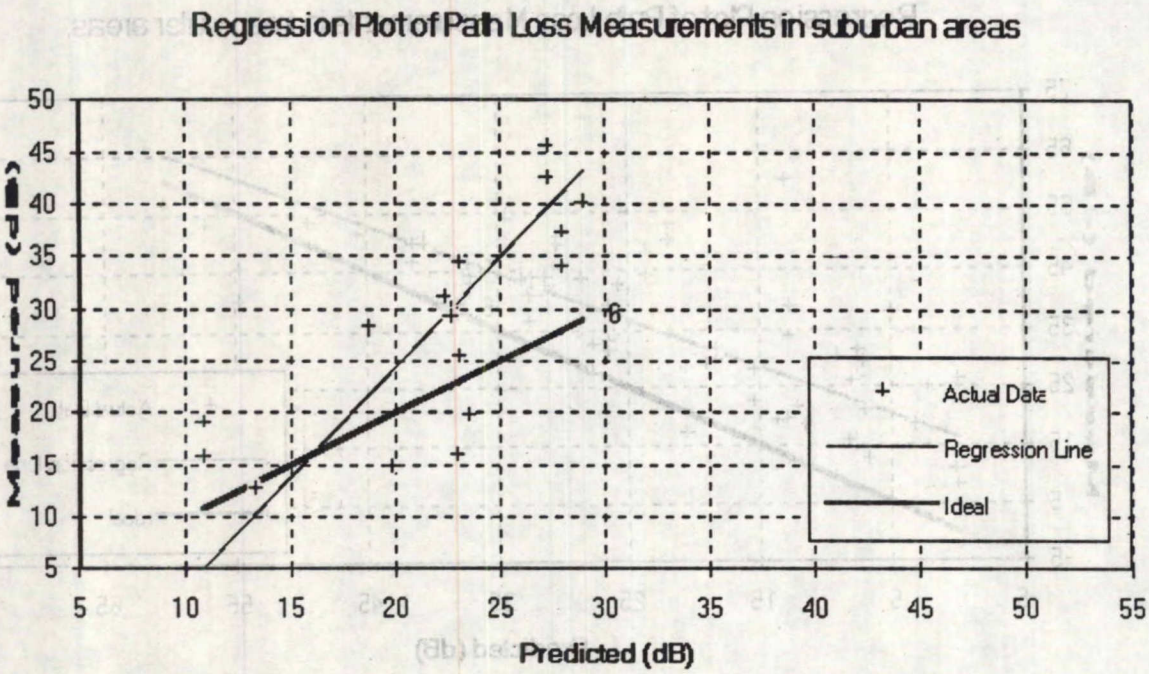


Figure A-59: Regression plot of prediction error for Trois Rivières (200m) in suburban areas

Vancouver

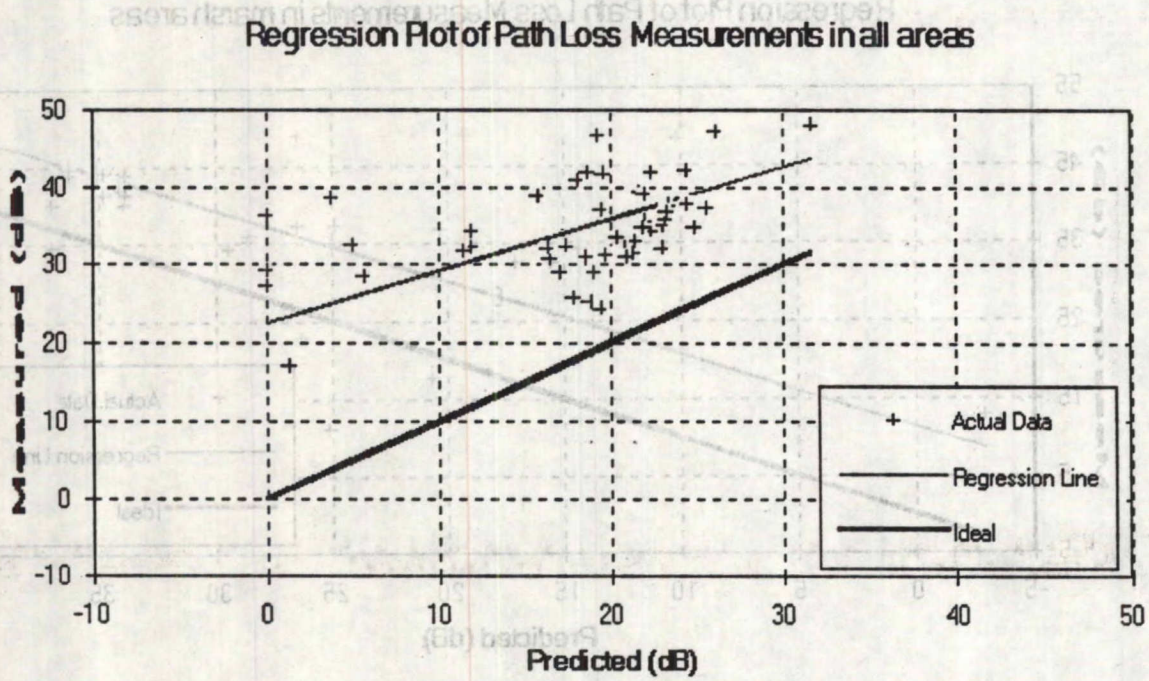


Figure A-60: Regression plot of prediction error for Vancouver in all areas

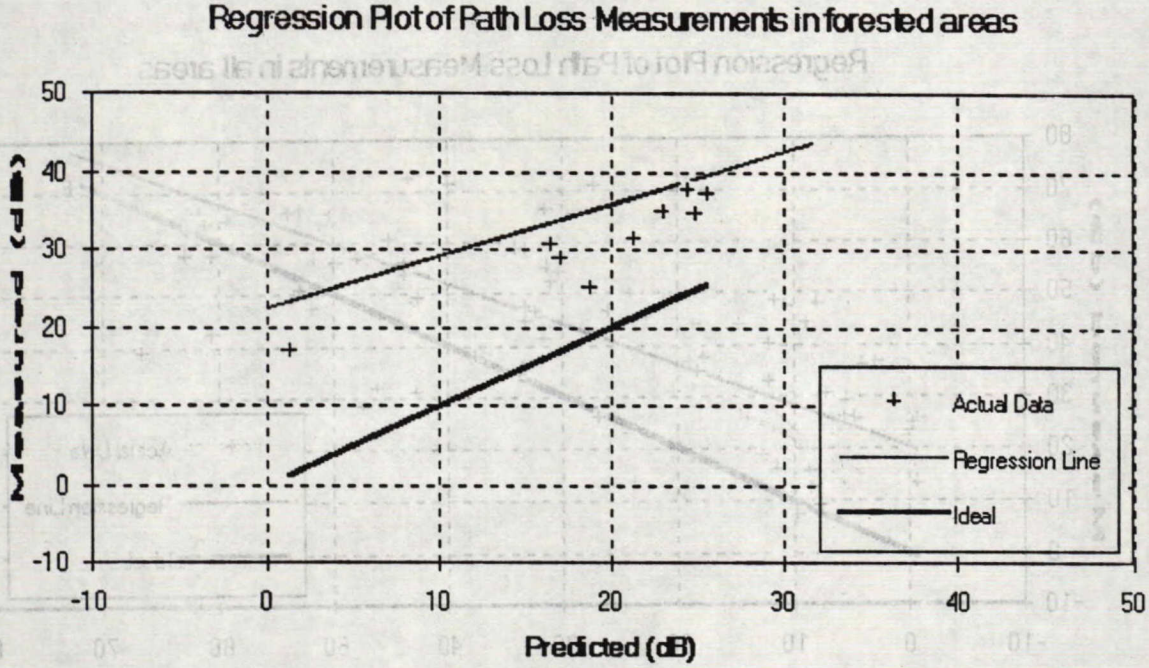


Figure A-61: Regression plot of prediction error for Vancouver in forested areas

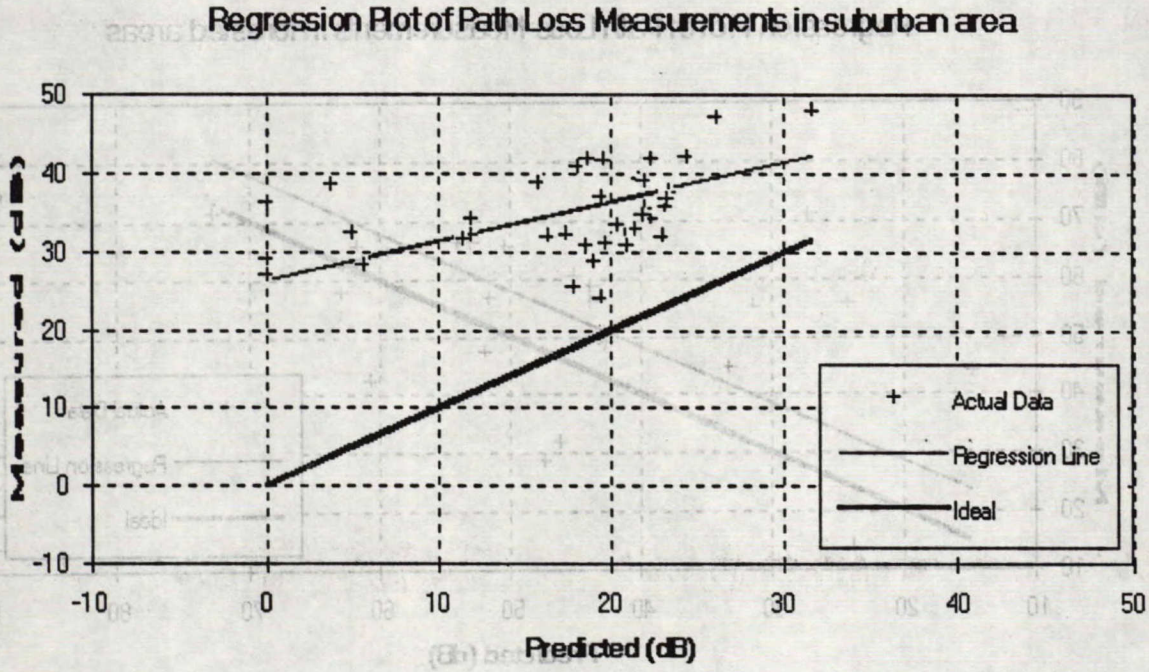


Figure A-62: Regression plot of prediction error for Vancouver in suburban areas

Edgar

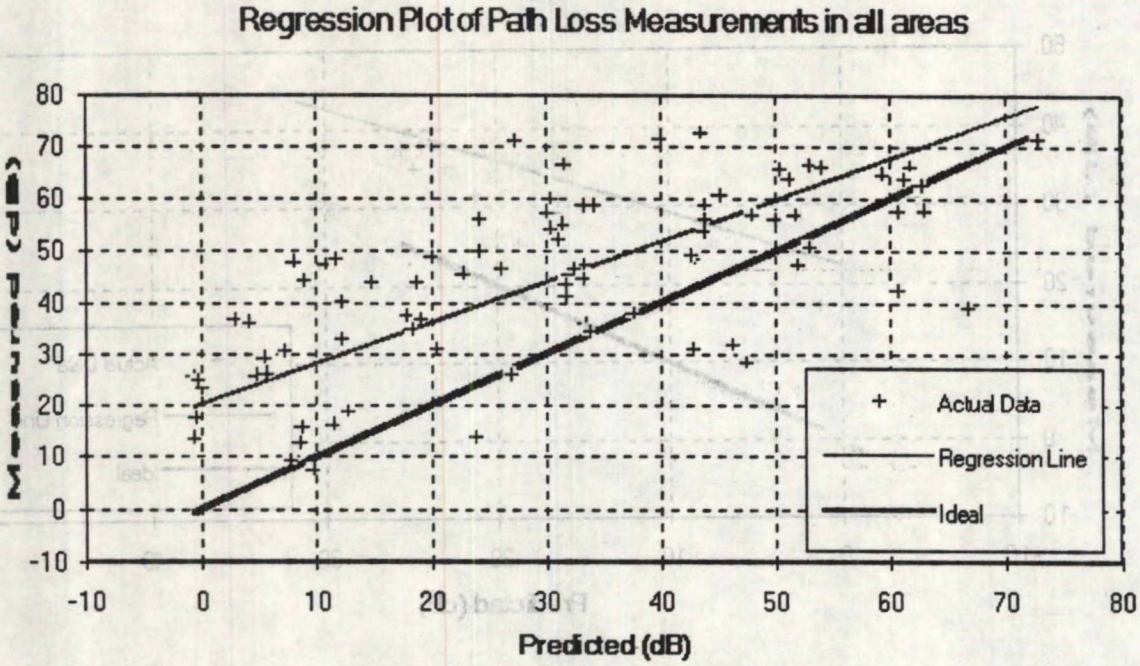


Figure A-63: Regression plot of prediction error for Edgar in all areas

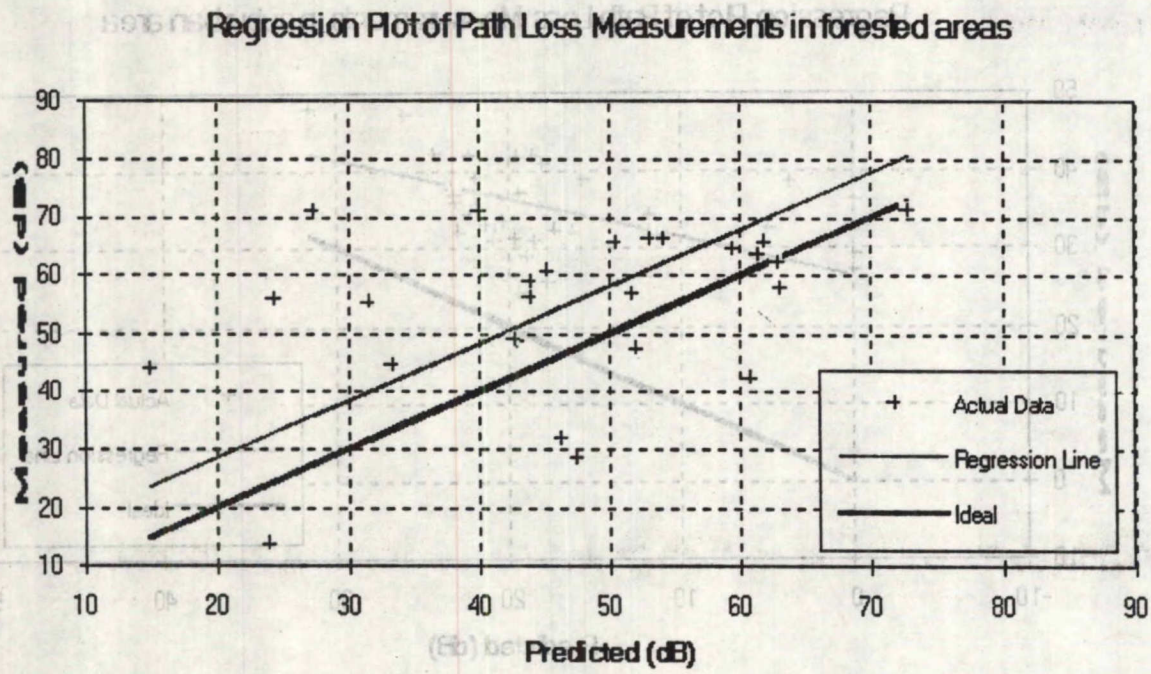


Figure A-64: Regression plot of prediction error for Edgar in forested areas

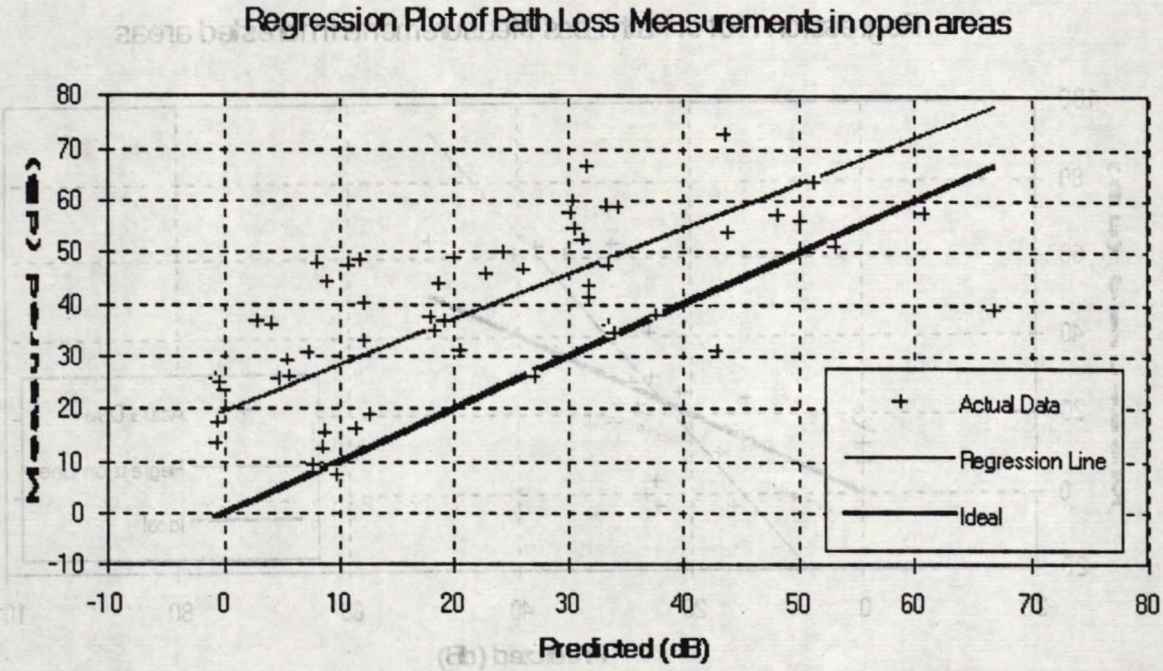


Figure A-65: Regression plot of prediction error for Edgar in open areas

St. Catherines

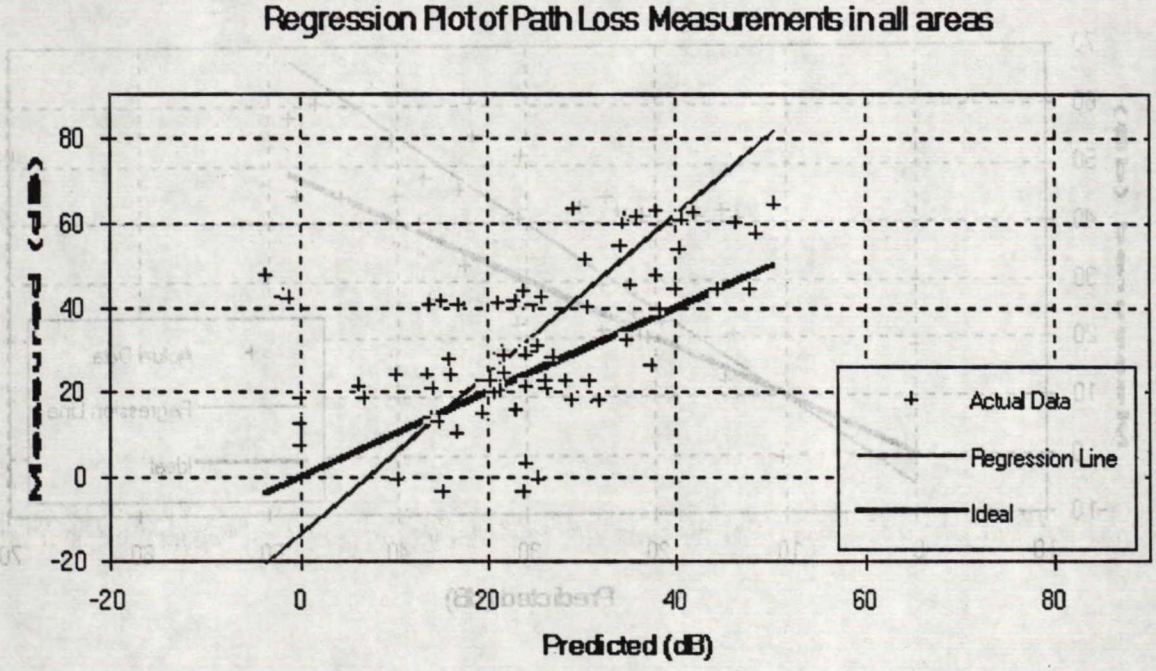


Figure A-66: Regression plot of prediction error for St. Catherines in all areas

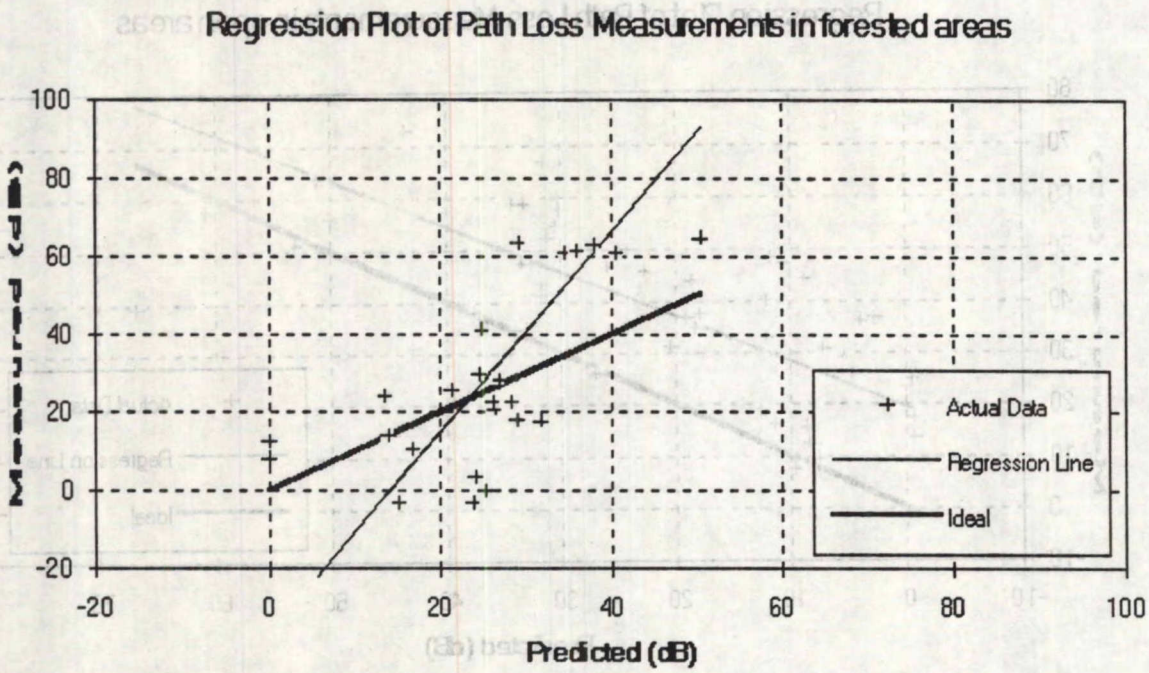


Figure A-67: Regression plot of prediction error for St. Catherines in forested areas

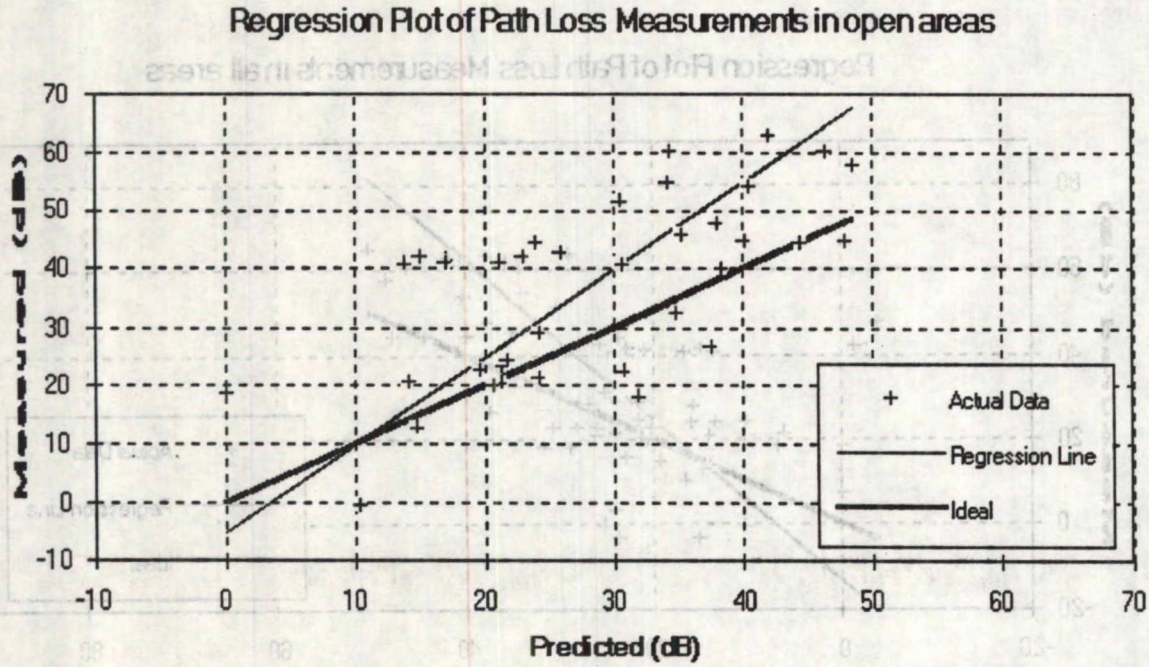


Figure A-68: Regression plot of prediction error for St. Catherines in open areas