Reference 1 (4)

May 20/77

METEOROLOGY RESEARCH INC
TECHNICAL REPORTS:

MRI 74R-1255: A meteorological evaluation of the combined wind and ice loadings for a portion of the Gull Island Transmission Line.

Sept 20, 1974

Revised wind and ice loadings for a portion of the Gull Island Transmission line.

Jan 30, 1975

MRI 75 FR-1378: The follow on meteorological evaluation of the proposed Gull Island Transmission Line network.

Oct 31, 1975

TL-12

2. MRI HAD FORWARDED TO R. BGW.
(1) IR (2) ZUBAHR (3) TAHLIS (4) FILE.

Instructions to Prepare Site Visit Report Forms

a. General Conditions

1. Site Number or Location
2. Date: Month, day, and year.
3. Time: Times of start and finish of observation. Use 24-hour clock and local time.
4. Sky Cover: Tenths of cloud cover, such as "8" or "fog".
5. Cloud Height Above Site Level: Estimated height in feet.
6. Wind
    a. Direction: By sector, such as, WNW
    b. Speed: In miles per hour.
    c. Indicate whether taken from chart or measured with hand set.
7. Temperature: In degrees Fahrenheit. Indicate whether from chart or psychrometer.
8. Relative Humidity: In percent. Indicate whether from chart or psychrometer.
9. Precipitation: Type and intensity of precipitation, if any, occurring at time of observation, such as, S--.
10. Icing Rate Meter Reading: Record both the chart and dial readings.

b. Boxes: Complete boxes for three or more positions along horizontal span and two or more, including top, along vertical span.

1. Photo Numbers: Number rolls and exposures consecutively from start of program. Write 22nd roll, 13th exposure as 22-13. If more than one picture taken at that spot, record them all, e.g. 22-13, 14, 15.
2. Overall Shape: Record as circular, oval, pennant-west, irregular, or very irregular. Always indicate direction pennant is pointing.

3. Dimensions: Measure with calipers where possible; otherwise, check "estimated". Give diameter for circular shape. Give greatest and least dimensions for oval. Give length and greatest width for pennant. Amplify under Remarks.

4. Character of Ice: Record one description from each of the following columns. Describe in more detail in Remarks.

Smooth	Clear	Hard
Rough	Opaque	Medium Hard
Mixture	Mixture	Soft and Crumbly Frost

5. Conductor Visible? Enter yes or no plus remarks, such as, yes, faintly, through smallest dimension.

6. Density: Enter approximate density obtained by specified technique. This will vary from about 0.2 for very soft rime to 0.9 for clear, hard ice. Enter only for those locations actually measured.

7. Layers: When layers can be identified, enter approximate thickness and the character (from table above) of each layer. Start with that nearest the conductor. If no apparent layers, so indicate and give character of innermost and outermost portions.

c. Remarks

1. General Photo Numbers: Record roll and exposure numbers of pictures not covered in data boxes. If there can be any question describe what picture is of.

2. Shape and Dimensions: Add amplifying remarks on shape and dimensions and how they vary along the conductor. We can reconstruct only as well as you describe.

3. Character: Add amplifying remarks on the character of the ice and how it varies along the conductor.

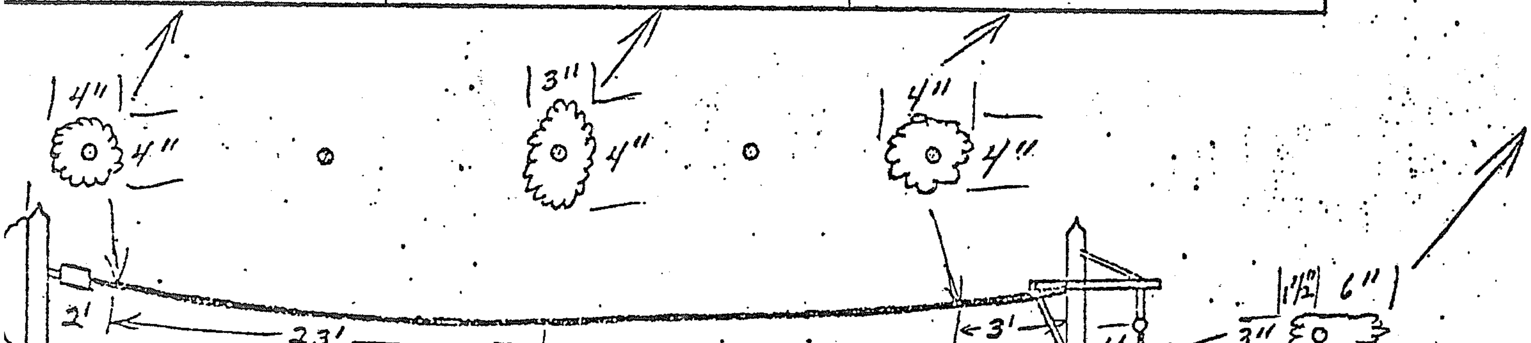
4. Ice on Towers: Describe the structure of any ice on the towers: shape, dimensions, character. Does it fill the tower interior? Does it encase the MWS?
5. Ice on Guys: Describe ice on guys the same as for towers.
6. Snow Depth and Character: Record average snow depth and character; e.g.,.wet and heavy, hard packed, drifted, etc.
7. General Remarks: Add Additional remarks about ice on surrounding trees and shrubs.

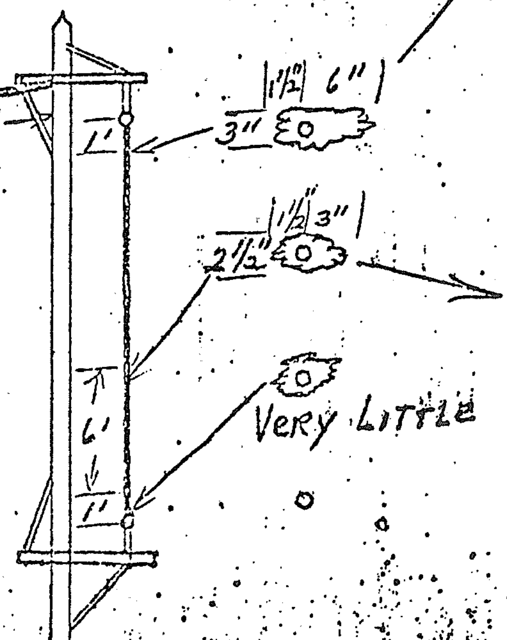
d. General Instructions:

1. Draw line from cross section to data box that describes it and to location along the conductor.
2. Include dimensions on all cross sections.
3. Indicate distance from end or top for each cross section.
4. Measure dimensions with calipers whenever possible.

Photo Numbers: 2-15	Photo Numbers: 2-15, 16	Photo Numbers: 2-17, 18	Site No. or Location:
Overall Shape: CIRCULAR	Overall Shape: OVAL	Overall Shape: CIRCULAR	Date: Nov. 20, 1972 Time: Start 0915 Finish 1110
Dim: Calipers X or Est.	Dim: Calipers or Est. X	Dim: Calipers X or Est.	Sky Cover: 8 Cloud Hgt. Above Site Level: 200 FT.
Character of Ice: Rough Opaque Med.	Character of Ice: Rough Opaque Med	Character of Ice: Rough Opaque Med	WD: WNW WS: 12 Chart or Measured X
Conductor Visible? No	Conductor Visible? No	Conductor Visible? No	Temperature: 21 °F Chart or Measured X
Density:	Density:	Density: 0.6	Rel. Humid.: 30 % Chart or Measured X
Layers: Thickness / Character	Layers: Thickness / Character	Layers: Thickness / Character	Precip.: None IRM Reading: (Dial) 825 (Chart) 800
1 1/2" Mix, Hard	1	1 1/2" Mix, Hard	
2 1 1/2" Opaque, Med	2	2 1 1/2" Opaque, Med	
3	3	3	
4	4	4	

Photo Numbers: 2-19, 20	Photo Numbers:
Overall Shape: PENNANT, WEST	Overall Shape: PENNANT, WEST
Dim: Calipers X or Est.	Dim: Calipers X or Est.
Character of Ice: Rough Opaque SOFT	Character of Ice: Rough Opaque SOFT
Conductor Visible? Yes, THIN SIDE	Conductor Visible? Yes, THIN Side
Density: 0.4	Density: 0.4
Layers: Thickness / Character	Layers: Thickness / Character
1 NONE ALL THE SAME	1
2	2
3	3
4	4





REMARKS:

General Photo Numbers: 2-10, 11, 12, 13, 14

Shape and Dimensions: CHANGES GRADUALLY FROM ROUND TO OVAL AND BACK

Character: PENNANT ICE ON VERT. IS SOFTER THAN ICE ON HORIZONTAL SPAN

Ice on Towers: Top 1/3 OF BOTH TOWERS FULL OF SOFT RIME. 14" PENNANT TO WEST

Ice on Guys: SOME SOFT ICE SEE PHOTO No. 2-14

Snow Depth & Character: 18" SOFT, THIN CRUST

General Remarks: DID NOT SEE ANY OTHER ICE BUT DEEP SNOW IN LOW AREAS

Attachment 1

SITE VISIT REPORT FORM

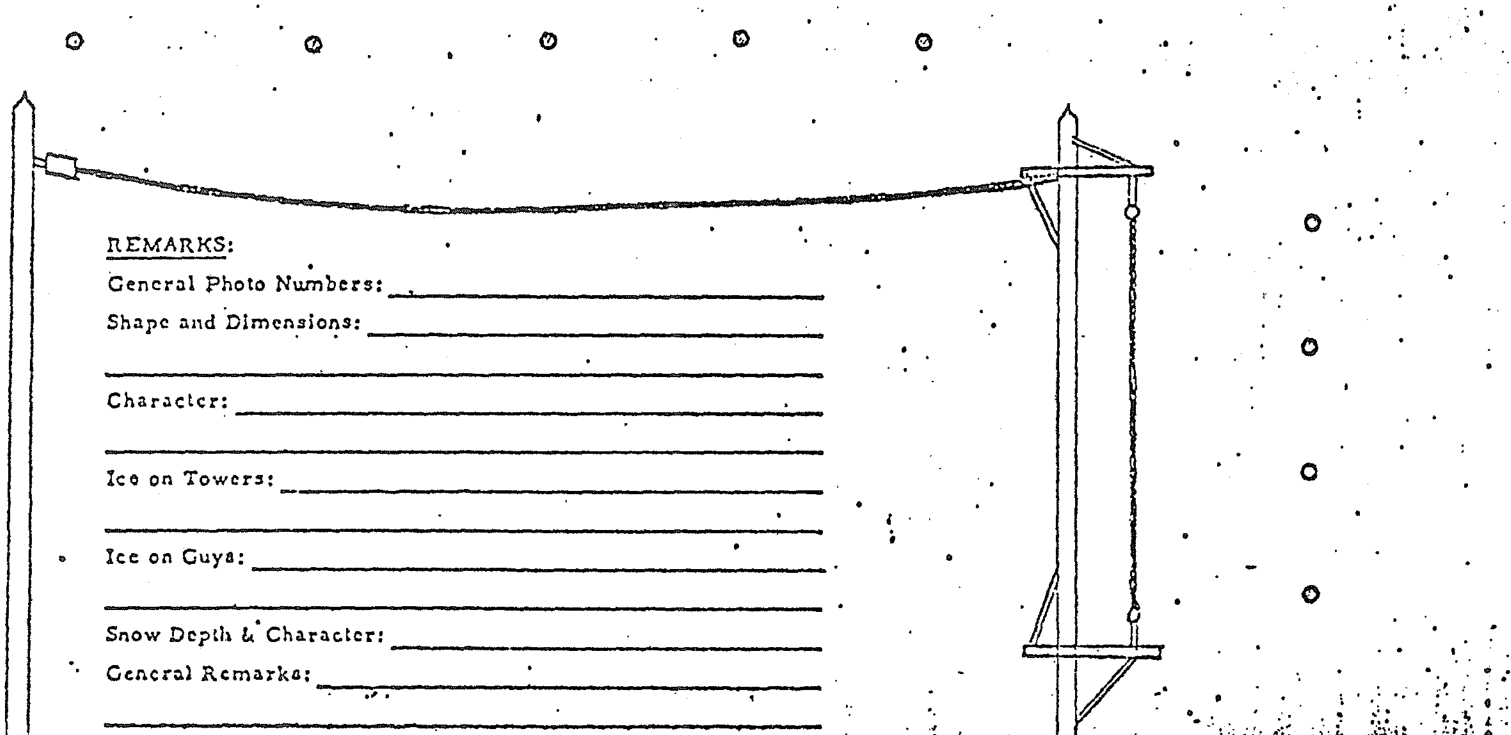
o ... bers: ______ ______
all Shape: ______
Calipers ______ or Est. ______
acter of Ice:
______ ______ ______
uctor Visible? ______
ity: ______
s: Thickness Character
1 ______ ______
2 ______ ______
3 ______ ______
4 ______ ______

Photo Numbers: ______
Overall Shape: ______
Dim: Calipers ______ or Est. ______
Character of Ice:
______ ______ ______
Conductor Visible? ______
Density: ______
Layers: Thickness Character
1 ______ ______
2 ______ ______
3 ______ ______
4 ______ ______

Photo Num. ______
Overall Shape: ______
Dim: Calipers ______ or Est. ______
Character of Ice:
______ ______ ______
Conductor Visible? ______
Density: ______
Layers: Thickness Character
1 ______ ______
2 ______ ______
3 ______ ______
4 ______ ______

Site No. or Location: ______ ______
Date: ______ Time: Start ______ Finish ______
Sky Cover: ______ Cloud Hgt. Above Site Level: ______
WD: ______ WS: ______ Chart ______ or Measured ______
Temperature: ______ °F Chart ______ or Measured ______
Rel. Humid.: ______ % Chart ______ or Measured ______
Precip.: ______ IRM Reading: (Dial) ______, (Chart) ______

Photo Numbers: ______
Overall Shape: ______
Dim: Calipers ______ or Est. ______
Character of Ice:
______ ______ ______
Conductor Visible? ______
Density: ______
Layers: Thickness Character
1 ______ ______
2 ______ ______
3 ______ ______
4 ______ ______



REMARKS:
General Photo Numbers: ______
Shape and Dimensions: ______
______
Character: ______
______
Ice on Towers: ______
______
Ice on Guys: ______
______
Snow Depth & Character: ______
General Remarks: ______
______

Photo Numbers: ______
Overall Shape: ______
Dim: Calipers ______ or Est. ______
Character of Ice:
______ ______ ______
Conductor Visible? ______
Density: ______
Layers: Thickness Character
1 ______ ______
2 ______ ______
3 ______ ______
4 ______ ______

Attachment I

SITE VISIT REPORT FORM

FILE COPY

meteorology research, inc. • 464 w. woodbury rd. • altadena, calif.

Mailing address:
Box 637, Altadena,
Calif. 91001
Phone 213 791-1901

30 January 1975
911 314 1027

Mr. Art Hannah
Teshmont Consultants, Ltd.
225-2025 Corydon Avenue
Winnipeg, Manitoba
R3P ON5
Canada

Dear Art:

Attached are five copies of the summary of the revised return period values of transverse wind loads and winds associated with icing storms. These values were obtained by reviewing hourly weather records for (5) several days after icing ceased. All values of icing given in the September, 1974 report remain the same.

If you have any questions about these results or need any additional information, please give me a call.

Sincerely,

Ronald J Boomer

Ronald J. Boomer
Meteorologist

Teshmont Consultants Ltd.
RECEIVED
FEB 4 1975

RJB/cm

Enclosures

IR
Zubmr
Tmb

133-60810

REVISED COMBINED WIND AND ICE LOADINGS FOR A PORTION OF THE GULL ISLAND TRANSMISSION LINE

During the analysis of weather records for eastern Newfoundland, only winds occurring during or up to six hours following icing storms were considered in deriving transverse wind load of ice-covered transmission lines. Subsequent conversations with Art Hannah, Harvey Young, and Ilmar Reinart, raised some doubt that all of the strongest winds will occur within this time span when ice remains on the conductors and towers. Microfilmed hourly records were analyzed to determine when the maximum transverse loads did occur.

The new criteria was quite simple. The highest wind speed during each icing period (or following it if the temperature remained below freezing) was recorded. If the temperature rose well above freezing, it was assumed that all of the ice melted; winds occurring during or after this period were not considered. This was done for periods up to five days following each icing storm.

Table 1 shows the results of extending the period of observation from six hours to five days following the storms. The first column indicates the number of storms investigated in the 19 years between 1953 and 1971. The second column shows the number of storms where the maximum wind speed and thus the maximum transverse wind load remained unchanged from the previous study. The third column shows the number of questionable increases in wind speed. The question lies in the uncertainty of whether or not the ice remained when the higher winds occurred. Occasional periods of temperatures in the range of 33° - 38° F lasting several hours may have been sufficient to melt the ice. When the higher winds occurred, however, the temperature was below freezing. The final column shows the number of storms where the wind speed was higher than that which occurred up to six hours following the storm.

New return period values for both St. John's-Torbay and Gander were calculated for both transverse wind load of glaze and rime-covered transmission lines and maximum winds associated with icing storms. These results are presented in Tables 2 and 3. The wind speeds in the questionable category were included in the new calculations. The number in parentheses are those values presented in the September, 1974 report.

It can be noted that in many cases the new values are actually lower than those in the previous report, despite wind speeds that were equal to or greater than those used previously. This results from the theory and method used to develop return periods and described by Weiss (1955). The extreme values for each year are listed, and the means and standard deviations are calculated. The return period values (denoted by X_t) are obtained from the equation:

$$X_t = \bar{X} + S_x K_{n,t}$$

where $\bar{X}$ is the mean of the extremes, S_x is the standard deviation of the extremes, and $K_{n,t}$ is a constant determined by the period of record n and the return period T.

It was found from examination of the microfilmed data that the lower annual extreme values were usually increased by extending observations to five days following the storm. However, those highest extremes that were found during the September, 1974 study (in several cases exceeding 50 mph) remained unchanged. This would result in a higher value of $\bar{X}$ but a lower value of S_x, since the range of extreme values decreases. The value of $K_{n,t}$ ranged from approximately 1.65 (for a 10-year return period) to 3.5 (for a 75-year return period). Thus the standard deviation can be a critical parameter. In this current study, the effect in several cases was to decrease the slope of the return period plot, and although the lower end of the plot would result in higher values for return periods less than 10 years, values for longer return periods were in many instances lower than those given in the earlier report.

Return period values of maximum icing winds and winds combined with maximum ice loads were again extrapolated to line segments and presented in Tables 4 and 5. These values are for sustained winds; wind gusts can be estimated by multiplying the results by the gust factor of 1.5. Segment numbers refer to those used in the September, 1974 report and described in the original meteorological study of November, 1973. All icing values derived in the September, 1974 report remain unchanged.

There seemed to be a general rule of thumb concerning the time of occurrence of maximum wind speeds after icing storms. If the maximum winds did not occur within the storm or a few hours thereafter, then they usually occurred within 24 hours following the occurrence of glaze icing and 48 hours following rime icing. There were some exceptions, generally at St. John's, where average wind speeds are high. Even these exceptions extended the time of the maximum winds only another 24 hours. After these time periods either the wind speeds decreased or the temperature increased, thus melting the ice.

REFERENCE

Weiss, L. L., 1955: A nomogram based on the theory of extreme winds for determining values for various return periods. Mon. Wea. Rev., 83, 69-71.

Table 1

	No. of Storms	Number Unchanged	Number Questionable	Number Changed
St. John's Glaze	37	28	3	6
St. John's Rime	41	32	5	4
Gander Glaze	28	14	3	11
Gander Rime	41	27	3	11

Table 2

TRANSVERSE WIND LOADS (lbs/lineal ft.)
FOR ICE-COVERED T/L (2.0-inch Diameter Conductor)
Result from September, 1974 Report in Parentheses

Return Period (years)	GANDER Glaze-Covered	GANDER Rime-Covered*	ST. JOHN'S Glaze-Covered	ST. JOHN'S Rime-Covered*
10	1.5 (1.2)	2.0 (2.0)	1.7 (1.7)	3.6 (3.6)
25	1.9 (1.4)	2.4 (2.5)	2.1 (2.1)	4.5 (4.6)
50	2.2 (1.7)	2.7 (2.7)	2.4 (2.3)	5.1 (5.3)
75	2.4 (1.8)	2.9 (2.9)	2.6 (2.5)	5.5 (5.7)

*Adjusted to 300-ft above station elevation.

Table 3

RETURN PERIOD VALUES FOR MAXIMUM SUSTAINED
WIND SPEEDS (mph) ASSOCIATED WITH ICING STORMS
Results from September, 1974 Report in Parentheses

Return Period (years)	GANDER Glaze Storms	GANDER Rime Storms	ST. JOHN'S Glaze Storms	ST. JOHN'S Rime Storms
10	42 (36)	46 (46)	45 (41)	54 (54)
25	48 (40)	52 (54)	51 (47)	61 (62)
50	52 (43)	57 (58)	56 (52)	67 (69)
75	54 (45)	60 (61)	58 (55)	70 (72)

Table 4

RETURN PERIOD VALUES FOR MAXIMUM SUSTAINED ICING WIND SPEEDS (mph) EXTRAPOLATED TO LINE SEGMENTS
Results from September, 1974 Report in Parentheses

Segment Number	Return Period, Years 10	25	50	75
1	51 (51)	59 (60)	65 (66)	69 (70)
2	54 (54)	61 (62)	67 (68)	70 (72)
3	46 (47)	53 (54)	61 (62)	65 (66)
4	53 (54)	61 (62)	67 (68)	71 (72)
20	53 (54)	61 (62)	67 (68)	71 (72)

Table 5

RETURN PERIOD VALUES FOR MAXIMUM SUSTAINED WIND SPEEDS (mph) ASSOCIATED WITH ICING, EXTRAPOLATED TO LINE SEGMENTS
Results from September, 1974 Report in Parentheses

Segment Number	Return Period, Years 10	25	Gust	50		75
1	40 (40)	44 (44)	71	47 (48)	72	49 (50)
2	43 (43)	47 (47)	75	50 (51)	77	52 (53)
3	36 (36)	40 (40)	66	44 (44)	66	46 (46)
4	43 (43)	47 (47)	77	51 (51)	77	53 (53)
20	43 (43)	47 (47)	77	51 (51)	77	53 (53)

Note: Wind gusts can be estimated by multiplying the above results by the gust factor of 1.5.

INDUSTRIAL METEOROLOGY DEPARTMENT
6 November 1974

- **Associate Director, Environmental Meteorology** — N. L. Hallanger
  - **Montreal Office** — R. DeChancenotte
  - **Administrative Manager, Industrial Meteorology** — B. R. Warr
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      - T. Peters (pt)
    - **Transmission Lines**
      - M. Richmond*
      - R. Boomer
      - T. Peters (pt)
    - **Special Studies**
      - M. Weinstein
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    - **Data Processing**
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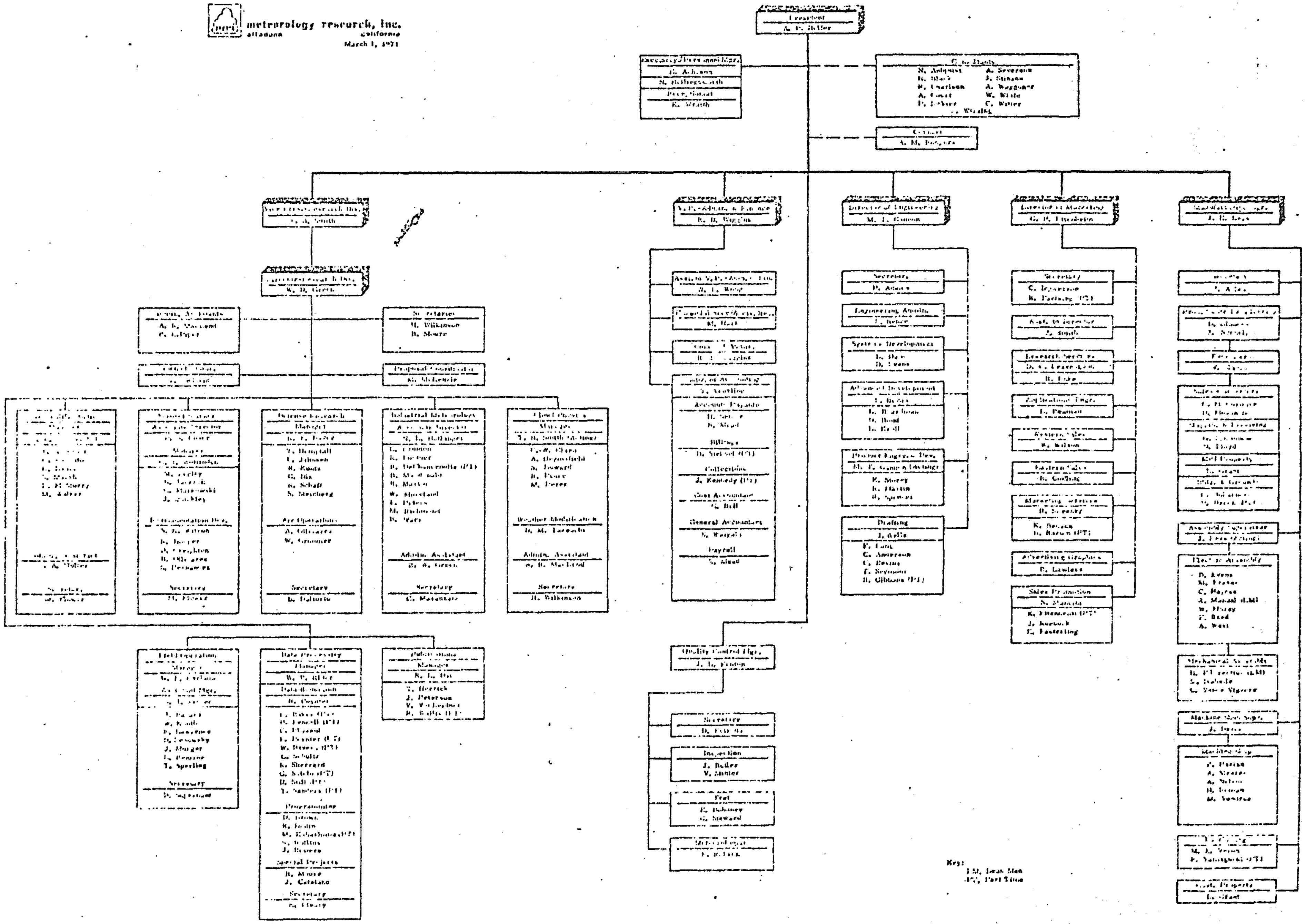
      - R. Poynter
      - W. Hodin
      - S. Rollins
      - G. Sotelo
      - E. Poynter
      - C. Swan
      - R. Hillestad
      - V. Uttayaya
      - G. Bosworth
      - S. Bristow
      - R. Ross
      - C. Veo
      - D. Nugent

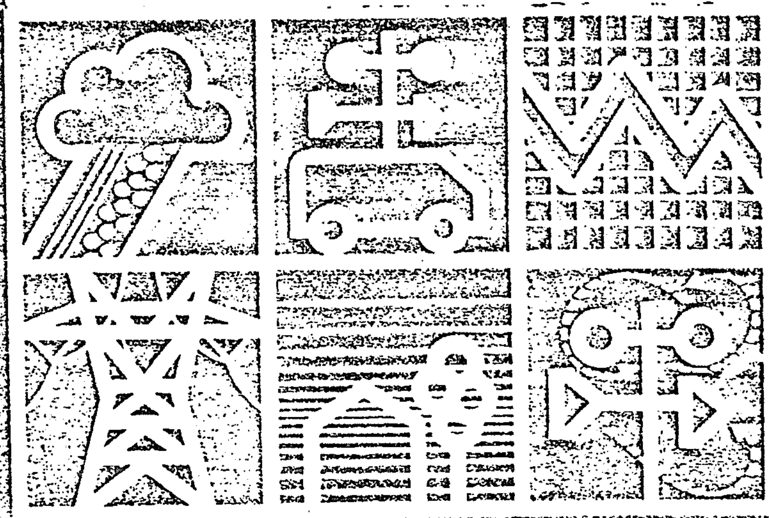
* Technical Deputy.

meteorology research, inc.
altadena, california
March 1, 1971



Report

Meteorology Research, Inc.



TECHNICAL

REPORT

A METEOROLOGICAL EVALUATION OF THE COMBINED WIND AND ICE LOADINGS FOR A PORTION OF THE GULL ISLAND TRANSMISSION LINE

MRI 74 R-1255

Submitted to

Teshmont Consultants Ltd.
225-2025 Corydon Avenue
Winnipeg, Manitoba R3P ON5
Canada

Contract No. 133-14110-1

Date September 20, 1974

By: R. J. Boomer
M. C. Richmond

METEOROLOGY RESEARCH, INC.
Box 637, 464 West Woodbury Road
Altadena, California 91001
Telephone (213) 791-1901
A Subsidiary of Cohu, Inc.

TABLE OF CONTENTS

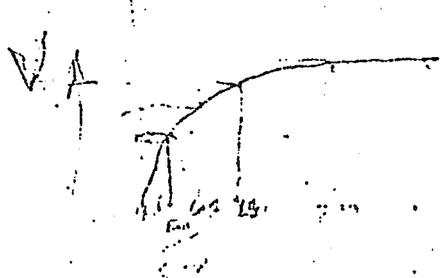
SUMMARY

A meteorological study was conducted to determine the extreme values of transverse ice and wind loading likely to be experienced along the proposed transmission line route between Holyrood and the northern Humber Valley. Analysis of data was in three phases: Completion of transverse ice and wind loadings for 10-, 25-, 50-, and 75-year return periods at six stations in Newfoundland; extrapolation of these values to the proposed route; and comparison of the results with computations based on values obtained in the November 1973 report. Also looked at were loadings in conjunction with wet snow on the conductors.

Highest transverse wind loads generally occurred with rime ice. Maximum transverse loads are expected to reach 4.9 lbs/linear ft in a 25-year return period near the isthmus. This is much less than the 9.35 lbs/linear ft estimated in the previous report by assuming independence of individual maximum wind and ice loadings. If it is assumed that wind gusts are 50 percent greater than the hourly wind values, then the maximum load becomes 11.0 lbs/linear ft.

Wet snow will occur occassionally, but the associated loadings (a maximum of 2.9 lbs/linear ft at Gander) are not great enough to be the limiting design values.

Combined wind and ice loads were computed using the winds and ice as independent variables, but using only winds which had occurred during or immediately following icing storms. These combined loads based on hourly winds were significantly lower than those derived in the November 1973 report. Combined loads based on gust-condition ice-storm wind speeds were found to be quite similar to the values in the 1973 report which were based on annual maximum hourly wind speeds.



I. INTRODUCTION

Teshmont Consultants Ltd., is in the process of designing a transmission line for the Newfoundland and Labrador Power Commission. The proposed line will extend from the Gull Island Hydro Site southwest of Goose Bay, Labrador to near Holyrood on the Avalon Peninsula of Newfoundland. This proposed route traverses some of the most severe wind and icing areas known to exist in North America. In recognition of the need for quantitative meteorological information on which to base the design, Meteorology Research, Inc., (MRI) was commissioned to conduct a meteorological study of the proposed routes. This study was completed in November 1973. Combined wind and ice loadings were expressed as wind speeds in miles per hour with glaze and rime ice in radial inches and pounds of ice per foot of conductor. These values were derived by treating the maximum ice loads and maximum winds as independent variables and using the same probabilities for each to develop combined probabilities. It was suggested in the 11 June 1974 meeting with representatives of the Natural Energy Board and of Energy, Mines, and Resources that the winds and ice are not always independent variables and that using equal probabilities for each might not always result in the maximum load.

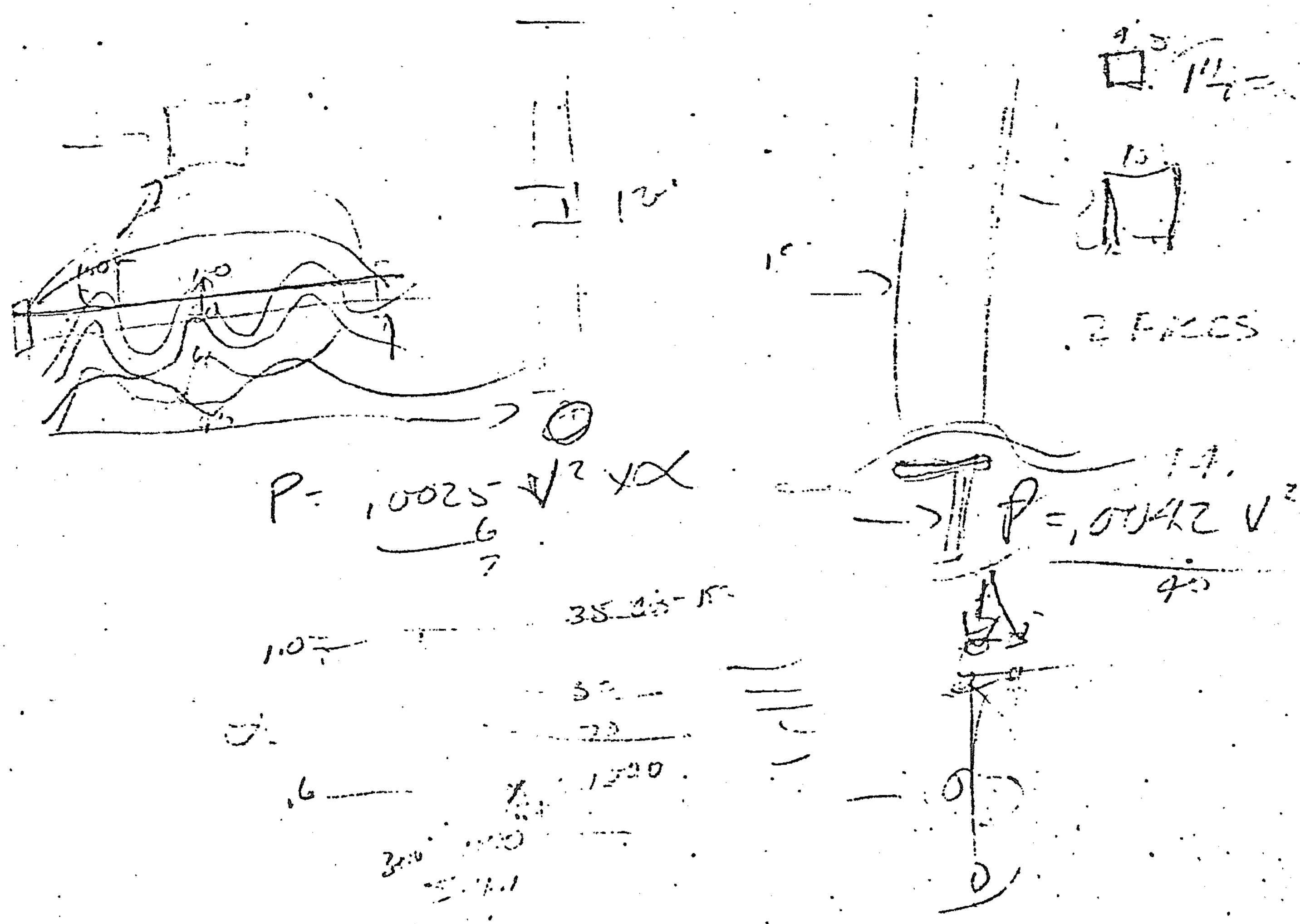
A study was conducted to review the individual storm data for several Newfoundland stations, to determine at what point during the storm the maximum transverse wind load would have occurred and what that value was, and to develop return period values for the maximum combined loadings expressed in terms of transverse wind load on the iced conductor. This method of approach has the advantage of being based directly on actual storm data and avoiding the debatable use of combined probabilities.

This report presents the results of that study. The scope of the study is presented in Section II. Data sources are described in Section III. The method of handling wind data is discussed in Section IV. Combined wind and ice loadings at individual stations are analyzed in Section V, and the results are extrapolated to the proposed route and compared with values obtained from the November 1973 report in Section VI. Section VII deals with treating individual wind and ice loads as independent variables, where only those winds occurring during ice storms were considered. Finally, conclusions are summarized in Section VIII.

II. SCOPE OF STUDY

This transmission line study consisted of analysis of actual storm data to determine potential transverse wind loads on ice covered transmission lines proposed for eastern and central Newfoundland. The maximum transverse wind load on ice covered conductors which would have occurred during or immediately following each of the glaze or rime producing storms identified in the climatological records were computed for stations near the planned route east of the Humber Valley. The maximum transverse wind loading for each year of record for each station was identified and return period probabilities developed. These values were then extrapolated to the route segments used in the November 1973 study for comparison with the values derived by the joint probability method. Combined wind and ice loadings similar to those presented in the November 1973 report, but based only on wind speeds recorded during icing storms, were also derived and extrapolated to the route segments.

This portion of the route was selected for the study because the available station data are more representative of the route than the sections north and west of the Humber Valley.



III. DATA SOURCES

The basic data available for study of the proposed transmission line route came from long-term records at a number of locations in the area. Observations of wind speed and direction, temperature, precipitation, and cloud conditions are reported by these stations to the Atmospheric Environment Service (AES). These data form the basis of the route study but are not normally available in the form required for this type analysis. In previous projects, the AES has developed for us special computer programs to condense the long periods of data into more usable forms for this analysis. These were used once again in this project.

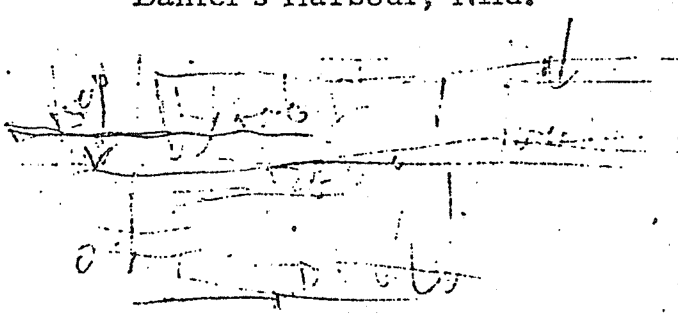
Listings of hourly observations during periods of potential accumulations of glaze ice, rime ice, or wet snow were generated by the AES. The criteria used to generate these listings include:

- Rime icing: Cloud ceiling 1000 ft or less and ambient temperature 25 to 38°F. (Only ceilings at or below line level were considered in the actual analysis.)
- Glaze icing: Precipitation at or below 35°F. (Only periods of freezing rain were considered in the actual analysis.)
- Wet snow: Temperature greater than 28°F with moderate or heavy snow lasting at least six hours.

In all cases, these listings were continued for six hours following the last hour that met these criteria.

The six stations for which data were analyzed and their length of record included:

St. John's-Torbay, Nfld.	1953-1971
Argentia, Nfld.	1953-1969
Gander, Nfld.	1953-1971
Buchans, Nfld.	1953-1964
Deer Lake, Nfld.	1966-1971
Daniel's Harbour, Nfld.	1966-1971



IV. WIND DATA

When used for maximum wind speeds, "hourly-wind" values are usually conservative. The hourly-wind recorded in the hourly weather observation consists of a one-minute average wind speed observed during the 10 minutes prior to the hour. Thus, if the actual maximum one-minute average does not occur in that ten minutes, it is not recorded. Wind gust records are normally available only for locations with full scale weather facilities.

In order to account for these gust values, a gust factor was employed, equal to G/V, where G is the maximum gust speed and V is the maximum sustained wind speed. Many studies have been made to determine this gust factor, which usually decreases with increasing wind speed. Sissenwine et al. (1973) calculated gust factors that ranged from about 1.3 for a one-minute steady wind speed of 20 knots down to 1.2 at 70 knots. Boyd (1970) developed a formula used by the AES to calculate speeds of wind gusts where

$$G = 5.8 + 1.29\ V$$

This formula results in gust factors ranging from 1.58 at 20 knots to 1.37 at 70 knots. For this study a constant gust factor of 1.5 was used, which would correspond to a steady wind speed according to Boyd's formula of 24 knots. This was found to be typical of those wind speeds associated with the highest transverse wind loads on the ice-coated transmission lines.

40 mph = 34.5 knots G = 5.8 + 1.29 × 34.5 = 5.8 + 44.5 = 50.3

G/SU Ratio = 1.46.

47 mph = 40.5 knots G = 5.8 + 1.29 × 40.5 = 5.8 + 52.2

G/SU Ratio = 1.43

24 knots = G = 5.8 + 1.29 × 24 = 5.8 + 31.0 = 36.8 knots

G/SU Ratio = 1.53

V. COMBINED WINDS AND ICING

Of extreme importance to the design engineer is the maximum effect on towers and conductors resulting from the combined loadings of the weight of the ice plus the pressure of the wind on the increased surface area. The determination of this combined effect is complicated in any specific case by several factors. The accretion rate of both glaze and rime ice is a function of wind speed; the faster the wind, the more rapidly ice will build up. To determine the maximum combination, it is necessary to know when during the storm the strongest wind occurred and how much ice had accumulated at that time. If the strongest wind occurred early in the storm, the greatest combined effect may have occurred later with a lesser wind speed and a greater surface area and weight of ice. Superimposed on this is the effect of wind direction both on accretion rate and transverse and longitudinal wind loadings. Going beyond this, we have the problem of how long the ice can be expected to stay on the conductors. The longer the ice stays on, the greater the vulnerability to high winds not associated with the storm which caused the ice.

In the original study a review of both the glaze and rime producing storm periods at the reporting stations revealed no pattern to the time within the storm period that the maximum wind occurred. The peak wind time appeared to have occurred randomly throughout the icing period and up to at least six hours subsequent to the termination of icing conditions. As was discussed in that report, how long the ice will stay on the conductors will vary with each storm. In some cases, the temperature rises immediately and the melting and cracking process starts. At the other extreme, a prolonged cold period may result in the ice remaining for several days or in some locations perhaps weeks.

Developing return period probabilities for maximum combined wind and ice loadings is a necessary but controversial area of effort. Several methods of arriving at these combined loading probabilities have been proposed and used by various people with no method being completely accepted as valid by all concerned. In this report, we have computed the maximum transverse wind load on the ice covered conductors which would have occurred during or immediately following each of the glaze and rime producing storms identified. The maximum transverse wind loading for each year was identified for the entire period of record for each station and return period probabilities developed as had been done for maximum wind speeds, glaze icing, and rime icing in the November 1973 study. The maximum combined wind and wet snow loadings that might have occurred over the entire period of record for each station were also computed. Loadings were computed for winds being perpendicular to the conductors. Computations were based on the relationship of $W_H = (0.0025\ V^2)D/12$ where W_H is the transverse wind load in pounds per linear foot, V is wind speed in miles per hour, and D is the total diameter of conductor and ice in inches.

This method has the advantage of being based on actual combined loads rather than joint probabilities of yearly maximum winds and icing loads occurring simultaneously. All computations were based on the winds being perpendicular to a 2.0-inch diameter conductor.

A. Combined Wind and Glaze Ice Loadings

Figures 1 through 6 show the return period plots of transverse wind loads of glaze-covered transmission lines for the six stations based on hourly wind speeds. Figures 7 through 12 are the corresponding plots computed using wind gusts calculated with the 1.5 gust factor. The extracted values for 10-, 25-, 50-, and 75-year return periods are listed in Table I.

On the return period plots for Buchans (Figs. 4 and 10), the 2.81 lbs/lin ft value based on hourly winds and the 6.32 lbs/lin ft value based on gust speeds (denoted by x's on the plots) are from a March 24, 1962 storm. The solid lines are drawn for all twelve plotted values. If we eliminate those extreme values and plot the next highest values for that year (1.41 and 3.17 lbs/lin ft, on February 12) the dashed lines result and the March values become 1000-year storms. (Use of these graphs beyond 100 years is debatable.) In Table I the values in parentheses are from the dashed curves.

B. Combined Wind and Rime Ice Loadings

Maximum transverse wind loads for transmission lines coated with rime were computed at specific elevations above the stations that are representative of the proposed route. Figures 13 through 17 show the return period plots using hourly winds for 300 ft above St. John's-Torbay, 300 ft above Gander, 300 and 800 ft above Buchans, and 1000 ft above Daniel's Harbour. Figures 18 through 22 show return period plots using the 1.5 gust factor. The extracted 10-, 25-, 50-, and 75-year return period values are listed in Table II.

C. Combined Wind and Wet Snow Loadings

Table III lists the maximum wind and wet snow loading at each of the six stations. Wet snow is not expected to be a major problem in Newfoundland. Although several of the values in Table III appear high, there were only 20 occurrences of wet snow storms lasting at least six hours among all six stations, eleven of which occurred at Argentia.

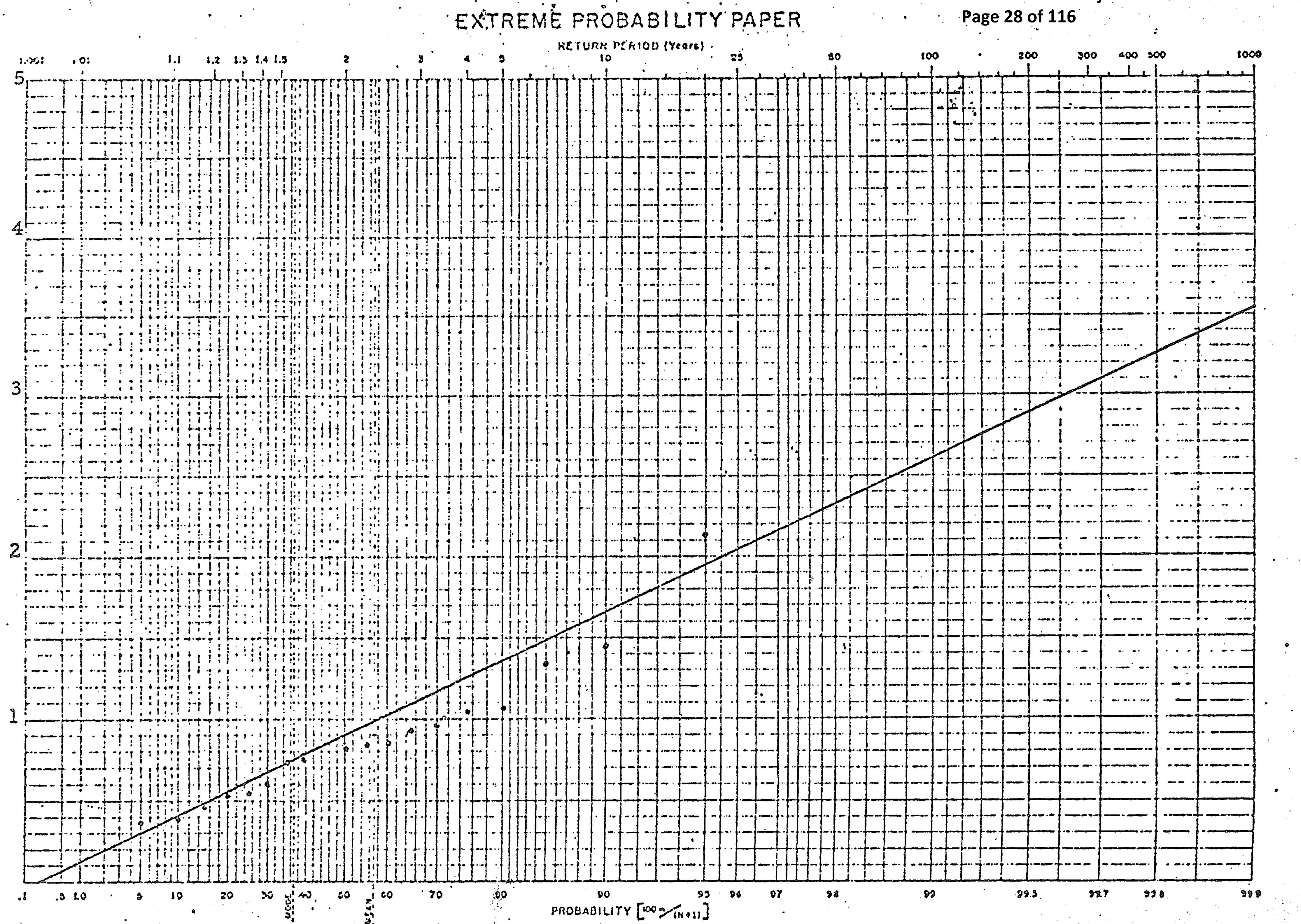


Fig. 1. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT TORBAY, NFLD BASED ON HOURLY WIND DATA

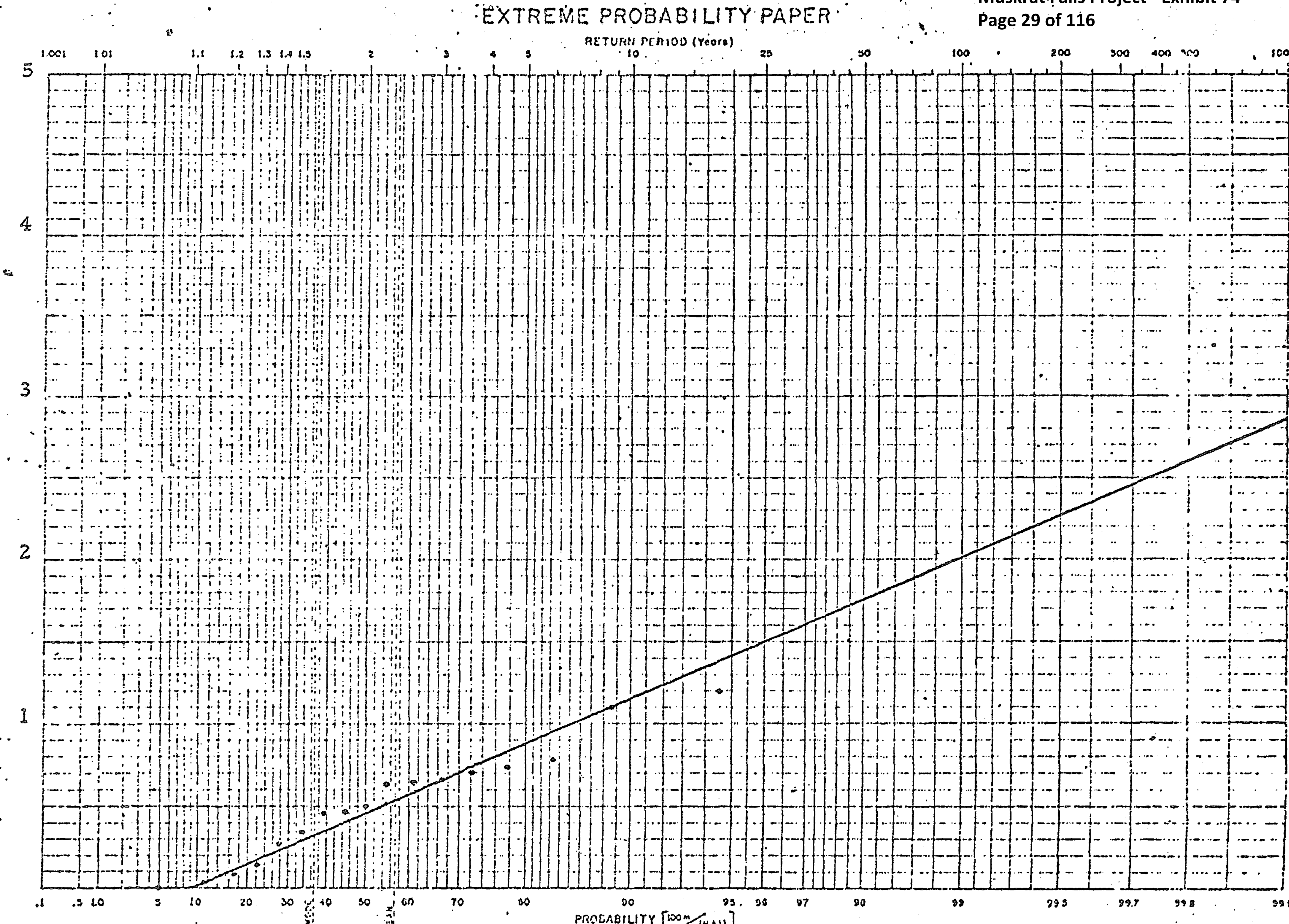


Fig. 2. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L LINE AT ARGENTIA, NFLD BASED ON HOURLY WIND DATA.

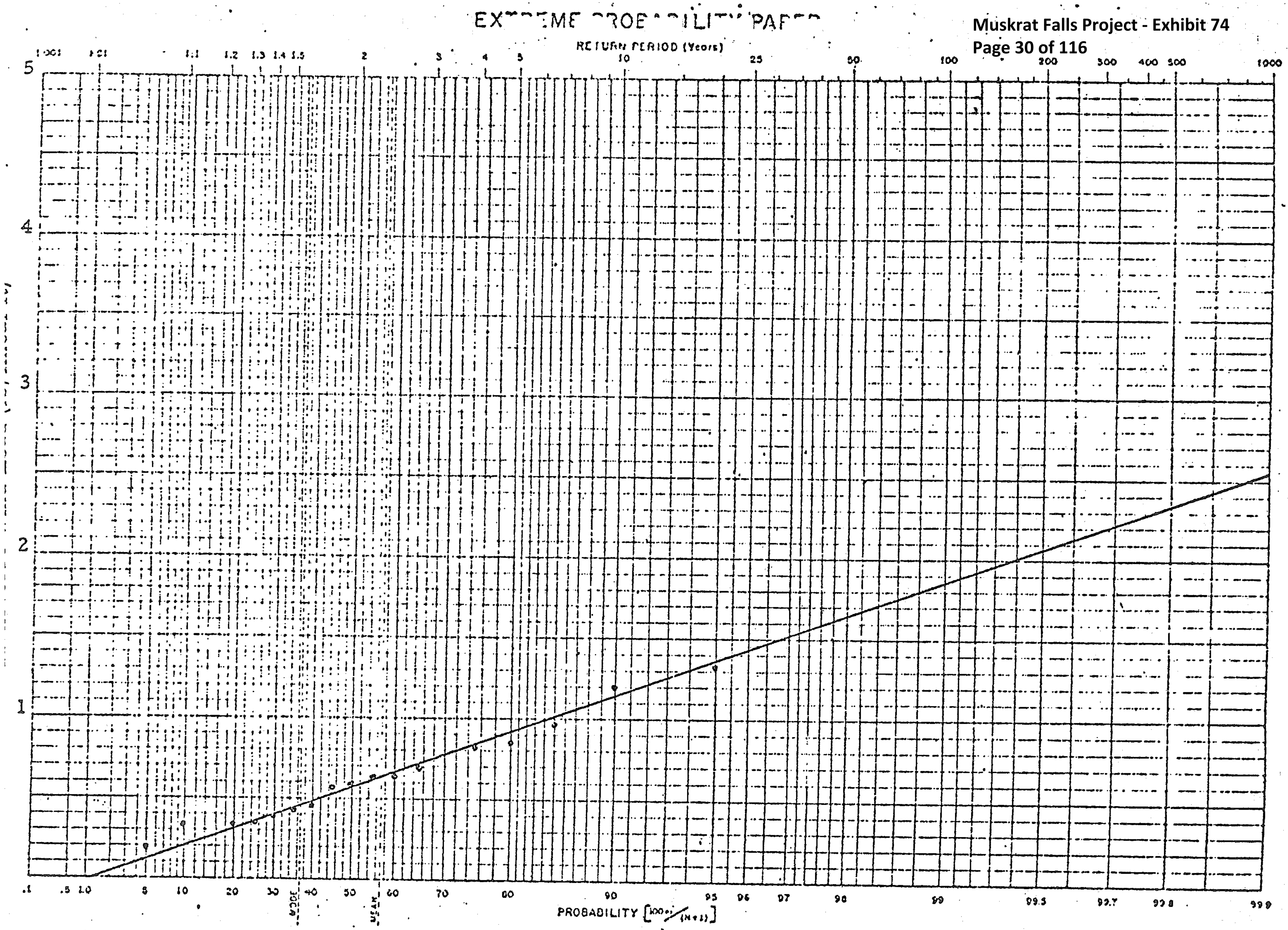


Fig. 3. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT GANDER, NFLD BASED ON HOURLY WIND DATA

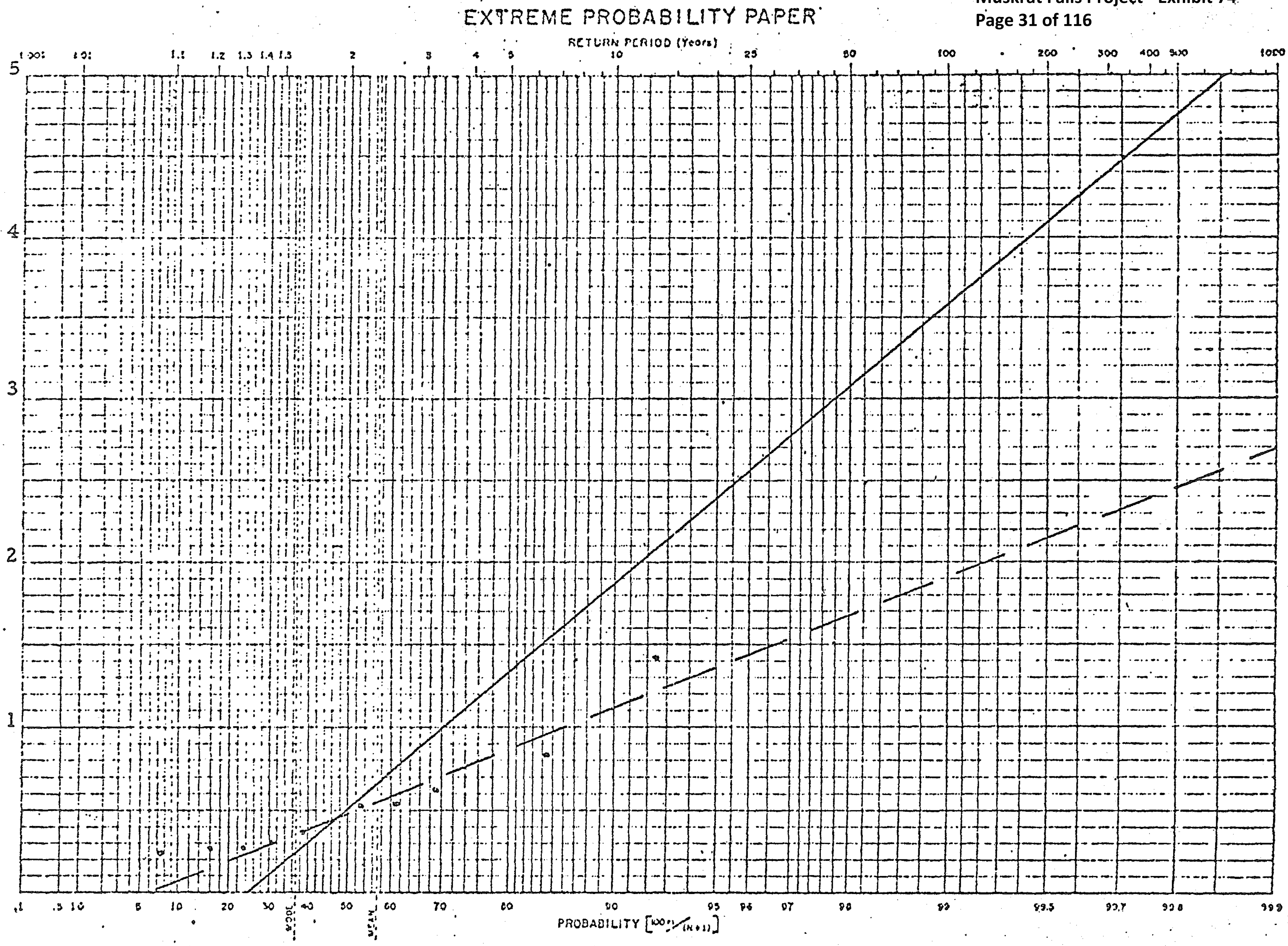


Fig. 4. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT BUCHANS, NFLD BASED ON HOURLY WIND DATA

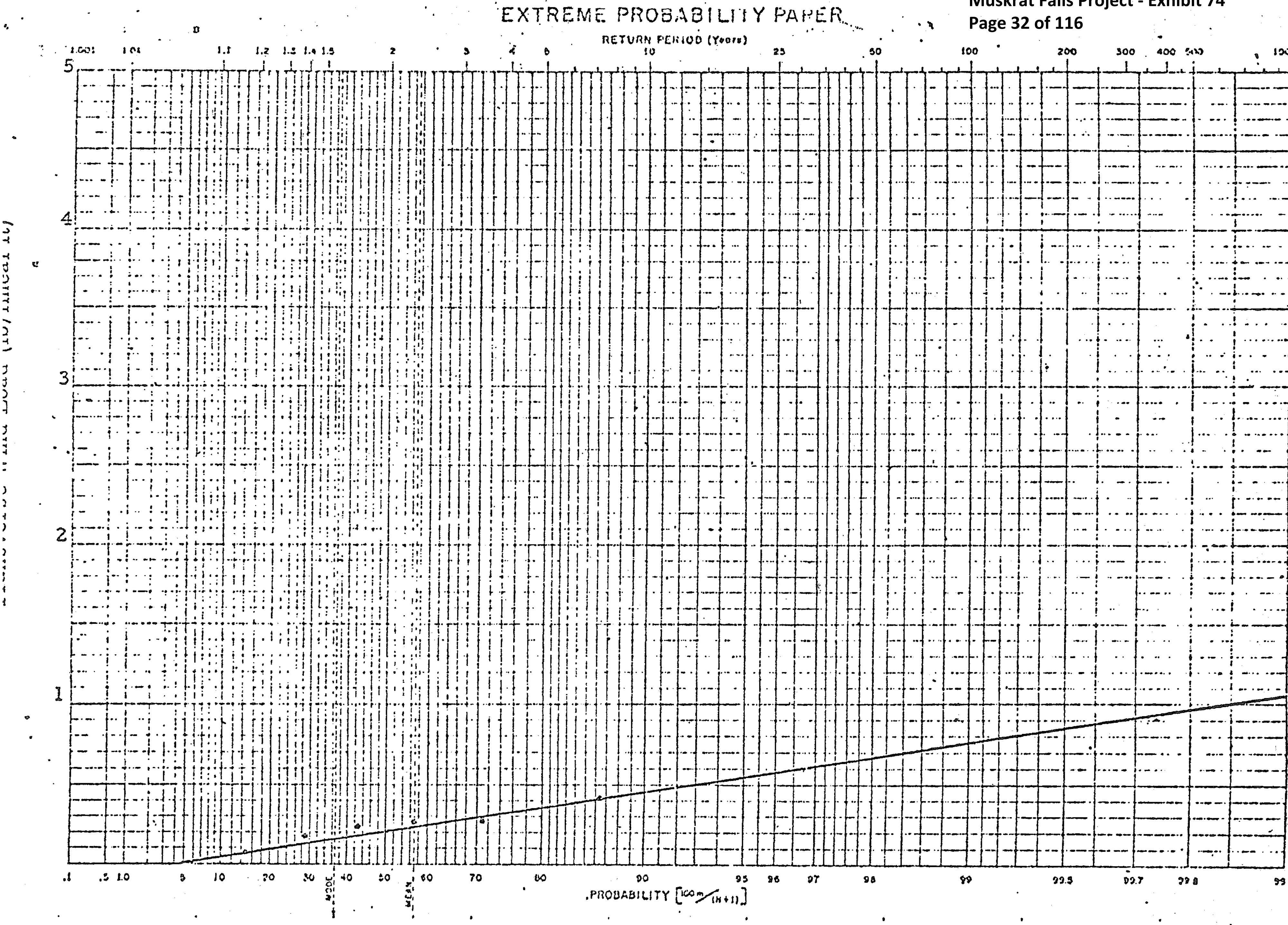


Fig. 5. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L FOR DEER LAKE, NFLD BASED ON HOURLY WIND DATA

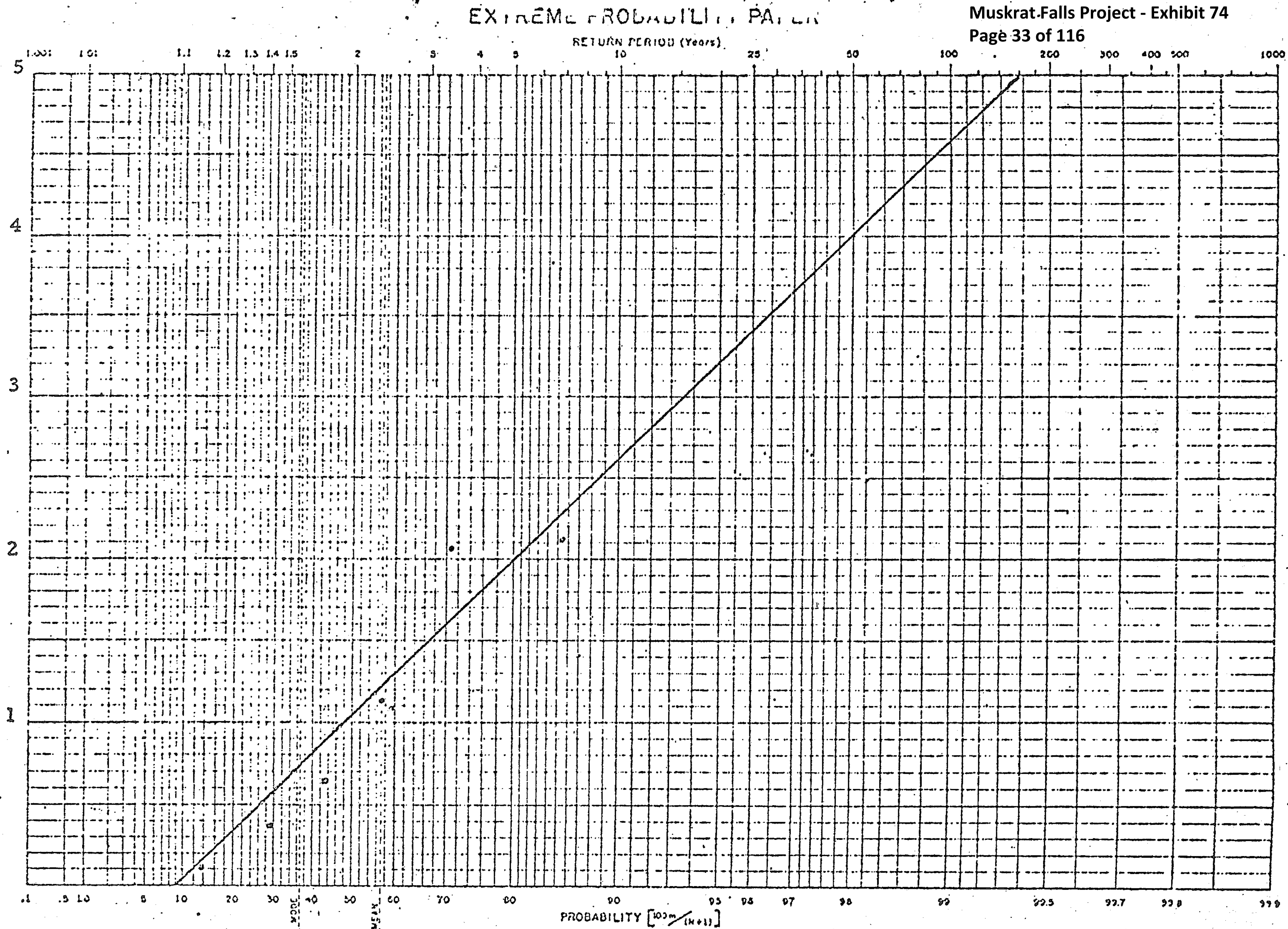


Fig. 6. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT DANIEL'S HARBOUR, NFLD
BASED ON HOURLY WIND DATA

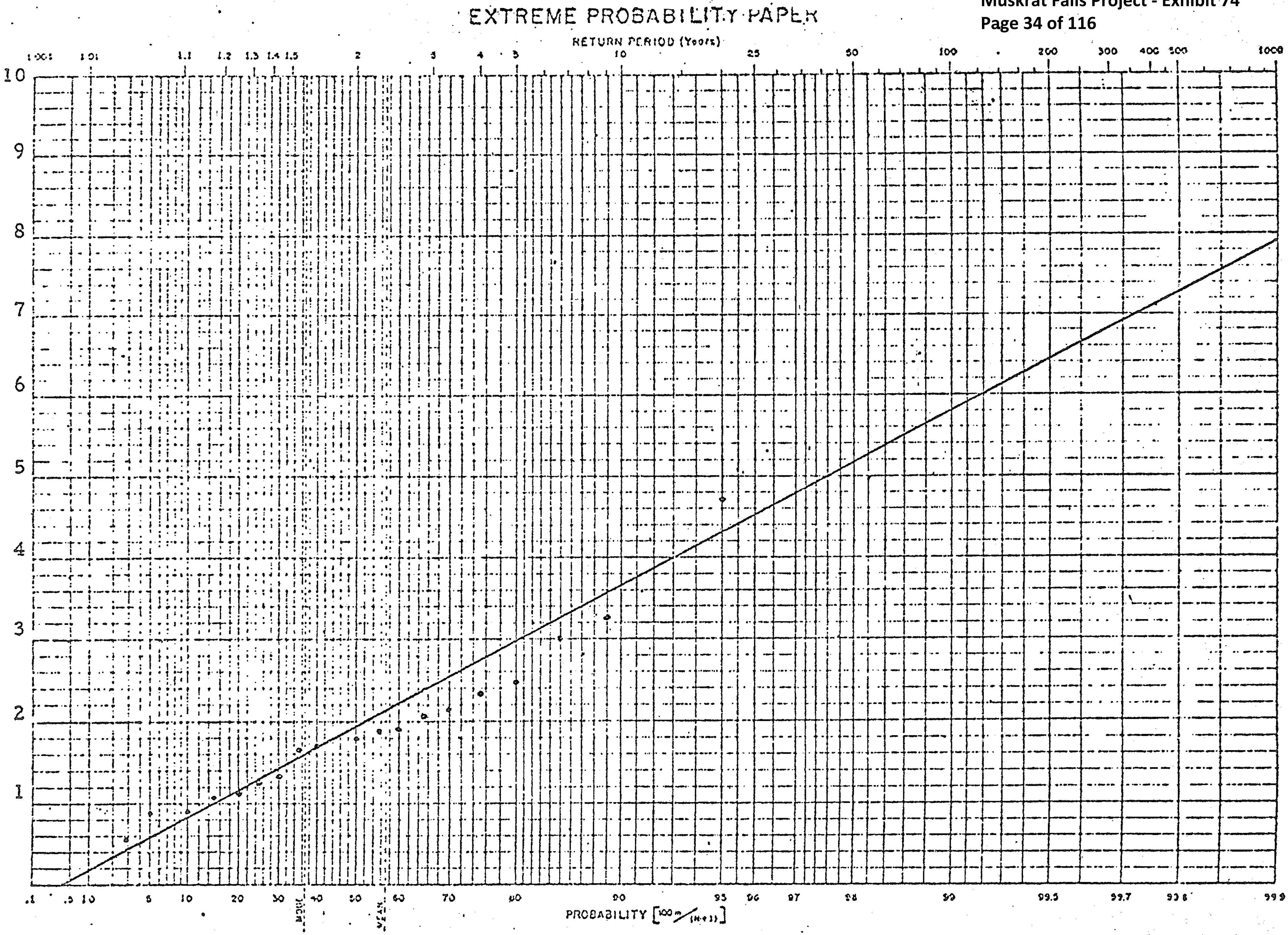


Fig. 7. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT TORBAY, NFLD
BASED ON WIND GUSTS

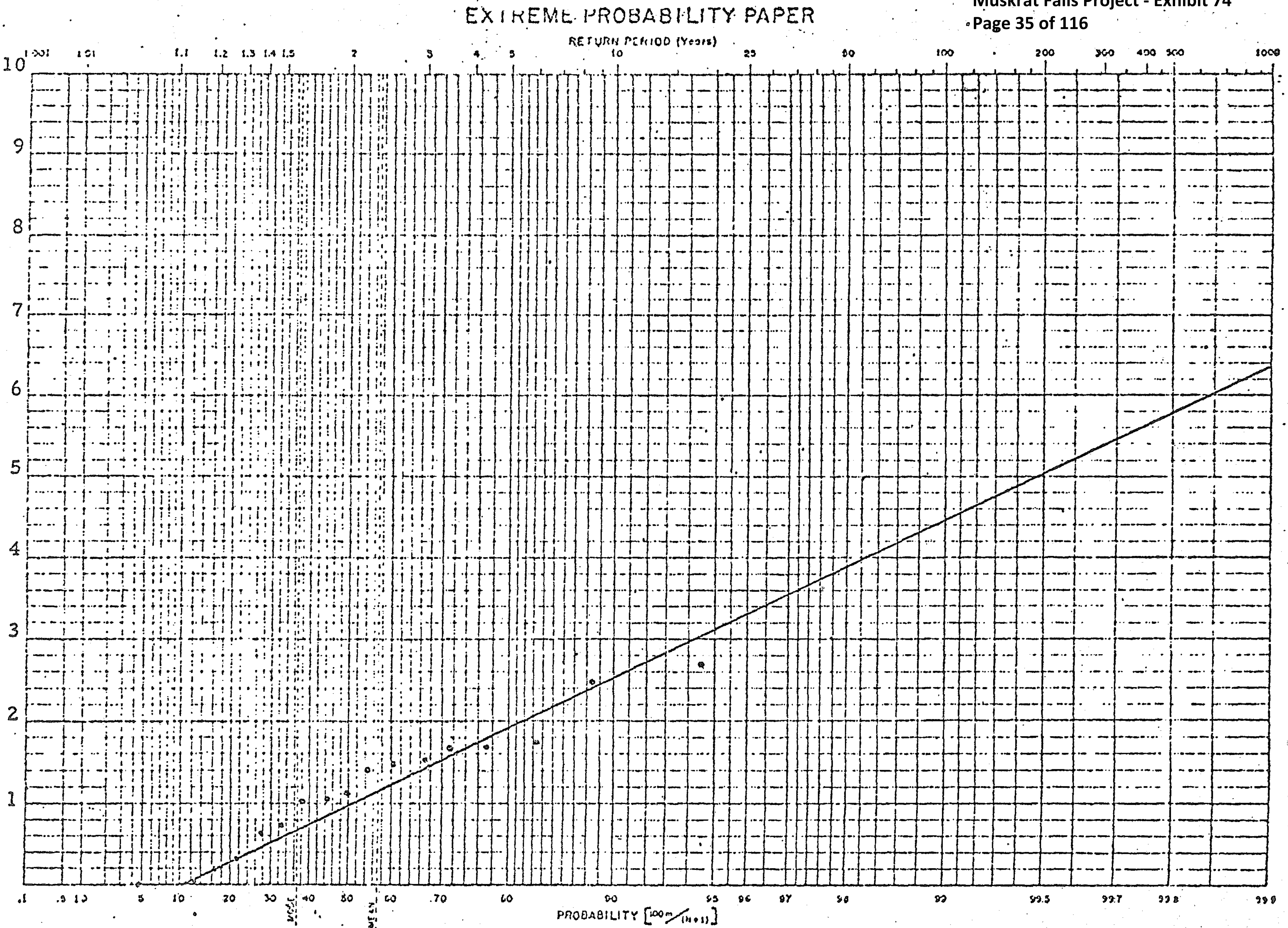


Fig. 8. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT ARGENTIA, NFLD BASED ON WIND GUSTS

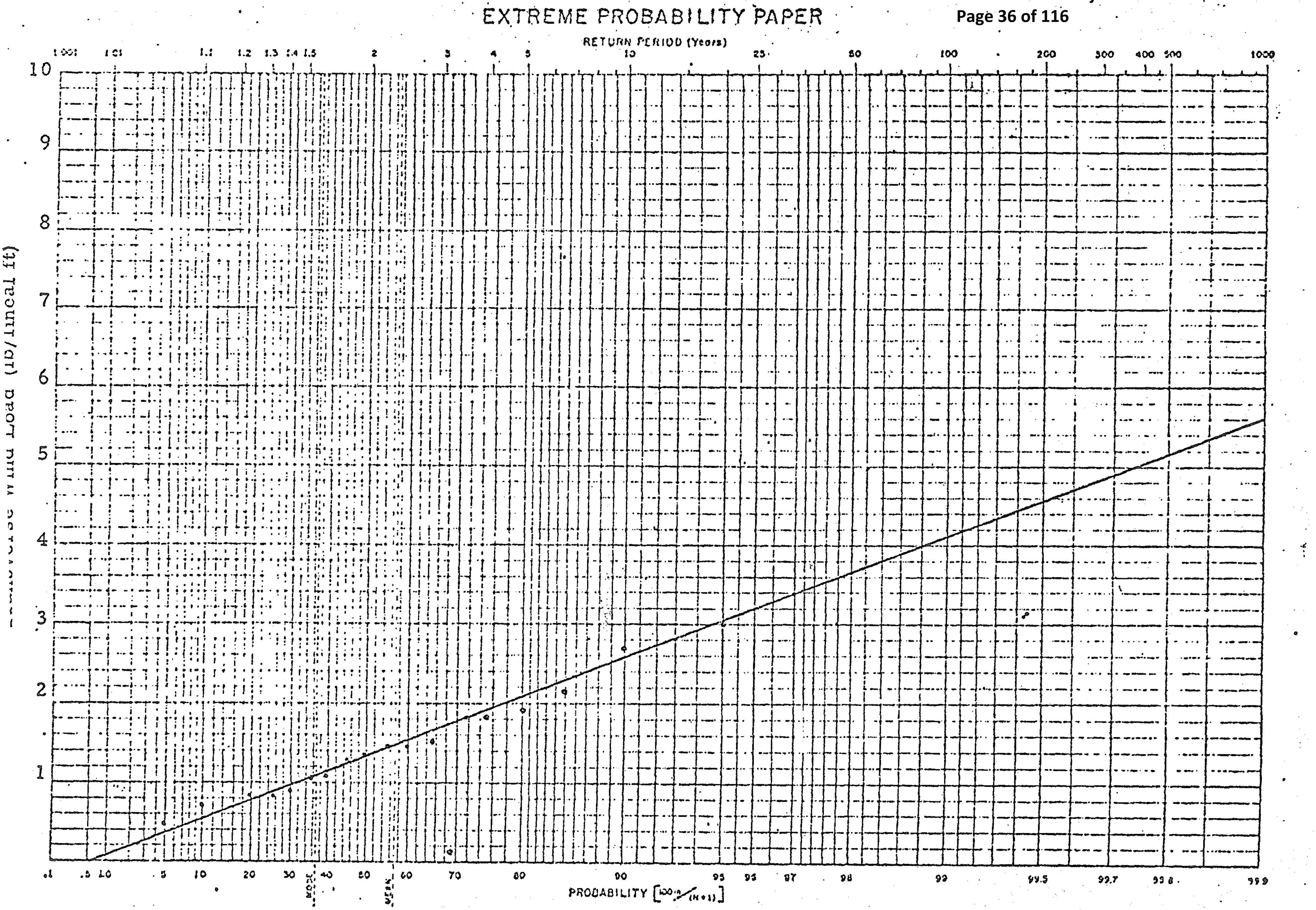


Fig. 9. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT GANDER, NFLD
BASED ON WIND GUSTS

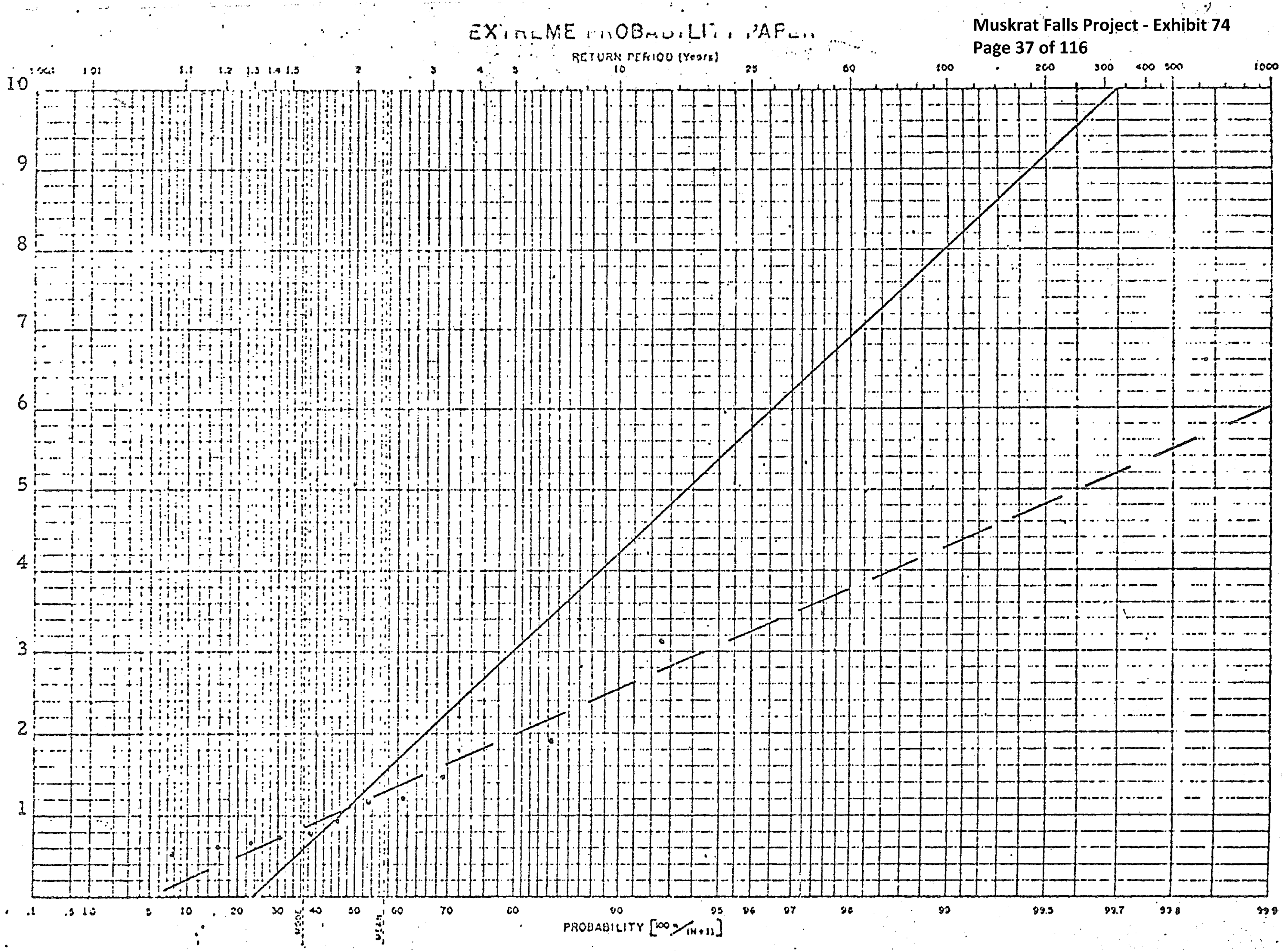


Fig. 10. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT BUCHANS, NFLD BASED ON WIND GUSTS

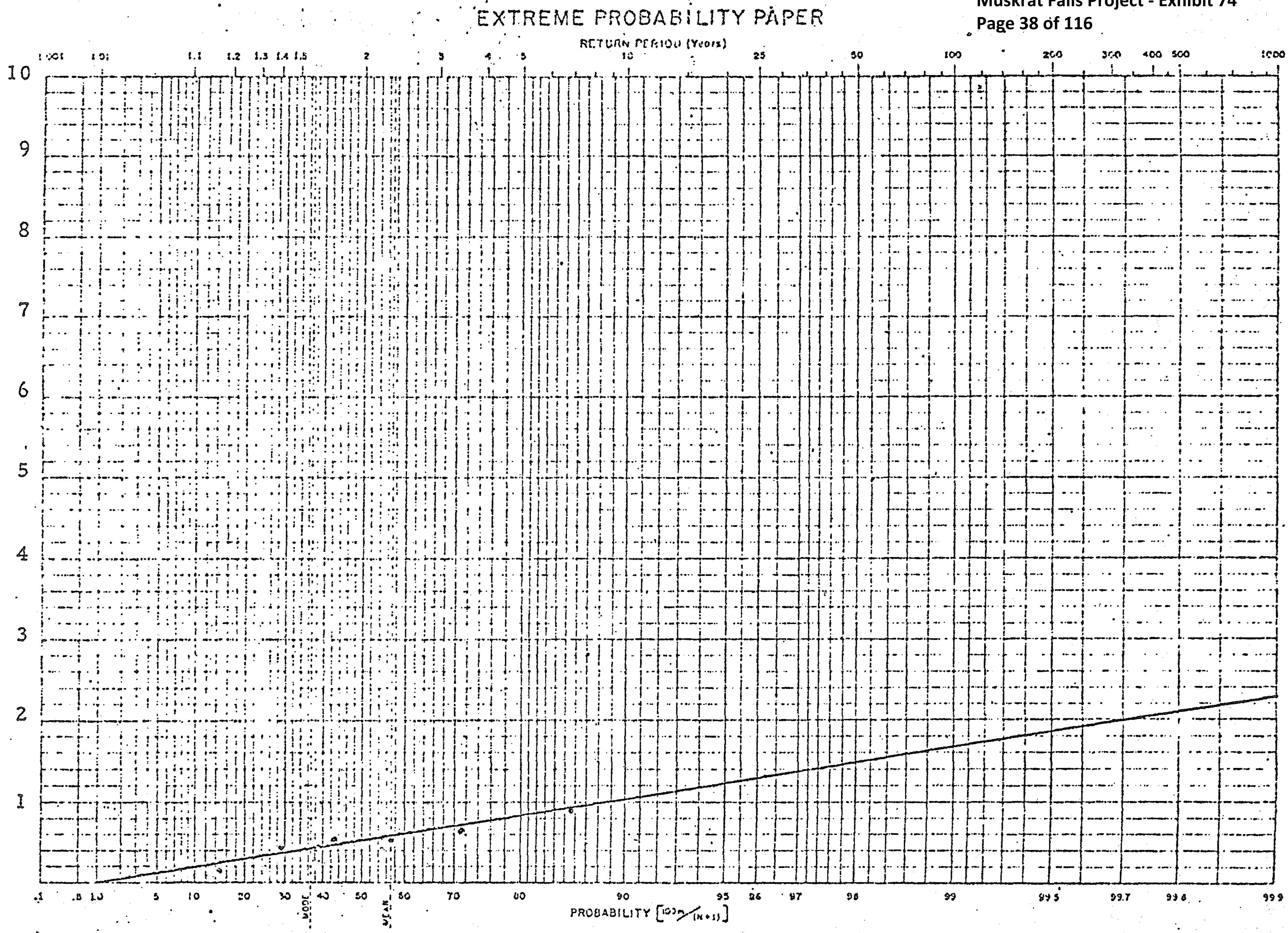


Fig. 11. TRANSVERSE WIND LOAD FOR GLAZE-COVERED T/L AT DEER LAKE, NFLD BASED ON WIND GUSTS

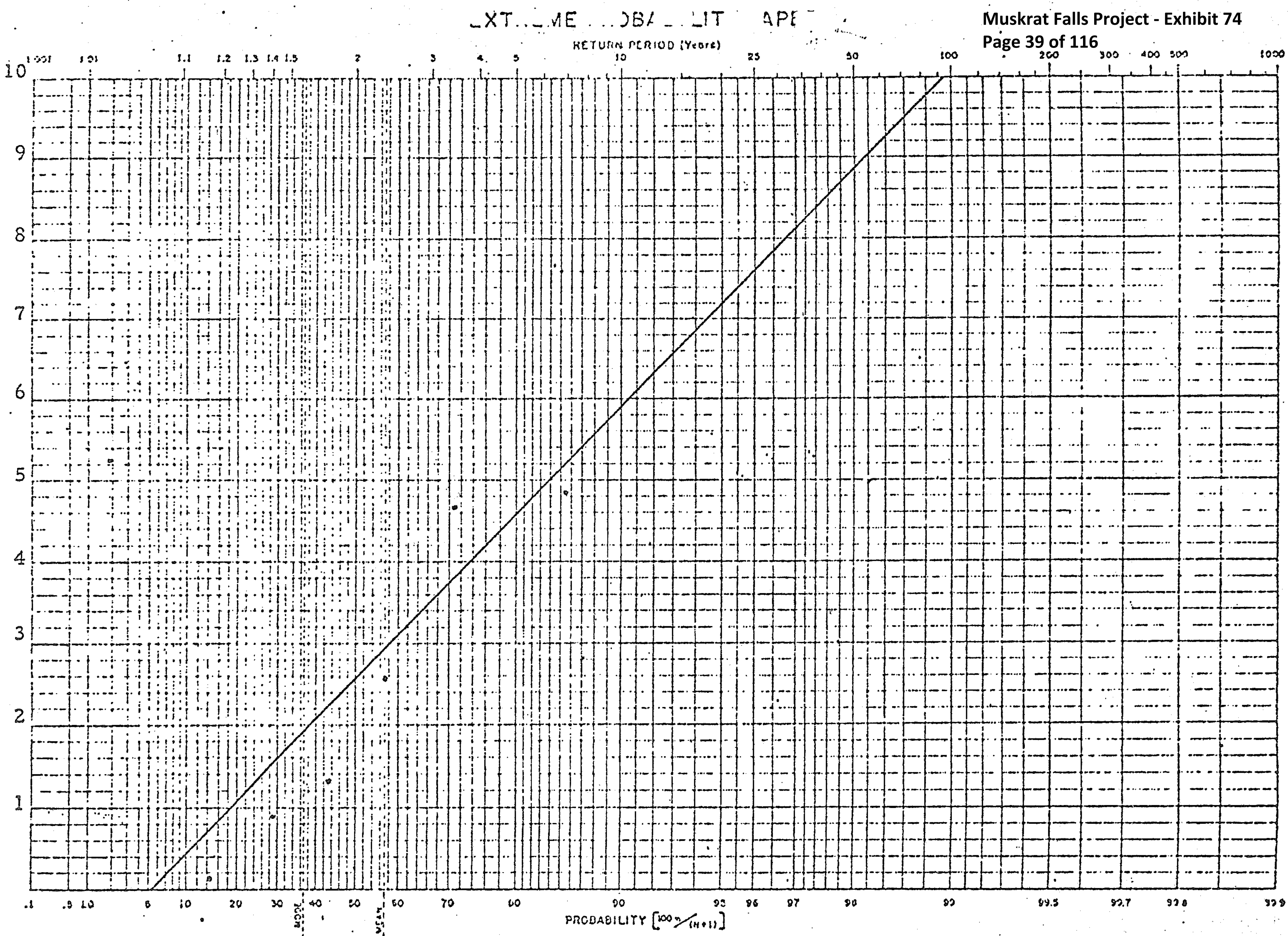


Fig. 12. TRANSVERSE WIND LOADS FOR GLAZE-COVERED T/L AT DANIEL'S HARBOUR, NFLD BASED ON WIND GUSTS

Table 1

RETURN PERIOD VALUES OF TRANSVERSE
WIND LOADS FOR GLAZE-COVERED T/L

Location	Return Period Amounts (lbs/linear ft)							
	10-year		25-year		50-year		75-year	
	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts
St. John's-Torbay	1.7	3.6	2.1	4.5	2.3	5.2	2.5	5.7
Argentia	1.2	2.5	1.5	3.3	1.8	4.0	1.9	4.5
Gander	1.2	2.6	1.4	3.2	1.7	3.7	1.8	4.2
Buchans	1.9	4.2	2.6	5.8	3.1	7.0	3.4	7.7
	(1.1)	(2.5)	(1.4)	(3.2)	(1.7)	(3.8)	(1.8)	(4.1)
Deer Lake	0.5	1.0	0.6	1.3	0.7	1.5	0.7	1.6
Daniel's Harbour	2.6	5.9	3.4	7.6	4.0	8.9	4.4	9.6

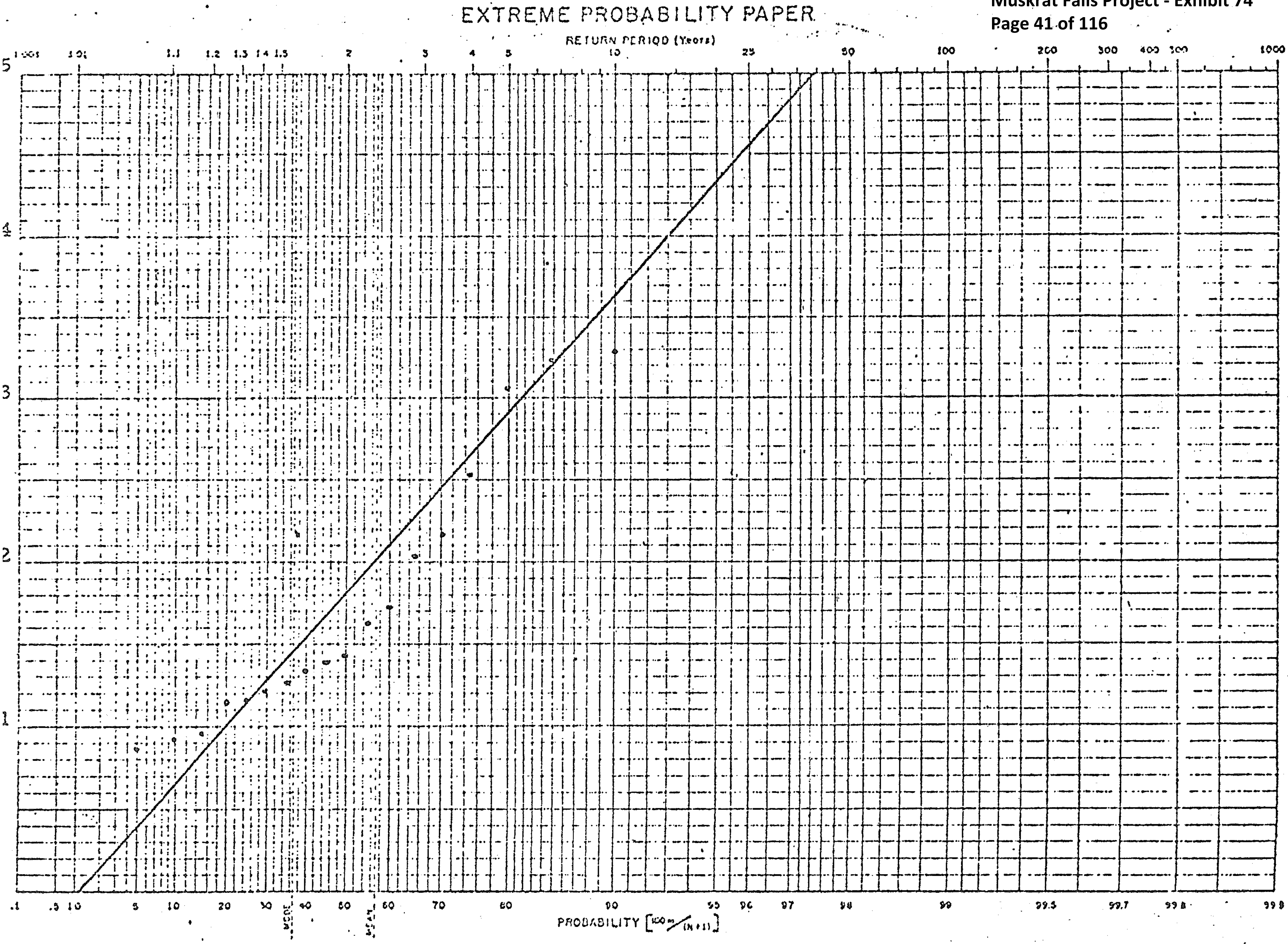


Fig. 13. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 300 FT ABOVE TORBAY, NFLD BASED ON HOURLY WIND DATA

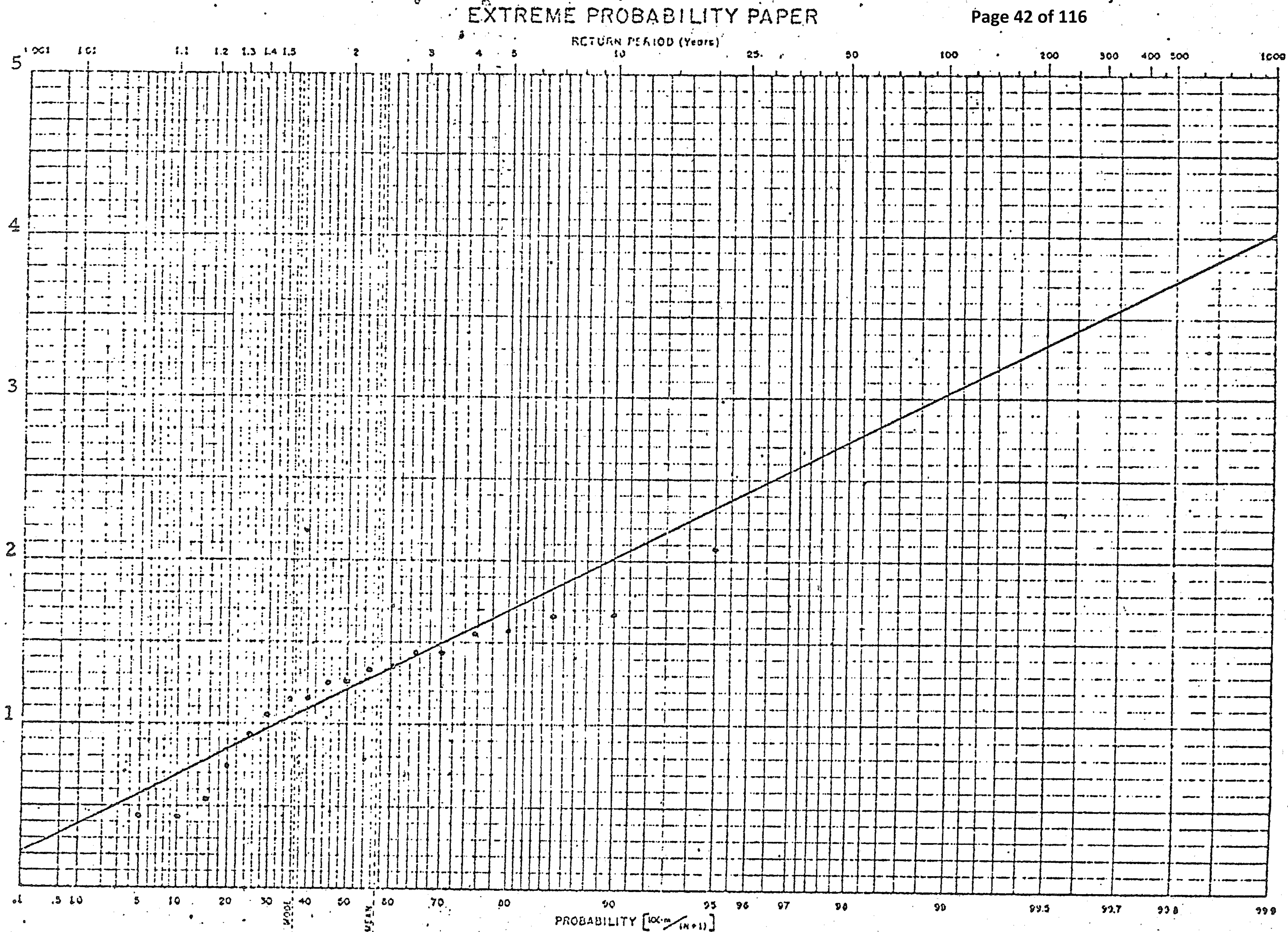


Fig. 14. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 300 FT ABOVE GANDER, NFLD BASED ON HOURLY WIND DATA

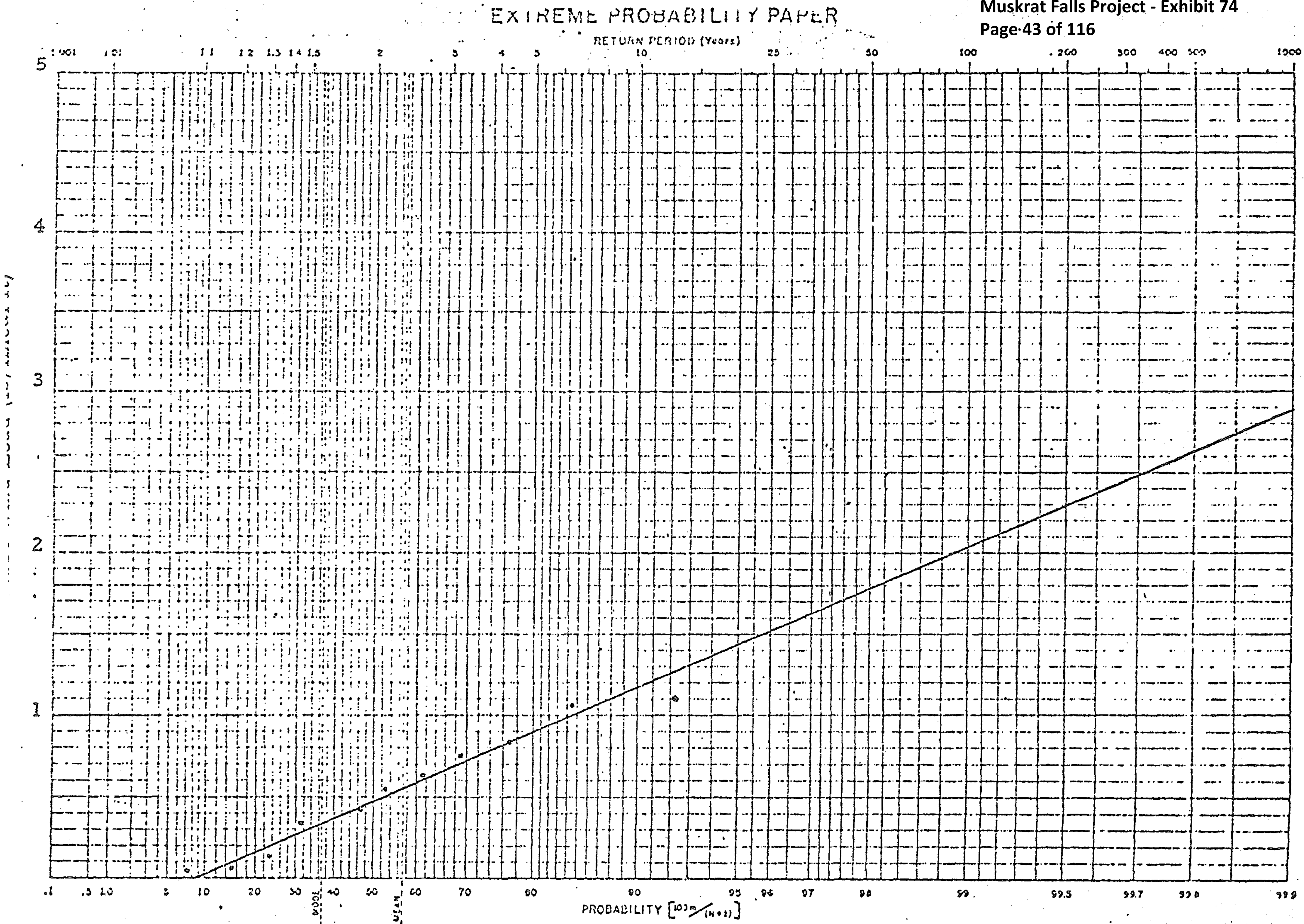


Fig. 15. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 300 FT ABOVE BUCHANS, NFLD BASED ON HOURLY WIND DATA

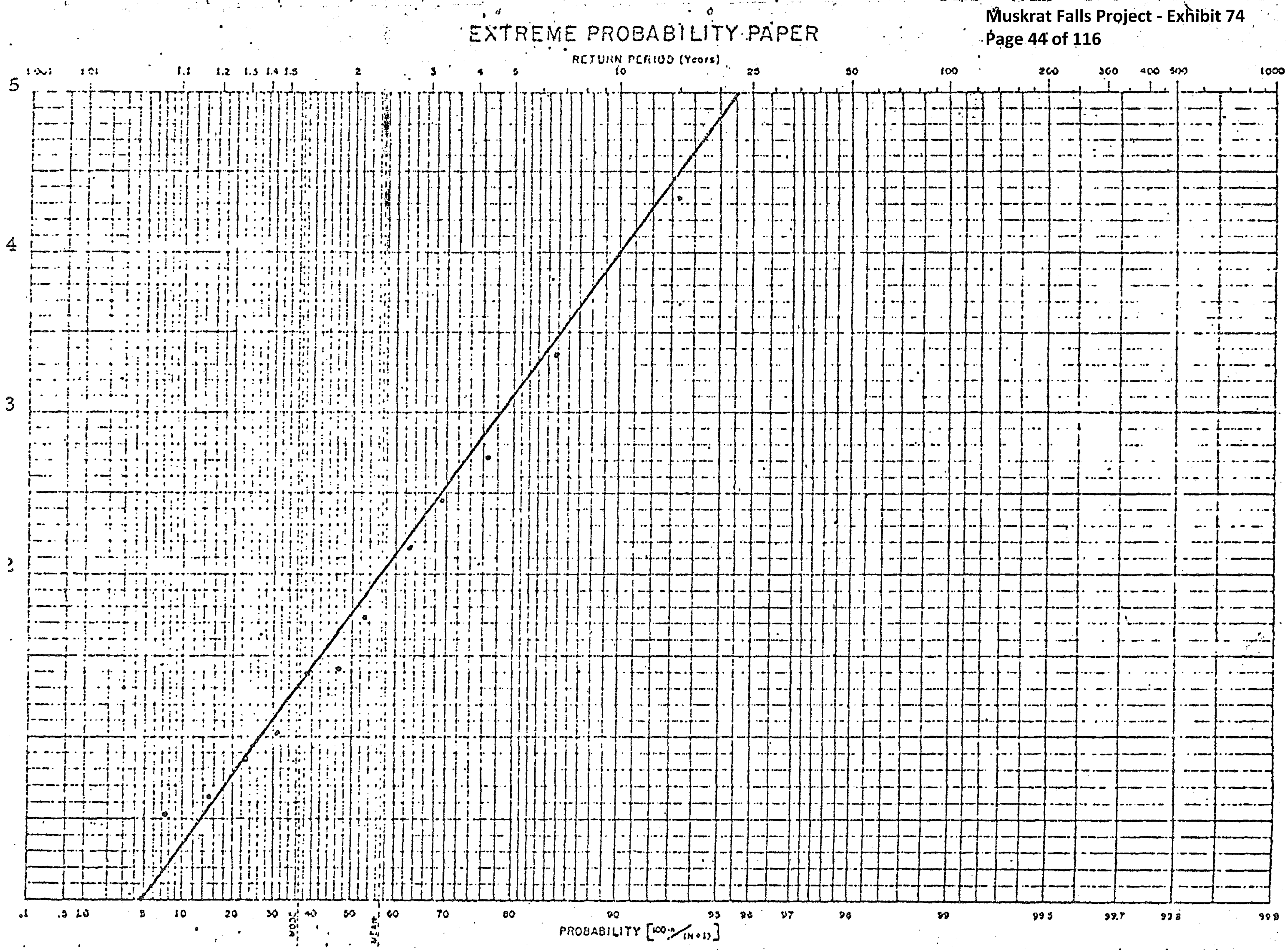


Fig. 16. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 800 FT ABOVE BUCHANS, NFLD BASED ON HOURLY WIND DATA

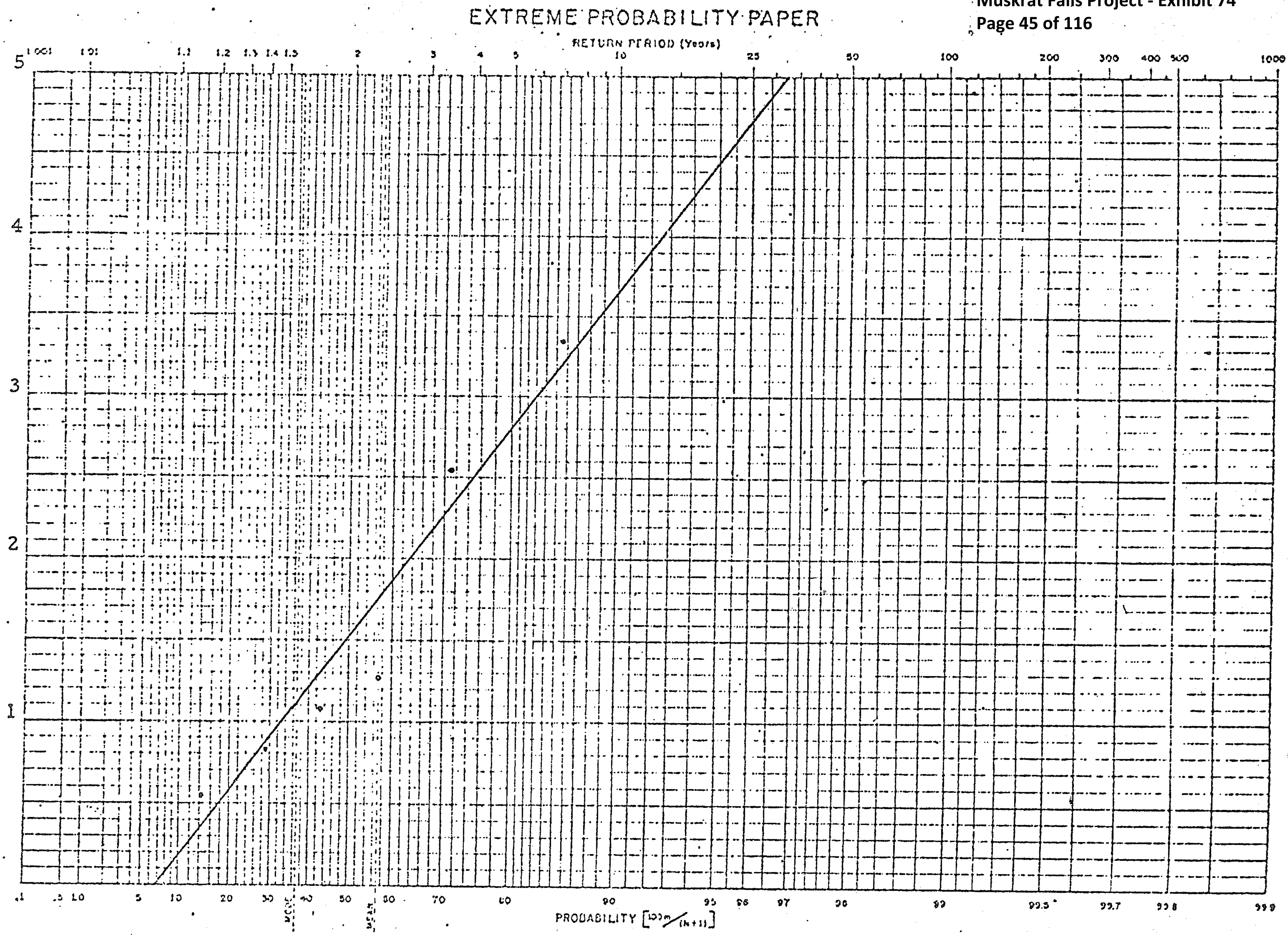


Fig. 17. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 1000 FT ABOVE DANIEL'S HARBOUR, NFLD -- BASED ON HOURLY WIND DATA

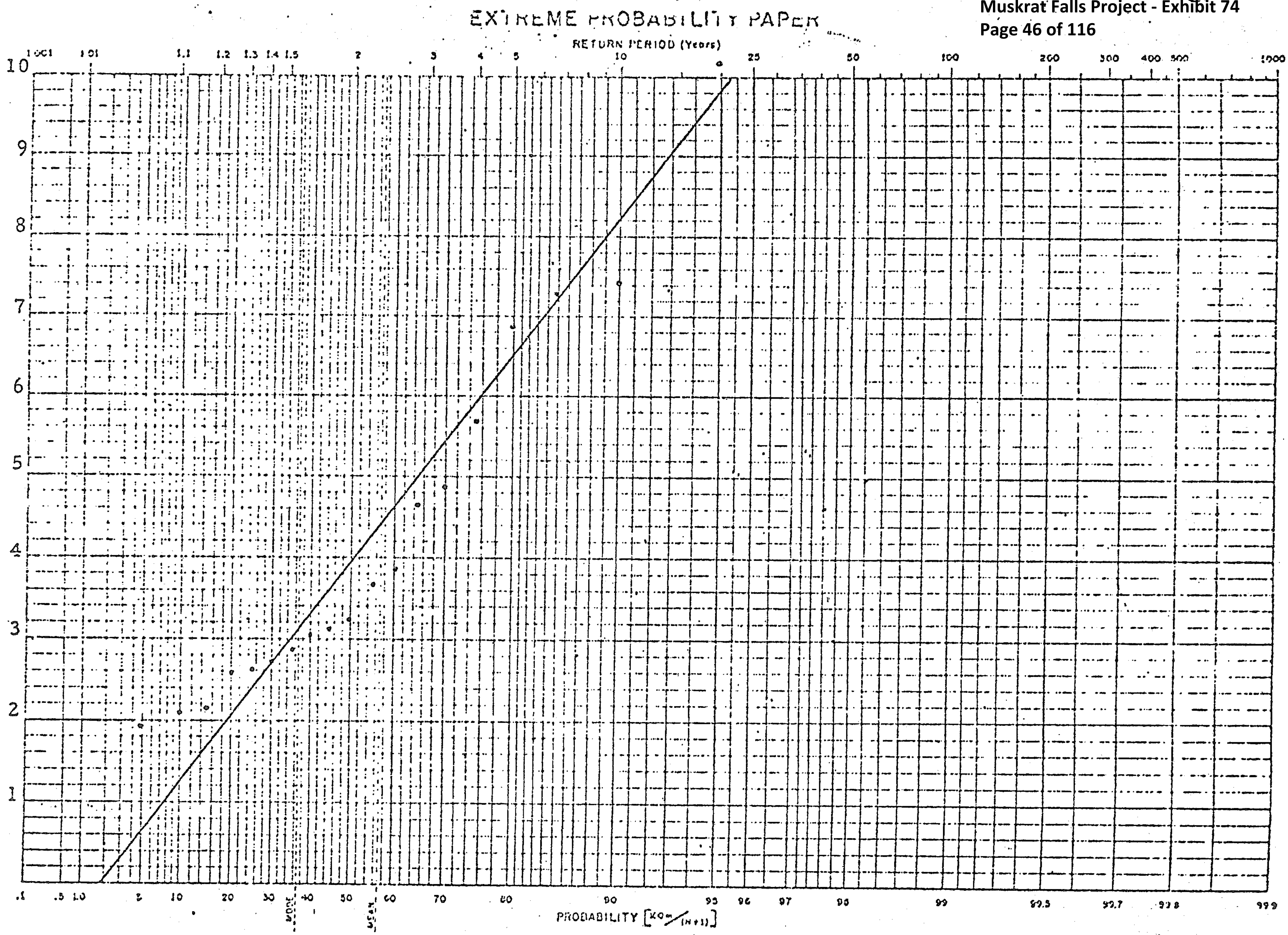


Fig. 18. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 300 FT ABOVE TORBAY, NFLD BASED ON WIND GUSTS

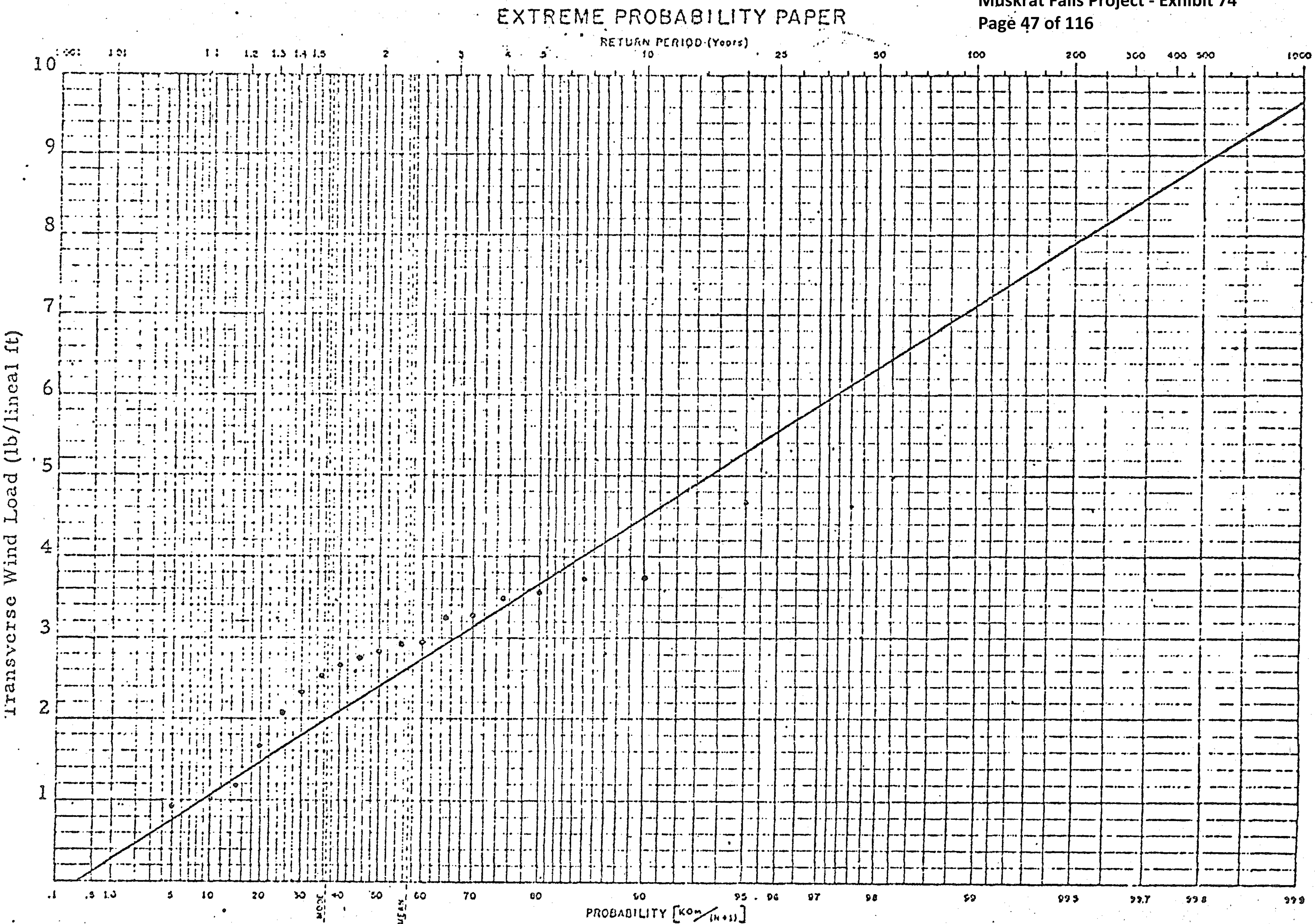


Fig. 19. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 300 FT ABOVE GANDER, NFLD BASED ON WIND GUSTS

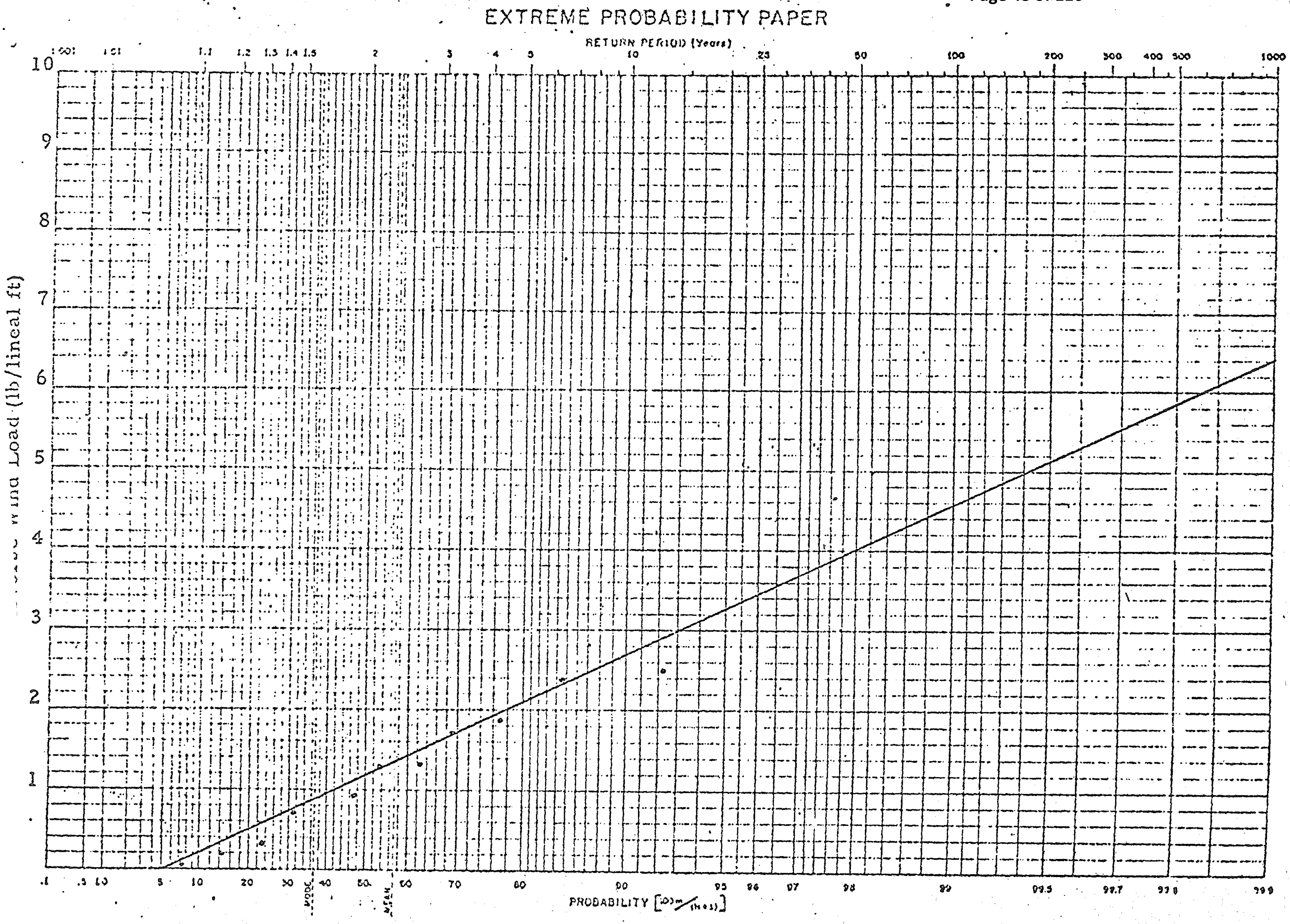


Fig. 20. TRANSVERSE WIND LOADS FOR RIME COVERED T/L
BASED ON WIND

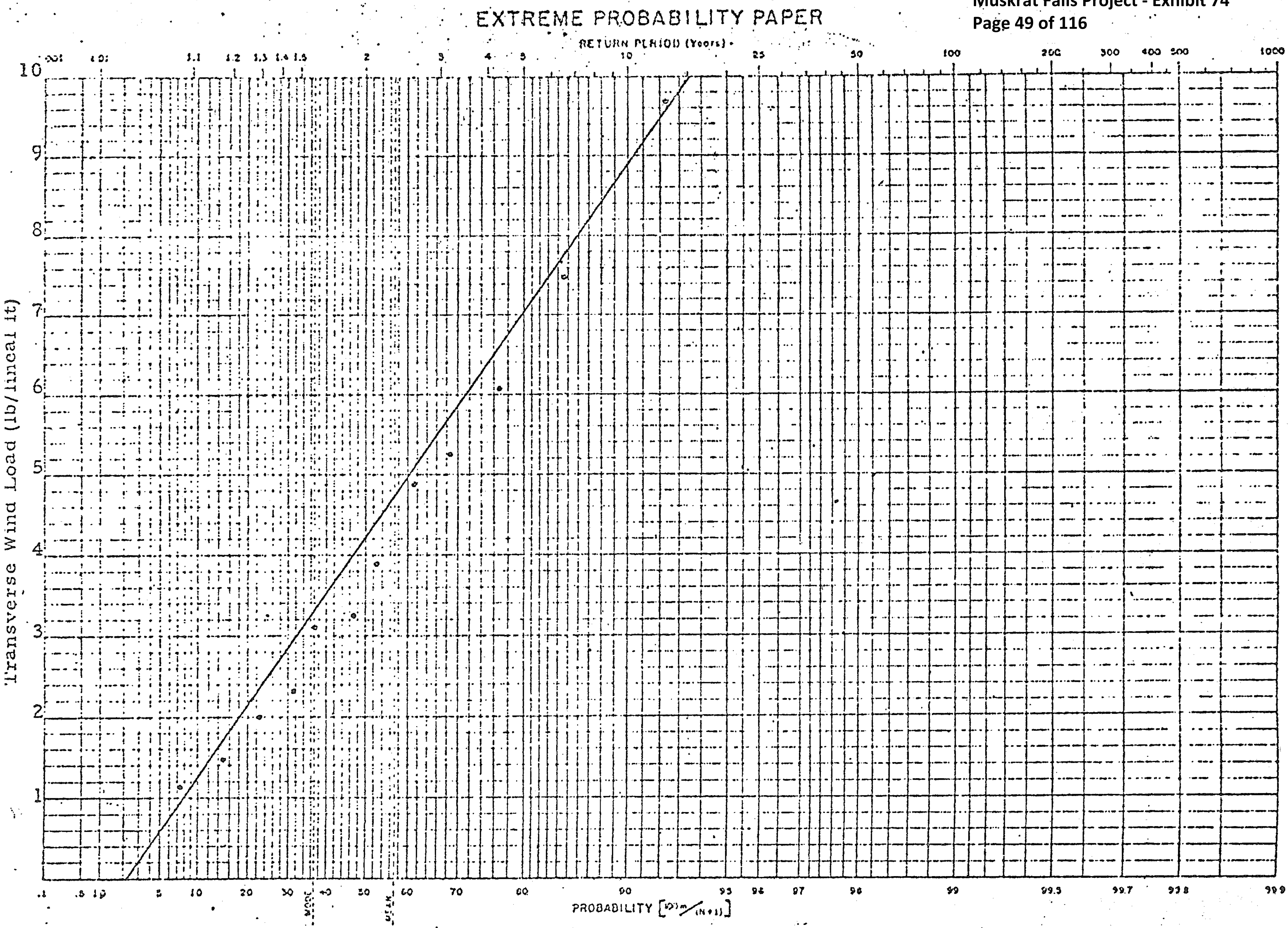


Fig. 21. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 800 FT ABOVE BUCHANS, NFLD BASED ON WIND GUSTS

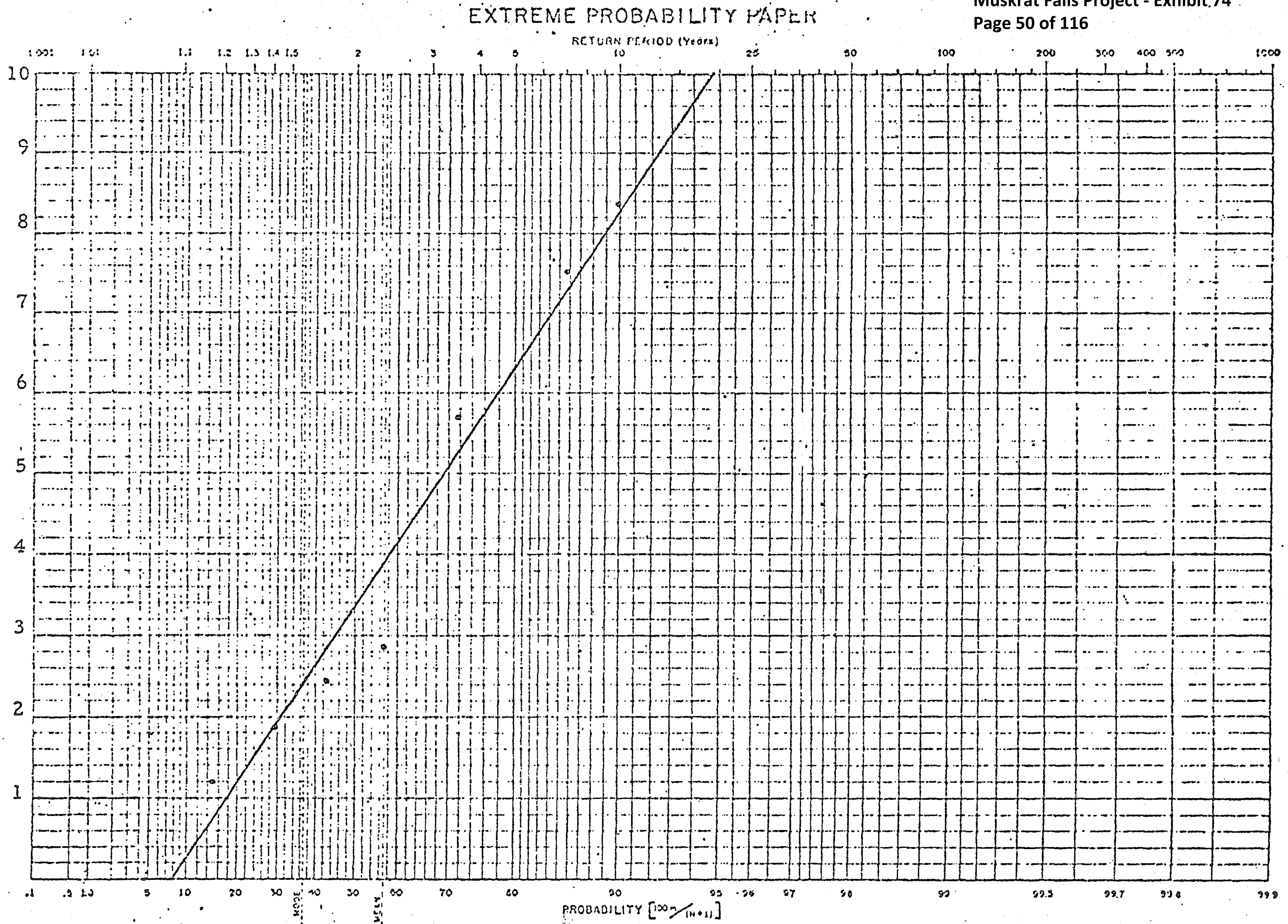


Fig. 22. TRANSVERSE WIND LOADS FOR RIME COVERED T/L 1000 FT ABOVE DANIEL'S HARBOUR, NFLD BASED ON WIND GUSTS

Table II

RETURN PERIOD VALUES OF TRANSVERSE WIND LOADS FOR RIME-COVERED T/L

Location	Return Period Amounts (lbs/linear ft)							
	10-year		25-year		50-year		75-year	
	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts	Sustained Wind	Wind Gusts
300 ft above Torbay	3.6	8.2	4.6	10.3	5.3	11.9	5.7	12.8
300 ft above Gander	2.0	4.5	2.5	5.5	2.7	6.3	2.9	6.8
300 ft above Buchans	1.2	2.7	1.5	3.4	1.8	4.0	1.9	4.6
800 ft above Buchans	4.0	8.9	5.1	11.4	6.0	13.4	6.4	14.6
1000 ft above Daniels Harbour	3.7	8.3	4.7	10.7	5.7	12.9	6.2	13.9

Table III

MAXIMUM TRANSVERSE WIND LOADS
DUE TO WET SNOW ON CONDUCTORS

Location	Period of Record	No. of Wet Snow Storms ≥ 6 Hrs	Date of Maximum Load	Duration of Wet Snow	Average Wind Speed	Maximum Wind Speed	Wet Snow Diameter	Transverse Wind Load (lbs/lin ft)	
	Yrs			(hrs)	(mph)	(mph)	(in.)	Sustained Winds	Wind Gusts
St. John's - Torbay	19	2	5-1-55	6	35	40	4.7	1.6	3.5
Gander	19	4	3-5-60	9	41	45	6.8	2.9	6.5
Buchans	12	1	3-19-64	6	33	37	4.7	1.3	3.0
Daniel's Harbour	6	1	1-11-69	6	13	24	3.0	0.4	0.8
Deer Lake	6	1	10-23-69	7	20	20	3.8	0.3	0.7
Argentia	17	11	12-18-65	6	39	46	5.1	2.3	5.1

VI. TRANSVERSE WIND LOADING PROBABILITIES OF ICE-COATED TRANSMISSION LINES BY LINE SEGMENT

A. Loadings Derived From the November 1973 Report

In the November 1973 report, individual wind and ice loadings were assumed to be independent variables. Thus the probability of their occurring simultaneously becomes a product of their individual probabilities. For a given combined probability there are many possible combinations of individual probabilities, the product of which would equal the selected combined probability. It was assumed that the probabilities of both variables were equal, and therefore the individual probabilities were equal to the square root of the combined value. The combined wind and ice loads (both glaze and rime) for the 10-, 25-, 50-, and 75-year return periods at each of the five line segments between Holyrood and the north end of Humber Valley were used to compute the corresponding transverse wind loads of iced transmission lines. Table IV lists these results.

B. Loadings Derived From Actual Storm Data

Table V lists the 10-, 25-, 50-, and 75-year return period values for transverse wind loads based on actual storm data as extrapolated to the proposed route. A comparison of glaze and rime ice loadings in Tables I and II indicates that the transverse wind loads in conjunction with rime ice is generally larger than that with glaze ice. Therefore the values in Table V are all associated with rime ice. The loadings for wind gusts are also presented. The values computed from the November 1973 report (Table IV) generally lie between those values computed from hourly winds and wind gusts.

All segment values have been computed for a level 80 feet above the most exposed terrain in the segment.

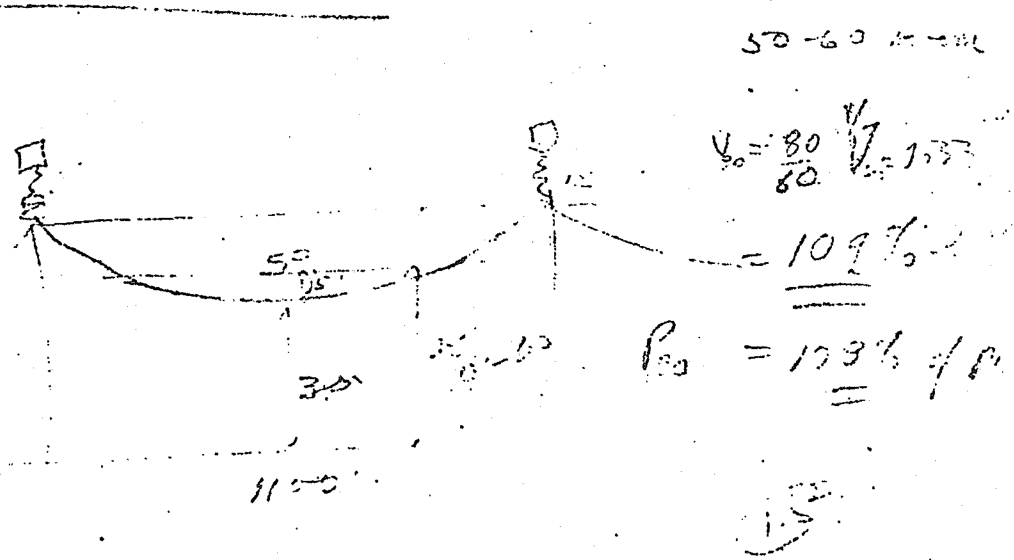


Table IV

TRANSVERSE WIND LOADS (lbs/linear ft)
FOR GLAZE AND RIME COVERED T/L
ASSUMING INDEPENDENCE OF WINDS AND ICING

Segment No.		Return Period in Years							
		10		25		50		75	
		Glaze	Rime	Glaze	Rime	Glaze	Rime	Glaze	Rime
1	Holyrood to Whitbourne (<500 ft)	5.1	5.5	7.2	8.2	9.2	10.6	10.1	12.2
2	Whitbourne to 10 miles west of Clarenville (<500 ft)	6.9	6.9	9.4	10.3	11.7	13.1	12.9	15.6
3	10 miles west of Clarenville to Grand Falls (≤800 ft)	3.8	3.8	5.6	5.5	7.1	7.4	8.0	8.4
4	(800-1200 ft elevations west of Gander Lake)	5.5	5.6	7.5	7.8	9.6	10.1	10.9	11.5
20	Grand Falls to north end of Humber Valley	5.5	5.6	7.5	7.8	9.6	10.1	10.9	11.5

Table V

TRANSVERSE WIND LOADS (lbs/linear ft)
OF RIME COVERED T/L USING ACTUAL STORM DATA

Segment No.		Return Period in Years 10 Hourly Winds	10 Wind Gusts	25 Hourly Winds	25 Wind Gusts	50 Hourly Winds	50 Wind Gusts	75 Hourly Winds	75 Win Gus
1	Holyrood to Whitborne (<500 ft)	3.6	8.1	4.6	10.3	5.3	11.9	5.7	12
2	Whitbourne to 10 miles west of Clarenville (<500 ft)	4.0	9.0	4.9	11.0	5.6	12.6	6.0	13
3	10 miles west of Clarenville to Grand Falls (≤800 ft)	2.3	5.2	2.7	6.1	3.0	6.8	3.2	7
4	(800-1200 ft elevations west of Gander Lake	3.8	8.6	4.6	10.3	5.2	11.7	5.6	12
20	Grand Falls to north end of Humber Valley	3.8	8.6	4.6	10.3	5.2	11.7	5.6	12

VII. COMBINED WIND SPEED AND ICE LOADS BY LINE SEGMENT

This report has presented transverse wind loads for ice-coated transmission lines for 10-, 25-, 50-, and 75-year return periods using predicted loadings from actual storm data. This probably represents the most accurate method of obtaining return period loadings directly. However, it has been pointed out that, for tower loading design, wind speed and ice thickness values will both be required. There is no reliable method of extracting the individual wind or icing data that are responsible for the combined loading return period values. Transverse wind loads are a function of both wind speed and ice diameter. A particular value of transverse wind load can result from many different combinations of wind speed and diameter. In the previous report, as described in Section VI, individual ice and wind loadings were treated as independent variables. In that study, the wind speeds used to generate return period values were annual maximum hourly wind speeds, without regard to when they occurred. The resultant transverse wind loads, shown in Table IV, were quite large.

Obtaining transverse wind loads by assuming independence of individual wind and ice loads is a valid method of approach. However, it is more realistic to use only those winds that occurred during icing situations. The rime ice storm data for St. John's-Torbay and Gander were isolated, and maximum wind speeds during ice storm for each year extracted. Return period values for these wind speeds were generated, as represented in Figs. 23 through 26. The 10-, 25-, 50-, and 75-year values were extracted from the figures and presented in Table VI.

The return period plots of wind speed, both hourly values, and wind gusts, were then extrapolated to conductor level for the five line segments. The return period values for rime and glaze icing along the proposed route were taken from the November 1973 report. The combined wind and ice loads were obtained using the method described in Section VI, and the results presented in Tables VII through X.

Caution should be exercised when comparing the transverse wind loads of ice-coated transmission lines as presented in Table V with the combined wind and ice loads listed in Tables VII through X. The former were derived from actual storm combined values, the latter, while also based on storm data, assumed individual wind and ice loads to be independent of each other. Examination of the storm data indicates that the largest transverse wind loads do not usually result from a combination of the highest winds with the heaviest icing. Since the loads are proportional to the square of the wind speed, storms relatively short in

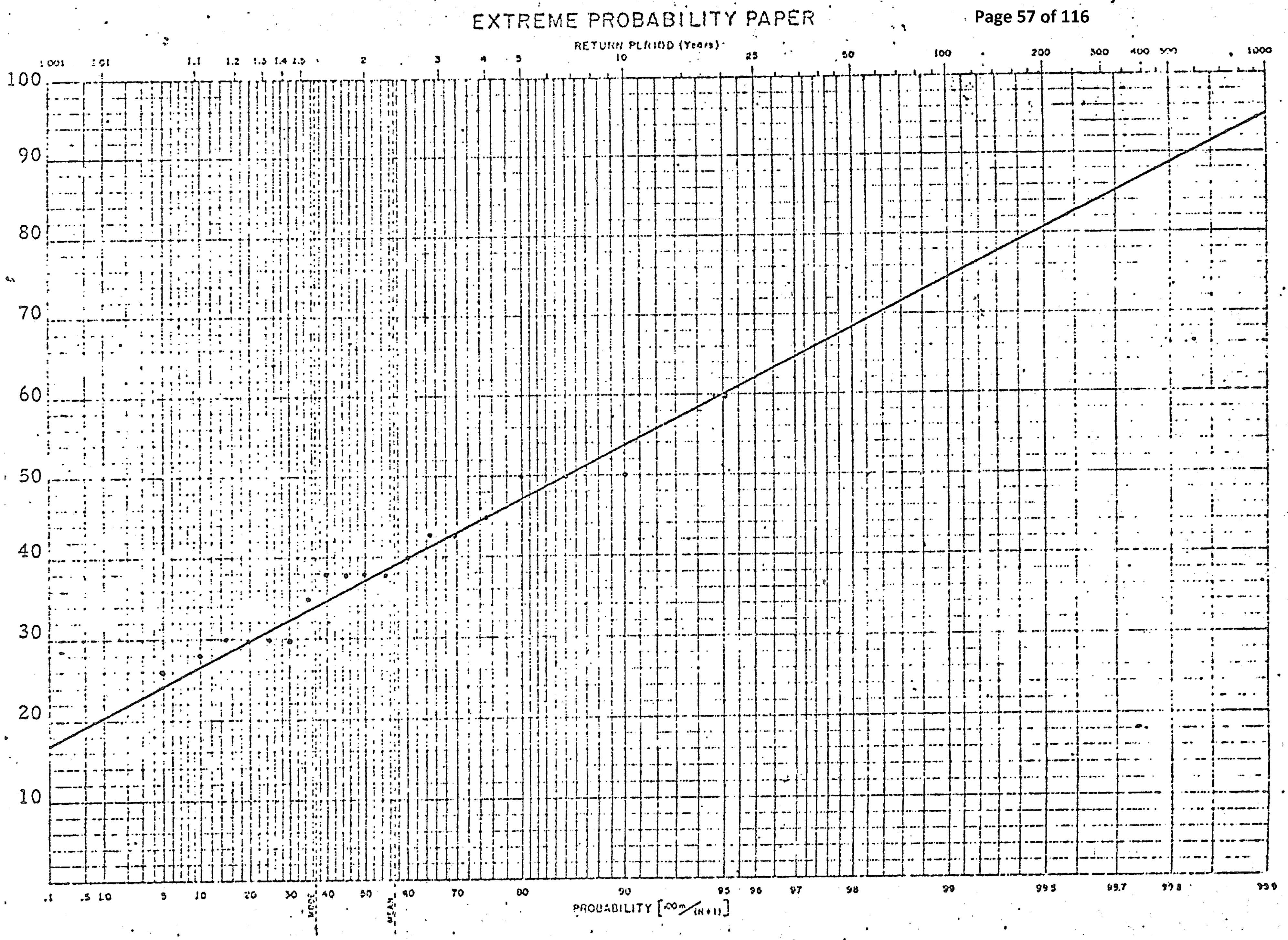


Fig. 23. WIND SPEED PROBABILITIES DURING RIMING CONDITIONS FOR ST. JOHN'S-TORBAY, NFLD

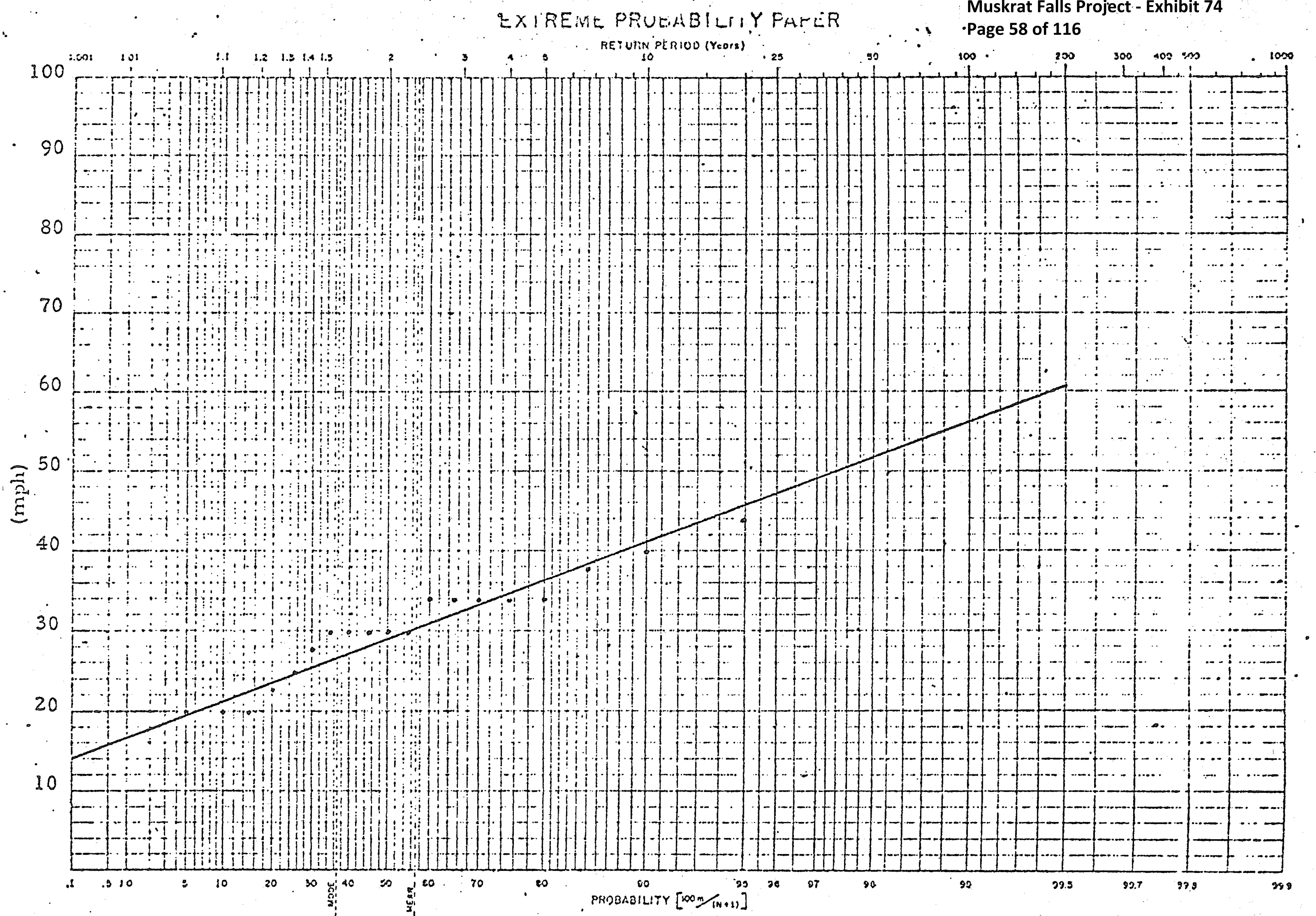


Fig. 24. WIND SPEED PROBABILITIES DURING GLAZE ICING CONDITIONS FOR ST. JOHN'S-TORBAY, NFL

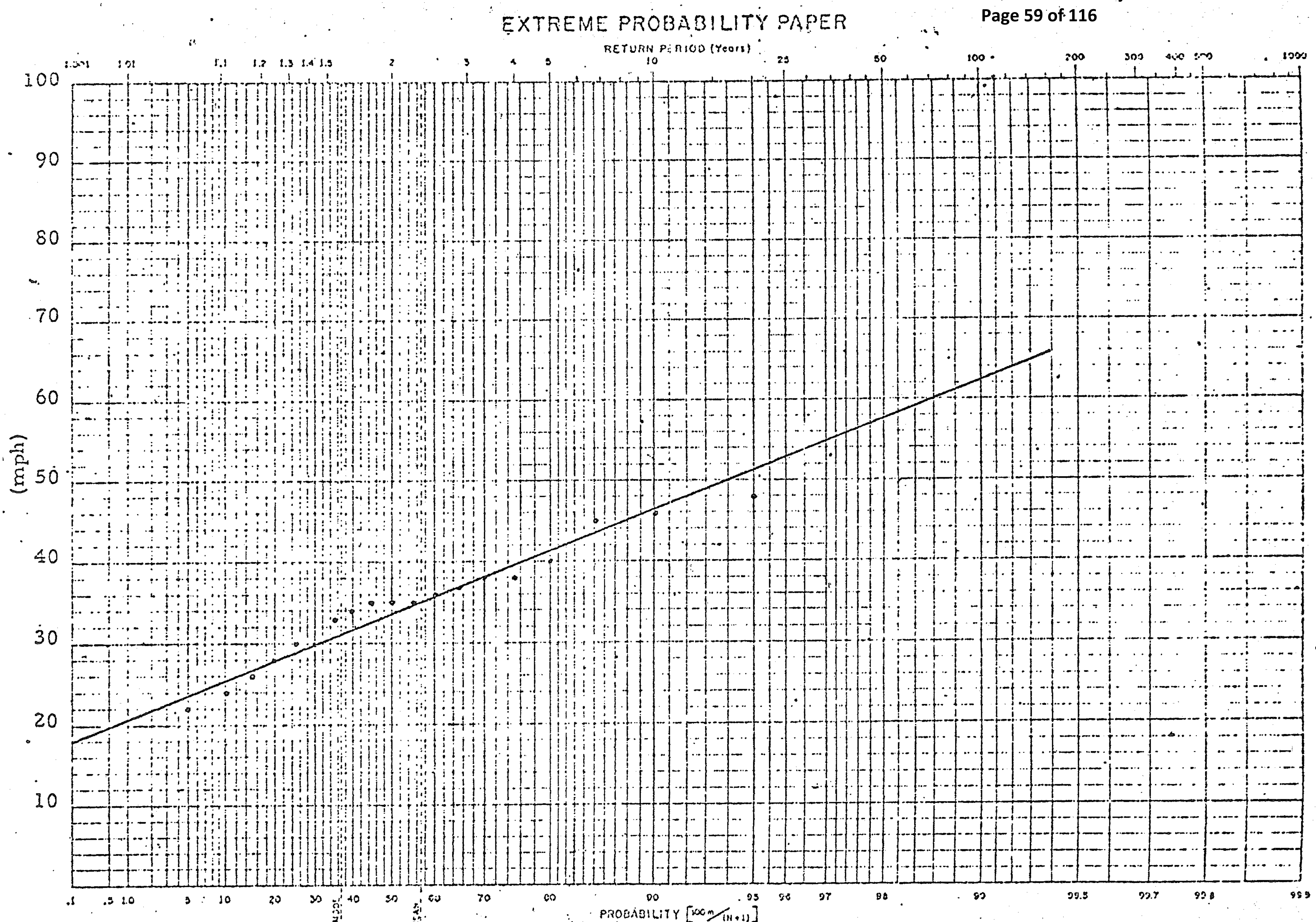


Fig. 25. WIND SPEED PROBABILITIES DURING RIMING CONDITIONS FOR GANDER, NFLD

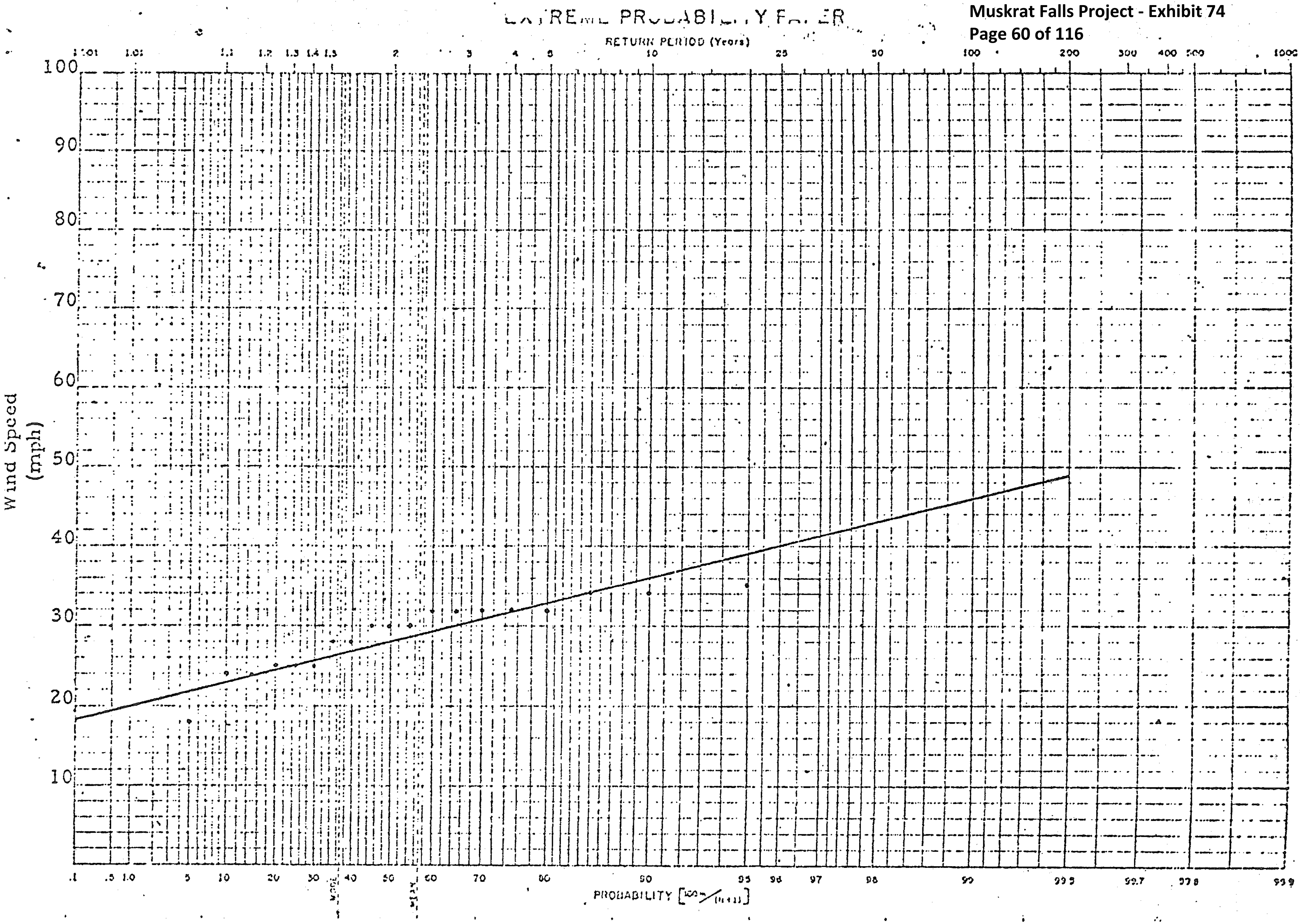


Fig. 26. WIND SPEED PROBABILITIES DURING GLAZE ICING CONDITIONS FOR GANDER, NFLD

Table VI

RETURN PERIOD VALUES OF
MAXIMUM WIND SPEEDS
DURING GLAZE AND RIME ICE STORMS
(mph)

LOCATION	RETURN PERIODS							
	10-yr		25-yr		50-yr		75-yr	
	Glaze	Rime	Glaze	Rime	Glaze	Rime	Glaze	Rime
St. John's-Torbay	41	54	47	62	52	69	55	72
Gander	36	46	40	54	43	58	45	61

Table VII

10-YEAR RETURN PERIOD VALUES

Segment	Maximum Icing Wind Speeds		Maximum Ice Loads				Combined Wind and Ice Loads					
			Glaze		Rime		Wind Speeds		Glaze		Rime	
	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ft (0.5)	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ (0.
1	51	76	2.9	17.4	3.8	15.0	40	60	2.2	11.3	2.4	7.
2	54	81	3.5	23.6	4.3	18.4	43	64	2.8	16.5	2.8	9.
3	47	70	2.4	12.9	3.1	10.8	36	54	1.7	7.7	1.7	4.
4	54	81	2.7	15.5	3.5	13.1	43	64	2.0	9.8	2.1	5.
20	54	81	2.7	15.5	3.5	13.1	43	64	2.0	9.8	2.1	5.

Table VIII

25-YEAR RETURN PERIOD VALUES

gment	Maximum Icing Wind Speeds		Maximum Ice Loads				Combined Wind and Ice Loads					
	Sustained (mph)	Gusts (mph)	Glaze Rad. in.	Glaze lb/ft (0.9)	Rime Rad. in.	Rime lb/ft (0.5)	Wind Speeds Sustained (mph)	Wind Speeds Gusts (mph)	Glaze Rad. in.	Glaze lb/ft (0.9)	Rime Rad. in.	Rime lb/ft (0.5)
1	60	90	3.4	22.5	5.0	23.8	44	66	2.5	13.8	3.0	10.2
2	62	93	4.0	29.4	5.5	28.1	47	70	3.1	19.4	3.5	13.1
3	54	81	2.9	17.4	4.0	16.3	40	60	2.1	10.5	2.0	5.4
4	62	93	3.2	20.4	4.4	19.2	47	70	2.3	12.1	2.4	7.2
20	62	93	3.2	20.4	4.4	19.2	47	70	2.3	12.1	2.4	7.2

Table IX

50-YEAR RETURN PERIOD VALUES

Segment	Maximum Icing Wind Speeds		Maximum Ice Loads				Combined Wind and Ice Loads					
			Glaze		Rime		Wind Speeds		Glaze		Rime	
	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ft (0.5)	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ft (0.5)
1	66	99	3.8	27.0	5.7	29.9	48	72	2.8	16.5	3.4	12.5
2	68	102	4.4	34.5	6.2	34.6	51	76	3.4	22.5	3.9	15.7
3	62	93	3.3	21.4	4.7	21.4	44	66	2.3	12.1	2.4	7.2
4	68	102	3.6	24.7	5.1	24.6	51	76	2.6	14.7	2.8	9.1
20	68	102	3.6	24.7	5.1	24.6	51	76	2.6	14.7	2.8	9.1

Table X

75-YEAR RETURN PERIOD VALUES

Segment	Maximum Icing Wind Speeds		Maximum Ice Loads				Combined Wind and Ice Loads					
			Glaze		Rime		Wind Speeds		Glaze		Rime	
	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ft (0.5)	Sustained (mph)	Gusts (mph)	Rad. in.	lb/ft (0.9)	Rad. in.	lb/ft (0.5)
1	70	105	3.9	28.2	6.3	35.6	50	75	2.9	17.4	3.7	14.4
2	72	108	4.5	35.8	6.8	40.7	53	79	3.4	22.5	4.3	18.4
3	66	99	3.4	22.5	5.1	24.6	46	69	2.4	12.9	2.6	8.1
4	72	108	3.7	25.8	5.5	28.1	53	79	2.7	15.5	2.9	9.7
20	72	108	3.7	25.8	5.5	28.1	53	79	2.7	15.5	2.9	9.7

duration (thus resulting in light icing) in conjunction with high wind speeds can produce the largest transverse wind load for a given year. Conversely, storms lasting a very long time, but with less severe winds, may result in the largest transverse wind load for a given year.

In all cases, the segment icing wind values were extrapolated from the rime ice storm winds, which were approximately 25 percent higher than the winds associated with glaze ice storms. (See Table VI.) As stated earlier, wind speed is the dominating factor in determining transverse wind loads for ice-covered conductors and towers.

VIII. CONCLUSIONS

The principal conclusions of the study are the following:

- Transverse wind loads were generally greater with rime ice than with glaze ice.

- Transverse wind loads derived from the November 1973 report were larger than those computed from actual storm data using hourly winds; however, using a 1.5 gust factor with the storm data results in loads larger than the earlier report.

- Combined wind and ice loads computed using the wind and ice as independent variables, as in the November 1973 report, but using only ice storm winds, result in gust-condition load values similar to the sustained-wind load values in the November report.

- Highest transverse wind loads can be expected along the isthmus west of St. John's. Lowest values occur along the segment south of Gander.

- Wet snow is not expected to be a problem east of Humber Valley; there were a total of only 20 occurrences of wet snow lasting at least six hours at the stations in the area of the proposed route.

- Much of these proposed transmission line routes are through areas of sparse, if any, recorded weather data. Some of the line segments used for loading estimation are quite long. Local variations within the segments could be large.

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Sissenwine, N., P. Tattelman, D. D. Grantham, and I. I. Gringorten, 1973: Extreme wind speeds, gustiness, and variations with height for MIL-STD 210B. Air Force Cambridge Research Laboratories Technical Rept. 73-0560, Aeronomy Laboratory, Project 8624, 72 pp.

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ENG. BD.		
A.E.C.L.		
HYDRO		
FILE NO.		

6 August 1974

Teshmont Consultants, Ltd.
225-2025 Croydon Avenue
Winnipeg, Manitoba
R3P 0N5
Canada

Attention: Mr. A. W. Hannah

Dear Art:

In our meeting of 11 June 1974 in Montreal, Mr. Stremlaw raised the question of why we had not taken the differences between anemometer heights and conductor heights into consideration in the wind and ice loadings in our original study. At the time I had nothing with me to indicate what consideration had been given this factor.

As I mentioned in our telephone conversation, when I returned to California after the meeting, I went through the original computations and the height differences had been taken into consideration in the extrapolation to the line segments. The extrapolation from anemometer heights at the stations, as shown in Table I of the report, to 80 feet above the terrain at the most exposed portions of the route segments was accomplished in one step rather than the two steps of standardizing all station wind curves at 80 feet, then proceeding with the extrapolation as was done in the Calgary Power study with which you were familiar.

The two step process is probably easier for the reader to envision, but is no more accurate. The segment values shown in the report are conductor-level values although this point was not brought out in the text of the report. Since the values in our report were determined to be valid, I took no action to publish an addendum.

$V_2 = V_1 \left(\frac{H_2}{H_1}\right)^{\frac{1}{9.66}}$

The relationship $v_1/v_2 = [\log(z_1/z_0)/\log(z_2/z_0)]^{1/P}$, where z_0 was taken at its turbulent value of 0.4 and P was taken at its unstable lapse-rate value of 2-, was used for height adjustment to wind speeds.

Since the most exposed portion of each of our route segments was used in the wind and ice computations, our values will be conservative (wind estimates too high and ice load estimates too heavy) for the more sheltered portions of the segments. The further combining of segments in Table 6-1 of your report increases that conservatism for many miles of the proposed routes.

I hope this will relieve the concern regarding conductor level values. The point should have been spelled out in our report, but was apparently left out in the crush to meet the deadline.

Work is underway on the combined wind and ice loading and on the proposal for instrumenting the measurement sites.

Sincerely,

M. C. Richmond

M. C. Richmond
Project Manager

MCR/cm

Teshmont Consultants Ltd
RECEIVED
AUG 8 1974

mri Technical Report

THE FOLLOW-ON METEOROLOGICAL EVALUATION OF THE PROPOSED GULL ISLAND TRANSMISSION LINE NETWORK

A.W. Hannah

MRI 75 FR-1378

Submitted to

Teshmont Consultants Ltd.
2025 Corydon Avenue
Winnipeg, Manitoba, Canada
R3P 0N5

Contract No. 133-61081-1

Date 31 October 1975

By M. C. Richmond
R. J. Boomer

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TABLE OF CONTENTS

SUMMARY

In 1973, a study was conducted of the possible meteorological problems involved in constructing a transmission line network from the Gull Island Hydro Site in Labrador to the Avalon Peninsula of Newfoundland. That report was presented in November, 1973. During the winter of 1974-1975, a second phase of the study was conducted to validate and refine the values of wind and ice load determined during the previous year. This study consisted of data acquisition, field surveys, analysis of field and climatological data, and revision of line sector values developed during the earlier study. Meteorological measurements were recorded at one site in the high terrain of Labrador, two sites in the Long Range Mountains of Newfoundland, and one site east of the mountains. Data from these sites were correlated with that recorded at nearby weather service stations, and probabilities of occurrence of specific ice and wind loadings were extrapolated to 16 route segments.

This year's data did not result in any revision of the icing estimates given in the 1973 report. It appears that the winter of 1974-1975 was a relatively light icing season throughout Newfoundland.

Wind speeds over the ridge of the Long Range Mountains were much greater than previously believed. The 50-year return period value was increased from 98 mph in the 1973 report to 140 mph in this study. The prevailing direction of the extreme winds has been changed from north-northwesterly to easterly. Measurements taken in Labrador have shown the 1973 estimates of return period wind speeds on the mainland to be somewhat low. The 50-year return period value for the higher elevations just north of the Strait of Belle Isle was increased from 93 mph to 100 mph.

The shifting of the proposed route eastward at the crossing of the Long Range Mountains will result in some decrease in ice and wind loads along most of this portion of the line. However, portions of the segment are exposed to the east and should be subject to the same extreme loadings as predicted by the past winter's measurement program.

I. INTRODUCTION

Teshmont Consultants, Ltd., is in the process of designing a 500-kv transmission line for Newfoundland and Labrador Hydro. The proposed line will extend from the Gull Island Hydro Site southwest of Goose Bay, Labrador, to near Holyrood on the Avalon Peninsula of Newfoundland.

It was known that portions of the line would be subjected to some of the highest wind and ice loads to be experienced in Canada. Northeastern Newfoundland was known to be especially susceptible to damaging icing storms in recent years. The proposed routes were to cross through that area as well as uninhabited areas where no past experience or reports were available. Two preliminary meteorological evaluations of the area and potential routes were conducted during the fall of 1973 and the summer of 1974. Those studies were based on the existing climatological records of the few weather stations located throughout the area supplemented by storm damage reports and conversations with personnel having first-hand experience with the winds and icing in the various regions of the province. It was readily apparent that existing data were not available from the remote areas most susceptible to high winds and/or icing. The need to collect meteorological data at some of the more vulnerable locations and to develop relationships between these locations and existing weather stations was recognized. A data collection program was established and data collected at four sites during the winter of 1974-1975. If necessary, the wind and ice loadings predicted for these remote portions of the proposed route could be refined to reflect the results of the measurement program.

There have been some changes in the proposed route since the two previous studies were made. The portion of the route in Labrador has not changed significantly since the November, 1973, report. After crossing the Strait of Belle Isle, the route will then run south-southwestward along the west coastal plain of the northwest peninsula of Newfoundland, remaining at elevations near or below 500 feet except where the route runs between the High Lands of St. John and the Long

Range Mountains. The elevation in this region briefly reaches 1500 feet. When the sites for the 1974-1975 meteorological program were chosen, the proposed route was expected to run between Portland Creek Pond and Inner Pond, stay on the coastal plain on the west side of West Hill, and then veer southeastward as it rapidly ascended to the ridge of the Long Range Mountains. One of the weather station sites was located near the highest point of the ridge. The current route also runs between Portland Creek Pond and Inner Pond, but then immediately begins a more gradual climb east of West Hill and crosses the mountains at slightly lower elevations. The new crossing of the Long Range Mountains should be slightly less exposed than the earlier route. South of the Main River the descent into the Upper Humber Valley is along the original route described in the November, 1973, report. However, the latest route then turns south of the original, running south of Sheffield Lake and close to the northern edge of the Top-sails. South of Gander the original and current routes become one again and remain essentially so, with only minor variations, until the terminus northeast of Holyrood.

This report presents the analysis of the data collected during the winter of 1974-1975. The scope of the study and data sources are described in Sections II and III. The four remote data collection sites are described in Section IV, and the results of the field program are analyzed in Section V. The wind and ice loading estimates given in the two previous reports are updated by line segment in Section VI. Finally, significant results and conclusions are summarized in Section VII.

II. SCOPE OF STUDY

This transmission line study consisted basically of three phases, as follows:

- Data acquisition (field program)
- Reduction and analysis of data
- Refining of segment values

The data acquisition phase consisted of making measurements of wind, temperature, and ice accumulations at four sites previously identified as being apparent critical locations to determine ice and wind loading extremes. These locations were selected as being representative of the highest and/or most exposed portions of the proposed route. Site locations and equipment installed are described in Section IV. Measurements were made from October 1974 through June 1975.

In the data reduction and analysis phase, the data gathered from the four instrumented sites and the corresponding weather records from the six area weather stations listed in Section III were processed together. They were related to the historical data for those stations to develop probabilities of occurrence of specific ice, wind, and combined ice and wind loads for the measurement sites.

Results of the analysis phase were used to refine the route segment values previously developed.

III. DATA SOURCES

A. Climatological Data

Historical meteorological data for twelve Department of the Environment stations in the area were available from previous studies conducted in 1973 and 1974. For six of the stations most nearly related to the instrumented sites, microfilms or photocopies of the hourly weather observations taken during the period 1 October 1974, through 30 June 1975, were procured from the Atmospheric Environment Service (AES). The twelve stations for which the historical data were available and their period of record are listed below. The stations for which hourly data during the past winter were acquired are designated by the asterisks.

* St. John's-Torbay, Nfld.	1953-1971
Argentia, Nfld.	1953-1969
* Gander, Nfld.	1953-1971
Buchans, Nfld.	1953-1964
* Deer Lake, Nfld.	1966-1971
Stephenville, Nfld.	1953-1971
* Daniels Harbour, Nfld.	1966-1971
* Battle Harbour, Labrador	1958-1971
* Goose Bay, Labrador	1953-1971
Wabash Lake, Labrador	1961-1971
Schefferville (Knob Lake), Quebec	1953-1971
Lake Eon, Quebec	1961-1971

Periods with wind speeds greater than 20 mph and/or peak gusts greater than 30 mph were extracted from wind charts obtained from Hawke Bay, Nfld., for the period November, 1974, through April, 1975. In addition, Monthly Climatological Summaries were available from St. John's Airport and Gander International Airport for the October, 1974, through May, 1975, period.

B. Field Data

Recorded data were obtained from four instrumented sites along the proposed route during the period from mid-October, 1974, through early June, 1975. The locations of these remote sites are shown in Figure III-1 and descriptions of their locations and instrumentation installed are detailed in Section IV.

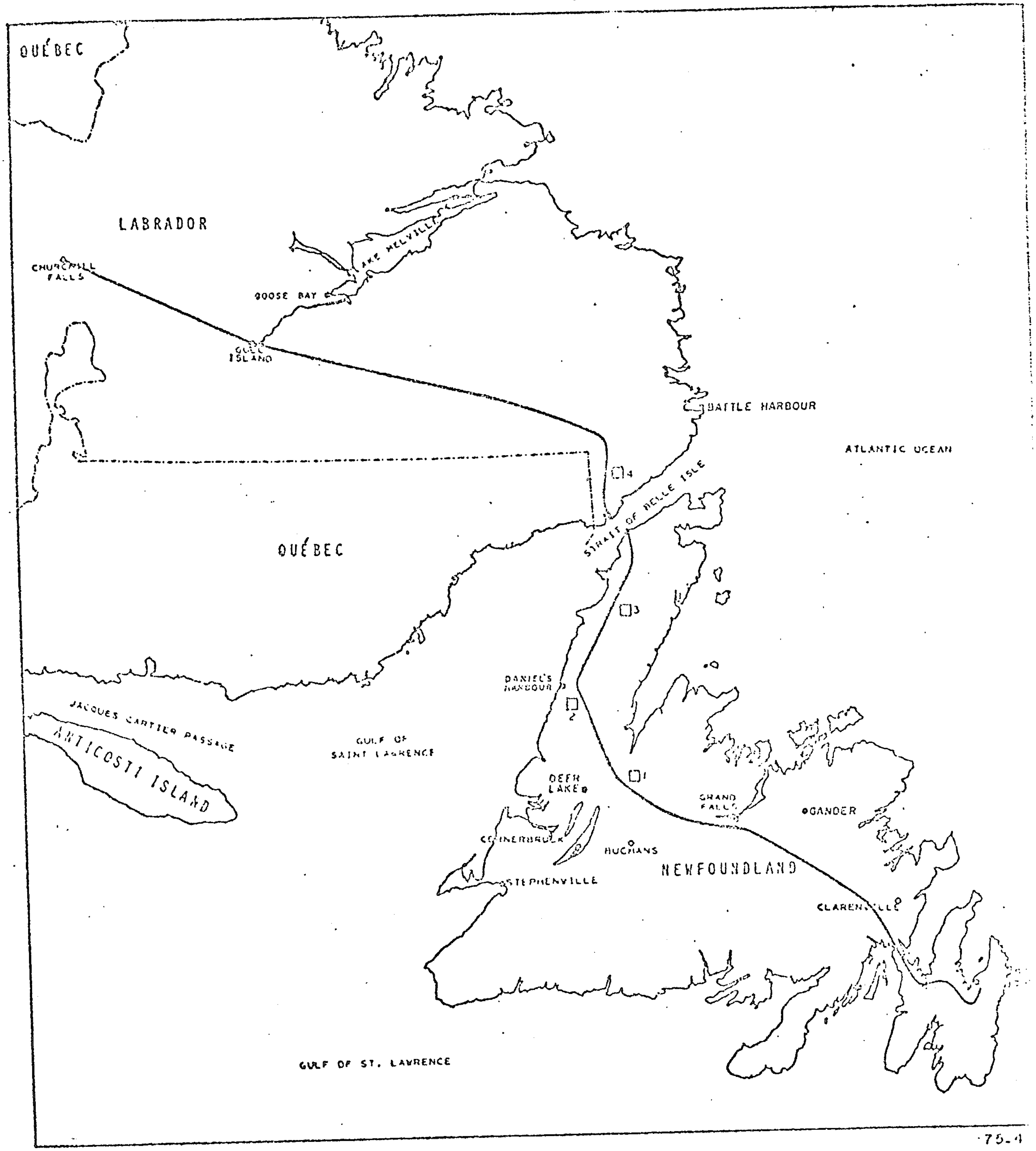

Fig. III-1. PROPOSED GULL ISLAND TRANSMISSION LINE SYSTEM. Measurement Sites are Indicated by the Squares.

IV. SITE DESCRIPTIONS

Site 1 was located near the microwave tower on a hill north of Sheffield Lake. At an elevation of 1500 feet, this station, approximately 1000 feet above the lake, was well exposed to the gradient wind flow from all directions. This site was chosen to represent the maximum exposure in an area where no regular observations are available. Of special interest was northeast winds coming off the Atlantic Ocean.

Site 2 was located eight miles south-southeast of Portland Creek on a ridge 2000 feet above sea level. This site, located near the area where the proposed route was expected to cross the ridge, is well exposed in all directions.

Site 3 was located between the High Lands of St. John and the Long Range Mountains, approximately eleven miles east of Barr'd Harbour. At an elevation of 1500 feet, the site is sheltered by higher terrain to the west. The possibility of channelling of north-northeast or south-southwest winds led to the selection of this site.

Site 4 was located on the mainland on a plateau about twenty-six miles north of the Strait of Belle Isle crossing point at an elevation of 1800 feet. It is well exposed in all directions and representative of high terrain in this area.

At each site two 30-foot towers were erected approximately 54 feet apart, spanned by a cable 1.338 inches in diameter. An ice rate meter (IRM) that measures increased tension due to ice loading was connected to the cable. Atop each tower was a Mechanical Weather Station (MWS) that recorded wind direction, wind run, temperature, and relative humidity. In addition, power was available at Site 1 which allowed for the installation of heat lamps atop one of the towers in an attempt to reduce the heavy ice accumulations that were expected at the site.

The IRM's began service in mid-October, 1974, and the MWS's in mid-November, 1974. All of the sites were deactivated in June, 1975.

V. ANALYSIS OF FIELD PROGRAM RESULTS

Mechanical Weather Station data recovery percentages by parameter were calculated for each site. The value of having two MWS's at each site is reflected in the comparison of the recovery percentages of each MWS. By station, only 73.4 percent of the data was recovered, yet, by site, 90 percent was recovered. These percentages include data that was questionable due to the likelihood of icing (e.g. wind speeds very low for several consecutive days with a constant wind direction during the same period). However, these data are still useful in that they give a good indication of the duration of severe icing conditions. One parameter not included in these recovery percentages was relative humidity. The somewhat delicate humidity element could not withstand the severity of the many winter storms that passed through Newfoundland and, thus, the resulting data were, at best, suspect during most of the season.

A. Winds

The Mechanical Weather Stations used at Sites 1 through 6 measure "wind run," the number of miles of wind which pass the station. Normal data reduction of MWS recordings results in hourly average winds, the total number of miles of wind which passed the station between 30 minutes before the hour and 30 minutes after the hour. The winds extracted from the microfilmed hourly weather reports of six stations in Newfoundland and Labrador are "hourly wind" speeds. The hourly wind consists of a one-minute average wind speed observed sometime during the ten minutes prior to the hour. Thus, if the actual maximum one-minute average does not occur in that ten minutes, it is not recorded. The fastest "hourly wind" values represent only samples of the wind conditions for each hour. The sample covers a period of from one to ten consecutive minutes just before the hour, depending upon the observer and the recording or indicating equipment used for the observation. Such a sample ignores the winds that occur during at least 5/6 of each hour and possibly as much as 59/60 of each hour. Thus, there is a consistent tendency for hourly wind values to understate the fastest wind occurrence during the hour. The degree of understatement is directly proportional to the variability of the wind speed.

Studies of the relationships between maximum wind speed values derived from different averaging times have resulted in a considerable range of conversion factors to be used. These relationships have been studied under the general category of wind gusts and gust factors.

1. Wind Gusts

Gusts are sudden brief increases in the speed of the wind resulting from eddies superimposed on the basic flow of air. Many studies of the relationship of gusts to the steady wind and their variation with speed, height, thermal stratification, and terrain have culminated in general agreement concerning the nature of these relationships (Davis and Newstein, 1968; Camp, 1968; Shellard, 1965; Mitsuta, 1962; Boyd, 1965; Brook and Spillane, 1970; Sissenwine et al., 1973; and others). However, quantitative results have varied, depending on the data and analytical methods used.

Most studies of gustiness are from micrometeorological research. Though measurements obtained from such experiments are generally superior to operational data because of refined anemometry, such studies hardly ever provide data for the very high wind speeds important in design of transmission towers and conductors. Sissenwine et al., 1973, analyzed a more meaningful spectrum of wind speeds and this work appears to be one of the better recent efforts in this field. Their study included the analysis of 548 wind observations taken at anemometer heights varying from 10 to 85 feet, with one-minute steady wind speeds varying from 20 to over 70 knots, and locations varying from tropical Pacific islands to Alaska and Greenland. Since recorder charts of steady winds greater than 70 knots were scarce (only 10 cases of the 548 studied), they also used 26 observations of gust factors for five-minute steady winds ranging from 71 to 163 knots taken at Mt. Washington, New Hampshire, and four values derived from wind data taken during hurricanes that passed close to the Blue Hill Observatory near Boston, Massachusetts. Actually, accurate data on short period gusts are quite rare. In weather station climatological records the steady state wind speed corresponding to maximum peak gusts is usually not available. The maximum hourly wind speed and maximum peak gust for the station frequently did not occur in the same storm and are related only in a qualitative sense.

2. Gust Factors

In discussion of gust relationships, a "gust factor" equal to G/V is commonly employed. In this expression G is the maximum gust speed and V is the maximum sustained wind speed. While there is general agreement that gust factors tend to decrease with increasing wind speed and height above the surface, past studies have resulted in a variety of gust factor relationships with as many different values as studies. There has been little apparent effort to standardize the type of wind speed used as the sustained wind or the duration of the gusts involved.

Sissenwine et al. found that a least-squares relationship (G. F. = $1 + 0.55\ e^{-0.0093V}$) best fit the median (50 percentile) two-second gusts related to five-minute steady speeds. Two-second gusts thus derived ranged from 1.46 times a five-minute steady speed of 25 knots to 1.22 times a five-minute steady speed of 100 knots. Table V-1 and Fig. V-1 show the relationship of other gust durations to five-minute steady speeds.

One of the most widely used relationships for computing gust speeds was derived by Boyd. His formula, $G = 5.8 + 1.29\ V$, gives gust speeds (G) in miles per hour based on hourly wind speeds (V) in miles per hour. At the time he derived this formula, the gust data used were thought to be of approximately three-second duration. Recently, Mr. Boyd stated that he now believes the response time of the pressure tube anemometer and its recorder, which his data were collected from, to be of the order of five to eight seconds.

Another often referenced authority, Durst (1960), developed a statistical model based on samples taken with a high speed recorder. Although his empirical data were taken at speeds less than 42 miles per hour, he applied his model to class intervals of speeds up to 80 mph. As Table V-2 shows, his probable gust factors for various duration gusts are nearly the same for all speed classes.

If the Durst relationships for hourly speeds to five-minute gusts (interpolated) are combined with the Sissenwine et al. relation of five-minute to two-second speeds, the resulting gust factors for two-second gusts from hourly winds vary from 1.6 at 20 mph to 1.4 at 80 mph. This is nearly exactly what the Boyd formula of $G = 5.8 + 1.29\ V$ results in for five-second gusts.

In 1964, the Bonneville Power Administration published gust factors for 52 stations in their area of operation (Bonneville Power Administration, 1964). These gust factors comparing maximum gusts to one-minute wind speeds ranged from 1.23 to 1.67 with a mean of 1.35. They detected no variation of gust factor with wind speed in the data used in their study.

Gust factors tend to decrease with height above the terrain. This decrease with height is generally accepted as theoretically reasonable in a qualitative sense; however, there is limited experimental data to develop firm quantitative values from. It is apparent that, since this variation with height is a function of eddy size, it must also be related to terrain roughness, wind speed, and atmospheric stability. Wind near the earth's surface is very sensitive to the terrain; consequently, any particular location is likely to have its own gust characteristics. It is certainly well within the state of the art in anemometry to experimentally develop gust factor height dependence values applicable to a selection of typical topographic and

TABLE V-1

GUST FACTORS VERSUS 5-MINUTE STEADY WIND SPEED

5-Minute Speed (knots)	Gust Factor (GF)		
	60-sec	30-sec	2-sec
20	1.120	1.172	1.4566
30	1.105	1.151	1.4160
40	1.094	1.134	1.3791
50	1.085	1.121	1.3454
60	1.077	1.111	1.3147
80	1.066	1.095	1.2613
100	1.057	1.081	1.2170
125	1.049	1.069	1.1719
150	1.042	1.059	1.1363
175	1.035	1.050	1.1080
200	1.028	1.040	1.0856

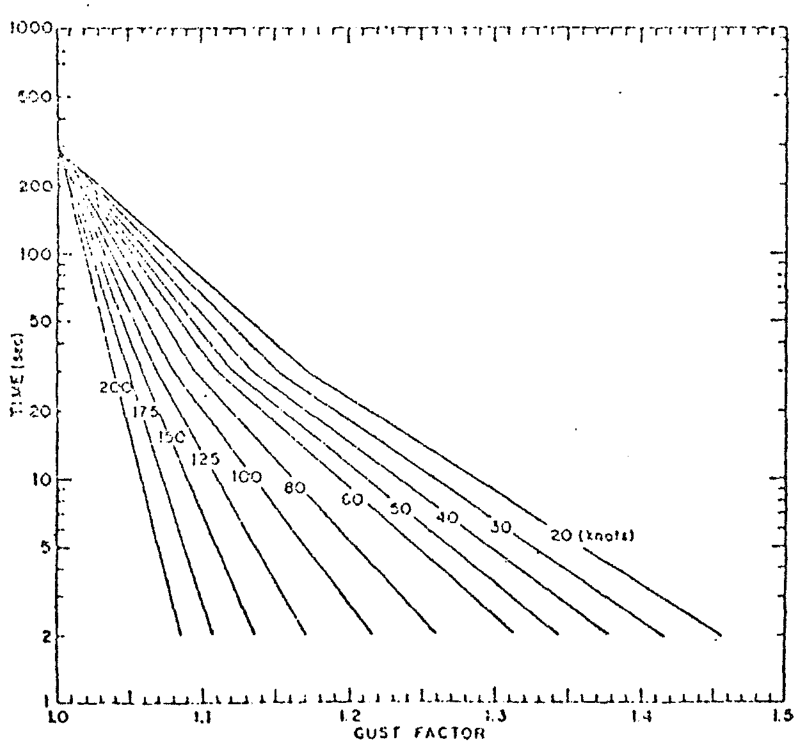

Fig. V-1. GUST FACTORS VERSUS 5-MINUTE STEADY WIND SPEED

TABLE V-2

PROBABLE (50 PERCENT) GUST FACTORS FOR 20- TO 80-MPH AVERAGE HOURLY SPEEDS USING DURST'S MODEL

Mean Hourly Speed (mph)	Gust Factor (GF)					
	600 sec	60 sec	30 sec	20 sec	10 sec	5 sec
20	1.05	1.25	1.30	1.35	1.40	1.50
30	1.07	1.23	1.33	1.37	1.43	1.47
40	1.07	1.25	1.32	1.35	1.42	1.48
50	1.06	1.24	1.32	1.36	1.42	1.48
60	1.07	1.24	1.32	1.35	1.42	1.48
70	1.06	1.24	1.31	1.36	1.41	1.49
80	1.06	1.24	1.33	1.36	1.43	1.48

geographic locales; however, this has not been pursued on any organized basis.

It is apparent from the above discussion of the currently most frequently referenced sources that there are no hard and fast relationships to use in relating speeds of different averaging times. Observations at high wind speeds in the range to be expected to occur in Newfoundland were included in the derivation of the relationship developed by Sissenwine, et al. For this reason, Sissenwine's least squares relationship is used in the estimation of peak gusts in this study. This formula may tend to underestimate gusts at lower one-minute speeds, but it appears to be more realistic for the higher wind speeds. In order to be consistent, the same formula was used throughout.

3. Results From 1974-1975 Measurement Program

Table V-3 lists the maximum hourly wind speeds and the peak gusts reported at the six weather stations this winter.* The peak gust is the

* Daniel's Harbour did not record gusts.

TABLE V-3

MAXIMUM STATION WINDS REPORTED DURING WINTER OF 1975-1975

(Wind Speeds in Miles Per Hour)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
St. John's								
Max. Hourly*	WSW 35	SSW 40	NNE 45	SE 50	W 45	WSW 52	NNW 46	N 63
Peak Gust	S 55	WSW 56	NE 65	S 71	NNW 61	WSW 72	S 70	N 91
G.F.	1.57	1.40	1.44	1.42	1.35	1.38	1.52	1.44
Gander								
Max. Hourly	S 45	SSW 32	E 28	SSW 41	W 28	W 35	NNW 30	N 40
Peak Gust	SSW 80	SSW 49	E 44	SSW 69	NNW 45	W 58	S 43	N 58
	1.78	1.53	1.57	1.68	1.61	[illegible]	1.43	1.45
Deer Lake								
Max. Hourly	SSW 35	SW 20	ENE 25	NNE 25	W 25	SW 23	ENE 23	NW 21
Peak Gust	SSW 80	WSW 35	ENE 45	NNE 45	W 35	SW 37	ENE 40	WNW 32
	2.28	1.75	1.80	1.80	1.40	1.61	1.74	1.52
Daniel's Harbour								
Max. Hourly	SW 64	ESE 42	WSW 36	WSW 45	WSW 36	ENE 36	ENE 41	SSW 32
Battle Harbour								
Max. Hourly	SW 35	SW 40	N 50	N 45	SSE 25	NNW 40	S 35	NNW 46
Peak Gust	SW 50	ENE 57	N 58	N 68	SSE 40	NNW 48	S 46	NNW 56
	1.43	1.43	1.16	1.51	1.60	1.20	1.31	1.22
Goose Bay								
Max. Hourly	WSW 27	ENE 58	NNE 26	W 40	SW 30	W 37	SW 35	NW 23
Peak Gust	WSW 45	ENE 70	NNE 40	W 52	SW 40	W 53	SW 55	NW 29
	1.67	1.21	1.54	1.30	1.33	1.43	1.57	1.26
Hawke Bay**								
Max. Hourly	--	NW 32	ESE 28	N 39	W 29	W 30	SW 26	--
Peak Gust	--	E 61	E 50	N 62	WSW 46	W 46	E 48	--
		1.90	1.78	1.59	1.59	1.53	1.85	

* Maximum Hourly Wind Speeds are one-minute averages
** Period of Record November through April

highest "instantaneous" wind speed recorded at a station during a specified period. Depending on the response time of the anemometer and recorder used, this value may represent anything from a two-second to an eight-second gust, or, if the wind is not gusting, simply the highest wind speed recorded. It should be noted that the maximum hourly winds and peak gusts are not necessarily associated. They frequently occur on different days.

Winds were generally lighter than normal at reporting weather stations in Newfoundland and Labrador during the winter and spring of 1974-1975. In November, an hourly wind speed of 58 mph was recorded at Goose Bay surpassing the previous all-time record by 6 mph. May was an exceptionally windy windy month over much of the province. St. John's recorded a peak gust of 91 mph, the highest ever recorded in May, but well below the all-time record of 120 mph. The average wind speed for the month was also a record 18.8 mph. At Gander, total wind mileage was above normal in May.

In contrast, February was relatively calm, with no wind storms during the month. For the remaining winter and spring months, the average wind speed was near or slightly below normal.

The maximum hourly average wind speeds recorded at each of the observation sites during this past winter are listed in Table V-4. The values in parentheses are the estimated maximum one-minute averages computed at 1.25 times the maximum hourly average and estimated peak gusts (two-second average) computed using the relationship of Sissenwine et al. Table V-5 breaks down the wind data into speed categories, both by number of hours and percentage of recovered data. By far, the highest wind speeds were recorded at Site 2. Over 15 percent of the wind data recovered at that site showed speeds in excess of 40 mph; over 8 percent of the data indicated average hourly wind speeds exceeding 50 mph. The highest speed recorded was from the east at 101 mph, on March 3. It is likely that this figure was equalled or exceeded during storms that resulted in damage to the MWS or that occurred when both stations were iced up. On December 18 the cups on both stations were blown off at wind speeds in excess of 80 mph from the east. One storm of note occurred between April 26-28 when one of the stations at Site 2 recorded 38 consecutive hours of winds above 50 mph and 14 consecutive hours of winds in excess of 80 mph. This highest wind speed recorded during this period was 93 mph. Once again, the prevailing direction of these winds was from the east. Although the site is well exposed in all directions, less than 10 percent of the winds in excess of 50 mph were from directions other than northeast through southeast. This would seem to indicate that the extreme winds at Site 2 are prevalent when the low pressure systems move to the south of Newfoundland.

TABLE V-4

MAXIMUM SITE WINDS RECORDED
WINTER OF 1974-1975
(Wind Speeds in Miles Per Hour)

	Nov.†	Dec.	Jan.	Feb.	Mar.	Apr.	May†
Site 1							
Max. Hourly Avg.	29*	33*	44	45	40	45	46
Est. 1-Min. Avg.	(36)	(41)	(55)	(56)	(50)	(56)	(58)
Est. Peak Gust	(46)	(52)	(68)	(70)	(63)	(70)	(72)
Site 2							
Max. Hourly Avg.	37*	95*	89*	50*	101	93*	75
Est. 1-Min. Avg.	(46)	(119)	(111)	(63)	(126)	(116)	(94)
Est. Peak Gust	(58)	(136)	(129)	(77)	(144)	(134)	(112)
Site 3							
Max. Hourly Avg.	54*	50*	55	57	49*	60	47
Est. Max. 1-Min. Avg.	(68)	(63)	(69)	(71)	(61)	(75)	(59)
Est. Peak Gust	(83)	(77)	(85)	(87)	(75)	(91)	(73)
Site 4							
Max. Hourly Avg.	54	60	58	50	57	54	70
Est. Max. 1-Min. Avg.	(68)	(75)	(73)	(63)	(71)	(68)	(88)
Est. Peak Gust	(83)	(91)	(89)	(77)	(87)	(83)	(106)

† Period of record began mid-November, ended mid-May
* Partial month of data due to equipment problems.

TABLE V-5

Number of Hours

Avg. Hourly Wind Speed (mph)	Site: 1	2	3	4
40-49.5	19	171	227	268
50-59.5		97	30	85
60.69.5		59	1	7
70-79.5		21		1
80-89.5		17		
90-99.5		7		
≥ 100		1		
Total	19	373	258	361

Percentage of Recovered Data

	Site: 1	2	3	4
40-49.5	0.47	6.93	5.13	6.08
50-59.5		3.93	0.68	1.93
60-69.5		2.39	0.02	0.16
70-79.5		0.85		0.02
80-89.5		0.69		
90-99.5		0.28		
≥ 100		0.04		
Total	0.47	15.11	5.83	8.19

On the mainland at Site 4, wind speeds exceed 40 mph over 8 percent of the period; however, speeds in excess of 50 mph occurred on only 85 hours, or little more than 2 percent of the period of record. The highest wind speed recorded was from the northwest at 70 mph on May 17. One storm of note occurred between December 3-5. Wind speeds exceeded 35 mph for 39 consecutive hours and 50 mph for 25 consecutive hours. The wind direction was north-northeast, changing to north later in the storm. Unlike Site 2, the extreme winds at Site 4 showed no obvious preference for any direction, although a majority of the strong winds were from the northwest through northeast. However, there were indications that the wind vane on one or both of the stations may have been shaken loose on one or more occasions and lost its orientation. Thus, more of a pattern to the direction of the extreme winds may have existed without being apparent.

The stations at Site 3 recorded winds in excess of 50 mph less than one percent of the time. A maximum wind speed of 60 mph from the northeast occurred on April 1. However, most of the strongest winds were from the southwesterly quadrant, indicative of low pressure systems passing to the north of the region.

Site 1 at Sheffield Lake did not record any winds above 50 mph, and very few of the wind speeds exceeded 40 mph. There did not appear to be any prevalent wind direction associated with the stronger wind speeds.

It was evident from a comparison of all four sites that the strongest winds at each location were not generally the result of the same storm systems. As noted earlier, the strong easterly winds at Site 2 were apparently due to storm systems passing to the south of the region, but at Site 3 the strong southwesterly winds resulted from the storm centers passing to the north. On only two occasions was one storm responsible for very high winds at more than one site. On January 19 southerly winds approaching 90 mph struck Site 2, while at Site 4 south-to-southwesterly winds reached 58 mph. The winds at Site 1 did not exceed 37 mph, and at Site 3 they peaked at only 31 mph. During the storm of April 26-28 described earlier for Site 2, northeasterly winds at Site 4 peaked at 53 mph, while at Site 3 the highest hourly wind speed recorded was 42 mph. The winds at Site 1 did not exceed 30 mph. However, during several severe storms at Site 2 the anemometer cups at one or more of the other sites were partially or completely frozen, and thus, were not recording the true wind speed.

A total of 30 wind storms were analyzed and the strongest winds recorded during each storm at the four sites were correlated with corresponding winds at the most representative reporting station in the area. The stronger winds at Site 1 were approximately 50 percent higher than the corresponding winds at Gander. The magnitude of the strong winds at Site 4 were, on the average, twice that of Battle Harbour, although the actual ratios of Site 4 winds to Battle Harbour winds ranged from 1.00 to 2.86. For winds above

40 mph at Battle Harbour, the range of ratios fell to between 1.00 and 1.91.

There was little correlation found between Site 2 and any of the six stations. The station nearest Site 2, Daniel's Harbour, is very sheltered from easterly winds by the ridge upon which Site 2 is located. At times, the winds at Site 2 were almost four times stronger than the winds at Battle Harbour, a station well-exposed to all directions, as was Site 2.

On March 3, the maximum wind speed recorded at Battle Harbour was 30 mph, while at Site 2 a one-minute average speed of 120 mph likely occurred during the hour when the average wind speed was 101 mph. On other occasions, Site 2 winds were less than twice the magnitude of the winds at Battle Harbour, but, on the average, the maximum wind speeds at Site 2 were approximately three times those at Battle Harbour. Unfortunately, during those days when the strongest winds were recorded at Battle Harbour, the anemometers at Site 2 were either frozen or otherwise not functioning. At these extreme wind speeds, the correlation between the two locations would probably be easier to ascertain.

Although Daniel's Harbour is sheltered from the east, strong winds from the east-northeast or east-southeast are occasionally recorded. At the same time, the winds at Site 2 are very strong. Generally, when Daniel's Harbour recorded winds from the easterly quadrant at speeds greater than about 30 mph, the average hourly wind speed at Site 2 exceeded 65 mph and has approached 100 mph this past season. This would indicate an estimated one-minute wind speed of 80 mph and above.

4. Height Factors

The wind speeds obtained from the MWS's have not been extrapolated from the measurement level of 30 feet up to an approximate conductor level of 80 to 100 feet above the ground. Wind speed generally increases with height above the surface of the earth. The rate of increase is dependent on the speed of the wind, the variation with height of the air temperature, and the roughness of the terrain over which the wind is flowing.

There have been many studies undertaken and theories presented on the variations of wind speed with height above the surface. There is general agreement that wind profiles tend to obey a power law (De Marris, 1959; Johnson, 1959; and Munn; 1966). This relationship is normally used when neutral stability exists. The power law is of the form $V_2/V_1 = (Z_2/Z_1)^P$ where V_1 is the wind speed at some known level, Z_1, and V_2 is the wind speed at the desired level, Z_2. The exponent, P, is dependent on the atmospheric temperature lapse rate, wind speed and ground roughness. There is less agreement as to what the value of P should be. It is larger under a stable vertical temperature gradient and smaller for neutral and unstable conditions; it decreases with increasing wind speeds and increases with terrain roughness (De Marris, 1959; Davenport, 1968). The typical value used for P is 1/7 or 0.143 (Sherlock, 1952). However, Sherlock recognised that this P value was applicable to steady or mean winds and that guests were better described with a value of P = 0.0625. Shellard (1963), in the Tables of Surface Wind Speed and Direction Over the United Kingdom, used P values of 0.17 for mean hourly wind speeds and 0.085 for three-second gusts.

The majority of studies of wind profiles are made under regimes of light to moderate wind speeds and P values resulting from such studies may not be applicable to high wind speeds. Sissenwine et al. (1973), using high wind speed data collected at the Argonne National Laboratory instrumented tower in Argonne, Illinois, derived the empirical equation $P = 0.077 + 1.56/V_1$ where the limiting P value approaches 0.077 as V_1 becomes very large.

The Argonne National Summaries presents a percentage frequency of P values versus the ten-minute average wind speeds. The data for the table contains about 35,000 observations. For wind speeds greater than 24 mph the median P value is about 0.125. It now appears that a P value of 0.125 should be used for wind speeds up to approximately 50 mph, and 0.080 for wind speeds above that, and for all gust speeds. However, one must be cautious when extrapolating the wind speeds recorded at Site 2, and to a lesser extent Site 4, to the approximate conductor level. The depth of the air mass streaming over the exposed ridge at Site 2 is not known, and thus, the vertical wind profile is uncertain. If it is relatively shallow, the wind speed at 100 feet may even be less than that at 30 feet. Conversely, a deep layer may result in higher wind speeds at 100 feet than at 30 feet. It is likely that the layer of streaming air is at least 100 feet deep. Although the depth of the layer is not known, it is readily apparent that the wind speeds in the layer are much greater than in the free air at 2000 feet above sea level at some distance from the ridge.

B. Temperatures

Ambient air temperatures were recorded at the four sites and extracted from station data. Tables V-6 and V-7 show the minimum temperatures by month recorded at these locations. Temperatures at the station were generally near or slightly below normal during the entire winter, except for quite cold weather during the last two weeks of January and all of February. Both Gander and St. John's reported February to be the coldest month on record. On the fourth, Gander recorded -24°F, setting an all-time record by eight degrees. Goose Bay recorded -33°F in January and -31°F in February, only a few degrees off the records for each month. Battle Harbour also came close to setting new low standards.

TABLE V-6
MINIMUM STATION TEMPERATURES
RECORDED DURING WINTER OF 1974-1975
(Temperatures in Degrees Fahrenheit)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
St. John's	26	22	14	- 5	-10	9	14	26
Gander	23	18	2	-15	-24*	1	12	25
Deer Lake	17	15	-10	-22	-27	-20	- 5	22
Daniel's Harbour	25	20	- 2	-13	-14	- 2	9	24
Battle Harbour	19	9	- 2	-28	-24	- 6	12	21
Goose Bay	5	1	-15	-33	-31	-23	3	18

* New all-time low temperature

TABLE V-7
MINIMUM SITE TEMPERATURES
RECORDED DURING WINTER OF 1974-1975
(Temperatures in Degrees Fahrenheit)

	Nov	Dec	Jan	Feb	Mar	Apr	May
Site 1	**	8*	8*	- 7	0	13	16
Site 2	**	0*	-24	-25	- 7	7	17
Site 3	- 3	3*	-30*	-23	- 8*	12	14
Site 4	- 5	- 9	-25	-23	- 3	3	10

Period of record began mid-November, ended mid-May
** Missing data due to equipment problems
* Partial month of data due to equipment problems

Temperature measurement was difficult at times due to the temperature elements frequently being covered with ice and thus recording a constant temperature for days at a time. However, enough data was recovered to make several observations. Temperatures below 0°F were quite common at Sites 2, 3 and 4. During the cold wave in January and February, the temperature seldom rose above 0°F at Site 2.

Often these cold temperatures were accompanied by relatively strong winds. Some examples of this are shown below:

Site 1:	-3°F with 37 mph (46)*, -7°F with 28 mph (35)
Site 2:	+12°F with 101 mph (126), +8°F with 89 mph (111), -23°F with 52 mph (65), -24°F with 45 mph (56)
Site 3:	-12°F with 56 mph (70), -15°F with 53 mph (66)
Site 4:	-25°F with 47 mph (59)

* Values in parentheses are corresponding estimated one-minute averages.

No precise correlation was established between temperatures at the sites and any of the stations in Newfoundland and Labrador. However, some generalizations can be made. The temperatures at Sites 2 and 4 were usually 5° to 15°F lower than the corresponding temperature at Battle Harbour, except during extremely cold temperatures when there was little or no correlation.

C. Icing

In general, the number of hours of freezing precipitation was below normal at the six weather stations in Newfoundland and Labrador during the 1974-1975 measurement period. However, with the exception of Battle Harbour, the totals at each station were within one standard deviation of the mean. Table V-8 shows the number of hours of freezing rain and total freezing precipitation for the six stations from October, 1975, through May, 1975. The number of hours of freezing rain was near normal for most stations. The frequency of occurrence of freezing precipitation was near or above normal in November, but in December it was below normal at all stations except St. John's. January was well below normal at all stations except St. John's. Battle Harbour and Goose Bay reported no freezing precipitation during the entire month of January. This continued into February, a month characterized by clear, relatively calm, and extremely cold weather. All stations had less freezing precipitation than normal, with Battle Harbour and Goose Bay once again receiving none. No definite pattern existed during March. St. John's and Battle Harbour were well below normal, but Goose Bay was well above normal, and Gander was near normal. April was also quite variable. Gander recorded 47 hours of freezing precipitation, compared to an average of 21 hours. Almost half

TABLE V-8
HOURS OF FREEZING PRECIPITATION AT STATIONS
DURING WINTER OF 1974-1975
(Number of Hours of Freezing Rain in Parentheses)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	1974-75 Total	Avg.	Yrs. of Record
St. John's	0	1(0)	14(0)	39(12)	20(9)	19(7)	23(12)	6(0)	122(40)	153(46)	19
Gander	0	12(1)	11(0)	11(2)	19(10)	33(8)	47(22)	0	133(43)	158(31)	19
Deer Lake	1(1)	19(13)	6(1)	2(2)	3(3)	2(2)	0	0	33(22)	43(22)	6
Daniel's Harbour	2(2)	6(6)	0	2(2)	2(2)	6(4)	2(0)	0	20(16)	22(15)	6
Battle Harbour	0	0	0	0	0	4(1)	13(3)	3(3)	20(7)	49(17)	12
Goose Bay	3(2)	3(3)	2(2)	0	0	13(5)	13(0)	0	34(12)	35(15)	19

of the precipitation was freezing rain. Battle Harbour and Goose Bay were also above normal, but St. John's was slightly below normal. Only St. John's and Battle Harbour recorded freezing precipitation during May.

Significant amounts of ice were measured frequently at Sites 2 and 4. Site 1 did not record any substantial icing during the entire winter season. At Site 3, minor icing occurred on four occasions. On December 21, approximately 140 pounds of ice were recorded. Unfortunately, the MWS at Site 3 was iced up, and thus very low wind speeds were recorded. At Battle Harbour, northerly winds of 20 mph with peak gusts of 30 mph were blowing. The cloud bases were around 3000 feet, with only occasional light snow and snow flurries. This suggests that the ice was rime. Temperatures were too low to suggest wet snow to be the cause.

On the three other occasions, less than 100 pounds of ice were recorded. During the day preceding one of those icing periods, on March 24, wind speeds peaked at 35 mph; it is likely that the wind speeds were at least as high during the ice accumulation as the ice built up on the MWS's throughout the day.

At Site 2 there were 12 periods ranging in duration from 1 to 166 hours when ice accumulations exceeded six pounds per foot of cable. Maximum amounts occurred at the end of the longest icing period, between January 13-20, when 14.5 pounds per foot was recorded. On the average, about 540 pounds of ice remained on the cable during the entire period. The cloud bases at Daniel's Harbour were less than 2000 feet, and the temperature at Site 2 was generally less than 0°F; therefore, it is likely that most of the ice was in the form of rime.

Upon examination of the Ice Rate Meter Chart for the afternoon of January 19, is appears that the tower and IRM were vibrating and the rime ice was being blown off the cable by the winds whose peak gusts undoubtedly exceeded 100 mph. This would account for a gradual decrease of ice until early evening, when 150 pounds of ice remained on the line. This ice was probably a glaze coating that is not easily removed by wind and vibration. The ice then began to increase again, during which time the wind was vibrating the instrument, and another 570 pounds of ice, again likely to be rime, accumulated in only 14 hours. Late in the morning, this new ice dropped off the cable, again leaving the 150 pound glaze ice base. Assuming a density of 0.5g/cm^3 for the 570 pounds of rime and 0.9 g/cm^3 for the glaze base, the 720 pounds of ice translates into 4.1 radial inches of ice. By this time the MWS's were gradually icing up; although the recorded wind speed was only 25 mph, the erratic IRM trace indicates that the winds were quite high. If the winds peaked at 50 mph during the period of maximum icing (not an unreasonable assumption), the transverse wind load would be almost five pounds per lineal foot (the diameter of the cable used was 1.338 inches).

Unfortunately, wind speeds during most periods of maximum ice loads were not recorded due to the inability of preventing ice build-up on the instrumentation. Maximum combined wind and ice loads may have occurred on December 18. The hourly average wind speed was 70 mph before the cups blew off; this is equivalent to a one-minute wind speed near 90 mph. The winds at Daniel's Harbour were from the east-northeast at speeds up to 34 mph, which could indicate that the average hourly wind speed at Site 2 approached 100 mph. The IRM recorded 460 pounds of ice during this time before malfunctioning. At a density of 0.5 g/cm^3, this weight is equivalent to 3.0 radial inches. At 70 mph, the average transverse wind load was 7.6 pounds per lineal foot. It is likely that wind gusts were much higher, and that more ice accumulated on the cable after the recorder failed.

The climate in the vicinity of Site 4 is more continental than that at Site 2. This results in colder, drier winters, and hence less icing during late December, January, and February, as reflected by the icing data at Site 4. Icing that occurs in the fall and spring is usually in the form of glaze ice that results from freezing rain. In mid-November 400 pounds of ice was recorded. The MWS's were not in operation at this time; however, Battle Harbour reported light rain and fog with winds gusting as high as 40 mph. Freezing rain could have been falling at Site 4, with 400 pounds of ice translating into two radial inches of glaze. Significant ice loadings were not recorded again until December 27, when 525 pounds accumulated on the cable. This ice was likely in the form of rime, because cold temperatures were prevalent over the entire area. January and February were very cold and virtually ice-free. Temperatures rarely exceeded 0°F. Finally, on February 25, the temperature rose into the teens and 650 pounds of mostly rime ice, equivalent to 3.8 radial inches, was recorded. Up to three radial inches remained on the cable when the site was serviced on February 28. Ice remained on the cable in varying amounts through March. On March 14-15, approximately 340 pounds, or three radial inches, of rime combined with a wind speed of 56 mph to produce an average transverse wind load of 4.8 pounds per foot. Higher wind gusts undoubtedly resulted in higher transverse loads. Ice recorded on March 25 appears to be glaze. Temperatures in the mid-20's were too cold for wet snow to occur. Freezing rain and drizzle was reported at several Newfoundland stations, including Goose, and this was likely responsible to the 490 pounds of ice which was equivalent to slightly over two radial inches of glaze. Icing was frequent throughout April and May, reaching a peak on May 7, when 650 pounds of ice was recorded. The synoptic situation on this day suggested that freezing rain was falling in the area. Battle Harbour reported light rain, light snow, and ice pellets, with temperatures near freezing during this period. At Site 4, average hourly winds accompanying the precipitation were as high as 45 mph. However, one of the two MWS's at the site was completely frozen, suggesting that the other station may have been partially iced up. Thus, it is possible that wind speeds could have been even higher.

The winds at Site 4 tend to be very steady at high speeds. It has been observed that this steadiness can result in a resonant frequency being set up in the guys, cable, and towers. This violent shaking may have been responsible for a shifting in the base line of the IRM recorder. It is uncertain as to what effect this had on the magnitude of the tension recorded by the IRM.

VI. REFINED LOADING ESTIMATES

Not all loading estimates were changed as a result of the 1974-1975 measurement program. Also, several estimates have been revised because of changes in the proposed route since the previous reports.

A. Changes in Route Segments

Segments 1, 2, 3, and 8 remain essentially unchanged. Segment 4, the higher elevations west of Gander Lake, is no longer necessary since the latest version of the proposed route crosses lower terrain to the south. Segments 5 through 7, the portion of the route running from Grand Falls to Buchans and up through the Humber Valley, have been eliminated and are replaced by Segment 20, previously an alternate route. Segment 9 now runs from the top of the ridge of the Long Range Mountains to the west coastal plain east-southeast of Portland Creek. Segment 10 still runs along the west coastal plain, but it now extends from east of Portland Creek north to 51°N. The elevation is generally less than 500 feet. A new segment, 10a, covers the portion of the route east of the high lands of St. John, where the elevation ranges from 500 to 1700 feet. Segments 11 and 12 remained virtually unchanged. Segment 13, defined as that portion of Segment 12 with elevations between 500 and 1500 feet, has been shifted slightly west of the original route, resulting in slightly lower elevations with less exposure to the east. The remaining portions of the proposed route are still described by Segments 14 through 17, 20, and 23. The alternate routes to Goose Bay (Segments 18 and 19) and to Stephenville (Segments 21 and 22) are no longer being considered in this report.

B. Refined Loading Estimates by Route Segment

1. Icing

The results of the 1974-1975 measurement program have not indicated that a change in the icing estimates from the previous reports is necessary. With the exception of Site 2, no unusual ice loads were recorded or observed during a winter when icing appeared to be below normal at most Newfoundland stations. Site 2 did record severe ice buildups during the past winter, but this was to be expected, and the estimates presented in the November, 1973, report reflect this expectation. However, the proposed route has been shifted from its previous location near Site 2 to an area further east. The elevation is generally lower, which affords some sheltering from the east. This should result in less icing, although there are several points along the new route that are well exposed to easterly winds, which would be nearly perpendicular to the proposed route. It is difficult to estimate the impact of this channelling effect on the icing amounts in an area where slight changes in elevation or exposure can result in large wind and icing differences. Two areas in question are the high elevations on the west end of Inner Pond and a point on the route almost directly east of Site 2. It is likely that the icing in these areas is similar to that at Site 2, and thus the November, 1973, estimates for Segment 9 are still valid. The remaining portion of the route segment crossing the ridge should have perhaps ten percent less ice for each of the return periods.

2. Winds

The maximum gusts for all segments have been recalculated using the relationship of Sissenwine et al. (1973) as was discussed in Section V. A. 1. This will result in slightly lower gust factors than were used in the November, 1973 report. The sustained winds from which these estimated gusts were calculated are one-minute average wind speeds. The wind speeds listed under the combined wind and ice loads were derived using only the winds associated with icing. The method was described in detail in the September, 1974, report. These winds will generally be associated with rime icing.

The one-minute average winds assigned to Segments 1 through 3, 8, 11, and 20, should remain unchanged from those appearing in the earlier reports. The return period winds for Segment 13, the higher elevations north of the Strait of Belle Isle, were increased due to information gained from Site 4. Although the highest hourly average wind speed recorded during the past winter at the site was "only" 70 mph, eight percent of the winds were above 40 mph. This suggests a more gradual slope to the return period plot than was used in the November, 1973, report. Thus, while the 50-year return period wind speed for Segment 13 was increased by less than ten percent, the ten-year wind speed was increased by 20 percent. The winds for Segments 14 through 17 and 23 were increased only slightly, also based on the winds recorded at Site 4.

The peak winds recorded at Site 2 during the past winter were much stronger than was previously expected. It is obvious from these results that hourly average wind speeds in excess of 90 mph (or one-minute wind speeds in excess of 110 mph) occur there almost every year. The slope of the return period plot should be small, like that of Segment 13. With these facts in mind, the ten-year return period value for Segment 9 was increased by almost 60 percent to 126 mph, while the 50-year value of 140 mph is over 40 percent higher than the 98 mph given in the earlier report. The prevailing direction has been changed to easterly from the north-northwest given previously. Virtually all of the strongest winds recorded at Site 2 were from the eastern quadrant.

Tables VI-1 through VI-4 give the 10-, 25-, 50-, and 75-year return period values for wind, ice, and combined wind and ice for the 16 remaining segments of the Gull Island Transmission Line System. Wherever possible, the segment numbers from the November, 1973, report were retained in this report. They are listed in order running from Holyrood in the east to Gull Island in the west.

TABLE VI-1: 10-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Wind: Wind Dir.	Maximum Wind: Wind Speed (mph)	Maximum Wind: Max. Gusts (mph)	Maximum Ice Loads: Glaze Rad. in	Maximum Ice Loads: Glaze lb/ft	Maximum Ice Loads: Rime Rad. in	Maximum Ice Loads: Rime lb/ft (0.9)	Maximum Ice Loads: Wet Snow Rad. in	Maximum Ice Loads: Wet Snow lb/ft (0.5)	Combined Wind and Ice Loads: Wind Speed (mph)	Combined Wind and Ice Loads: Glaze Rad. in	Combined Wind and Ice Loads: Glaze lb/ft (0.9)	Combined Wind and Ice Loads: Rime Rad. in	Combined Wind and Ice Loads: Rime lb/ft (0.5)
1	Holyrood to Whithouse (< 500 ft)	W	75	91	2.9	17.4	3.8	15.0	0.8	1.5	40	2.2	11.3	2.4	7.2
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	80	97	3.5	23.6	4.3	18.4	0.8	1.5	43	2.8	16.5	2.8	9.1
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	70	86	2.4	12.9	3.1	10.8	1.2	2.6	36	1.7	7.7	1.7	4.3
20	Grand Falls to north end of Humber Valley	NNE	80	97	2.7	15.5	3.5	13.1	1.7	4.3	43	2.0	9.8	2.1	5.9
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	62	77	2.2	11.3	1.7	4.3	1.4	3.2	36	1.4	5.8	1.0	2.0
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	126	143	3.5	23.6	7.3	46.2	1.7	4.3	67	2.8	16.5	5.8	30.8
10	Along west Coastal Plain (≤ 500 ft)	SW	68	83	2.7	15.5	2.1	5.9	0.9	1.8	36	2.0	9.8	1.3	2.9
10a	East side of High Lands of St. John (500-1700 ft)	SW	80	97	2.7	15.5	4.3	18.4	1.7	4.3	44	2.0	9.8	2.8	9.1
11	51°N to Strait of Belle Island (≤ 500 ft)	NNE	75	91	2.9	17.4	3.8	15.0	2.2	6.3	40	2.2	11.3	2.4	7.2

TABLE VI-1: 10-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze Rad.	Glaze lb/ft	Rime Rad.	Rime lb/ft (0.9)	Wet Snow Rad.	Wet Snow lb/ft (0.5)	Wind Speed (mph)	Glaze Rad.	Glaze lb/ft (0.9)	Rime Rad.	Rime lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (≤ 500 ft)	NNW	75	91	2.7	15.5	2.1	5.9	2.2	[illegible]	40	2.0	9.8	1.3	2.9
13	Same area (500-1500 ft)	NNW	90	108	2.9	17.4	4.8	22.2	3.1	10.8	44	2.2	11.3	3.4	12.5
14	30 miles inland to 58°40'W (1000 to 1400 ft)	NNW	62	77	1.3	5.3	1.7	4.3	1.4	3.2	36	0.6	1.9	1.0	2.0
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	62	77	1.5	6.4	3.1	10.8	1.7	4.3	36	0.8	2.7	1.7	4.3
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	53	66	0.6	1.9	1.1	2.3	1.2	2.6	32	0.5	1.5	0.7	1.3
17	60°30'W to Gull Lake Valley (> 1400 ft)	NW	68	83	1.3	5.2	3.1	10.8	1.4	3.2	36	0.6	1.9	1.7	4.3
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	68	83	0.6	1.5	2.1	5.1	0.8	1.3	36	0.5	1.2	1.3	2.5

TABLE VI-2: 25-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad.	in lb/ft	Rad.	in lb/ft (0.9)	Rad.	in lb/ft (0.5)	Wind Speed (mph)	Rad.	in lb/ft (0.9)	Rad.	in lb/ft (0.5)
1	Holyrood to Whitbourne (< 500 ft)	W	85	102	3.4	22.5	5.0	23.8	1.0	2.0	44	2.5	13.8	3.0	10.2
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	90	108	4.0	29.4	5.5	28.1	1.0	2.0	47	3.1	19.4	3.5	13.1
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	80	97	2.9	17.4	4.0	16.3	1.5	3.6	40	2.1	10.5	2.0	5.4
20	Grand Falls to north end of Humber Valley	NNE	90	108	3.2	20.4	4.4	19.2	2.0	5.4	47	2.3	12.1	2.4	7.2
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	70	86	2.5	13.8	2.0	5.4	1.8	4.7	40	1.5	6.4	1.1	2.3
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	134	151	4.0	29.4	8.5	60.8	2.0	5.4	78	3.1	19.4	6.4	36.6
10	Along west Coastal Plain (≤ 500 ft)	SW	75	92	3.2	20.4	2.8	9.1	1.3	2.9	40	2.3	12.1	1.5	3.6
10a	East side of High Lands of St. John (500-1700 ft)	SW	90	108	3.2	20.4	5.5	28.1	2.0	5.4	48	2.3	12.1	3.5	13.1
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	85	102	3.4	22.5	5.0	23.8	2.5	7.7	44	2.5	13.8	3.0	10.2

TABLE VI-2: 25-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in	lb/ft	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)	Wind Speed (mph)	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	85	102	3.2	20.4	2.8	9.1	2.5	7.7	44	2.3	12.1	1.5	3.6
13	Same area (500-1500 ft)	NNW	96	114	3.4	22.5	6.0	32.7	3.5	13.1	48	2.5	13.8	4.0	16.3
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	70	86	1.7	7.7	2.0	5.4	1.8	4.7	40	0.7	2.3	1.1	2.3
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	70	86	1.9	9.1	3.8	15.0	2.0	5.4	40	0.9	3.2	1.8	4.7
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	60	74	1.0	3.7	1.4	3.2	1.5	3.6	36	0.5	1.5	0.3	1.5
17	60°30'W to Gull Lake Valley (≥ 1400 ft)	NW	75	91	1.7	7.7	4.0	16.3	1.8	4.7	40	0.7	2.3	2.0	5.4
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	75	91	1.0	3.1	2.8	8.2	1.0	1.7	40	0.5	1.2	1.5	3.1

TABLE VI-3: 50-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze Rad. in	Glaze lb/ft	Rime Rad. in	Rime lb/ft (0.9)	Wet Snow Rad. in	Wet Snow lb/ft (0.5)	Wind Speed (mph)	Glaze Rad. in	Glaze lb/ft (0.6)	Rime Rad. in	Rime lb/ft (0.5)
1	Holyrood to Whitbourne (< 500 ft)	W	93	110	3.8	27.0	5.7	29.9	1.2	2.6	48	2.8	16.5	3.4	12.5
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	98	116	4.4	34.5	6.2	34.6	1.2	2.6	51	3.4	22.5	3.9	15.7
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	88	106	3.3	21.4	4.7	21.4	1.8	4.7	44	2.3	12.1	2.4	7.2
20	Grand Falls to north end of Humber Valley	NNE	98	116	3.6	24.7	5.1	24.6	2.3	6.7	51	2.6	14.7	2.8	9.1
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	76	92	3.1	19.4	2.2	6.3	2.0	5.4	44	2.0	9.8	1.2	2.6
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	140	157	4.4	34.5	9.5	74.4	2.3	6.7	87	3.4	22.5	6.8	40.7
10	Along west Coastal Plain (≤ 500 ft)	SW	80	97	3.6	24.7	3.2	11.3	1.5	3.6	44	2.6	14.7	1.8	4.7
10a	East side of High Lands of St. John (500-1700 ft)	SW	93	116	3.6	24.7	6.2	34.6	2.3	6.7	51	2.6	14.7	3.9	15.7
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	93	110	3.8	27.0	5.7	29.9	2.7	8.6	48	2.8	16.5	3.4	12.5

36

TABLE VI-3: 50-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze Rad. In	Glaze lb/ft	Rime Rad. In (0.9)	Rime lb/ft (0.9)	Wet Snow Rad. in (0.5)	Wet Snow lb/ft (0.5)	Wind Speed (mph)	Glaze Rad. in (0.9)	Glaze lb/ft (0.9)	Rime Rad. in (0.5)	Rime lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	93	110	3.6	24.7	3.2	11.3	2.7	8.6	48	2.6	14.7	1.8	4.7
13	Same area (500-1500 ft)	NNW	100	118	3.8	27.0	6.7	39.7	3.8	15.0	51	2.8	16.5	4.4	19.2
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	76	92	2.1	10.5	2.2	6.3	2.0	5.4	44	1.0	3.7	1.2	2.6
15	58°40'W to 60°05'W (≥ 1500 ft)	NNW	76	92	2.3	12.1	4.3	18.4	2.3	6.7	44	1.2	4.7	2.0	5.4
16	60°05'W to 60°30'W (< 1300 ft and protected from north)	W	65	83	1.4	5.8	1.6	3.9	1.8	4.7	40	0.5	1.5	1.0	2.0
17	60°30'W to Gull Lake Valley (> 1400 ft)	NW	80	97	[illegible]	10.5	4.7	21.4	2.0	5.4	44	1.0	3.7	2.4	7.2
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	80	97	1.4	5.0	3.2	10.2	1.2	2.2	44	0.5	1.2	1.3	4.0

TABLE VI-4: 75-YEAR RETURN PERIOD VALUES

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Glaze Rad.	Glaze lb/ft	Rime Rad.	Rime lb/ft (0.9)	Wet Snow Rad.	Wet Snow lb/ft (0.5)	Wind Speed (mph)	Glaze Rad.	Glaze lb/ft (0.9)	Rime Rad.	Rime lb/ft (0.5)
1	Holyrood to Whitbourne (< 500 ft)	W	97	115	3.9	28.2	6.3	35.6	1.3	2.9	50	2.9	17.4	3.7	14.4
2	Whitbourne to 10 miles west of Clarenville (< 500 ft)	W	102	120	4.5	35.8	6.8	40.7	1.3	2.9	53	3.4	22.5	4.3	18.4
3	10 miles west of Clarenville to Grand Falls (≤ 800 ft)	WSW	92	109	3.4	22.5	5.1	24.6	2.0	5.4	46	2.4	11.3	2.6	8.1
20	Grand Falls to north end of Humber Valley	NNE	102	120	3.7	25.8	5.5	28.1	2.4	7.2	53	2.7	15.5	2.9	9.7
8	North end of Humber Valley to top of ridge of Long Range Mountains on north side of Main River ~ 49°50'N (300 ft to 1200 ft)	NNW	30	97	3.2	20.4	2.4	7.2	2.2	6.3	46	2.1	10.5	1.4	3.2
9	Crossing Long Range Mountains (1200 ft to 1800 ft)	E	143	160	4.5	35.8	10.0	81.7	2.4	7.2	92	3.4	22.5	7.5	48.5
10	Along west Coast Plain (≤ 500 ft)	SW	83	100	3.7	25.8	3.5	13.1	1.7	4.3	46	2.7	15.5	2.0	5.4
10a	East side of High Lands of St. John (500-1700 ft)	SW	102	120	3.7	25.8	6.8	40.7	2.4	7.2	53	2.7	15.5	4.3	18.4
11	51°N to Strait of Belle Isle (≤ 500 ft)	NNE	97	115	3.9	28.2	6.3	35.6	2.9	9.7	50	2.9	17.4	3.7	14.4

TABLE VI-4: 75-YEAR RETURN PERIOD VALUES (Continued)

Seg. No.		Maximum Winds			Maximum Ice Loads						Combined Wind and Ice Loads				
					Glaze		Rime		Wet Snow			Glaze		Rime	
		Wind Dir.	Wind Speed (mph)	Max. Gusts (mph)	Rad. in	lb/ft	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)	Wind Speed (mph)	Rad. in	lb/ft (0.9)	Rad. in	lb/ft (0.5)
12	Strait of Belle Isle to 30 miles inland from coast near corner of Quebec (< 500 ft)	NNW	97	115	3.7	25.8	3.5	13.1	2.9	9.7	50	2.7	15.5	2.0	5.4
13	Same area (500-1500 ft)	NNW	102	120	3.9	28.2	7.3	46.2	4.0	16.3	53	2.9	17.4	4.6	20.7
14	30 miles inland to 58°40'W (1000 ft to 1400 ft)	NNW	80	97	2.2	11.3	2.4	7.2	2.2	6.3	46	1.1	4.2	1.4	3.2
15	58°40'W to 60°05'W (≤ 1500 ft)	NNW	80	97	2.4	12.9	4.6	20.7	2.4	7.2	46	1.3	5.3	2.3	6.7
16	60°05'W to 60°30'W (≤ 1300 ft and protected from north)	W	68	83	1.5	6.4	1.8	4.7	2.0	5.4	42	0.5	1.5	1.3	2.9
17	60°30'W to Gull Lake Valley (≥ 1400 ft)	NW	83	100	2.2	11.3	5.1	24.6	2.2	6.3	46	1.1	4.2	2.6	5.1
23	Gull Lake to Churchill Falls (500-1600 ft)	NNW	83	100	1.5	5.5	3.5	11.9	1.3	2.5	46	0.5	1.2	2.0	4.8

VII. SIGNIFICANT RESULTS AND RECOMMENDATIONS

It is difficult to reach any absolute conclusions based on only seven months of on-site data. However, several observations can be made:

- The icing observed and/or measured during the winter of 1974-1975 was no more extreme than had been predicted in the earlier studies.

- Less ice occurred at Site 1 than had been expected; however, this was a relatively light icing year throughout the Province.

- Windspeeds recorded at Site 2 on the ridge of the Long Range Mountains were much higher than predicted in the 1973 study. Windspeeds recorded 30 feet above the surface of the ridge were much greater than at any levels below 5000 feet in the free air upstream of the ridge. It is quite apparent that windspeeds at Site 2 result from vertical convergence of the air stream as it is forced up and over the obstructing ridge. For the Site 2 location, the return period values developed for Segment 9 in the 1973 study are much too low. A new return period graph with a higher average annual extreme windspeed but with less slope was required. A mean annual extreme wind of 110 mph and a 50-year return period of 140 mph resulted.

- In a subjective sense, it appears that shifting the line route eastward at the crossing of the Long Range Mountains will result in some sheltering and reduce the wind loads on the line. The actual quantitative magnitude of this reduction is not readily apparent. The windspeeds in the more sheltered portions are likely to be as much as 20 percent lower than at Site 2; however, there are two locations along the new route where windspeeds comparable to Site 2 should be expected. Both locations appear to be vulnerable to the full force of the easterly winds. One location is at the top of a small east-west canyon and nearly directly east of Site 2. The other location is on the ridge just before the route dips down to Inner Pond.

- Comparison of winds measured at Site 4 with corresponding winds recorded at Battle Harbour resulted in small increases in the return period values predicted for the mainland segments of the route. Once again, the decreased slope of the graphs resulted in greater increases in the mean annual extremes in the 50-year return period values.

- The combined wind and ice load estimates were readjusted in accordance with the method described in the September 1974, study using winds which occurred in conjunction with icing conditions. Once again, Segment 9 in the Site 2 area has the highest transverse wind loads, combining 87 mph winds with 6.8 radial inches of rime for the 50-year return period value

- Major uncertainties exist in evaluating the sheltering which will be achieved by re-routing to the east of Site 2. The only way to realistically determine the magnitude of the sheltering is to instrument a site in that area in conjunction with instrumentation at Site 2. Experience during the winter of 1974-1975 dictates that power will be required to operate deicing equipment if the wind recorders are to be kept operational.

- Of prime importance during the winter of 1975-1976 is the erection of a 100-foot guyed tower to serve as a passive ice collector. This simple device will serve as a visual indicator of the change in ice accumulation with height. It was observed that during the 1974-1975 winter ice thickness on the 30-foot towers varied from 6 inches near the ground to 14 inches near the top. It will be important that, to evaluate the effect of successive storms, the ice be allowed to accumulate until it is melted or blown off. Pictures of this tower-collector will need to be taken at each site visit as well as a written description of what is observed.

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