NORTEC

WIND SPEED MEASUREMENTS AND EXTREME WIND SPEED ESTIMATES
ANCHORAGE-FAIRBANKS INTERTIE PROJECT

Prepared for

COMMONWEALTH ASSOCIATES, INC.
Jackson, Michigan

February, 1982

NORTHERN TECHNICAL SERVICES

ANCHORAGE, ALASKA

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ALASKA POWER AUTHORITY

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1.0 EXECUTIVE SUMMARY

1.1 General

Northern Technical Services (NORTEC) was contracted by Gilbert/ Commonwealth to establish four wind speed/direction and barometric pressure stations along the proposed Anchorage-Fairbanks Intertie Project route and to develop a meteorological model for evaluation and statistical summary report of extreme wind conditions at specific locations along the route.

1.2 Study Area

The study area followed the proposed route along the Parks Highway, Susitna River, Alaska Railroad and Nenana River from Willow to Healy, Alaska. Along the route four site locations were chosen in likely areas of high winds. These sites were selected after careful study of the potential of the topography for wind "funneling" and downslope effect. Site selection criteria also included available climatological data, the location of existing National Weather Service stations, the acquisition of land use permits, and accessibility by road. The locations selected along the Parks Highway were "Mile 243.3" (Moody Bridge), "Mile 221.0" (Carlo River), "Mile 217.0" (Windy) and "Mile 171" (Hurricane).

1.3 Method

Towers were erected at each site to provide standard 10 meter heights for the Weather Measure Model W102-P Skyvane anemometer, mountings for the Weather Measure B242 pressure sensor and Sea Data Corporation Model 650-8 data logger.

Wind speed and direction were sensed continuously and magnetic recordings were made of the "128 second" average wind speed direction and peak gusts. Barometric pressure was recorded every hour.

Periodic visits to the stations were made at 30-, 60-, and 90-day intervals to recover the data tapes, inspect the hardware and replace the batteries.

1.4 Field Data

Four wind data stations were programmed to record calculations of two minute average wind speed/directions and gusts. Due to intermittent failure of the Sea Data Logger (SDL) at "Mile 171", no usable data was obtained from this station. Maximum speeds recorded during this program are shown in Table 1 below:

	Maximum Wind Speeds	
Location	128 Sec Average MPH	Gust MPH
Mile 243.3	66.4	125.1
Mile 221	38.1	117.5
Mile 217	46.5	78.9

Table 1 Maximum Wind Speeds Recorded: January-June 1981

1.5 Extreme Values

The estimates of extreme wind wind presented in this report were fitted to the Fisher-Trippett Type I Distribution:

$$F(V) = \exp\left[- \exp\left(\frac{V - \mu}{\sigma}\right)\right]$$

Application of this distribution, also known as a double-exponential distribution, was made using the methods of Gringorten and Simiu.

Table 2 indicates the estimates of extreme wind speeds at each station for 25, 50, and 100 year periods at the 99 percent confidence levels.

Location	Period YRS	Estimated Extreme Speeds - MPH: 128-Sec Average	Estimated Extreme Speeds - MPH: Peak Gust
Mile 243.3	25	99	178
	50	104	188
	100	109	196
Mile 221	25	55	142
	50	57	150
	100	60	157
Mile 217	25	78	130
	50	82	137
	100	86	143

Table 2 Estimated Extreme Wind Speeds for various periods.

1.6 Extreme Speed Isotachs for the Transmission Line Corridor

Isotachs of the estimated 50 year, 99% confidence extreme wind speeds for the entire transmission line route have been drawn on the route selection maps. These isotachs, representing our professional judgment of the extreme speeds for the areas shown, are based on the 50 year extreme speed estimates made in this report for the Mile 217, 221 and 243.3 locations, in our first report for Summit and Talkeetna, and with qualitative consideration for the topography of the area.

1.7 Conclusions

The following specific conclusions have been drawn from this study:

(1) Highest average and peak gust wind speeds during the period of measurement were experienced during the winter months of January, February and March. Weekly maximum speeds were much lower during April, May and June.

(2) All of the highest winds speeds during the winter months were from a southerly direction. At Mile 217 all gusts in the 70 to 79 MPH range (the fastest at this location) were from 130 degrees through 150 degrees. At Mile 221 all gusts over 70 MPH were from 140 degrees through 240 degrees while all gusts over 100 MPH (7 cases) were from 180 degrees through 230 degrees. At Mile 243 all gusts over 70 MPH were from 160 degrees through 220 degrees while all gusts over 100 MPH (15 cases) were from 170 degrees through 200 degrees.

(3) At all locations, the gust factors were higher than gust factors typically found at non-mountainous locations. The minimum gust factors were found to be 1.72 at Mile 217, 2.57 at Mile 221 and 1.62 at Mile 243. These gust factors are the average for all speeds of the ratio of hourly maximum peak gusts recorded to the hourly maximum average speed. They are minimum gust factors since the maximum gust and maximum average speed were not necessarily recorded during the same 128 second period. Gust factors during periods of very high peak gusts were higher, especially at Mile 221 (sensor 8) where gust factors during gusts over 100 MPH were approximately 3.0 to 3.5.

2.0 THE STUDY AREA

2.1 Existing Climatological Data

In an October 1980 report, NORTEC reviewed available climatological data for the proposed Willow to Healy transmission line. Sufficient data was available to prepare estimates of extreme wind speeds at Anchorage, Fairbanks, Summit, Talkeetna and Healy. The Healy data was obtained from records kept by Golden Valley Electric Association at their Healy plant over a 2.4 year period. Although a 2.4 year period is far too short to be meaningful for climatological purposes, wind speeds of over 70 MPH had been recorded, resulting in all estimates of extreme wind speeds at Healy being in excess of 100 MPH. Furthermore, on December 13, 1967, a wind storm at Healy had blown down 2 towers of an existing Healy to Fairbanks transmission line even though these towers should have withstood a 100 MPH wind. Because of the manner in which these towers failed, investigators concluded that "wind loads of any consequence on the line will be caused by turbulent high velocity gusts of short duration rather than by steady winds."

Since the October 1980 study indicated the possibility of unusually strong winds in the Healy area, Commonwealth Associates, Inc. contracted with NORTEC to install anemometers to monitor wind speeds during the winter of 1980-81.

2.2 Topography of the Study Area

This study investigated wind speeds in the Nenana Gorge, a valley one or two miles wide running approximately north-south through the Alaska Range from Windy to Healy. The Alaska Range curves in a nearly 500 mile long arc through southcentral Alaska, passing just south of Healy in an approximately east-west direction. Elevations along the valley floor are about 2000 feet, while peaks in the immediate area rise to 6000 feet. Within about 25 miles to the WSW and ENE, peaks rise to about 75 miles to the WSW. The topography induces wind speeds greater than would be expected from the large scale meteorological situation through two mechanisms, funneling and mountain waves.

2.3 Funneling

Sensors 7, 8 and 15 were located in the Nenana Gorge, which runs approximately north-south through the WSW-ENE oriented Alaska range of mountains. Elevations in the valley reach approximately 2,400 feet, while mountain peaks in the immediate area are approximately 6,000 feet. Within about 25 miles to the WSW and ENE peaks rise to about 10,000 feet. Mt. McKinley, at 20,120 feet, is approximately 75 miles WSW. Thus, air flowing from south to north at low levels is funneled through the Nenana Gorge, with a resultng increase in speed over the unrestricted flow.

2.4 Mountain Waves

While the Nenana Gorge is a funnel through the Alaska Range, it is also in effect a mountain in itself. Approaching from the south through Broad Pass, the elevation of the valley floor rises to about 2,400 feet at Summit, the highest point in the valley. The Gorge then descends to an elevation of 1,300 feet at Healy. According to Klemp and Lilley "The hydrostatic mountain wave is one of the important wave forms generated in stable air passing over mountainous terrain having a characteristic width of 50 to 200 km".[1] They further note that "At certain locations in the lee of large mountain ranges, intense and damaging surface winds arise when these waves attain large amplitude". Winds of this nature are often observed in the Boulder, Colorado area, where these severe downslope wind storms have, during several recent winters, resulted in winds of over 100 MPH. A storm during January 1982 resulted in over $10 million damage in the Boulder area. Wayne Sangster, of the National Weather Service, has developed an objective forecast technique for Colorado downslope winds.[2] Sangster, using regression to identify predictors of strong downslope winds, found that vertical temperature differences and pressure surface height differences were important. Brinkman, investigating Boulders wind storms, found that "Upper air conditions favorable for Boulder's wind storms were found to be the existence of a stable layer above the mountain top and a less stable layer above that. Winds are high at the level of the stable layer but, contrary to general belief, strong winds in the upper atmosphere are not necessary".[3] Also, "At the surface, a strong pressure gradient across the mountains is clearly important but may be superimposed upon either a general pressure rise or fall.".

3.0 METEOROLOGICAL EQUIPMENT

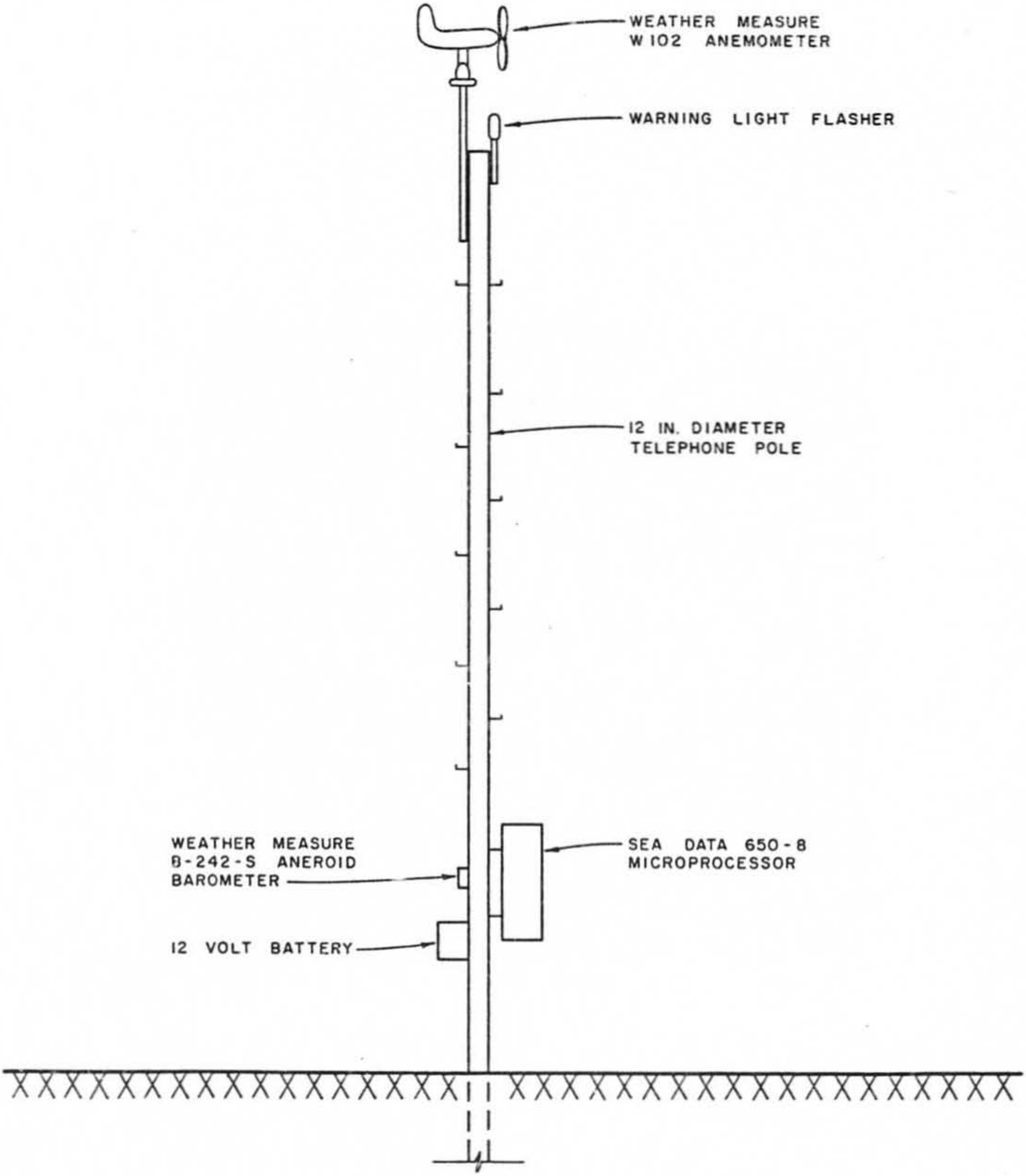
A diagram of the meteorological measuring equipment installed at each site is shown in Figure 1. Figures 2 through 5 show the actual site locations at different times of year. Detail descriptions of the sensors and data acquisition system follow.

3.1 Weather Measure W102-P Wind Speed Sensor

The W102 Skyvane I Wind Sensor is designed to withstand severe environments such as icing and hurricane winds. Wind speed is measured by means of a four-bladed propeller which is coupled to a DC generator. The balanced propeller fabricated of a special low density fiberglas-reinforced plastic to yield a maximum sensitivity and strength. The DC generator is used in applications where a rectifier circuit is not practical. It has excellent linearity but somewhat higher threshold due to brush friction. Dual wiper precious metals slip rings are used to bring the wind speed signals to the base of the sensor. These have been essentially trouble-free after many years of use, even in adverse environments. Wind direction is measured by means of a dual wiper 1000 ohm long life conductive, plastic potentiometer housed in the base of the sensor. It is attached to the stainless steel shaft which supports and rotates with the upper body assembly. The sensor body is constructed from fiberglas reinforced plastic mounted on a cast aluminum base.

Specifications

Size:	29 3/4L x 30"H
Propeller:	4 Blades, 13 3/4", Fiberglas reinforced plastic
Starting Speed:	1 MPH (0.45 m/s)
Complete Tracking:	3 MPH (1.35 m/s)
Maximum Speed:	200 MPH (91 m/s)
Wind Speed Sensor:	DC generator: 15VDC @ 100 MPH(45.5 m/s)
Distance Constant (30 MPH(13.6 m/s)):	6.2' (1.9m)



CONFIGURATION OF 10-METER
REMOTE METEOROLOGICAL STATION

Figure 2. Meteorological Station Mile 243.3 (Moody Bridge)

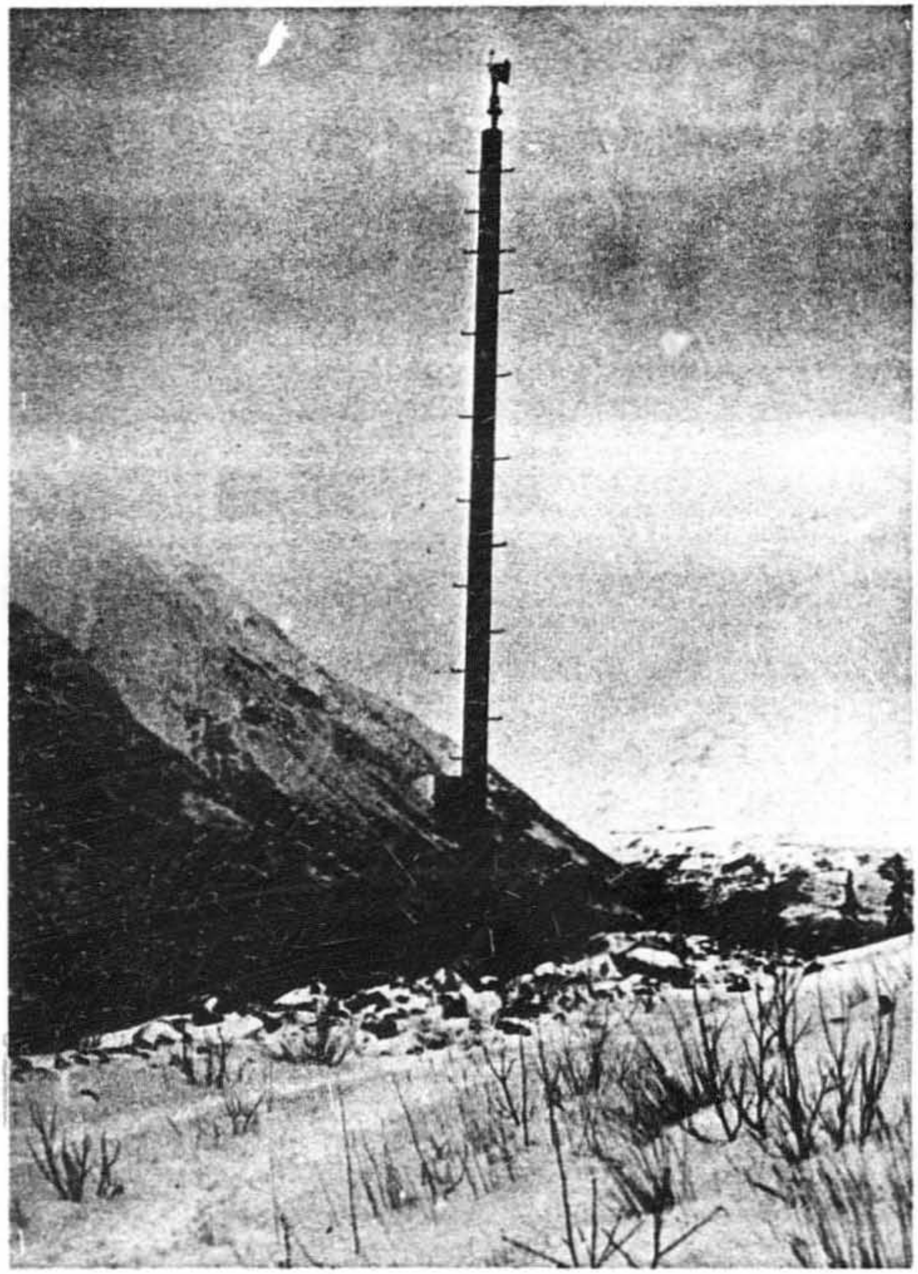


Figure 3. Meteorological Station Mile 217 (Windy)

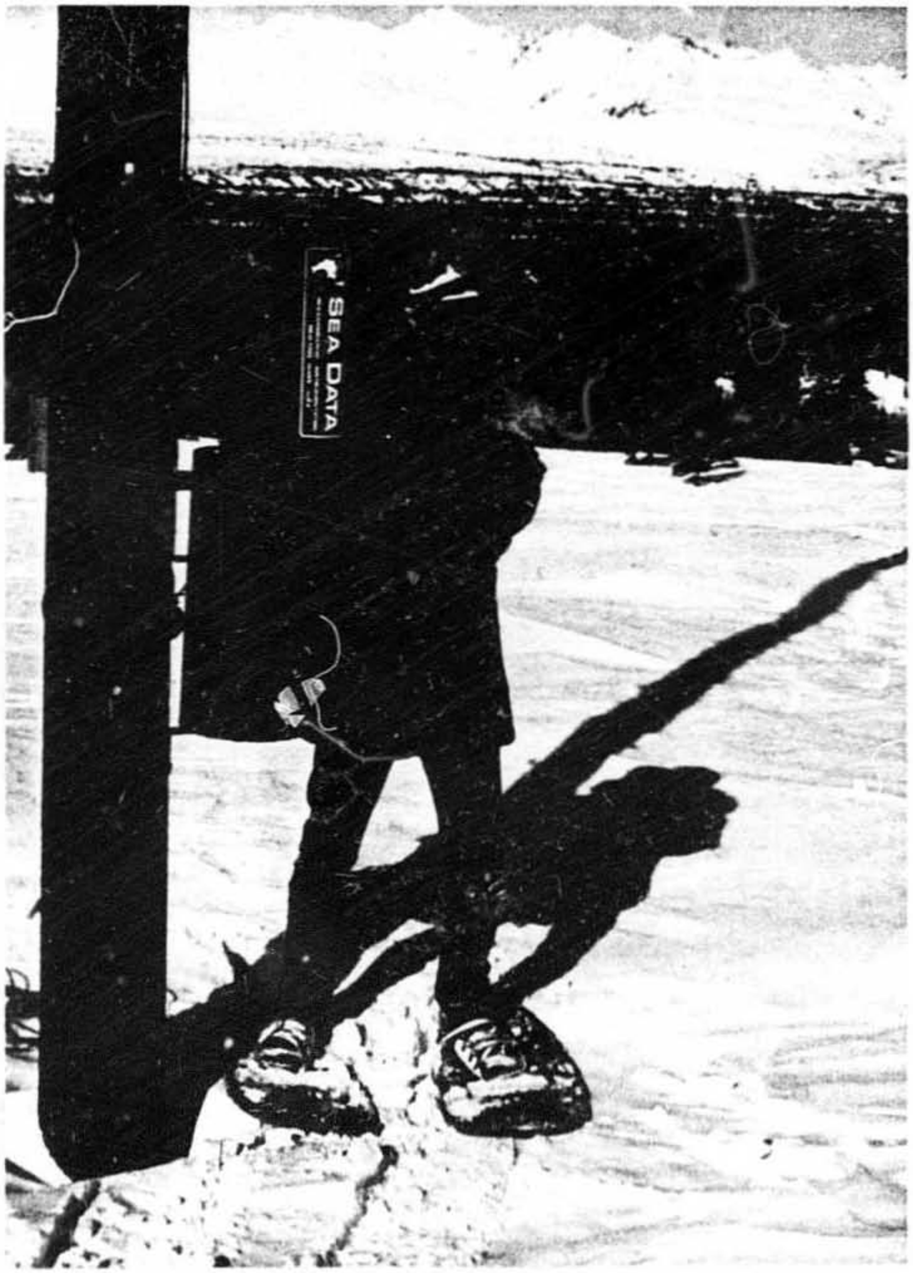


Figure 4. Sea Data Logger at "Mile 172"

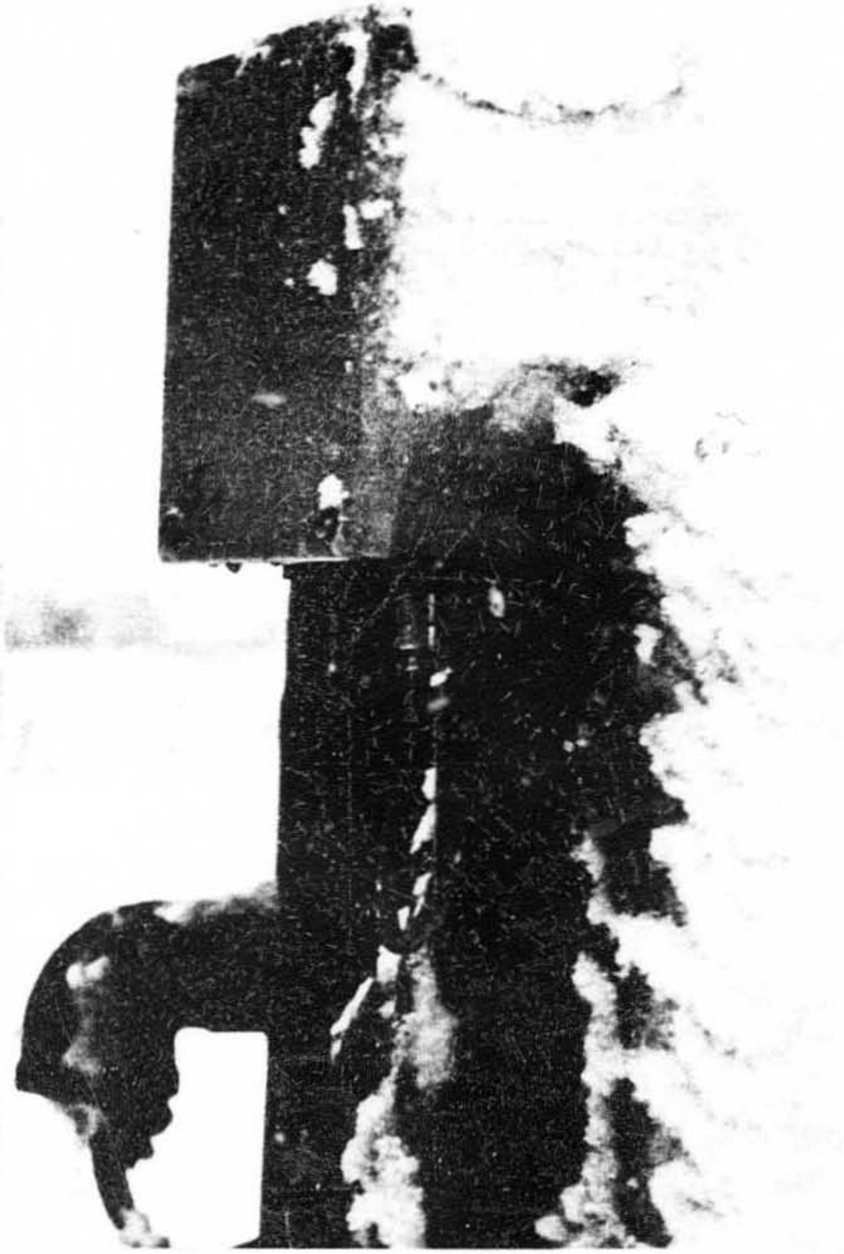


Figure 5. Barometric Pressure Sensor at Station "Mile 172"

Accuracy:	$\pm$ 1% below 25 MPH (9.1 m/s); $\mp$ 3% above 25 MPH (9.1 m/s)
Time Constant (30 MPH(13.6 m/s)):	0.145 sec.
Wind Speed Sensor:	1000 conductive plastic potentiometer, dual wiper - standard. Other values or sine-cosine on special order. 115VAC selsyn motor may be substituted.
Weight/Shipping Weight:	11 3/4 lbs./25 lbs. (5.3 Kg/11.4 Kg)

3.2 Weather Measure B242-S Barometer Sensor

The Model B242-S contains a multicell aneroid sensor which positions the core of a linear variable differential transformer (LVDT). The output voltage of the LVDT, which is linear with core position (hence with pressure), is amplified to the level desired. All mechanical and electrical components are designed to achieve linearity and a low temperature coefficient. The aneroid cells are of NiSPAN-C and have a thermal expansion coefficient of essentially zero.

The gain and zero point of the amplifier may be adjusted to produce an output varying from 0 to 1 VDC over any 100 mb interval between 600 and 1065 mb. The gain is normally set at the factory and the zero point set in the field to correspond to the elevation of the installation.

The sensor housing is airtight and provided with a pressure fitting so that atmospheric pressure in the range of 600 mb (to 1050 MB) may be measured.

Specifications:

Range:	Any 100 mb interval from 600 to 1065 mb
Linearity:	$\pm$ 0.5 mb over 100 mb interval (0-40°C)
Resolution:	Infinite
Ambient Temperature:	-20 to 40°C
Power Required:	10 to 12 VDC
Output:	0 to 0.2 VDC

3.3 Sea Data Logger Model 650-8

The Model 650-8 Data Logger is designed to record the amplitudes of a number of analog inputs at regular intervals. Both the number of channels to be recorded and the recording interval are determined by the setting of rotary switches on the front panel of the logger. In the recording process, the analog inputs are first digitized and then recorded on a cassette tape, along with a time word plus a record header that records the measurement rate switch setting and 11 additional parallel inputs. High density recording methods are used, making it possible to record as many as 16 analog inputs once every minute for 40 days, without exceeding the capacity of a 450' cassette tape.

High density recording in the 650-8 is accomplished by using four cassette tracks, and shortening inter-record gaps through the use of a stepping motor drive. These two devices make it possible to write 10 megabits of data on a 300' cassette without increasing the writing density per channel above 800 bpi. High density writing is thus accomplished without sacrificing reliability. The recorder electronics employs all C-MOS circuitry to minimize power drain, yielding a typical power-off drain of less than 0.8 mA for the 650-8.

The cassette transports are built on precision machined castings, ensuring the close tolerances necessary for high reliability. In addition, the unusual four-track head is mounted with cast and precision-ground guides for accurate tape guiding. Finally, a tough industrial 200 step per revolution stepping motor with unique 8-phase current-source drive yields trouble-free tape motion for the 800 bpi phase-encoded recording.

Specifications:

Scan Interval:	1 to 2048 sec in 12 steps
Channel-scan Rate:	15 msec per channel
Channels:	8 single-ended analog
Resolution:	Each channel is converted to a 12-bit binary word
Input range:	-5 to +5 volts standard
Selector:	Switch selects 2, 4, 6, 8, (12 or 16) channels
Connectors:	Glass-epoxy terminal strip on rack for connection to user-wired endcap penetrator pigtails
Data Storage Medium:	Standard digital certified 300' or 450' cassette tapes
Capacity:	10 megabits on 300' cassette yielding 536,000 12-bit data
Format:	12 parallel-input bits from user 4 bits showing time switch setting on front panel 20-bit internally-generated time word 4 or 8 analog 12-bit data channels--panel selected 4 parity bits (one for each track)
Timebase Accuracy:	16.384 kHz quartz crystal Stable to +/-10 ppm over 10°C to 40°C Correctable to +/-5 ppm over -5°C to +55°C
Power:	SBD-4 Sea Data 15 volt, 20 Ahr Alkaline battery pak
Rack Size:	12" long by 5.8" diameter
Weight:	10 pounds, including Alkaline SDB-4 battery

3.4 O.A.R. XF-501 Series Flasher

The O.A.R. XF-500 Series of Surface Flashers are high-intensity, general purpose xenon markers designed to aid in relocation of surface objects such as buoys, towed and stationary platforms, free-floating instruments, etc. A xenon gas discharge lamp element gives a high-intensity 0.1 watt-second flash at a rate of 1 flash every 2 seconds (standard settings) that can be seen at horizontal distances of 6 to 10 miles under clear, dark atmospheric conditions. Slant visibility range from aircraft, under similar operating conditions is up to 25 miles. The unit has a clear, solid plastic lens installed on top of a cylindrical PVC case. It is designed for short or long term operation in the marine environment. Lamp-life is estimated to be in excess of 1 year of continuous operation (at standard output level and flash rate setting). Design configurations are available for operation from self-contained or external DC power, and unit dimensions/ weight vary accordingly. Flash rate settings of 1 flash/second to 1 flash/4 seconds are optional, along with increased or reduced light intensity level.

Specifications:

Light Output:	Typically 0.07 lumen-second/flash/foot^2 at a distance of 2 feet
Power Input:	0.1 Joule (watt second) minimum
Lamp:	Type - Xenon gas discharge
Flash Rate:	Standard - 1 flash/2 seconds
Duty Cycle:	Standard - Photocell shutoff circuit turns lamp off during normal daylight hours
Power Supply:	Standard - 12VDC @ 20 ma
Electronics:	Latest solid state components
Construction:	Sealed PVC tubing case with solid, clear plastic lens. Mounting collar with 1 1/4" male pipe threads. Stud-type power input terminals.
Weight:	0.5 pound (250 grams)

3.5 Meteorological Towers and Permits

Land use permits and installation of 10-meter towers were the responsibility of Dryden and LaRue Consulting Engineers. The towers were standard telephone poles approximately 35 feet long. Height of the anemometer was adjustable when mounted at the top of the telephone pole to insure the proper distance (10-meters) above the ground. Data loggers, barometers and batteries were mounted on the side of the telephone pole at a height of approximately six feet above the ground.

4.0 EXPERIMENTAL DATA ACQUIRED

4.1 Period of Record

Acquisition of data began January 8, 1981. All sensors were inoperative during the period February 14 through February 19, 1981, apparently due to low temperatures (approximately -30°F) in the area. However, synoptic data indicates the winds in the area would be light during that period. Sensor 7 recorded data through the week of May 14, sensors 8 and 15 recorded data through the week of June 4, 1981.

4.2 Maximum Wind Speeds Recorded

The maximum wind speeds recorded during the experiment are shown in Table 3 below.

	Maximum Wind Speed-MPH	
	128-Sec Average	Peak Gust
Sensor 7 Mile 217 Parks Hwy.	46.5	78.9
Sensor 8 Mile 221 Parks Hwy.	38.2	117.5
Sensor 15 Mile 243.3 Parks Hwy.	66.4	125.1

Table 3 Maximum Wind Speeds Jan. 8 - June 10, 1981.

Weekly maximum wind speeds are tabulated below for each sensor. All maximum speeds recorded during the experiment occurred during January or February. Furthermore, the weekly maximums showed a sharp decline at the beginning of April.

TABLE 4 Weekly Maximum Wind Speeds Recorded in MPH.

Week	Dates	Maximum Average #7	Peak Gust #7	Maximum Average #8	Peak Gust #8	Maximum Average #15	Peak Gust #15
1	1/ 8-1/14	33.9	61.1	30.5	106.4	50.9	85.9
2	1/15-1/21	36.0	64.1	38.2	117.5	55.0	92.8
3	1/22-1/28	39.4	68.0	28.2	98.4	51.8	93.4
4	1/29-2/4	46.5	78.9	29.6	87.4	66.4	118.3
5	2/ 5-2/11	27.9	42.6	28.0	60.8	46.3	78.2
6	2/12-2/18	32.1	54.4	19.8	33.0	12.6	18.6
7	2/19-2/25	28.8	49.2	33.8	84.3	66.0	125.1
8	2/26-3/4	36.8	65.7	31.8	94.7	64.8	112.4
9	3/ 5-3/11	34.4	61.5	21.8	62.0	40.9	69.9
10	3/12-3/18	39.2	69.4	30.2	85.2	50.3	82.9
11	3/19-3/25	32.2	46.5	18.8	40.2	33.5	50.8
12	3/26-4/1	20.7	36.3	21.7	40.3	42.7	71.6
13	4/ 2-4/8	25.4	48.3	15.2	29.9	29.7	M
14	4/ 9-4/15	31.0	41.9	18.5	34.7	29.2	M
15	4/16-4/22	20.2	33.8	18.6	31.7	32.6	M
16	4/23-4/29	19.3	30.4	14.1	20.9	27.6	M
17	4/30-5/6	27.2	43.0	22.3	43.5	43.5	M
18	5/ 7-5/13	19.9	31.3	20.7	39.8	26.0	M
19	5/14-5/20	25.3	39.6	21.7	32.7	46.4	M
20	5/21-5/27	M	M	18.8	29.5	29.7	47.9
21	5/28-6/3	M	M	18.8	29.5	28.9	48.3
22	6/ 4-6/10	M	M	22.5	31.6	39.3	64.5

4.3 Prevailing Wind Direction

A two-way frequency table of wind direction versus wind speed (both average and peak gust) prepared for each site using the SPSS "CROSSTABS" procedure is included in the Appendix. (In referring to these charts note that wind speeds in MPH are labelled across the top.) At each site the strongest winds were from the southerly quadrant. For example, at sensor 15, which experienced a maximum wind of 125.1 MPH during the experiment, the peak wind speeds from northerly directions (270° through 090°) were less than 30 MPH. At sensor 15 all peak gusts of 60 MPH or more were from 150 degrees through 220 degrees, all gusts of 100 MPH or more (15 hours total) were from 170 degrees through 200 degrees.

Also presented are simpler, but less informative, histograms of wind speed versus direction for each site. The histograms of direction of average wind speed include only those cases in which the wind speed was greater than or equal to 30 MPH, the histograms for direction of peak wind speed include only those cases with gusts greater than or equal to 40 MPH. Note that SPSS prints only the directions for which cases occurred. Thus, for example, the histogram for PKDIR 15 shows the frequency of hourly recordings for codes 14 through 22, representing directions 140 degrees through 220 degrees. No gusts of 40 MPH or more were recorded from directions 230 degrees clockwise through 130 degrees (Codes 1 through 13 and 23 through 36), as indicated by an absence of these codes. It's interesting to note that sensor 7 had 296 cases, sensor 8 had 394 cases, and sensor 15 had 844 cases of gusts $\geq$40 MPH. Average ind speeds were greater than or equal to 30 MPH for 114 cases at sensor 7, 15 cases at sensor 8 and 634 cases at sensor 15, out of approximately 1,650 cases.

4.4 Gust Factors

In order to evaluate the gust factors at the 3 sites the SPSS Scattergram procedure was used. This procedure produced the graph shown in Appendix (TAB "GUST") in which P7, sensor 7 maximum peak gust wind speed is plotted against A7, sensor 7 average wind speed. Scattergram does linear regression of P7 against A7, and, in this case the statistics indicate a regression equation of $P7 = 1.72 * A7 - 1.09$. The constant term in this equation should be zero of course, but -1.09 is quite close. The slope, 1.72, indicates that the average wind speed should be multiplied by 1.72 to find the corresponding gust speed. The Scattergram for sensor 15 produced very similar results, with a slope of 1.62. At sensor 8 the slope was computed to be 2.57.

At all sensors, the maximum average wind speed was the greatest 128 second average wind speed recorded during a given hour. The maximum peak wind speed is the maximum instantaneous wind speed recorded during the same hour. However, it is not possible to determine from the data if the maximum average and the maximum peak wind speed occurred during the same 128 second period of each hour. Therefore the slope of each regression equation represents a minimum gust factor. In general it seems likely that maximum peak wind speed would occur with the maximum average speed. However the appearance of the P8/A8 Scattergram creates room to speculate if this is always the case. In examining the graph keep in mind that 1644 cases were plotted, and the SPSS prints a star for each plotted case, the number 2 through 8 when 2 through 8 cases occupy the same location, and the number 9 when 9 or more cases occupy the same location on the graph. The large majority of the cases are concentrated in the area where P8 is less than 50 MPH, and these cases also account for the majority of input to the R-square of .82. Therefore, in some instances it appears that the gust factor at sensor 8 was 3.0 or greater, and that a linear relation between gust and average speeds at sensor 8 during gusts above 80 MPH did not exist.

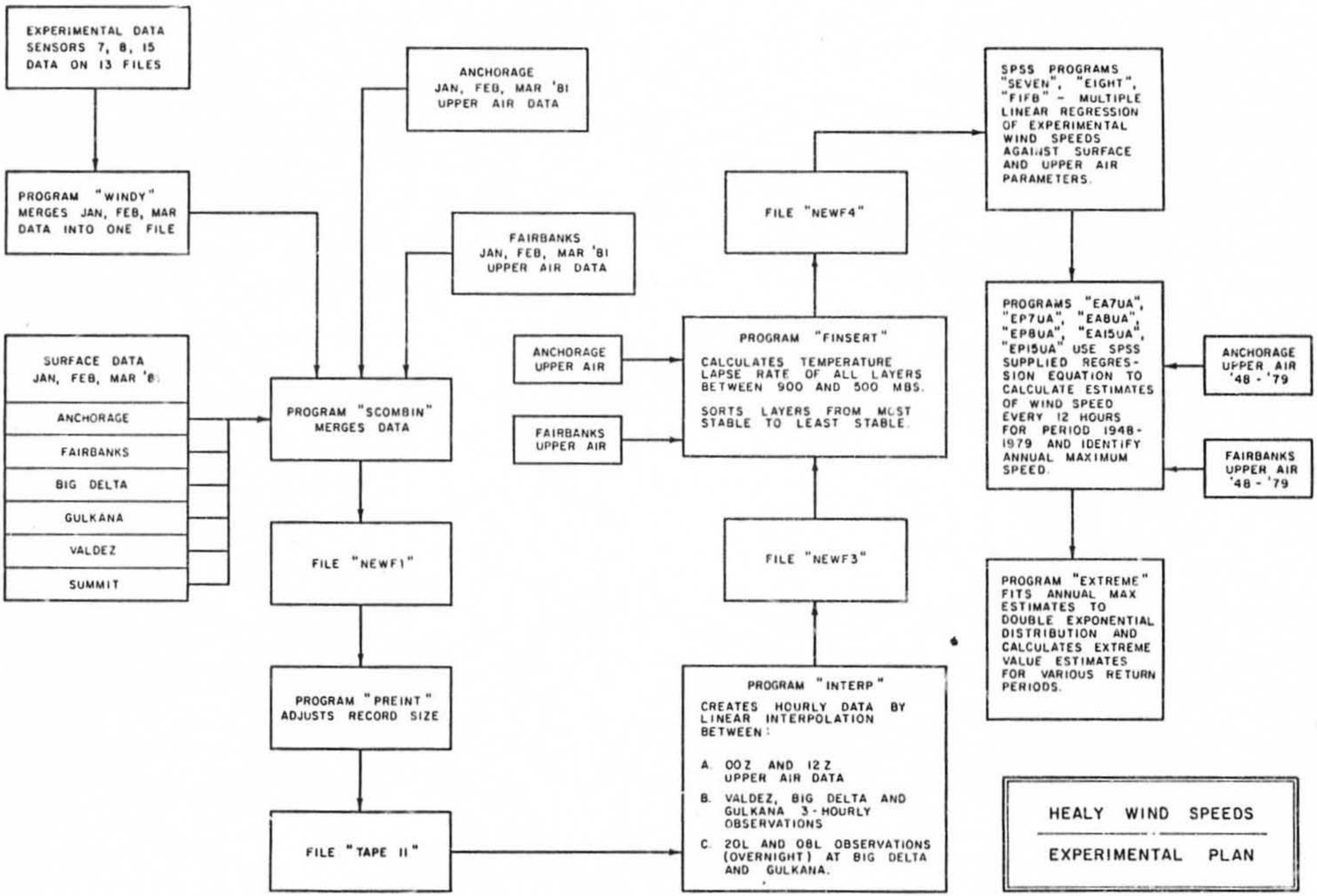
5.0 THE STATISTICAL MODEL

5.1 Experimental Plan

The essential feature of this method is the correlate the wind speed observed at these sites with surface and upper air meteorological parameters recorded at surrounding locations having long periods of record. The correlation was accomplished using the multiple, linear, least-squares reqression procedures of the Statistical Package for Social Sciences (SPSS). The overall plan of the model is shown in Figure 2.

5.2 Surface Data

Surface pressure differences were the first parameters investigated since wind is the result of pressure differences, and begins to flow from areas of high atmospheric pressure to areas of low atmospheric pressure. However, the wind is deflected to the right by coriolis force, and thus flows clockwise around areas of high pressures and counterclockwise around areas of low pressure. Therefore, since we have established that the strongest winds in the experimental area are always approximately southerly, we would expect to correlate those wind speeds with east-west surface pressure differences generated by low pressure systems located south or west of the Healy area. While there are no ideally located weather observing stations for measuring east-west gradients in the experimental area the following pressure differences were investigated: Anchorage-Valdez (AV), Anchorage-Gulkana (AG), Fairbanks-Big Delta (FB), Fairbanks-Gulkana(FG), and Fairbanks-Summit (FU). However, only intermittent 1981 data was available for Summit, and the period of record for Valdez (since 1976) was much too short, so AV and FU were deleted from the regression equation.



EXPERIMENTAL DATA SENSORS 7, 8, 15 DATA ON 13 FILES
PROGRAM "WINDY" MERGES JAN, FEB, MAR DATA INTO ONE FILE
SURFACE DATA JAN, FEB, MAR '81
ANCHORAGE
FAIRBANKS
BIG DELTA
GULKANA
VALDEZ
SUMMIT
ANCHORAGE JAN, FEB, MAR '81 UPPER AIR DATA
FAIRBANKS JAN, FEB, MAR '81 UPPER AIR DATA
PROGRAM "SCOMBIN" MERGES DATA
FILE "NEWF1"
PROGRAM "PREINT" ADJUSTS RECORD SIZE
FILE "TAPE 11"
PROGRAM "INTERP"
CREATES HOURLY DATA BY LINEAR INTERPOLATION BETWEEN:
A. 00Z AND 12Z UPPER AIR DATA
B. VALDEZ, BIG DELTA AND GULKANA 3-HOURLY OBSERVATIONS
C. 20L AND 08L OBSERVATIONS (OVERNIGHT) AT BIG DELTA AND GULKANA.
FILE "NEWF3"
ANCHORAGE UPPER AIR
FAIRBANKS UPPER AIR
PROGRAM "FINSERT"
CALCULATES TEMPERATURE LAPSE RATE OF ALL LAYERS BETWEEN 900 AND 500 MBS.
SORTS LAYERS FROM MOST STABLE TO LEAST STABLE.
FILE "NEWF4"
SPSS PROGRAMS "SEVEN", "EIGHT", "FIFB" - MULTIPLE LINEAR REGRESSION OF EXPERIMENTAL WIND SPEEDS AGAINST SURFACE AND UPPER AIR PARAMETERS.
PROGRAMS "EA7UA", "EP7UA", "EA8UA", "EP8UA", "EA15UA", "EP15UA" USE SPSS SUPPLIED REGRESSION EQUATION TO CALCULATE ESTIMATES OF WIND SPEED EVERY 12 HOURS FOR PERIOD 1948-1979 AND IDENTIFY ANNUAL MAXIMUM SPEED.
ANCHORAGE UPPER AIR '48 - '79
FAIRBANKS UPPER AIR '48 - '79
PROGRAM "EXTREME" FITS ANNUAL MAX ESTIMATES TO DOUBLE EXPONENTIAL DISTRIBUTION AND CALCULATES EXTREME VALUE ESTIMATES FOR VARIOUS RETURN PERIODS.
HEALY WIND SPEEDS
EXPERIMENTAL PLAN

Figure 6

5.3 Upper Air Data

Because of the possibility of the funneling and mountain wave mechanisms previously described, upper air data was selected for the regression equation. Initially, the height, temperature, relative humidity, wind direction, and wind speed from the 850 millibar, 700 millibar, and 500 millibar levels were included. Later program "Finsert" was developed that calculated the lapse rate of every reported layer in the upper air observations between 900 and 500 mb and sorted the layers in order from the most stable to least stable. Therefore, the height, pressure, thickness, temperature lapse rate, base temperature, relative humidity, wind speed and wind direction of the 6 most stable layers were incorporated into the regression equation. A complete list of variable names and definitions is given in Appendix 1.

5.4 Regression Results

The complete regression results have been included in the Appendix 2. As an example, we examine the regression of P15 against the surface and upper air variables (see tab marked "P15 REGR SUM"). As seen on Page 10 of the SPSS output there were 1841 cases. The mean and standard deviation of each variable are shown here, note the P15 had a mean speed of 38.67 MPH. Regression results are shown in the summary table on P-27 of the output. The best single predictor of P15 is entered into step 1. In successive steps additional variables are entered in order from the greatest improvement of the R square, in conjunction with the variables already in the equation, to the least improvement in R^2. We note that FG, the Fairbanks-Gulkana pressure difference, is the best single predictor of the peak wind speed at sensor 15. AT58, the Anchorage 500 mb temperature - the Anchorage 800 mb temperature, is entered in step 2 since it increases the R square by .05182, even though an R of .02128 indicates there is virtually no direct correlation between P15 and AT58. The simple R of A7Y, entered on step 3, is -.66683, indicating nearly as good a correlation with P15 as FG has. The 60th step indicates an R^2 of .74529. That is, the regression equation explains 74% of the variation in wind speed.

After many runs, experimenting with different variables, the following results were obtained.

	R-SQUARE					
	A7	P7	A8	P8	A15	P15
Upper Air Data Only	.62	.64	.56	.64	.68	.69
Upper Air and Surface Data	.64	.67	.58	.65	.73	.74

Since the inclusion of surface data resulted in only a 2 to 5 percent increase in the accuracy, it was decided to use only the upper air data in calculating the estimates.

The results of the regressions for each sensor using only upper air data are shown in Appendix 2. We note that A7Y, the Y component of the Anchorage 700 mb wind speed, is always the best single predictor of site wind speed.

5.5 Calculation of the Estimates

Upper air data for Anchorage and Fairbanks for the period 1948 through 1979 was obtained from the National Weather Service. Six programs, EA7UA, EP7UA, EA8UA, EA15UA, EP15UA, were prepared to calculate the estimates of average and peak wind speeds at each site. The 6 programs were identical except for the coefficients of the predictor variables. Each program calculated an estimate of the site wind speed for every 12-hourly upper air observation from 1948 through 1978. However, 1948 and 1949 were found to have considerable missing data, making it impossible to calculate the estimates about half the time. Therefore, estimates from these years were not used.

6.0 EXTREME VALUE STATISTICS

6.1 Extreme Value Distributions

The three distributions that have been used to model extreme wind speeds are:[5]

1. The Fisher-Tippett Type I Distribution:

$$F(V) = \exp\left[- \exp\left(\frac{V - \mu}{\sigma}\right)\right]$$

The Type I distribution was used by <u>Gumbel</u>. The double-exponential distribution advanced by Gringorten as generally best for extreme values in the Type I distribution. The National Building Code of Canada assumes a Type I distribution of extreme wind speeds.

2. The Fisher-Tippett Type II Distribution:

$$F(V) = \exp\left[- \left(\frac{V - \mu}{\sigma}\right)^{-\gamma} \right]$$

Also known as the Frechet Distribution, the Type II distribution has been advanced by <u>Davenport</u> and <u>Thom</u> for use in describing the distribution of extreme wind speeds. Type II distribution is assumed by certain American National Standards. If $\gamma = \infty$, a Type II distribution reduces mathematically to a Type I distribution.

3. The Weibull distribution:

$$F(V) = 1 - \exp\left[- \left(\frac{V - \mu}{\sigma}\right)^{\gamma} \right]$$

A Weibull distribution with $\gamma = 2$ is called Rayleigh distribution.

In all three distributions u is called the location parameter, because it specifies the location of the center of the distribution. Usually $\overline{V}$, the mean of the observed extreme wind speeds, is used to approximate μ . The scale parameter σ is a measure of how "spread out" the distribution is and is usually approximated by the standard deviation s of the observed extreme speed. The shape parameter, γ , of the Weibull and Type II distributions, sometimes called the tail-length parameter, can be determined empirically from the data.

The applicability of Type I and Type II distributions to annual extreme wind speeds was investigated by Simiu.[5] After calculating both distributions for 21 locations in the United States, Simiu concluded that no single distribution was universally applicable to all locations. However the Type I (double exponential) distribution provided the best fit in 45% of the cases, while the Type II with various values of provided the best fit in the remainder. Best fit was determined by the distribution having the highest maximum probability plot correlation coefficient.

Simiu's publication provided the FORTRAN code to fit Type I and Type II distributions to extreme data. The resulting probability plot correlation coefficients, taken from the output included in Appendix 2 and shown in Table 5, indicate that data from sensors 7, 8 and 15 was best fit by a Type 1 distribution. Therefore, the estimated extreme wind speeds in Table 2 are based on a Type 1 double exponential distribution.

Location		TYPE I	TYPE II	OPTIMUM GAMMA
Sensor 7	Average Speeds	.988	.974	10
Sensor 7	Peak Speeds	.992	.975	14
Sensor 8	Average Speeds	.989	.982	Infinity
Sensor 8	Peak Speeds	.985	.970	3
Sensor 15	Average Speeds	.992	.974	Infinity
Sensor 15	Peak Speeds	.989	.968	Infinity

Table 5 Probability Plot Correlation Coefficients.

Therefore the Type I distribution provided an excellent, and the best, fit to the estimated data.

6.2 Length of Record Required for Reliable Predictions

Simiu investigated the length of records required for reliable extreme value predictions using 37 year records from 21 U.S. locations. These records were broken into 30, 25, and 20 year overlapping records that were separately analyzed. At those locations where Type I distribution was optimal, Simiu found an average difference of 39% between the largest and smallest 1000 year return period estimate calculated from separate 20 year portions of the 37 year record. Errors in estimates for very long return periods are significant because, as explained in Section 6.3, a 50 year 99% confidence estimate requires a 5000 year return period estimate.

6.3 Confidence Levels for Specified Design Life

In order to design a structure to withstand various climatological extremes for a given period of time appropriate design values must be determined. For example, it is likely that a structure with a 50 year life will have to withstand wind speeds greatly in excess of the 50 year return period wind speed. To determine what return period a structure should be designed for, consider the following:

Let x = the design maximum value of a climatological parameter (precipitation amount, wind speed, etc.)

p = the probability that the design maximum value will be exceeded during a given year

$p(x)$ = probability that the design maximum value will not be exceeded during a given year

Since it is certain that the design maximum value will either be exceeded or not be exceeded during a given year

$$p + p(x) = 1$$

$$p = 1 - p(x) \tag{1}$$

We define R = return period (or mean recurrence interval)

From Simiu[6] $$R = \frac{1}{p} \tag{2}$$

by substitution from (1) $R = \dfrac{1}{1 - p(x)}$

rearranging

$$1 - p(x) = \frac{1}{R}$$

$$p(x) = 1 - \frac{1}{R} \tag{3}$$

Since we know P(X), the probability of the value "X" not being exceeded during a given year, we can find the probability of "X" not being exceeded during N years.

To begin with, we note that the probability of two independent events both occurring is given by:

$$P(A \cap B) = P(A)P(B) \tag{4}$$

Therefore, for example, the probability, P2, of V not being exceeded during a 2-year period is the probability of V not being exceeded during one-year times the probability of V not being exceeded during one year, or,

$$P_2 = p(X) \cdot p(X) = (\ p(X)\ )^2$$

similarly for 3 years

$$P_3 = p(X) \cdot p(X) = (\ p(X)\ )^3$$

For N years, where we define P_N as the probability that X will not be exceeded during the N-year period:

$$P_N = (\ p(X)\ )^N \tag{5}$$

For example, suppose that X = 100 MPH, p(x)=.98, p=1-p(x)=.02, and R= $\frac{1}{1 - p(x)}$ = 50 years. That is, the 50 year return period wind is 100 MPH. If we wish to find the probability that the wind will not exceed 100 MPH during any given 10-year period, we apply equation (5).

$$P_N = (\ p(X)\ )^N = (.98)^{10} = .817$$

That is, there is an 81.7% chance that the wind will not exceed 100 MPH during a 10 year period. Since we have taken as our example a 50 year return period wind, it is interesting to note that the probability of 100 MPH not being exceeded during any 50 year period is

$$P_N = (\ p(X)\ )^N = (.98)^{50} = .364.$$

Thus there is a 36.4 chance that 100 MPH will not be exceeded. Therefore there is a 1-.364, or a 63.6% chance, that 100 MPH will be exceeded during the 50 years. It can be shown that during any period of N years there is a 63.6% chance of the N year return period wind speed being exceeded by at least once.[7]

We can find the return period needed to assure a specified confidence level as follows:

From EQ (5) $$P_N = \left[p(x)\right]^N$$

By substitution from EQ 3

$$P_N = \left[1 - \frac{1}{R_D}\right]^N$$

$$\left[P_N\right]^{1/N} = 1 - \frac{1}{R_D}$$

$$\frac{1}{R_D} = 1 - \left[P_N\right]^{1/N}$$

$$R_D = \frac{1}{1 - \left[P_N\right]^{1/N}}$$

Therefore, we have found the required return period, R_D, of the design maximum value of X in terms of the probability, P_N of the design windspeed not being exceeded during the period N.

For example, if we want to find a value X that will have a 95% probability of not being exceeded during any 50 year period, we are declaring P =.95 and N=50 years. Therefore:

$$R_D = \frac{1}{1-[P_N]^{1/N}} = \frac{1}{1-[.95]^{1/50}} = \frac{1}{1-[.95]^{.02}} = 975 \text{ years.}$$

We therefore would calculate using the double-exponential function the value of X having a return period of 975 years to use as the 95 percent confidence value for a 50 year period. Similarly, to calculate the 99% confidence values used in this report for 50 year life periods, we calculate:

$$R_D = \frac{1}{1-[P_N]^{1/N}} = \frac{1}{1-[.99]^{1/50}} = \frac{1}{1-[.99]^{.02}} = 4975 \text{ years.}$$

Therefore the 50 year estimates used in this report are taken from the 5000 year return period values on the output of program "Extreme". Repeating the above calculation shows that for a 25 year life a 2487 year return period should be used, while for a 100 year life a 9,950 year return period is used.

7.0 EXTREME WIND SPEED ISOTACHS

7.1 General

Estimates of the 50 year, 99% confidence, extreme wind speed for the entire transmission line route in the form of isotachs have been drawn on the route selection maps. These isotachs, representing our professional judgment of the extreme speeds for the areas shown, are based on the 50 year extreme speed estimates made in this report for the sensor 7, 8 and 15 locations, the estimates in our first report for Summit and Talkeetna, and with qualitative consideration for the topographic effects outlined below.

7.2 Topographic Effects

The topography of an area influences wind speed through several mechanisms. Topographic features indicative of high wind speeds are:

1. High elevation plains and plateaus will have higher wind speeds than similar flat low elevation areas, but are unlikely to experience extraordinary extreme wind values because of the absence of wave or downslope mechanism over the flat terrain (see #4).

2. Exposed mountain summits and ridges in areas of strong upper air winds. Again downslope effects, and funneling, will be absent in this case. Therefore exceptionally strong winds, i.e. 100 MPH plus, would only be likely at elevations above, say, 10,000 ft.

3. Gaps, passes and gorges through mountain barriers in areas of frequent strong pressure gradient may experience wind speeds in excess of the pressure gradient wind due to funneling of the wind through the opening. Parameters determining the amount of increase in wind speed resulting from funneling include
   a. height of the mountain barrier
   b. cross-sectional area of the funnel opening
   c. shape of the funnel opening
   d. roughness of the funnel surface

4. The lee (downwind) side of mountain ranges frequently experience extremely strong winds known variously as mountain wave, downslope, foehm and bora winds. The winds occur on the lee slopes of the mountains, and may extend a short distance (10-20 km) out onto adjacent flat areas. The several theories advanced to explain the mechanism of these winds involve the generation by the mountain range of wave motion in the stratified flow of the atmosphere under certain atmospheric conditions. The following observations and results have been obtained:

   a. A mountain wave numerical model indicates that the surface wind speed has its maximum half-way down the lee side of the mountain when atmospheric conditions for the formation of a wave are optimal.[4] The point of maximum wind speed will move further downstream under certain non-optimal conditions.

   b. The numerical model also indicates that the maximum surface wind produced by a ramp-shaped mountain is about 50% greater than the corresponding maximum for the isolated, symmetrical mountain.

c. Observations at Boulder, Colorado indicate that the point of wind speed maximum shifts up and down the slopes and out into the plains to the east.[3] Highest speeds occur when the maximum is located at the foot of the mountains. With the surface wind maximum at the foot of the mountain, wind speeds recorded upstream on the lee slope of the mountain, the downstream about 10 km east on the plains, were 50% less than speeds in the area of maximum velocity. Wind velocities in the mountains can be very low during wind storms over the foothills and adjacent plains.

Topographic features indicating low wind speeds include:

1. Areas of high surface roughness, forested areas or hilly terrain will both inhibit wind flow, forested hilly terrain having a maximum retarding effect on the wind.

2. Sheltered basins.

3. Valleys and canyons which are short, or perpendicular to the prevailing winds aloft.

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APPENDIX 1

APPENDIX 1

VARIABLE LIST

The following variables from the NEWF4 were read into the SPSS program.

Year -	Calender year of observation (81 in all cases)
MTH -	Month of observation (1 = January, 2 = February, 3 = March)
DAY -	Day of the month of observation
TIME -	Alaska Standard Time of observation
FAI -	Fairbanks surface pressure
BIG -	Big Delta surface pressure
GKN -	Gulkana surface pressure
VDZ -	Valdez surface pressure
ANC -	Anchorage surface pressure
UD -	Summit Wind Direction
US -	Summit average wind speed
UP -	Summit peak gust wind speed
UA -	Summit altimeter setting (inches mercury)
A5P -	Anchorage 500 mb pressure (always 500 mb.)
A5H -	Anchorage height of 500 mb surface (meters)
A5T -	Anchorage 500 mb temperature (°C)
A5RH -	Anchorage 500 mb relative humidity (percent)
A5D -	Anchorage wind direction at 500 mb (degrees true)
A5S -	Anchorage wind speed at 500 mb (meter/sec)
A7P -	Anchorage 700 mb pressure (always 700 mb)
A7H -	Anchorage height of 700 mb surface (meters)
A7T -	Anchorage 700 mb temperature (°C)
A7RH -	Anchorage 700 mb relative humidity (percent)
A7D -	Anchorage wind direction at 700 mb (°true)
A75 -	Anchorage wind speed at 700 mb (meter/second)
A8P -	Anchorage 850 mb pressure (always 850 mb)
A8H -	Anchorage height of 850 mb surface
A8T -	Anchorage 850 mb temperature (°C)
A8RH -	Anchorage 850 mb relative humidity (percent)

VARIABLE LIST
(Continued)

A8D -	Anchorage wind direction at 850 mb (°T)
A8S -	Anchorage wind speed at 850 mb (meter/record)
F5P -	Fairbanks 500 mb pressure (always 500 mb)
F5H -	Fairbanks 500 mb height (meters)
F5T -	Fairbanks 500 mb temperture (°C)
F5RH -	Fairbanks 500 mb relative humidity (percent)
F5D -	Fairbanks 500 mb wind direction (°true)
F5S -	Fairbanks 500 mb wind speed (meters/second)
F7P -	Fairbanks 700 mb pressure (always 700 mb)
F7H -	Fairbanks 700 mb height (meters)
F7T -	Fairbanks 700 mb temperature (°C)
F7RH -	Fairbanks 700 relative humidity (percent)
F7D -	Fairbanks 700 wind direction (°true)
F7S -	Fairbanks 700 wind speed (meters/record)
F8P -	Fairbanks 850 mb pressure (always 850 mb)
F8P -	Fairbanks 850 mb height (meters)
F8T -	Fairbanks 850 mb temperature (°C)
F8RH -	Fairbanks 850 mb relative humidity (percent)
F8D -	Fairbanks 850 mb wind direction (°true)
F8S -	Fairbanks 850 mb wind speed (meters/second)
A7 -	Sensor 7 average wind speed (MPH-128 second averaging period)
AVGDIR7 -	Sensor 7 direction of average wind speed (°T)
P7 -	Sensor 7 peak wind speed (instantaneous measurement)
PKDIR7 -	Sensor 7 direction of peak wind speed (°T)
A8 -	Sensor 8 average wind speed (MPH-128 second averaging period)
AVGDIR8 -	Sensor 8 direction of average wind speed (°T)
P8 -	Sensor 8 peak wind speed (MPH-instantaneous measurement)
PKDIR8 -	Sensor 8 direction of peak wind speed (°T)

VARIABLE LIST
(Continued)

A15 - Sensor 15 average wind speed (MPH-128 second averaging period)

AVGDR15[1]- Sensor 15 direction of average wind speed (°T)

P15 - Sensor 15 peak wind speed (MPH-instanteous measurement)

PKDIR15 - Sensor 15 direction of peak wind speed (°T)

(Note: The 6 most stable layers between 900 and 500 MB at Anchorage and at Fairbanks have variable names of the form AXXXn where XXX is the name of the parameter and n is the number of the level.

APn - Anchorage pressure (mb)

FPn - Fairbanks presure (mb)

AHn - Anchorage height (meters)

FHn - Fairbanks height (meters)

ATKn - Anchorage layer thickness (from the nth layer to the n + 1 layer)

FTKn - Fairbanks layer thickness (from the nth layer to the n + 1 layer)

ALRn - Anchorage temperature lapse rate (°C per meter, between n and n + 1 layers)

FLRn - Fairbanks temperature lapse rate (°C per meter, between n and n + 1 layers)

ADIRn - Anchorage wind direction (°T)

FDIRn - Fairbanks wind direction (°T)

ASPn - Anchorage wind speed (meter/second)

FSPn - Fairbanks wind speed (meter/second)

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[1] Note that variable name is AVGDR15, not AVGDIR15, due to limit of 7 characters in a variable name for SPSS.

VARIABLE LIST

(Continued)

The following variables were calculated within the SPSS program.

UMM - Summit surface pressure (mb-calculated from UA)

AF - Anchorage surface pressure - Fairbanks surface pressure

FB - Fairbanks surface pressure - Big Delta surface pressure

FG - Fairbanks surface pressure - Gulkana surface pressure

FU - Fairbanks surface pressure - Summit surface pressure

The 2 most stable layers of the atmosphere in the Healy vicinity were estimated from the Fairbanks 6 most stable layers, unless the Fairbanks wind direction (at those layers) was between 130 degrees and 270 degrees, in which case the Anchorage most stable layers were used. The variables were named as follows, with n = 1, 2.

SPn - Pressure of nth most stable layer (mbs)

SHn - Height of nth most stable layer (meters)

STKn - Thickness of nth most stable layer (meters)

STn - Relative humidity of nth most stable layer (percent)

SRHn - Relative humidity of nth most stable layer (percent)

SLRn - Temperature lapse rate of nth most stable layer (°C per meter)

SSPn - Wind speed of nth most stable layer (meter/second)

Also computed were:

A5x - Anchorage x component of 500 mb wind velocity (m/s)

A5y - Anchorage y component of 500 mb wind velocity (m/s)

A7x - Anchorage x component of 700 mb wind velocity (m/s)

A7y - Anchorage y component of 700 mb wind velocity (m/s)

VARIABLE LIST
(Continued)

A8x - Anchorage x component of 850 mb wind velocity (m/s)
A8y - Anchorage y component of 850 mb wind velocity (m/s)
F5x - Fairbanks x component of 500 mb wind velocity (m/s)
F5y - Fairbanks y component of 500 mb wind velocity (m/s)
F7x - Fairbanks x component of 700 mb wind velocity (m/s)
F7y - Fairbanks y component of 700 mb wind velocity (m/s)
F8x - Fairbanks x component of 850 mb wind velocity (m/s)
F8y - Fairbanks y component of 850 mb wind velocity (m/s)

AT58 = Anchorage 500 mb temperature-Anchorage 800 mb temperature
AT57 = Anchorage 500 mb temperature-Anchorage 700 mb temperature
AT78 = Anchorage 700 mb temperature-Anchorage 800 mb temperature
FT58 = Fairbanks 500 mb temperature-Fairbanks 800 mb temperature
FT57 = Fairbanks 500 mb temperature-Fairbanks 700 mb temperature
FT78 = Fairbanks 700 mb temperature-Fairbanks 800 mb temperature
DEL5T = Anchorage 500 mb temperature-Fairbanks 500 mb temperature
DEL7T = Anchorage 700 mb temperature-Fairbanks 700 mb temperature
DEL8T = Anchorage 850 mb temperature-Fairbanks 850 mb temperature

After inspecting the scattergrams of various variables to determine their range during high wind events, the following binary variables were set to 1, and reset to 0 when the controlling variable of each binary predictor was outside the range during which high winds occurred:

FGBP = 0 when FG > 2
BP1 = 0 when DEL5T > 5 or DEL5T < -3
BP2 = 0 when DIF8 > 55or DIF8 < -3
BP3 = 0 when A8H > 1410 or A8H < 1150

VARIABLE LIST

(Continued)

BP4	= 0	when	A5H	>	5460
BP5	= 0	when	STK2	>	280
BP6	= 0	when	F5X	<	-13
BP7	= 0	when	DIF5	>	50
BP8	= 0	when	DEL8T	>	0
BP9	= 0	when	DEL7T	>	1

APPENDIX 2

Meteorological Hindcast
Study for Alaska Power
Authority Anchorage
Fairbanks Intertie Project

prepared
for

Commonwealth Associates, Inc.

by

Northern Technical Services
October 2, 1980

Introduction

In preparing this report, Northern Technical Services (NORTEC) assumed that the transmission line route would generally follow the Susitna River, Parks Highway, Alaska Railroad and Nenana River from Willow to Healy. Along this route records usable for statistical purposes were available at Healy, Summit and Talkeetna. Estimates of various parameters were prepared for those locations. In addition, estimates for Anchorage and Fairbanks were prepared since their records are by far the most extensive for any point on or near the proposed route. Small amounts of data in summarized form were available from Clear, McKinley Park, Nenana and Willow. Although this data was not usable for statistical analysis, it is presented in Table 26.

Topography of the Route

At an elevation of 220 feet, Willow lies in the broad Susitna River Valley. From Willow northward to approximately Talkeetna, the route is within a wide valley, although to the east the foothills of the Talkeetna Mountains are less than five miles distant. Temperatures here have a much greater range than at Anchorage, as the area is well away from the moderating influence of Cook Inlet. Otherwise the topography has little effect.

Just north of Talkeetna, curving in an arc through southcentral Alaska, the Alaska Range is oriented east-west as it passes just south of Healy. Immediately south of Healy, mountain peaks are on the order of 5,000 to 6,000 feet. But many Alaska Range peaks are over 10,000 feet, while the portion of the range known as Mt. McKinley reaches 20,000 feet. The Alaska Range forms a barrier to the low-level movement of air. But under certain barometric conditions, wind is funneled through openings in this barrier at a much greater speed than would occur over flat terrain. Strong northerly winds can be expected when a large high pressure center is located over the Fairbanks area, and a low pressure center is over the Anchorage area. Strong southerly winds are present with just the reverse of the pressure patterns.

The Nenana River Canyon from Windy to Healy is the main wind funnel for a 100-mile stretch of the Alaska Range. The canyon drops from an elevation of 2,000 feet near Windy to 1,300 feet at Healy, forming a 30-mile-long wind funnel bringing southeasterly chinook winds to Healy. Consequently, Healy has recorded the greatest wind speeds of any location along the proposed route for which records are available. A detailed discussion of data and wind damage at Healy will be found later in this report.

Because no known wind speed records exist for the remainder of the Nenana River Çanyon, we recommend that equipment for additional wind speed measurements be installed at Moody, Carlo, Windy, Garner and Hurricane, Alaska (See Figure 1 foldout).

Sources of Transmission Line Icing

There are three sources of transmission line icing*: (a) wet snow, (b) in-cloud icing, and (c) freezing precipitation.

Wet snow accretes on electric wires in significant quantities when the air temperature is between 30°F and 36°F and the rate of snowfall is .15 inches per hour or more.[1] Although such conditions are common at Valdez and other places on Prince William Sound, they occur rarely, if ever on the proposed Anchorage-Fairbanks route. Therefore, accretion of wet snow was not investigated in this study.

The second source of transmission line icing is in-cloud icing. The mechanism of transmission line in-cloud icing is similar to that of aircraft icing, and occurrs when clouds or

---

* Other than blowing spray for structures on or near bodies of water.

ground fog deposit an ice coating on an exposed surface. Significant in-cloud icing may occur when the temperature is between 32°F and 23°F. In order to estimate the amount of in-cloud icing, upper air data including temperature lapse rates and water content are required.[2] Along the proposed route, this data is available only for Anchorage and Fairbanks, and only from the National Climatic Center, Ashville, N.C. Since conversations with engineers at Golden Valley Electric Association, Matanuska Valley Electric Association and Chugach Electric Association indicated that in-cloud icing is not significant in the area of the proposed line, and to avoid delay, in-cloud icing was not addressed in this report.

Ice Density

The ice density depends on the type of icing. Three types occur:[3]

> Glaze is hard, highly adhesive, usually clear and has a density of about .9 gm per cm^3. Freezing precipitation always deposits glaze, as may in-cloud icing under certain conditions.
>
> Rime, sometimes referred to as hard rime, contains air bubbles giving it an opaque appearance, moderate adhesiveness and a density of .3 to .8 gm per cm^3. In-cloud (fog) icing usually deposits rime.
>
> Hoar frost, sometimes called soft rime, is a frost-like deposit from frost on in-cloud icing that has low adhesive qualities and a density of less than .6 gm per cm^3.

Figure 2 (after Kuroima) shows the wind and temperature conditions producing each type of in-cloud icing.[4]

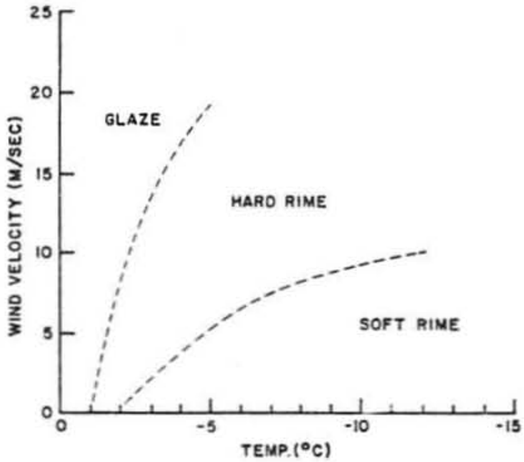


FIGURE 2. Relation Between Icing Type and Meteorological Conditions

Method of Estimation

The estimates of extreme wind speed and estimates of extreme temperatures presented in this report were calculated according to the procedure specified by Irving Gringorten in his paper "Extreme-Value Statistics in Meteorology-A Method of Application".[5]

In order to estimate the maximum wind speeds likely to occur during icing events, hourly records were searched, and maximum wind speeds were recorded for the period applicable to each freezing precipitation event. The applicable period was defined as beginning at the start of the freezing precipitation and end either 24 hours after the end of the freezing precipitation, or when the temperature rose to 34°F, whichever occurred first. Annual maximums of wind speeds occurring with freezing precipitation were then determined, and extreme speed estimates were then made according to Gringorten's method.

Confidence Level of the Estimates

Except for Healy wind speeds, all estimates in this report are at the 99 percent confidence level. Therefore, we can expect that there is only a one-percent chance of the extreme value being exceeded, provided that the extremes of the parameter in question are truly double-exponentially distributed, and that the sample mean and standard deviation are identical to the mean and standard deviation of the extreme value population. For Anchorage and Fairbanks, we assume that the sample and population statistics are very close to each other, because the period of record is adequately long. At Summit and Talkeetna, the period of record is considerably shorter, and, therefore, less confidence can be assumed for the mean and standard deviation of those populations. At Healy, the period of record was too short to calculate estimates with 99 percent confidence. Therefore, 95 percent confidence estimates were used. However, it is not reasonable to assume that the mean and standard deviation of our small sample (about 2.5 years) are truly the mean and standard deviation of the population of extreme wind speeds at Healy. Furthermore it is possible that, because of its special topography, the extreme wind speeds at Healy are not actually double-exponentially distributed. During the 2.5 years of record at Healy, maximum wind speed records include two 61 MPH events, as well as several events in the 50-59 MPH range. Subjectively, then, the estimates such as a 114 MPH 1 minute average wind at the 32.8 foot (10 meter) level seem reasonable.

Application of the Estimates

All of the estimates of extreme wind speeds are for a 1 minute average wind speed at a height of 32.8 feet (10 meters) above the surface. The following formula is generally accepted for finding the wind speed at other heights near the surface:[6]

$$V_x = V\left(\frac{Z}{32.8}\right)^{1/7}$$

V = speed at 32.8 feet

Z = height above surface in feet

V_X = speed at height Z

Maximum gust wind speeds will be greater than the 1 minute average speed. The following formula may be used to calculate the maximum instantaneous gust speed:[7]

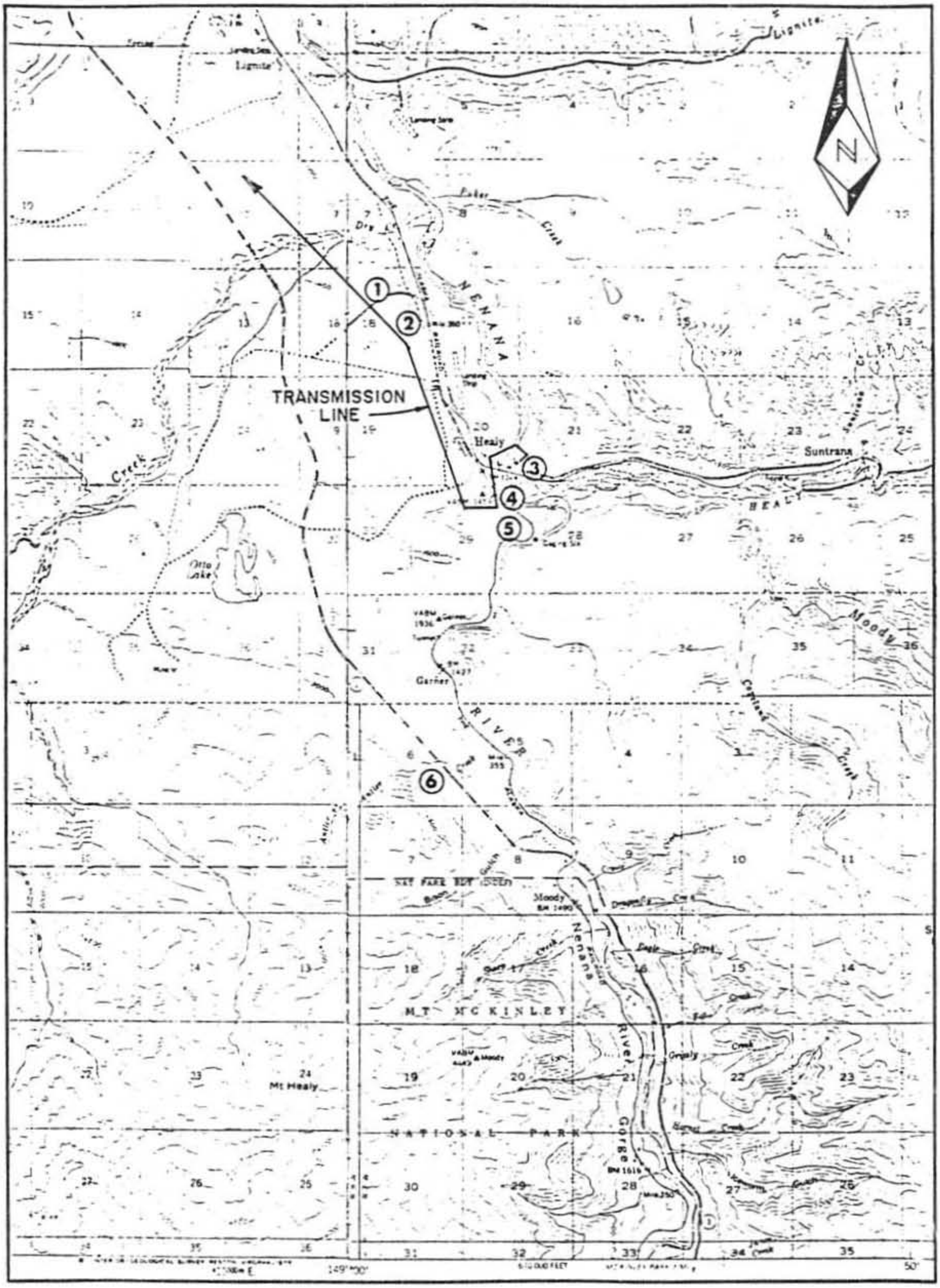
$$G = 1.29V + 5.8$$

V = average wind speed (MPH)

G = maximum instantaneous gust speed (MPH)

Extreme Winds at Healy

For all return periods at Healy the extreme wind estimates are for over 110 MPH. Estimates are based on a 2.4 year period of record at Healy, during which speeds of over 70 MPH were recorded. The speeds are, however, the power plants operator's hourly entry into his log, and it is possible that higher speeds did occur between these observations. Furthermore, by examining Figure 3, a map of the Healy area, we note that other locations in the area probably experience higher extreme wind speeds than the Healy power plant, where the record observations were made. The power pant is at the mouth of the Healy River Canyon, but is approximately 2 miles east of the air streamline for winds from the Nenana River Gorge. It seems likely that the greatest wind speeds in the Healy area occur closer to the air streamline centerline as orographic constrictions such as the Healy River Gorge. The strongest winds along the Nenana River Gorge from Windy to Healy probably do occur close to Healy, and are the result of temperature-gradient drainage (chinook) forces being added to large-scale pressure gradient forces. Therefore, the areas of maximum wind speed are at the bottom of the canyon.



POINTS OF WIND DAMAGE

① TRANSMISSION TOWER 470

② TRANSMISSION TOWER 471

③ HEALY POWER PLANT

④ TRANSMISSION TOWER 484

⑤ RAILROAD ROUNDHOUSE

⑥ HIGHWAY CONSTRUCTION CAMP

Figure 3.

MAP OF HEALY, ALASKA AREA

Wind Damage at Healy

On December 13, 1967, a wind storm blew down Towers 470 and 471 of an existing Healy to Fairbanks transmission line (See Figure 3). Tower 484 was damaged, as were the Healy Power Plant walls and roof, and the Alaska Railroad Roundhouse. At a highway construction camp, closer to the mouth of the Healy River Canyon than the power plant, one building was destroyed and a 6,000 gallon fuel tank (half-filled) was overturned and rolled downhill.

The Stanley Engineering Company report estimated the wind direction at "between 15 and 19 degrees from the longitudinal".[8] Stanley Engineering calculated the minimum wind speed for these failures to be 106 MPH for a longitudinal wind and 100 MPH for a quartering wind. However, the two towers blown down did not fail in the manner indicated by these calculations. Therefore, Stanley Engineering concluded that the failures were not caused by static wind loading, but rather due to dynamic loading caused by wind gusts. Consequently, it is not possible to infer the wind speed experienced during this event from the steady-state wind speed required to cause failure. However, the failure does seem to confirm the design study's conclusion that "wind loads of any consequence on the line will be caused by turbulent high velocity gusts of short duration rather than by steady winds".[9]

Recommendations at Healy

If the transmission line is to connect the existing Healy Power Plant this area of extreme winds cannot be avoided. Therefore, NORTEC recommends installation of equipment measuring wind speeds at several locations in the Healy area in order to determine design winds and the least hazardous route.

TABLE 1 Anchorage Estimated Extreme One Minute Average Wind Speed for Various Return Periods (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	87.0	9.2
50	92.0	10.0
100	95.7	10.8

Data Base: 27 years annual extreme winds (1953-1979)

V_E = 39.15

S_V = 8.32

TABLE 2 Anchorage Freezing Precipitation Estimated Annual Extreme of Accumulation on a Horizontal Surface (99% confidence)

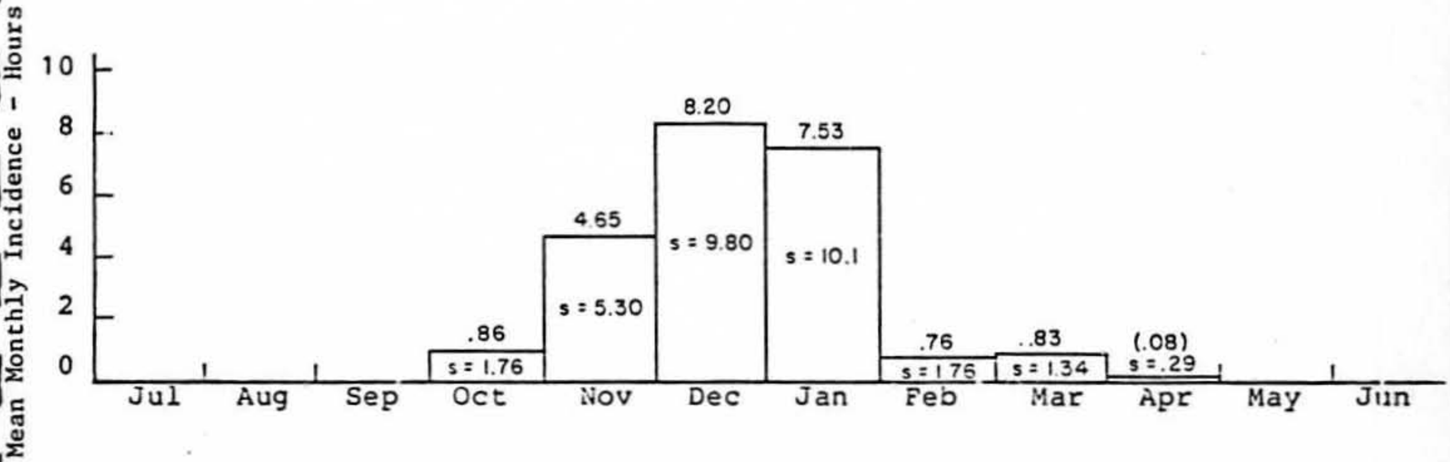
Period (Yrs)	Accumulation (inches)	Standard Deviation
25	.542	.162
50	.591	.170
100	.627	.178

Data Base: 11 1/2 years (1969-1980)

D = .076

S_D = .081

TABLE 3 Anchorage Mean Monthly Incidence of Freezing Precipitation



Data Base: 11.5 years surface observations (January, 1969 - May, 1980)

TABLE 4 Anchorage Estimated Extreme Temperature (99% confidence)

Period (Yrs)	Maximum* (°F)	Standard Deviation	Minimum (°F)	Sta[illegible]rd Dev[illegible]on
25	97.1	3.6	-54.9	[illegible]
50	99.0	4.3	-58.4	[illegible]
100	100.5	4.6	-61.9	8.2

Data Base: 27 years annual extreme temperature

Maximum extreme temperature: $\overline{T}$ = 78.19 °F, S_T = 3.28

Minimum extreme temperature: $\overline{T}$ = -21.41 °F, S_T = 5.87

* These statistically-based temperature estimates do not take into account the heat-absorbing capacity of the water surrounding Anchorage and may, therefore, be somewhat higher than practical experience would indicate.

TABLE 5 Anchorage Frequency of Maximum Wind Speeds Occurring with Freezing Precipitation

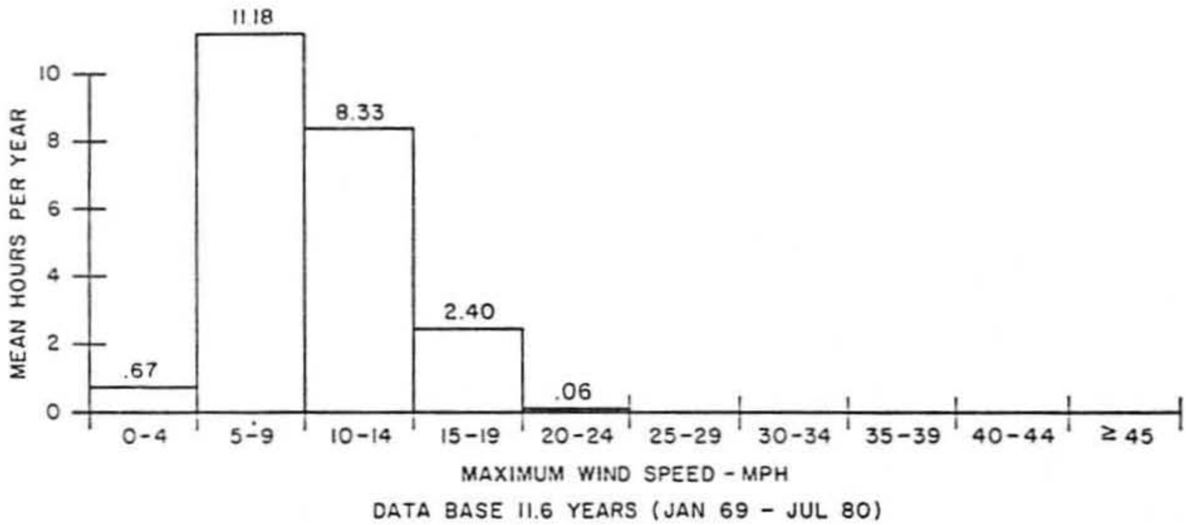


TABLE 6 Anchorage Estimated Maximum Wind Speed Occurring with Freezing Precipitation (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	32.4	6.6
50	34.4	7.2
100	36.0	7.9

Data Base: 11 years (1969-1979)

$\overline{V} = 12.55$, $S = 3.45$

TABLE 7 Fairbanks Estimated Extreme One Minute Average Wind Speed for Various Return Periods (99% confidence)

Period (Yrs)	Speed MPH	Standard Deviation
25	70.9	7.6
50	75.0	8.3
100	78.1	9.0

Data Base: 31 years annual extreme winds (1949-1979)

$\overline{V}_E = 31.13$

$\overline{S}_V = 6.91$

TABLE 8 Fairbanks Freezing Precipitation, Estimated Annual Extreme of Accumulation on a Horizontal Surface (99% confidence)

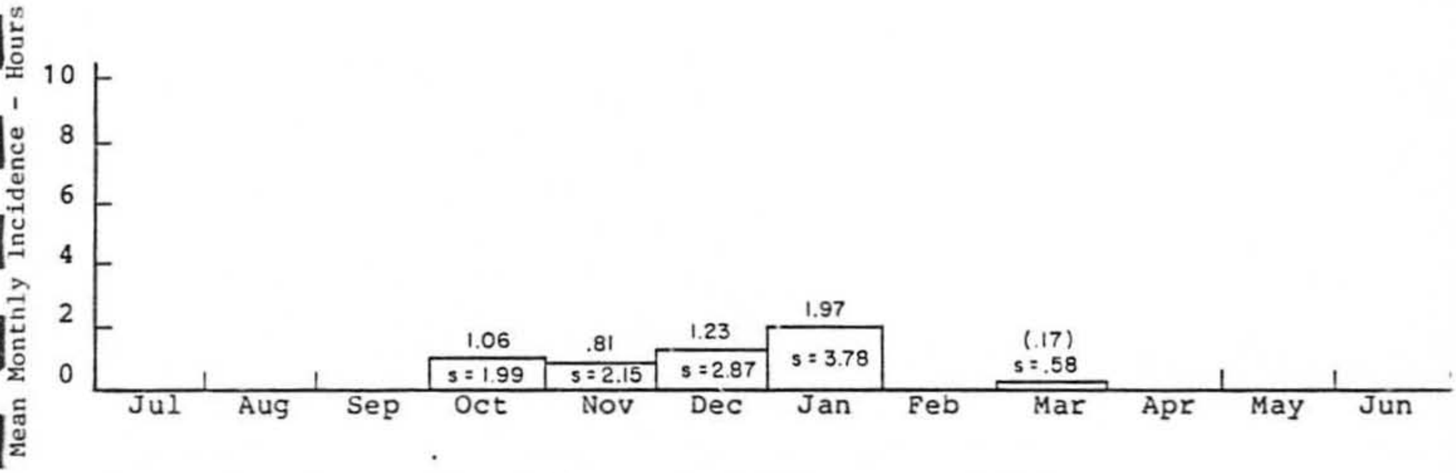
Period (Yrs)	Accumulation (inches)	Standard Deviation
25	.206	.066
50	.226	.069
100	.241	.073

Data Base: 11 1/2 years (January, 1969 - July, 1980)

$\overline{D} = .015$

$\overline{S}_D = .033$

TABLE 9 Fairbanks Mean Monthly Incidence of Freezing Precipitation



Data Base: 11 1/2 years (January, 1969 - July, 1980)

TABLE 10 Fairbanks Estimated Extreme Temperature (99% confidence)

Period (Yrs)	Maximum (°F)	Standard Deviation	Minimum (°F)	Standard Deviation
25	108.9	4.2	-84.3	6.4
50	111.2	5.3	-87.8	8.1
100	112.9	5.7	-91.3	8.7

Data Base: 31 years annual extreme temperatures

Maximum extreme temperature: $\overline{T} = 87.26$ °F, $S_T = 3.77$

Minimum extreme temperature: $\overline{T} = -51.39$ °F, $S_T = 5.78$

TABLE 11 Fairbanks Frequency of Maximum Wind Speeds Occurring with Freezing Precipitation

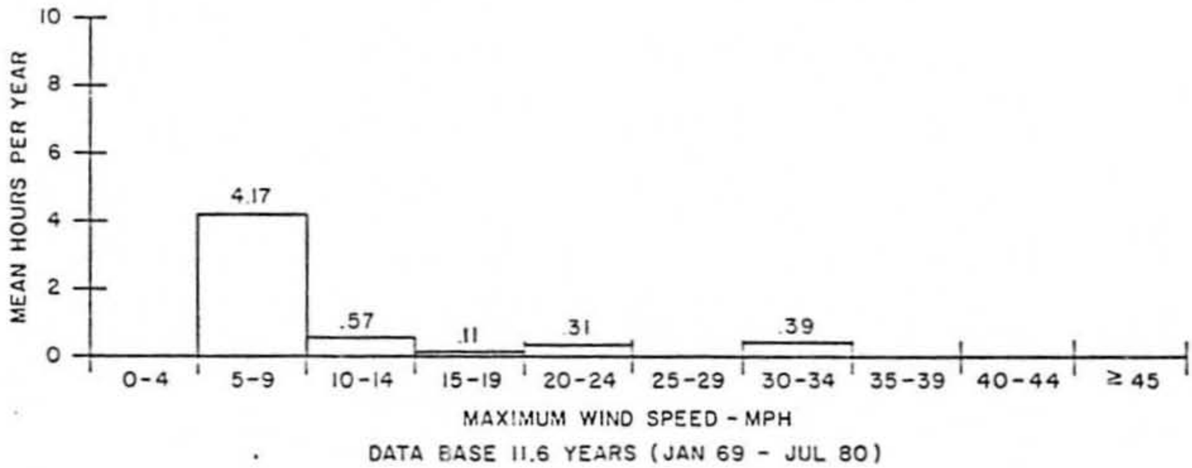


TABLE 12 Fairbanks Estimated Maximum Wind Speed Occurring with Freezing Precipitation (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	58.8	15.9
50	63.5	18.3
100	67.1	19.9

Data Base: 10 years (1970-1979)

$\overline{V} = 13.0$, $s = 7.96$

TABLE 13 Healy Estimated Extreme One Minute Average Wind Speed for Various Return Periods (95% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	114.4	12.2
50	118.2	13.3
100	124.9	14.4

Data Base: Monthly Maximum Wind Speeds (January, 1978 - May, 1980)

$\overline{V}_E = 42.2$, $S_V = 11.1$

NOTE: Period of record is too short to calculate estimates with 99% confidence.

TABLE 14 Summit Estimated Extreme One Minute Average Wind Speed for Various Return Period (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	69.2	12.8
50	72.0	14.2
100	74.2	14.7

Data Base: 7 years annual extreme winds (1968-1975, 1973 missing)

$\overline{V}_E = 42.0$

$S_V = 4.73$

TABLE 15 Summit Freezing Precipitation, Estimated Annual Extreme of Accumulation on a Horizontal Surface (99% confidence)

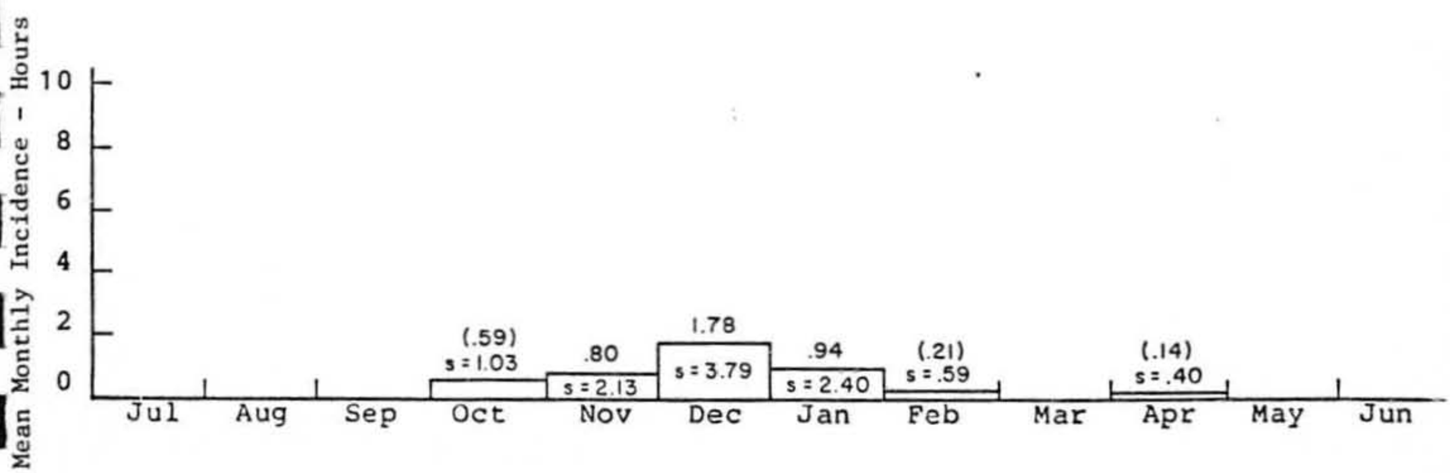
Period (Yrs)	Accumulation (inches)	Standard Deviation
25	.283	.115
50	.310	.129
100	.331	.133

Data Base: 8 years (1968-1975)

$\overline{D} = .018$

$S_D = .046$

TABLE 16 Summit Mean Monthly Incidence of Freezing Precipitation



Data Base: 8.75 years surface observations

TABLE 17 Summit Estimated Extreme Temperature (99% confidence)

Period (Yrs)	Maximum (°F)	Standard Deviation	Minimum (°F)	Standard Deviation
25	104.3	11.6	-64.8	12.4
50	107.0	12.5	-67.8	14.9
100	109.1	13.0	-70.7	17.4

Data Base: 8 years annual extreme temperatures

Maximum extreme temperature: $\overline{T}$ = 77.63 °F, S_T = 4.63

Minimum extreme temperature: $\overline{T}$ = -36.5 °F, S_T = 4.96

TABLE 18 Summit Frequency of Maximum Wind Speeds Occurring with Freezing Precipitation

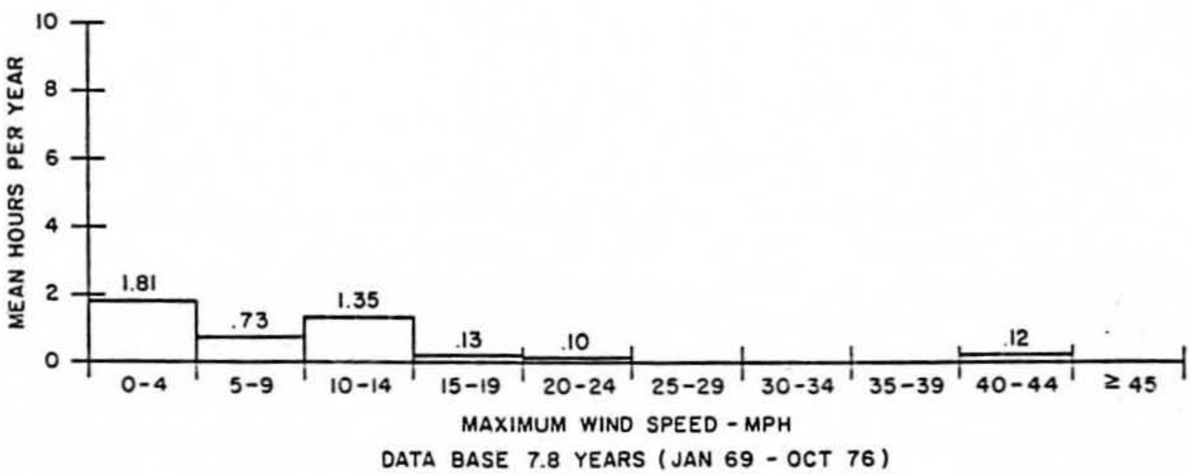


TABLE 19 Summit Estimated Maximum Wind Speeds Occurring with Freezing Precipitation (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	68.4	25.0
50	73.8	26.8
100	77.8	27.7

Data Base: 7 years (1968-1976, except 1970, 1976)

$\overline{V} = 17.0$, $s_V = 8.94$

TABLE 20 Talkeetna Estimated Extreme One Minute Average Wind Speed for Various Return Periods (99% confidence)

Period (Yrs)	Speed MPH	Standard Deviation
25	51.5	8.0
50	53.9	8.4
100	55.7	8.8

Data Base: 11 years annual extreme winds (1968-1979 inclusive, 1975 missing; part-time operation 1977-1979)

$\overline{V}_E = 28.45$

$S_V = 4.01$

TABLE 21 Talketeena Freezing Precipitation Estimated Annual Extreme of Accumulation on a Horizontal Surface (99% confidence)

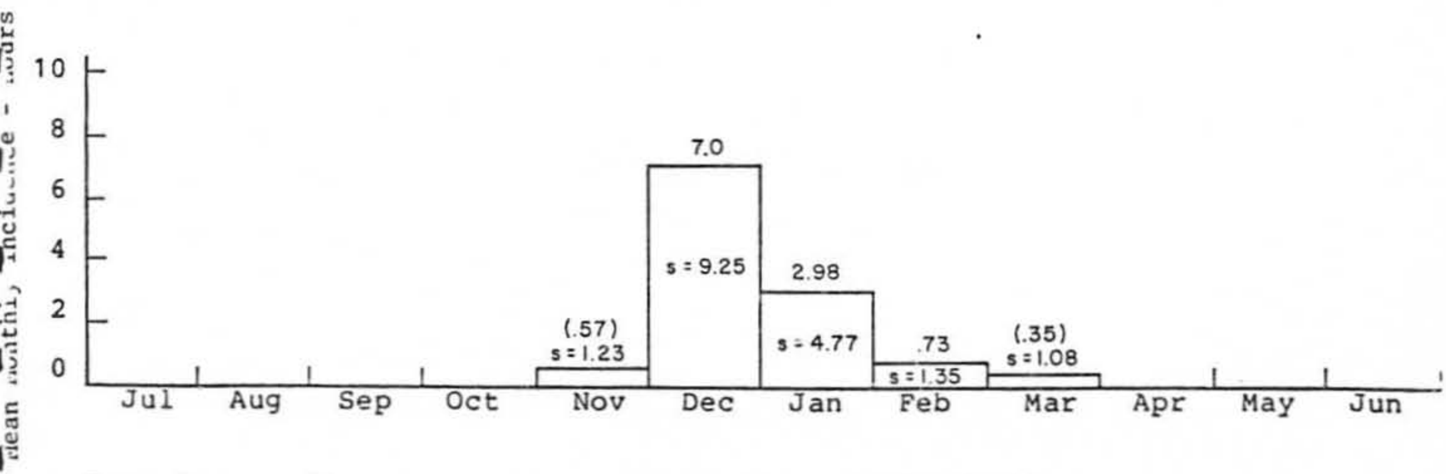
Period (Yrs)	Accumulation (inches)	Standard Deviation
25	.285	.084
50	.311	.088
100	.331	.092

Data Base: 12 years (1968-1979; part-time 1977-1979)

$\overline{D} = .030$

$S_D = .044$

TABLE 22 Talkeetna Mean Monthly Incidence of Freezing Precipitation



Data Base: 12 years surface observations (1968-1979)

TABLE 23 Talkeetna Estimated Extreme Temperature (99% confidence)

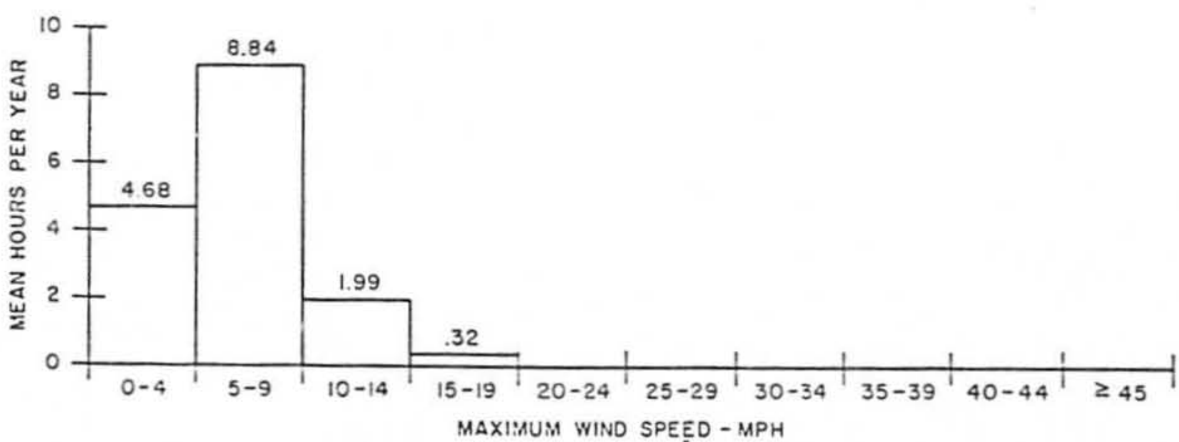
Period (Yrs)	Maximum (°F)	Standard Deviation	Minimum (°F)	Standard Deviation
25	100.9	5.2	-87.1	16.6
50	102.6	5.7	-92.4	17.5
100	103.9	6.0	-97.6	18.4

Data Base: 12 years annual extreme temperatures

Maximum extreme temperature: $\overline{T}$ = 84.4 °F, S_T = 2.87

Minimum extreme temperature: $\overline{T}$ = -37.25 °F, S_T = 8.75

TABLE 24 Talkeetna Frequency of Maximum Wind Speeds Occurring with Freezing Precipitation



DATA BASE 9.1 YEARS (1 DEC 68 - 31 DEC 77)

TABLE 25 Talkeetna Estimated Maximum Wind Speeds Occurring with Freezing Precipitation (99% confidence)

Period (Yrs)	Speed (MPH)	Standard Deviation
25	32.8	7.3
50	35.1	8.0
100	36.8	8.8

Data Base: 11 years (1968-1979, except 1974)

$\overline{V} = 10.82$, $s_V = 3.82$

TABLE 26 Climate of Locations Without Estimates

For some stations along the proposed route, the data available was not usable for statistical purposes. However, it may still be of some interest, and is tabulated below.

Clear:

Extreme Wind Speed	not available
Record High Temperature	96°F
Record Low Temperature	-62°F
Period of Record	8 years (1966-1974/part-time)

Eielson Air Force Base (Fairbanks):

Extreme Wind Speed	69 MPH (1 min average, SW)
Record High Temperature	92°F
Record Low Temperature	-62°F
Period of Record	4.5 years (1944-1951, incomplete)

Elmendorf Air Force Base (Anchorage)

Extreme Wind Speed	93 MPH (peak gust, 1 minute average not available, north)
Record High Temperatures	not available
Period of Record	15 years (1946-1967, incomplete)

Ladd Air Force Base (Fairbanks):

Extreme Wind Speed	70 MPH (Southwest)*
Record High Temperature	92°F
Record Low Temperature	-62°F
Period of Record	5 years (1946-1967, incomplete)

---

* Record does not indicate if this is a 1 minute average of a gust.

McKinley Park:

Extreme Wind Speed	not available
Record High Temperature	89°F
Record Low Temperature	-54°F
Period of Record	53 years (1922-1975/part-time)

Nenana:

Extreme Wind Speed	not available
Record High Temperature	98°F
Record Low Temperature	-69°F
Period of Record	46 years (1922-1968)

Wasilla:

Extreme Wind Speed	not available
Record High Temperature	90°F
Record Low Temperature	-38°F
Period of Record	24 years (1951-1975/part-time)

Willow:

Extreme Wind Speed	not available
Record High Temperature	90°F
Record Low Temperature	-56°F
Period of Record	13 years (1963-1976, part-time)

Source of Data

Golden Valley Electric Association, Inc.
Box 1249
Fairbanks, Alaska 99707

National Climatic Center
Federal Building
Asheville, North Carolina 28801

University of Alaska
Arctic Environmental Information and Data Center
(Repository for National Climatic Center records within Alaska).
707 A Street
Anchorage, Alaska 99501

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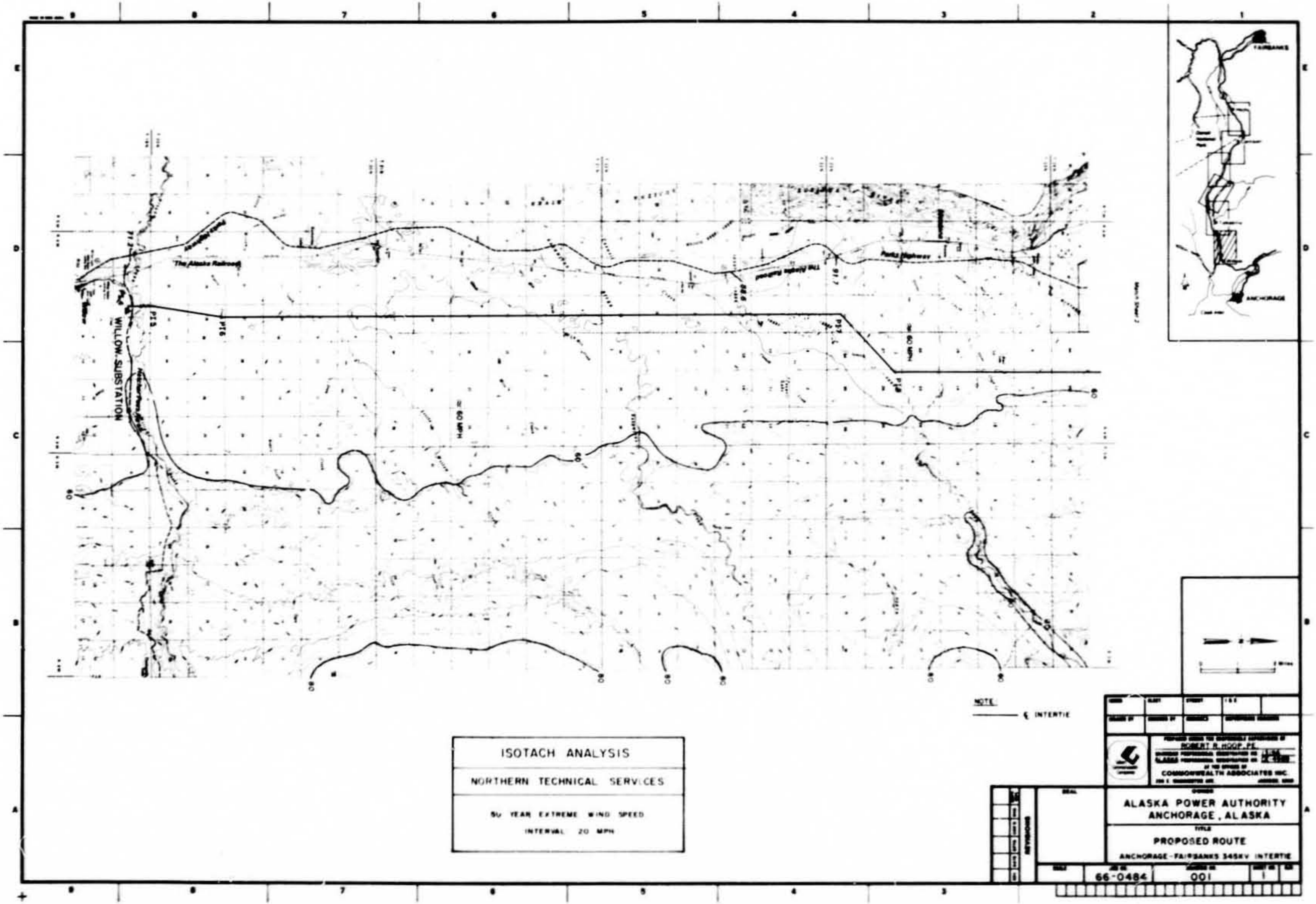
APPENDIX 3



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ANCHORAGE
The Alaska Railroad
Parks Highway
WILLOW SUBSTATION
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PI 7
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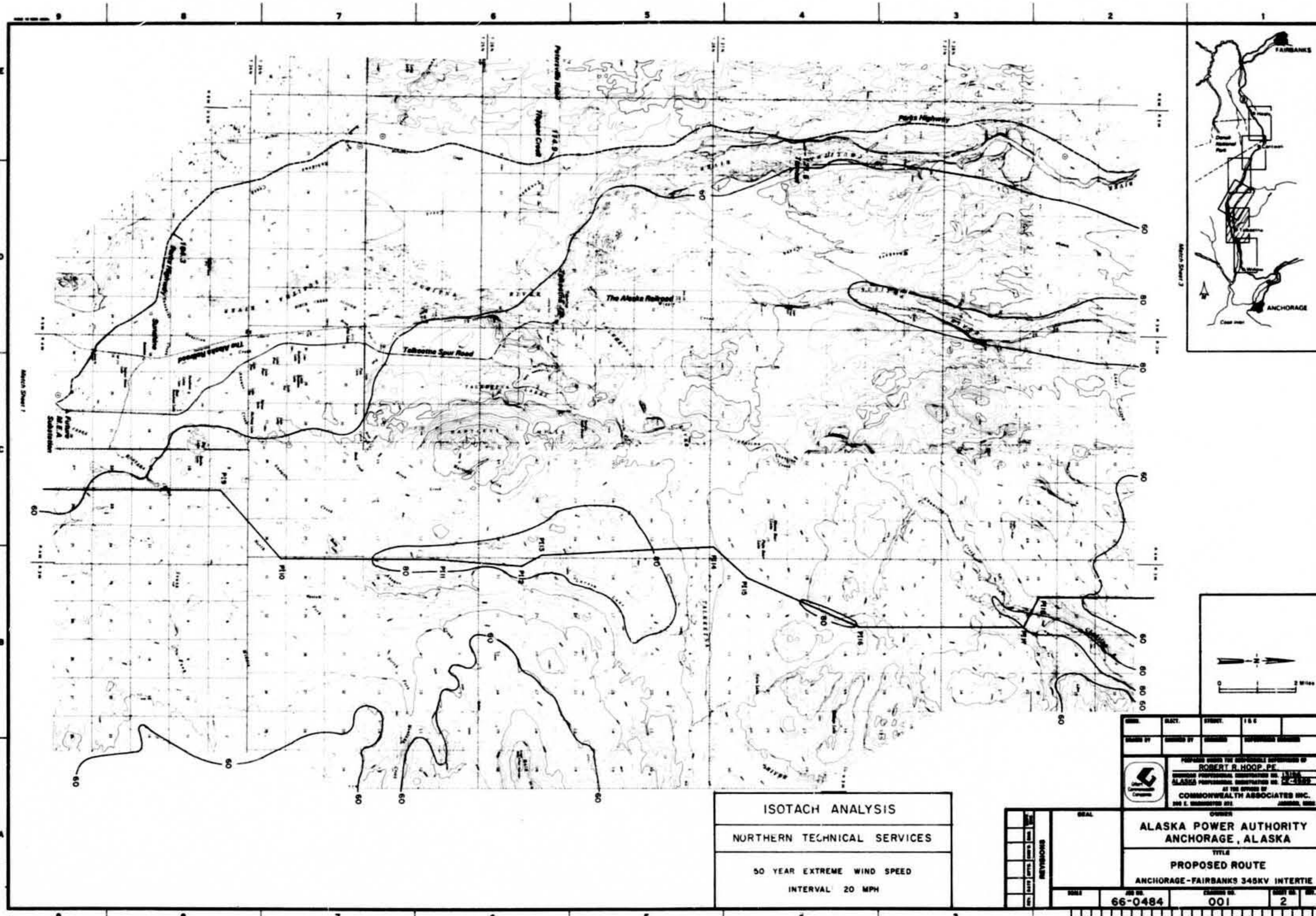
ISOTACH ANALYSIS
NORTHERN TECHNICAL SERVICES
50 YEAR EXTREME WIND SPEED
INTERVAL 20 MPH
ROBERT R. HOOP, P.E.
COMMONWEALTH ASSOCIATES INC.
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA
PROPOSED ROUTE
ANCHORAGE - FAIRBANKS 345KV INTERTIE
66-0484
001
1


Parks Highway
The Alaska Railroad
Talkeetna Spur Road
Petersville Road
Trapper Creek
Match Sheet 1
Match Sheet 3
FAIRBANKS
ANCHORAGE
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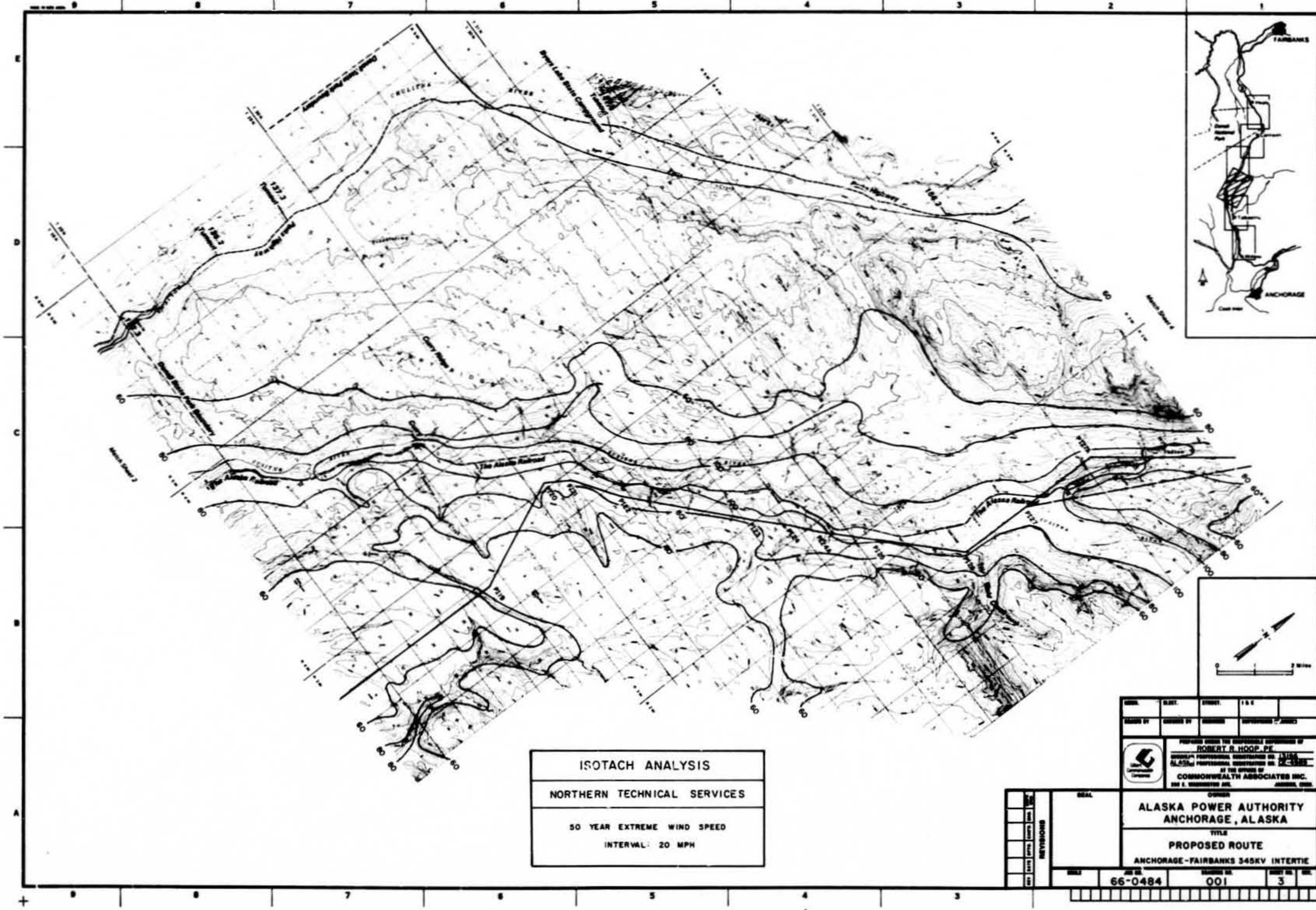
80
ISOTACH ANALYSIS
NORTHERN TECHNICAL SERVICES
50 YEAR EXTREME WIND SPEED
INTERVAL 20 MPH
ROBERT R. HOOP, PE
COMMONWEALTH ASSOCIATES INC.
REVISIONS
SEAL
OWNER
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA
TITLE
PROPOSED ROUTE
ANCHORAGE-FAIRBANKS 345KV INTERTIE
66-0484
001
2


ISOTACH ANALYSIS
NORTHERN TECHNICAL SERVICES
50 YEAR EXTREME WIND SPEED
INTERVAL: 20 MPH
FAIRBANKS
ANCHORAGE
0 1 2 Miles
ROBERT R. HOOP, PE
COMMONWEALTH ASSOCIATES INC.
REVISIONS
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA
TITLE
PROPOSED ROUTE
ANCHORAGE-FAIRBANKS 345KV INTERTIE
66-0484
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The Alaska Railroad
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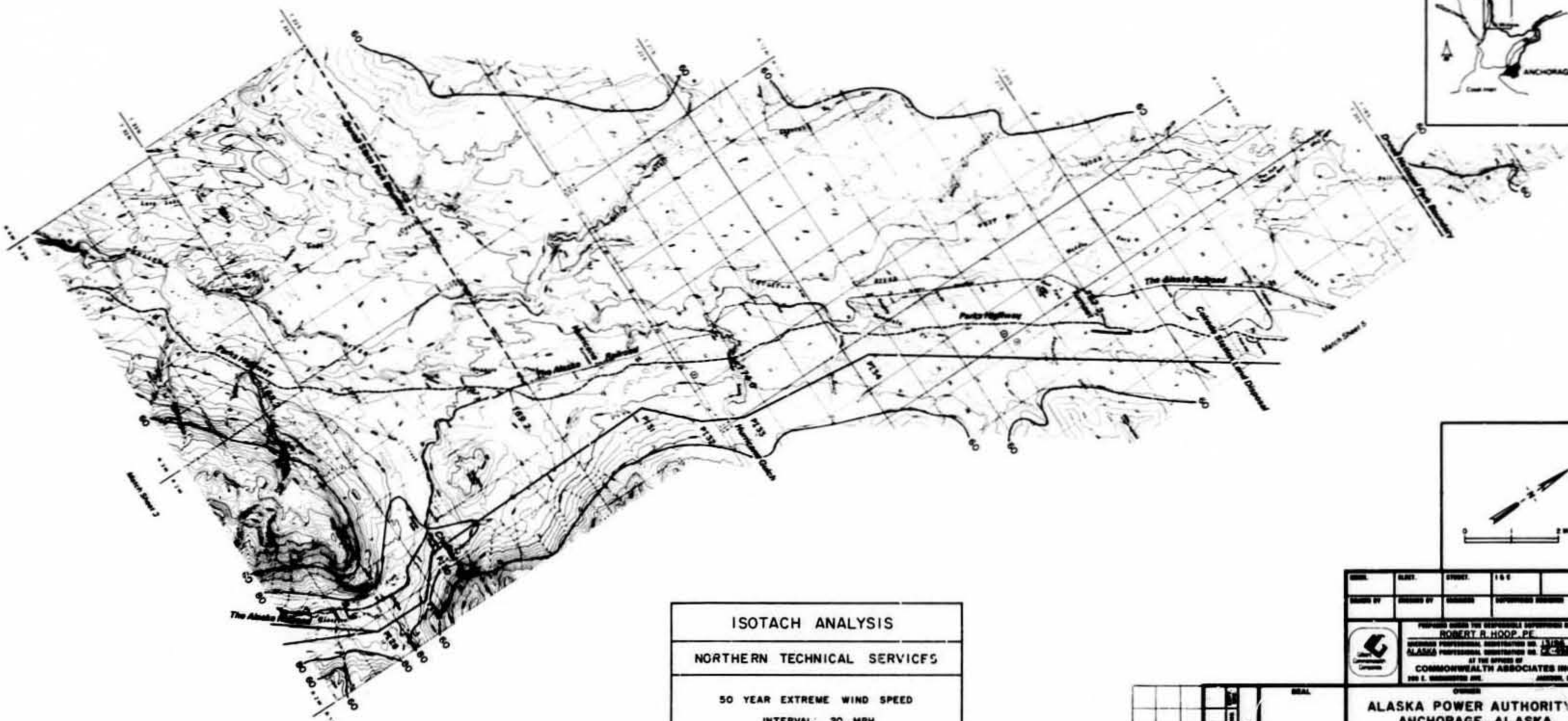
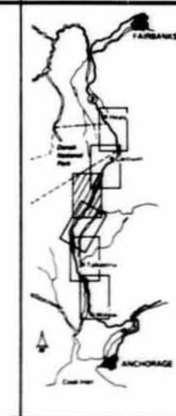




ISOTACH ANALYSIS

NORTHERN TECHNICAL SERVICES

50 YEAR EXTREME WIND SPEED

INTERVAL: 20 MPH

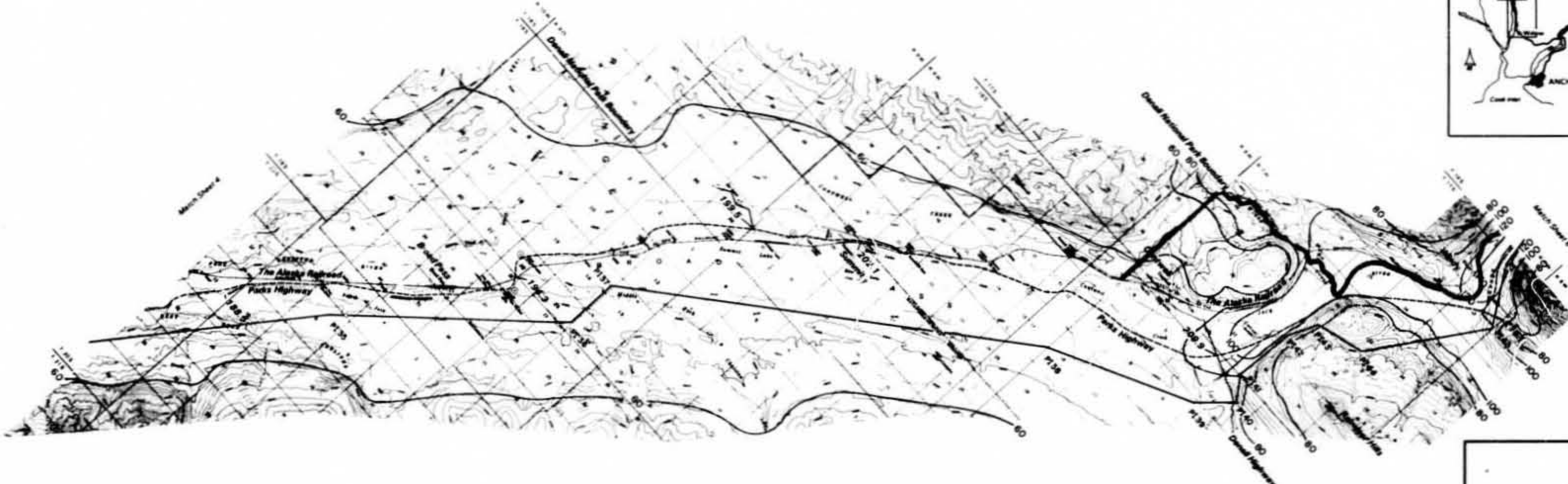
PREPARED UNDER THE RESPONSIBLE SUPERVISION OF ROBERT R. HOOP, PE.

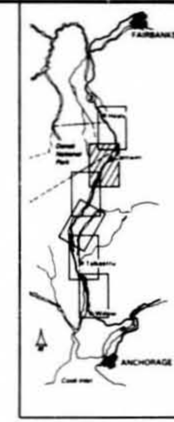
AT THE OFFICES OF COMMONWEALTH ASSOCIATES INC.

OWNER: ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

TITLE: PROPOSED ROUTE
ANCHORAGE-FAIRBANKS 345KV INTERTIE

SCALE	JOB NO.	DRAWING NO.	SHEET NO.	REV.
	66-0484	001	4	





ISOTACH ANALYSIS

NORTHERN TECHNICAL SERVICES

50 YEAR EXTREME WIND SPEED

INTERVAL: 20 MPH

REVISIONS

PREPARED UNDER THE RESPONSIBLE SUPERVISION OF
ROBERT R. HOOP, PE

COMMONWEALTH ASSOCIATES INC.

OWNER

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

TITLE

PROPOSED ROUTE

ANCHORAGE-FAIRBANKS 345KV INTERTIE

JOB NO.	DRAWING NO.	SHEET NO.
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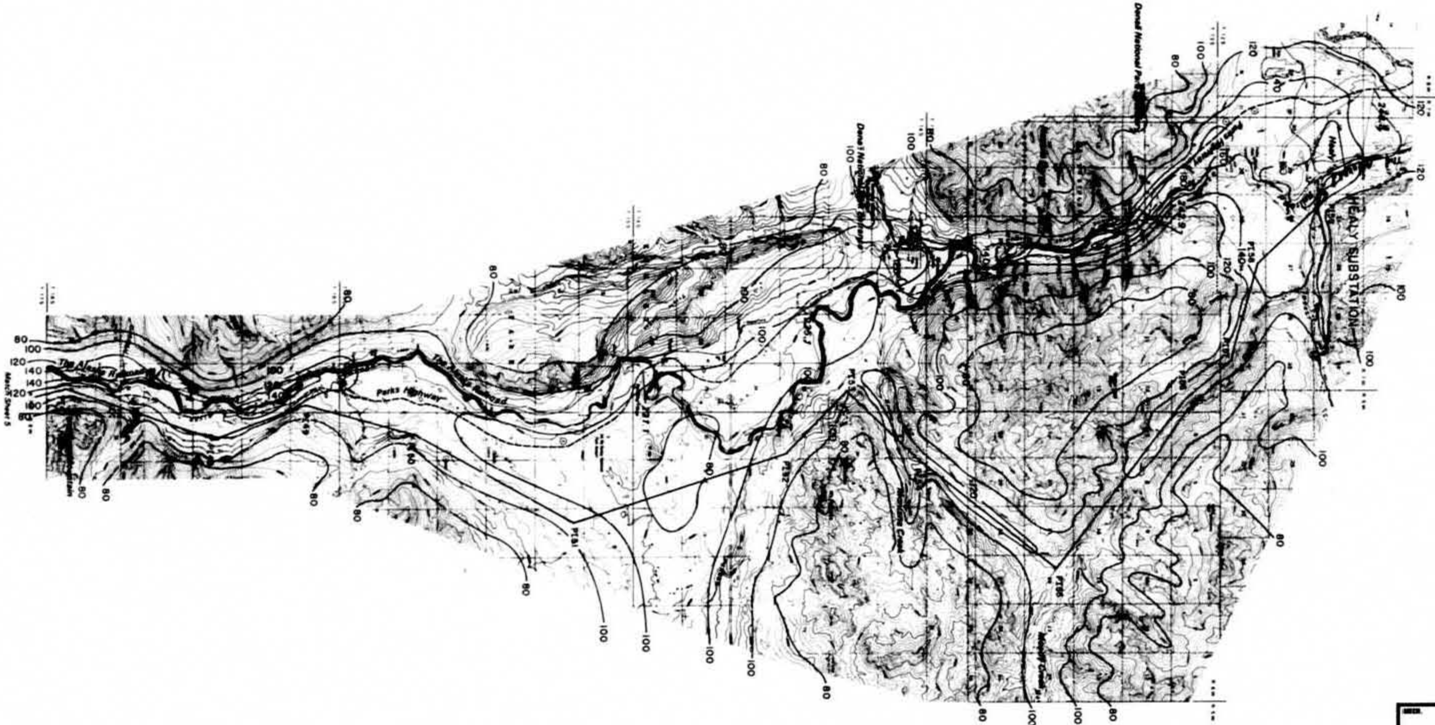

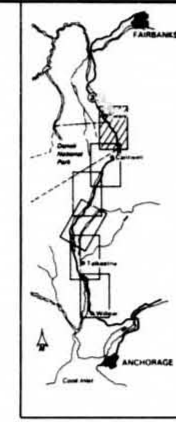

0 1 2 Miles

ISOTACH ANALYSIS
NORTHERN TECHNICAL SERVICES
50 YEAR EXTREME WIND SPEED INTERVAL 20 MPH

PREPARED UNDER THE RESPONSIBLE SUPERVISION OF
ROBERT R. HOOP, PE
MICHIGAN PROFESSIONAL REGISTRATION NO. 13196
ALASKA PROFESSIONAL REGISTRATION NO. CE-4989
AT THE OFFICES OF
COMMONWEALTH ASSOCIATES INC.

OWNER
ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

TITLE
PROPOSED ROUTE
ANCHORAGE-FAIRBANKS 345KV INTERTIE

SCALE	JOB NO.	DRAWING NO.	SHEET NO.	REV.
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