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TITTEL

RISK OF AN OPERATIONAL DELAY BECAUSE OF UNFAVOURABLE WIND CONDITIONS IN DIGERNESSUNDET.

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NORWEGIAN CONTRACTORS

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OPPDRAGSNR.

SAMMENDRAG

The report contains a probability analysis based on data from the weather station Sola, 1957 - 1986. The probalility for periods of 1 - 2 days which have a maximum mean wind speed within a given upper limit (3 or 4 Beaufort) are calculated for the months January and February.

The results are presumed to be valid for Digernessundet.

The risk for a delay of an operation planned to start at January 15, and the duration of the delay with different probability levels is given.

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S U M M A R Y

This report contains a probability analysis based on wind data from the weather station Sola, 1957 - 1986. The probability for a 2 days period that have a maximum 10 minute wind speed, FX, not exceeding 3 Beaufort (B) the first day and not exceeding 4B during the second day is determined.

In the winter season the probability for such events is calculated to 0.17 in January and 0.28 in February. Also probabilities for some other events are given:

SOLA 1957-1986

PROBABILITY	JAN	FEB
P(3)	0.22	0.33
P(33)	0.10	0.21
P(4)	0.47	0.58
P(44)	0.33	0.46
P(34)	0.17	0.28
P(3)3	0.47	0.64
P(4)4	0.71	0.80
P(4)3	0.76	0.85

P(3) : The probability for 1 day with FX ≲ 3.
P(33): The probability for 2 days with FX ≲ 3.
P(34): The probability for 2 days with FX ≲ 3 the first day and FX ≲ 4 the next day.
P(3)3: The probability for 1 day with FX ≲ 3, if FX ≲ 3 also the day before.
P(4)3: The probability for 1 day with FX ≲ 4, if FX ≲ 3 the day before.

The operation is planned to start at January 15. The probability, PD, for a delay is given in the table below for different wind speed criteria. For example, if the criterion is FX ≲ 3B, the risk of delay is 0.76, and it is 50% chance of starting within 4 days, 75% chance of starting within 10 days, and 90% chance of starting within 16 days. Due to the "long tail" of the distribution the levels of high probabilities are rather poorly determined.

CRITERION	PD	START DAY 50%	75%	90%	95%	99%
FX≲4B	0.53	2.	4.	6.	9.	11.
FX≲4B FOR 2 DAYS	0.64	3.	7.	12.	19.	31.
FX≲3B	0.76	4.	10.	16.	23.	27.
FX≲3B 1.DAY, FX≲4B 2.DAY	0.80	7.	19.	32.	39.	41.

1. INTRODUCTION.

The background for this report is a request from Norwegian Contractors concerning operational criteria in Digernessundet. The problem is: How long do we have to wait for a given weather situation, that is, a day when the maximum 10 minute wind speed, FX, does not exceed 3 Beaufort (B) the first day, and 4B the following day. Also asked for are the risks of waiting for periods characterized by FX $\lesssim$ 3B in one or two days, and FX $\lesssim$ 4B in two days. The operation is planned to start at January 15.

Our institute have earlier made a report concerning low wind speed conditions at Digernessundet (1). That report contains a probability analysis based on wind data from the weather stations Sola and Flesland, 1957 - 1985. The probability for a 3 days period that have a maximum 10 minute wind speed, FX, not exceeding 5 ms^{-1} ($\approx$3B) the first day and not exceeding 10 ms^{-1} ($\approx$5B) during the following two days was determined at both stations. It was argued that the data from Sola were the most representative ones to Digernessundet.

We also have made a report concerning the low wind speed conditions in Gandsfjorden (2) in May and June, using data from Sola.

2. DATA BASIS.

2.1. Locality. Weather stations in the area.

Digernessundet is situated in Western Norway in the southern part of Hordaland county. The sound between Bømlo and Stord branches off to Digernessundet in the southern part. Digernessundet is situated between the little island Føynö and Stord, and is directed ESE-WSW (Fig. 1). The sound is landlocked in the sector WSW-N-NE. In the sector ENE-SE there is a relatively large fjord bassin, with the islands Borgundøy, Fjelbergøy and Halsnøy. Towards S and SSW is Bømlofjorden. Thus Digernessundet has a relatively free exposition in the sector ENE-S-SW, and is more sheltered from the remaining sector.

It is only a few weather stations in the area which may be representative for Digernessundet, due to its location. That means that the distance to the coast line must be of a corresponding length. Moreover, the relatively free exposition at the weather stations should be from the same sectors as for Digernessundet. Now we consider maximum wind forces of light or moderate forces. Estimations of maximum wind forces between the hours of observation frequently are of poorer quality than the corresponding estimations at the regular hours of observation. We will therefore only make use of instrumental data. In (1) we argued that Sola is the most representative station.

2.2. Instrumentation and data.

Sola weather station is equipped with the anemometer type Fuess 90z. The anemograph is recording the instantaneous wind speed and wind direction and give in addition 10 minute mean wind speed. The area around the weather station is entirely flat. The only obstacles are habitation in the surroundings. The anemometer height is 11 m above the ground. Sola have data series from 1957. The anemometer position is unchanged through the period, apart from a minor moving in 1969 (10-12 m). The data are found to be homogeneous for the period 1957-1986.

3. METHOD AND RESULTS.

3.1. Probability of events.

Our task is to find the probability for a 2 days period that have a maximum 10 minute wind speed, FX, not exceeding 3 Beaufort (B) the first day and not exceeding 4B during the following day. Here a day means the 24 hours period from 19 to 19 o'clock local time. The probability for such a 2 days period is here called P(34).

At first we will find the relative frequency, f(E), of occurrence of an event, E, by counting the number of successes and then divide with the total possibility for successes.

We have used a data programme that makes such countings (unfortunately for only the same event for the concerning period), where the result day by day is listed in a table, and where the relative frequency for 1 day with a given event is computed.

Example :
The total number of successes in one month are 1 less than number of days of that month. Suppose a period is looking like : 2363343323446. The numbers represent the daily maximum wind forces (Beaufort). Here the number of cases of 34 are 7. Further we suppose that the total number of cases during a period of 30 years is 151 in January. Then the relative frequency is f(34)=151/((31-1)x30)=0.17.

Consequently we must do a manual counting of the cases when the event 34 has occurred. That work is based on two tables (mentioned above) with the events 3 and 4 Beaufort respectively. As a result we get the relative frequency of the event 34 for each month.

As known from the statistical theory the probability of an event is taken as the relative frequency of occurrence of that event when the number of observations is very large. For our problem we must use the relative frequencies as approximate probabilities.

SOLA 1957-1986

	JAN	FEB
f(3) ~ P(3)	0.22	0.33
f(33) ~ P(33)	0.10	0.21
f(4) ~ P(4)	0.47	0.58
f(44) ~ P(44)	0.33	0.46
f(34) ~ P(34)	0.17	0.28
f(3)3 ~ P(3)3	0.47	0.64
f(4)4 ~ P(4)4	0.71	0.80
f(4)3 ~ P(4)3	0.76	0.85
Range of successes with 34 in one month.	0-14	1-17
Number of years with :		
0 cases	4	0
1- 5 "	13	11
6-10 "	9	12
11-15 "	4	4
16-20 "	0	3
>20 "	0	0

P(3) : The probability for 1 day with FX $\lesssim$ 3.

P(33): The probability for 2 days with FX $\lesssim$ 3.

P(34): The probability for 2 days with FX $\lesssim$ 3 the first day and FX $\lesssim$ 4 the next day.

P(3)3: The probability for 1 day with FX $\lesssim$ 3, if FX $\lesssim$ 3 also the day before.

P(4)3: The probability for 1 day with FX $\lesssim$ 4, if FX $\lesssim$ 3 the day before.

Table 1. Some relative frequencies, f, interpreted as probabilities and the frequency distribution of the event 34 in the period 1957-86 at Sola.

The probabilities for the different events of low wind speeds are higher in February than in January. Such differences has been shown to be significant (1) and the reason probably the more frequent situations of blocking high in the North Atlantic area at February.

By comparing results above and from (2), we also see that the probability of having a day of FX $\lesssim$ 3B is higher in January (0.22) and February (0.33) than in May (0.12) and June (0.15). The low summer values were due to the sea breeze effect.

3.2. Risk of delay.

The operation is planned to start at January 15. What is the risk then that it will be postponed ? And for how long time may the delay last ? We have calculated this delay with different levels of probability (i.e. relative frequencies interpreted as probabilities).

Example:
We look at FX $\lesssim$ 3B. The 30 years record of days of delay then is: 3 23 0 0 1 10 2 1 4 0 0 3 24 12 0 13 3 7 3 0 1 0 3 1 2 0 24 5 0 0. The 90% level (reached when 27/30 of the years first obey the criterion) here is found after 13 days of waiting, while the 95% level is reached after 24 days. It is easily seen that the long tail of the distribution produce poor estimates of how long we do have do wait to be fairly sure of finding a suitable day (period).

To reduce the effect of random errors without introducing seasonal disturbance, we have produced a set of data by varying the start day from January 8. to 22. (15. ± 7 days). However, it is only the determination of the risk of delay together with the probability levels which is reached within 10 - 20 days that is significantly improved by such an extension of the data. The few years of long periods with bad weather propagate through the data when the tail of the distribution is concerned. The standard deviations of the higher levels therefore cannot be estimated from the data set, and it is an unknown parameter.

FX $\lesssim$ 3B

SOLA 57-86	PD	50 %	75 %	90 %	95 %	99 %
8/1	0.73	3	7	12	17	31
9/1	0.73	4	6	11	16	30
10/1	0.80	4	8	12	18	29
11/1	0.73	3	7	11	17	28
12/1	0.73	2	6	10	16	27
13/1	0.80	2	5	12	26	26
14/1	0.70	2	5	14	25	25
15/1	0.67	2	5	13	24	24
16/1	0.73	2	10	18	23	23
17/1	0.70	2	9	17	22	22
18/1	0.70	3	9	16	21	21
19/1	0.77	4	8	20	22	27
20/1	0.87	6	14	19	26	26
21/1	0.90	5	17	20	25	25
22/1	0.87	4	16	19	24	24
MEAN	0.76	3.2	8.8	14.9	21.5	25.9
SD	0.07	1.3	3.9			
START DAY		4.	10.	16.	23.	27.

FX $\lesssim$ 4B

PD	50 %	75 %	90 %	95 %	99 %
0.47	0	5	6	13	15
0.50	0	5	8	12	14
0.63	2	4	7	11	13
0.57	1	4	6	10	12
0.53	1	3	5	9	11
0.63	1	3	5	8	10
0.53	1	3	4	7	9
0.40	0	2	5	8	8
0.53	1	2	5	7	9
0.47	0	3	5	6	8
0.40	0	2	4	5	7
0.60	1	3	4	6	11
0.50	0	3	5	9	10
0.57	1	2	5	8	9
0.63	1	2	4	7	8
0.53	0.7	3.1	5.2	8.4	10.3
0.08	0.6	1.0	1.2		
	2.	4.	6.	9.	11.

Table 3a. Probability, PD, for a delay for an operation limited by the given FX - criteria, at January 15 (± 7 days). The duration of the delay (in days) with different probability levels (%) is given. Also mean and standard deviation (SD) are presented when meaningful.

1.DAY: FX ≲ 3B & 2.DAY: FX ≲ 4B.

SOLA 57-86	PD	50 %	75 %	90 %	95 %	99 %
8/1	0.77	6	20	38	45	48
9/1	0.83	8	19	37	44	47
10/1	0.80	7	18	36	43	46
11/1	0.77	6	17	35	42	45
12/1	0.83	5	16	34	41	44
13/1	0.90	4	15	33	40	43
14/1	0.77	3	14	32	39	42
15/1	0.77	3	13	31	38	41
16/1	0.73	3	12	30	37	40
17/1	0.70	3	18	29	36	39
18/1	0.80	8	21	28	35	38
19/1	0.83	8	20	27	34	37
20/1	0.90	7	21	27	33	36
21/1	0.90	12	25	26	32	35
22/1	0.93	11	24	25	31	34
MEAN	0.82	6.3	18.2	31.2	38.0	39.5
SD	0.07	2.3				
START DAY		7.	19.	32.	39.	41.

1.DAY: FX ≲ 4B & 2.DAY: FX ≲ 4B.

PD	50 %	75 %	90 %	95 %	99 %
0.57	2	9	13	14	29
0.70	5	8	12	13	28
0.67	4	7	11	12	27
0.67	3	6	10	11	26
0.70	2	6	9	11	25
0.77	2	5	8	10	24
0.60	1	4	8	12	23
0.60	2	5	8	22	37
0.67	1	5	7	21	36
0.57	1	4	9	20	35
0.67	3	5	8	26	34
0.57	2	7	18	25	33
0.57	2	6	17	24	32
0.57	2	6	16	23	31
0.77	4	6	16	22	30
0.64	2.4	5.9	11.3	17.7	30.0
0.07	1.2	1.4			
	3.	7.	12.	19.	31.

Table 3b. Probability, PD, for a delay for an operation limited by the given FX - criteria, at January 15 (± 7 days). The duration of the delay (in days) with different probability levels (%) is given. Also mean and standard deviation (SD) are presented when meaningful.

If we require that FX ≲ 4 B for 24 hours (19-19), it is a risk of delay of 0.53. It is a probability of 0.90 to satisfy the criterion within six days, and one should be fairly sure within 11 days. For a two days period it is a risk of delay of 0.64, a probability of 0.90 to satisfy the criterion within 12 days, and one should be fairly sure within a month.

If we require that FX ≲ 3 B for 24 hours (19-19), it is a risk of delay of 0.76. It is a probability of 0.90 to satisfy the criterion within sixteen days, and one should be fairly sure within 4 weeks. For a two day period where FX ≲ 3B the first day and ≲ 4B the second day, the risk of delay is 0.82. The probability of 0.90 to satisfy the criterion is reached at one month, and one should be fairly sure within 40 days.

The results illustrate that a period with bad weather can last very long at the winter time. However, the risk of long delay is considerably lowered when the criterion of daily maximum 10 min wind speed is changed from FX ≲ 3B to FX ≲ 4B.

As seen from Table 1 the frequency of low wind speeds is higher in February than in January. A more detailed analysis of the data shows that this is especially true from the second to the fourth week of February. A start point within the first two weeks of this month as a consequence has a significantly lower risk of delay than is the case at January 15.

4. REFERENCES.

(1) Andresen, L. and Harstveit, K.:
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(2) Andresen, L. and Harstveit, K.:
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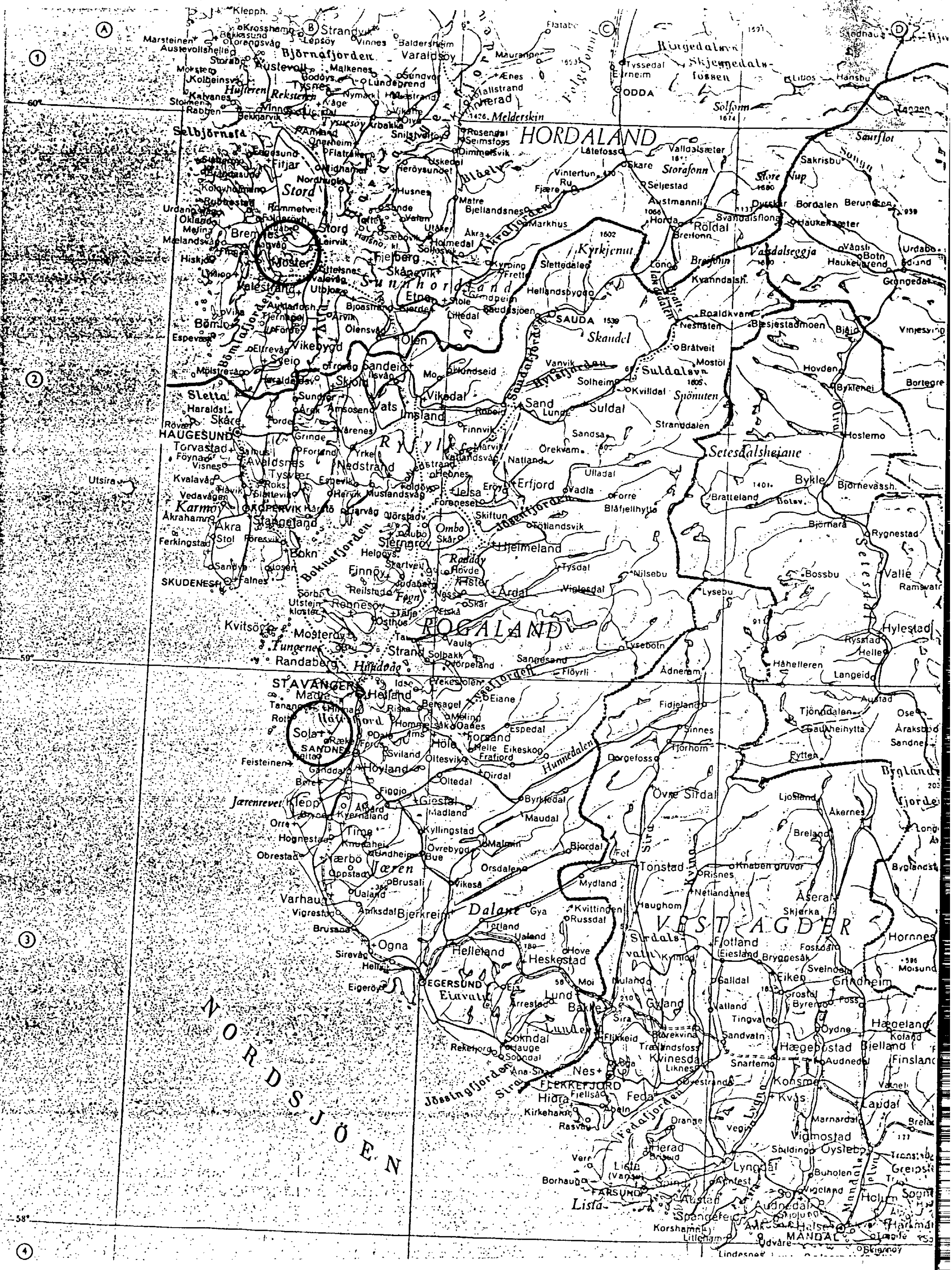

Figure 1. Map showing the location of Digernessundet and the weather station Sola.