Analysis of Alberta Hourly Wind Data

Introduction

Design wind speed values are used in wind setup and wave runup calculations used in determining the freeboard required at dams. The draft CDA Guidelines (2006) suggest combining the effects of wind speeds with certain return periods with a range of reservoir water levels to determine the required freeboard. As a result, the freeboard calculations are very dependent on available wind data.

All available wind speed data for Alberta has been compiled and analysed within the context of dam freeboard calculations. Statistical analysis has been used to determine design values at gauge locations. Spatial analysis has been used to derive maps of design wind speed values throughout the province.

Data

Hourly wind speed and direction data has been recorded by Environment Canada at their hourly recording stations. Data is available at approximately 160 sites across the province (see Figure 1). However, many of these gauges have relatively short records (see Table 1). The maximum record length is just over 50 years.

Observation of the largest values in the data-sets for each of these gauges suggests that there is a typical range of highest wind speed. At most gauges there are less than 5 values that appear as outliers, out of datasets exceeding 100,000 points. The dates and times of the largest values are widely distributed, suggesting that hourly wind speeds are relatively independent of each other, as opposed to rainfall and runoff data which are storm based.

One gauge (Vauxhall), shows significant irregularities in its data-set that are not consistent with the others. One other gauge (Nakiska Ridge) is located at Elevation 2400m, much higher than any other gauge and is likely not representative of wind speeds at the base of valleys or on the plains, where reservoirs are typically located. These two gauges have been eliminated from the current analysis.

Analysis

These record lengths would appear to be unsuitable for statistical analysis with extrapolation to some of the return periods suggested by the CDA guidelines (up to 1000 years). However, the apparent independence of the hourly wind speeds and the strong trends noted at each gauge suggests that a modified statistical approach could be suitable for meeting the CDA requirements.

This approach involves selecting the largest ‘n’ values from a data set with ‘n’ years of record, as opposed to selecting the largest value for each year. The statistics resulting from this approach result in higher means but lower standard deviations. The standard

approach of selecting only the largest value for each year artificially increases the standard deviation by skipping independent data values. Using the Gumbel distribution, analysis over all gauges with at least 10 years of record shows that typically the ratio of the 1000 year to 2 year wind speed is about 1.2 and the ratio of 100 year wind speed to 2 year wind speed is about 1.1 (see table 2). It can also be seen that these results are relatively insensitive to record length. These relatively low standard deviations require little extrapolation from known condition to meet the CDA guidelines.

Traditionally, wind rose diagrams have been used to select the wind speed for the direction that lines up with the longest fetch on the reservoir approaching the dam. However, the CDA guidelines suggest that the maximum wind speed should be used, independent of direction, as conditions at the dam may be different than those of the nearby gauges. Analysis of the Alberta data suggests that the largest wind speeds at almost all gauges comes from the west (between SW and NW). This direction is likely to coincide with the fetch direction at most reservoirs in Alberta, due to the natural runoff characteristics. Statistical analysis of wind speed for each direction shows that the largest directional wind speed is typically about 90% of the values when direction is ignored (see Figure 2). The values for the weakest direction (typically from the east) are about 70% of those from the strongest direction. Therefore, it appears reasonable to follow the CDA guideline and ignore wind direction and use the entire data-set.

Map

Plotting the 2 year return period hourly wind speeds geographically shows some overall geographic trends along with significant local variance (see Figure 3). The variance can be seen at sites with clusters of gauges. This variance can exceed the standard deviation at any of the affected gauges.

However, the geographic trend can be used to group sites together to from geographic regions with assigned design values. Much of the province has values in the 50 – 70 km/hr range, and can be assigned a 2 year hourly wind speed of 70 km/hr. An assigned value of 100 km/hr seems appropriate for an extended region in the vicinity of Pincher Creek. An assigned value of 50km/hr seems appropriate for the Rockies and most of northern Alberta. A map of these assigned areas can be seen in Figure 4.

Conclusion

The wind speed data available for Alberta is rather limited in geographic distribution and record length relative to rainfall and runoff data-sets. However, the data at each gauge shows a significant trend and can be used to derive statistical estimates of design wind speeds consistent with the CDA guidelines without excessive extrapolation. The wind direction can be ignored without being too conservative.

Although geographic analysis shows significant variance, the overall trends have been used to derive a map of design 2 year wind speeds (Figure 3). These values can be multiplied by 1.1 to yield 100 year values and 1.2 for 1000 year values, as appropriate for

use with the CDA guidelines for dam freeboard calculations. This map can be supplemented by the results for nearby gauges (Table 2), for refinement and judgement on a project basis. The increase in calculated freeboard amounts with increase in wind speeds shows an approximately linear response.

Table 1 – Wind Speed Gauge Record Length Distribution

Min. Record Length (Years)	Number of Gauges
0	160
10	70
20	30
30	20

Table 2 – Wind Gauge Summary Data

Long	Lat	Gauge	Yrs	Loc	Elev	Dir	Wavg	Wsd	Wmx	W100	W1000
-113.883	52.167	3025480	53	RED DEER A	905	NW	75	3.4	84	85	92
-114.017	51.100	3031093	53	CALGARY INT'L A	1084	NW	79	4.1	89	92	99
-112.800	49.617	3033880	53	LETHBRIDGE A	929	W	100	4.6	113	115	123
-110.717	50.017	3034480	53	MEDICINE HAT A	717	W	73	3.2	80	83	89
-111.217	56.650	3062693	53	FORT MCMURRAY A	369	W	52	3.6	63	63	70
-118.883	55.167	3072920	53	GRANDE PRAIRIE A	669	W	72	1.8	77	78	81
-113.517	53.567	3012208	52	EDMONTON CITY CENTR	671	NW	64	2.1	68	70	74
-110.267	54.417	3081680	52	COLD LAKE A	541	NW	66	3.2	72	76	82
-113.467	53.667	3012210	51	EDMONTON NAMAO A	688	NW	74	2.9	80	83	89
-117.450	56.217	3075040	51	PEACE RIVER A	571	W	56	1.9	61	62	66
-113.567	53.317	3012205	45	EDMONTON INT'L A	723	NW	69	2.7	76	77	82
-118.067	52.867	3053520	43	JASPER	1062	NE	48	4.0	56	60	67
-111.450	52.067	3011880	41	CORONATION A	791	NW	69	3.1	77	79	85
-115.567	51.167	3050520	40	BANFF	1384	SW	53	5.2	64	69	79
-112.017	54.767	3063685	40	LAC LA BICHE (AUT)	567	W	57	6.9	76	78	91
-111.117	58.767	3072658	39	FORT CHIPEWYAN A	232	W	54	3.2	61	64	69
-111.167	50.267	3036240	38	SUFFIELD A	770	SW	70	1.8	74	75	79
-117.150	58.617	3073146	36	HIGH LEVEL A	338	NW	47	2.0	52	54	58
-110.817	53.350	3016800	29	VERMILION A	619	NW	60	2.7	64	69	73
-115.783	54.133	3067372	28	WHITECOURT A	782	NW	49	2.7	56	58	62
-116.467	53.567	3062244	26	EDSON A	927	NW	55	1.8	58	60	64
-111.450	52.067	3011885	25	CORONATION (AUT)	791	NW	64	2.0	69	70	74
-114.917	52.367	3015520	25	ROCKY MTN HOUSE	1015	NW	49	2.5	56	57	62
-114.767	55.300	3066001	25	SLAVE LAKE A	581	W	70	2.6	76	78	83
-115.667	54.117	3067370	25	WHITECOURT	741	NW	53	3.2	61	63	68
-110.067	53.300	3013961	24	LLOYDMINSTER A	668	NW	61	4.7	74	76	85
-113.967	49.517	3035206	24	PINCHER CREEK (AUT)	1190	W	97	3.4	104	107	113
-114.900	52.417	3015523	23	ROCKY MTN HOUSE (AU	988	NW	44	1.1	46	48	50
-114.367	51.100	303F0PP	22	SPRINGBANK A	1201	W	70	2.6	74	78	83
-113.950	49.500	3035201	19	PINCHER CREEK	1155	W	115	4.4	122	129	137
-113.617	50.000	3031640	18	CLARESHOLM	1012	W	89	4.3	98	103	111
-112.050	49.117	3044533	18	MILK RIVER	1050	W	77	2.7	82	85	90
-115.067	51.067	3050778	18	BOW VALLEY	1298	W	52	1.4	54	56	59
-118.017	52.917	3053536	18	JASPER WARDEN	1020	N	36	1.7	39	41	44
-114.967	55.350	3066920	18	WAGNER	584	W	61	2.0	64	67	71
-114.667	51.767	3026KNQ	18	SUNDRE A	1114	NW	52	2.0	56	59	62
-111.850	50.550	3030QLP	18	BROOKS	747	NW	63	1.5	67	67	70
-112.100	53.517	3016GF0	17	VEGREVILLE	639	NW	62	2.6	67	70	75
-114.917	52.417	3015522	16	ROCKY MTN HOUSE A	988	NW	47	2.0	52	53	57
-115.267	56.550	3075488	16	RED EARTH	546	W	40	1.6	44	45	48
-112.667	51.417	30221LG	16	DRUMHELLER EAST	678	NW	49	2.2	52	56	60
-114.000	49.517	3035202	15	PINCHER CREEK A	1190	SW	105	2.4	109	112	117
-110.467	49.117	3044923	15	ONEFOUR CDA	935	NW	76	1.4	78	80	82
-115.567	51.167	3050521	15	BANFF (AUT)	1397	SW	34	1.0	35	37	38
-113.750	52.450	3023722	14	LACOMBE CDA 2	860	NW	56	1.7	59	61	64
-114.217	51.067	3031875	14	COP UPPER	1235	NW	66	4.7	76	80	89
-110.200	51.667	301B460	14	ESTHER 1	707	NW	63	1.5	65	67	70
-114.467	49.617	3051R4R	14	CROWSNEST	1303	W	53	1.4	56	58	60
-112.867	53.667	3012275	13	ELK ISLAND NAT PARK	716	SE	41	1.7	43	46	49
-114.467	53.450	3013247	13	HIGHVALE	747	NW	62	1.7	65	67	70
-111.450	49.717	3030768	13	BOW ISLAND	817	W	70	2.4	74	78	82
-111.900	50.567	3030838	13	BROOKS	755	SW	57	1.0	59	61	62
-111.550	57.033	3064528	13	MILDRED LAKE	310	NW	47	2.4	52	54	59
-116.050	58.367	3072730	13	FORT VERMILION	283	W	46	1.4	48	50	53
-118.350	53.383	306GE70	13	WILLOW CREEK 1	1402	N	26	0.7	28	29	30
-113.867	58.700	307KPFP	13	GARDEN RIVER	241	W	32	1.4	35	37	39
-112.817	53.017	3011240	12	CAMROSE	739	NW	57	0.5	57	58	59
-113.200	51.817	3026479	12	THREE HILLS	907	NW	68	1.7	70	73	76
-113.267	49.200	3031322	12	CARDSTON	1136	W	55	1.2	57	59	61
-112.767	49.700	3033890	12	LETHBRIDGE CDA	921	W	68	1.1	70	71	73
-113.800	49.117	3056214	12	WATERTON PARK GATE	1296	SW	87	1.6	89	92	95
-116.467	53.600	3062242	12	EDSON A	925	W	46	0.9	48	49	51
-114.767	55.267	3065999	12	SLAVE LAKE A	583	W	67	1.7	70	73	76
-111.100	52.817	301S001	11	WAINWRIGHT CFB AIRFII	686	NW	56	1.7	59	62	65
-113.867	50.167	3036099	10	STAVELY AAFC	1364	W	90	2.2	93	97	101
-116.417	53.567	3062241	10	EDSON	924	NW	70	4.6	80	85	93
-110.050	54.750	3065304	10	PRIMROSE LAKE DND	702	NW	41	2.6	44	49	54

Figure 1 - Hourly Wind Gauge Location Map

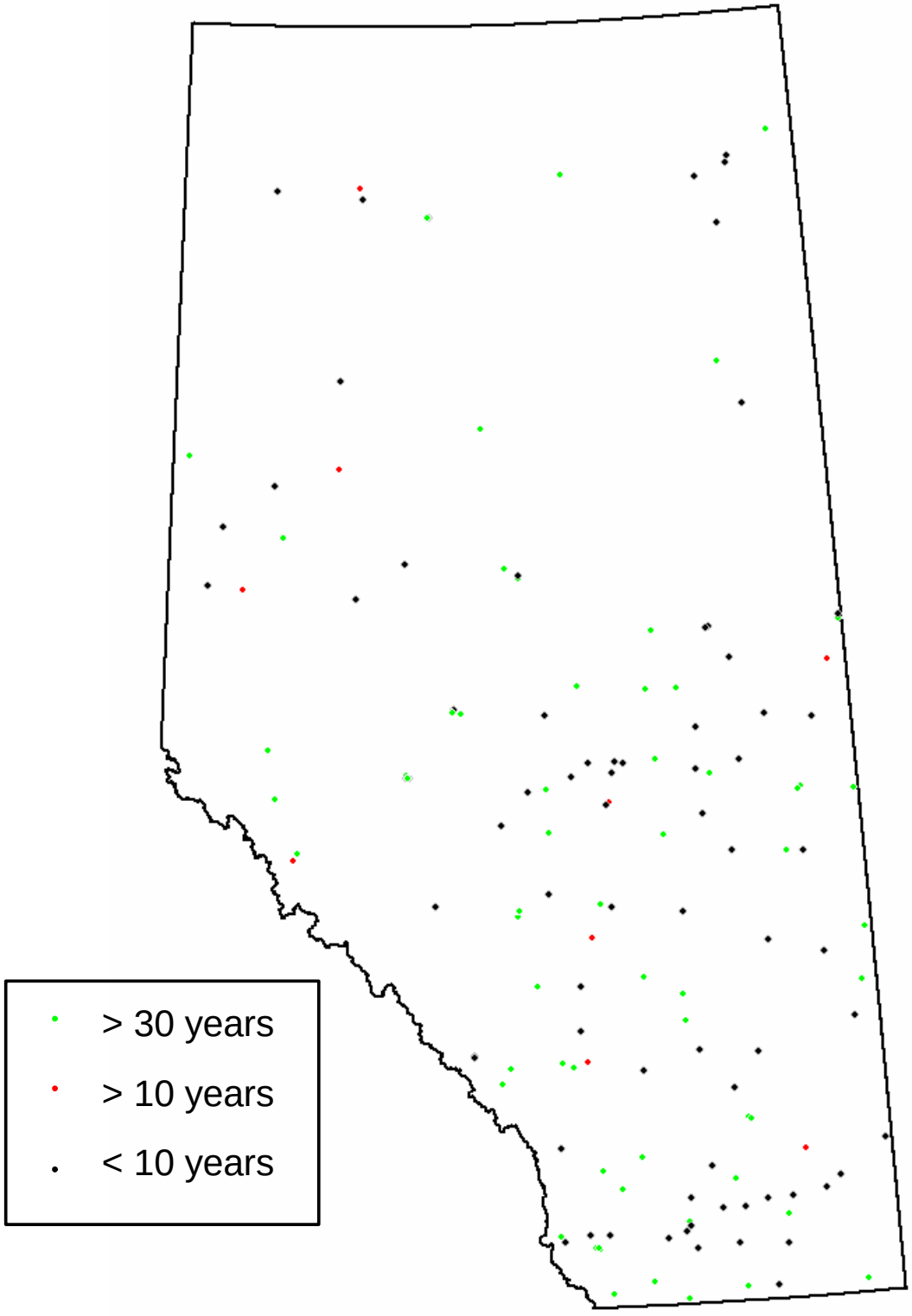

Figure 2 – Ratio of Directional to Overall 2 Year Wind Speed

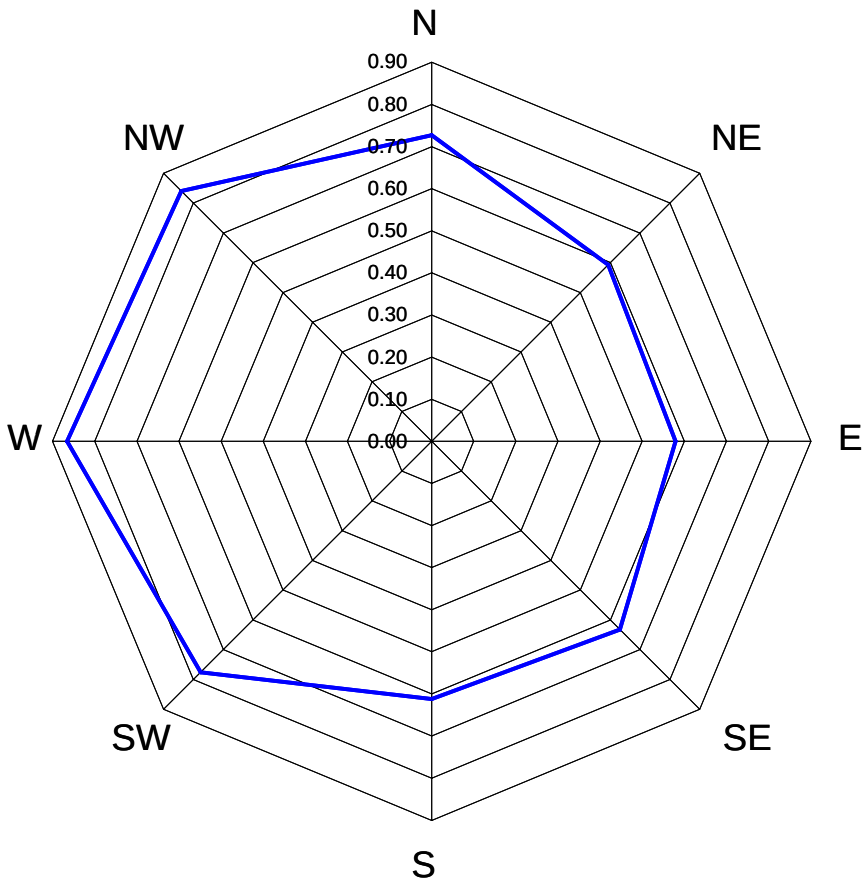

Figure 3 - Design 2 Year Wind Speed Map (km/hr)