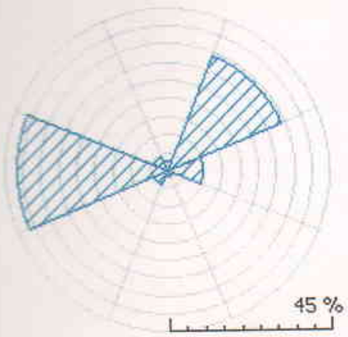
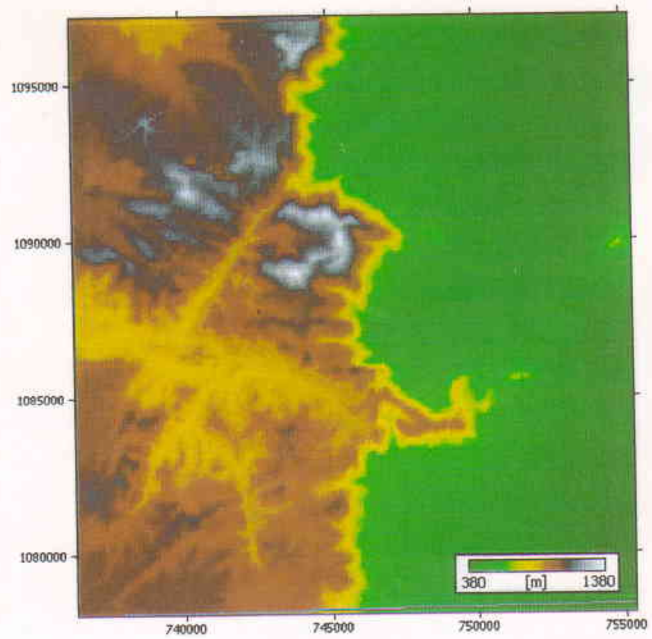
REPORT ON MICROSITING FOR WIND FARM PROJECTS AT RAMAKKALMEDU & PUSHPAKANDAM IN IDUKKI DISTRICT, KERALA

Project funded by
Agency for Non Conventional Energy & Rural Technology (ANERT),
Thiruvananthapuram





C-WET

An ISO 9001:2000 Organisation

WIND RESOURCE ASSESSMENT UNIT
CENTRE FOR WIND ENERGY TECHNOLOGY (C-WET)
Chennai 601 302

March 2005

C-WET/WRA/CP-20/2004-05

REPORT ON MICROSITING FOR WIND FARM PROJECTS AT RAMAKKALMEDU & PUSHPAKANDAM, IN IDUKKI DISTRICT, KERALA

FINAL REPORT

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CENTRE FOR WIND ENERGY TECHNOLOGY, CHENNAI

EXECUTIVE SUMMARY

Agency for Non Conventional Energy & Rural Technology (ANERT) Thiruvananthapuram vide letter no. PD/WPC/ANERT/2005 dated: 13-01-05 has requested C-WET to conduct micrositing at Ramakkalmedu and Pushpakandam areas in Idukki district of Kerala . C-WET has undertaken this work and carried out the micrositing in time and prepared the report.

The wind data used for the energy estimation was generated at the site by this Centre during the period 1992-95

The Wind Atlas Analysis and Application Program (WAsP 8.1) model was used for the analysis of wind resources and estimation of annual energy production in the proposed wind farm sites.

The contour maps of both the sites with an interval of 2 m were provided by the Agency.

The C-WET personnel along with M/s ANERT and M/s EMC , Thiruvananthapuram team have visited the site for the ground truth verification . Based on the availability of land, micrositing have been carried out. The client has provided power curves of the machines.

The total installable capacity is found to be 5 MW and 3.75 MW with 1250 kW and 750 kW machines respectively at Ramakkalmedu site and 2.5 MW and 1.5 MW at Puspakandam. The Sulappara ridge in Pushpakandam area could be utilized, provided logistics and other infrastructures are made available.

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Wind Resource Assessment Unit.

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CENTRE FOR WIND ENERGY TECHNOLOGY, CHENNAI

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CENTRE FOR WIND ENERGY TECHNOLOGY CHENNAI

REPORT ON MICROSITING FOR WIND FARM PROJECT IN RAMAKKALMEDU & PUSHPAKANDAM, IN IDUKKI DISTRICT, KERALA

1.0. Background of the project

Agency for Non Conventional Energy & Rural Technology (ANERT) established by Govt. of Kerala , vide letter no. PD/WPC/ANERT/2005 dated: 13-01-05 has requested C-WET to conduct micrositing at two locations in Ramakkalmedu and Pushpakandam area in Idukki district of Kerala . A proposal was prepared for undertaking the micrositing and sent to ANERT on 17.01.2005. Subsequently ANERT issued a work order, vide their order No. 5330(a)/P/ANERT/04 dated 25 -01-05. The client has provided required inputs for the proposed work. The map file of Pushpakandam was made available on 11-02-05.

The site was visited on 27th & 28th of January 2005 by C-WET official for field verification along with the representatives of M/s ANERT and EMC , Thiruvananthapuram.

2.1. Site locations and Description

The proposed wind farm locations under consideration are two separate pieces of land in Ramakkalmedu and Pushpakandam area and are 7 km aerially and 12 km by road from Nedumkandam town towards east and north east direction. The distance between the two locations is 2.5 km . The proposed wind farm area in Ramakkalmedu is a 1 km long narrow , uneven L – shaped ridge with half of the orientation exactly east – west and rest being north- south. The Kerala – Tamilnadu border line divides the ridge equally and it confines the utilization of lands for wind power projects. The average elevation of the ridge top is found to be 1050 m. The elevation difference between the highest and the lowest point given in the contour map is 160m . A tarred road is available up to the foot of the ridge at the southern side. The ridge top is open in appearance with boulders and grass in between.

The location at Puspakandam area is one of the highest ridges in the Western ghats.. The ridge is a 1.5 km long narrow uneven ridge with sharp slopes on both the sides and the orientation is roughly east - west. The maximum elevation of the ridge is about 1428m at the eastern end and the minimum is 1058m at the west. A jeepable road is available up to the southern side foot of the ridge but there is no proper accessibility to the top of the ridge.

The terrain details of the site can be seen in the Survey of India 1: 50,000 scale Topo-Map no.58G/1 grid C3. No: 58B/8.

2.2. Wind Data acquisition

The wind measurements were made at a height of 20 m a.g.l. at Ramakkalmedu site. Mean wind speeds were measured using NRG #40 maximum cup anemometers, recording consecutive 60-minute averages and 2-s gust speeds. The NRG #200 wind vanes recorded the instantaneous wind direction. The data were collected using Second wind data storage units over a period of about 3years from January 1992 to December 1995.

Details of Ramakkalmedu wind-monitoring Station is given in table.1.

Table.1.Details of Ramakkalmedu wind monitoring Station

1. NAME OF THE SITE	Ramakkalmedu
Lattitude/ Longitude/Elevation	$9^0 48$ .967'/77^0 14.482'/1070 m
Toposheet NO.	58G/1
2. STATE/DISTRICT/.TALUK/ VILLAGE	Kerala/Idukki/Udumbachola/Parathode
3. APPROACH DETAILS/ ACCESSIBILITY	About 14 km from Nedumkandam town. An approach Road is available from Nedumkandam to Ramakkalmedu. Mast was located atop of a ridge.
	Hilly terrain/ Complex
4. NATURE OF TERRAIN	Open appearance
5.EXPOSURE	Forest loam
6. TYPE OF SOIL	1992 January-1995December
7. PERIOD OF DATA	Second Wind
8. INSTRUMENTS USED	20 m
9. MAST HEIGHT	10m and 20 m level
10. LEVELS OF OBSERVATION	

The Ramakkalmedu wind mast is located over a ridge at a height of 1070 m (GPS Value) above mean sea level and at a distance of 1 km from Ramakkalmedu village. The orientation of the ridge is North- South. The entire area is with an open appearance. The map depicting the Region of Interest in Idukki District is shown in fig. 1 and the map of the Region of Interest is given in fig 2.

Fig.1 Region of Interst in the map of Idukki district.

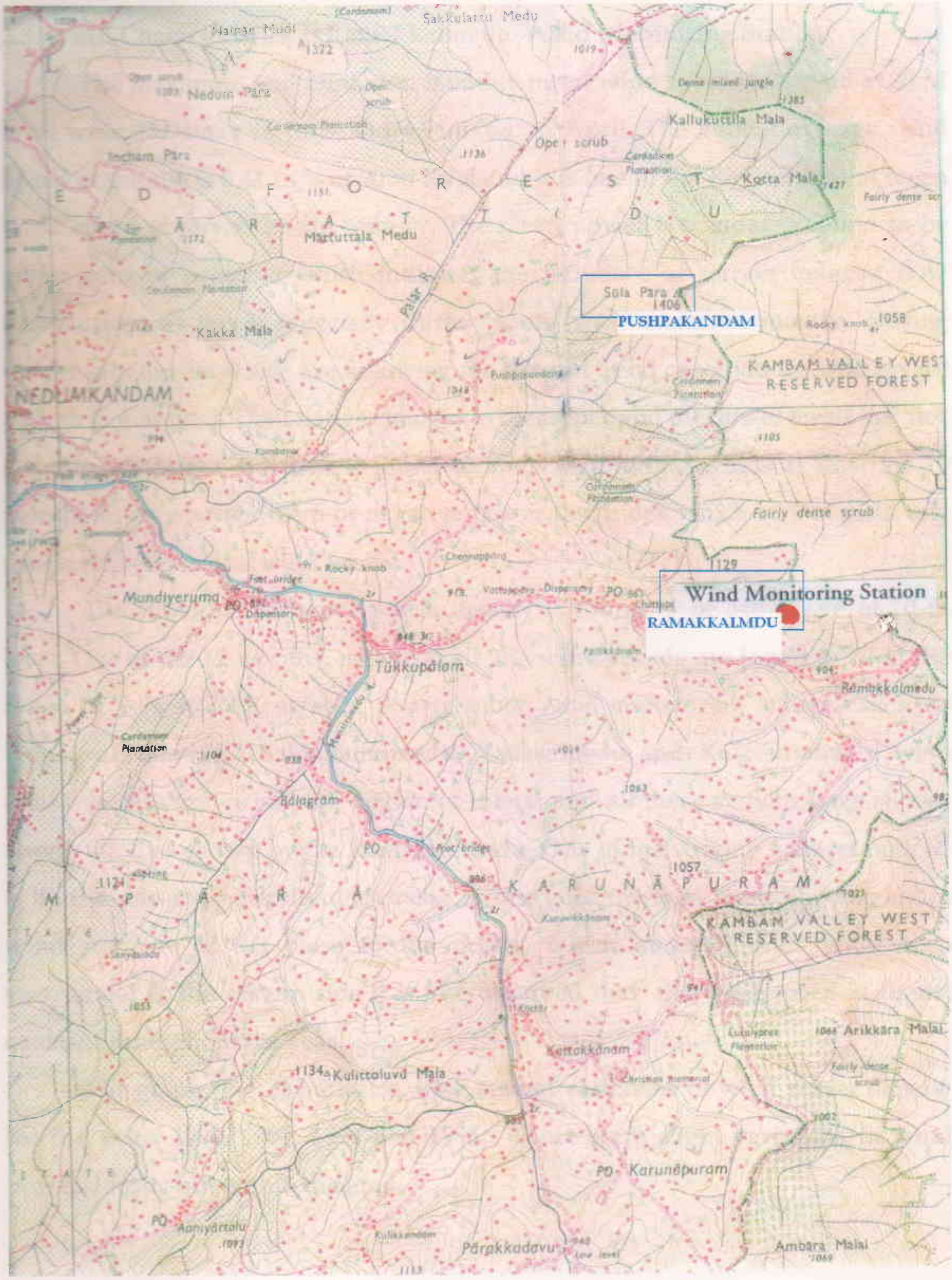


Fig. 2 Map of Proposed Wind farm sites

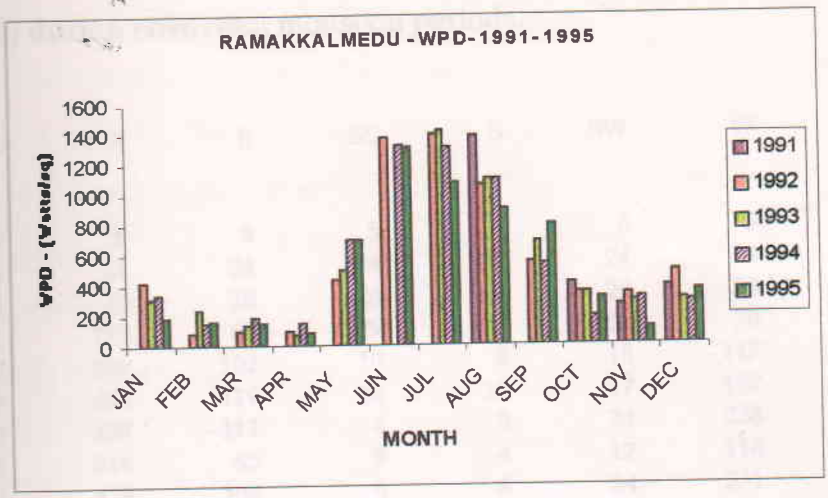
2.3. Wind Characteristics at Ramakkalmedu Wind Monitoring Station

The maximum and minimum monthly mean wind speeds observed at 20 M level were 13.04m/s in June and 4.96m/sec in April. The annual average wind speed at the site is 8.41 m/s at 20 m level and it is one of the highest annual mean wind speed observed in the country. The mean power law index is found to be either zero or negative which indicates the influence of terrain induced flow distributions at levels especially during south west monsoon months. During winter months the winds are following the general trend of variations with height though is marginal. The relative changes in the upper and the lower levels are not significantly large. The area is found to have very strong winds at least for 10 months in an year and zero or negative power law index which cannot yield any conclusion on vertical wind profile.

The annual mean wind power density is found to be 546 W/m^2 at 20 m level. Out of the 12 months, except April ,the wind speeds are found to be in the range of 6.94 to 14.5 m/secs. A few more wind monitoring stations such as Perampukettimedu , Sakkulathumedu, Kailasamedu and Kulathummedu were established in the vicinity of region of interst and all these stations have shown strong wind as shown by the Ramakkalmedu. One of the striking features noticed is that winds are generally decreasing as one goes towards west. The maximum wind pressure is felt close to the points, which abruptly ends with steep escarpment in the eastern side It is also observed that the wind speed is almost constant throughout the year.

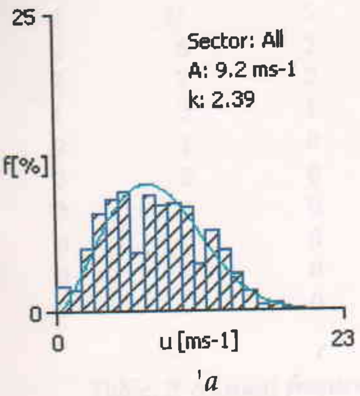
The graph (Fig..3) indicates, inter annual variations of wind power density for the years 1992, 1993, 1994 and 1995. There were slight variations in wind power density but within the limit.

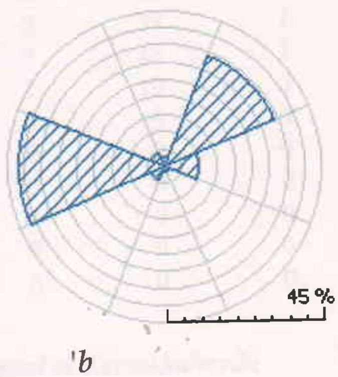
Fig..3 Inter annual variations of wind speed



Frequency distribution

Apart from the distribution of the wind speed over a day or a year, it is important to know the number of hours per day or per year during which





. Fig .6 a .Histogram of annual wind speed and fitted Weibull distribution curve . b wind direction rose diagram is shown in figure b.

the given wind speed occurred i.e. frequency distribution of wind speed. Sector wise annual frequency distribution of the site is given in table.2. Histogram of annual wind speed and fitted Weibull distribution curve is given in the figure 6 a and wind direction rose diagram is shown in figure.6b. Wind rose indicates that the predominant wind direction is west (32%) during south west monsoon and northeast (18%) during north east monsoon periods.

m/s	N	NE	E	SE	S	SW	W	NW	Total
0	5	5	5	5	5	5	5	5	40
1	24	24	24	24	24	24	24	24	192
2	20	20	20	20	20	20	20	20	160
3	31	173	64	29	28	31	70	37	463
4	17	389	102	10	8	15	117	33	691
5	19	454	119	12	10	17	137	39	807
6	12	437	111	6	8	24	238	32	868
7	6	216	55	3	4	12	118	16	430
8	12	423	108	6	8	24	231	31	843
9	16	236	61	2	4	35	388	30	772
10	16	241	62	2	4	35	397	31	788
11	19	159	43	2	3	38	473	25	762
12	10	37	12	1	1	19	253	9	342
13	17	63	21	1	2	33	434	16	587
14	13	48	16	0	2	25	330	12	446
15	9	30	10	0	0	16	208	7	280
16	4	16	5	0	0	8	110	4	147
17	2	6	2	0	0	3	39	1	53
18	2	7	2	0	0	3	45	2	61
19	1	3	1	0	0	1	19	0	25
20	0	1	0	0	0	0	6	0	7
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0

Table. 2 Annual frequency distribution of wind speed at Ramakkalmrdu

3.0 Methodology

Wind Atlas Analysis and Application Program (WAsP) is a PC program developed by the Wind Energy and Atmospheric Physics Department, Riso National Laboratory, Denmark that is used extensively to estimate wind energy resources. The program can generalize a long-term meteorological data series at a (reference) site and may then be used to estimate conditions at a second (predicted) site within certain limits of climate and terrain. The data generalisation is done through the WAsP Analysis procedure, which corrects the measured data series for local effects that only affect the reference site (met. station), but is not more general in nature. The generalised data are stored in the Atlas file which may then be used through the reverse process of the WAsP Application procedure in order to estimate the mean wind speeds and wind energy at a second (predicted) site, often referred to as a wind turbine site..

The WAsP model and wind atlas methodology was used for the analysis of wind resources in Ramakkalmedu area.

The WAsP has its own limitations. In view of the practical limitations imposed by climate and terrain , it is recommended that proper use of the programme is confined to terrain which may have low, smooth hills of small to moderate dimensions with sufficiently gentle slopes for areas of flow separation to be insignificant. For detailed wind turbine siting, WAsP allows for modelling complications in the form of terrain inhomogeneities, sheltering obstacles and terrain height differences. Therefore identification of such complexities are very important before concluding WAsP results. In order to apply the modelling techniques and obtain reasonable results, it is essential to carry out a computation known as *Ruggedness Index (RIX) Analysis*. The value of the index defined above will of course depend on the size of the area, the radius and the threshold slope.

The European Wind Atlas prepared with the help of WAsP indicates that the prediction may differ up to +/- 15% or more.

4.0 Wind Resource Assessment at the proposed site.

In order to predict the wind characteristics at some points other than the point of observation, terrain characteristics of extended area are to be taken in to account. The drawing was then prepared to extract the orographic and roughness models for the area of interest.

The vectorised contour maps of the region of interest with 2 m interval were provided by the client and the same was used for the assessment. Actual details of the terrain characteristics were collected during the visit to the site and its surroundings. A regional wind atlas of 20*20 sq.km area around the Ramakkalmedu wind monitoring station on 20 m contour map was prepared and correlated with results of region of interest. Roughness of the site is taken as 0.03m.

The wind atlas contains data for 4 reference roughness lengths (0.000 m, 0.030 m, 0.100 m, 0.400 m) and 5 reference heights (10 m, 25 m, 50 m, 100 m, 200 m) above ground level and given in the table 3. Isometric views of the proposed sites are given in figures 7 and 8.

- Ht amgl	-Parameters	0.00 m	0.03 m	0.10 m	0.40 m
10.0 m	Weibull A [m/s]	9.8	6.7	5.8	4.5
	Weibull k	2.21	2.01	2.01	2.04
	Mean speed U [m/s]	8.68	5.96	5.15	4.02
	Power density P [W/m²]	695	247	159	74
25.0 m	Weibull A [m/s]	10.7	8.0	7.1	5.9
	Weibull k	2.24	2.10	2.09	2.11
	Mean speed U [m/s]	9.47	7.05	6.30	5.25
	Power density P [W/m²]	893	393	280	161
50.0 m	Weibull A [m/s]	11.4	9.1	8.2	7.1
	Weibull k	2.29	2.23	2.21	2.21
	Mean speed U [m/s]	10.12	8.04	7.30	6.27
	Power density P [W/m²]	1073	550	414	264
100.0 m	Weibull A [m/s]	12.3	10.5	9.6	8.4
	Weibull k	2.28	2.38	2.38	2.38
	Mean speed U [m/s]	10.88	9.31	8.52	7.46
	Power density P [W/m²]	1338	807	619	416
200.0 m	Weibull A [m/s]	13.4	12.6	11.5	10.1
	Weibull k	2.26	2.42	2.41	2.41
	Mean speed U [m/s]	11.85	11.14	10.18	8.91
	Power density P [W/m²]	1741	1370	1048	702

Table 3. Regional wind climate summary (without air density correction)

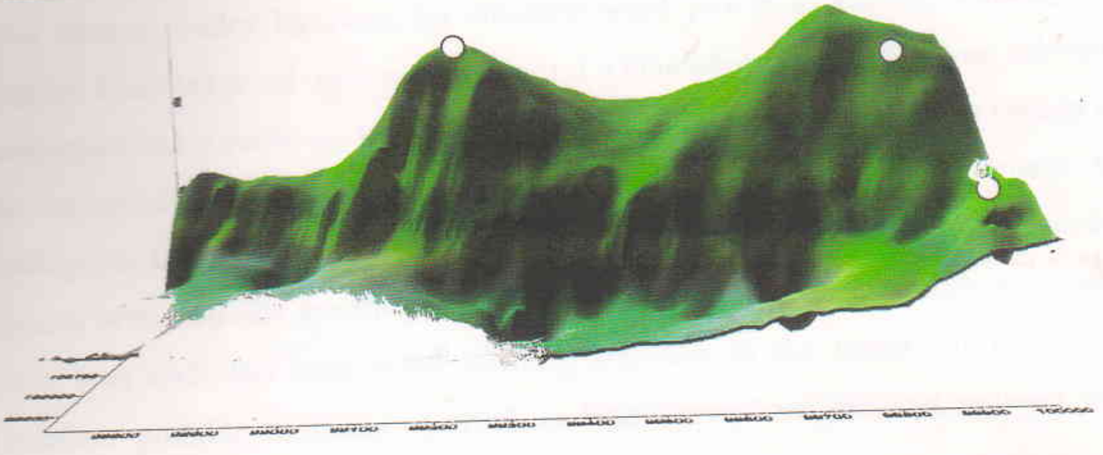


Fig 7 An isometric c view of the proposed site at Ramakkalmedu

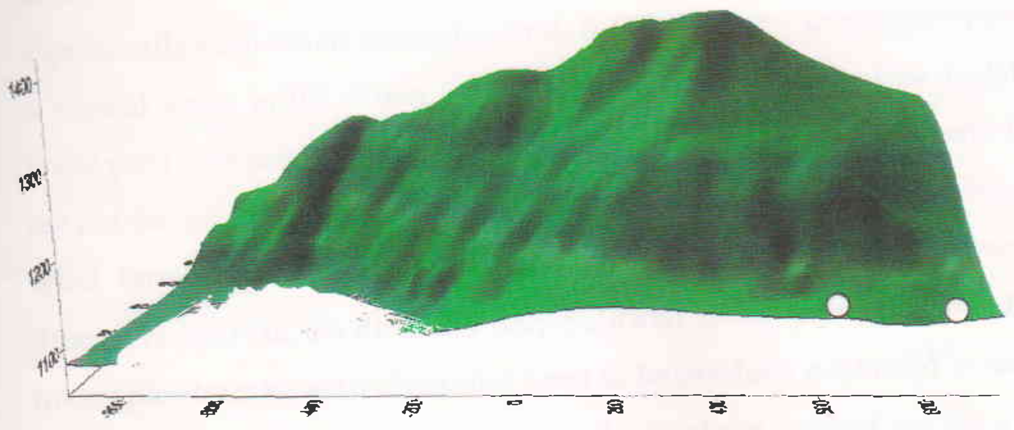


Fig 8 An isometrc view of the proposed site at Pushpakandam

5.0. Micrositing & Lay out of Wind Farm.

Micrositing of wind farm in complex terrain remains a formidable task subject to potentially significant error. Ramakkalmedu and Pushpakandam areas are a typical examples of such a complex terrain with multiple peaks and saddles. For a given wind condition, any peak can be either upwind or downwind of another peak, complicating the matter of which peak influences other downwind peaks or valleys. In fact a detailed study would be necessary to evaluate specific peak sites or valley locations for effective wind power utilization. This would require knowledge of the regional wind climatology and all other relevant meteorological conditions. Many existing micrositing tools can address certain of the issues surrounding such a siting evaluation, but most tools would be inadequate in exploring the effects of flow separation and reattachment in the regions with extreme terrain geometry. Because of these uncertainties Sulappara ridge was excluded from wind farming activities in the micro survey study.. However possible locations of wind turbines have been marked without any annual energy prediction.

In general, a wind farm consists of wind turbines, which are often installed, in rows perpendicular to the predominant wind direction. Positioning of Wind turbines need careful lay out to ensure that individual machines do not affect significantly each others access to wind. A Wind turbine during its operation sheds a conical wake in the down wind direction. Any wind turbine installed in this wake produces lesser power and experiences higher turbulences and thus proper lay out for wind turbines is crucial in a wind farm. As a rule of thumb, turbines in wind farms on flat terrain are usually spaced somewhere between 3 and 5 diameters apart in the direction perpendicular to the prevailing winds. However in complex terrain, individual sites need to be carefully evaluated to make best use of wind resource as this spacing have to be carefully worked out, on a case-to-case basis.

The predominant wind direction at Ramakkalmedu is west Orientation of the proposed site is east - west and it limits the number of machines that can be deployed. However the maximum number of machines have been accommodated in the first row of wind farm with spacing 2.5 D. WAsP 8.1 version was used for micrositing & lay out studies. Based on the availability of land, micrositing have been carried out. Boundary of the area has limited the flexibility of deploying machines. If there are any border issued related to use of land they need to be addressed separely. The client has provided power curve of the machines NM48 750 kW and Suzlon 1250 kW at standard air density.

The layout of the Wind Farm with NM48 750 kW and Suzlon 1250 kW rating WEGs at proposed sites are given in the Drawings No: CWET/WRA/ANE/1 to 4 respectively. Some photographs of the region are also given.

5.1 Estimation of Annual Energy Production

The WAsP generated Annual Energy Productions by 1250 kW and 750 k W are given in the table 4a & 4b and table 5a & 5b. The average capacity factors worked out to be approximately 33 % and 32 % at Ramakkalmedu by these machines respectively. The annual energy production is arrived by considering 10 % loss on grid frequency fluctuation and remaining 10 % on other losses. Array efficiency was computed by the WAsP.

Site description	X-location [m]	Y-location [m]	Elev. [m]	Wake Loss [%]	Net AEP GWh	CF%
Turbine site 1	99919	99896	959	1.69	3.5	32
Turbine site 2	99980	100071	965	0.97	3.5	32
Turbine site 3	99834	100350	1031	1.14	3.7	34
Turbine site4	99240	100421	1024	0.53	3.6	33
		Average	994.75	1.1	3.6	33

Table 4.a Estimated annual energy production at-the site by Suzlon 1250 kW

Site description	X-location [m]	Y-location [m]	Elev. [m]	Wake Loss [%]	Net AEP GWh	CF%
Turbine site 1	99920	99879	957	1.63	2.0	31
Turbine site 2	99956	100001	965	1.66	2.0	30
Turbine site 3	99984	100128	971	1.19	2.1	32
Turbine site4	99849	100342	1029	0.63	2.1	33
Turbine site 5	99172	100447	1026	0.34	2.1	32
		Average	989.6	1.09	2.1	32

Table 4 b Estimated annual energy production at the site by NEG 750 kW

Machines are marked in the contour map in the Fig 4. and 5

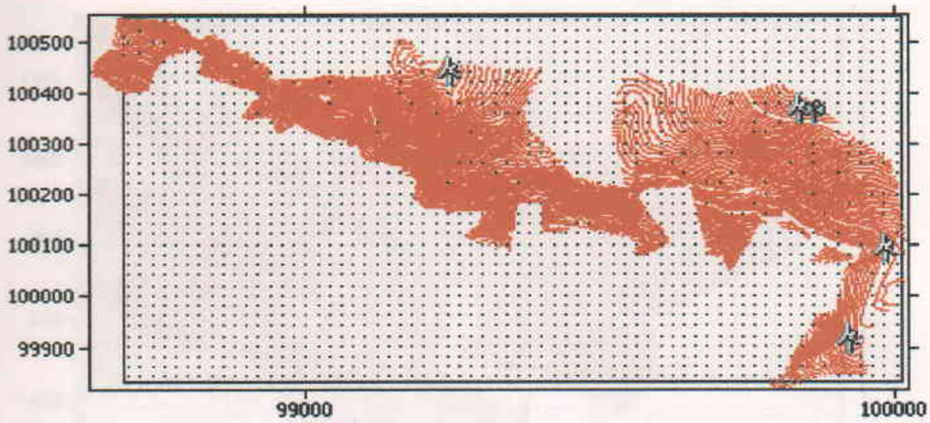


Fig.9 Map showing layout of wind farm with Suzlon 1250 kW

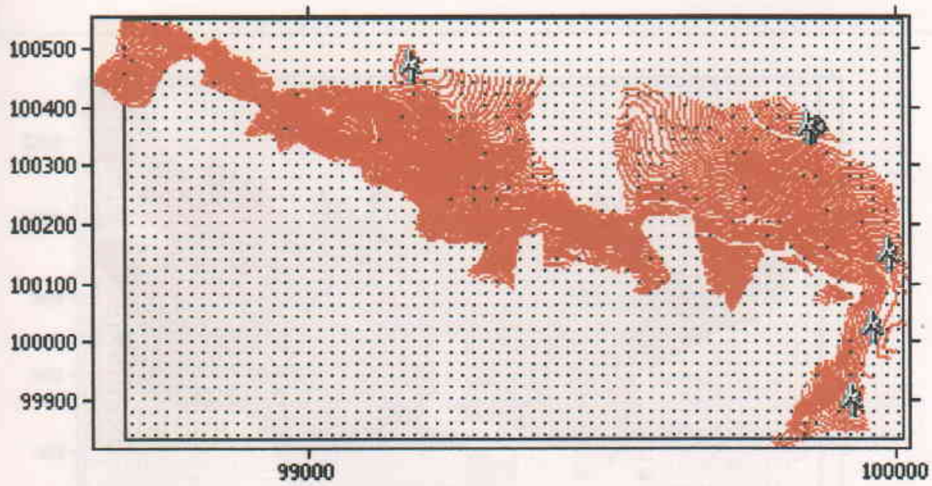


Fig.10 Map showing layout of wind farm with NEG 750 kW

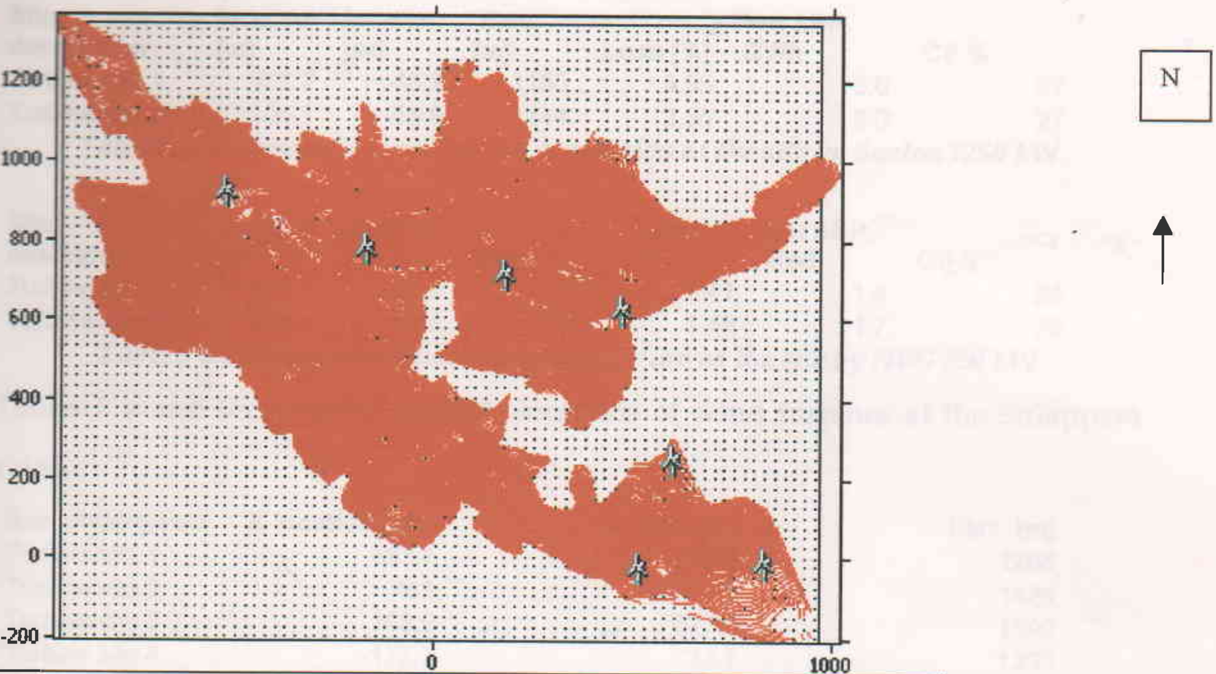


Fig.11. Map showing layout of wind farm with Suzlon 1250 kW

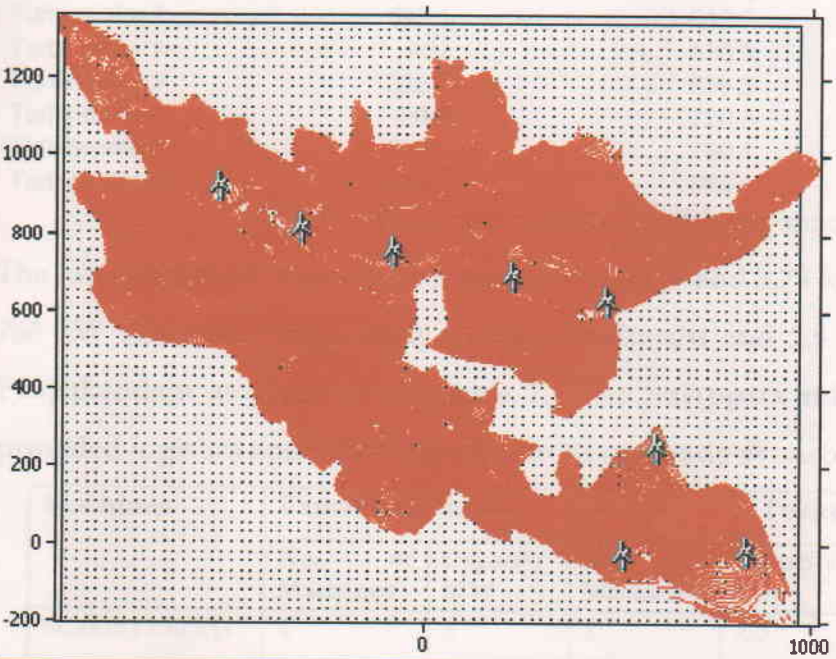


Fig.12. Map showing layout of wind farm with NEG 750 kW

Site description	X-location [m]	Y-location [m]	Elev. [m]	Loss [%]	Net AEP, GWh	CF %
Turbine site 1	822.7	-48.1	1150	3.95	3.0	27
Turbine site 2	506.1	-58.8	1144	2.35	3.0	27

Table 5.a Estimated annual energy production at the site by Suzlon 1250 kW

Site description	X-location [m]	Y-location [m]	Elev. [m]	Loss [%]	Net AEP, GWh	CF %
Turbine site 1	822.7	-48.1	1150	3.41	1.6	24
Turbine site 2	506.1	-58.8	1144	1.68	1.7	25

Table 5 b Estimated annual energy production at the site by NEG 750 kW

Tables 6 a and 6b give the possible locations of wind turbines at the Sulappara ridge.

Site description	X-location [m]	Y-location [m]	Elev. [m]
Turbine site 1	593.1	213.9	1268
Turbine site 2	462	590.9	1428
Turbine site 3	168.9	677.8	1399
Turbine site 4	-175.7	743.7	1330
Turbine site 5	-531.1	887.8	1262

Tables 6 a. Turbine locations for 1250 kW machines

Site description	X-location [m]	Y-location [m]	Elev. [m]
Turbine site 1	593.1	213.9	1268
Turbine site 2	462	590.9	1428
Turbine site 3	222.8	655.3	1408
Turbine site 4	-88.5	720.5	1342
Turbine site 5	-322.1	780.1	1283
Turbine site 6	-536.7	889.1	1262

Tables 6 b Turbine locations for 750 kW machines

The total installable capacity is found to be 5 MW and 3.75 MW with 1250 kW and 750 kW machines respectively at Ramakkalmedu and 2.5 MW and 1.5 MW at Puspakandam as given in the table 7. The Sulappara ridge could be utilized, provided logistics and other infrastructures are made available.

Machines	Ramakkal medu		Pushpakandam			
	No. of Machines	Capacity MW	No. of Machines	Capacity MW	No. of Machines *	Capacity MW *
Suzlon1250 kW	4	5	2	2.5	5	6
NEG 750 kW	5	3.75	2	1.5	6	4.5

If logistics and other infrastructures are made available.

Table 7. Installable potential at Ramakkalmedu and Pushpakandam sites

Photo 1. A view of proposed wind farm area at Ramakkalmedu

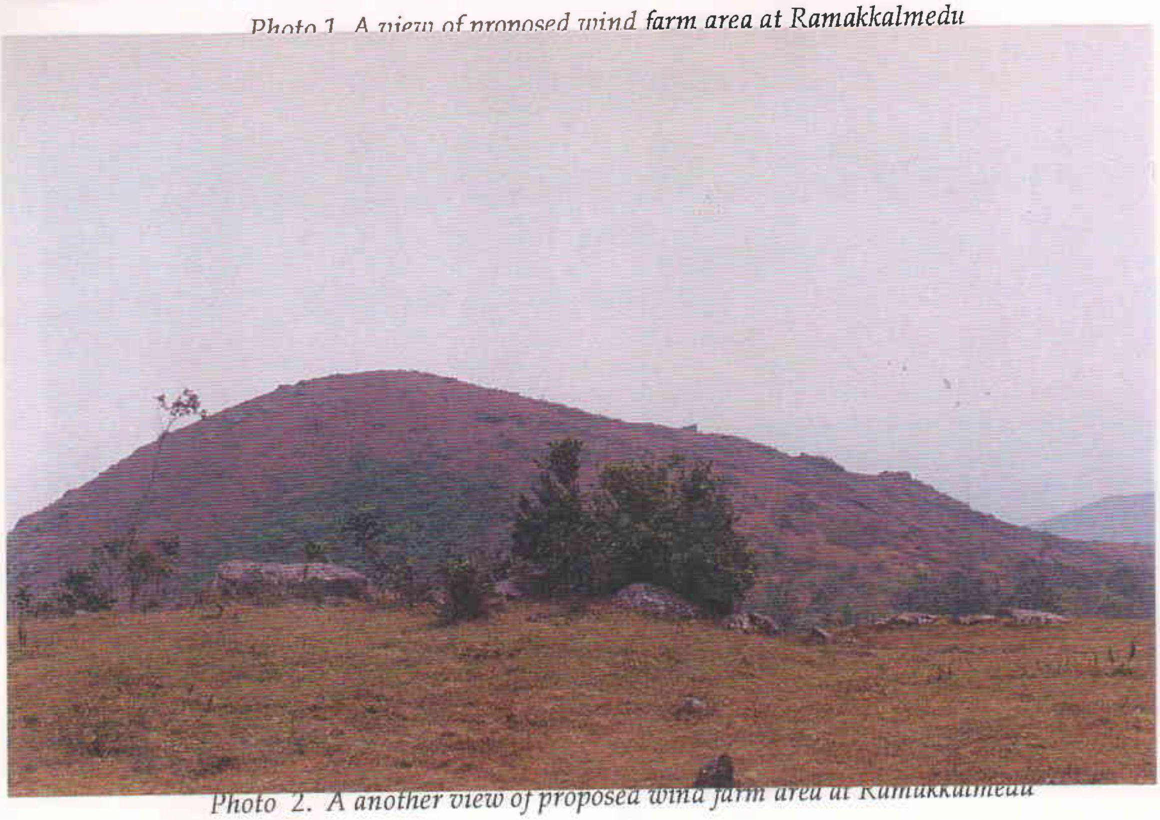


Photo 2. A another view of proposed wind farm area at Ramakkalmedu

Photo 3. A view of Sulappara ridge

Photo 4. A view of proposed wind farm area at Pushpagiri

ANNEXURE A . Power curve of Suzlon 1250 kW

65.0	64.0	
1.00	1000	1.225kg/m^3
3.0	0.0	
3.5	14.2	
4.0	35.1	
4.5	62.3	
5.0	88.8	
5.5	114.7	
6.0	147.9	
6.5	205.3	
7.0	274.8	
7.5	359.1	
8.0	445.9	
8.5	534.4	
9.0	621.4	
9.5	717.2	
10.0	810.6	
10.5	896.7	
11.0	980.5	
11.5	1060.8	
12.0	1127.3	
12.5	1177.5	
13.0	1197.7	
13.5	1235.3	
14.0	1250.0	
14.5	1250.0	
15.0	1250.0	
15.5	1250.0	
16.0	1250.0	
16.5	1250.0	
17.0	1250.0	
17.5	1250.0	
18.0	1250.0	
18.5	1250.0	
19.0	1250.0	
19.5	1250.0	
20.0	1250.0	
20.5	1250.0	
21.0	1250.0	
21.5	1250.0	
22.0	1250.0	
22.5	1250.0	
23.0	1250.0	
23.5	1250.0	
24.0	1250.0	
24.5	1250.0	
25.0	1250.0	

ANNEXURE B . Power curve of NM 48 750 kW

WTG Type NM48 750

55.0	48	
1.0	1000	1.225 kg/m^8
3.0	0	1.00
4.0	19	0.936
5.0	51	0.828
6.0	92	0.733
7.0	148	0.865
8.0	232	0.798
9.0	330	0.735
10.0	438	0.672
11.0	539	0.603
12.0	621	0.535
13.0	681	0.472
14.0	718	0.416
15.0	741	0.369
16.0	750	0.330
17.0	749	0.298
18.0	742	0.272
19.0	733	0.249
20.0	723	0.231
21.0	714	0.215
22.0	707	0.201
23.0	704	0.189
24.0	705	0.180
25.0	710	0.171

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DISCLAIMER

The analysis and interpretations of wind potential of the site is based on the power curve and location contour maps as given by the client M/s ANERT, Thiruvananthapuram. Any disputes arising out of projections made using these data shall not be the responsibility of C-WET.

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