AWARUA WETLANDS FIRE 27th OCTOBER 2005

A CASE STUDY

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Introduction

This case study provides an analysis of the fire that burned across part of the Awarua Wetlands on the 27th of October 2005. The Awarua wetlands (Figure 1) are situated near the Tiwai Point Aluminium Smelter, approximately 17km from Invercargill city. This wetland region covers an area of 14,000 hectares and holds significant importance as a Department of Conservation (DoC) scientific reserve. The area is a key site for migratory birds that use it as a site for resting, feeding and breeding. Wetland areas in this region contain mainly bogs rather than swamps, which contain saturated, stagnant and infertile water and are characterised by peat[1]. The aluminium smelter at Tiwai Point is a major contributor to the regional, and indeed national, economy. The Awarua area also has a well-documented history of fire events. It is here in this area, almost nineteen years to the day after the 1986 Awarua Wetlands Fire, that another fire threatened the flora and fauna of the area, as well as life and property.

Fire Chronology and Development

Ignition and initial attack

The New Zealand Fire Service Communications Centre in Christchurch recorded the first call reporting a fire at Awarua Siding Road at 1158[2] on Thursday the 27th of October 2005. However it is possible that the fire may have started on either Tuesday the 25th or Wednesday the 26th of October. At this initial stage, strong northerly winds of approximately 35km/h fanned the fire. The fire initially made a short head fire run south towards Awarua Bay. This long narrow elliptical run is shown in Figure 2 and travels south for 2.3km from the point of origin. The head fire reached the bay at around 1311. Flanking fires accounted for the majority of the rest the area burned throughout the day. The fire was later attributed to a local farmer conducting a burn off, which escaped from him two days later. The farmer had tried to extinguish a hotspot, which arose from the burn, but unfortunately weather conditions were unfavourable.

The first fire suppression unit arrived on the scene at 1200, with subsequent units arriving over the next forty-five minutes. The deputy Principal Rural Fire Officer (PRFO) for the Southland Rural Fire District (SRFD) was airborne at 1245 and began fire observations as well as monitoring fire developments and growth. In the early stages of the fire, the initial attack

[1] http://www.doc.govt.nz/Conservation/Wetlands/020~Wetlands-in-New-Zealand/013~Southland/index.asp. Site visited 23/02/06.

[2] Please note that times throughout this case study are presented in daylight savings times (NZDT) unless otherwise stated.

capability consisted of three ground crews. Since the area is a wetland, aerial suppression was deployed rather than ground units, as conditions were too dangerous for ground crews, which would have likely become stuck in the wetlands.

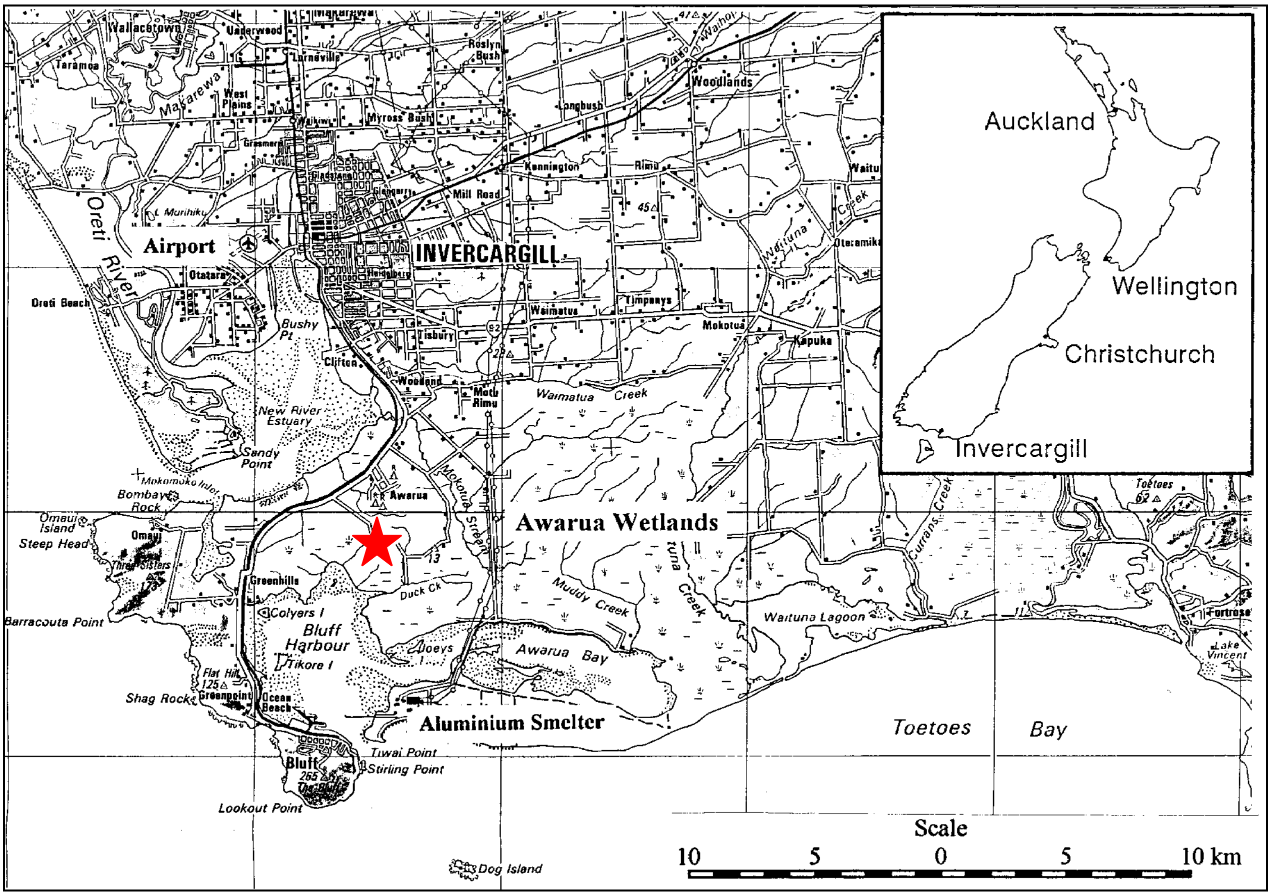

Figure 1. Location of the 2005 Awarua Wetlands Fire. (Source: Pearce et al 1994). The star denotes the fire's approximate point of origin.

Fire growth and suppression

By 1515 the fire had spread southeast through flank fire spread (Figure 2), then with a wind shift around this time from the NW it spread to the east. This second run was essentially a flanking fire. It was in this area that the fire continued to burn east under ponds of water. The fire then joined back up into the scrub fuels near the gravel pit, east of Joey's Island. Ironically the suppression crews were using these ponds as natural fire breaks at the time. A spot fire was observed on the NE corner of Joey's Island at 1604. The distance between the coastline and the island is approximately 230 metres, which is a significant spotting distance for scrub fuels. Around this time winds were recorded gusting northerly at up to 70km/h. The fire reached the gravel pit (located west of Joey's Island) at approx 1620. This was most likely due to a slight wind shift from N to NW. Throughout the duration of the fire, flame lengths were estimated between 8 and 10m and flame heights at 6-8m. These values, estimated from observers, seemed to be consistent throughout the day.

The fire continued to burn overnight and was declared contained on Friday the 28th at 0630, with the total area burned being 1400 hectares. The fire spread through wetlands; scrub and a small pine (*Pinus radiata*) plantation aged 6-7 years. The blue line in Figure 2 denotes the total area burned. Fortunately the fire only burned in surface fuels and not into the peat, avoiding prolonged mop-up difficulties.

A flare-up occurred on the 1st November at approximately 1350, four days after the original fire. This flare up happened in a gorse patch located next to the gravel pit (Figure 2). Weather readings from 1535 recorded[3] winds of 65km/h gusting to 95km/h from a W/SW direction, a temperature of 14.7ºC and RH of 82%. This flare-up had the potential to burn across into the gorse fuels on the seaward side of the gravel pit, but was successfully contained.

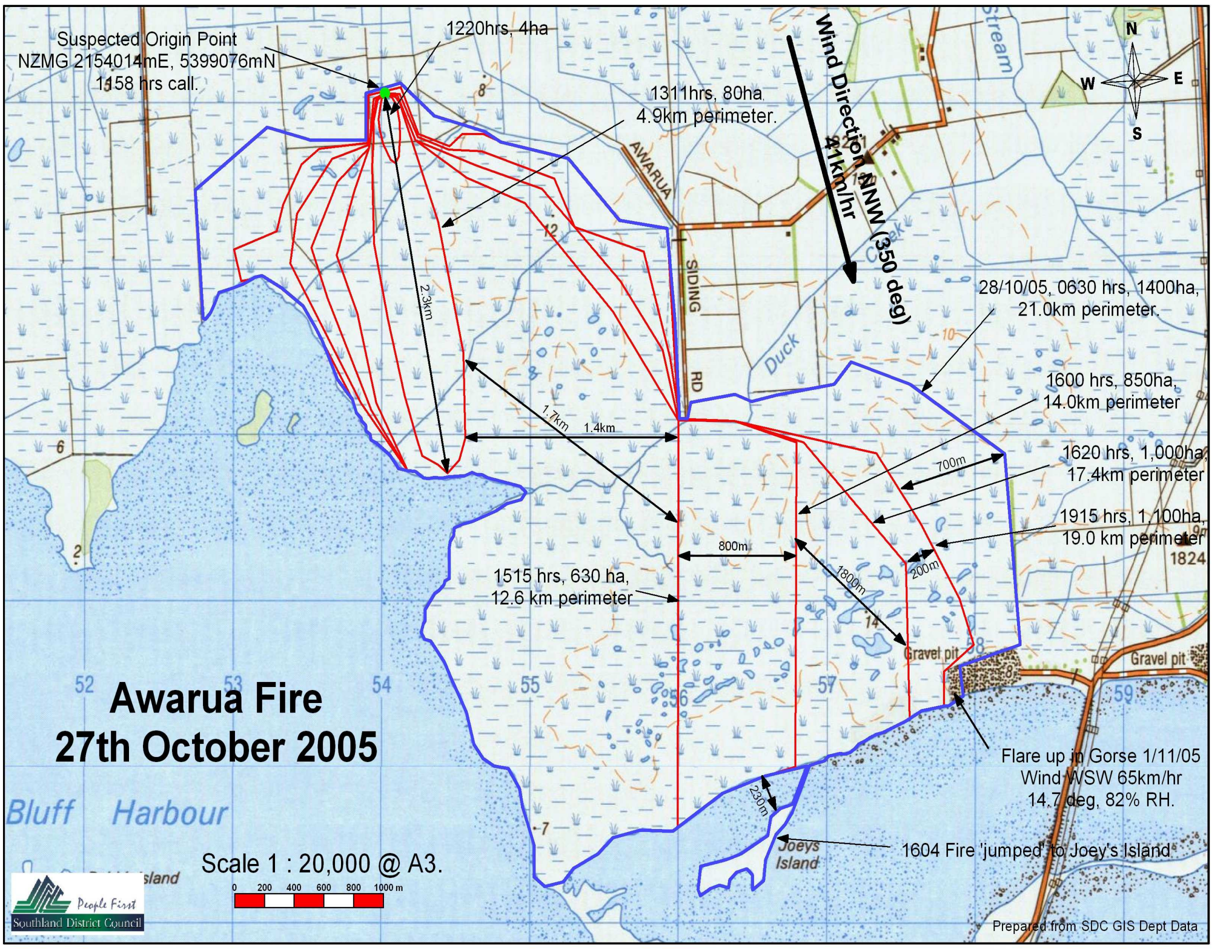

Figure 2. Area burned and major features of the Awarua Fire. (Source: Southland District Council).

Suppression strategies

The emphasis on aerial suppression was due to the nature of the terrain, and was undertaken by helicopters dip filling out of nearby ponds. Six helicopters were used during the day of the fire for operational use and one helicopter for observational use. Use of retardant on the fire was initially considered but the height of the vegetation was quite tall (2-3 metres). Due to this height it was deemed that the effectiveness of the retardant would be insignificant due to a lack of penetration into the vegetation, and the fire would continue to burn underneath. The amount of available retardant in the Southland district also posed a problem due to small amounts being kept in storage. Difficulties with aerial suppression were encountered due to the high wind speeds, therefore helicopters had to make their drops quite low to the ground. They also had to fly into the wind, rather than with the wind. It was found that using long strops on the helicopters was more effective because they were able to get down low to make the drops. These were used extensively in areas of greater fire intensity. Safety issues for the helicopters included snags located in the ponds used for dip filling and also low water levels in these ponds. Another significant safety issue for the pilots was that there was a lot of smoke and ash in the air, decreasing visibility.

[3] http://www.tomsweb.co.nz/weather_data/Toms_weather.htm. Site visited 01/11/05.

Values-at-risk and safety considerations

The Awarua Fire posed a significant risk to the Tiwai Aluminium Smelter (Figure 1). The power lines that feed the smelter run across the wetlands and are located very close to the location of the final perimeter of the fire. If the power was cut from the Tiwai smelter and not restored within two hours, then it would take up to 6 months to reinstate full production with major direct and indirect costs to the Southland Region and national economy estimated of up to $1 billion (including downstream costs)[4]. The impact on the power lines from the fire and smoke is that the heat causes the lines to sag. The amount of sag depends on the heat release by the fire[5]. This sag can then potentially lead to the lines shorting out and causing power loss. It was also determined that smoke plumes cannot cause shorting of power lines, but it can act to contaminate insulators, so an insulator can flash over[6]. Local authorities advised residents situated near the Tiwai Bridge that they could be in danger from the smoke and ash during the night. The New Zealand Fire Service Incident Report (ICAD Number M548071) reported that numerous bystanders were present during the time of the fire and two police units were called in to manage the traffic and close down nearby roads.
The area is a DoC managed scientific reserve, which holds considerable ecological values for bird life. The effects of the fire on bird life at the reserve have yet to be identified. The regeneration of wetland plant species after fire events has been examined in detail in Johnson (2001). He states that manuka is the most common and rapidly regenerating shrub species, but it is the seasonality of fire that has a differential effect on what species survive. The frequency of fire helps to determine whether certain plants become progressively more abundant.

There were no significant safety issues for fire fighters. Fortunately the fire did not burn into the peat. If it had done so, fire crews would have been committed to several days containing and suppressing the fire in treacherous terrain. Smoke and fire under the nearby power lines would also have posed a significant hazard to fire fighters.

Mop-up

As already explained, heavy machinery was not an option due to the nature of the terrain. During mop-up, ground crews were therefore forced to use shovels and 20 litre buckets to suppress hotspots, estimated to be burning approximately 30–50cm underground. Residual burning was also noted in *Pinus radiata* and Kahikatea (*Dacrycarpus dacrydiodes*) stumps. Water used for the mop-up was obtained from ditches and foam was added to this. Currently there is no issue with the Department of Conservation and the SRFD using foam on the wetlands. Mop-up continued for several days after the fire was contained, although a flare-up did occur four days later. At 1350 on Thursday the 1st of November 2005, re-ignition occurred in gorse near the gravel pit. The Tiwai Smelter fire crew assisted volunteer fire fighters at this time to suppress the fire.

Fire Environment

Topography

The Awarua Plains Wetland is situated in an extensive area of low-lying land with gentle ridged topography and contains the large water bodies of the New River Estuary, Awarua Bay, Toetoes Harbour and Waituna Lagoon[7].

[4] Pers. Comm. Mike Grant – Southern Rural Fire District, Invercargill. 02/03/06.
[5] http://www.fws.gov/southeast/refuges/flametip.html. Site visited 19/04/06.
[6] http://www.fws.gov/southeast/refuges/flametip.html. Site visited 02/05/06.
[7] http://www.doc.govt.nz/Publications/004~Science-and-Research/Miscellaneous/PDF/nzwetlands13.pdf. Site Visited 27/02/06.

Much of the Awarua plain has been drained and converted to pasture, but extensive areas remain in public ownership and are being managed for biological conservation (Johnson 2001). Altitude for this gently undulating area is between 0 and 20 metres above sea level, although it is essentially flat for fire behaviour purposes.

Fuels

The area is dominated by scrub and rushes, with the dominant species being Manuka (*Leptospermum scoparium* var. *scoparium*) and Wirerush (*Empodisma minus*). These two species account for approximately 90% of the total species present. Manuka is the only serotinous species present in the Awarua bog (Johnson 2001). Other notable species include:

- Tangle fern (*Gleichenia dicarpa*)
- Swamp turpentine shrub (*Dracophyllum* aff. *olierii*)
- Flax (*Phormium tenax*)
- Red tussock (*Chinochloa rubra*)
- Bracken fern (*Pteridium esculentum*)
- *Sphagnum* moss (occurs in wet depressions)

Flaxes and bracken fern predominantly occur in areas that have been opened up through human activity. This includes tracks created by duck shooters using the manuka for their shelters during hunting season. Small amounts of gorse are present but it seems to be insignificant at the moment. The fire did burn into a small radiata pine (*Pinus radiata*) plantation. Similar wetland vegetation is found on Joey's Island (refer to Figure 2) but vegetation present here is generally smaller and sparser.

From a previous case study (Pearce et al. 1994), actual fuel sampling was undertaken in this area. It was found that the height of the vegetation sampled was between 0.8 and 1.2m, and available fuel load was between 11 and 19 tonnes/ha. The available fuel load derived from fuel load tables was 18.4 t/ha (This value is taken from Pearce and Anderson 2004 available fuel load for scrublands and assumes a manuka/kanuka fuel type at an average height of 1m). From a site inspection shortly after the fire, it was found that vegetation in the majority of parts were in this height range.

Fire weather

The Invercargill airport automatic weather station (Invercargill Aero) is located 3km from the city centre. Data from this weather station was used for this analysis instead of the Tiwai Point Aluminium Smelter weather station, even though the Smelter weather station is situated only a few kilometres away from the fire site. No significant difference was found between the two stations and it was deemed that Invercargill Aero data was more reliable. Detailed weather data from Invercargill can be found in Appendices 1 and 2.

Fire danger conditions using the Fire Weather Index (FWI) System (Figure 3) showed that the area had been exhibiting a general drying trend since the 11^{th} of October 2005. This dry spell occurred after regular rain events over the past two months. This had kept the Duff Moisture Code, Drought Code and Buildup Code relatively low by national standards, but high enough to present problems in wetland fuels. From the 11^{th} of October up to the day of the fire, these index codes had increased significantly which provided the right conditions to sustain a fire.

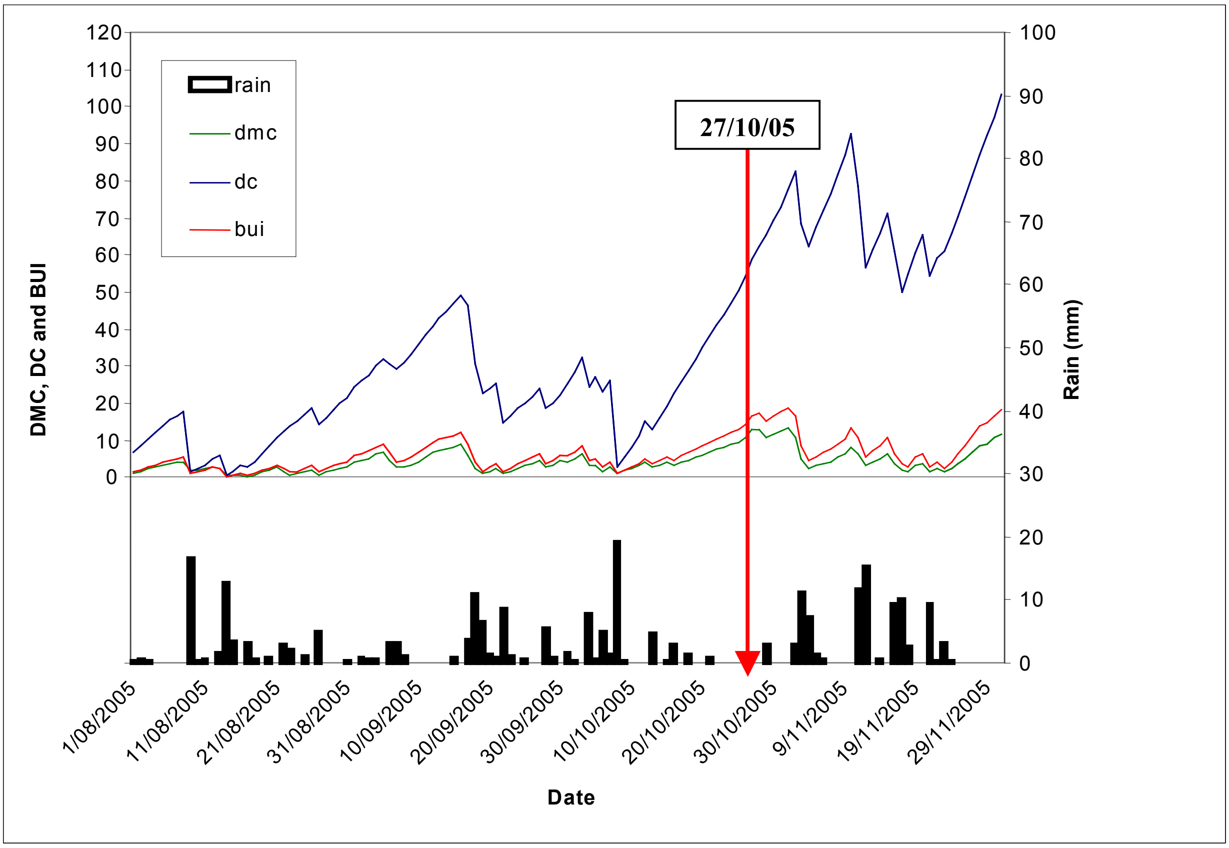

Figure 3. Duff Moisture Code (DMC), Drought Code (DC), Buildup Index (BUI) and rainfall for the period 1 August 2005 to 1 December 2005. Please note that the red arrow denotes the day of the fire.

Table 1 identifies the daily Fire Weather Index (FWI) system values taken at 1200 NZST for the day of the fire. Fine Fuel Moisture (FFMC) is an indicator of the ease of ignition of fine fuels and has a maximum value of 101. Ignition is possible when the FFMC is above 70 and nearly 100% chance of ignition is attainable when the FFMC is above 86. The FFMC of 87.5 on the day of the fire indicates that fine fuels at the wetland would have almost certainly ignited. Duff Moisture Code (DMC) indicates the fuel consumption in moderate duff layers and medium-size woody material, and the Drought Code (DC) indicates the effects of seasonal drought and smouldering in deep duff layers. Due to the nature of the terrain and composition of flora at the wetlands, both values of DMC (13) and DC (59), were well below their threshold values of 20 and 300 respectively. Threshold values are a sign that fire weather severity is worsening, and in this case it relates to duff moisture and seasonal drought effects. No or very little burning occurred in the peat. This was due to the low DC (59) and wet peat. The Initial Spread Index (ISI) indicates the expected Rate of Spread (ROS) of the fire and takes into account the effects of wind and FFMC. An ISI value greater than 10 indicates the fire will spread rapidly. Ignition and spread of the fire can be attributed to the low fuel moisture and ISI observed at the fire ground on the day. The Buildup Index (BUI) indicates mop up and control difficulty of the fire and also the total fuel available for combustion. BUI combines the values of DMC and DC. The actual value for the day was 17, which is again well under the threshold value of 40, which means deep-seated burning would not occur. Finally the FWI combines the values of ISI and BUI, and gives us a general index of fire danger throughout the forested and rural areas of New Zealand (Pearce and Anderson 2004). The observed value for the day of the fire was 21.3, which indicates a fire under these conditions would burn with high intensity.

Table 1. Standard noon daily FWI values for the day of the fire (27/10/05).

FFMC	DMC	DC	ISI	BUI	FWI
87.5	13	59	19.5	17	21.3

The synoptic weather chart for noon (NZST) on the 27th of October 2005 (Figure 4) showed a cold front approaching the South Island with an occluded front to the west of the lower South Island. A large anticyclone was sitting to the east, which accounted for the north to NW winds experienced over the fire ground. The closeness of the isobars over the Invercargill area indicates winds of moderate strength, as experienced on the fire ground.

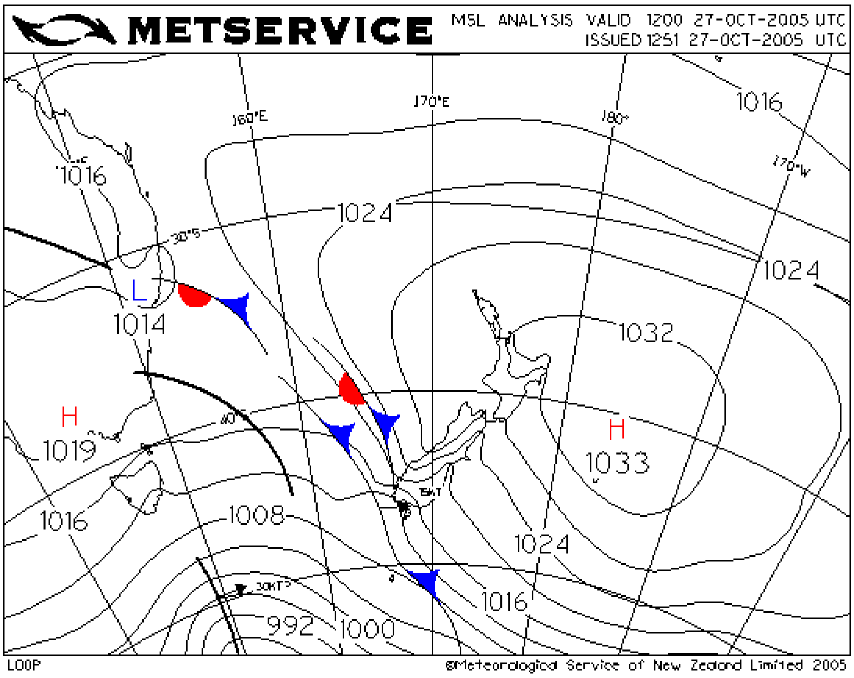

Figure 4. Synoptic weather chart for noon on 27 October 2005. (Source: MetService).

Wind speed and direction throughout the day of the fire is shown in Figure 5. It shows that the average wind speed increased considerably from 0830 in the morning and maintained its strength of around 35km/h for the duration of the main fire run. Wind direction remained northerly throughout this period. This is evident from the behaviour of the fire as it travelled south in its first run.

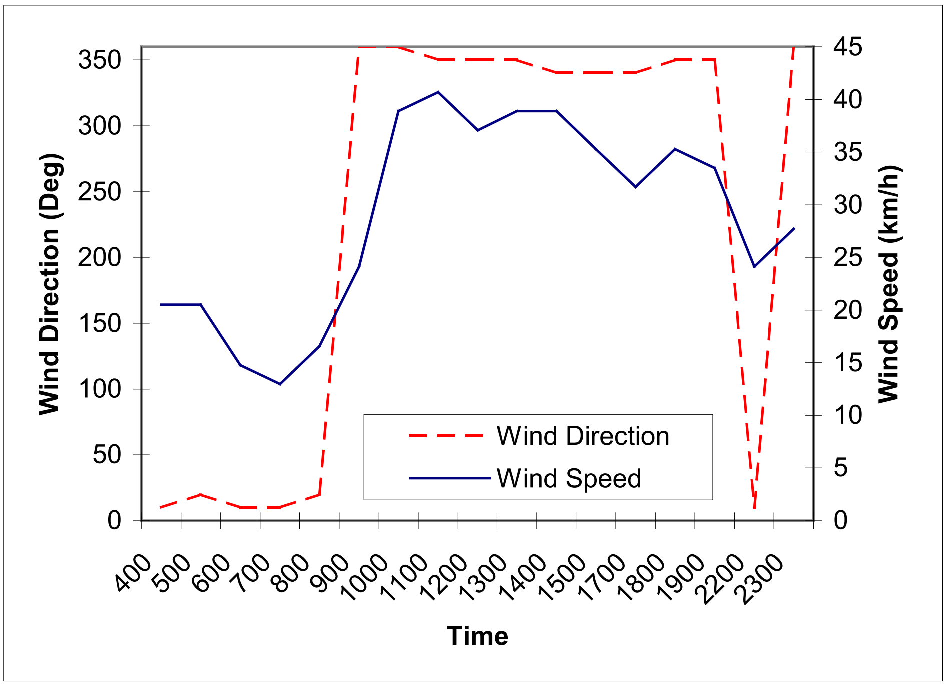

Figure 5. Hourly wind speed and direction for the day of the fire. Readings taken from Invercargill Aero.

Hourly weather readings and FWI values for the day of the fire are shown in Table 2. Conditions during the main run of the fire remained fairly constant. One notable point from the table is the hourly FWI values. There was a significant increase in the ISI and FWI values just before the time of ignition due to the presence of stronger winds, higher temperatures and lower RH values. The fire began at 1058 and the FWI value at this time was 3.2, but as a result of higher wind speeds this value had nearly tripled to 11.9 in the space of an hour. Weather conditions did become more favourable for fire fighters after 2200 when temperatures and wind speed dropped, and the relative humidity increased, aiding in containment of the fire.

Table 2. Hourly weather readings recorded at Invercargill Aero on the 27th October 2005.

Time (NZST)	Temp (ºC)	Relative Humidity (%)	Wind Direction (deg)	10m Wind Speed (km/h)	Rain (mm)	Max Wind Gust (km/hr)	Hourly FFMC	Hourly ISI	Hourly FWI
0400	14	55	10	21	0	-	68.9	1.7	0.3
0500	14	51	20	21	0	-	70.9	1.8	0.4
0600	14	59	10	15	0	-	72.3	1.4	0.3
0700	13	67	10	13	0	-	73.3	1.4	0.3
0800	19.5	53	20	17	0	-	75.1	1.8	0.4
0900	19	52	360	24	0	-	76.8	2.9	0.6
1000	21	49	360	39	0	39	78.8	7.1	2.3
IGNITION 1100	**20**	**46**	**350**	**41**	**0**	**67**	**80.5**	**9.3**	**3.2**
1200	**20**	**46**	**350**	**37**	**0**	**65**	**81.9**	**9.1**	**11.9**
1300	**21**	**43**	**350**	**39**	**0**	**69**	**83.2**	**11.7**	**14.6**
1400	**19**	**49**	**340**	**39**	**0**	**72**	**84.0**	**13.0**	**15.8**
1500	**19**	**49**	**340**	**35**	**0**	**74**	**84.6**	**11.8**	**14.6**
1700	**18**	**49**	**340**	**32**	**0**	**59**	**85.5**	**11.1**	**14.0**
1800	**18**	**52**	**350**	**35**	**0**	**69**	**85.7**	**13.8**	**16.5**
1900	**18**	**45**	**350**	**33**	**0**	**54**	**86.1**	**13.3**	**16.1**
2200	15	51	10	24	0	61	-	-	-
2300	16	52	360	28	0	59	-	-	-

Fire Behaviour

Head fire rates of spread (ROS) for this fire are only applicable to the first main run, as the majority of the fire spread throughout the rest of the day was attributed to flanking fire. From the point of origin to the tip of the bay (Figure 2), the fire travelled 2.3km in 51 minutes. This equates to an observed ROS of 2700m/h. The predicted ROS using the scrublands ROS model (Pearce and Anderson 2004) was 2500m/h. The scrubland model was representative of the main fuel type present at the wetlands was scrub.

Using a ROS of 2700m/h and an average fuel load of 18.4 t/ha, the head fire intensity for the main run of the fire was determined to be 25000 kW/m[8]. To calculate the available fuel load required for the calculations, an average scrub height of one metre was used. This value compares well with actual sampling data from Pearce et al. 1994.

The observed flame length at the fire ground was between six and eight metres and this seemed constant throughout the fire's duration. It was of interest to note that the flames from the fire were visible from the DOC offices, 17km away. Comparing this observed value with predicted flame length values, using Byram's formula[9], a flame length of 8.2m was calculated. This matches well with observed flame lengths.

[8] Calculated using the formula I=(w x r)/2, where I is the head fire intensity (kW/m); w is the available fuel load (t/ha) and r is head fire rate of speed (m/h) (Alexander 2000).

[9] Byram's formula (1959): $I = 259.833 \times (L)^{2.174}$ (Pearce and Anderson 2004).

A summary of the observed and predicted values for fire behaviour observations is shown in Table 3. There is little difference between the observed and predicted values. This shows that the predicted fire behaviour closely matched what actually happened on the day.

Table 3. Comparison between observed and predicted values of ROS, HFI and flame length for the Awarua wetlands fire 27/10/05.

	Observed Value	**Predicted value**
Rate of Spread (m/h)	2700	2500
Head Fire Intensity (kW/m)	25000	24000
Flame Length (m)	6 to 8	8

Two flank fires were examined in detail to determine their rates of spread. Using the rule of thumb that predicted flank fire ROS = ½ observed head fire ROS (Pearce and Anderson 2004), the observed flank fire ROS was quite different to that calculated using this equation. The first flank fire was recorded from 1311 to 1515 (Figure 2). It travelled 1400m in 116 minutes, with a ROS of 724 m/h. The second flank fire spread from 1515 to 1600 (Figure 2). It travelled 800m in 45 minutes, which equates to a ROS of 1066m/h. The predicted ROS using the rule of thumb was 1350m/h. The difference between predicted and observed values can be attributed to wind speed variations and differences in fuel type, distribution and continuity.

Conclusion

Documenting wildfires can assist researchers and ultimately crews on the fire ground by providing an invaluable source of fire behaviour information (Anderson 2003). The 2005 Awarua fire is the second fire in this same area to be documented, the other fire previous to this being the 1986 Awarua Wetlands fire (Pearce et al. 2004). From the data obtained from the 2005 fire, it showed that observed fire behaviour was very similar to that predicted using the Scrub Rate of Spread Model. This provides valuable wildfire data to validate current ROS models, as well as allowing continual improvement of fire behaviour models.

A major issue that arose from this case study is the management implications of burning off in strong winds. In this case a local farmer conducted a burn off and a fire started two days later from a hotspot under adverse weather conditions. Current fire education to farmers needs to be addressed, as fires that are started by escaped burn offs are all too common throughout New Zealand. Farmers and landowners also have a duty to be aware of current and forecasted conditions and need to be responsible with their use of fire. Fortunately for the Awarua area, a post fire vegetation recovery study was completed in 2001 to help identify the effects of fire on fauna and flora. Johnson (2001) states that with adequate long-term fire prevention and containment it should be possible to manage the area for retention of botanical diversity, wildlife habitat and natural landscape. Therefore more effort needs to be placed on education to help prevent fires of this nature.

Acknowledgements

Grateful thanks to Mike Grant, Elton Smith and Trevor Tidey of the Southland Rural Fire District for their assistance in supplying accounts of the fire, details of suppression efforts and mapping resources. I would also like to express thanks to Stuart Anderson and Grant Pearce of the Ensis Bushfire Research Group for their help and comments on writing this case study.

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Appendices

Appendix 1. Hourly FWI records from Invercargill Aero for Awarua Wetlands fire 27/10/05.

Hourly FWI Calculation

Weather Station: Invercargill Aero **Fire/Burn Name:** Awarua wetlands fire 27/10/05

								Hourly FWIs			Daily FWIs							Forest				Grassland					Scrubland			
Date	Time (NZST)	Temp (ºC)	RH (%)	Wind dirn (deg)	Wind speed (km/h)	Rain (mm)	Rain 24h (mm)	FFMCh	ISIh	FWIh	FFMC	DMC	DC	ISI	BUI	FWI	DSR	ROS (m/h)	FFI (kW/m)	FFDC	POI% (C-6)	DoC (%)	ROS (m/h)	GFI (kW/m)	GFDC	POI% (O-1)	ROS (m/h)	SFI (kW/m)	SFDC	POI% (S-1)
27/10/2005	400	14	55	10	21	0		68.9	1.7	0.3								0	0	L	29%	45	0	0	L	36%	304	3039	VH	54%
27/10/2005	500	14	51	20	21	0		70.9	1.8	0.4								0	0	L	31%	45	0	0	L	37%	332	3317	VH	59%
27/10/2005	600	14	59	10	15	0		72.3	1.4	0.3								0	0	L	26%	45	0	0	L	34%	238	2382	VH	63%
27/10/2005	700	13	67	10	13	0		73.3	1.4	0.3								0	0	L	25%	45	0	0	L	34%	222	2218	VH	65%
27/10/2005	800	19.5	53	20	17	0		75.1	1.8	0.4								0	0	L	31%	45	0	0	L	36%	322	3224	VH	69%
27/10/2005	900	19	52	360	24	0		76.8	2.9	0.6								0	0	L	50%	45	0	0	L	43%	620	6200	E	73%
27/10/2005	1000	21	49	360	39	0		78.8	7.1	2.3								0	0	L	96%	45	0	0	L	67%	1795	17954	E	77%
27/10/2005	**1100**	**20**	**46**	**350**	**41**	**0**		**80.5**	**9.3**	**3.2**								**0**	**0**	**L**	**99%**	**45**	**0**	**0**	**L**	**77%**	**2309**	**23087**	**E**	**80%**
27/10/2005	**1200**	**20**	**46**	**350**	**37**	**0**	**0.0**	**81.9**	**9.1**	**11.9**	**87.53**	**13**	**59**	**19.5**	**17**	**21.3**	**6.10**	**152**	**89**	**M**	**99%**	**45**	**0**	**0**	**L**	**77%**	**2265**	**22652**	**E**	**82%**
27/10/2005	1300	21	43	350	39	0		83.2	11.7	14.6								249	147	M	100%	45	0	0	L	87%	2823	28226	E	84%
27/10/2005	1400	19	49	340	39	0		84.0	13.0	15.8								298	175	M	100%	45	0	0	L	90%	3048	30481	E	85%
27/10/2005	1500	19	49	340	35	0		84.6	11.8	14.6								251	148	M	100%	45	0	0	L	87%	2831	28311	E	86%
27/10/2005	1600	19	49	340	33	0		85.1	11.5	14.4								241	142	M	100%	45	0	0	L	86%	2781	27811	E	87%
27/10/2005	1700	18	49	340	32	0		85.5	11.1	14.0								226	133	M	100%	45	0	0	L	85%	2702	27021	E	87%
27/10/2005	1800	18	52	350	35	0		85.7	13.8	16.5								329	194	M	100%	45	0	0	L	91%	3181	31813	E	88%
27/10/2005	1900	18	45	350	33	0		86.1	13.3	16.1								311	183	M	100%	45	0	0	L	90%	3104	31043	E	88%

Appendix 2. Daily FWI records from Invercargill Aero for Awarua Wetlands fire 01/08/05 – 01/12/05.

Date	Temp (ºC)	RH (%)	Wind dir (deg)	Wind speed (km/h)	Rain (mm)	FFMC	DMC	DC	ISI	BUI	FWI	Forest FDC	Grass Curing %	Grass FDC	Scrub FDC
1/08/2005	10	80	270	15	0.2	74.1	1.3	7.0	1.6	1.7	0.5	0	45	0	3
2/08/2005	10	80	350	11	0.4	76.9	1.6	8.5	1.5	2.2	0.5	0	45	0	3
3/08/2005	13	69	340	11	0.2	80.5	2.2	10.5	2.1	2.9	0.7	0	45	0	4
4/08/2005	11	69	350	9	0	81.7	2.7	12.2	2.2	3.5	0.8	0	45	0	4
5/08/2005	11	69	60	9	0	82.3	3.2	13.9	2.3	4.1	0.9	0	45	0	4
6/08/2005	10	71		2	0	82.3	3.7	15.4	1.6	4.6	0.7	0	45	0	3
7/08/2005	8	78	20	7	0	82.1	4.0	16.5	2.0	5.0	0.9	0	45	0	3
8/08/2005	8	75	20	9	0	82.1	4.3	17.7	2.3	5.3	1.1	0	45	0	4
9/08/2005	9	80	160	19	16.6	37.4	1.8	1.3	0.1	1.3	0.0	0	45	0	0
10/08/2005	7	77	10	11	0.2	53.3	2.0	2.3	0.4	1.7	0.1	0	45	0	0
11/08/2005	7	81	30	7	0.4	62.0	2.3	3.3	0.7	2.0	0.2	0	45	0	2
12/08/2005	11	62	350	15	0	75.0	2.9	4.9	1.6	2.7	0.6	0	45	0	3
13/08/2005	8	82	310	24	1.6	66.5	2.6	6.1	1.9	2.6	0.6	0	45	0	3
14/08/2005	5	86	290	33	12.6	32.5	0.8	0.6	0.0	0.3	0.0	0	45	0	0
15/08/2005	11	69	340	20	3.4	47.6	0.5	1.7	0.3	0.6	0.1	0	45	0	0
16/08/2005	11	85	240	33	0	62.6	0.8	3.4	2.5	1.0	0.7	0	45	0	4
17/08/2005	12	79	270	39	3	59.5	0.4	2.8	2.8	0.6	0.7	0	45	0	0
18/08/2005	10	86	320	9	0.6	64.9	0.6	4.3	0.8	0.9	0.2	0	45	0	2
19/08/2005	13	62	350	22	0	77.8	1.4	6.4	2.8	1.8	0.8	0	45	0	4
20/08/2005	15	67	340	13	0.8	79.1	2.1	8.8	2.0	2.6	0.7	0	45	0	3
21/08/2005	14	62	350	15	0	82.6	2.9	11.0	3.3	3.5	1.8	0	45	0	4
22/08/2005	10	88	60	15	2.8	55.5	1.6	12.5	0.6	2.4	0.2	0	45	0	0
23/08/2005	10	87	0	0	2.2	40.8	0.9	14.0	0.0	1.5	0.0	0	45	0	0
24/08/2005	9	90	290	19	0	51.4	1.0	15.3	0.5	1.7	0.1	0	45	0	0
25/08/2005	10	64	260	33	1	69.1	1.6	16.8	3.2	2.5	1.3	0	45	0	4
26/08/2005	12	75	270	33	0	77.2	2.0	18.7	4.6	3.2	2.8	0	45	0	4
27/08/2005	7	71	310	19	4.8	52.3	0.8	14.1	0.6	1.5	0.2	0	45	0	0
28/08/2005	13	63	300	22	0	72.5	1.6	16.1	2.1	2.5	0.7	0	45	0	3
29/08/2005	13	71	310	13	0	78.4	2.1	18.2	1.9	3.3	0.7	0	45	0	3
30/08/2005	12	84	130	7	0	78.8	2.4	20.1	1.4	3.7	0.5	0	45	0	3
31/08/2005	10	85	120	6	0.2	78.9	2.7	21.6	1.4	4.1	0.5	0	45	0	3

Date	Temp (ºC)	RH (%)	Wind dir (deg)	Wind speed (km/h)	Rain (mm)	FFMC	DMC	DC	ISI	BUI	FWI	Forest FDC	Grass Curing %	Grass FDC	Scrub FDC
1/09/2005	17	49	20	28	0	85.4	4.2	24.3	9.2	5.9	7.5	0	45	0	4
2/09/2005	11	73	260	37	0.8	80.8	4.7	26.0	8.0	6.5	6.9	0	45	0	4
3/09/2005	10	74	50	13	0.4	81.2	5.2	27.5	2.5	7.1	1.9	0	45	0	4
4/09/2005	16	62	50	15	0.4	83.6	6.3	30.1	3.7	8.2	3.6	0	45	0	4
5/09/2005	11	70	230	7	0	83.7	6.9	31.8	2.5	8.9	2.3	0	45	0	4
6/09/2005	12	82	70	7	3.2	54.9	4.7	30.7	0.4	6.8	0.2	0	45	0	0
7/09/2005	11	96	170	19	3.2	34.7	2.7	29.4	0.0	4.4	0.0	0	45	0	0
8/09/2005	10	87	90	11	1	44.2	2.9	30.9	0.1	4.7	0.1	0	45	0	0
9/09/2005	14	83		2	0	54.4	3.3	33.2	0.3	5.3	0.1	0	45	0	0
10/09/2005	16	65	350	11	0	72.3	4.3	35.8	1.2	6.6	0.6	0	45	0	2
11/09/2005	16	53	340	15	0	82.2	5.7	38.3	3.1	8.3	2.9	0	45	0	4
12/09/2005	16	59	350	7	0	84.2	6.8	40.9	2.7	9.6	2.6	0	45	0	4
13/09/2005	12	76		2	0	83.4	7.3	42.8	1.9	10.3	1.6	0	45	0	3
14/09/2005	12	91		2	0	80.1	7.5	44.7	1.3	10.6	0.8	0	45	0	3
15/09/2005	13	81	250	11	0.8	76.9	8.0	46.7	1.5	11.2	1.0	0	45	0	3
16/09/2005	14	63	320	20	0	81.9	8.9	48.9	3.9	12.2	4.7	0	45	0	4
17/09/2005	9	88	240	24	3.6	51.4	5.8	46.4	0.7	8.8	0.4	0	45	0	0
18/09/2005	7	90	260	22	10.8	25.1	2.5	30.7	0.0	4.2	0.0	0	45	0	0
19/09/2005	5	76	170	33	6.6	34.7	1.0	22.5	0.1	1.7	0.0	0	45	0	0
20/09/2005	9	57	230	30	1.2	61.5	1.7	23.8	2.0	2.9	0.7	0	45	0	3
21/09/2005	11	67	280	35	0.8	74.1	2.3	25.5	4.3	3.8	2.7	0	45	0	4
22/09/2005	10	82	160	4	8.6	33.2	0.9	14.9	0.0	1.6	0.0	0	45	0	0
23/09/2005	10	67	250	37	1	60.8	1.5	16.4	2.8	2.4	0.9	0	45	0	4
24/09/2005	14	59	0	13	0	76.0	2.5	18.6	1.6	3.8	0.6	0	45	0	3
25/09/2005	10	68	260	32	0.4	80.5	3.1	20.1	6.0	4.5	4.4	0	45	0	4
26/09/2005	12	64	250	11	0	82.4	3.9	22.0	2.6	5.4	1.6	0	45	0	4
27/09/2005	12	57	20	9	0	84.0	4.8	23.8	2.9	6.4	2.2	0	45	0	4
28/09/2005	9	73	260	39	5.4	57.6	2.7	18.5	2.5	3.9	1.0	0	45	0	0
29/09/2005	11	65	100	4	0.8	66.8	3.4	20.2	0.7	4.7	0.3	0	45	0	2
30/09/2005	13	43	70	13	0	80.8	4.7	22.2	2.4	6.1	1.5	0	45	0	4
1/10/2005	12	89	260	32	1.6	67.5	4.4	25.4	2.9	6.1	2.1	0	45	0	4
2/10/2005	12	77	210	4	0.2	73.2	4.9	28.5	0.9	6.9	0.4	0	45	0	2
3/10/2005	17	64	10	9	0	80.4	6.2	32.5	1.9	8.4	1.2	0	45	0	3

Date	Temp (ºC)	RH (%)	Wind dir (deg)	Wind speed (km/h)	Rain (mm)	FFMC	DMC	DC	ISI	BUI	FWI	Forest FDC	Grass Curing %	Grass FDC	Scrub FDC
4/10/2005	11	86	280	13	7.8	38.4	3.1	24.5	0.0	4.7	0.0	0	45	0	0
5/10/2005	8	81	220	33	0.4	57.7	3.4	26.9	1.8	5.2	0.8	0	45	0	0
6/10/2005	6	90	310	9	4.8	32.0	1.5	23.2	0.0	2.6	0.0	0	45	0	0
7/10/2005	12	54	70	17	1.4	59.4	2.7	26.3	0.9	4.3	0.4	0	45	0	0
8/10/2005	10	75	220	28	19.2	40.1	1.2	2.8	0.1	1.1	0.0	0	45	0	0
9/10/2005	10	65	130	6	0.2	58.9	1.9	5.5	0.5	2.0	0.2	0	45	0	0
10/10/2005	10	76	110	33	0	72.0	2.4	8.3	3.5	2.8	1.7	0	45	0	4
11/10/2005	12	66	70	15	0	78.9	3.3	11.4	2.2	3.8	0.8	0	45	0	4
12/10/2005	15	67	160	7	0	81.7	4.3	15.0	2.0	5.0	0.8	0	45	0	3
13/10/2005	12	69	240	28	4.6	61.0	2.7	13.0	1.8	3.6	0.7	0	45	0	3
14/10/2005	12	69	230	15	0	73.5	3.5	16.1	1.5	4.5	0.6	0	45	0	3
15/10/2005	12	69	60	7	0.2	78.4	4.3	19.2	1.4	5.5	0.6	0	45	0	3
16/10/2005	13	70	250	33	2.8	68.1	3.3	22.5	3.1	4.8	2.0	0	45	0	4
17/10/2005	13	73	260	41	0	77.9	4.0	25.8	7.4	5.8	6.1	0	45	0	4
18/10/2005	12	73	160	6	1.4	70.5	4.7	28.9	0.9	6.7	0.4	0	45	0	2
19/10/2005	12	67	110	13	0	77.9	5.5	32.0	1.8	7.7	0.9	0	45	0	3
20/10/2005	11	74	150	17	0	80.1	6.1	34.9	2.7	8.5	2.4	0	45	0	4
21/10/2005	12	71	260	22	0.8	79.2	6.8	38.1	3.2	9.4	3.2	0	45	0	4
22/10/2005	11	62	260	11	0	82.0	7.7	41.0	2.5	10.5	2.5	0	45	0	4
23/10/2005	11	71	260	26	0	82.2	8.3	43.9	5.4	11.3	6.3	0	45	0	4
24/10/2005	11	77	250	30	0	82.3	8.9	46.9	6.7	12.0	7.8	1	45	0	4
25/10/2005	14	76	250	20	0	82.3	9.6	50.3	4.1	13.0	5.1	0	45	0	4
26/10/2005	17	64	120	9	0	83.8	10.8	54.4	2.8	14.4	3.7	0	45	0	4
27/10/2005	20	46	350	41	0	87.6	12.9	58.9	23.8	16.7	24.5	1	45	0	4
28/10/2005	13	91	240	22	0	80.3	13.2	62.2	3.6	17.2	5.3	1	45	0	4
29/10/2005	13	63	230	17	2.8	67.4	10.8	65.5	1.4	15.3	1.2	0	45	0	3
30/10/2005	15	66	50	6	0	76.5	11.8	69.1	1.1	16.6	0.9	0	45	0	2
31/10/2005	15	70	350	11	0	80.5	12.7	72.8	2.1	17.7	3.0	0	45	0	4
1/11/2005	14	75	260	59	0	81.6	13.5	77.7	26.7	18.9	27.9	2	45	0	4
2/11/2005	13	71	250	37	2.8	69.1	11.0	82.5	3.9	16.4	5.6	1	45	0	4
3/11/2005	13	95	240	32	11.2	26.0	5.2	68.3	0.0	8.8	0.0	0	45	0	0
4/11/2005	15	96	10	6	7.2	12.5	2.4	62.5	0.0	4.4	0.0	0	45	0	0
5/11/2005	14	78	250	59	1.4	52.0	3.1	67.4	4.0	5.6	3.1	0	45	0	0

Date	Temp (ºC)	RH (%)	Wind dir (deg)	Wind speed (km/h)	Rain (mm)	FFMC	DMC	DC	ISI	BUI	FWI	Forest FDC	Grass Curing %	Grass FDC	Scrub FDC
6/11/2005	11	74	270	9	0.4	65.5	3.8	71.8	0.8	6.7	0.4	0	45	0	2
7/11/2005	13	81	250	35	0	74.5	4.4	76.6	4.4	7.6	4.1	0	45	0	4
8/11/2005	15	71	250	13	0	79.6	5.3	81.7	2.1	9.2	1.7	0	45	0	4
9/11/2005	15	75	290	6	0	80.9	6.2	86.8	1.7	10.5	1.3	0	45	0	3
10/11/2005	19	52	340	19	0	85.6	8.3	92.6	6.0	13.5	7.5	1	45	0	4
11/11/2005	21	41	350	50	11.6	77.3	6.4	78.6	11.0	10.7	11.3	1	45	0	4
12/11/2005	13	83	250	32	15.4	42.3	3.1	56.6	0.3	5.5	0.1	0	45	0	0
13/11/2005	12	61	190	11	0	64.8	4.2	61.2	0.9	7.1	0.5	0	45	0	2
14/11/2005	13	74	260	30	0.4	75.9	5.0	65.9	3.7	8.4	3.5	0	45	0	4
15/11/2005	16	56	330	17	0	83.0	6.6	71.2	3.8	10.7	4.2	0	45	0	4
16/11/2005	12	69	270	41	9.2	57.2	3.8	61.1	2.7	6.5	1.9	0	45	0	0
17/11/2005	12	78	250	35	10	45.6	1.9	49.9	0.5	3.5	0.2	0	45	0	0
18/11/2005	14	75	260	46	2.6	61.3	1.6	54.8	4.5	2.9	2.6	0	45	0	4
19/11/2005	19	61	320	17	0	78.6	3.2	60.6	2.3	5.7	1.3	0	45	0	4
20/11/2005	13	89	220	30	0	78.6	3.5	65.3	4.5	6.2	3.8	0	45	0	4
21/11/2005	9	86	200	28	9.4	39.1	1.5	54.5	0.1	2.8	0.0	0	45	0	0
22/11/2005	13	74	250	22	0.2	62.6	2.3	59.3	1.4	4.2	0.6	0	45	0	3
23/11/2005	12	84	250	30	3	54.4	1.4	61.0	1.2	2.6	0.4	0	45	0	0
24/11/2005	13	72	160	24	0.2	71.4	2.2	65.8	2.2	4.1	0.9	0	45	0	4
25/11/2005	12	51	120	6	0	80.0	3.6	70.4	1.5	6.3	0.7	0	45	0	3
26/11/2005	15	57	70	20	0	83.9	5.0	75.5	5.0	8.6	5.0	0	45	0	4
27/11/2005	18	59	150	7	0	85.0	6.7	81.1	3.0	11.1	3.3	0	45	0	4
28/11/2005	19	56	170	6	0	85.8	8.6	86.9	3.2	13.7	4.1	0	45	0	4
29/11/2005	16	86	250	22	0	81.8	9.1	92.2	4.2	14.6	5.6	1	45	0	4
30/11/2005	15	55	260	13	0	84.5	10.6	97.3	3.8	16.7	5.5	1	45	0	4
1/12/2005	14	64	270	9	0	84.6	11.8	103.2	3.1	18.4	4.8	0	45	0	4