Trajectory Study for Current & Proposed Designs
Combined Report
Bonnie Doon Golf Course 11th Hole

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Introduction

This is a combined report of the trajectory studies for the Bonnie Doon 11th current and proposed layouts. More detail is provided in the original reports. Each study simulates potential errant golf balls from the 11th before and after remodelling. The location of tees and survey data were provided.

Bonnie Doon Eleventh Hole

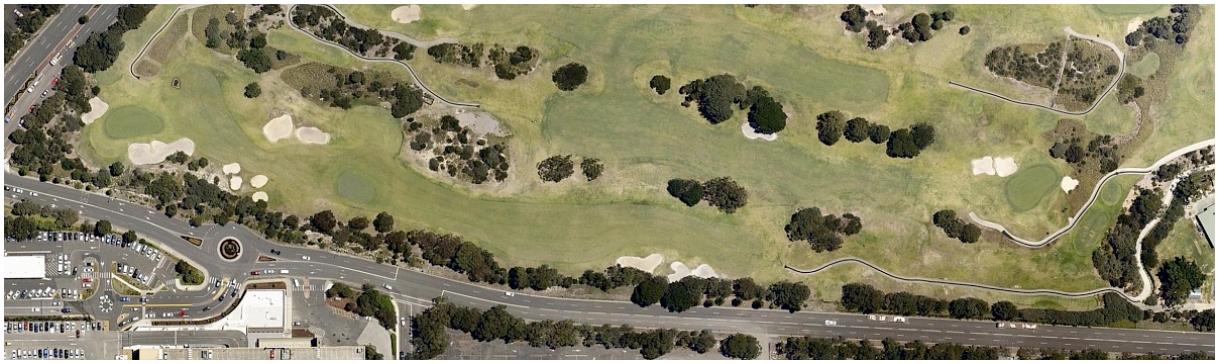


Figure 1

The image above has been provided by the client. Images below vary slightly as they have been sourced via the Sketchup program (used for accurate measurements).

Golf ball flights are modelled to assess the potential for, the most suitable size (width and height), and placement of barriers to reduce golf ball impacts from the tees into an identified *Area at Risk*.

The impacts determined by the trajectory models also take into consideration terrain elevation and wind effects, and are plotted on diagrams showing major features (tees, fairway) and the *Area at Risk*. Simulations of golf ball flight paths (also called trajectories) are calculated in three dimensions, based on ball launch data for a wide range of player abilities, recorded with a radar launch monitor on a practice fairway. The simulation models do not account for vegetation.

Area at Risk

The road along the left side lower section of Fig.1 above) is to be protected – *Area at Risk* – mapped in red over the current layout below (Fig 2). The location of this has been confirmed by the client.

Figure 2

The following errant ball analysis considers the current and redesigned layouts in turn.

BEFORE REMODELLING (CURRENT)

Tee Locations and Lines of Play

The *Area at Risk* is potentially vulnerable to shots from the tee. The two (2) tee-off points for modelling the 11th are shown below (Fig 3) as yellow circles in the tee areas.

The lines of play are from the tee-off points shown, to the centre of the target at 240m from the rear tee. The fairway outline (below) is used in modelling output diagrams as a reference.

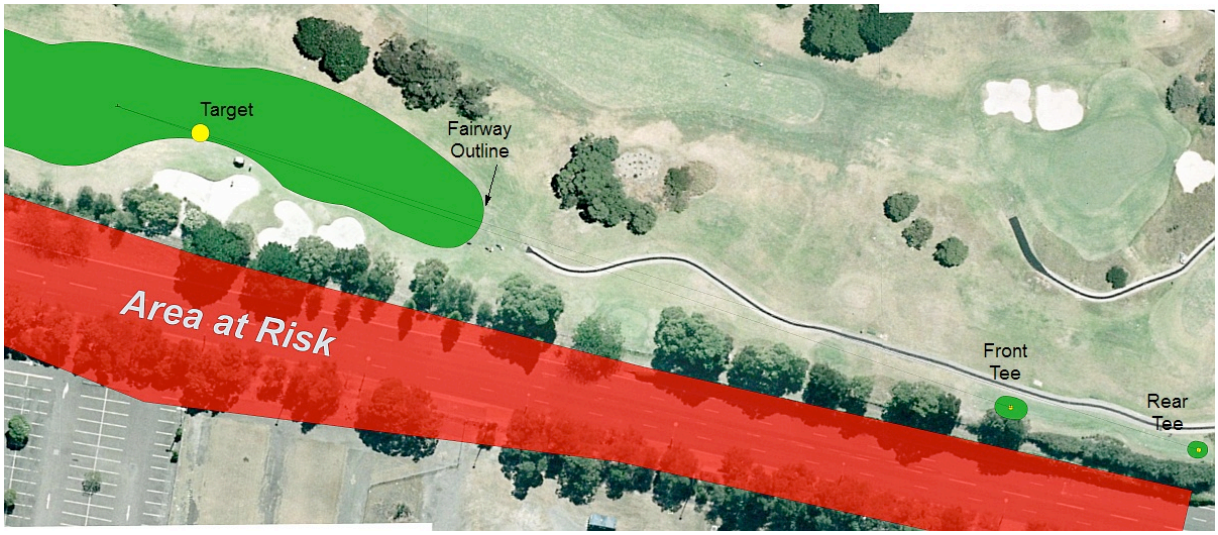
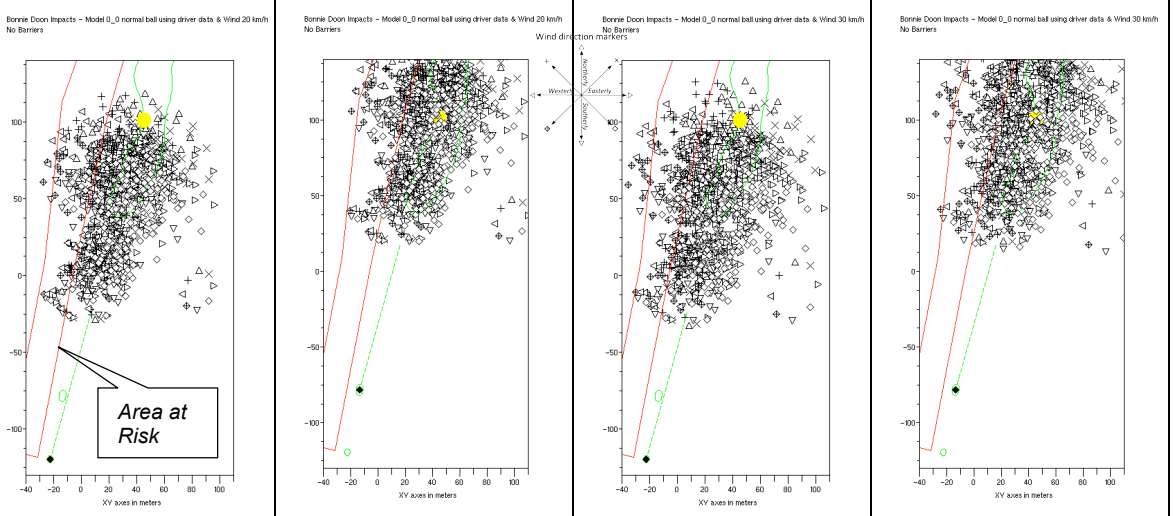


Figure 3

Modelled impacts for the current layout, with winds of 20 and 30km/h, are shown below.

Current 11th Tee 20, 30 km/h winds from 8 directions, no barriers



Back tee – 20 km/h wind	Front tee – 20 km/h wind	Back tee – 30 km/h wind	Front tee – 30 km/h win

These show significant errant ball impacts in the Area at Risk, at both wind speeds.

Winds at the 11th

The line of play for the 11th is approximately south. Thus, the head wind is from the South, and crosswinds from the West and SW will also have an effect. The North and NW tailwinds may also push balls longer and across. From the table, about 58% of all winds are from these five directions and 9.1% are over 30 km/h. The majority (4.7%) are head winds (Southerly).

There are also some winds over 40km/h – about 4% in all and 3.2% are head or tail winds that move balls toward the *Area at Risk.* More detail and monthly averages are in Appendix 2.

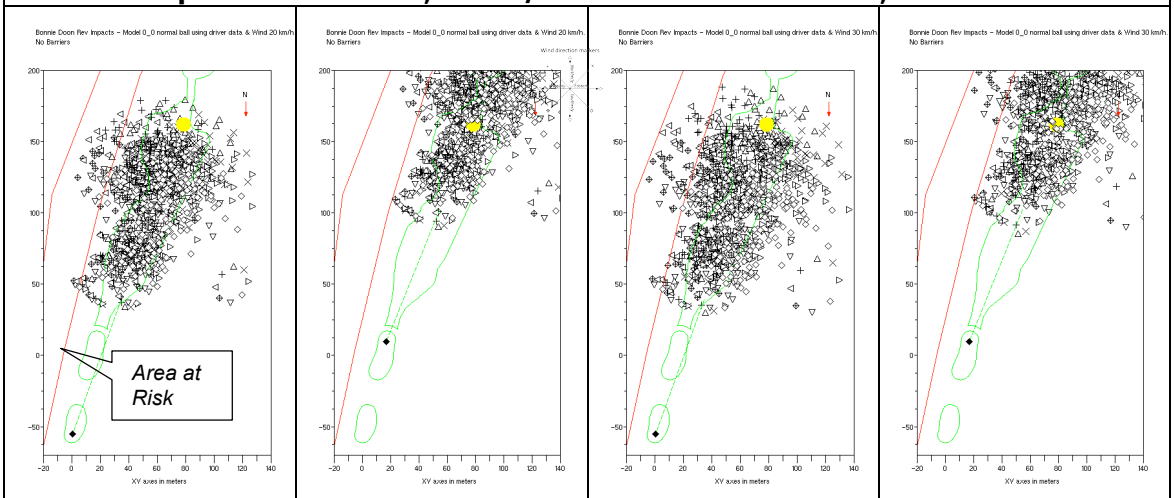
PROPOSED DESIGN

The revised layout of the 11th hole is set out below (Fig. 4). This design moves the tees forward by 25-30m, and lowers these about 3-4m.

Figure 4

The changes alter the lines of play from the tee by between 2-5°W - away from the *Area at Risk*. The resulting impact patterns from tee-offs at the rear of the back tee and front of the front tee are shown below.

Proposed 11th Tee 20, 30 km/h winds from 8 directions, no barriers



Back tee – 20 km/h wind	Front tee – 20 km/h wind	Back tee – 30 km/h wind	Front tee – 30 km/h win

ERRANT BALL ANALYSIS

The two designs were modelled without barriers for winds at 0, 10, 20, 30 and 40 km/h from eight directions, the occurrences of errant balls determined, and adjusted for the available wind speed/ direction frequency.

CONCLUSIONS

Conclusion 1 – Revised Design (No barriers)

Modelling the two layouts suggests the proposed design would significantly reduce the occurrence of errant balls in the Area at Risk.

The frequency of errant balls was reduced to 4-5% for the proposed design (after) - from 15-17% for the current design (before). Under all these wind conditions the revised design was less likely to result in errant balls and almost none for winds from N, NE E and SE. Most errant balls occurred for winds from the N, NW, and W. Details of the analysis and the wind frequency adjustment are given in Appendix 1.

Conclusion 2 – Barriers for current layout.

The following conclusions refer to the current layout of the 11th hole.

The models show that for ball flights from the tees that are consistent with the play of the course – that is, following the broadly expected lines of play toward the target – numerous impacts will occur in the identified *Area at Risk.* When the front tee (40m further on) is taken into account, the impact zone extends some distance along the main fairway.

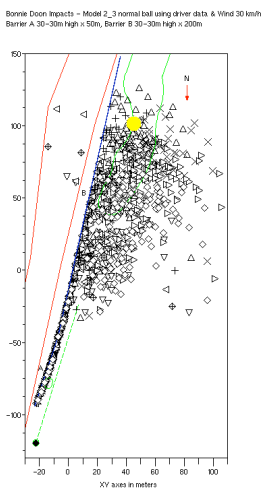
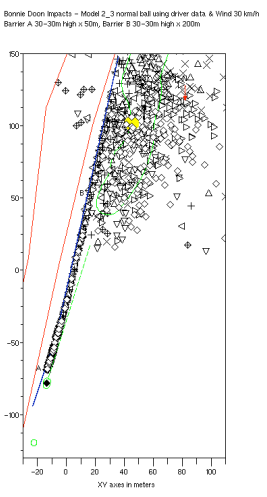
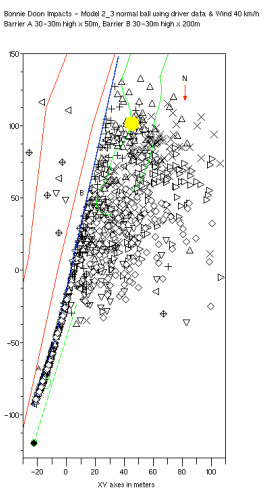
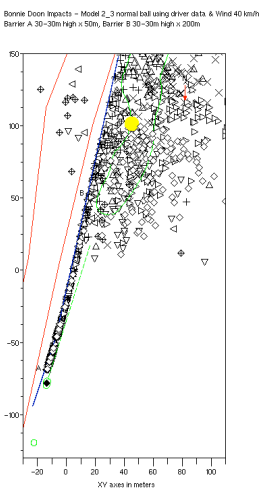
Blinker barriers near the tees were modelled for both the proposed and current designs but were ineffective – the frequent head and cross winds and the long boundary next to public areas both contributing.

The boundary has significant vegetation (mostly trees which act as barriers of some form, but unknown) but the models are not able to include any barrier effect these may have. In the absence of this effect, boundary barriers are effective solutions to reduce errant balls to very low levels in both cases. For the current layout of the 11th, two joined barriers along the left side of the 11th with a 250m combined length will provide substantial protection for the boundary; the barriers are 50m and 200m respectively and are shown below (Fig. 5).

Figure 5

The first 50m barrier (A) is set roughly parallel to the line of play so it acts both as protection and as a visual guide to players (Fig 6). This angle also increases its effectiveness as a blinker barrier for both tees.

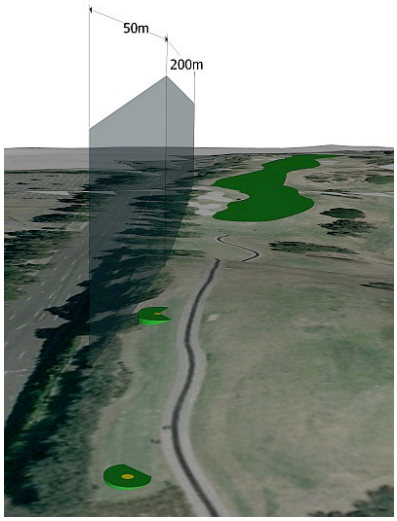
The effect of these barriers is to reduce impacts significantly for winds up to 30km/h, somewhat lessened with winds at 40km/h.

11th Tee – 30 & 40 km/h winds, joined barriers (50m & 200m long), 30 & 35m high			
			
Back tee – 30m high, 30 km/h winds	Front tee - 30m high, 30 km/h winds	Back tee - 30m high, 40 km/h winds	Front tee - 30m high, 40 km/h winds

The long (200m) second barrier follows the line of the boundary and is mostly protective in effect. Shorter second barriers considered (50 or 115m) do not provide the same coverage, in part because there is 40m between the rear and front tees.

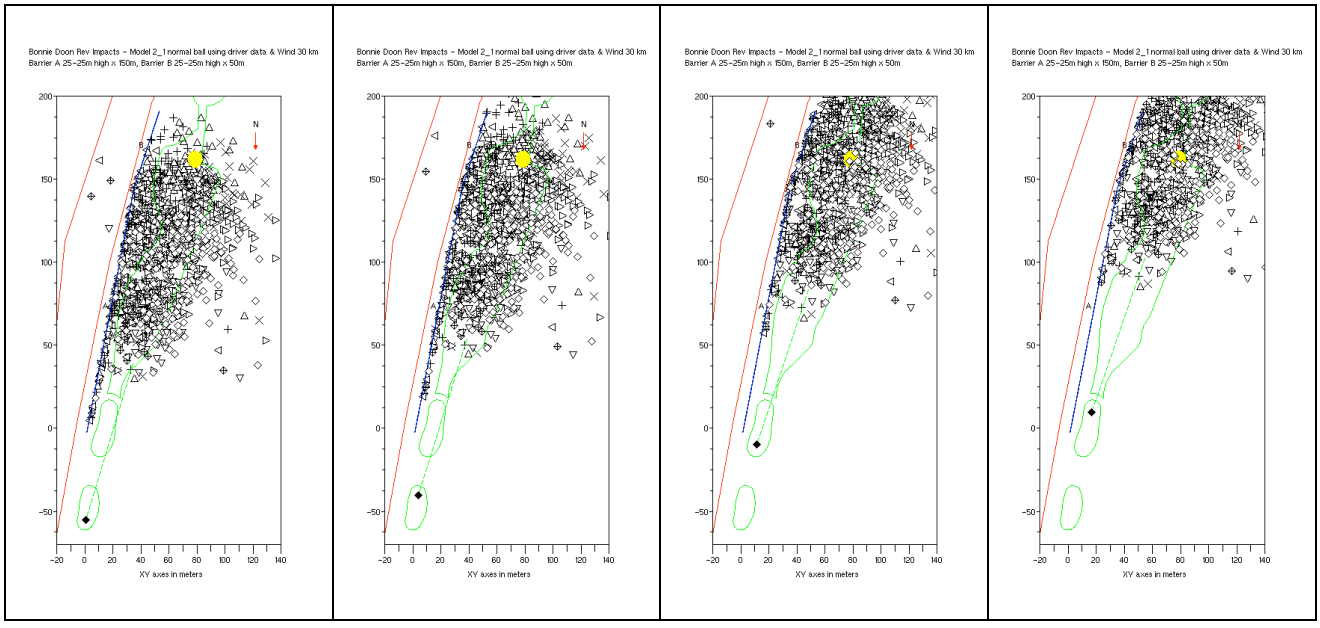
Various barrier heights were modelled, but the prevalence of southerly (head) and westerly (cross) winds over 30km/h - about 7% of all winds - makes it important that errant balls caused by these winds are greatly reduced.

The most effective height for both barriers is 30m, but this assumes that high winds at Bonnie Doon Golf Course are less than at the Sydney Airport weather station. Winds occur there over 40km/h about 3% of the time (10 days/ year). If this is not the case, the height of both barriers should be increased to 35m.



Conclusion 3 – Barriers for the Revised Layout

With the new design, there is less need for barriers. As there are still errant balls falling in the Area at Risk, protective barriers for this layout were also considered. For the revised design, the impact diagrams below for a shorter (200m long) and lower (25m high) show a slightly better protective effect than the original recommendation on the current layout.



It should be borne in mind that the winds from the west and south are the most frequent. More details of the wind regime are given in the Appendix 2.

APPENDIX 1

Errant Ball Modelling

Note – Direction (Dir) is wind, not compass direction

Current Layout Rear & Front Tees

Frequency of errant balls

Rear Tee

	km/h				
Dir	0	10	20	30	40
S		13%	15%	15%	16%
SW		16%	24%	41%	47%
W		16%	30%	47%	54%
NW		15%	16%	23%	33%
N		9%	9%	8%	9%
NE		8%	5%	4%	1%
E		8%	4%	3%	1%
SE		10%	7%	6%	4%
	13%				

Wind adjusted frequency of errant balls

	km/h					
Dir	0	10	20	30	40	Total
S		0.3%	0.6%	0.9%	0.7%	*2.5%*
SW		0.3%	0.5%	0.8%	0.5%	*2.1%*
W		0.8%	1.3%	1.3%	1.1%	*4.5%*
NW		0.9%	0.8%	0.3%	0.2%	*2.3%*
N		0.2%	0.3%	0.1%	0.1%	*0.6%*
NE		0.2%	0.2%	0.2%	0.0%	*0.6%*
E		0.2%	0.1%	0.1%	0.0%	*0.3%*
SE		0.2%	0.4%	0.2%	0.0%	*0.9%*
Total	*1%*	*3%*	*4%*	*4%*	*3%*	**15%**

Front Tee

	km/h				
Dir	0	10	20	30	40
S		14%	16%	14%	17%
SW		16%	21%	36%	37%
W		20%	37%	65%	67%
NW		16%	21%	30%	42%
N		12%	10%	9%	10%
NE		9%	8%	4%	1%
E		9%	4%	3%	1%
SE		10%	7%	7%	4%
	14%				

	km/h					
Dir	0	10	20	30	40	Total
S		0.3%	0.6%	0.9%	0.8%	*2.6%*
SW		0.3%	0.5%	0.7%	0.4%	*1.8%*
W		1.0%	1.6%	1.8%	1.3%	*5.7%*
NW		1.0%	1.0%	0.4%	0.3%	*2.8%*
N		0.3%	0.3%	0.2%	0.1%	*0.8%*
NE		0.2%	0.3%	0.2%	0.0%	*0.7%*
E		0.2%	0.1%	0.1%	0.0%	*0.4%*
SE		0.2%	0.4%	0.3%	0.0%	*0.9%*
Total	*1%*	*3%*	*5%*	*4%*	*3%*	**17%**

Revised Design Rear & Front Tees

Frequency of errant balls

Rear Tee

	km/h				
Dir	0	10	20	30	40
S		6%	7%	6%	7%
SW		7%	8%	13%	23%
W		7%	9%	13%	28%
NW		6%	6%	6%	7%
N		1%	1%		
NE		1%			
E		1%			
SE		2%	2%	1%	1%
Total	4%				

Wind adjusted frequency of errant balls

	km/h					
Dir	0	10	20	30	40	Total
S		0.1%	0.3%	0.4%	0.3%	*1.1%*
SW		0.1%	0.2%	0.2%	0.2%	*0.8%*
W		0.3%	0.4%	0.4%	0.5%	*1.6%*
NW		0.3%	0.3%	0.1%	0.1%	*0.8%*
N		0.0%	0.0%			*0.1%*
NE		0.0%				*0.0%*
E		0.0%				*0.0%*
SE		0.1%	0.1%	0.0%	0.0%	*0.2%*
Total	*0%*	*1%*	*1%*	*1%*	*1%*	**5%**

Front Tee

	km/h				
Dir	0	10	20	30	40
S		3%	5%	6%	7%
SW		6%	7%	11%	17%
W		6%	8%	10%	19%
NW		3%	5%	6%	6%
N		1%			
NE					
E					
SE		1%	0%		
Total	1%				

	km/h					
Dir	0	10	20	30	40	Total
S		0.1%	0.2%	0.3%	0.3%	*0.9%*
SW		0.1%	0.2%	0.2%	0.2%	*0.6%*
W		0.3%	0.4%	0.3%	0.4%	*1.3%*
NW		0.2%	0.2%	0.1%	0.0%	*0.6%*
N		0.0%				*0.0%*
NE						
E						
SE		0.0%	0.0%			*0.0%*
Total	0%	1%	1%	1%	1%	**4%**

APPENDIX 2

Wind Information for Sydney Airport (Station 066037)

Wind Frequency by direction and speed range									
Wind type	Direction	Calm	0-10	10-20	20-25	25-30	30-40	40+	Grand Total
Head/ cross	S		1.9%	4.0%	2.9%	3.2%	3.0%	1.7%	**16.7%**
	SW		1.7%	2.2%	1.0%	0.9%	0.7%	0.3%	**6.8%**
	W		4.9%	4.4%	1.6%	1.3%	1.2%	0.7%	**14.1%**
Subtotal			*8.5%*	*10.6%*	*5.4%*	*5.3%*	*4.9%*	*2.8%*	***37.6%***
Tail /cross	N		2.1%	2.9%	1.0%	0.7%	0.5%	0.1%	**7.4%**
	NW	0.0%	6.1%	4.8%	0.8%	0.6%	0.5%	0.2%	**13.1%**
Subtotal		*0.0%*	*8.3%*	*7.7%*	*1.8%*	*1.3%*	*1.0%*	*0.4%*	***20.6%***
Other	E		1.9%	3.3%	1.1%	0.5%	0.2%	0.0%	**7.1%**
	NE	0.0%	2.0%	4.2%	2.5%	2.2%	1.7%	0.4%	**12.9%**
	SE		2.4%	4.9%	2.4%	1.6%	1.0%	0.4%	**12.6%**
Subtotal		*0.0%*	*6.3%*	*12.4%*	*6.1%*	*4.3%*	*2.8%*	*0.8%*	***32.7%***
Calm		9.1%	0.0%						**9.1%**
Grand Total		***9.1%***	***23.1%***	***30.7%***	***13.3%***	***10.9%***	***8.8%***	***4.0%***	***100.0%***

Sydney Ap Weather Station – Monthly Averages (km/h)

Avg	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9am	14.4	13.8	12.9	12.9	12.6	13.4	13.3	14.4	15.5	16.3	16.0	14.8	14.2
3 pm	24.1	23.0	21.0	19.3	17.1	17.8	18.2	20.8	23.1	24.6	25.3	25.2	21.6

APPENDIX 3

Barrier Modelling Detail – Current and Proposed

It is not possible to simulate all golf shots under all conditions, nor will any barrier always stop every errant ball. This analysis is limited by the wind information available, model parameters, and launch data collected. Model assumptions are set out in Appendix 1.

Ball flight data set

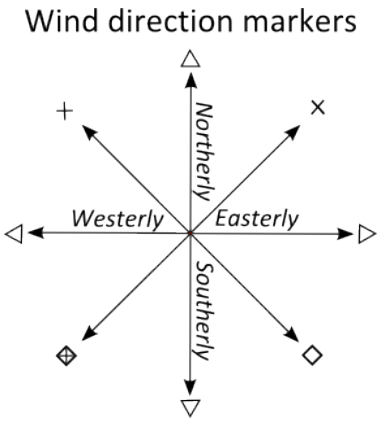
There are three sets of launch data that are currently available for modelling.

1. **Normal Driver** - the general set - normal drives from a tee, with a range of abilities.
2. **Extended** - the extended data set - additional drives by a group of longer hitters.
3. **180m** –played at a specific point at 180m, using preferred club (3, 4 irons, hybrid and rescue clubs).

The data set used for the 11th at Bonnie Doon is the **Normal** driver data, as this is a good approximation to the playing characteristics of most golf players.

Wind data

The trajectory models include the effect of higher risk wind conditions. The line of play for the 11th is approximately south. Thus, the head wind is from the South, and crosswinds from the West and SW will also have an effect. The North and NW tailwinds may also push balls longer and across. From the table, about 58% of all winds are from these five directions and 9.1% are over 30 km/h. The majority (4.7%) are head winds (Southerly).

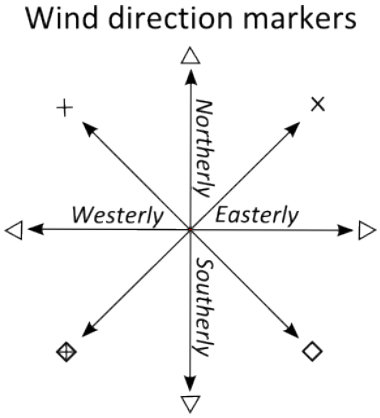


There are also some winds over 40km/h – about 4% in all and 3.2% are head or tail winds that move balls toward the *Area at Risk.* More detail and monthly averages are in Appendix 2.

Wind frequency is determined from Bureau of Meteorology data. The course is located not far (5km) from Sydney Airport weather station; the wind speed used in the simulations is 30 km/h.

Wind Frequency by direction - Station 066037 Sydney Ap								
Wind type		Compass	Calm	0-10	10-20	20-30	30 +	Total
Head wind	▽	S		1.9%	4.0%	6.0%	4.7%	**16.7%**
	⊕	SW		1.7%	2.2%	1.9%	1.0%	**6.8%**
	◁	W		4.9%	4.4%	2.8%	1.9%	**14.1%**
Subtotal				*8.5%*	*10.6%*	*10.7%*	*7.7%*	***37.6%***
Tail wind	△	N		2.1%	2.9%	1.7%	0.7%	**7.4%**
	×	NW		6.1%	4.8%	1.4%	0.7%	**13.1%**
Subtotal				*8.3%*	*7.7%*	*3.2%*	*1.4%*	***20.6%***
Other	▷	E		1.9%	3.3%	1.7%	0.2%	**7.1%**
	+	NE		2.0%	4.2%	4.6%	2.1%	**12.9%**
	◇	SE		2.4%	4.9%	4.0%	1.3%	**12.6%**
Subtotal				*6.3%*	*12.4%*	*10.4%*	*3.7%*	***32.7%***
Calm			9.1%	0.0%				9.1%
Total			***9.1%***	***23.1%***	***30.7%***	***24.3%***	***12.8%***	***100.0%***

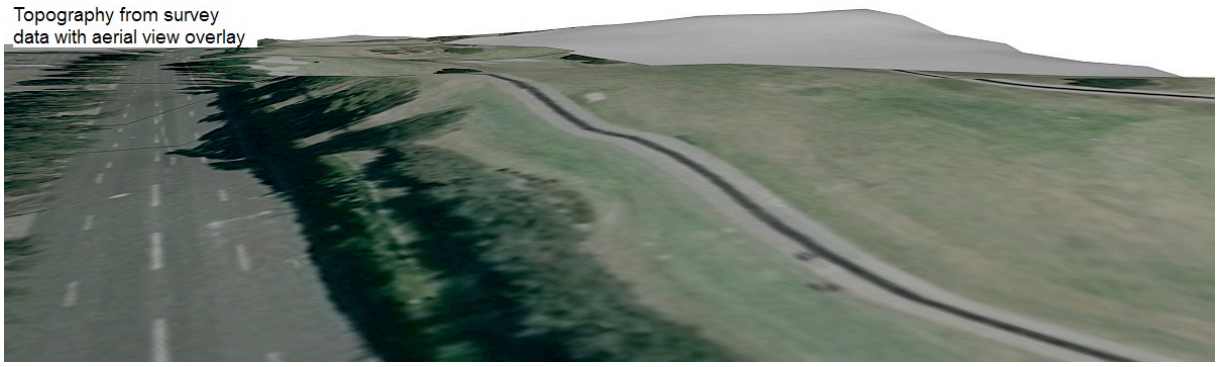
The line of play for the 11th is approximately south. Thus, the head wind is from the South, and crosswinds from the West and SW will also have an effect. The North and NW tailwinds may also push balls longer and across. From the table, about 58% of all winds are from these five directions and 9.1% are over 30 km/h. The majority (4.7%) are head winds (Southerly).



There are also some winds over 40km/h – about 4% in all and 3.2% are head or tail winds that move balls toward the *Area at Risk.* More detail and monthly averages are in Appendix 2.

As the measurements are taken at the relatively open spaces of Sydney airport, it is likely that the Bonnie Doon course will not be as exposed as its location is inland and more built-up. Taking this into consideration, a wind speed of 30km/h is used for the modelling.

Topography



(Illustrative only) Figure 7

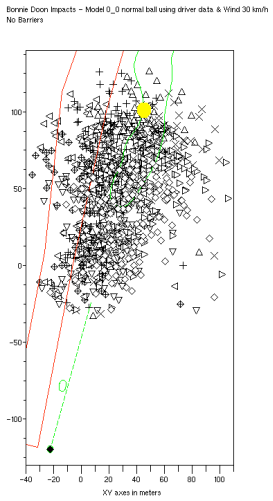
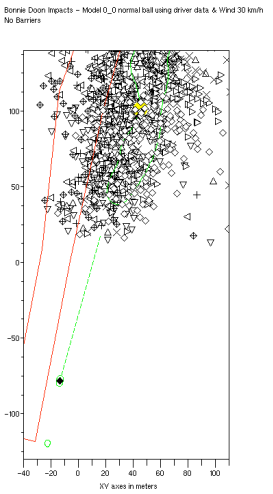
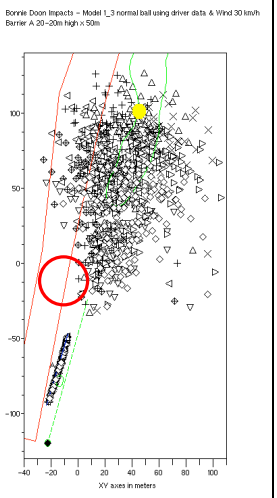
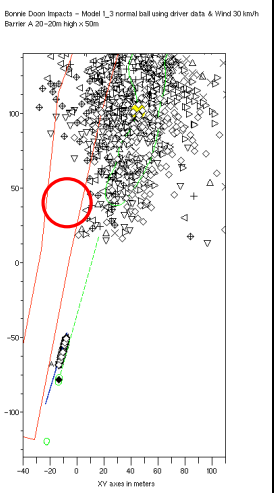
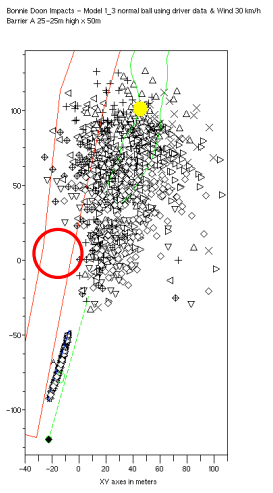
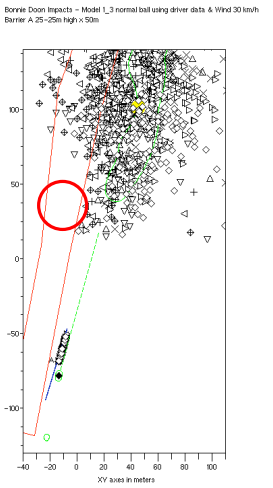
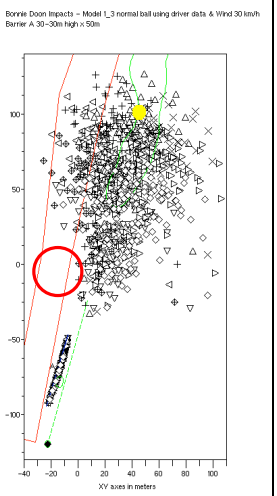
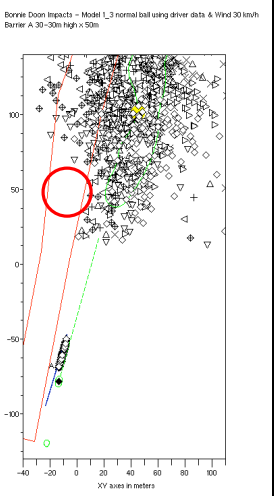
The terrain used in the models is based on topography of the site using supplied survey data (2m) and overlays of Sketchup images. This information is used under licence. Other more current images may be available, but Sketchup allows the accurate placement of barriers and extraction of location information.

Barriers for reducing errant balls - Current

The impact diagrams below show the modelled impacts for a normal ball, played with a driver, and without barriers. Numerous balls reach the *Area at Risk* regardless of wind speed.

Impacts in the diagrams are the first impact – the ball may bounce and run on, but this is not modelled. Note that the play direction is from bottom of diagram to top. The placement and size of physical barriers needed to interrupt the flights of golf balls and minimise the number of impacts in the *Area at Risk* is considered next – initially a single blinker barrier along the left side to stop balls that deviate left early from the tee.

11th Tee - Single Barrier 50m long, various heights, 30km/h winds from 8 directions

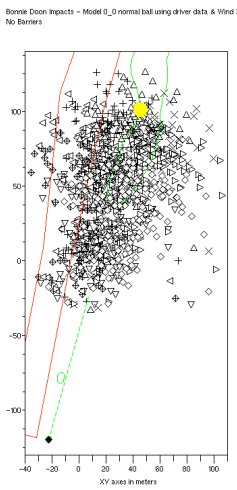
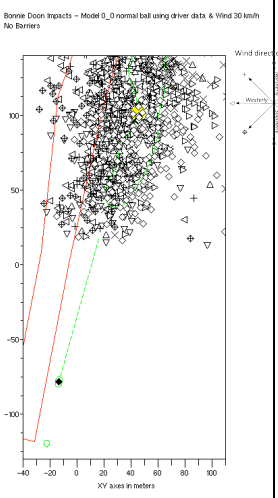
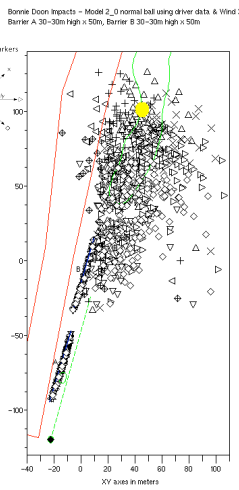
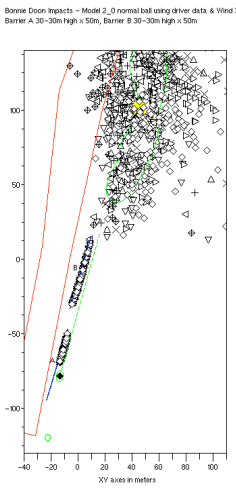
			
Back tee – NO barrier	Front tee – NO barrier	Back tee – 20m barrier	Front tee– 20m barrier
			
Back tee – 25m barrier	Front tee – 25m barrier	Back tee – 30m barrier	Front tee– 30m barrier

This single barrier is not effective, as it is only reducing errant balls by a small number in one area (circled) – and higher barriers are no more effective.

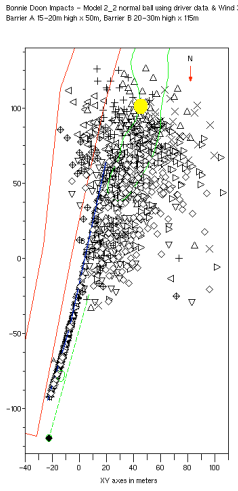
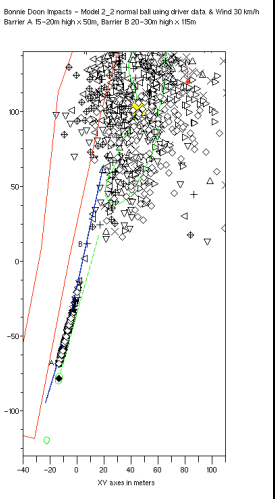
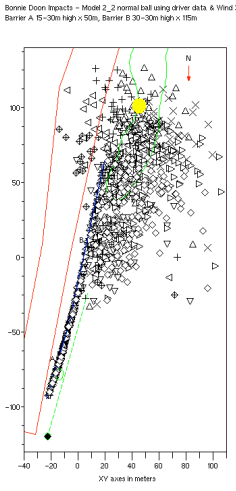
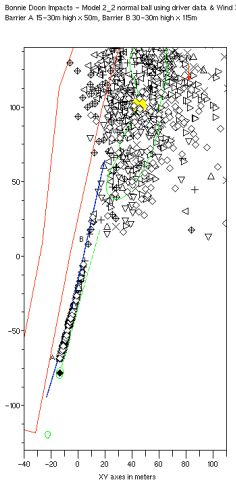
Adding a short barrier is considered next some 14m from the first

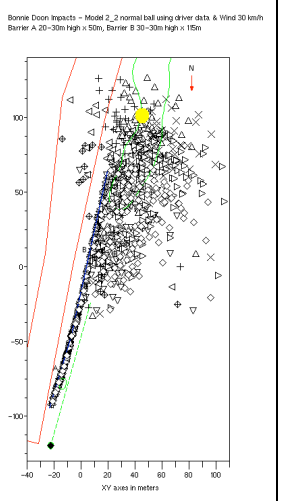
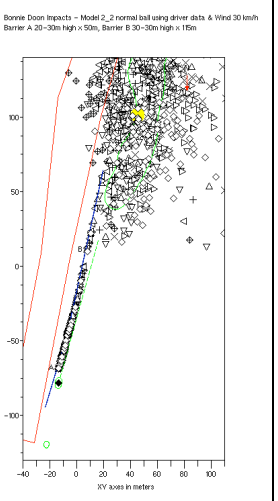
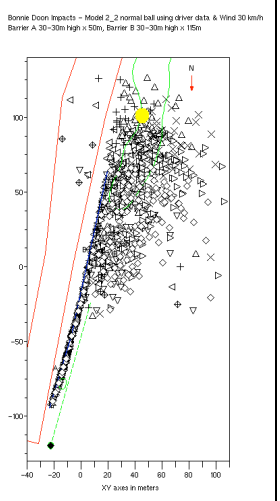
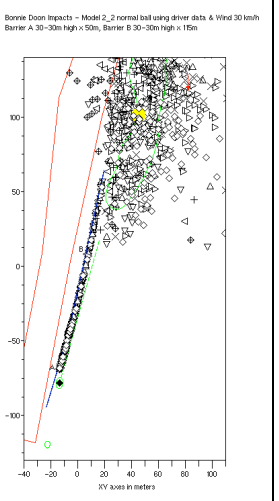
barrier (50m long – labelled "B" at right).

Figure 8

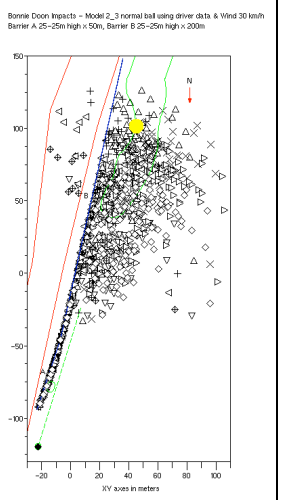
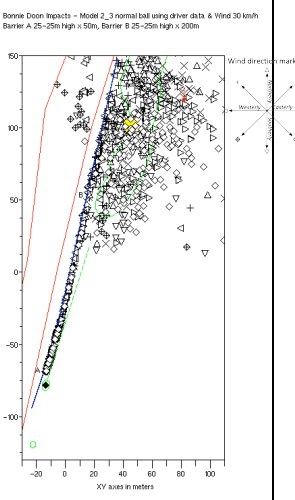
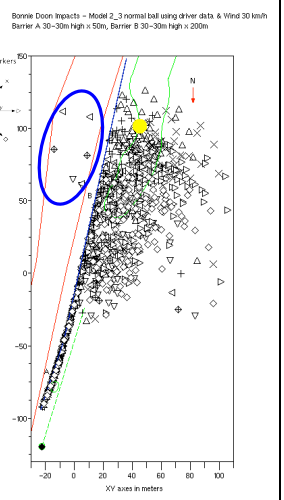
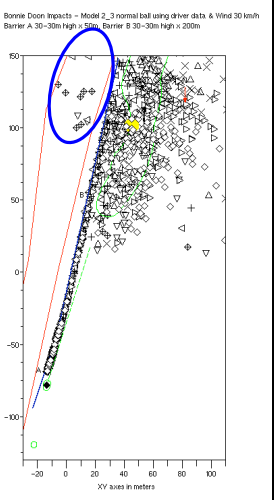
11th Tee - Two 50m long Barriers, 30m high, driver data and 30km/h winds			
			
Back tee – No barriers	Front tee – No barriers	Back tee – two 50m barriers 30m high	Front tee – two 50m barriers 30m high

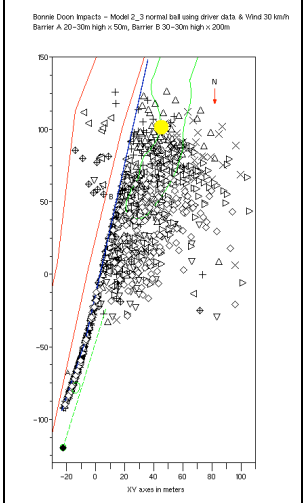
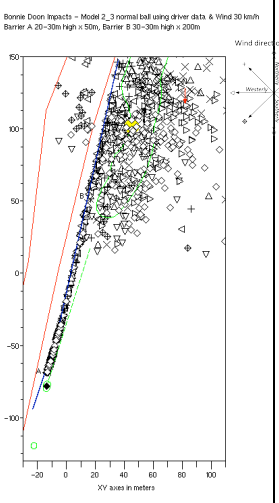
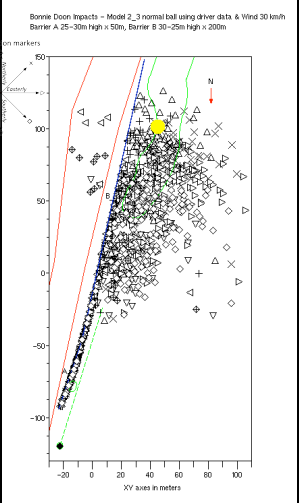
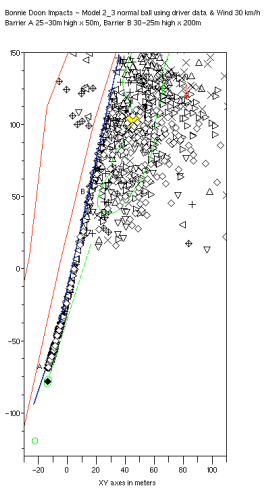
Adding the second 50m long barrier has only a limited effect on the number of impacts in the *Area at Risk.* Next, the second barrier B is extended and joined up with the barrier A.

11th Tee - Two joined Barriers (50 and 115m long), various heights, 30km/h winds			
			
Back tee – 50 & 115m barriers 15-20-30m high	Front tee – 50 & 115m barriers 15-20-30m high	Back tee – 50 & 115m barriers 15-30-30m high	Front tee– 50 & 115m barriers 15-30-30m high

11th Tee - Two joined Barriers (50 and 115m long), various heights, 30km/h winds			
			
Back tee – 50 & 115m barriers 20-30-30m high	Front tee – 50 & 115m barriers 20-30-30m high	Back tee – 50 & 115m barriers all 30m high	Front tee– 50 & 115m barriers all 30m high

By joining the two, extending the second barrier further down the fairway and setting both barriers to 30m high, a significant improvement is achieved. Some errant balls are still impacting the *Area at Risk*, including one affected by the frequent Southerly headwinds. The next set investigates extending this barrier to 200m long on the boundary. Various barrier height combinations are shown.

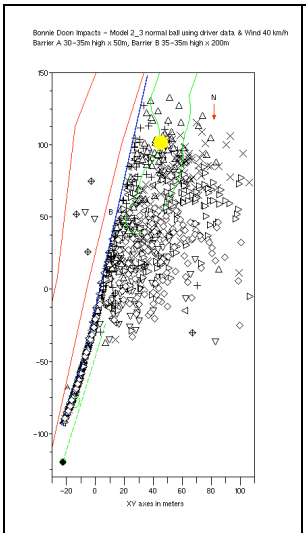
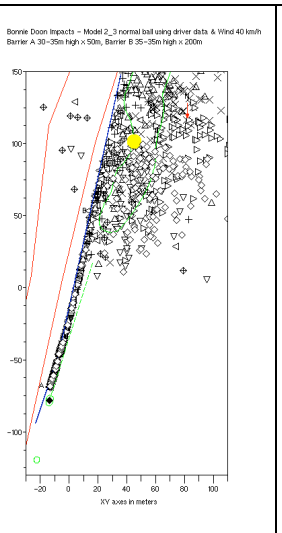
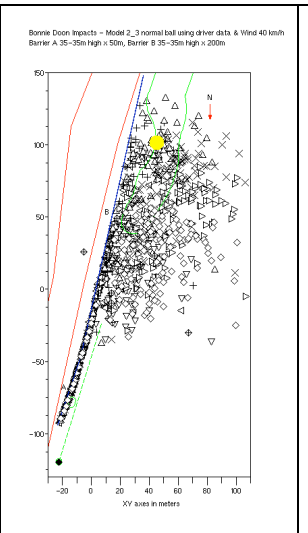
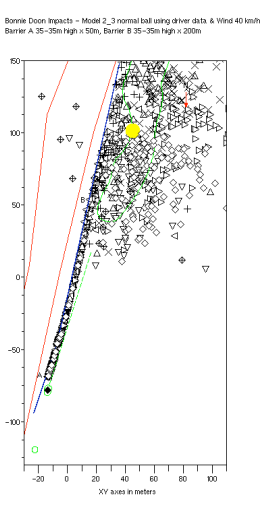
11th Tee - Two joined Barriers (50 & 200m long), 25 and 30m high, 30km/h winds			
			
Back tee - 25m high	Front tee - 25m high	Back tee - 30m high	Front tee - 30m high

11th Tee - Two joined Barriers (50m and 200m) various heights, 30 km/h winds			
			
Back tee – 20–30m high	Front tee 20–30m high	Back tee - 25–30-25m high	Front tee -25–30-25m high

Neither of these performed comparably. Finally, modelling of the 50 and 200m barrier was carried out using wind speed of 40km/h.

Winds of 40 km/h or over occur 3.2% of the time at Sydney Airport for the wind directions that affect the Area at Risk, or the equivalent of 10-11 days per year.

It is likely that the more inland location of the golf course will reduce the chances of experiencing these winds at the golf course. The 35m high barriers are used to compare the effect of 30 km/h to 40 km/h winds, shown next.

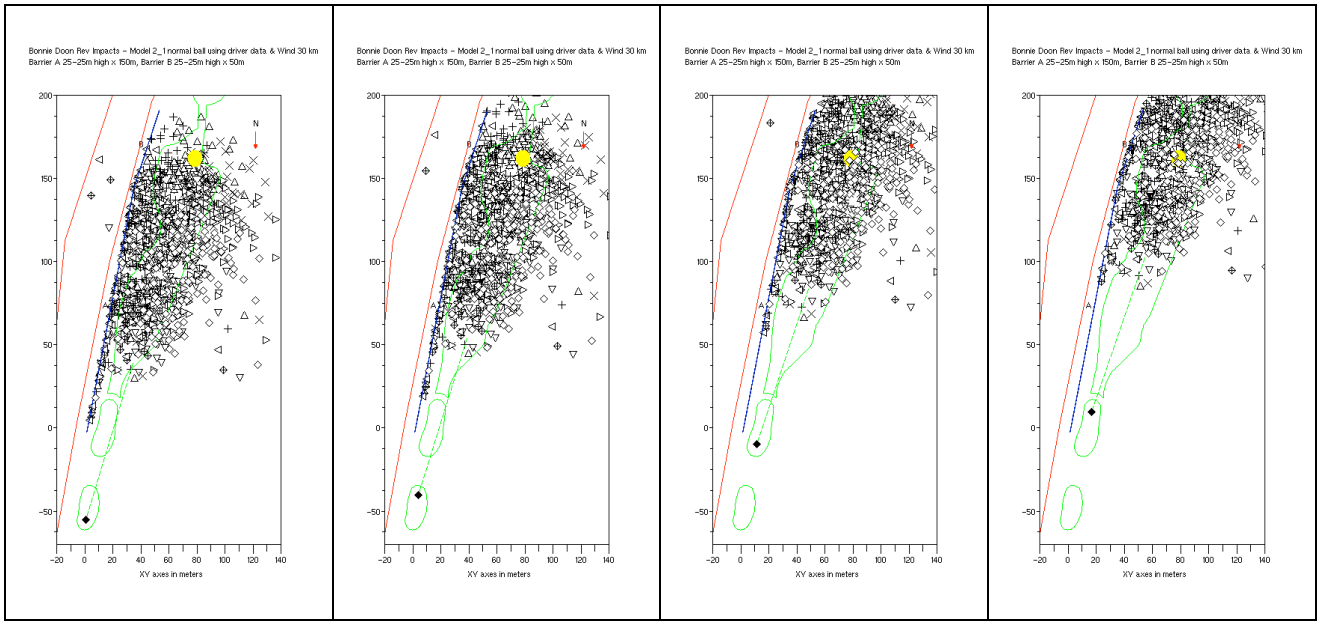
			
Back tee – 30-35-35m high, 30 km/h winds	Front tee – 30-35-35m high, 30 km/h winds	Back tee - 35m high, 40 km/h winds	Front tee - 35m high, 40 km/h winds

The 30m high barriers are not nearly as effective in the higher winds. Using a 35m second (200m) barrier improves performance.

Barriers for reducing errant balls – Proposed

Impact diagrams for the current rear and front two tees for the 200m + 50m long and 30m high barriers (as shown and recommended in the Summary Report) are shown at right.

These allow a comparison with similar diagrams for the revised design - the 150m + 50m long and 25m high barrier shown below and that the for the proposed layout a 200m long and 25m high barrier has a slightly better protective effect than the original recommendation on the current layout. It should be borne in mind that the winds from the west and south are the most frequent. More details of the wind regime are given in the Summary Report.



The remaining impact diagrams show the effect of changing barrier heights – revised design.