DEVELOPMENT OF RULES FOR CERTIFICATION OF RIFLE RANGES
FOR
NATIONAL RIFLE ASSOCIATION OF NZ

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THE NATIONAL RIFLE ASSOCIATION OF NZ

RULES FOR THE CERTIFICATION OF NO DANGER AREA RIFLE RANGES

1 BACKGROUND

The Trentham Rifle Range in Upper Hutt near Wellington, New Zealand was declared a public reserve for "the purpose of a rifle range" in 1903. The control and administration of the Reserve was vested in the Minister of Defence. The NZ Army acting as advisors to and agent of the Minister, closed the Range in November 2000 on "safety" grounds. These grounds were that, in essence, the ranges did not comply with JSP403 "Handbook of Defence Land Ranges Safety, Volume II Design, Construction and Maintenance of Small Arms and Infantry Weapon Systems Ranges" (JSP403).

The National Rifle Association of New Zealand (NRANZ) and its predecessors have carried out firing on the Trentham ranges since the late nineteenth century without any recorded incident of the public outside the Range Danger Area (RDA) being endangered. Furthermore, the NRA is unaware of any such incidents occurring during 140years of NRANZ conducted shooting on any rifle range in NZ. It is clear that most, if not all, of the ranges used by the NRANZ do not comply with all the requirements of JSP403. It has to be concluded, therefore, that either JSP403 is excessively conservative or that NRANZ shooting practices are inherently much safer than those from which the document has been derived.

Discussions with the Army's technical advisors addressed this subject and concluded from some data and some anecdotal evidence that NRANZ shooting provides a much tighter cone of fire (COF) than that assumed in JSP403. On the basis of this reduced COF the NRANZ was given a dispensation to carry out its National Championships in early January 2001 provided stringent conditions were met. A further dispensation under the same conditions was given to hold the Hawkes Bay Championships at Easter 2001 as the range on which they were normally held was also closed for the same reasons. The data from those Championships was analysed and the actual COF that can be expected for NRANZ shooting assessed in accordance with the methodology of JSP403.

The calculated COF was then used to determine the appropriate RDA for NRANZ shooting.

This RDA was determined on the basis that it provides, at least, the same level of confidence that JSP403 provides for the forms of military shooting for which it has been derived.

Throughout the analysis, wherever there was a possible range of effects the conservative alternative was adopted.

The analysis is set out below.

2 CONDITIONS OF SHOOTING

Both Championships from which data was collected were carried out under a number of conditions which have a bearing on the COF achieved by the shooters. These conditions included normal NRANZ rules under which NRANZ shooters operate including:

- Prone firing only with single shot bolt-action rifles (TR Class)
- Either sling supported (TR) or shot off a rest (F Class)
- Firing only from 300 to 1000yards (274 to 914m)
- Bolt removed from the rifle at all times except when on the mound and permitted to fire
- Bolt not to be closed except when the butt is in the shoulder and the rifle is pointing at the target
- Normal time limits for deliberate string shooting

Extra conditions were applied for these events as part of the dispensations. They were:

- The stop butt and mantlet dimensions were to be adjusted to comply with the Gallery Range requirements of JSP403 prior to the competitions.
- Only hollow point or plastic tipped projectiles were to be used
- Service rifles were not to be used
- A maximum muzzle velocity of 1000m/sec (3280ft/sec) was allowed
- The muzzle energy was not to exceed 4500joules (3170ft-lbs)
- Sight elevations were to be independently checked before all practices to ensure errors due to incorrect settings were eliminated
- Cross lane firing in strong winds was to be limited to 2 lanes maximum
- The RDA adopted for the events followed the JSP403 Gallery RDA except it was terminated at the crest of the hill, which at Trentham is 800 to 1000metres beyond the targets and 180 to 240m higher. Permission to shoot had to be obtained from the owners of all land within the modified RDA.

It is noted that the only special condition that could have a bearing on the COF is the checking of sight elevation settings as this should eliminate gross errors such as shooting at 900 yards with 800 yard sight setting. These errors would increase the elevation component of the COF. Allowance is later made for this in the development of the COF.

The effective prohibition on ball projectiles (since lifted) was based on the presumption that it may have different ricochet characteristics to match projectiles. As these projectiles have a lower ballistic coefficient than modern match projectiles
they would have increased the COF marginally. Very few of these projectiles are likely to be used because of their lower accuracy. The increase in group size at 1000 yards due to these projectiles alone is considered to be less than ± 0.5 minutes of angle (or ± 0.15 mil) which is insignificant in the final COF and has therefore been ignored.

3 DATA USED TO CALCULATE COF

The result of every shot fired in the Grand Aggregate at the 2001 National Championships was incorporated in the analysis. The Grand Aggregate consists of the following matches:

300yards 2 sighters and 7 to count; 2 sighters and 10 to count twice

500yards 2 sighters and 7 to count; 2 sighters and 10 to count twice

600yards 2 sighters and 7 to count; 2 sighters and 10 to count twice

800yards 2 sighters and 10 to count three times

900yards 2 sighters and 10 to count three times

Sighters are "optional" i.e. neither or the second or both may be converted to count and then sufficient shots fired until the required number of counting shots is recorded.

The complete series was shot by 75 A, 42B, 26C graders plus 11 under F Class conditions. One extra A grade and one B grade shooter arrived late and shot most of the series.

A total of 24,001 shots, including all non-scoring sighters, were fired in the grand Aggregate.

All counting shots plus all non-counting sighters fired for the 2001 Hawkes Bay Championships were also incorporated in the analysis. The results of a coached team's match and the NZ Champion of Champions final were also recorded and analysed.

The HB Championship consisted of 2 convertible sighters and 10 to count at 300, 500 and 600 yards and 2 convertible sighters and 15 to count at 900 and 1000 yards. The series was shot by 40A, 27B, 14C and 2T (Tyro) graders plus 4F (F Class) on the short ranges and 40A, 30B, 10C IT and 4F on the longs.

A total of 5164 shots, including all non-scoring sighters, were fired in the HB Championships.

The HB Champion Team's Match was competed for by eight 5/person Club teams with each member shooting 2 convertible sighters and 7 to count at 300, 500 and 600 yards. All sighters were included in the analysis, which totalled 909 shots. Ali shots were fired under the direction of wind coaches. This analysis is included as an attempt to determine the effects of wind judgement, which can be expected to be minimised by the involvement of a wind coach.

The NZ Champion of Champion's Match is also held during the HB Championships between the winners of all the Provincial and National Championship Aggregates during the immediately completed season. It consists of one 15shot match at 600 yards, 15 shooters took part giving a total of 225 counting shots. This result is included as an indication of the grouping ability of the leading (though not necessarily in-form) shooters.

A total of 30,299 shots were therefore recorded and included in the analysis. This is considered to provide a sufficiently large sample to provide a valid result. The calculated statistical standard error of the mean ("margin of error") is 0.6%.

4 METHOD OF ANALYSIS

4.1 TARGETS

The following targets were used (scoring rings in mm):

Distance	Target (W X H)	V	5	4	3	2
300yds	1200 X 1200mm	80	140	370	600	830
500/600yds	1800 X 1800mm	200	330	790	1250	1710
800/900/1000yds	2400 X 1800mm	400	700	1350	2100	RoT

4.2 CALCULATION OF STANDARD DEVIATION (SD) FROM SCORES

At each range the number of shots in a particular scoring ring was totalled. On the assumption that the shots are evenly distributed linearly across any scoring ring (this is generally conservative) the deviation of these shots from the centre is taken as the distance from the centre of the ring to the centre of the target. 8mm must be added to the ring diameter as the marking is to the outside of each ring. The distance to the mid-ring position for each range is as follows:

	Dimension from target centre to mid-point of scoring ring									
Score	V		5		4		3		2	
Distance	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils
300yds	22	0.08	59	0.22	132	0.48	247	0.90	362	1.32
500yds	52	0.11	137	0.30	284	0.62	514	1.12	744	1.63
600yds	52	0.09	137	0.25	284	0.52	514	0.94	744	1.36
800yds	102	0.14	279	0.38	517	0.71	867	1.19	1127	1.54
900yds	102	0.12	279	0.34	517	0.63	867	1.05	1127	1.37
1000yds	102	0.11	279	0.31	517	0.57	867	0.95	1127	1.23

From the above the mean deviation (MD) can be calculated. For example at 300 yards:

MD = [No. Vs x 0.08 + No. 5s x 0.22 + No. 4s x 0.48 + No. 3s x 0.90 + No. 2s x 1.32 + No. misses x a dimension to be assessed based on the information provided] divided by the total number of shots.

The SD is then $\sqrt{[\Sigma\{N_v(0.08\text{-MD})^2 + N_5(0.22\text{-MD})^2 + \ldots\ldots\} \div \Sigma N_v]}$ where N_v is the number of Vs, N_5 is the number of 5s etc.

Note that calculations are carried out in mils. 1 mil = the angle subtended by 1 unit at a distance of 1000 units

4.3 ANALYSIS OF NON-SCORING SHOTS

Shots receive a zero value for a number of reasons. These are as follows:

- The shot hits the target but is not recorded due to marker error. This occasionally happens when two shot holes touch each other and the marker patches both holes without realising that the second shot has key-holed the first.
- The shot is unintentionally fired at and hits the wrong target.
- The shot hits the target outside the scoring zones.
- The shot misses the target due to a shooter error such as mis-reading the wind, flinching, incorrectly setting sights, etc.

- The shot misses the target due to external factors such as disintegration of the projectile in flight or accidental bird-strike.

All non-scoring shots during the Championships were recorded and the scorers were required to write on the back of the score card the reasons for the zero score.

Hits on wrong targets were included in the analysis of the SD on the basis of their value but the target on which they landed recorded for future addition into the COF. In this way the accuracy with which the shot was fired is included in the analysis of the basic SD and then the incorrect aiming error over-laid.

The distance by which shots miss the target entirely can normally be estimated accurately because there is nearly always a good indication of where such shots go - either from evidence of the impact on the stop butt or from the corrections required to bring the rifle onto the target. Often the markers in the Butts provided confirmation from their own observations of the impact point on the stop butt or whether a shot hit near the top of the mantlet. Nearly all scorers use telescopes and watch the flight of shots and therefore have a good indication of their impact points.

Any miss for which there was no explanation was allowed for conservatively in the calculation of SD by assuming that at the long ranges it has impacted the stop butt half way between the two targets. This is done on the grounds that there are no known cases where a miss hit the next target (unless aimed at it) and the mean position of all unexplained misses will therefore be nearer the target aimed at than the half distance to the next. The targets at Trentham are spaced at 3.6m centre to centre. The targets sed are 1.2m wide at 300yards, 1.8m wide at 500 and 600yards and 2.4m wide at 800, 900 and 1000yards. The distance from the target centre to the mid-point between targets at the various distances is thus:

Range (yards)	**300**	**500**	**600**	**800**	**900**	**1000**
Distance to Mid-point between targets (mils)	**6.6**	**4.0**	**3.3**	**2.5**	**2.2**	**2.0**

For simplicity, unexplained misses at the long ranges (800 to 1000yards) were all conservatively entered as being 2.5mils deviation. (It is noted that the distance to the edge of the next target at 1000yards is 2.6mils and even at that range there is no record of hits from shots fired at the adjacent target). As the deviation due to wind at the short ranges (300 to 600yards) is less, a figure of 2.3mils was used. The record at the National Championships which showed only 1 complete miss out of 4637 shots at 300yards (which is 2.2mils to the edge of the target) and 2 misses out of 4525 shots at 500yards (2.0mils) supports this as a conservative approach.

4.4 RECORD OF NON-SCORING SHOTS

The following non-scoring shots were recorded. This record includes both counting shots and sighters that were not counted for score. The notation V(1) indicates a V bull one target away from the intended target. R denotes right and L denotes left of the target. The distance of the bullet strike from the centre of the target was assessed where possible from the information given by the markers and/or scorers who observed the strike. One mil is approximately equal to 3.4 minutes of angle but to 4.0 "minutes" on the typical rifle sights being used by most shooters in NZ in 2001.

National Championships Grand Aggregate

Match	Dist	A	B	C	F	No
1	**300**	V(1)		Hit mantlet (2.3mils low) V(1)		**3**
2	**500**	V(1)		5(1)	V(1)	**3**
3	**600**	5(1);5(1)	Sight on 0 in 6 mins L wind (1.7R) 5R for 5L (2.9mils R) V(1) 5Lfor 5R (2.9mils L) Off L edge (1.8mils)	Pull to R (1.8) Off edge R (1.7mils) Off R (2.0)	V(1)	**11**
4	**800**	Hit Stopbutt High L (3mils) 5(1); 4(2)	Low (1.4mils) Off L edge (1.8mils) 5(1)	Low (1.4mils) Wind wrong way (2mils) 2 shots between mantlet and target low (1.3mils)		**10**
5	**900**	4(2) 2 shots low (1.7mils) High (1.7mils)	Wind wrong way (2mils) Low R (2mils) High (1.5mils)	3(1) 3 shots R (2mils) 3 shots L (2 mils) 1 L just off edge (1.6mils)	L (1.8mils)	**18**

6	**300**	4(1)	4(1)			**2**
7	**300**	V(1)	V(1); V(1): V(1)			**4**
8	**800**	V(1)	5(1) Unexplained miss in the middle of a run of V bulls Wrong Target?			**3**

9	**900**	V(1); 5(1) Low (1.8mils)	V(1); V(1) 4(1)	Low between mantlet and Target (1.2mils) Wind error (2mils) Low (sight loose) hit mantlet (1.6mils) Mo explanation but next shot well on target Wind error? (1.8mils)		**10**
10	**500**	5(1)	V(2) Low L Sight set wrong (2.5mils)			**3**
11	**600**	V(1); V(1)	4(1)	4(1) Non-scoring hit Wind wrong way (1.5mils)		**5**
12	**800**	5(1) High L (2,5mils) L (1,8mils)	Low L (2 mils)	Left (2mils)		**5**

13	**900**	2 L and 1 R wind errors (2mils)	Low (sight on 800) (2mils) V(1); V(1); V(1) 3 shots L(2mils) High (1.8mils)	Three shots wind on wrong way 2L 1R (2mils) Low between mantlet and target (1.2mils) Low L (2.3mils)		**18 (16?)**
14	**500**	R (900yd wind still on sight (2.5mils)		4(2)		**2**
15	**600**	5(1)	V(1); V(1); 4(1)			**4**
Totals		**28 (17)**	**37 (19)**	**32 (5)**	**4 (2)**	**101**

The figures in brackets in the bottom line are the number of hits on wrong targets. These 43 shots have been included in the standard deviation calculations. The total number of non-scoring shots remaining is 58 which have been included in the calculation as being 2.5mils from the centre of the 300,500 and 600yard targets and 2.3 mils at 800 and 900yards. This is obviously conservative compared to the assessments included above but has been done for simplicity of calculation and because there is an element of doubt about the assessments.

Hawkes Bay Championships

Match	Distance	A	B	C	F	No
1	**300**		L Top of mantlet (2.6) L on Target (2.0)	High x 2 (2.6) L on target 5mins on sight (1.4) Tyro Low L x 2 (2.6)		**7 (7S)**
2	**500**			Tyro low Low L		**2**
3	**600**			Low L (2,2) Tyro 2 x R (2.3) L on tgt (1.6) High R (2.0)		**4 (2S)**

4	**900**	Low just under tgt (1.2)	Low just under tgt (1.2) 4(1) 4(1) Low (2.0) R just off (1.2)	Hit top mantlet (1.2) Between mantlet and target (1.1) 5(1) Just over top (1.2) Tyro low just under tgt (1.2)		**11 (5S)**
5	**1000**	Low between target and mantlet (1.1) (4(1) L (1.5)	Hit mantlet (1.2) High R (1.2) High x 2 (1.6)	L x 2 (1.4) High x 2 (1.4) Low (1.2) R (2.0) L (2.0) Tyro High (2.0) Low R (1.2) Low (1.0)		**17 (8S)**
Team 1	**300**		On tgt (1.2)			**1**
Team 2	**500**					
Team 3	**600**		High (2.0)			**1**
Totals		**4 (1)**	**12 (2)**	**12 (1)**	**0**	**43(4)**

4.5 CALCULATION OF CONE OF FIRE

After consideration was given to wind effects, typical ratios of shooters of each grade, etc. a realistic SD for all shooting for both elevation and azimuth was developed from the SD calculated above for each grade at each range. Normal practice is to multiply the SD by ± 5 to give a COF with a confidence of containing 99.99994% of all shots (ie all shots except 1 in 1.67million).

5 ACTUAL CALCULATED STANDARD DEVIATION

The SD was calculated in mils for all grades at all ranges. The following results were obtained (note the subscripts show the number of non-scoring shots for that match):

National Championships

Match No	Dist (yds)	Total No Shots	Standard Deviation (mils)				
		A+B+C	A	B	C	A+B+C	F
1	**300**	1149	0.155	0.168	0.247_1	**0.185_1**	0.116
6	**300**	1598	0.167	0.176	0.202	**0.181**	0.166
7	**300**	1567	.0153	0.172	0.189	**0.170**	0.128
2	**500**	1128	0.177	0.216	0.238	**0.205**	0.160
10	**500**	1530	0.142	$.0205_1$	0.214	**0.184_1**	0.123
14	**500**	1546	0.186_1	0.206	0.273	**0.216_1**	0.140
3	**600**	1172	0.207	0.301_4	0.334_3	**0.270_7**	0.186
11	**600**	1578	0.164	0.208	0.234_1	**0.198_1**	0.147
15	**600**	1622	0.201	0.191	0.208	**0.201**	0.126
4	**800**	1560	0.245_1	0.281_2	0.378_4	**0.295_7**	0.213
8	**800**	1575	0.221	0.282_1	0.281	**0.255_1**	0.268
12	**800**	1558	0.253_2	0.283_1	0.314_1	**0.276_4**	0.220
5	**900**	1587	0.267_3	0.336_5	0.426_7	**0.328_{15}**	0.304
9	**900**	1569	0.217_1	0.247	0.329_3	**0.255_4**	0.215
13	**900**	1585	0.292_3	0.350_5	0.411_6	**0.377_{14}**	0.327

The SD at each range is therefore as follows:

Distance	Total Number of Shots (A +B+C+F)	Standard Deviation (mils)
All 300s	**4637**	**0.178_{01}**
All 500s	**4525**	**0.200_{02}**
All 600s	**4690**	**0.221_{08}**
All 800s	**5054**	**0.274_{12}**
All 900s	**5095**	**0.311_{35}**
All Ranges	**24001**	**0.251_{58}**

Hawkes Bay Championships

Match No	Distance (yards)	Total No Shots	Standard Deviation (Mils)				
		A+B+C+T	A	B	C+T	A+B+C+T	F
1	**300**	833	0.155	0.166	0.325_2	**0.215_2**	0.137
2	**500**	830	0.179	0.220	0.314_2	**0.250_2**	0.212
3	**600**	833	0.174	0.222	0.360_2	**0.253_2**	0.193
4	**900**	1220	0.185_1	0.272_3	0.405_4	**0.272_8**	0.148
5	**1000**	1208	0.216_2	0.300_4	0.568_{10}	**0.329_{16}**	0.168

The SDs for the coached teams match were (it is noted that not all team members were A graders and all the non-scoring shots were fired by B graders):

Distance	Number of Shots	Standard Deviation (mils)
300yds	315	0.197_1
500 yds	292	0.181_0
600 yds	302	0.204_2

There were 225 shots fired in the Champion of Champions Match at 600 yards and the standard deviation of these was 0.139.

6 DEVELOPMENT OF CONE OF FIRE

6.1 CORE DISTRIBUTION

The core distribution of the cone of fire is that resulting from the inherent spread of shots from the rifle and its ammunition plus the unintentional deviation of competently fired shots due to unintentional shooter error. These shooter errors include incorrect aiming, unintentionally holding or moving the rifle away from a perfect aim and incorrectly assessing the wind corrections required.

The standard deviations above were calculated from shots fired in a large range of weather conditions, which will generally affect azimuth but have very little effect on elevation. Because the orientation of the shots could not be recorded practically it was therefore necessary to make an assessment of the contribution of wind effects to the standard deviations in order to develop a credible core distribution.

An added complication is the decrease in accuracy of the rifle and its ammunition with distance. This is effectively an elevation variation. Using Sierra's ballistic program for their Sierra 155grain Match King projectile (which was used by the great majority of shooters at the two Championships analysed) the following was obtained.

Vertical drop of Sierra 155gr Match King projectile for differing muzzle velocities

Muzzle Velocity	300yds	600yds	800yds	900yds
2960 ft/sec	20.2ins	96.2ins	261.7ins	346.1ins
2800 ft/sec	22.7ins	108.4ins	296.5ins	392.7ins
Difference for 160 ft/sec change	2.5ins	12.2ins	38.8ins	46.6ins
∴ Difference for 100ft/sec change	1.56ins	7.6ins	21.8ins	29.1ins
Difference in mils	0.14	0.35	0.67	0.81
Linear variation for same difference at 300yds (mils)	0.14	0.28	0.42	0.47
Increase in core distribution elevation due to ammunition	0	0.07	0.25	0.34

Most well-loaded ammunition will have a muzzle velocity variation of 50ft/sec or less. Some shooters are less careful with loading and often are those with lesser skills and less accurate rifles. As these have a disproportionate effect on the standard deviation a range of muzzle velocities of 100ft/sec was used. The other components of the elevation variation of the core distribution are all linear with distance.

It was therefore considered that the elevation of the core distribution should increase with distance. The increase over the 300yard core elevation was assessed at zero mils at 500yards, 0.1 mils at 600 yards, 0.2 mils at 800 yards, 0.3 mils at 900 yards and 0.4 mils at 1000yards.

In most conditions the wind effects at 300yards are not great. The SDs for the A grade at the 4/300 yard matches were 0.155, 0.167, 0.153 and 0.155. These were consistent enough to adopt a figure of 0.16mils for the SD for A graders at 300yards. All these shoots were fired in conditions that resulted in groups typically twice as wide as high. Further observation of grouping at 300 yards in light wind conditions suggested that a better approximation of the ellipse corresponding to a circular distribution would be one with a ratio of width to depth of 1.5 rather than 2. By comparing a circular distribution to an elliptical one a vertical component of the core distribution for A grade shooters of 0.13mils and an azimuth component of 0.20mils would result.

At 300yards the B grade SDs are 0.168, 0.176, 0.172 and 0.166. A SD of 0.17 was therefore adopted which gave an elliptical core distribution of 0.14mils elevation x 0.21mils azimuth.

At 300yards the C and Tyro grade SDs are 0.209, 0.202, 0.189 and 0.249 after the misses are excluded for later inclusion overlaid on the core distribution. A SD of 0.21 was therefore adopted which gave an elliptical core distribution of 0.17mils elevation x 0.20miis azimuth.

The core SDs above needs to be multiplied by 10 to give the Cone of Fire. (SD is a plus or minus distance so the 5xSD requirement is actually 10x the SD from above.)
The elliptical core distribution at 300yds were thus 1.3 X 2.0 mils for A, 1.4 X 2.1 mils for B and 1.7 X 2.6 mils for C and Tyro grades.

Adding the effect of increasing elevation to the core distribution calculated above
gave the following elliptical core elevations with distance:

Grade	300yds	500yds	600yds	800yds	900yds	1000yds
A	1.3	1.4	1.4	1.5	1.6	1.7
B	1.4	1.4	1.5	1.6	1.7	1.8
C+T	1.7	1.7	1.8	1.9	2.0	2.1

As the depth of the targets at 1000yards is 2.0mils this suggests that all C and Tyro shots would hit the target with all shots, provided the rifle is zeroed, there is no wind and no gross over-lying errors are made. This fits well with normal experience.

By a similar approach the assessed SD for each grade, after smoothing the gross variations at each range, was as follows:

Grade	300yds	500yds	600yds	800yds	900yds	1000yds
A	0.16	0.17	0.19	0.23	0.25	0.27
B	0.17	0.19	0.21	0.26	0.28	0.30
C+T	0.21	0.24	0.26	0.31	0.33	0.35

Multiplying the above by 10 gives the circular cone of fire which can then be adjusted to elliptical by using the core distribution elevations from the previous table.

This approach resulted in the following:

Elliptical Core Distributions of Cone of Fire (width x height in mils)

Grade	300yds	500yds	600yds	800yds	900yds	1000yds
A	2.0 x 1.3	2.2 x1.3	2.6 x 1.4	3.5 x 1.5	3.9 x1.6	4.3 x 1.7
B	2.1 x 1.4	2.6 x 1.4	2.9 x 1.5	4.2 x 1.6	4.6 x 1.7	5.0 x 1.8
C+T	2.6 x 1.7	3.4 x 1.7	3.8 x 1.8	5.1 x 1.9	5.4 x 2.0	5.8 x 2.1

6.2 ADJUSTMENT OF CORE DISTRIBUTION FOR VARYING PERFORMANCE LEVELS

To produce a core distribution for NRANZ the above graded distributions needed to be combined in accordance with the proportions of shots fired by the members of each grade.

The NRANZ grades its shooters in accordance with their performances at Championship meetings. To account for differing courses of fire, different venues and varying weather conditions a statistical system is used that gives 1000 points to the median score, 1040 to the 90percentile score (beats 90% of the other scores) and pro-rata points for all other scores. An adjustment is made for the quality of the field by adjusting the median and 90%lle positions in accordance with the number of A graded shooters competing. The points are recorded on computer and periodically gradings issued on the basis of the best 7 of the last 8 performances. The leading 35% are graded A, the next 35% B and the remaining 30% C. Tyro graders are first year shooters.

The adjustment to the field for grading is based on a normal attendance of 45% A graders. An analysis of all Championship meetings for the 2000/2001 season showed the following grading split: 44% A, 29% B, 19% C and Tyro and 8% F Class. The F Class shooters are not included in the grading system which adjusts the proportions to 48% A, 31% B and 21% C + T.

Club shooting tends to follow the same pattern with the higher grade shooters more active and therefore over- represented in the total number of shots fired. The National grading is applied by comparison to Club shooters who do not compete in open competition thus making the limiting proportions the same as the grading at 35A:35B:30C+T.

To reflect the actual shooting done by the various grades of shooter a split of 42%A to 31% B to 27% C+T was considered appropriate and conservative.

By factoring the above core distributions in this ratio the following core distribution for the NRA of NZ resulted.

Core Distribution of Cone of Fire for NRA of NZ

Elliptical Core Distributions of Cone of Fire (width x height in mils)

Range	300yds	500yds	600yds	800yds	900yds	1000yds
	2.2 X 1.5	2.6 X 1.5	3.0 X 1.6	4.1 X 1.7	4.5 X 1.8	4.9 X1.9

6.3 SUPERIMPOSED ABERRATIONS

6.3A Wind Reading Errors

Errors of wind assessment and/or of timing when to fire the shot are already incorporated as part of the core distribution and are the reason for the increasing width of the distribution with distance. The errors would be proportional to distance if the projectile flew at the same speed throughout its flight to the target. Because it slows dramatically as distance increases beyond 300yards the wind has longer to deflect its flight and therefore the errors are compounded. This is the reason for the increase in azimuth with distance of the core distribution.

6.3.2 Sight Setting Errors — Azimuth

The record of non-scoring shots above indicates the various errors that occur from time to time in setting wind sights. These include

- forgetting to zero the sight after the previous range
- putting the wind on the wrong way eg putting on 5 minutes left instead of 5
- minutes right
- forgetting to put any wind correction on
- winding the sight the wrong way

All except the last are typically errors made for the first sighting shot. The maximum credible error of this sort is to put the wind on the wrong way at 1000yards in a very strong cross wind. Once the wind exceeds 20 rifle minutes of angle at 1000 yards shooting is normally halted because of the difficulty in assessing it, the unpleasantness of being exposed to such a strong wind and the risk of damage to the targets and injury to the markers. It is almost inconceivable that someone would put 20minutes left on in a 20minute right wind but it could happen and similar errors do occur. An allowance of 40 rifle minutes (10mils in azimuth) should therefore be added to the core distribution to allow for this possibility at 1000yards.

A wind that requires a correction of 20 rifle minutes at 1000yards will require approximately the following settings at the other distances:

	300yds	500yds	600yds	800yds	900yds	1000yds
Wind Setting	3.3' (0.8mils)	7' (1.8mils)	9.2' (2.3mils)	14' (3.5mils)	17.7' (4.4mils)	20' (5.0mils)

The addition for these errors that should be added at the various distances is thus 1.6mils at 300yards, 3.6mils at 500yards, 4.6mils at 600yards, 7mils at 800yards, 8.8mils at 900yards and 10mils at 1000yards.

6.3.3 Sight Setting Errors — Elevation

The largest potential for elevation error with NRA shooting is the incorrect setting of sights. Shooting takes place only on distances from 300 to 1000yards. The maximum error due to this fault is therefore to fire at 1000yards with a 300yard setting or at 300 yards with a 1000yard setting. The Sierra Ballistics programme shows that for typically loaded ammunition the bullet drop at 1000yards is 336inches compared to 20inches at 300 yards. The maximum credible variation in elevation due to this error is in the table below:

It should be noted that this is an extremely conservative approach. This is because the short ranges are nearly always shot first and the lowest credible setting would therefore be that of the previous range if the shooter had forgotten to adjust the sight. In the worst case this would be a 300yard setting at 1000yards.

The only time a zero setting could be put on the sights would be by an inexperienced shooter who thought that zero was used at the shortest range (300yards). The low sight setting error is thus -1.8mils at 300yards, -1.6mils at 500yards, -2.5mils at 600yards, -4.7mils at 800yards, -6.0mils at 900yards and —7.5mils at 1000yards. This approach tallies with the record of low sighting shots hitting the mantlet at 300yards extremely rarely but unrecorded at 500yards although the angle to the top of the mantlet is less.

As 1000yards is the longest distance shot there is no possibility of the wrong range setting being applied that would give a high shot. There is a possibility at all ranges of incorrect reading of sights and of making an elevation correction the wrong way. At ranges shorter than 1000yards these errors will be more than covered by the allowance for sights accidentally being set for a different distance. At 1000yards this adjustment does not apply and an allowance needs to be made for high elevation sight setting errors. The highest such error observed is 5 rifle minutes of angle or approximately 1.3mils. To continue the conservative approach it would be prudent to allow 1.5mils above the top of the core distribution at 1000yards.

These elevation sight setting errors can be summarised as follows:

Distance	Sight on 1000yds	Sight on 0yds	Sight on 300yds
300yds	7.5 mils high	1.8 mils low	OK
500yds	5.9 mils high		1.6 mils low
600yds	5.0 mils high		2.5 mils low
800yds	2.8 mils high		4.7 mils low
900yds	1.5 mils high		6.0 mils low
1000yds	OK	1.5 mils low sight set wrongly	7.5 mils low

6.3.4 Targets not Fully Raised

It is reasonably common for the targets to not be fully raised. The target carriers at Trentham are of the Loughnan cantilever design which incorporates an automatic back-catch to hold the target down, especially in a wind blowing on the back of the targets. The catch is tripped by pulling on a rope to allow the target to be lowered for marking. Markers generally dislike using the catches and wedge them so they do not operate and normally adjust the counterweights to make the target slightly front heavy to speed lowering it. As a result targets are quite often not fully raised. This results in a corresponding lowering of the centre of the target and therefore the centre of the cone of fire. A full target will be seen by the firer at the various distances when the centre is below its highest position by the following amounts. These should be added to the cone of fire below the core distribution.

Distance	300yds	500yds	600yds	800yds	900yds	1000yds
Centre of low target	0.95 mils	0.67 mils	0.56 mils	0.42 mils	0.37 mils	0.33 mils

6.3.5 Firing at Wrong Targets

As can be seen from the record of non-scoring shots, this is a reasonably common occurrence, with 47 such shots in the record of 30,299, or 1 in 645. Four of these were two targets away and the rest on the adjacent target. However in a lead-up match, the Wellington Championships, for which the detailed records are not available, there were two instances of shooters firing 10 targets away. As the targets at Trentham are in blocks and numbered 1 to 10 in each block this is an understandable error as the correct number has been fired at. These incidents both occurred at 600 yards. It is not considered possible for this to occur at 300yards due to the very acute angle that would result. The maximum credible error due to this effect is thus considered to be at 500yards. As the targets at Trentham are spaced at 3.6m centres the azimuth error involved is ±80mils at 500yards. At 300yards the maximum credible error is to shoot three targets away or ±40mils.

It is self-evident that firing on wrong targets can only occur within the targets and does not contribute to an error outside the flank targets.

6.3.6 Projectile Break — up

There is some anecdotal evidence that match projectiles have occasionally broken up in flight with the core of the projectile stripping from the casing. If this did occur the bullet would lose most of its aerodynamic properties and fly erratically. It would probably miss the target and could impact the range short of the mantlet and there would be no indication of its path. There was only one incident in the record of 30,000 shots where this could have been the reason for an unexplained miss in the middle of a string of central bulleyes. It is more likely however that the shot went on another target and was not noted.

Such an event may cause the disintegrating projectile to fall out of the cone of fire but as the components will have low aerodynamic properties and reduced energy any potential ricochet is likely to be minor and to be captured by the mantlet or bullet catcher.

6.3.7 Bird Strike

Another possible cause of unexplained misses is a bird-strike. There are a number of birds that frequent the Trentham range and often fly during shooting between the firers and the targets. In the event of one being hit the projectile would be deflected and its energy depleted and it would most likely be badly deformed. It is possible it would travel outside the cone of fire but unlikely that it would cause a significant ricochet that would miss both the mantlet and the bullet catcher.

7 NRANZ CONE OF FIRE

From the above the cone of fire for NRA of NZ shooting can be summarised as follows:

- There is an elliptically shaped core distribution:

Elliptical Core Distribution of Cone of Fire (width X height in mils)

Distance	**300yds**	**500yds**	**600yds**	**800yds**	**900yds**	**1000yds**
	2.2 x 1.5	2.6 x 1.5	3.0 x 1.6	4.1 x 1.7	4.5 x 1.8	4.9 x 1.9

- An azimuth allowance should be added to allow for wind sight setting errors. This allowance increases with distance thus:

	300yds	**500yds**	**600yds**	**800yds**	**900yds**	**1000yds**
Allowance	±1.6 mils	±3.6 mils	±4.6 mils	±7.0 mils	±8.8 mils	±10 mils

- A separate allowance should be made in azimuth to allow for unintentional shooting at targets up to 10 away at distances from 500yards back. This equates to ±80mils at 500yards, ±67mils at 600yards, ±50mils at 800yards, ±44mils at 900yards and ±40mils at 1000yards. At 300yards an allowance of ±40mils should be made to allow for firing shots up to three targets away.

- A separate elevation allowance should be made for incorrectly set sights. This allowance is +7.5mils or -1.8 at 300yards; +5.9mils or -1.6mils at 500yards; +5.0mils or -2.5mils at 600yards; +2.8mils or -4.7mils at 800yards; +1.5mils or -6.0mils at 900yards; +1.5 or -7.5mils at 1000yards.

- A separate elevation allowance should be made to allow for the possibility of the target not being fully raised. This allowance lowers the core distribution by 0.95mils at 300yards; 0.67mils at 500yards; 0.56mils at 600yards; 0.42mils at 800yards; 0.37mils at 900yards; 0.33mils at 1000yards.

The cone of fire needs to be calculated as a two-stage process to properly reflect the extremes of possible strikes.

The COF adopted by JSP403 (Table 3) for single shot static to static practices is ± 40 mils in both elevation and azimuth. This compares with the largest COF for NRANZ (at 1000yards) of ± 12.45 mils in azimuth and + 2.45 mils or - 8.78 mils in elevation and indicates the gross conservatism involved in applying JSP403 to NRANZ shooting.

The difference in these COFs is easily explained.

- The ± 40 mils COF in JSP403 is intended to cover all static to static single shot rifle shooting which can include rapid (semi-automatic) shooting from the standing position (not necessarily from the shoulder) with out sling support using military issue rifles firing ball ammunition including tracer.

- The NRANZ COF is developed for prone sling-supported deliberate shooting under strictly enforced rules limiting bolt closure to the time the rifle is supported and aiming at the target generally using purpose-made target rifles using carefully loaded match projectiles.

8 RANGE DANGER AREA (RDA)

Fullbore TR (Target Rifle) and F Class shooting is commonly carried out on ranges certified to comply with military rules including their range danger areas (RDA). In NZ the rules used are contained in JSP403. The Gallery Range RDA (Chapter 15 of JSP403) is normally applied to ranges for NRANZ shooting.

This Gallery Range RDA allows the following:

- Quadrant Elevation (QE) of 50 mils. The QE is the angle of the bore above the horizontal when the firearm is sighted. *The maximum QE for TR shooting (from 1000 yards) is less than 8 mils on flat ranges.*

- The use of tracer rounds which are notorious for erratic flight and are prone to ricochet. (IRSAG Discussional Document No 7/98 at 22a. states "7.62mm ball — ricochet falls off rapidly between impact angles of 12 and 20 degrees and there is a high level of assurance that ricochet will not occur beyond an impact angle of 25 degrees." At 22b. it states "7.62mm Tracer — ricochet is more variable, with ricochet being almost certain up to an impact angle of 17 degrees and there still being a 20% chance of ricochet occurring at 32 degrees." *Tracer is specifically prohibited for NRANZ shooting.*

- Moving targets. *NRANZ shooting is only on static targets.*

- Muzzle velocity of 1000m/second. *The maximum allowable muzzle energy of 4,500joules for NRANZ shooters using 155grain (9.9gram) projectiles limits maximum muzzle velocity to 933m/second (3060ff/second).*

- Muzzle energy of 7000joules. *NRANZ shooting is limited to muzzle energy of 4,500joules (3,170ft/lbs) for TR shooting and 5160joules for F Class fired from no less than 300 yards for which the residual energy at the target will be less than 4,500joules.*

JSP403 states at clause 02101 that "Gallery type ranges ... are constructed to capture the full COF" and at 2102 "A gallery range designed to capture the full COF also reduces the probability of ricochet from the range floor..." Table 3 of Chapter 2 defines the COF for static to static single shot firing as ± 40 mils in elevation and azimuth. The COF is defined in clause 0214 as "... the distribution of fired projectiles within a margin of error in the vertical and horizontal planes. The COF accounts for acceptable deviation caused by errors associated with the firer and machining or manufacturing tolerances, and allows an additional margin for unacceptable firer error."

The NRANZ COF determined above from the records of over 30,000 shots includes all such deviations and is very much smaller than the COF in JSP403.

It is therefore self-evident that, to have the same level of risk of a shot leaving the RDA, the Gallery Range RDA of JSP403 is excessively large for NRANZ shooting.

8.1 RISK

IRSAG 7/98 sets out the normal statistical approach for determining the COF i.e. multiplying the standard deviation of all the shots fired in a sufficiently large sample by 5 (and this is the approach used above). The statistical probability of all shots being contained by the COF is then calculated to be 0.9999994, or put another way, the probability of a shot being outside the COF is approximately 1 in 1.7 million. Conventionally a risk of **1** in 1 million is accepted for the risk of a shot leaving an RDA and as the RDA is designed to capture the full COF this equates to the same level of risk of a shot leaving the COF. In fact it is dear that many shots that are outside the COF will still not leave the RDA and therefore the risk of a shot not being captured by the RDA is very many times higher.

In setting an acceptable level of risk of a shot leaving the RDA the consequences of such an event should be considered. Most fullbore rifle ranges in NZ are in lowly populated areas (for reasons of land cost and particularly compliance with noise criteria) and the possibility of an errant shot or ricochet hitting a person or damaging property would be of the same order of probability. In that case if there is a risk of 1 shot in 1 million leaving the chosen RDA and a risk of 1 in 1000 of a person outside the RDA being hit (population density of 10 people per hectare) then the risk of hitting someone is 1 in I billion. As even the busiest range in NZ would have less than 100,000 shots fired in NRANZ practices in a year that relates to the risk of hitting someone outside the RDA once every 10,000 years. That is seen as a negligible and therefore acceptable risk. It should be noted that most farm land adjacent to rifle ranges in NZ is more likely to have an occupant density between 5 and 100 hectares per person which would increase this risk period to 500,000 to 2,000,000 years.

8.2 MODIFYING THE GALLERY RANGE RDA FOR NRANZ SHOOTING

The Gallery Range RDA is shown as Figure 15-1 of JSP403. This RDA includes the following dimensions (see Figure 1). Note that the tracer DA is not included in this sketch because it does not apply to NRANZ shooting.

A. The width of the firing points from the longest distance to the far extent of the RDA. For example if there are ten targets spaced at 3.5m centre to centre then A will be 9 x 3.5 = 31.5m.

B. The distance outside the centre of the flank targets to the edge of the RDA on both sides of the range width, A. For the GR RDA this distance is 150m.

C. The distance outside the range width, A, to the edge of the RDA on both sides commencing distance D beyond the target line and extending for a further distance D. For the GR RDA this distance C is 350m. The RDA widens linearly from 150m to 350m both sides from the target line to the distance D behind the targets.

D. Half the length of the RDA beyond the target line. For the GR RDA length D is 915m.

The RDA also includes the triangle each side of the range between the outer ends of the firing point at the longest distance and the point 150m outside the range width at the target line.

This RDA is restricted to MV (muzzle velocity) of 1000m/s and maximum permitted ME (muzzle energy) of 7,000joules.

Muzzle energy is directly proportional to muzzle velocity squared. The range of a projectile in a vacuum is also directly proportional to velocity squared. The range of a projectile in air is approximately directly proportional to velocity squared. The range of a projectile is thus essentially directly proportional to muzzle energy.

The GR RDA includes all credible ricochets (with the exception of no more than 1 in I million) from the ammunition for which it applies. It necessarily includes allowance for the military COF for which it has been developed. For static to static practices for single shot ranges the military COF in JSP403 is ± 40mils in both elevation and azimuth.

The GR RDA includes this COF for a nominal 600m distance. The COF component of dimension B is thus 24m (40mils @ 600m). The balance of dimension B is 126m.

Dimension C must also include a component for COF. The distance to the point where the RDA reaches dimension C is 600m + D. For the GR RDA ID = 915m so the COF component in C is thus 60.6m = (915 + 600) x 40mils. The balance of B is 289.4m.

If it is presumed that the balance of dimensions B and C is to allow for lateral spread of projectiles after range floor ricochets then as range is proportional to muzzle energy then the range of ricochets in all directions must also be proportional to their residual energy at impact. The maximum allowable muzzle energy for NRANZ is 4,500joules compared to 7,000joules for the GR RDA. The residual energy at impact of a range floor ricochet must therefore be in the same ratio. The various dimensions should therefore be factored by the ratio of these energies thus:

BNRA = 126 x 4,500 ÷7,000 + 24 = 105m

CNRA = 289.4 x 4,500 ÷ 7,000 + 60.6 x 1162 ÷ 1515 = 232.5m

DNRA = 915 x 4,500 ÷7,000 = 588m

Note that the calculation for COF in C is based on the reduced dimension D

However, the NRA COF should be added back to the factored distance rather than the 40mils COF component. This would change the dimensions for B and C as follows:

BNRA = 126 x 4,500 ÷ 7,000 + 11.4 = 92.4m

CNRA = 289.4 x 4,500 ÷ 7,000 + 1476.4 x 0.01245 = 204.4m

The COF components added are based on the worst case of 12.45mils from 1000yards (914.4m).

For simplicity and conservatism the dimensions have been rounded to

B = 90m

C = 200m

D = 600m

The resulting NRANZ RDA is shown on Figure 2.

A further reduction in the RDA is possible for ranges on which no firing is permitted forward of 300yards and F Class is limited to a muzzle energy of 4130joules. (Note that NRANZ practices are virtually never fired forward of 300yards and virtually all F Class rifles have a muzzle energy less than 4000joules so such a restriction would be quite acceptable).

It is understood that the ricochet data from which the GR RDA has been developed was based on shots fired generally from 100m or less. Even for projectiles with a very high ballistic coefficient the energy lost over the first 100m is of the order of 14%. The loss of energy for the first 300yards (274m) is thus of the order of 35%. (refer Sierra .308Win 155 MK with muzzle velocity of 3,000ft/sec (914m/s) which has a muzzle energy of 4114joules and energy of 3584joules at 100yards, 3111joules at 200yards and 2689joules at 300yards). For conservatism assume that the least muzzle energy loss for NRANZ shooting is 10% at 100m and 30% at 300yards. There is thus 20% less energy at the target line where ricochets can be initiated (the NRANZ COF does not impact the range floor) than the RDA calculation would presume. For a range on which shooting in front of 300yards is not permitted and muzzle energy is limited to 4,500joules for all firing the calculations above should be based on an energy of 80% of the maximum allowed i.e. 3600joules.

Using the same approach as above the following dimensions for the modified NRA RDA result:

BNRAMOD = 73.3m

CNRAMOD = 159.2m

DNRAMOD = 449.7m

These have been rounded conservatively to 75m, 160m and 450m respectively. These reduced dimensions are shown in brackets on Figure 2.

8.3 AIR DANGER HEIGHT

The air danger height (ADH) is defined as the maximum height above ground level at which hazards may exist and is effectively the top of the RDA. For 7.62mm ball ammunition JSP403 requires an ADH of 500 feet (152m).

The muzzle energy of a 150gr 7.62mm ball projectile fired with a muzzle velocity of 2,800 feet/second (850m/sec) is approximately 3450joules. This is virtually identical to the residual energy of a 155gr projectile fired at 3000 feet/second (915m/second) after it has travelled 300 yards (274m). It is therefore reasonable to set the ADH for NRA shooting at 150m at the targets.

By the time a 155gr projectile fired at 300 yards has travelled a further 900m beyond the targets (i.e. 1174m in total) its residual velocity will be 1,200 feet/second (366m/second) and its residual energy will have reduced to 662joules. The ADH corresponding to 662 joules is thus 96 feet (29.2m).

The top of the RDA is thus set at 150m at the targets falling linearly to 30m at the far extent of the RDA. Where the top of the RDA intersects rising ground behind the target the RDA finishes at that point.

8.4 CONSTRUCTION

The Gallery Range RDA in JSP403 is based on strict limits on construction of the range. In general these are all adopted for the NRANZ RDA with the exception of the construction of mantlets and butt stops.

The forward slopes of mantlets and butt stops for the GR RDA to JSP403 are required to be constructed at 34° (a batter of 2:3) and maintained at a minimum angle of 30°. These ranges are designed for higher muzzle energies and muzzle velocities than NRANZ ranges but, more importantly, are also designed for tracer ammunition. IRSAG Discussional Document No 7/98. states at 22b "7.62mm Tracer — ricochet is more variable, with ricochet being almost certain up to an impact angle of 17 degrees and there still being a 20% chance of ricochet occurring at 32 degrees." It is therefore prudent for the GR RDA to require earthworks to be built to the highest practical angle (and for its RDA to cater for ricochets). The natural angle of repose of most soils is of the order of 30° and it would be impractical to require construction to a greater forward slope than 34° or maintenance to more than 30°.

For NRANZ shooting, for which tracer is specifically prohibited, a lesser angle can be used taking into account the comment from the same document at 22a. which states "7.62mm ball — ricochet fails off rapidly between impact angles of 12 and 20 degrees and there is a high level of assurance that ricochet will not occur beyond an impact angle of 25 degrees." For that reason, NRANZ has adopted a minimum of 25° for these structures.

The GR RDA requires a minimum mantlet height of 1800mm. The NRANZ COF will not impact the range floor in front of the mantlet if its height is 1300mm for distances of 600m or less. With a mantlet height of 1800mm there will be range floor impacts in front of the mantlet for shots from further than 600m if there are gross errors in setting sight elevations. It would be prudent to initiate independent checking of sight elevation settings prior to shooting at long ranges (more than 600m up to 1000yards) where the nature of the range floor is such that it could induce ricochets (in spite of the fact that the RDA is designed to contain such ricochets). With checking at the long ranges, the COF at all ranges will be contained by an 1800mm high mantlet. The NRANZ RDA therefore requires mantlets to be at least 1300mm high for ranges up to 600mm and 1800mm (the same as the GR RDA) for longer ranges. The NRANZ RDA sets butt stop heights based on the calculated COF. Therefore, if long range sight setting elevation errors are eliminated by sight checking, all shots fired within the NRANZ COF will impact either the stop butt or mantlet. The RDA beyond the targets is designed to capture all ricochets induced by gross elevation errors for shots fired from the long ranges. It should be noted that these ricochets will be induced at impact velocities less than 1750 feet/second (533m/second) when the residual energy of the projectile is less than 1400joules — or 20% of that for which the GR RDA has been designed. It could be argued that the length of the NRANZ RDA could be limited to much less than the figure adopted.

8.5 ALTERNATIVE APPROACH TO DEVELOPING THE NRANZ RDA

The NRANZ RDA was determined above by factoring the GR RDA in accordance with the actual energy contained in NRANZ fired projectiles. A different approach was also taken by calculating the required RDA to contain all ricochets from the range floor by using the information for 7.62mm ball ammunition contained in the IRSAG Discussional Document 7/98. This document reported on ricochets tracked by radar from thousands of shots. Such a RDA is unaffected by the accuracy of sight setting and checking processes.

The determination of this RDA was as follows. (Note that the worst case is consistently taken throughout this analysis. For example, where velocity or energy governs data for the heavier more aerodynamic 7.62mm match ammunition has been used).

IRSAG Figures 11 and 12 show the fall of ricochets from 3 and 10 degree slopes onto flat land. Copies of these are attached with the area relating to 7.62mm ball outlined and cross-hatched. It can be seen that off a 10° slope all ricochets land within 1000m of the impact point and within 300m either side of the range. For ricochets off a 3° slope the landing area extends to 2650m and is still within 300m each side of the range. It is clear from these diagrams and from the accompanying text that many of the ricochets off the 3° slope are low and long ranging with little damage to the projectile.

There are a significant number that have landed within 800m and tended to splay outwards much more than the long ranging ones. By the time the ricochet angle reaches 10° there is considerable loss of velocity with ricochet combined with significant damage. This interpretation is reinforced by IRSAG Figures 3b and 4b. Figure 3b show that the velocity of the ricochet relative to that of impact is generally between 80% and 90% for a 3° slope but varies from 10% to 70% for a 10° slope with a tendency for the projectile to break up. Figure 4b shows that the increase in azimuth angle of ricochets increases with the reduction in velocity ratio, i.e. the slow ricochets are those that stray most from the line of fire.

Calculations were carried out based on the lowest point of the COF from each range — i.e. including gross errors made in setting sights for elevation. These showed that the range floor would be impacted at varying distances in front of the targets. The velocity and residual energy at each impact was also calculated. Only shots fired from 800 to 1000 yards impact the range floor while the lowest shots from short ranges (less than 600m) all strike the mantlet. Only the long range shots are therefore included in the following summary table.

Firing Point	**Range Floor Impact**				**Ricochet**	
	Distance travelled to impact (m)	**Impact distance in front of target**	**Speed at impact**	**Energy at impact**	**Range of ricochet**	**Final impact beyond targets (m)**
800yds (732m)	**669**	**63**	**524**	**1357**	**1199**	**1136**
900yds (823m(	**711**	**112**	**504**	**1256**	**1109**	**997**
1000yds (914m)	**760**	**154**	**482**	**1148**	**1014**	**860**

The range of the ricochets is calculated by multiplying the extreme range from the ricochet data (2650m) by the energy at impact divided by 3000 joules, being the typical energy of a 7.62mm ball projectile having travelled 100m at impact as typically used in the trials.

As can be seen from this result the length of the NRANZ RDA at 1200m behind the targets on flat land would contain all ricochets induced by impact off the range floor.

The worst case for azimuth deflection of a ricochet in the data is the right hand side off a 10° slope which strays 300m laterally from the range centreline at 550m from the ricochet point. It is presumed that there was a significant COF inherent in the trials to minimise the shots all impacting from the same point and changing the effective angle. As approximately 18% of the shots were fired standing or kneeling and the rest prone it is reasonable to assume that the COF for static to static military shooting of ± 40 mils would apply. An allowance for ±40mils in azimuth variation would allow for approximately 20m of the lateral spread at the widest point.

The highest muzzle energy at impact is that from 800 yards of 1357joules. Therefore, the lateral deviation from the line of fire would be (300m - 20m) x 1357/3000 = 127m The width of the NRANZ RDA at 550m beyond the targets is 190m.

The ricochet data has been superimposed on the NRANZ RDA for each of the firing distances 800, 900 and 1000 yards taking the lowest point of the COF for each and factoring the ricochet plot in the ratio of the muzzle energy at impact with that of a 7.62mm ball fired from 100m — assumed to be 3000 joules at impact. As can be seen the ricochet pattern is almost entirely contained within the RDA in each case.

It should be noted that the risk of range floor impact is extremely low. There were no such impacts in the 30,299 shots tracked to produce the COF. A conservative estimate would be that the risk of range floor impact for NRANZ shooting is no more than I in 10,000 shots. As there are more than 1,000 ricochets from 7.62mm ball in the data used to create Figures 11 and 12 in the IRSAG document, the risk of a range floor ricochet leaving the NRANZ RDA is thus less than 1 in 10 million shots or ten times the level of acceptable risk.

The shape of the GR RDA does not relate well to the ricochet data which clearly shows a much wider spread of ricochets in the first half of the RDA with a narrower width where the less damaged long ranging ricochets occur. The NRANZ RDA is therefore conservative also in following this shape. If future ricochet testing is carried out to the extent that more confidence can be placed in the data, it is probable that the maximum width of the RDA could be reduced to 150m each side of the line of fire starting at 300m beyond the targets and continuing to the end of the RDA at 1200m.

It should also be noted that the longest ranging — least damaged ricochets will be at very low angles to the horizontal and therefore mostly be stopped by either the mantlet or butt stop.

It is considered that this alternative approach, based on actual extensive ricochet data, confirms that the NRANZ RDA developed by factoring the GR RDA is probably conservative.

9 NO DANGER AREA RANGES

9.1 GENERAL

The development of the NRANZ no-danger-area RDA (NDA) is also based on the definitions and methodology JSP403. The NRANZ NDA is designed to contain all the calculated Cone of Fire (COF) for NRA of NZ shooting.

The following definitions are copied from JSP403.

"0231. **Range (Zone).** A range is a space reserved, authorised and normally equipped for hazardous firing (weapons or lasers). The following are types of range:

> **No Danger Area Range.** A no danger area (NDA) range is a range where, for all practical purposes, the design precludes the risk of injury or damage to persons or property beyond the range floor caused by shot, direct or ricochet, fired in accordance with authorised procedures and aimed within the bounds of accepted aimer deviation. The minimum design requirement is to contain all correctly aimed shots fired within the bounds of accepted weapon deviation."

> "0236. **Range Floor.** The range floor comprises the ground from the furthest firing point to the target including any range construction intended for or capable of capturing correctly aimed shots or inducing ricochet."

> Note: When the range definition is applied to NRANZ documents "weapon and lasers" is replaced with either firearm" or "rifle".

Sections 0291 to 0297 of JSP403 set out the general requirements, design criteria and specific details for military NDA ranges. The general clause refers to the definition in 0231 (above) and notes that no additional danger area is required for such ranges beyond the constructed part of the range. It also notes that ricochet from ground strike is often a greater deviation than the COF.

The design criteria are prefaced with the statement ***"the advice and data used is based on legitimate and authorised practices, and cannot prevent a shot fired with unacceptable aimer deviation from leaving the range boundary."*** This comment also applies to gallery ranges and the corresponding NRANZ RDA.

In essence the JSP403 design criteria and prescriptive details for NDA are designed to ensure all acceptably aimed shots and all range floor ricochets are captured by the mantlet and/or butt stop.

The NRANZ NDA is based on eliminating all ricochets and therefore capturing all the COF by the mantlet and bullet catcher or other structures.

This is to be achieved by

- Constructing any mantlet and butt stop with vertical or near-vertical faces so that ricochets cannot be induced from these. *Conventional mantlets and stop butts (and the NRANZ RDA) rely on the slope of the front face of earth structures being maintained at a large enough angle to have* a *zero probability of ricochet. There is however always a risk with these earth structures that continual projectile impacts will cause local reduction in the angle below this confidence limit if maintenance is not carried out often enough.*

- Requiring the height of the stop butt and any mantlet to be sufficient to catch all the COF from all ranges.

- As the above would require targets placed much higher above the range floor than normal with a resulting prohibitively high butt stop for ranges of more than 600m length, sight elevation settings must be independently checked before firing at any distance greater than 600m. *This will have the effect of removing the component of the NRANZ COF included to allow for gross errors in setting sights (such as shooting at 1000yards with* a *300yard setting on the sight).*

9.2 DETERMINATION OF SAFETY FACTOR

The gallery range RDA of JSP403 commences at the outer end of the furthest firing point and extends as a straight line to a point 150m outside the centre of the flank target. Included in this dimension of 150m are allowances for the cone of fire, lateral ricochet from range floor impact and a safety factor as an additional margin for unacceptable firer error. The amount allowed for this factor of safety is not advised in JSP403. The following approach has been made to determine the order of this safety factor and therefore a reasonable allowance to be made in determining the no-danger-area RDA for which all ricochets are eliminated.

IRSAG Discussional Document No 7/98 reports on ricochet tests using 7.62mm ball ammunition fired at damp sand at distances of 50 to 300m with the majority of rounds fired from 100m. Figures 3(b) and 4(b) (attached) show the relationship of impact angle and velocity ratio and the azimuth deviation after ricochet plotted against velocity ratio respectively. The velocity ratio is the that of the velocity after ricochet to that before.

These firings were carried out by typical military practices and therefore include the cone of fire which is assessed as ±40mils.

The maximum range of ricochets off a 3° slope during the tests was 2,600m for which the velocity at ricochet was a maximum of 2,600 feet per second. It is presumed that the maximum range of a projectile after ricochet will be proportional to the square of the velocity ratio. Using the data plotted in Figure 4(b) the azimuth deviation was calculated presuming shots were fired from 600m and impacted the range floor 100m in front of the rifle. In only one case out of the approximately 300 results plotted was the azimuth deviation in excess of 150m. in this case the velocity ratio was 0.52 and the angle of departure 17° with the resulting azimuth deviation of 153m. The next largest deviations in order of magnitude are 108m, 89m, 88m, 87m and 81m. It is noted that once the angle of departure is less than 16.7° the ricochet will pass the targets before it can reach a 150m deviation irrespective of the velocity ratio. The combination of angle of departure and velocity ratio needed to have the ricochet deviate by 150m at the target line is overlaid on the attached data.

Further to that, the assumption of no damage and therefore a ricochet flight proportional to that of the longest ranging ricochets off a 3°slope is obviously grossly conservative. Figure 3(b) (attached) shows that the velocity ratio will not exceed 0.4 off a 12°slope. The extreme result shown above with a velocity ratio of 0.52 and a 17° change in direction is probably from a freak deflection off a stone and is likely to have a very low trajectory which will quickly contact the ground again and not achieve the theoretically calculated range.

From the data it seems reasonable to assume that the combination of COF and lateral ricochet will account for 90m of the 150m offset in the GR RDA at the targets. That assumption means that the extra allowance for safety factor is 60m. The width of the NDA at the target line should therefore be the COF + 60m as there is no allowance required for ricochet. As NRANZ shooting practices are far more controlled than similar military ones for which the safety factor has been set it is logical to reduce it by the same factor as the reduction in the GR RDA i.e. by 90/150 = 0.6. The offset would thus be COF + 36m at 1000 yards.

For ranges where the furthest distance shot is less than 1000yards it is also logical to reduce the safety factor with distance. In other words the allowance for shots fired with unacceptable firer deviation would be expected to subtend the same angle for the same level of risk as there is no influence from muzzle energy, ricochet effects, etc.

The width of the azimuth offset at the targets for an NRANZ no-danger-area range would therefore be as follows:

Distance (yards)	300	500	600	800	900	1000
Max. COF (m)	0.7	2.2	3.3	6.6	9.1	11.4
Safety Factor (m)	10.8	18.0	21.6	28.8	32.4	36.0
Total Offset (m)	11.5	20.2	24.9	35.4	41.5	47.4

The following offsets are therefore adopted for no-danger-area ranges operated strictly to NRANZ rules (which prohibits bolts in rifles at all times except when allowed onto the firing point by the RO and prohibits bolts being closed except when the rifle is in the shoulder and generally aimed at the target and requires sight checking before all long range shooting).

Ranges where the furthest firing distance is 300yards - 12m (Actual SF =11.3m)

Ranges where the furthest firing distance is 600yards - 25m (Actual SF = 22.8m)

Ranges where the furthest firing distance is 800yards - 36m (Actual SF = 29.4m)

Ranges where the furthest firing distance is 900yards - 42m (Actual SF = 32.9m)

Ranges where the furthest firing distance is 1000yards - 48m (Actual SF = 36.6m)

In each case the safety factor is an angle of 2.3°.

The NRANZ RDA for no danger area ranges is shown on Figure 3.

9.3 DESIGN AND CONSTRUCTION

There are many techniques for designing and constructing no-danger-area ranges to ensure all the COF is trapped and no ricochets can occur. Examples are:

- Ranges with conventional firing points, markers' gallery and butt stop
- Electronic target ranges where no markers' gallery *is* required
- Single firing point ranges where the targets are moved or are in separate butts.
- Combinations of the above

In all cases the forward faces of bullet stopping structures should be near vertical to preclude ricochet. Construction can be of earth filled timber walls, concrete, etc with local protection from steel or sacrificial replaceable material such as sand bags or timber at highly impacted areas.

Steel can be used to stop projectiles as long as care is taken to avoid the risk of backsplash into markers' galleries or anywhere there may be people. Backsplash off vertical steel can be expected to travel up to 50m. Steel deflector plates can be successfully used behind targets and set at an angle of 30° to 50° to deflect all projectiles down to ground level where they can be trapped and contained (and thereby remove a lot of potential contamination). The forward facing top edge of such plates should be bevelled to avoid making a ricochet-inducing surface. All such steel must have a Brinell hardness of 500. Typically 12mm AR500 armour plate is used for angled deflector plates behind NRANZ targets.

Baffle walls can be used in conjunction with butt stop walls and markers' gallery mantlets to ensure all shots within the COF are captured. Baffle walls can be used on the sides of ranges to limit the land area required and across the range floor to preclude any range floor ricochets - especially on single firing point ranges. Top baffles can also be used to trap any stray shot above the COF but need to be designed in conjunction with cross range walls to ensure there cannot be a range floor ricochets up through the baffles and out of the range.

Each case should be designed by reference to the NRANZ COF and taking into account the trajectory so that all walls are high enough. Some guidelines are attached as follows:

9.3.1 Butt Stop Walls and Side Baffle Walls

Figure 4 shows a typical approach to limiting the side areas of the RDA by installing &de baffle walls. The essential requirement is that there must be a baffle wall stopping all shots from all firing point positions fired up to and including the angle of the RDA that is required outside the flank target for the longest distance. This angle is shown on Figure 4 as α.

The length of the butt stop wall must be extended sufficiently past the flank target to work with the side baffle walls to ensure this is achieved.

Figure 5 shows how the minimum height of the baffle walls is determined.

For a conventional range the top of the COF is determined from each firing point to the butt stop wall and the tops of the side baffle walls (and the butt stop wall) are set to give a minimum of lm clearance above the highest trajectory. Fn the example for a 1000 yard range with the target centre line at 3.1m above the range floor this relates to wall heights rising from 3m at 1000 yards to 8.5m at 500 yards. For this case the slowest credible projectile speed of 2,500 feet per second is used as this is the most conservative.

For a single firing point range, the same approach requires the butt stop wall, and the walls between 500 yards and the targets, to be 11m high. This could be reduced if the target centreline at 300 yards was lowered but such a change will increase the length over which shots from 300 yards will need to be stopped by cross walls to avoid range floor ricochets so it needs to be carefully considered. For this case the maximum credible muzzle velocity of 3,000 feet per second is used as it is the most conservative.

Another way in which the height of the walls can be reduced for a single firing point range is to institute independent sight elevation settings at all ranges. This will have the effect of eliminating the allowance for a sight set on 1000 yards being shot at 300 yards and could reduce the requirement for baffle walls heights to be reduced from 11 m high to 8m. This must be calculated for each case specifically.

9.3.2 Cross Range Baffle Walls

Figure 6 shows the trajectories of bullets with an MV of 3,000 feet per second on a conventional range. These presume effective independent checking of elevation settings before shooting at all firing distances greater than 600 yards. This is an essential requirement for the certification of all NRANZ no danger area ranges and must be included in the Range Standing Orders.

Provided sight checking is carried out the COF will not impact the range floor at any point. However it would be prudent to construct the firing points and install some extra cross walls to ensure low shots fired with unacceptable firer error are also trapped and cannot ricochet off the range floor.

Figure 6 also shows the bottom of the COF for all ranges fired from a single 1000 yards firing point. The slowest muzzle speed is used for conservatism. Cross walls are required from 600 yards on to catch virtually all such shots from all distances. The height and spacing of these walls must be such that the slowest bullet that just clears one wall will not impact the range floor beyond it but will impact the next cross wall. Again, for prudence, extra walls can be installed in the first half of the range to preclude ricochets from shots fired with unacceptable firer error out of the COF.

Figure 7 shows some typical details for cross range walls and for firing points on conventional ranges combined with cross range walls. Walls are also shown that can be used on single firing point ranges where they are out of the COF from all distances and therefore will rarely, if ever, be hit.

Figure 8 shows some typical details for walls that will be hit by properly fired shots on single firing point ranges. Details such as these must be used for such cross walls at least for 600mm each side of the centre line of each lane. Outside that area very few hits should occur and damage to walls can be accepted or patched.

The use of sacrificial timber, sandbags or other protection to cross walls must be combined with regular maintenance. This is not only to maintain the wall protection but also to avoid scoops occurring and inducing ricochets.

Where steel plate is used for bullet stopping it must have a Brinell hardness of 500 and should be 12mm thick where it is regularly hit and 6mm thick where it is at least 600 yards for the firing point and in less often hit areas where it can eventually be replaced if necessary. A typical specification for this plate is AR500 Armour Plate.

AAM Loughnan BE(Civil), FIPENZ(Structural), CPEng, IntPE
6 September 2010

10 REFERENCES:

JSP403 Issue 2 "Handbook of Defence Land Ranges Safety" Volume II, Ministry of Defence (UK)

IRSAG (International Range Safety Advisory Group) Discussional Document No 7/98 "A Study into Small Arms Range Safety" Maj Chris Holland (UK)

Rules for Certification of Rifle Ranges for NRANZ Fullbore Rifle Shooting

Rules for Certification of No Danger Area Rifle Ranges for NRANZ Fullbore Rifle Shooting

Attachments:

Figure 1 - JSP403 Figure 15-1 Gallery Range RDA

Figure 2 - NRANZ Range Danger Area

Figure 3 - NRANZ No Danger Area Range RDA

Figure 4 - NRANZ No Danger Area Range RDA with side baffle walls

Figure 5 - NRANZ No Danger Area Ranges - Minimum heights for side baffle walls and butt stop walls

Figure 6 - NRANZ No Danger Area Ranges — Cross range baffle walls positions

Figure 7 - NRANZ No Danger Area Range — Possible details for cross range baffle walls that are unlikely to be hit

Figure 8 - NRANZ No Danger Area Range — Possible details for cross range baffle walls that are likely to be hit. Bullet catcher detail

Figure 9 - Copy of Figure 11 from IRSAG 7/98 with 7.62mm ball ricochet cross-hatched

Figure 10 - Copy of Figure 12 from IRSAG 7/98 with 7.62mm ball ricochet cross-hatched

Figure 11 - Composite of Figures 11 and 12 from IRSAG 7/98

Figure 12 - Comparison of the NRANZ RDA with the ricochet composite - 800 yards

Figure 13 - Comparison of the NRANZ RDA with the ricochet composite - 900 yards

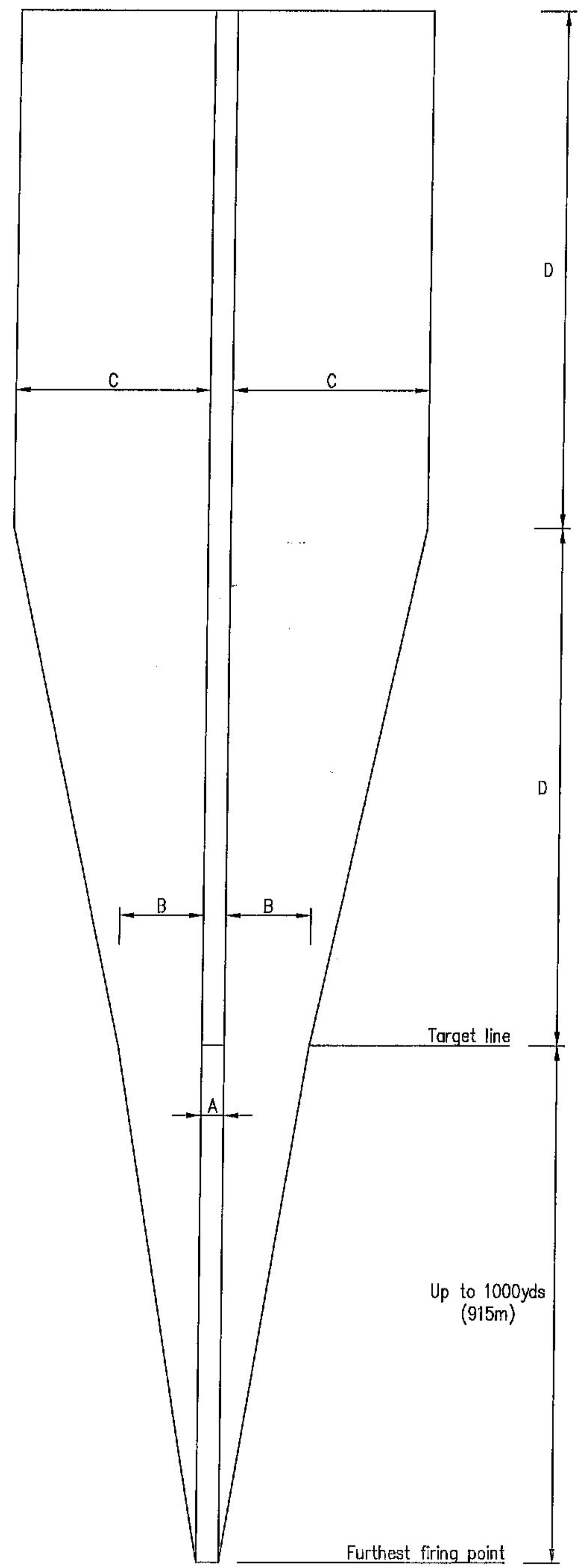
Figure 14 - Comparison of the NRANZ RDA with the ricochet composite - 1000 yards

Figure 15 - Copy of IRSAG Figure 3(b)

Figure 16 - Copy of IRSAG Figure 4(b) with calculated lateral ricochets overlaid

FIGURE 1.

From Fig.15-1
<u>JSP 403 Gallery Range RDA:</u>



A = Width of firing points and targets

B = 150m

C = 350m

D = 915m

Scale 1:10000

FIGURE 2.

NRANZ RDA

A = Width of firing points and targets

B = 90m

C = 200m

D = 600m

For cases where no shooting at less than 300yds(274m) and F Class ME no greater than 4130joules:

B = 75m

C = 160m

D = 450m

Scale 1:10000

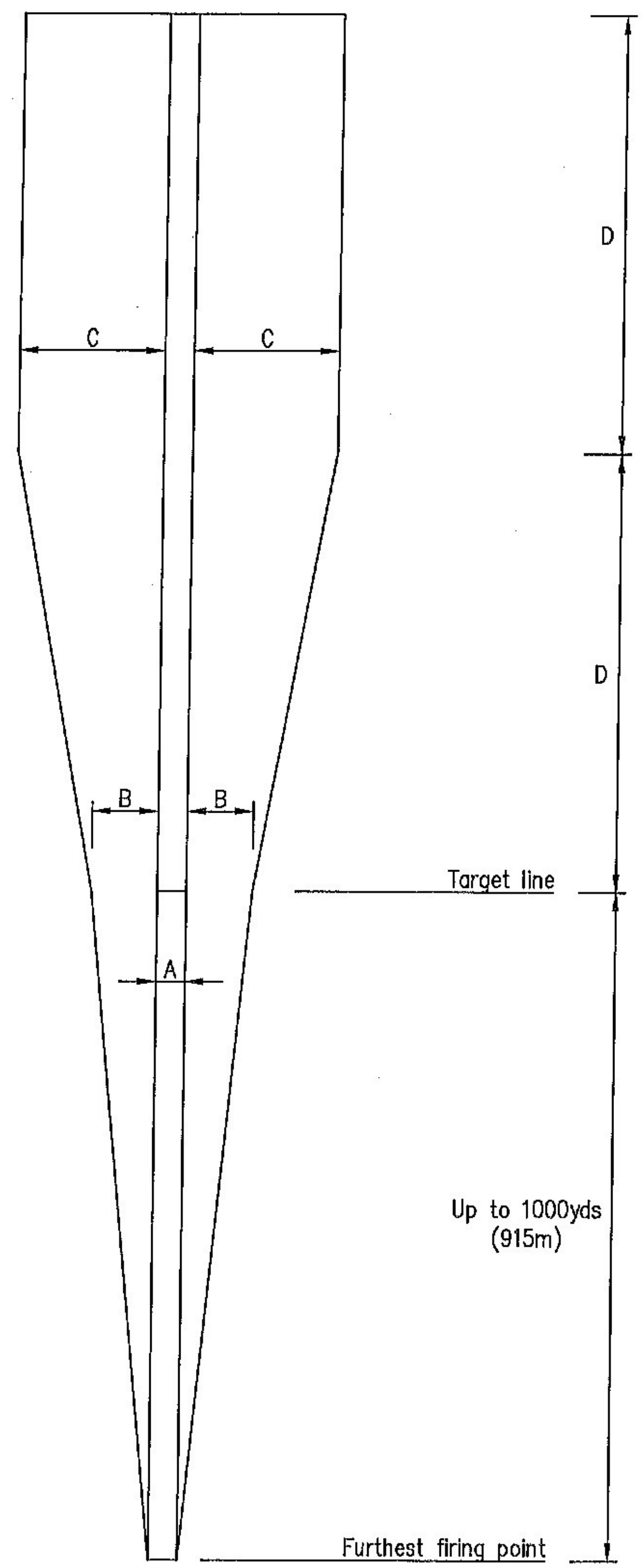
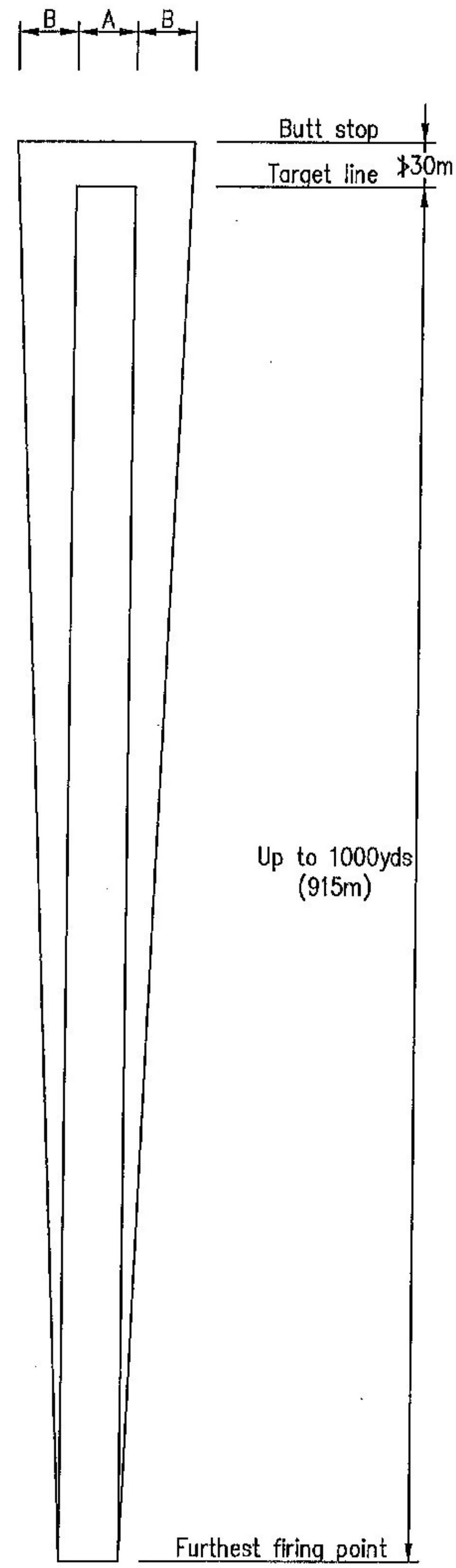


FIGURE 3.

NRANZ RDA FOR NDA RANGES

(Only to be used in strict compliance with the relevant NRANZ rules for the certification of NDA ranges)



A = Width of firing points and targets

Longest firing distance	B
300m	12m
500yds(457m)	20m
600yds(549m)	25m
800yds(732m)	36m
900yds(823m)	42m
1000yds(915m)	48m

Scale 1:5000

FIGURE 4.

NRANZ RDA FOR NDA RANGES

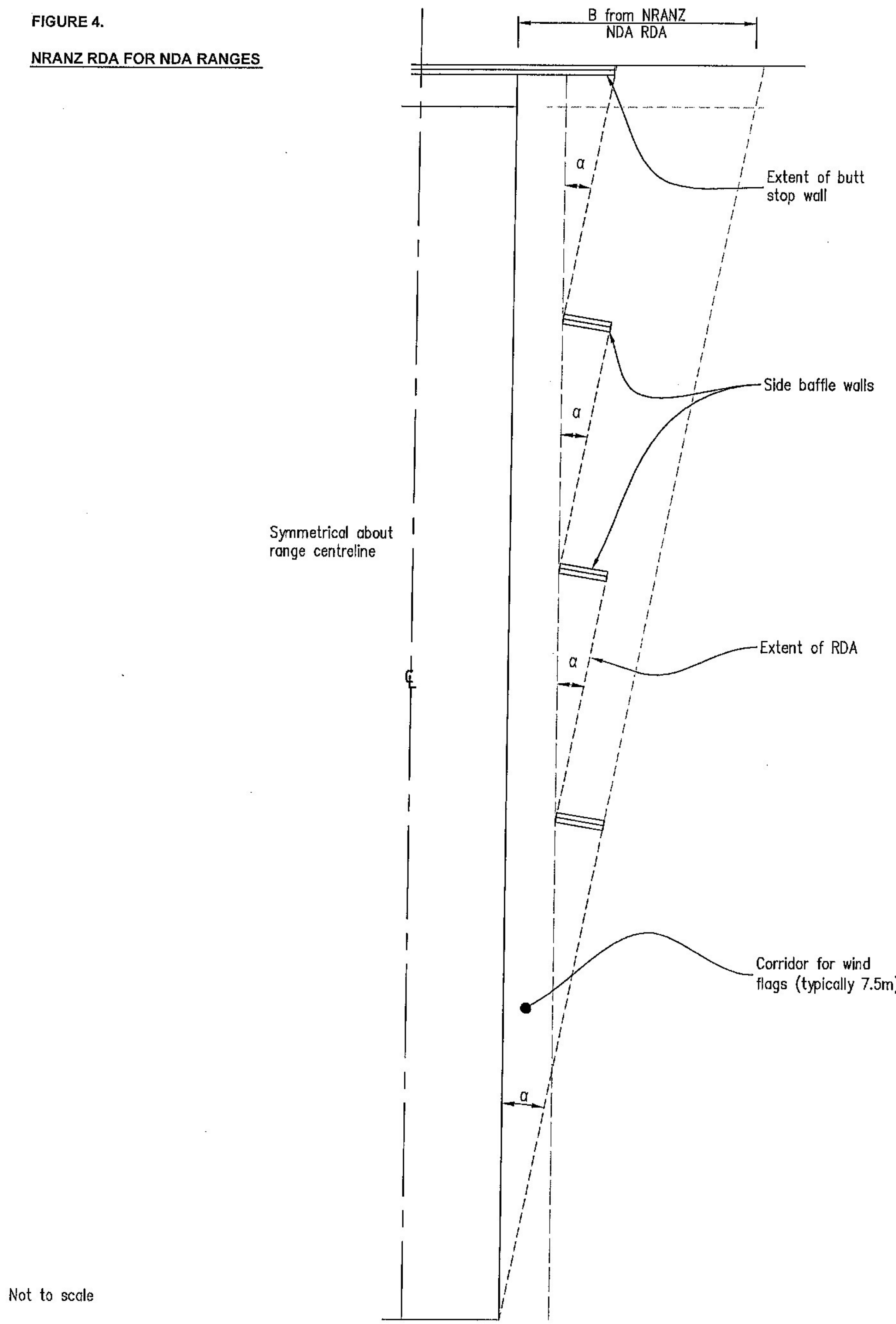
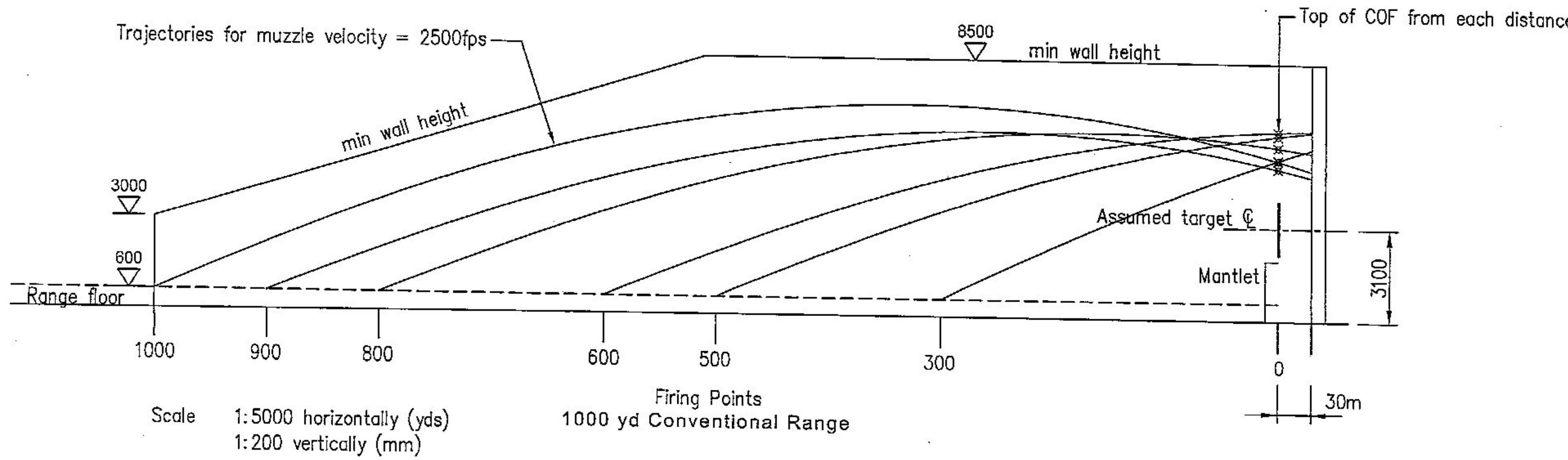
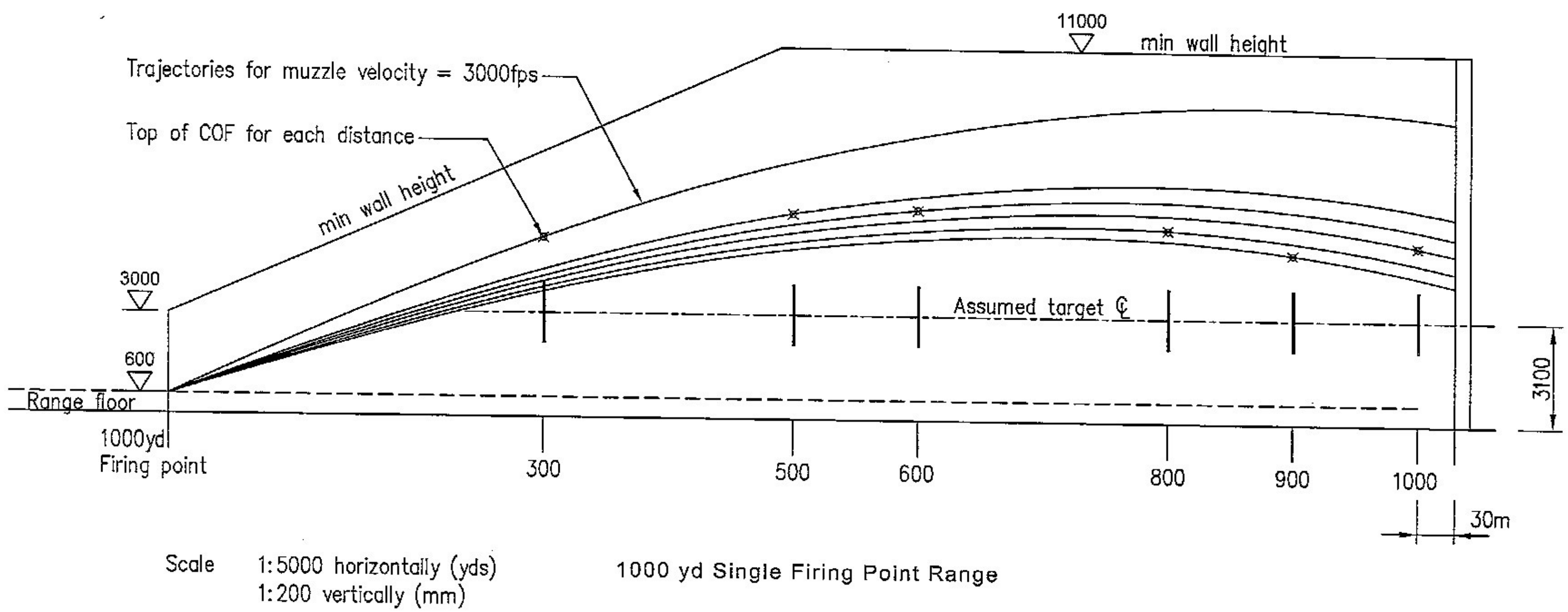


FIGURE 5.

Minimum heights for side baffle walls for NRANZ NO DANGER AREA ranges



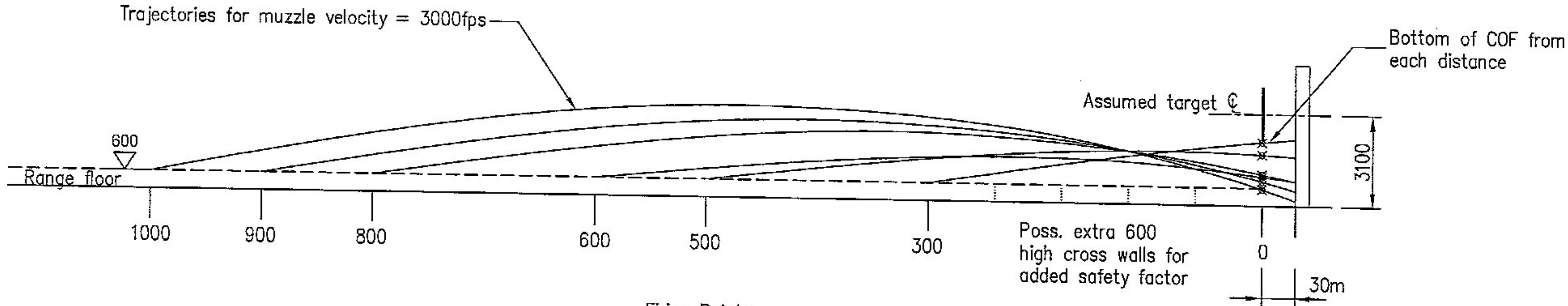
Firing Points
1000 yd Conventional Range



1000 yd Single Firing Point Range

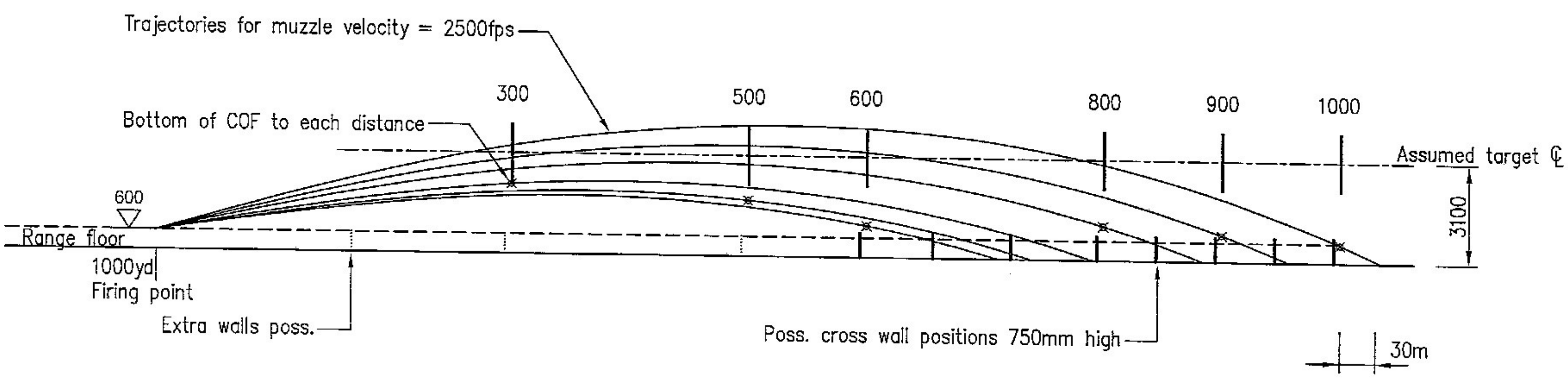
FIGURE 6.

Cross range baffle walls for NRANZ NO DANGER AREA ranges



Scale 1:5000 horizontally (yds)
1:200 vertically (mm)

Firing Points
1000 yd Conventional Range



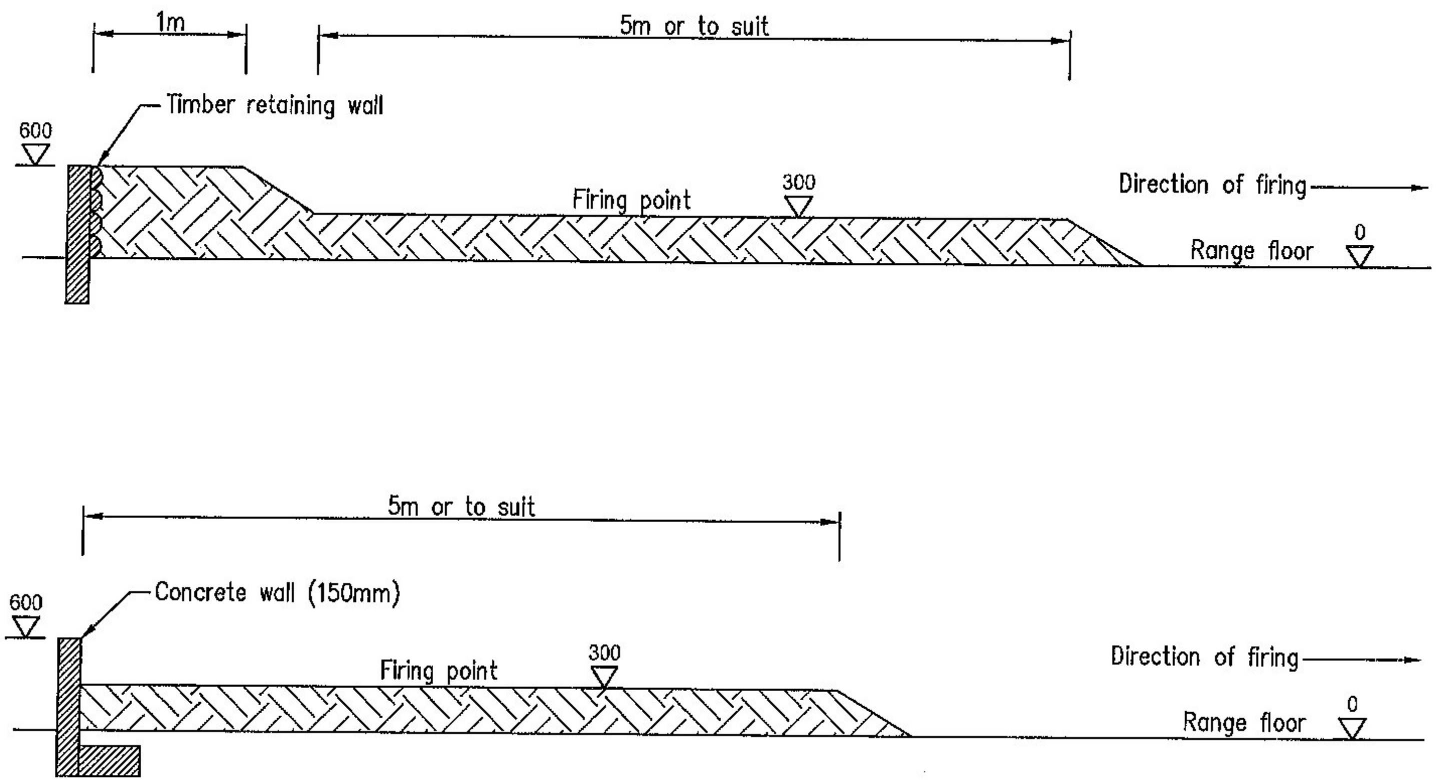
Scale 1:5000 horizontally (yds)
1:200 vertically (mm)

1000 yd Single Firing Point Range

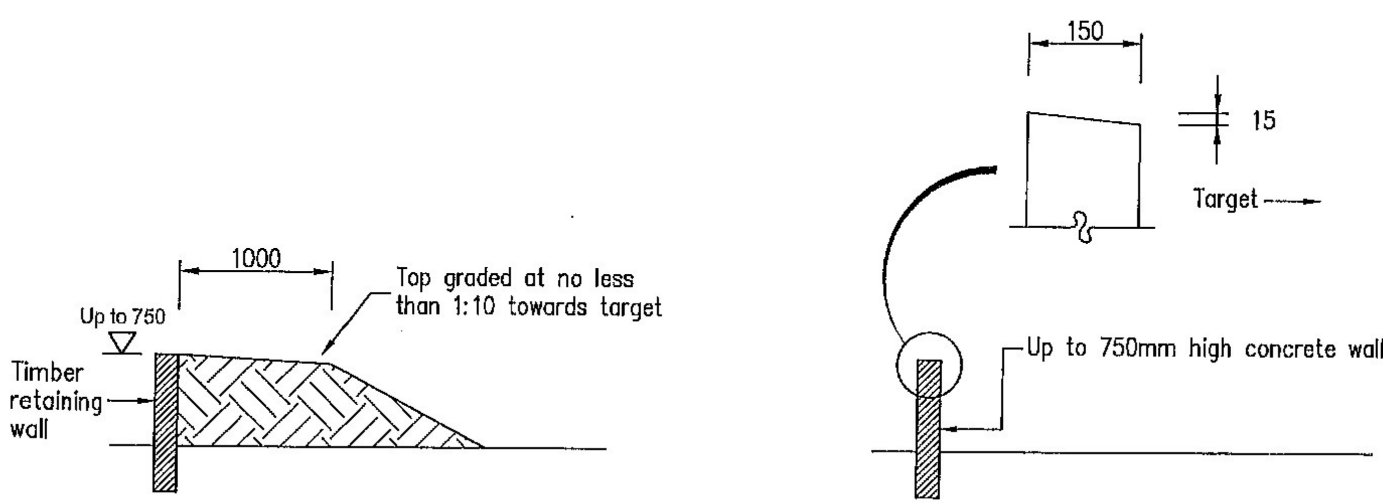
FIGURE 7.

POSSIBLE DETAILS FOR CROSS RANGE WALLS ON NRANZ NO DANGER AREA RANGES -

Walls unlikely to be hit (out of COF).



Typical cross walls/firing points on conventional range

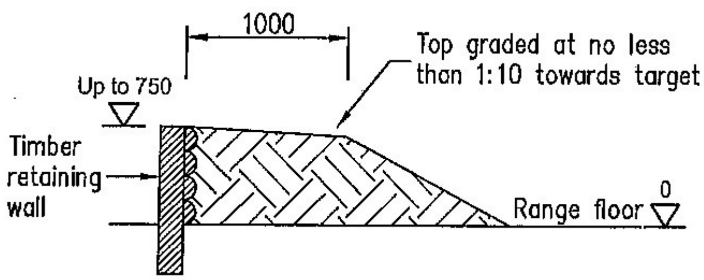


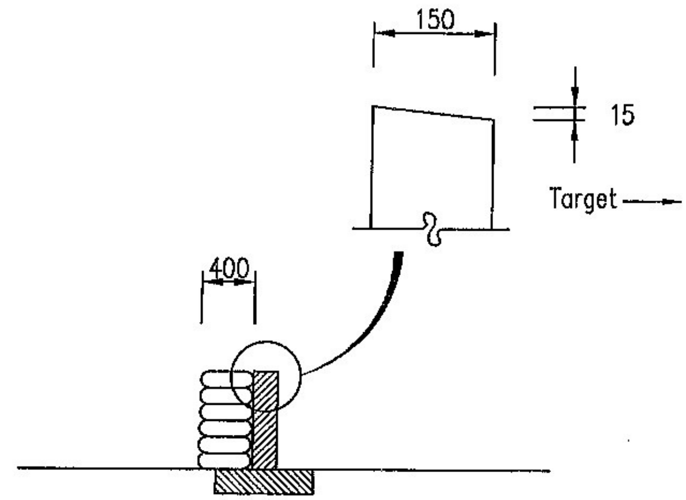
Typical cross wall details (out of COF)

FIGURE 8.

POSSIBLE DETAILS FOR CROSS RANGE WALLS ON NRANZ NO DANGER AREA RANGES -

Walls likely to be hit (within COF from a firing distance but at least 500yds from firing point).





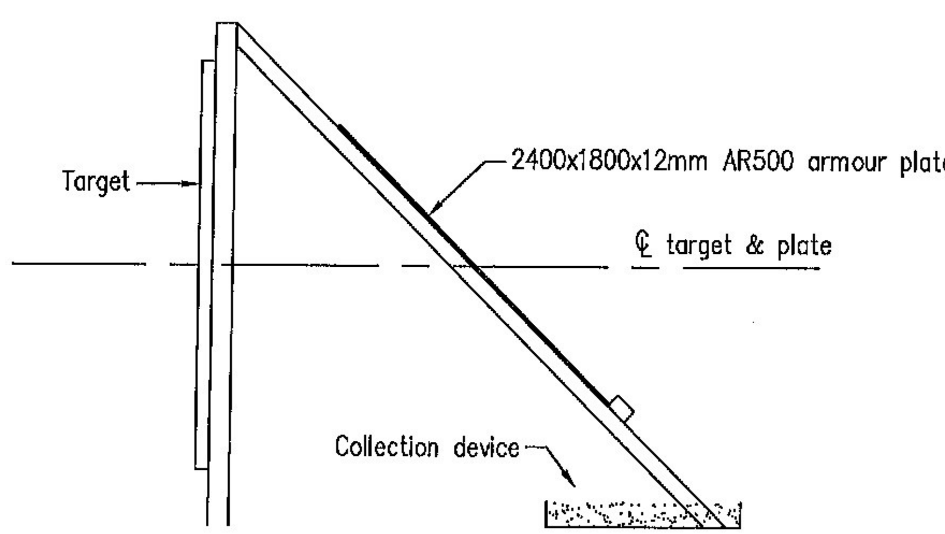
Protection may be placed in front of front of wall 1200mm wide x height of wall (600mm each side of direct line to target from firing point)

Protection options:

- At least 400mm thickness of sand bags (must be continuously maintained)
- 200mm sacrificial timber
- 6mm AR500 steel plate

BUTT STOP WALLS

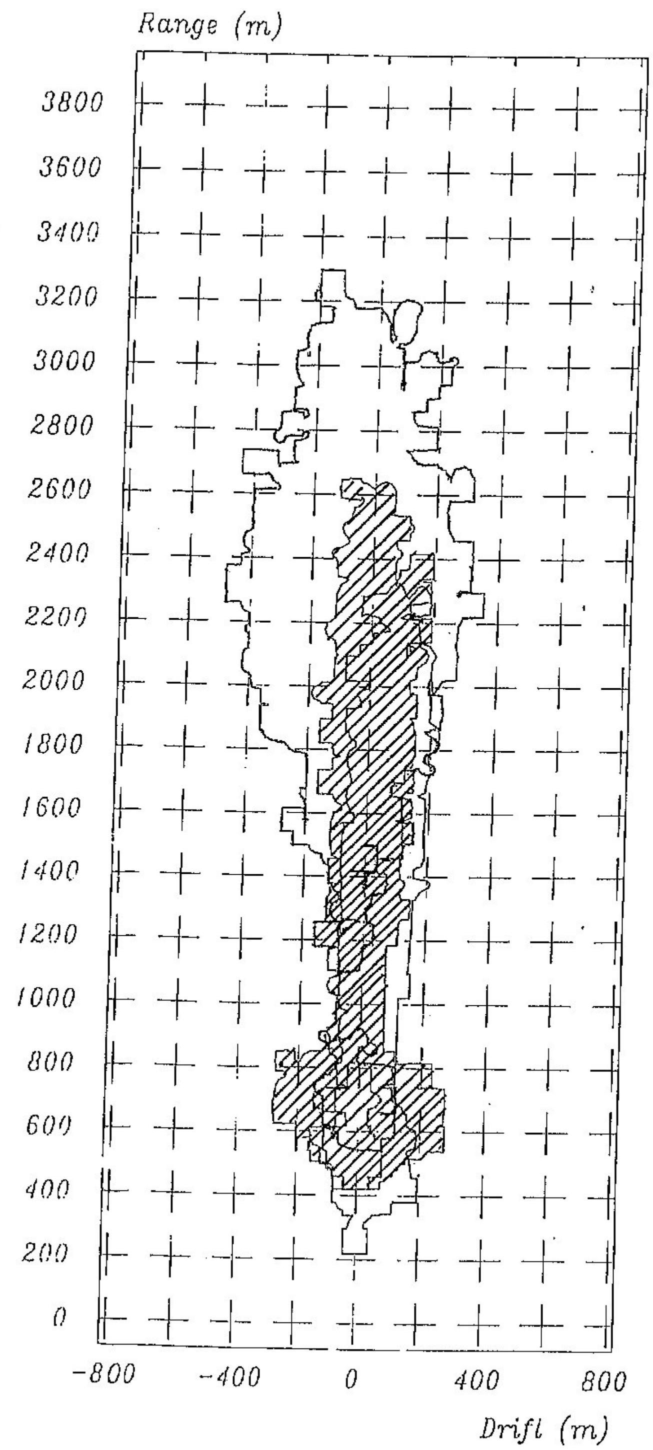
- Single firing point at least 600yds away. Protect as for cross walls.



Conventional range bullet catcher

FIGURE 9

FROM IRSAG 7/98



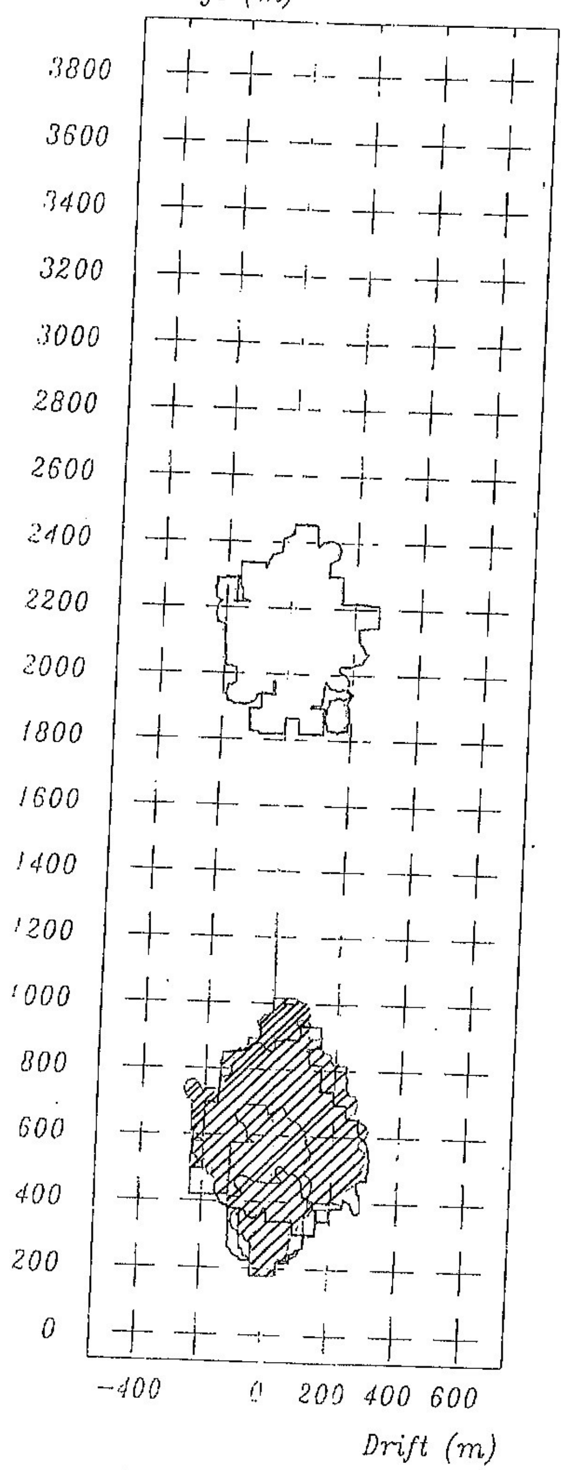
7.62 mm ball cross hatched

'e 11. Ricochet off 3 degree slope: 5.56 mm ball (Red), 5.56 mm tracer (Green), 7.62 mm ball (Light Blue) and 7.62 mm tracer (Dark Blue).

FIGURE 10

FROM IRSAG 7/98

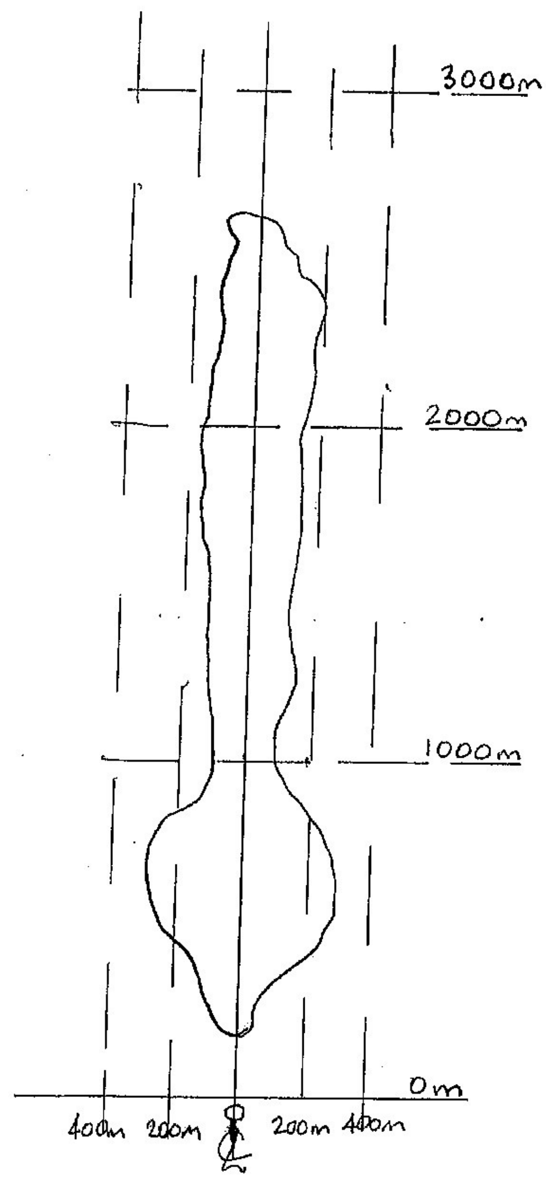
42985



(7.62mm ball cross hatched)

gure 12. Ricochet off 10 degree slope: 5.56 mm ball (Red). 5.56 mm tracer (Green), 7.62 mm ball (Light Blue) and 7.62 mm tracer (Dark Blue).

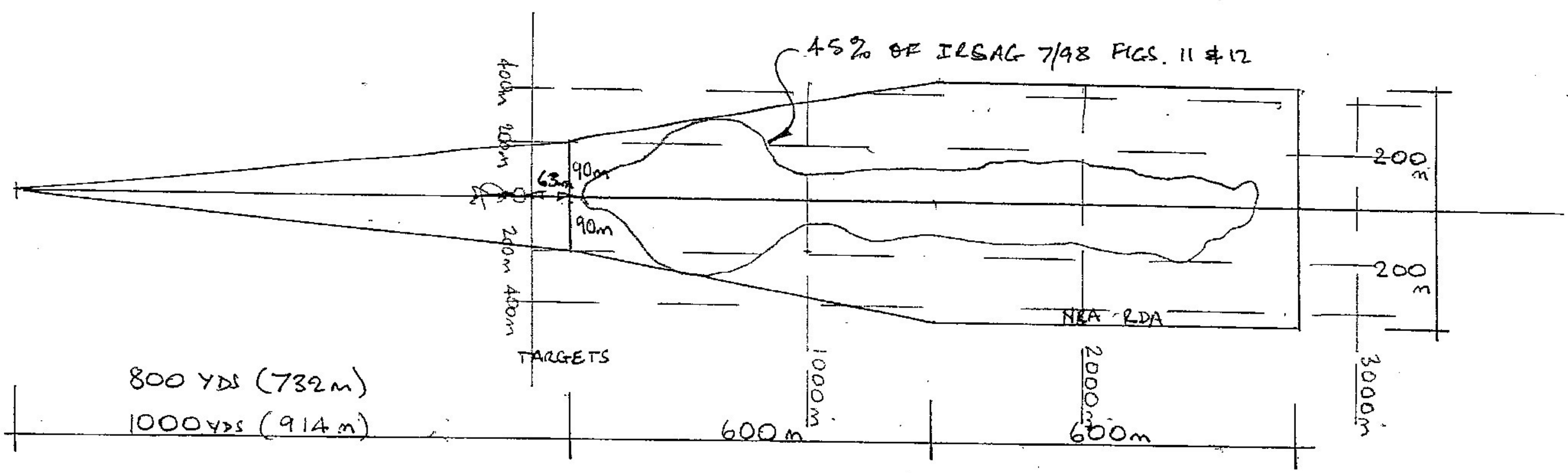
FIGURE 11



RICOCHET OF 7·62MM BALL OFF 3° & 10° SLOPES OVERLAID (FROM IRSAG 7/98)

FIGURE 12

RICOCHET FROM RANGE FLOOR FOR SHOT FIRED FROM 800 YARDS FOR BOTTOM OF NRANZ COF. IMPACT AT 63M IN FRONT OF TARGETS. RESIDUAL ENERGY AT IMPACT 45% OF IRSAG 7/98



NRANZ RDA

FIGURE 13

RICOCHET FROM RANGE FLOOR FOR SHOT FIRED FROM (900 YARDS) FOR BOTTOM OF NRANZ COF. IMPACT AT 112M IN FRONT OF TARGETS. RESIDUAL ENERGY AT IMPACT 42% OF IRSAG 7/98

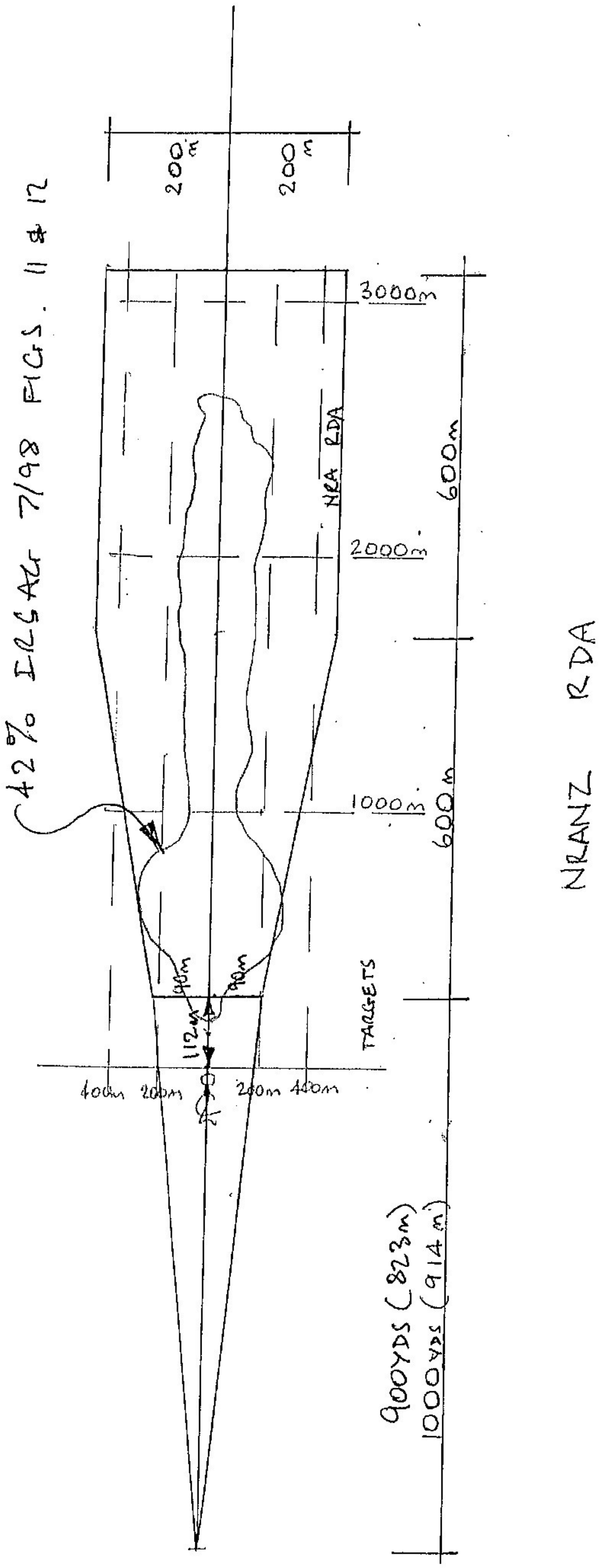


FIGURE 14

RICOCHET FROM RANGE FLOOR FOR SHOT FIRED FROM (1000YDS) FOR BOTTOM OF NRANZ COF IMPACT AT 154m IN FRONT OF TARGETS. RESIDUAL ENERGY AT IMPACT 38% OF IRSAG 7/98

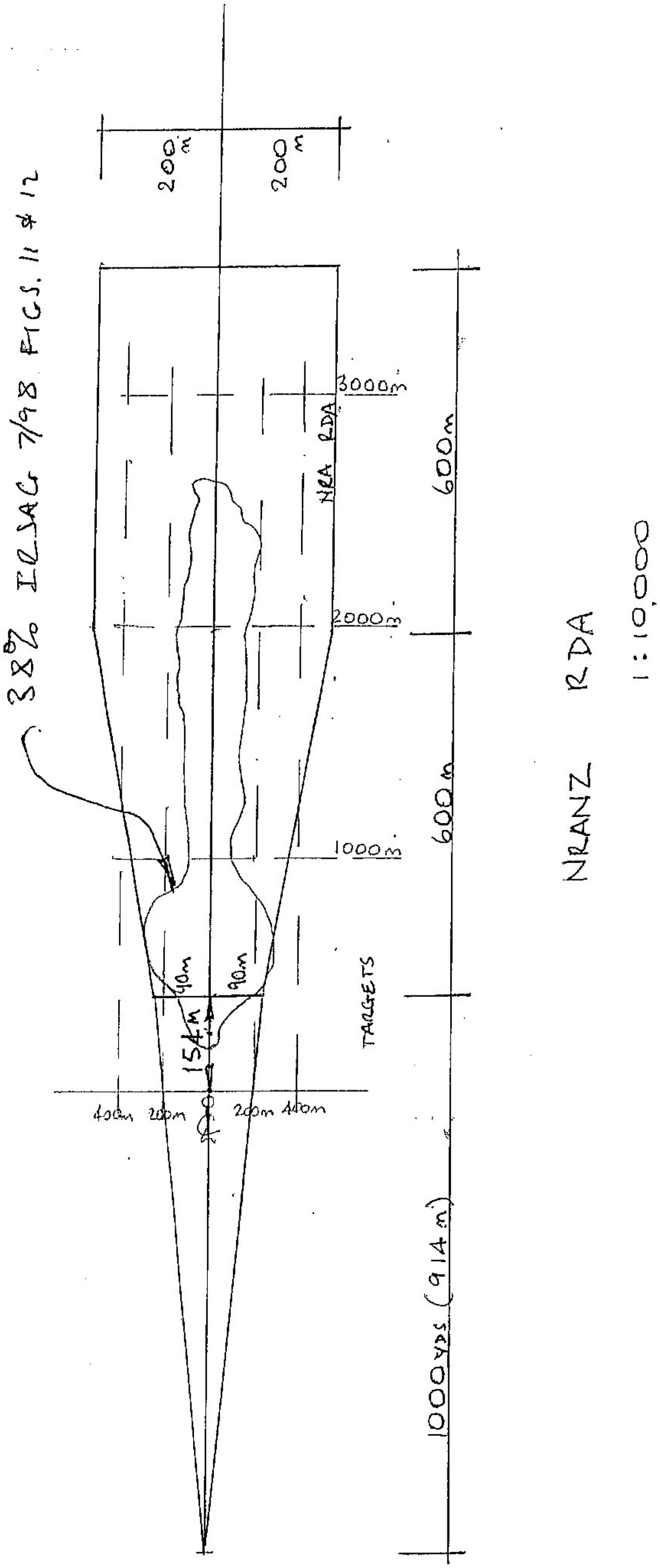


FIGURE 15

FIG. 3(b) IRSAG 7/98

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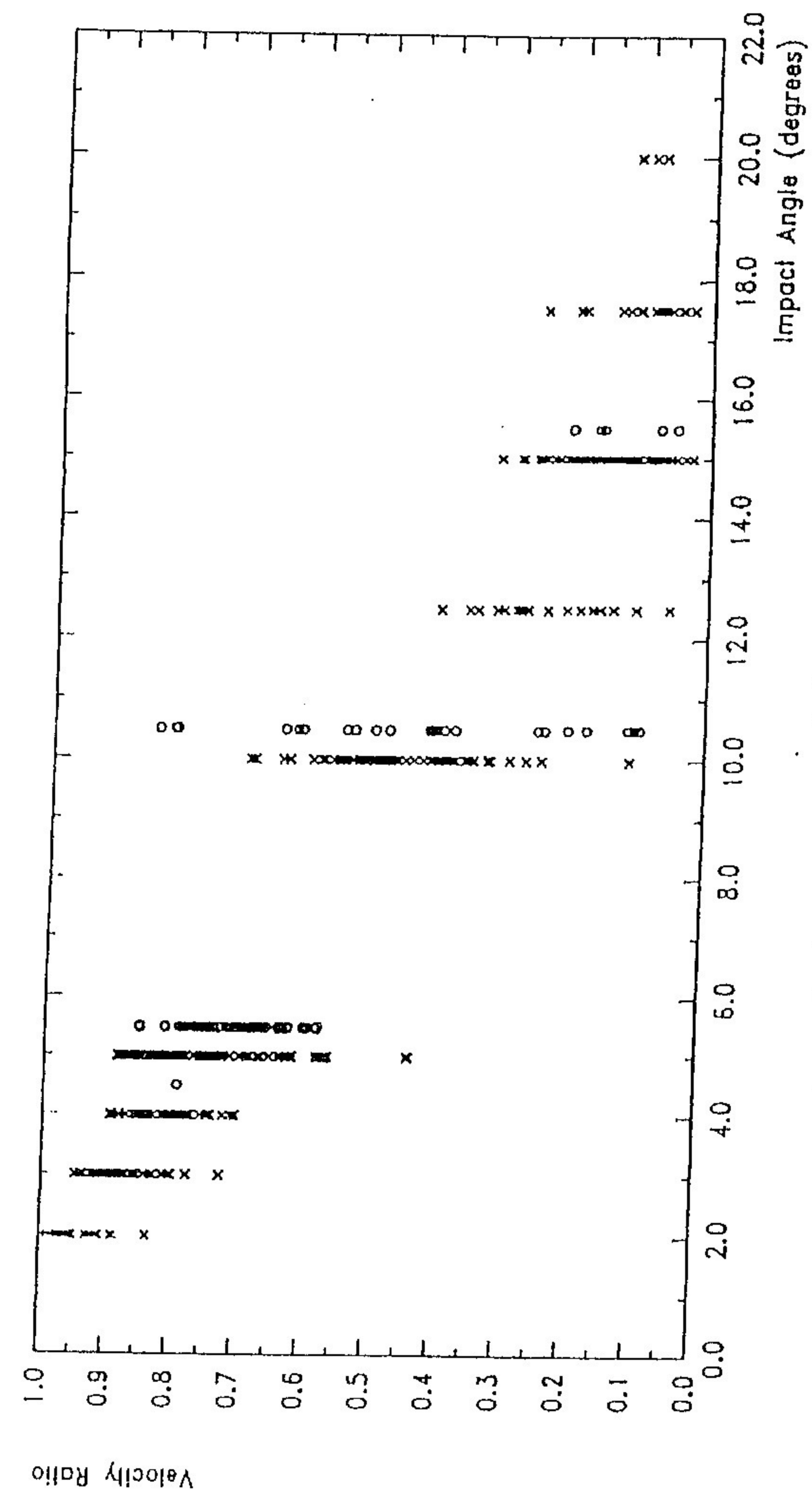


× whole projectile ricochet

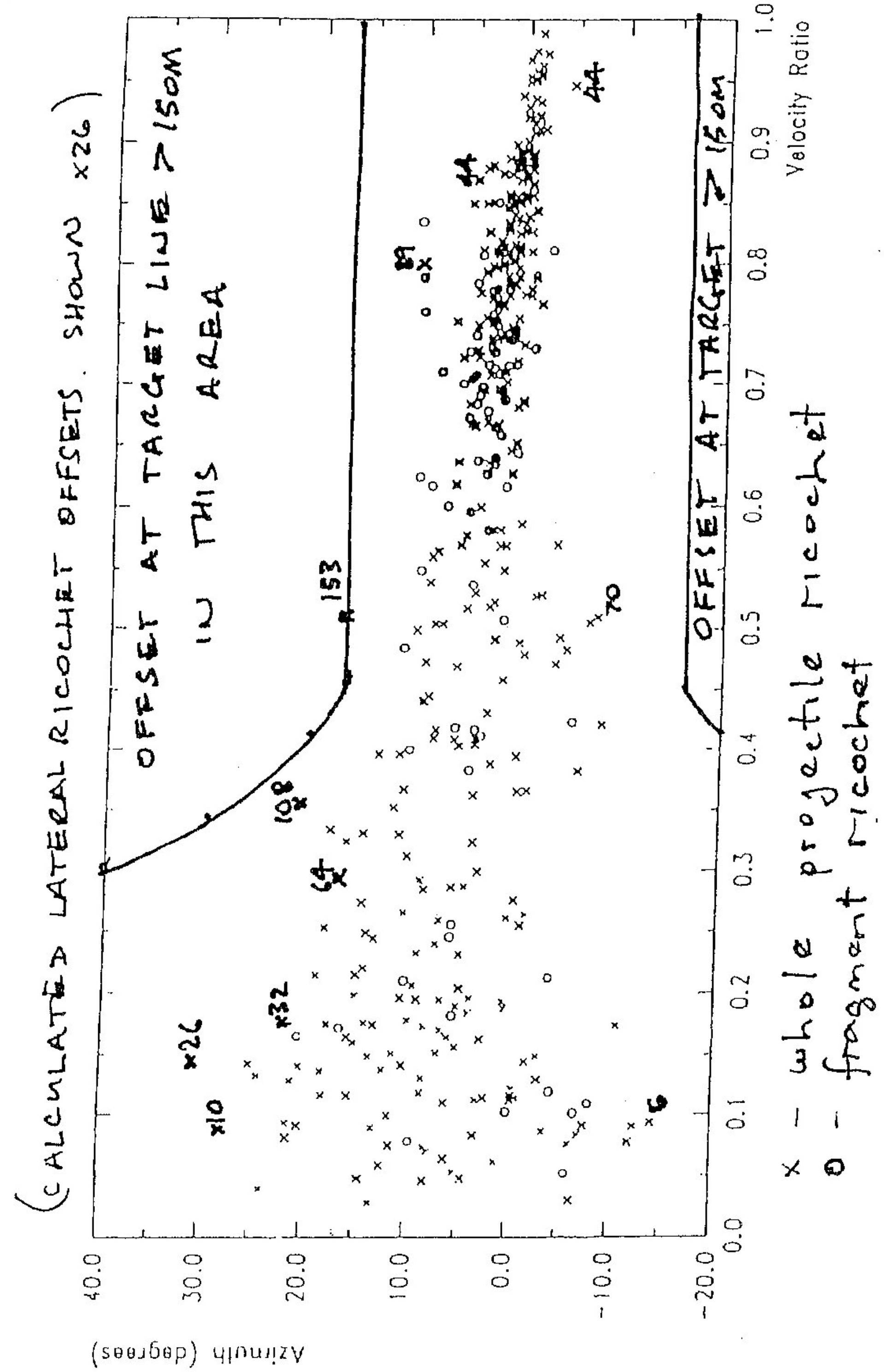
o fragment ricochet

7.62 mm B.II. damp sand at 100 m.

FIGURE 16

FIG. 4 (b) IRSAG 7/98

42985



7.62 mm Ball, dump sand at 100 m.