IMPACT ON AUSTRALIAN DEFENCE ORGANISATION OPERATIONS OF LOCATING THE NATIONAL RADIOACTIVE WASTE REPOSITORY AT SITE 52A WITHIN THE WOOMERA PROHIBITED AREA

AT

WOOMERA, SOUTH AUSTRALIA

Prepared for

Property Services
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Prepared by the following as part of the HLA-Envirosciences Defence Environmental Panel Team

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Executive Summary

Introduction

The Department of Defence (Defence) has prepared this report to provide information to the Department of Education, Science and Training (DEST) formerly the Department of Industry Science and Resources (DISR) and the Environmental Impact Statement (EIS) process regarding the implications for Defence operations at the Woomera Prohibited Area (WPA) if the proposed National Radioactive Waste Repository (NRWR) is located within the WPA at Site 52A. Three sites have been identified as suitable locations for the NRWR, Site 52A DEST's preferred location and Sites 40A and 45A, both located outside the WPA.

The Woomera Prohibited Area

The WPA is an area of land of approximately 127,000 square kilometres (12.7 million hectares). The south-eastern corner of the area is located approximately 450 kilometres north of Adelaide and immediately adjacent to the townships of Woomera and Roxby Downs.

The WPA was created for the testing of space launch and war like materials. The uniqueness of the WPA is in large part due to its remote location and consistent weather. These characteristics mean the WPA can be used for test and evaluation with little or no risk to people and property and in an environment that is devoid of air traffic control restrictions and that is electromagnetically 'clean'. These characteristics make the WPA unique, not only in Australia, but also the world, and it is for these reasons that many foreign countries have either used, or expressed interest in using the WPA for development and evaluation of civil and military aerospace systems.

Within the WPA, Defence has nominated several areas as Defence Practice Areas where weapons practices and test activities may be conducted. The primary practice areas located within the WPA are at Lake Hart, the Woomera Instrumented Range (WIR) and within the WIR the Range E Target Area (RETA).

The WIR is an area approximately 55 kilometres long and 25 kilometres wide orientated in a north-west direction from the Range head at Lake Koolymilka, some 40 kilometres from the Woomera township. Within the WIR there are four main target areas; RETA, the Parakylia Standoff Target Area (PASTA) and Targets A and B. The DEST preferred location for the NRWR site (Site 52A) is located adjacent to RETA target area within the WIR.

Operations in the WPA cover a range of activities including test and evaluation of both military and civilian aerospace systems, training by the Australian Defence Force and overseas forces and in the future, commercial space launch activities.

The test and evaluation of new and existing weapons systems conducted in the WPA has and will continue to include the following:

- Acceptance testing of new systems to confirm performance.
- Concept demonstration of experimental systems under consideration for possible future acquisition.
- Identification and rectification of problems identified with in-service systems.
- Collection of experimental data for the evaluation and enhancement of in-service systems by agencies such as Defence Science Technology Organisation (DSTO).

- Research and development activities using mature and experimental systems by commercial agencies.

Defence has a policy to promote the use of the WPA by commercial organisations and foreign defence forces. Considerable interest has been expressed by a number of commercial organisations for the use of the unique capabilities of the WPA. In particular, strong domestic and international interest has been expressed in the development of the WPA as a centre for commercial space launch activities and in the use of the range for advanced aeronautical research activities.

Safety Templates

To mitigate the risks associated with the weapon release activities conducted at Woomera, Defence has applied an acceptable risk factor per test (i.e. per drop) of 1×10^{-6}. This risk factor is then used to determine safety templates that provide the bounds of a danger area for the different hazards associated with the conduct of aerospace vehicle testing, trials and training including weapons launch, release and impact activities. Safety templates are used to describe a ground area in which personnel and equipment are in danger of injury or damage due to the impact, fragmentation or ricochet of a functioning military or commercial aerospace system.

Based on the use of a safety template for a relatively low capability weapon system, the proximity of the proposed Site 52A will place the NRWR well within the danger area for a significant proportion of existing weapons that Defence will be required to test at the WIR. The proximity of the Range E Target Area (RETA) to the proposed NRWR means that safety templates for the majority of weapons employed at this target area will overlay the NRWR. It is probable that the application of even the smallest safety template will preclude operations at this target.

Defence is in the process of procuring systems with medium range Stand off Weapon (SOW) capabilities as well as a new class of Stand Off Weapon designated Long Range SOW (LRSOW). These weapons will have range capabilities in the order of several hundred kilometres and will require extremely large safety templates and innovative operating protocols to accommodate their associated testing. The testing required to confirm the correct functionality of these systems, in particular the terminal phase of operation of the weapon, often requires analysis using data obtained from the WIR instrumentation systems. The location of the proposed NRWR at Site 52A will place the repository within safety templates for these weapons.

The proposed design for the NRWR comprises an outer area of 1.5 km by 1.5 km with the actual repository located within a 100 m by 100 m area positioned centrally within the larger set aside area. It is proposed that the repository will be constructed to a maximum depth of 15-20 m below ground level. The waste will be placed in trenches and be contained within steel or concrete drums. A layer of 2.0-5.0 m, comprising material suitable to control surface water ingress to the waste, will cap the repository.

Based on the proposed repository design and the type of weapons tested at the WPA, approximately 70% of the weapons released have the potential to penetrate the repository resulting in a release of radioactive material from the repository.

Risk Assessment

An assessment of the risks associated with locating the NRWR at Site 52A was undertaken which showed that Site 52A falls within contours for the probability of impact greater than 1×10^{-6} per test for several of the weapons likely to be tested at the WIR. A review of Aircraft Research and Development Unit (ARDU) tests conducted in past 10 years indicates that over 600 weapons have been released at the WPA by Defence alone. Future bookings of the range and the WPA programme indicate that a considerable number of weapons tests will be conducted and more commercial users will take advantage of the facilities at the range. ARDU has booked three weapons testing periods of one month each in each of the next three years.

Based on previous test programmes, it has been conservatively assumed that there would be a requirement for up to 60 weapons tests per annum over the next three years, and that each of these tests would require a template that impinges on the Site 52A location for the NRWR. Hence, the potential risk of impact on the NRWR would be 60 p.a. x $1x10^{-6}$ = $6.0x10^{-5}$p.a., during this period. The potential release frequency of radioactive materials would be 0.7 (the fraction of weapons that may breach the NRWR) x $6x10^{-5}$ p.a. = $4.2x10^{-5}$ p.a.

Industry published criteria states that the risk of an undesired outcome (e.g. fatality, catastrophic environmental impact, catastrophic plant/equipment damage, national media/public impact, etc.) is unacceptable at a frequency exceeding $1x10^{-5}$ per annum. As the release of radioactive material could be classified as a catastrophic environmental event (particularly from the public and media angle), and as the frequency of such an incident has been calculated to be $4.2x10^{-5}$ per annum for Site 52A, this risk is unacceptable by industry standards. In addition, ARDU has indicated that a weapon impact on the NRWR as a result of testing at the WIR would be classified as a “Disastrous” incident using the RAAF Aviation Risk Management (AVRM), as it would incite wide spread public condemnation of the ADF. Under the CAF Directive 02/01, ARDU has indicated that any operation resulting in a consequence classification of “Disastrous” would not be undertaken. Defence considers that such an incident could potentially result in the permanent closure of the WPA.

If the decision was made to locate the NRWR at Site 52A and keep the range facilities in situ, it would be necessary to ensure safety templates for weapons released on the range did not infringe the NRWR. The only way this could occur would be to ensure high performance, long range and experimental weapons systems were not employed on the range. Such a decision would compromise Defence’s ability to test and operate such weapons and would have significant implications for Australia’s weapons T&E and training capabilities.

Alternatively, the existing infrastructure at the WIR would need to relocated if a suitable alternative location could be identified. Defence has previously completed an analysis of the likely costs to relocate WIR infrastructure and concluded that expenses in the order of $ A180 million could be expected. In addition, a significant non-effective operating time for the range during this relocation process would occur, combined with the requirement to re-establish, calibrate and validate the instrumentation systems from the WIR would also be a major activity which would severely impact ARDU’s ability to support programmed Defence test and evaluation activities.

Conclusions

The review conducted for Defence on the implications of locating the NRWR at Site 52A has identified the following major concerns:

- The experimental nature of the materiel tested at the WPA generates higher than normal levels of risk of failure.
- The current and future expected operations on the WIR would expose the NRWR if located at Site 52A and the WIR to risk levels that exceed the requirements of the ADF’s Aviation Risk Management Policy.
- The level of risk associated with aerospace test and evaluation and training activities conducted at the WPA is incompatible with location of the NRWR at Site 52A.

- Defence's main concern has been and remains the negative publicity that would result from a weapon impact on the range and the fact that such publicity could ultimately result in range closure and consequent significant loss to the Commonwealth's defence capability.
- The level of security currently available at the proposed Site 52A is unlikely to provide sufficient protection from outside intrusion, and is likely to require significant upgrade.
- Of the three technically acceptable sites for the NRWR selected by DEST, Sites 40A and 45A do not impact Defence operations at the WPA that require the use of the WIR. Both sites are described as highly suitable by DEST.
- Selection of Site 40A or Site 45A may require greater expenditure than that required for Site 52A, however, this is likely to be extremely small in comparison to the whole of government cost of relocating the range facilities in order for the Commonwealth to retain the existing weapons T&E and training capability provided by the WPA.
- In order to comply with the As Low As Reasonably Practical (ALARP) and As Low As Reasonably Achievable (ALARA) principles stated in the various published risk criteria, one of the two alternative sites not impacted by the operation of the WIR/WPA should be selected.

Recommendations

It is recommended with respect to the proposal to locate the NRWR at Site 52A in the WPA that:

- Site 52A should be removed from consideration for the NRWR.
- Based on the results of an environmental impact study, one of the identified alternative sites should be selected as the preferred location for the NRWR.

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1.0 INTRODUCTION

1.1 Background

The Department of Defence (Defence) has prepared this report to provide information to the Department of Education, Science and Training (DEST) formerly the Department of Industry Science and Resources (DISR) and the Environmental Impact Statement (EIS) process regarding the implications for Defence operations at the Woomera Prohibited Area (WPA) if the proposed National Radioactive Waste Repository (NRWR) is located within the WPA at Site 52A, DEST's currently preferred location. Defence wishes to ensure that the current EIS process takes into account the nature of activities undertaken by Defence within the WPA which include the release of bombs and other air to ground and air to air weapons in close proximity to Site 52A. Locating the NRWR within the WPA is seen as a significant land use conflict by Defence and will result in restrictions to ongoing activities at the site and could result in the closure of the Woomera Instrumented Range (WIR) site based on current regulatory guidelines. The information presented in this report will demonstrate the significant issues associated with the co-location of these two conflicting land uses and will demonstrate the substantial economic impact on Defence and the Woomera township if the NRWR is located at Site 52A.

The report specifically addresses the implications of the selection of an NRWR location for the following:

Existing military operations at the WPA.

Future military usage of the WPA.

Risks applicable to the NRWR due to WPA activities.

Discussion of the implications for commercial space launch activities and the potential costs associated with a decision to locate the NRWR at Site 52A are presented for completeness but should not be considered comprehensive.

1.2 Background to the EIS

Australia has accumulated over 3,500 cubic metres of low level radioactive waste as a result of operations involving radioactive materials and this material is stored temporarily at over 50 sites around Australia. The process of finding an appropriate site to locate the NRWR to store this low level radioactive material commenced in 1992. A series of studies and investigations have occurred since that time and in 1997 the preferred region for the location of the repository, based on specified site selection criteria, was narrowed down to the central-north of South Australia. In January, 2001 a preferred site and two alternative sites were identified as potential locations for the NRWR. Site 52A (within the WPA) was selected as the preferred location and two alternative sites, Site 45A and Site 40A, east of the Woomera to Roxby Downs road were also identified as suitable locations. The location of the WPA and Sites 52A, 45A and 40A are illustrated in Figure 1.1.

Defence has provided a range of submissions to DEST during this process, including both general and site specific advice in relation to the location of the NRWR within the Woomera area. Responses include correspondence to Mr Jeff Harris, DISR in October, 1999; March, 2000; July, 2000 and November, 2000.

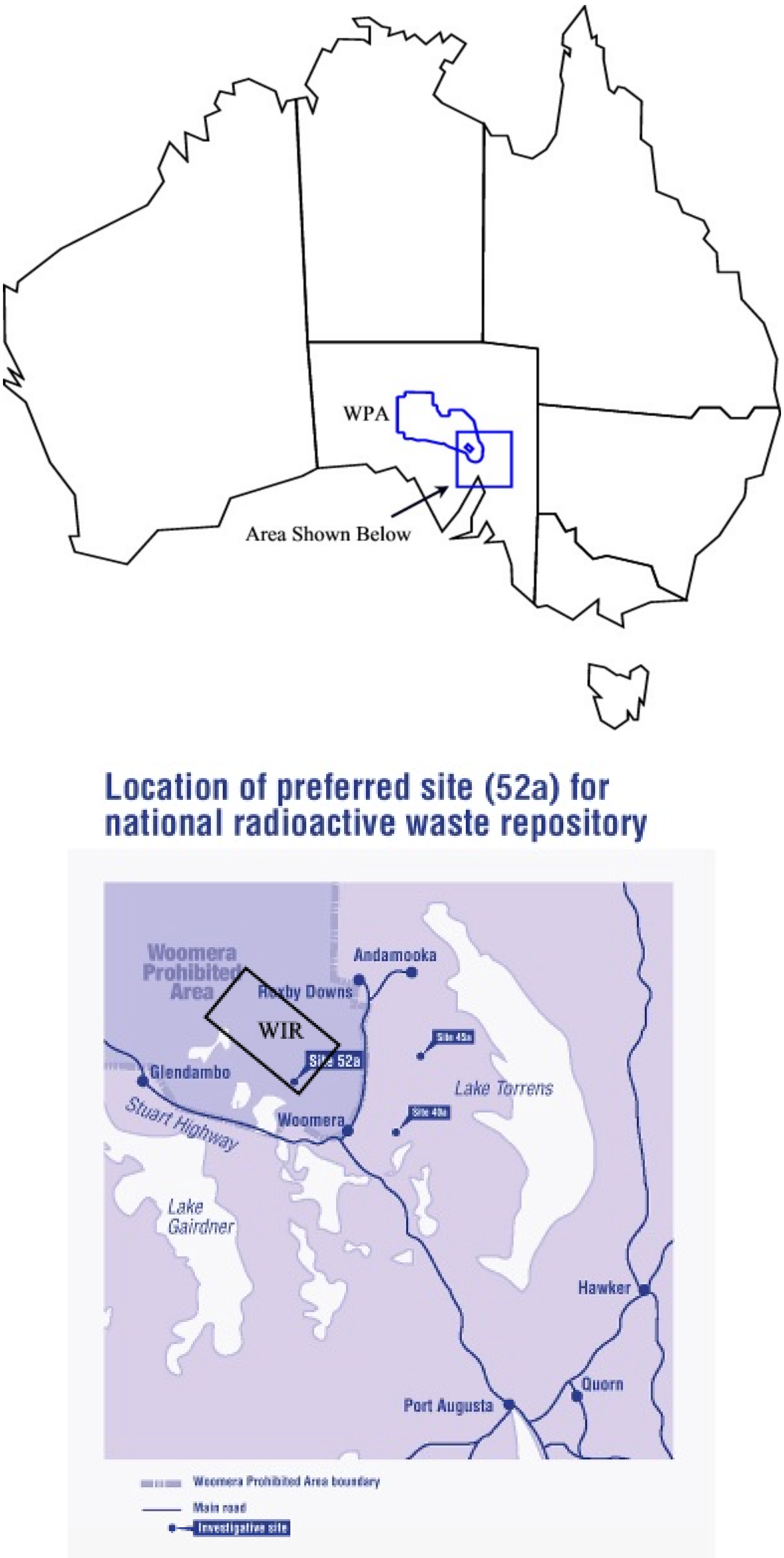

Figure 1.1 – Woomera Prohibited Area

1.3 The EIS Process

An environmental assessment is now being undertaken to determine the suitability of the three proposed locations. The EIS process is part of the requirements of the Commonwealth Environment Protection and Biodiversity Conservation Act (1999). The EIS process is required to consider amongst other things the need for the repository, transportation of waste to the repository, impacts and risks to the natural and human environments and environmental safeguards to minimise these impacts and risks.

A draft EIS is currently being prepared and it is anticipated that it will be released for public comment in early 2002. A supplementary EIS will be prepared in response to public comment. Following a final decision on the location of the site, three licences must be obtained from ARPANSA for the siting, construction and operation of the facility.

2.0 THE WOOMERA PROHIBITED AREA

2.1 Background

The WPA is an area of land of approximately 127,000 square kilometres (12.7 million hectares). The south-eastern corner of the area is located approximately 450 kilometres north of Adelaide and immediately adjacent to the townships of Woomera and Roxby Downs. Figure 1.1 shows the dimensions of the WPA and the relative locations of the nearby townships as well as the location of the NRWR sites under consideration (sites 40A, 45A and 52A).

The WPA has been set aside for the testing of war materials under Defence Force Regulation 35. The majority of the WPA is state owned land, about half of which is leased to pastoralist or mining companies. Portions of the WPA are also designated lands of the Maralinga Tjarutja Aboriginals.

The WPA and its associated weapons test ranges were initially developed in the late 1940's for the test of guided weapons and other rocket powered vehicles. The vehicles were launched in a westerly direction from sites near the range head which is located adjacent to the Evetts Field aerodrome approximately 40 kilometres North-West of the town of Woomera.

2.2 Range Areas

Within the WPA Defence has nominated several areas as Defence Practice Areas where weapons practices and test activities may be conducted. These areas provide an environment in which the flight dynamics and other physical properties of aircraft and weapons systems can be assessed. Large numbers of air to ground and air to air weapons have been tested at these facilities. The primary practice areas located within the WPA are at Lake Hart, the Woomera Instrumented Range (WIR) and within the WIR the Range E Target Area (RETA).

The WIR is an area approximately 55 kilometres long and 25 kilometres wide orientated in a north-west direction from the Range head at Lake Koolymilka, some 40 kilometres from the Woomera township. Within the WIR there are four main target areas; RETA, the Parakylia Standoff Target Area (PASTA) and Targets A and B. Figure 2.1 shows the relative locations of Targets A and B and the RETA within the WIR and Site 52A.

2.3 WIR Infrastructure

The WPA and, in particular the WIR, have an extensive suite of facilities and equipment for the conduct, control and reporting of weapons testing and rocket launch activities. The facilities currently in service include communications, telemetry and tracking infrastructure incorporating surveyed instrumentation and tracking equipment emplacements, launch sites and rocket preparation and recovery facilities. The range has the capability to track, via radar and optical means, a wide variety of aircraft and aerospace systems including weapons in free flight and rockets. The instrumentation is also used to assess weapon performance including impact scoring and miss distance measurement.

Key components of the WPA infrastructure include the main instrumentation building and associated structures and workshops, two radar sites, several prepared and accurately surveyed kinetheodolite sites, rocket launch emplacements, microwave repeater masts and several explosive preparation and test workshops. Defence has previously compiled information on the costs associated with the replacement of these facilities should it become necessary to move the WIR. A discussion of these costs and the viability of moving the WIR is contained in section 7 of this report. A diagram detailing the relative locations of these facilities is provided at Figure 2.1.

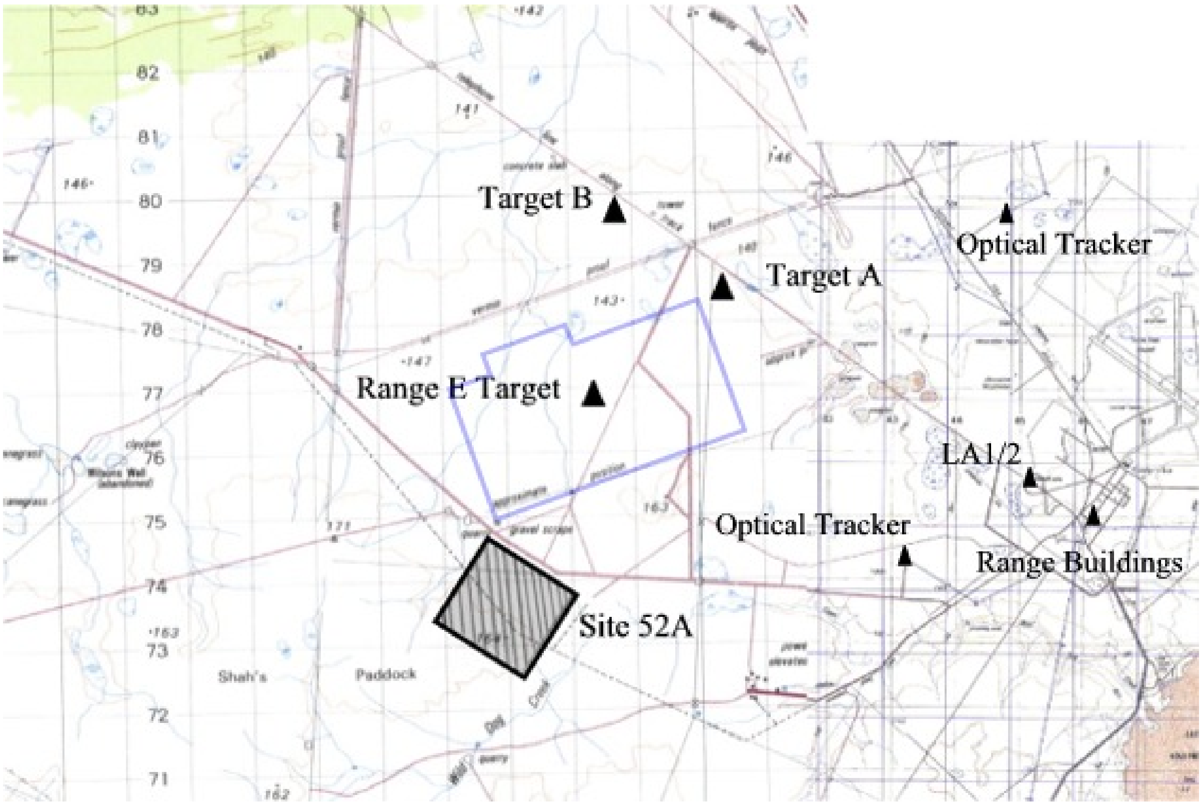

Figure 2.1 – WIR Infrastructure

2.4 Operational Control of the WPA and WIR

Defence Instruction (General) ADMIN 38-1 details the management responsibilities for the WPA. The Area Administrator Woomera (AAW) who is the head of the Defence Support Centre Woomera (DSCW) is responsible for the operational and administrative management of the WPA. Users of the WPA are required to adhere to the regulations applicable to the area and work in consultation with Defence who in turn co-ordinate with other Defence and commercial users of the area.

2.5 Unique Characteristics of the WPA

The WPA was created for the testing of space launch and war like materials. The uniqueness of the WPA is in large part due to its remote location and consistent weather. These characteristics mean the WPA can be used for test and evaluation with little or no risk to people and property and in an environment that is devoid of air traffic control restrictions and that is electromagnetically 'clean'[1]. These characteristics make the WPA unique, not only in Australia, but also the world, and it is for these reasons that many foreign countries have either used, or expressed interest in using the WPA for development and evaluation of civil and military aerospace systems.

[1] Low electromagnetic activity is frequently important for the testing of navigation and communication systems and the operation of Flight Termination Systems associated with aerospace weapons systems.

Instrumentation has been positioned at the WIR to take maximum advantage of these features for the purpose of testing complex weapon systems. Radars have been located to provide highly accurate coverage of a wide expanse of airspace and optical tracking devices are able to be positioned at various points on the WIR to provide extremely accurate tracking and recording of weapon system behaviour in free flight.[2]

The facility is also located in relatively close proximity to the Woomera Township which provides domestic and commercial support for the activities at the range. The township is used for the domestic accommodation of range personnel and as a convenient nearby airfield for test aircraft to operate from.

[2] Optical tracking methods provide the best source of high accuracy weapons free flight behavioural and trajectory information.

3.0 OPERATIONS AT THE WPA

3.1 General

Operations in the WPA cover a range of activities including test and evaluation of both military and civilian aerospace systems, training by the Australian Defence Force and overseas forces and, in the future, commercial space launch activities.

3.2 Test and Evaluation of Aerospace Systems.

The test and evaluation of new and existing weapons systems conducted in the WPA has and will continue to include the following:

- Acceptance testing of new systems to confirm performance.
- Concept demonstration of experimental systems under consideration for possible future acquisition.
- Identification and rectification of problems identified with in-service systems.
- Collection of experimental data for the evaluation and enhancement of in-service systems by agencies such as Defence Science Technology Organisation (DSTO).
- Research and development activities using mature and experimental systems by commercial agencies.

These activities encompass the entire spectrum of aerospace weapon systems. They include the testing of ballistic free fall weapons such as 500 and 2000 lb general purpose bombs, precision guided bombs such as the Paveway II and III Laser guided 500 and 2000 lb bombs, air-to-air missiles including the AIM-7 Sparrow and AIM-9 Sidewinder missiles, air-to-ground missiles including the CRV-7 unguided missile and the AGM-142 3000 lb stand off weapon and ground to air missiles such as the Rapier Air Defence missile. There have also been numerous atmospheric and space research vehicles and high speed aerodynamic test vehicles launched from the various launch areas at the WPA. In the past 10 years, in excess of 600 weapons have been released at the WPA by Defence alone.

It is well accepted that the early test iterations of complex weapon systems are likely to experience higher failure rates than for similar mature in-service systems. Aircraft Research and Development Unit's (ARDU) experience with the test and evaluation of aerospace systems over the past 50 years confirms this axiom.[3]

Significant effort is employed to analyse and assess the likely behaviour and risks associated with the test and evaluation of experimental weapons systems. However, the possibility of an unexpected occurrence is extremely difficult to preclude and problematic to quantify for such experimental test activities. The risks and implications of such failure rates for operations at the WPA are further discussed in more detail later in this paper.

The failures usually encountered during the operation of these systems can be broadly divided into three categories; Launch or Release Failures, Guidance and Control System Failures and Functional Failures.

[3] Meeting-Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / T Bearman Nova - 21 Nov 01

Launch or release failures generally include the failure of the weapon to correctly separate from the test aircraft or the launch vehicle to lift as expected from the launch pad. At best, this mode of failure for the system will usually result in the weapon and or launch vehicle returning to the preparation area for fault investigation. At worst the system will separate from the test aircraft or launch from the launch pad in an uncontrolled and unpredictable manner, resulting in the damage or loss of the launch aircraft or launch facility.

Guidance and control system failures encompass a wide spectrum of in-flight control system failures broadly relating to the failure of the weapon or launch vehicle to follow an allowable and/or predicted trajectory. This mode of failure will almost certainly result in the weapon or launch vehicle diverging from the predicted / allowable trajectory and impacting in an area of much larger dimensions than the desired impact zone applicable to a correctly functioning system. The impact point resultant from such a failure is likely to be dislocated from the desired point of impact by a distance proportional to the severity of the failure mode encountered and actual performance of the weapon.

Functional failures are of a similar nature to guidance and control system failures and encompass a broad range of failures related to the correct operation (detonation of explosives or operation of engines/rockets) of the weapon system or launch vehicle under test. This mode of failure may also result in the system diverging from the desired trajectory or failing to behave as expected (detonate, penetrate, deploy sub-munitions, etc). It will therefore be important to the test agency to recover the test article (or wreckage thereof) as soon as possible in order to investigate the cause of the failure. In the case of military weapon systems, recovery will typically involve excavation of the article and in the case of explosive ordnance, specialist activities required to make safe the explosive content of the weapon. Such a recovery would of course be problematic if it occurred in the vicinity of the NRWR.

Even for in-service systems the underlying premise of these activities is that uncertainty exists as to the correct operation of the system under test, hence the test activity. This makes the activities performed in the WPA vastly different to those performed at other weapons ranges in Australia where operations will generally be limited to in-service, certified and functional weapons. A result of the unique experimental activities performed in the WPA is that safety templates, that provide protection for personnel and equipment during weapons employment, can be less accurately determined for much of the operations in the WPA when compared to activities performed at other ranges. As such, these safety templates may be significantly larger than for in-service weapons of the same class. There are numerous Defence documents[4,5,6,7] applicable to range operations that discuss in detail the various requirements for safety assessments and the philosophy applied to these assessments that must be made prior to the operation of experimental systems at the WPA.

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[4] DI(G) ADMIN 59-1

[5] DI(AF) AAP 8600.001 RAAF Air Weapons Practices (Operations and Operational Requirements Manual) Issued 15 April 1999

[6] Range Commanders Council Range Safety Group, Standard 321-97, Common Risk Criteria for National Test Ranges, February 1997

[7] Safety Criteria for Australian Defence Force Aerospace Training and Test Ranges, Dr M Choa

3.3 Current Use of the WPA

The WPA was created for the testing of space launch and war like materials. The uniqueness of the WPA is in large part due to its remote location and consistent weather. These characteristics mean the WPA can be used for test and evaluation with little or no risk to people and property and in an environment that is devoid of air traffic control restrictions and that is electromagnetically 'clean'[8]. These characteristics make the WPA unique, not only in Australia, but also the world, and it is for these reasons that many foreign countries have either used, or expressed interest in using the WPA for development and evaluation of civil and military aerospace systems.

Instrumentation has been positioned at the WIR to take maximum advantage of these features for the purpose of testing complex weapon systems. Radars have been located to provide highly accurate coverage of a wide expanse of airspace and optical tracking devices are able to be positioned at various points on the WIR to provide extremely accurate tracking and recording of weapon system behaviour in free flight.[9]

The facility is also located in relatively close proximity to the Woomera Township which provides domestic and commercial support for the activities at the range. The township is used for the domestic accommodation of range personnel and as a convenient nearby airfield for test aircraft to operate from.

ARDU regularly operates at the WPA to collect data on the performance of aircraft and aerospace weapon systems. Range usage for these test activities typically involves activation of the instrumented range facilities for weapons testing operations using any suitable area within the field of view of the optical and radar emplacements. Recent activities have included the testing of a wide variety of air-to-air and air-to-ground guided and unguided weapon systems, including both in-service and experimental systems. Among the more significant programmes undertaken have been the evaluation of GBU-24 and GBU-10 2000 lb and GBU-12 500 lb Laser Guided Bombs dropped by the F-111 strike aircraft, and the MK-82 500 lb and MK-84 2000 lb General Purpose bombs dropped from the F/A-18 aircraft. Both of these test activities were focussed on the assessment of the aircraft bomb aiming system as well as the correct functionality of the weapon. The WPA has also been used recently for test firing of the AIM-120 Advanced Medium Range Air to Air Missile (AMRAAM), AIM-7 Sparrow Radar Guided air to air missile and AIM-9 Sidewinder heat seeking air to air missile. These test activities were conducted to verify the integration of the missile with the launch aircraft weapon system and the correct function of the missile guidance system in free flight.

Other users of the WPA include agencies performing weapons employment practices, explosive demolition activities and atmospheric research activities. In the past ten years Defence has used the WPA for the test, evaluation and employment of in excess of 600 individual weapons and research vehicles.[10] These activities have included the testing associated with the introduction to service of air-to-air and air-to-ground missiles, ballistic and precision guided bombs and the launch and recovery of atmospheric research vehicles by Australian and overseas agencies. Imposition of restrictions on the scope and frequency of these activities is therefore likely to adversely affect the continued viability of the WPA for these activities. There would also appear to be no existing viable options to the WPA, with the next largest range in Australia only 212,000 ha or 1.7% the size of the WPA.

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[8] Low electromagnetic activity is frequently important for the testing of navigation and communication systems and the operation of Flight Termination Systems associated with aerospace weapons systems.
[9] Optical tracking methods provide the best source of high accuracy weapons free flight behavioural and trajectory information.
[10] ARDU –Range Operation Plans 1990 - 2001

3.4 Future Use of the WPA

Defence has a policy to promote the use of the WPA by commercial organisations and foreign defence forces. Considerable interest has been expressed by a number of commercial organisations for the use of the unique capabilities of the WPA. In particular, strong domestic and international interest has been expressed in the development of the WPA as a centre for commercial space launch activities and in the use of the range for advanced aeronautical research activities.

Future WPA bookings and the WPA annual program are managed by the AAW, DSCW. In the near term the primary user of the area will continue to be Defence. However, several proposals for use of the range by commercial agencies have the potential to significantly increase the range use for non-military activities.

Table 3.1 details the current programmed usage of the area until 2004. The table demonstrates that increasing usage of the range by commercial space launch operators and a steady usage by ARDU and other defence users is expected.[11] In anticipation of this increase in the predicted rate of usage of the WPA facilities, ARDU has booked three four week blocks for exclusive use of the area during each of the next three years.[12]

3.4.1 Future Commercial Use

Four commercial projects are currently at various stages of their planning process.[13] The National Aerospace Laboratory of Japan is close to completing construction of a launch facility within the WIR for flight trial of the Japanese Small Supersonic Experimental Aircraft (SSEA). These trials will involve the rocket boosted launch of a large scale model of the proposed aircraft design for the purpose of gathering aerodynamic data on the vehicle performance. Other interests include the Falcon Project (a consortium from the UK), Kistler Aerospace (an American company) and Spacelift Australia. These three organisations propose to use the WPA for the establishment and operation of space launch and recovery facilities. Significant funds have been invested in the area for this purpose. As an example, the existing space launch facilities at the Lake Hart launch area are estimated to be worth more than $20 million[14] and are planned to be used by the Falcon Project. Of note is that the launch flight path for this project traverses Site 52A[15] and so any decision to continue will probably require the resiting of the launch facility if the NRWR is placed at Site 52A.

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[11] The WPA bookings presented at Table 3.1 are indicative of the heavy usage of the area expected in the near future

[12] ARDU has booked these periods for the exclusive use of the WPA in order to be assured of an opportunity to use the range for anticipated ADF test and evaluation exercises in response to the numerous WPA bookings now becoming apparent.

[13] DISR – SLASO 'Launching Safely Into Space' August 2000

[14] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

[15] DISR – SLASO 'Launching Safely Into Space' August 2000

Table 3.1 – WPA Program 2001 – 2004

Expected Dates	Activity	Status
Late 2001		
15 Oct – 2 Nov	**Hyshot (Complete)**	Complete
2002		
March	**NAL – SST (R1 & TDC Total System Test)**	Subject to change
March	**NAL – SST (R1 & TDC EMC Test)**	Subject to change
March	**ASRI: Falcon, FARISpace, Hankuk (Korea), Hyshot x2)**	Tentative
TBA	**Hyshot 2**	
6 – 31 May	**ARDU Missile Tests**	Confirmed
17 – 28 Jun	**National Aerospace Laboratory (NAL) – SST Flight Test #1 (JAPAN)**	Subject to change
15 – 31 Jul	**NAL – SST Flight Test #2 (JAPAN)**	Subject to change
12 Aug – 6 Sep	**ARDU – Bombing Tests**	Confirmed
15 –26 Jul	**NASA – X38 Pallet Drop Test (USA)**	Subject to change
16 Sep – 5 Oct	**DIRECTOR of TRIALS – Explosive Trial**	Confirmed
8 – 25 Oct	**ARDU – Bombing Tests**	Confirmed
TBA	**Falcon Launch Test (UK)**	Proposed Activity
TBA (2-3 weeks)	**16 Air Defence Regt. (ADR) – Air Defence Exercise**	Annual Event
TBA (2-3 weeks)	**RSAF - Air Defence Exercise**	Annual Event
2003		
Jan	**Instrumentation installation and Training**	Proposed Activity
10 – 28 Feb	**NAL – SST Flight Test #3 (JAPAN)**	Subject to change
2 –14 Mar	**NAL – SST Flight Test #4 (JAPAN)**	Subject to change
Feb (4 wks)	**Taurus Captive Carriage Trial**	Tentative
Mar/Apr (3 wks)	**Taurus Flight Test (Germany)**	Tentative
Mar (3 Weeks)	**NASA – X38 CRV Flight Test (USA)**	Subject to change
5-30 May	**ARDU Deployment**	Confirmed
Jun (2 weeks)	**ARDU – AGM-142 Flight Test**	Tentative
Jul	**ARDU-Stormshadow Flight Test (UK)**	Tentative
21 – 28 Jul	**RAF Bombing Tests following Stormshadow Tests**	Tentative
11 Aug – 5 Sep	**ARDU Deployment**	Confirmed
20 Oct – 14 Nov	**ARDU Deployment**	Confirmed
TBA	**Falcon Launch Test (UK)**	Proposed Activity
TBA (2-3 weeks)	**16 ADR – Air Defence Exercise**	Annual Event
TBA (2-3 weeks)	**RSAF - Air Defence Exercise**	Annual Event
2004		
4 weeks	**Maintenance / Training**	As Required
3 – 28 May	**ARDU Deployment**	Confirmed
9 Aug – 3 Sep	**ARDU Deployment**	Confirmed
18 Oct – 12 Nov	**ARDU Deployment**	Confirmed
TBA (2-3 weeks)	**16 ADR – Air Defence Exercise**	Annual Event
TBA (2-3 weeks)	**RSAF - Air Defence Exercise**	Annual Event

3.4.2 Future Defence Use

Defence is in the process of procuring a new family of aerospace weapons known as Stand Off Weapons (SOWs). SOWs possess significantly greater range and performance than the current in-service precision guided weapons and consequently require a larger range area to provide for their safe operation. As a result, the ability to utilize range facilities other than Woomera for testing and training is likely to be extremely limited. As these weapons are introduced to service, extensive testing to determine their limitations and capabilities will be required. This will be followed by an increase in the use of Woomera for training in the use of these weapons. Examples of systems of this type include the US Joint Stand Off Weapon (JSOW), UK Storm-shadow and German Taurus. These weapons have launch to target capabilities in excess of 200 km. It is important to note the WPA is one of the few remaining facilities available in the world for the test and evaluation of these systems. It is for this reason that foreign defence agencies have previously used the area to test SOWs and will continue to seek approval from the Australian Government for the use of the area for this purpose.[16] Further discussion is contained later in this paper on how the increasing requirement to test and train with SOWs will affect the proposed NRWR location at Site 52A.

Other Defence projects such as Project Air 87, Armed Reconnaissance Helicopter and Project Air 6000, are also likely to make extensive use of the range facilities for both developmental and in-service test and evaluation. Both of these projects will acquire advanced platforms with weapons systems that will significantly out perform those of the current generation and it is likely that the facilities at the WIR will be among only a few in the world capable of supporting the Test &Evaluation (T&E) programmes required.

The WPA will also be increasingly used to support ground based weapons training exercises. Currently, ground to air missile firing training exercises are conducted at the WPA for four to six weeks per year by the Australian Army and Republic of Singapore Air Force[17] (RSAF). These operations are conducted at the Lake Hart Impact Area and due to the proximity of the WIR, flight operations over Site 52A occur regularly[18].

3.5 Defence Risk Management - Safety Templates

To mitigate the risks associated with the weapon release activities conducted at Woomera, Defence has applied an acceptable risk factor per test (i.e. per drop) of 1 x 10^{-6}. This risk factor is then used to determine safety templates that provide the bounds of a danger area for the different hazards associated with the conduct of aerospace vehicle testing, trials and training including weapons launch, release and impact activities[19]. Safety templates are used to describe a ground area in which personnel and equipment are in danger of injury or damage due to the impact, fragmentation or ricochet of a functioning military or commercial aerospace system.

It should be noted that Safety Templates are based on the release of the weapon from a very tightly defined point in the sky, and based on release aircraft direction and speed. The templates take no account for release outside these parameters that occur as a result of an aircraft system malfunction leading to inadvertent release, or pilot or weapon system operator error that results in accidental release outside these

[16] The UK has exercised the ALARM air-to ground missile and the US have employed the AGM-142 air to ground missile (both SOWs) at Woomera in recent years.
[17] CSIG – Director Training Area Management – E-mail 02 Nov 01, 09:50
[18] CSIG – Director Training Area Management – E-mail 02 Nov 01, 09:50
[19] AAP8600.001-RAAF Air Weapons Practices (Operations and Operational Requirements)

parameters. As an example a weapon released from a "toss type" attack six miles from the intended target would only need to be released 10 degrees off attack direction to result in a weapon impact a point 1800 metres from the intended target. Equally, the incorrect input of target coordinates into the aircraft bombing system when using an automated bomb release profile could also result in accidental targeting of an area significantly displaced from the intended target. This issue is discussed later in section 5.3.

Figure 3.1 shows an example of an air to ground weapons safety template applied to the target area on the Woomera Instrumented Range. The template is representative of an extended range weapon released with Target A as the intended point of impact and dropped in a south-west direction. It is important to note that this template is indicative of in-service weapons systems that are currently tested and trained with at the WIR.[20] The templates associated with the experimental systems that defence will continue to test at the WIR are likely to be commensurately larger than this example due to the uncertainties associated with systems under test and the expansion of capabilities being procured.

The template in Figure 3.1 clearly demonstrates that the proximity of the proposed Site 52A will place it well within the danger area for a significant proportion of the weapons Defence will be required to test at the WIR (the template presented is for a relatively low capability weapon system). The proximity of the Range E Target Area (RETA) to the proposed NRWR means that safety templates for the majority of weapons employed at this target area will overlay the NRWR. It is probable that the application of even the smallest safety template will preclude operations at this target.

[20] The size of these templates should therefore be considered conservative in comparison to experimental systems of the same class likely to be tested at the WIR.

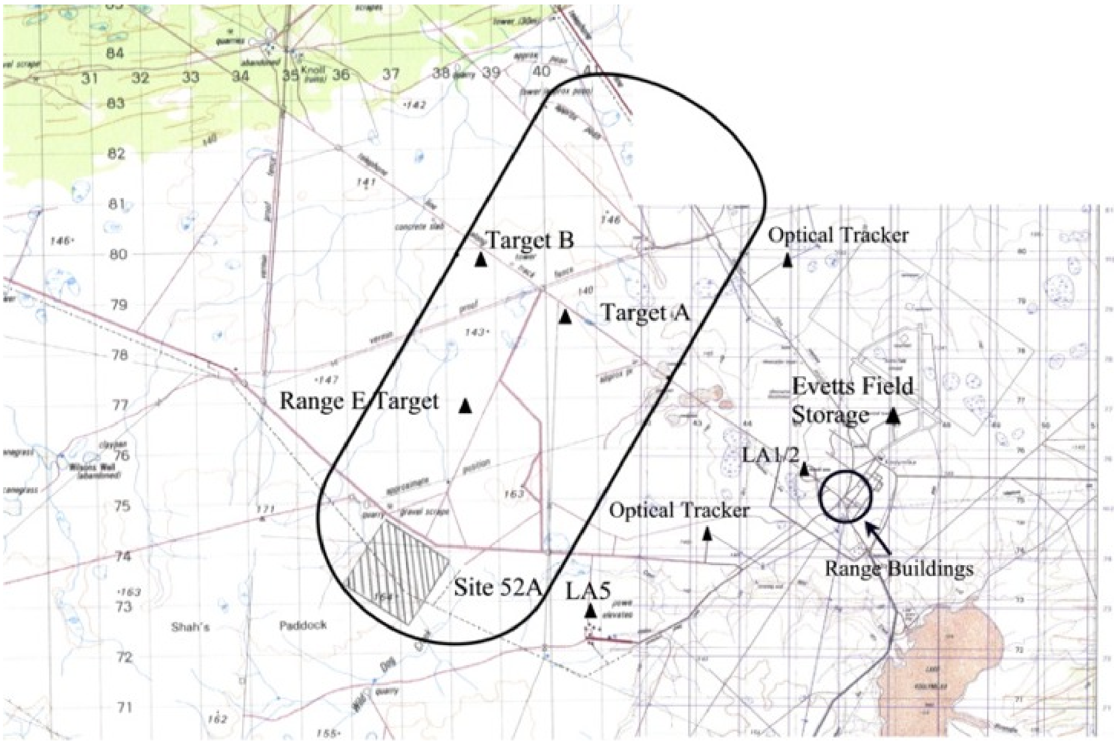

Figure 3.1 – Application of Safety Templates at the WIR

Not shown on Figure 3.1 is a representation of a safety template for any of the Stand Off Weapons Defence is in the process of procuring. As previously discussed, these systems are designed to be employed long distances from the intended target and consequently have very large ground safety templates associated with their flight paths. Figure 3.2 gives a representation of a previously used ground safety template for a medium range version of such a weapon.

Defence is in the process of procuring systems with the capabilities represented by Figure 3.2 as well as a new class of Stand Off Weapon designated Long Range SOW (LRSOW). These weapons will have range capabilities in the order of several hundred kilometres and will require extremely large safety templates and innovative operating protocols to accommodate their associated testing. The testing required to confirm the correct functionality of these systems, in particular the terminal phase of operation of the weapon, often requires analysis using data obtained from the WIR instrumentation systems. As part of the development of systems required for the test and training of these new weapons, ARDU has already completed trials of a prototype upgrade of the optical trackers used on the range. This upgrade will allow their un-manned operation so that the next generation of weapons with significantly larger safety templates can be assessed at the WPA. Use of un-manned facilities and tracking equipment means that the range will be able to used for testing these weapons without the requirement to expose personnel to the increased risk associated with operating inside a weapon safety template. However, the result of the requirement to test these weapons at the WIR is that the proposed NRWR at Site 52A will be exposed to an even higher risk of weapon impact.

The use of un-manned facilities will allow testing of these weapons whose safety templates will overlay components of the range infrastructure. However, placing the NRWR at Site 52A will negate any benefit the development of un-manned facilities will provide, thereby rendering the current range facilities and targets useless for the testing of these weapons.

Not shown in either Figures 3.1 or 3.2 is a representative safety template for an air to air missile system and its associated targets (usually an un-manned drone aircraft). Defence has an ongoing requirement to assess the performance of these missiles as they are procured (two procurement programs are currently underway)[21] and to train with these missiles in a controlled environment. The range capabilities of these missiles are of the same order as that of stand off weapons and the safety areas required to employ them are of similar dimensions.

Defence has recently obtained the only certification outside of the continental United States for the test and evaluation of one of these systems.[22] The approval to test this weapon outside the USA was, amongst other reasons, provided specifically as a result of the unique characteristics of the WPA, the availability of instrumentation in the WIR and the ability to test the weapon using operationally representative profiles that were not unduly restricted by weapon and aircraft flight path constraints. Restrictions on the use of the WIR and the airspace available at the WPA to employ such weapons systems have the potential to compromise Defence's ability to continue the testing and in-service firing of these weapons, and will reduce Defence's ability to accurately evaluate current and future air to air weapons.[23]

[21] Defence Materiel Organisation – Project Air 5400 – Acquisition of the AIM-120 and AIM-132 air to air missile systems

[22] Approval to test the AIM-120 AMRAAM air to air missile system at the WPA has been obtained from the US DOD.

[23] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

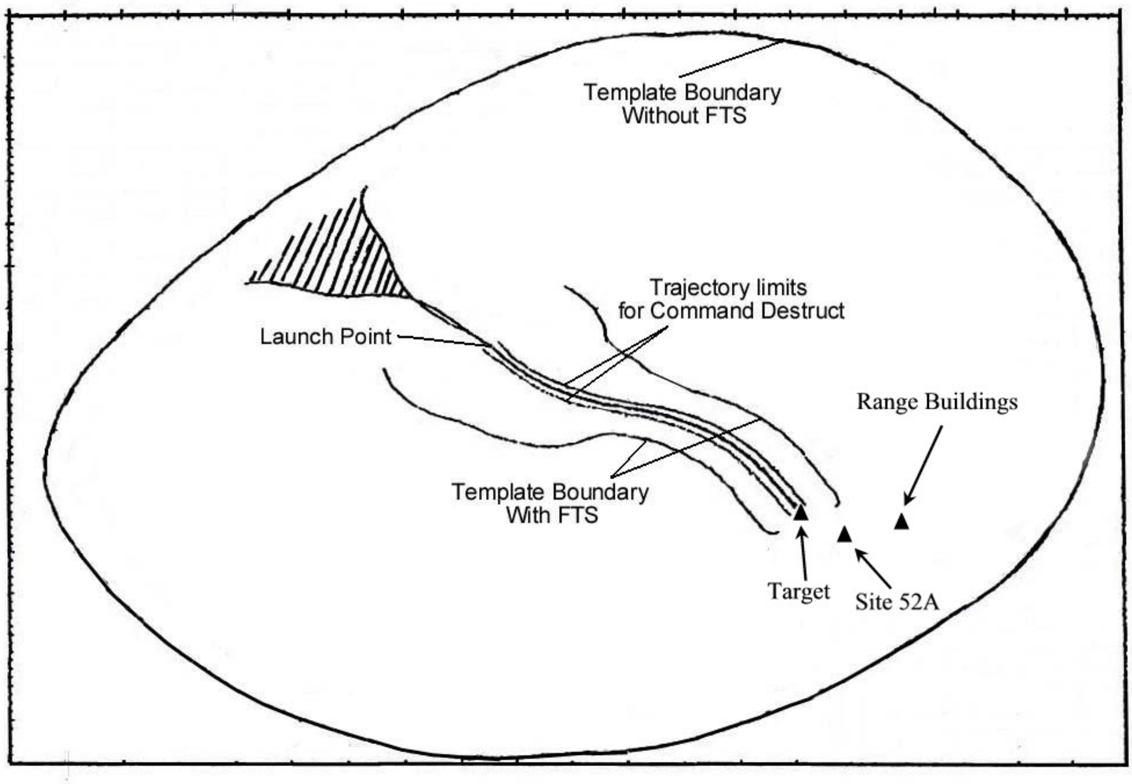

Figure 3.2 – Medium Range SOW Template

3.6 Flight Termination Systems

The incorporation of Flight Termination Systems (FTS) into these missiles, a system to destroy the missile if ground tracking shows it has deviated from its authorized flight path, has the potential to reduce the dimensions of the ground safety template as shown in Figure 3.2. The large circle shown in Figure 3.2 illustrates the safety template for a missile without an FTS fitted and is approximately 70 nautical miles across. The parallel lines at the centre of the diagram illustrate the containment area for the missile when an FTS is fitted. The area within this corridor represents the boundaries of the 1 x 10^{-6} risk level area applicable to the missiles flight path with a functioning FTS. The larger area represents a level of risk not greater than 1 x 10^{-6} if the FTS fails.

Understanding the potential reduction in size of the template possible by the incorporation of a FTS and the consequent reduction in restrictions to the operation of the missile are important in that it makes the usage of the instrumented range for the measurement and analysis of the missile's performance possible. However, even with the incorporation of an FTS the dimensions of the safety area required remains significant, as can be seen from Figure 3.2, and would still infringe Site 52A if Target A, B or RETA were utilised (a requirement for terminal phase testing).

Commercialisation of the Radio Frequency (RF) spectrum is causing increasing difficulty to Defence with respect to allocation of frequencies used for telemetry and flight termination systems. These issues have the potential to reduce or remove the reliability and effectiveness of utilising flight termination systems as a means of safety template reduction, further increasing the risk of impact to facilities in or around a surface target. It should also be noted that in some cases it may be impractical or prohibitively expensive to fit flight termination systems to many experimental and in service weapons, which once again creates that requirement for large safety templates.

While testing of FTS and non-FTS equipped systems requires the installation and utilisation of procedures to reduce the risk to manned and un-manned range facilities, these procedures are currently workable and do not unduly effect operations. However, the locating of the NRWR at Site 52A will result in significantly more limitations on weapon releases, and could remove the capability to evaluate and train with such systems as a result of the NRWR's proximity to the target areas.[24]

3.7 Target and Attack Direction Selection

It is clear from Figure 3.1 that moving target and the direction in which weapon launches are performed has the potential to remove Site 52A from some of the safety templates discussed, in particular those for some of the current generation weapons. However, the targets and attack directions used at Woomera are specifically selected to ensure correct weapons performance and operation and to also ensure satisfactory tracking of weapons and launch aircraft.

The location of the optical tracking devices, for example, takes into account the existence of a line of native vegetation approximately 12 km from the Instrumentation Building. It is important during weapons test activities to be able to accurately determine, not only the trajectory and in-flight performance of a weapon, but also the so called 'Terminal Behaviour' of the system. This is particularly the case for precision guided weapons where the ability of the weapon to strike a target in a particular manner is integral to the correct function and performance of the system. The tree line limits the ability of the optical tracking devices to record this behaviour and hence the available area for the positioning of ground targets is also restricted. Moving targets into the treed area would make this issue even more problematic. Firstly, because of the tracking difficulties already discussed and secondly, because locating and recovering weapons that have impacted within the tree line will be extremely difficult. Recovery of such weapons is essential for the investigation of malfunctions and the T&E process as a whole.

Being able to accurately track the weapons used on the range is vital, particularly for many of the experimental and in service systems under test. As the WPA begins to be utilised more and more for the test and training of stand off weapons it will become even more important that restrictions to flight path of weapons and launch aircraft are minimised. For the next generation of weapons, change of attack direction is also unlikely to take Site 52A out of the safety templates specified, even when flight termination systems are provided. Relocation of the targets and the imposition of restrictions on attack directions is therefore impractical unless the range facilities themselves are relocated.

3.8 Space Launch Safety Requirements

The Australian approach to space launch safety is mandated by the Space Activities Act 1998. Licences, Permits and Certificates may not be issued unless the Minister responsible is satisfied that the risk associated with the activity is low.[25] The Space Licensing and Safety Office (SLASO), an office of DEST is responsible for advising the Minister on the granting of the required permissions and the implementation of the applicable regulations for Australian space activities. The required set of approvals encompasses every matter of environmental protection, safety and operation and design of the vehicle itself. In particular they address the flight path approval for the vehicle. SLASO has also recently

[24] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01
[25] DISR – SLASO 'Launching Safely Into Space' August 2000

commissioned the Commonwealth Scientific Investigation and Research Organisation (CSIRO) to produce a paper detailing the risk benchmarks to be applied when evaluating the risks associated with space launch activities[26].

Defence Estate Organisation has highlighted the proximity of proposed NRWR sites to the proposed launch corridors for the Kistler, Spacelift Australia and Falcon Projects respectively.[27] Any proposal to locate the NRWR in proximity to the airspace and ground areas required for these activities should consider the potential adverse implications for their conduct. Defence has also highlighted to DEST that one of the identified alternative NRWR sites (45A) has no impact on any Defence activities at the WPA and one has no impact on either commercial or Defence activities at the WPA (site 40A)[28].

While it is not within the scope of this paper to present a detailed analysis of the implications for Space Launch activities due to the proposed Site 52A location for the NRWR, these comments have been included for completeness.

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[26] CSIRO, Benchmark Public Risk Levels for Australian Space Launch Activities, 28 August 2000

[27] ASPM 857/99, National Radioactive Waste Repository Site Selection Study, dated October 1999

[28] ASPM /00, National Radioactive Waste Repository Site Selection Study, dated March 2000

4.0 DESIGN AND OPERATION OF THE NRWR

4.1 The NRWR

The proposed design for the NRWR comprises an outer area of 1.5 km by 1.5 km with the actual repository located within a 100 m by 100 m area located centrally within the larger set aside area.

It is proposed that the repository will be constructed to a maximum depth of 15-20 m below ground level. The waste will be placed in trenches and be contained within steel or concrete drums. A layer of 2.0-5.0 m comprising material, suitable to control surface water ingress to the waste, will cap the repository.

The repository will be operated for a period of 50 years and monitoring will occur for a period of approximately 200 years following closure. Low level radioactive waste is generated at a rate of 50 cubic metres per year and it is anticipated that once the repository is constructed, material will be placed into the facility annually.

4.2 Effect of Weapon Impact on the NRWR.

There are two outcomes associated with a weapon impact on the NRWR, the first is the physical damage that could occur to the NRWR following a weapon impact and penetration of the repository and the second is negative publicity that would result from an impact on or in close proximity to the NRWR.

4.2.1 Physical Effect of Weapon Impact

As previously discussed, the location of the NRWR at Site 52A will place it in close proximity to targets currently used for Defence weapons test and training activities. Figure 4.1 shows examples of possible weapon trajectories and penetration profiles. It is important to note that a bomb may not continue on a direct trajectory once the ground is penetrated. The bomb may encounter objects (rocks, etc.) underground which cause its course to deviate. This is not an uncommon occurrence with ARDU having experienced several examples of bombs at the range entering the ground and resurfacing significant distances from the original impact point.[29] For a direct penetration, potential travel distances into the ground are provided in Table 4.1.

It is evident from Figure 4.1 and Table 4.1 that the bomb types tested at the WIR have the potential to penetrate the repository. The consequence of such a penetration will be a breach of the repository confinement, leading to the potential release of stored materials via the crater or hole created by a bomb travelling through the repository. Future weapons are being designed to penetrate to greater depths and to penetrate concrete.

In the worst case scenario, a bomb may strike the ground clear of the repository, ricochet from an underground object, or defract through the ground, travel through the repository and remain in the ground in or on the opposite side of the store. In this case, it may not be readily evident that the repository has been breached.

[29] ARDU has experience with ballistic weapons exhibiting this type of behaviour during weapons test activities at the WPA.

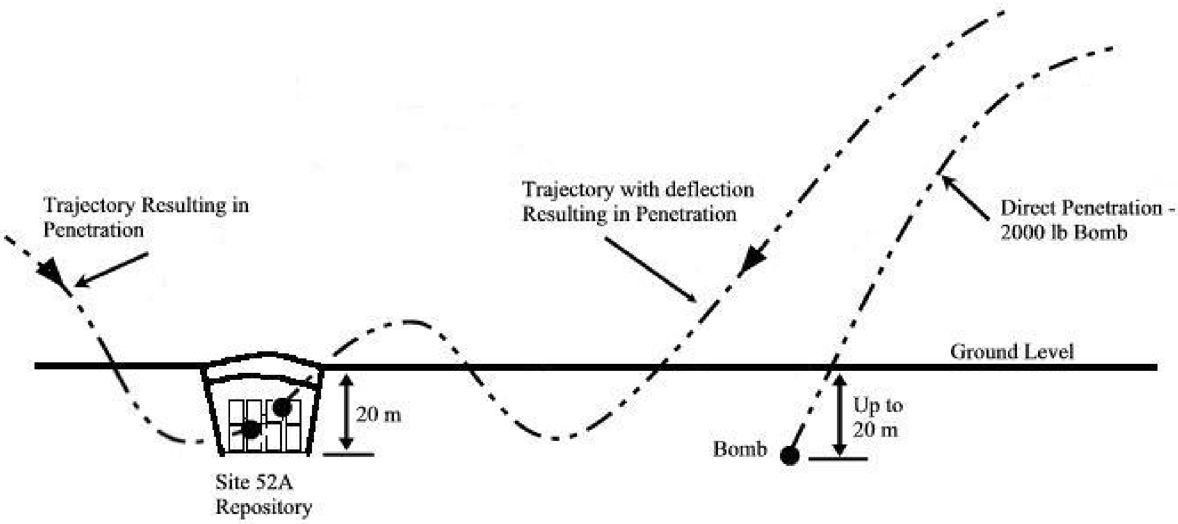

Figure 4.1 – Ballistic Trajectory and Penetration Profiles

Table 4.1 – Ballistic Ground Penetration Distances

Bomb Type	Penetration Distance (m)
2000lb Bomb	5-20m
500lb Bomb	5-10m
25lb Practice Bomb	0-5m

4.2.2 Adverse Publicity Resulting from Weapon Impact

In addition to the physical results of a weapon impact on the NRWR, the negative publicity resulting from such an impact, either on the NRWR or in close proximity must be considered. Defence believes that the outcome of such negative publicity could be significantly greater than any physical damage to the NRWR and that regardless of the level of damage incurred the cessation of range activities would be called for. The result of this would be a significant loss to the Commonwealth's defence capability. This issue is perhaps the most significant concern to Defence.

5.0 RISK ASSESSMENT

5.1 ARPANSA Safety Requirements

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has adopted the National Heath and Medical Research Council's Code of Practice for the Near Surface Disposal of Radioactive Waste in Australia.[30] This code lists a fatality criteria of $1x10^{-6}$ per annum for low level radioactive waste repositories. ARPANSA also uses the risk criteria published in the "Regulatory Assessment Principles for Controlled Facilities (RD-STD-42-001). This document lists criteria stating the frequency of exposure to a maximum effective dose or radiation in milli-Sieverts (mSv). The criteria indicates that a maximum exposure risk of $1x10^{-5}$ per annum just meets the safety limits and a maximum exposure risk of $1x10^{-7}$ per annum just meets the safety objectives. The document also states that the risk must be shown to be as low as reasonably achievable (ALARA).

5.1.1 Risk to Personnel following a Weapon Impact

If a weapon did impact and breach the NRWR, there would obviously be a requirement to recover parts of the weapon and to repair damage to the repository itself. DEST has performed a detailed assessment of the risk to personnel involved in a clean up and investigation and determined that the level of radiation to which these people would be exposed is highly unlikely to result in fatalities[31]. Defence does not disagree with the finding of this analysis and as such it has not been included as a component of the risk assessment considered in this paper, although it would obviously need to be added to any risk determined. Defence's main concern has been and remains the negative publicity that would result from a weapon impact on the range and the fact that such publicity could ultimately result in range closure and consequent significant loss to the Commonwealth's defence capability.

5.2 ADF Aviation Risk Management Policy

Defence has recently implemented an Aviation Risk Management policy[32] that designates the different consequences of any single or series of events. This policy includes not only safety risk but Public/Image/Morale risk among other elements. The consequence of a Public/Image/Morale issue that results in widespread public condemnation of the ADF is defined as "disastrous" under the AVRM and is akin to a safety issue that results in many fatalities or numerous aircraft losses. A Public/Image/Morale issue that results in widespread public discontent with the ADF or Service or prolonged adverse national media attention is categorised as "critical" and is akin to a safety issue resulting in few fatalities or a single aircraft loss. Details of these consequence categories are provided in Appendix A.

The negative publicity to the ADF that would result from a weapon impact either on or in close proximity to the NRWR is viewed by Defence as a significant issue. In line with this, ARDU has recommended that a weapon impact on the NRWR be classified as falling into the 'disastrous' category[33]. Since the Aviation Risk Management Policy equates any consequence of "critical" or higher to that of a fatality (or multiple fatalities where the consequence is defined as "disastrous") it is not unreasonable to apply the same

[30] National Health and Medical Research Council (1992), "Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia".
[31] Presentation, Dr Jane Smith Briggs, Nukem plc,Russell Offices, 23 Jan 02.

[32] Chief of Air Force Directive 02/01-RAAF Aviation Risk Management (RAAF AVRM) dated12 Sep 01.
[33] E-mail-Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance - 28 Nov 01

probability thresholds for such consequences to that of a fatality. Using the ARPANSA guidance provided above, the acceptable threshold for occurrence of such an event or consequence is 1 x 10^{-5} per annum. This means that Defence would potentially violate its own risk management policy if the NRWR was located within an area where the probability of a weapon impact was greater than 1 x 10^{-5} per annum and hence would be required to cease operations in the area.

5.3 Probability of Weapon or Aerospace Vehicle Impact on NRWR

The methodology for the risk assessment conducted to assess the probability of a weapon or aerospace vehicle impacting on the NRWR is detailed in Appendix A and the findings of this assessment are discussed below. It is important to note that the assessment provided only considered the Defence activities at the WPA associated with weapon releases. It does not consider any Space Launch activities and the risk of impact of one of these vehicles, nor does it quantify the risk of manned aircraft impact (discussed later).

The safety templates discussed in section 3 provide the boundary of a 1 x 10^{-6} probability of weapon impact and therefore potential fatality. It should be remembered that the templates provide a probability based on a single weapon release. It should also be noted that the closer the NRWR is to the intended target, the higher the probability of a weapon impact.

A major number of the weapon releases carried out in the WPA are of experimental weapon systems, and as such the safety templates used will be significantly larger than for comparable in service, proven weapons of the same class. The template provided in section 3 has been used as the basis of discussion due to the large variations in safety templates applicable to experimental weapons systems, and the large varieties of weapons on which actual testing is performed. The safety template provided is therefore optimistic, and the probabilities of impact within the areas discussed (and in particular Site 52A) are necessarily higher.

As previously mentioned, it should also be noted that the safety templates are based on weapon release or launch from a fixed point in space under certain pre-defined conditions. Human and software errors in the launch/ release platform (aircraft) are not accounted for in the safety templates and must be considered in addition (eg weapon release computation in aircraft mission computer is incorrect, pilot releases on wrong target through either mis-identification or through input of incorrect target coordinates to aircraft mission computer). As an example their have been at least two incidents in the last 10 years of weapons impacting in close proximity to manned range facilities at the Delamere Air Weapons Range in the Northern Territory and the Salt Ash Air Weapons Range in New South Wales due to incorrect target identification by the pilots.

Since 1990 the number of releases by Defence alone in the WIR has averaged in excess of 60 per year. The probability calculations contained in Appendix A show that for 60 weapon releases per year of which 70% (see Appendix A) have the capability to penetrate the NRWR, the frequency of impact and penetration of the proposed NRWR at Site 52A is 4.2 x 10^{-5}. Since this is an optimistic figure the actual frequency may be assumed to be significantly higher. This is particularly the case for the next generation of SOW that will have significantly greater kinematic performance than that of the weapons for which safety templates have been provided in Section 3. As discussed, this is the case even when an FTS has been fitted.

It should also be noted that the WPA is likely to be the only range in Australia on which these weapons will be able to be released. As such the number of releases to occur in the future is likely to increase due to the requirement for training to be carried out at the WPA as these systems are introduced to service and consequently the probabilities of impact within the safety templates will also increase.

5.4 Probability of Manned Aircraft Impact on NRWR

The above calculations do not include the probability of a manned aircraft impacting the NRWR, which was beyond the initial scope of this paper. Information on the probability of manned aircraft impact in Australia is difficult to obtain. However, information provided by Dr Jane Smith-Briggs[34], a consultant employed by DEST, indicated that in the UK this probability would be in the order of 2.4×10^{-4}. Despite the high amount of aircraft traffic in the UK generally, it is not unreasonable to assume that the within the confines of the WIR the level of traffic would be as great, due to the dedicated flight and weapons testing performed at the facility. This figure is clearly significant and would, if included, raise the probability of an impact on the NRWR by almost one order of magnitude. Additionally, the effort (and exposure to personnel) required to clean up a manned aircraft impact of the area would be higher than for a weapon impact and the publicity that would result would also be significantly greater.

5.5 Defence Risk Assessment-Land Engineering Agency View

The Land Engineering Agency (LEA) is an organisation within Defence, which has the responsibility of the provision of risk and hazard analysis for ADF weapons ranges. LEA has provided information related to the locating of the NRWR at Site 52A which discusses the construction of safety templates, and in particular those required for experimental systems. It is LEAs opinion that the necessary adherence to the safety template approach for weapons test activities at Woomera is likely to preclude the employment of many experimental and long range weapons in the WIR. In correspondence received from LEA they have recommended that the co-location of the NRWR at site 52A and WIR be avoided[35].

[34] Presentation, Dr Jane Smith-Briggs, Russell Offices, 23 Jan 02.

[35] LEA 751/Y/18 National Radioactive Waste Repository – Woomera Implications dated 6 Dec 01

6.0 IMPLICATIONS IF SITE 52A SELECTED

6.1 Implications for Defence Activities

The risk assessment process detailed in Appendix A demonstrates that the risk of a weapon impacting the NRWR if located at Site 52A could be significantly higher than 1 x 10^{-5} p.a. for any given year. In accordance with the ADF risk management policy, Defence would be unable to continue operations without the introduction of significant operating restrictions on the activities performed.

If the decision was made to keep the range facilities in situ it would be necessary to ensure safety templates for weapons released on the range did not infringe the NRWR. The only way this could occur would be to ensure high performance, long range and experimental weapons systems were not employed on the range. Such a decision would compromise Defence's ability to test and operate such weapons and would have significant implications for Australia's weapons T&E and training capabilities.

6.2 Implications for Commercial Operations.

A similarity exists between the test of military weapons systems at the WIR and the launch into space or recovery from space of large objects. It is therefore apparent that the design of the NRWR is also unlikely to completely protect the contained material in the event of the accidental impact of space launch debris. As an example the Japanese SSEA booster rocket (which weighs approximately 2200kg or 4800 lbs) is expected to impact the ground at a velocity in excess of mach 1.5 (or 1500 km/h)[36] a velocity comparable to that of many of the weapons evaluated on the range.

[36] ARDU Japanese SSEA Safety and Operations Liaison Officer, Record of Conversation 13Nov01.

7.0 POTENTIAL ALTERNATIVE SITES AND COSTS OF RELOCATING THE WIR

7.1 Sites 40A and 45A

Sites 40A and 45A are both sites described by DEST as highly suitable locations for the proposed NRWR. Site 52A is nominated as the preferred site because it is reported to provide a better location with respect to geology, groundwater, transport and security. A review of the Bureau of Rural Sciences (BRS) report prepared for the three sites suggests that the differences in geology and hydrogeology are minor with respect to the suitability of each site to prevent the migration of waste material from the repository. The BRS report identifies that all three sites have an estimated unsaturated zone residence time for recharge water moving downwards to the watertable exceeding 9,000 years, based on chloride mass balance calculations. Even if a component of this flow is preferred pathway flow, as is potentially identified at Site 45A, the residence time in the unsaturated zone is still predicted to be not less than 3,000 years. For all three sites this significantly exceeds the 200 year reported time frame before the waste decays to safe levels. Based on this assessment Defence considers that there is no significant difference between the three sites on geology/hydrogeology grounds.

Sites 40A and 45A (Figure 1.1) are well displaced from the range area and will have little or no impact on Defence operations in the WPA. If the NRWR is located at Site 52A it may become necessary for Defence to relocate the infrastructure of the WIR in order to maintain the T&E and training capabilities the current site provide. However, if the NRWR is located at one of the alternative sites (40A or 45A) the increase in cost to the Commonwealth over that required for Site 52A, is likely to be small in comparison to the overall cost of the NRWR and will be significantly less than the cost (both in financial and capability terms) of relocating the range facilities.

Security implications associated with siting the NRWR at Site 52A are discussed in Section 8 of this report.

7.2 Costs of Relocating the WIR

In Appendix A and Section 4, a discussion on the likely consequences of direct hits and near misses at the NRWR from military weapon systems is presented. It is also apparent from this discussion that the design of the NRWR is unlikely to protect the contained material from damage due to an accidental impact by a weapon of the class likely to be tested at the WIR. As discussed previously, the probabilities of such an impact are also significant and as such Defence would have little choice but to move the range instrumentation and targets to ensure the NRWR was removed from the areas of possible weapon impact, based on current ARPANSA and LEA guidelines. This would be the only alternative if the NRWR is located at Site 52A and the Commonwealth wished to maintain its current capability to test ballistic, precision guided and stand off weapons.

The existing infrastructure at the WIR has been developed over a period of years and is specific to the unique activities conducted at the WPA. Defence has previously completed an analysis of the likely costs to relocate WIR infrastructure and concluded that expenses in the order of $ A180 million could be expected[37]. A detailed breakdown of the asset value of WPA infrastructure, commissioned by Defence is presented at Appendix B. In addition, the costs and complexity associated with the identification of a

[37] CSIC – SA Infrastructure Division, Cost Estimates – Woomera Asset Value Spreasheet compiled for DEO

suitable alternative location for a facility that is capable of providing the unique characteristics of the WPA must be considered. Any relocation is also likely to move the range facilities further from the Woomera township. This has major implications for transport and support of people and equipment on the range and is likely to result in increased costs of range operations. The movement of the range facilities further from Woomera airfield will also have an effect on airborne operations in the WPA. Increased distance from the airfield to the range and target areas will mean increased transit time and reduced time for actual weapons release. This has the potential to also significantly increase the costs of operations in the range area. Finally, the significant non-effective operating time for the range during the relocation process combined with the requirement to re-establish, calibrate and validate the instrumentation systems from the WIR would also be a major activity which would severely impact ARDU's ability to support programmed Defence test and evaluation activities as detailed in Table 3.1.[38]

Any decision to locate the NRWR at Site 52A must acknowledge the high probability of having to relocate a significant portion of the existing WIR infrastructure. The cost savings associated with selection of Site 52A over the other alternatives must therefore be considered in comparison to the costs associated with moving the range facilities, if Site 52A is selected.

7.3 Existing Repositories at Evetts Field and Launch Area 5

Figure 3.1 shows the proximity of the existing Evetts Field and Launch Area 5 storage sites to the WIR. These two facilities are the current temporary storage sites for low level radioactive waste and will be replaced by the NRWR. Current ARDU policy is to restrict test activities at the WIR for systems that require safety templates that may impinge the LA5 and Evetts Field facilities. Aircraft operating on the Instrumented Range are also required to avoid direct overflight of either of the sites. The limitations imposed by these sites reduce the flexibility with which testing is able to be performed on weapons at present. To ensure overflights with experimental systems are not conducted, attack headings must be carefully selected (taking into account other restrictions relating to the position of the target and radar and optical tracking devices). The combined effect then, is to substantially reduce the flexibility currently available to Defence for the conduct of the core business of the WPA. Defence has also operated in the presence of these restrictions with the understanding that the facilities are temporary and if required could be removed. Importantly, the Evetts Field and LA 5 sites are displaced from the WIR target areas a considerably larger distance than the proposed Site 52A repository and so are exposed to a correspondingly lower probability of impact due to WPA activities. The relocation of the waste currently stored in these sites to the NRWR will remove these restrictions, however, the location of the NRWR at Site 52A will create even more significant restrictions.

[38] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

8.0 SECURITY IMPLICATIONS OF SITING THE NRWR WITHIN THE WPA

8.1 Existing Security Infrastructure

DEST has stated that one reason Site 52A has been selected as the preferred location for the NRWR is that its location will provide additional security[39]. This is despite the advice that the WPA has no permanent security presence.

An inspection of the proposed Site 52A location and the WPA in general will confirm to even the most casual observer that the WPA is a prohibited area in name only. Access to the area is virtually unrestricted during periods of inactivity. In addition, the limitations imposed on the locally employed private security guards with respect to powers of arrest and denial of access and the extended reaction for the deployment of Australian Protective Services and South Australian STAR Division personnel in the event of an incident further erode the actual level of security enforcement possible in the WPA. The public's perception of the WPA as a secure site is likely to remain only whilst ignorance of the actual physical security precautions at the site exists.

It is likely that environmental and political action groups will object to the construction of a NRWR irrespective of its location. Security of the site will therefore need to be more robust than that which exists at the WPA presently. Advice from DSCW indicates that access to Site 52A is currently uncontrolled and unrestricted[40].

Defence has additional concerns that the possibility for uncontrolled protestor activity at the site will increase the risk of damage to nearby Defence facilities and the uncontrolled access of personnel to the range areas will unacceptably delay and disrupt important and high cost range operations for safety reasons[41].

Weapons performance information of the type typically collected during test and evaluation operations at the WIR is often highly classified. The increase in public awareness and associated reporting requirements in the event of an incident within the NRWR site could unacceptably increase the awareness of sensitive Defence trials where need to know security principles are typically applied.[42]

Therefore, when considering the security provided by the geographic location of the NRWR, each of the three short listed sites should be considered equal and the assumption that Site 52A is preferable to other sites based on the perceived protection provided by the WPA should be removed from consideration. It may be more pertinent to include for consideration the potential adverse public perception generated when the situation of the NRWR in close proximity to an active Defence bombing range and proposed commercial space launch facilities becomes widespread regardless of the actual outcome of a weapon impact. Based on current public sentiment towards the NRWR there should be little doubt that a facility of this type will attract protests.

[39] DISR – 'The Monitor' January 2001 and 'Radioactive Waste The facts, not the fiction' July 2001
[40] Telecon Mr Bruce Henderson DSCW – Ranges Safety Manager / T Bearman ARDU – 15 Nov 01
[41] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01
[42] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

9.0 ECONOMIC AND STRATEGIC IMPLICATIONS OF THE NRWR ON THE WPA

9.1 Defence Activities

Defence is likely to remain the major user of the WPA in the near to medium term thereby providing significant revenue to the Woomera economy and contributing to the continued development of the WIR infrastructure. In addition, it is likely that foreign military users, who are experiencing increasing difficulty identifying suitable test locations for their emerging systems, will increase their usage of the WPA facilities. The Republic of Singapore Air Force currently uses the WPA for missile firing exercises annually. The USAF and the Royal Air Force have previously used the area for missile firings and are likely to request further use in the future. The German Department of Defence is currently investigating use of the range for firing trials of a Long Range SOW. Restrictions on operations at the WPA that require the use of the WIR will adversely affect the ability of the WPA to support these activities.[43]

If a decision was made to proceed with the NRWR at Site 52A, Defence would have little option under current guidelines to either move the range facilities (at significant cost in both time and resources to the Commonwealth), or severely limit the profiles and types of weapon releases able to be performed on the WPA. Limiting the types of weapons and weapon release profiles that can be used in the WPA would severely impinge on Defence’s ability to test and evaluate not only current in-service weapons, but also weapons likely to be acquired by Defence in the near, medium and long term. The inability to effectively test and assess such weapons would have major implications for Australia’s ability to make informed acquisition decisions and to effectively determine the operational capabilities and deficiencies of such weapons. It would also reduce the ability to accurately determine the capabilities of in service weapons systems and thus will significantly affect Defence’s offensive operational capabilities.[44]

In the future it is intended to upgrade the current optical and radar tracking devices at the WIR to allow their un-manned operation and hence reduction in safety template requirements to allow the testing of the next generation of SOWs[45]. Placement of the NRWR at Site 52A will negate the advantage provided by this upgrade and will remove the capability of the range to test these types of weapon systems under current guidelines.

9.2 Commercial Operations

Several commercial users of the WPA have already been identified in this paper. In summary the Japanese National Aerospace Laboratory, NASA and several commercial space launch organisations are identified users of the WPA. Restrictions to operations at the WPA may preclude the conduct of proposed activities and are likely to reduce the attractiveness of the WPA for commercial operations. The end result of this may be a decision by such operators to relocate their operations outside Australia with the consequent loss of revenue generated by these activities and the commercial operations supporting them.

The number of sites within the WPA suitable for launch and recovery of space craft are limited due to the proximity of the Woomera and Roxby Downs townships and the mining complex at Olympic Dam. In addition to these restrictions, the launch inclinations required by civil users and the launch site topography further restrict the availability of suitable launch sites within the area. The sites that have been selected as

[43] The UK MOD has expressed interest in using the WPA to trial the ‘Stormshadow’ SOW and the German MOD is in the planning phase for trials of the ‘Taurus’ SOW at the WPA.
[44] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01
[45] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

suitable are located near the WIR, the Woomera airfield and at Lake Hart. It is known that the launch azimuth required for at least one of these proposed sites and the associated ground danger area is in direct conflict with the proposed Site 52A location for the NRWR[46].

The risk of a space vehicle impacting the proposed NRWR at Site 52A is difficult to quantify and is beyond the scope of this paper. However, the proposal to use Site 52A for the NRWR has already precipitated the re-location of a planned National Air and Space Administration (NASA) activity at considerable cost to the customer[47]. The site also has implications for one proposal to operate a space launch facility from the existing Lake Hart launch area infrastructure.

It is feasible to assume that the location of the NRWR at Site 52A will continue to preclude some commercial operations at the WPA and contribute to a negative impression of the ability of the facility to achieve cost effective outcomes for potential commercial operators of the range.

[46] DEO – AD Property Services – Issue Paper 01 Nov 00
[47] Meeting -Mr Malcolm Tutty ARDU Director of Aircraft Stores Clearance / Mr T Bearman Nova - 21 Nov 01

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

Defence remains concerned that the siting of the NRWR within the WIR in the WPA will preclude the use of parts of the WPA for its designated purpose. Any restriction on the Commonwealth's ability to conduct test and training activities will have a negative impact on the development and maintenance of the nation's military capabilities. The proposed location of the NRWR at Site 52A within the WIR and the proposed commercial space launch centres at the WIR and Lake Hart, will result in a loss of this test and training capacity, and this will only be regained at substantial cost.

It remains Defence's position that potential new users of the WPA must take into account, and accommodate the existing use of the area. This is particularly important when it is considered that the existing use of the WPA is for the testing of warlike material in the national interest.

The review conducted for Defence on the implications of locating the NRWR at Site 52A has identified the following major concerns:

- The experimental nature of the materiel tested at the WPA generates higher than normal levels of risk of failure.
- The current and future expected operations on the WIR would expose the NRWR if located at Site 52A and the WIR to risk levels that exceed the requirements of the ADF's Aviation Risk Management Policy.
- The level of risk associated with aerospace test and evaluation and training activities conducted at the WPA is incompatible with location of the NRWR at Site 52A.
- Defence's main concern has been and remains the negative publicity that would result from a weapon impact on the range and the fact that such publicity could ultimately result in range closure and consequent significant loss to the Commonwealth's defence capability.
- The level of security currently available at the proposed Site 52A is unlikely to provide sufficient protection from outside intrusion, and is likely to require significant upgrade.
- Of the three technically acceptable sites for the NRWR selected by DEST, Sites 40A and 45A do not impact Defence operations at the WPA that require the use of the WIR.
- Selection of Site 40A or Site 45A may require greater expenditure than that required for Site 52A, however, this is likely to be extremely small in comparison to the whole of government cost of relocating the range facilities in order for the Commonwealth to retain the existing weapons T&E and training capability provided by the WPA.
- In order to comply with the ALARP and ALARA principles stated in the various published risk criteria, one of the two alternative sites not impacted by the operation of the WIR/WPA should be selected.

10.2 Recommendations.

It is recommended with respect to the proposal to locate the NRWR at Site 52A in the WPA that:

- Site 52A should be removed from consideration for the NRWR.
- Based on the results of an environmental impact study, one of the identified alternative sites should be selected as the preferred location for the NRWR.

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Impact on Australian Defence Organisation Operations
Of Locating the National Radioactive Waste Repository
At Site 52A within the Woomera Prohibited Area
Woomera, South Australia

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APPENDIX A

OPERATIONAL RISK ASSESSMENT

FOR THE AUSTRALIAN DEFENCE ORGANISATION AEROSPACE TEST RANGE AND NATIONAL RADIOACTIVE WASTE REPOSITORY AT WOOMERA, SOUTH AUSTRALIA

Prepared for

Property Services
Department of Defence
Russell Offices
Canberra ACT 2601

HLA-Envirosciences Project No DO166

by

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17 April 2019

EXECUTIVE SUMMARY

Introduction

The Australian Department of Defence (Defence), manages the Australian Defence Organization Aerospace test Range at Woomera, South Australia. The range is used for the testing of ordnance (bombs and missiles) and for aerospace research (rocket flights). The Radioactive Waste Section of the Department of Education, Science and Training (DEST) formerly within the Department of Industry Science and Resources (DISR) has been tasked with locating the National Radioactive Waste Repository (NRWR) for the storage of low level radioactive waste. DEST has proposed three sites; One to the north east of Woomera (Site 45a), one to the east of Woomera (Site 40a) and one in the Woomera Protected Area (WPA), being located close to the WIR (Site 52a).

At Site 52a, Defence has raised concerns regarding the potential for ordnance impact on the NRWR and the requirement that should the NRWR be located close to the WIR, range testing may be restricted. Defence has commissioned HLA-Envirosciences Pty Limited (HLA) to facilitate a review of the hazards and risks associated with the simultaneous operation of the WIR and NRWR.

National Radioactive Waste Repository

The NRWR will be a shallow trench repository, about 20m deep, with a 2-5m cover to prevent infiltration of rain water, inhibit erosion and prevent intrusion by humans and animals. The repository will be about 100m long by 100m wide and will be located in a buffer zone area 1.5kms x 1.5kms. The preferred NRWR Site is located about 9km west of the existing WIR range head and immediately adjacent to target areas on the range. The Site has been designated 52a.

Weapons Instrumented Range

The WIR was initially developed in the late 1940's for the testing of guided weapons and other rocket powered vehicles. The WIR has a range head installation and a number of instrumented points for the monitoring and control of weapons tests. A number of target points have been established on the range and each test is conducted to impact a selected target. Weapons tested include:

- Bombs (ballistic – guided and ballistic – non-guided);
- Rockets (unguided);
- Air-to-ground precision guided munitions (aircraft launched missiles); and
- Air-to-air missiles.

The experimental nature of the weapons testing conducted at the WPA necessarily means that during weapons tests there is a potential for weapon component failure or human error, leading to failure of the weapon to strike the selected target. As personnel are located at selected instrument points on the range there is a potential for a failed weapon to strike a staffed location. To ensure the risk of such events is minimised, a safety template is developed for each weapons test. The safety template is a series of fatality risk contours surrounding the target point which decrease in fatality risk as the distance from the target increases. The risk is determined to be acceptable when the 1×10^{-6} fatality probability contour does not impact any personnel staffed points on the range.

Hazard and Risk Assessment

In the event of an object (for example a bomb or missile) striking the repository, there is a potential for the object to penetrate the repository cover and, depending on the size and speed of the object, considerable damage may result causing radioactive materials to be ejected from the repository (either at the surface or carried through the repository by the object). Data provided by ARDU indicates that up to 70% of the weapons tested at the WIR have the capacity to breach the NRWR. It is noted, however, that the proposed storage is for low level radioactive waste only and that any materials ejected from the repository would be diluted by the surrounding land and soils, resulting in a negligible raising of the background radiation level and negligible potential for fatality. Nonetheless, a release of radioactive materials would be considered a severe if not catastrophic environmental and public/media condemnation incident by the majority of published consequence criteria.

As the preferred Site (Site 52a) for the NRWR is located close to the WIR, a review of a number of safety templates was undertaken. It was identified that Site 52a falls within contours for the probability of impact greater than $1x10^{-6}$ per test for several of the weapons likely to be tested at the WIR. The range is used at a varying frequency for such tests and in some past years weapons testing has not be conducted. However, in other years the range has been subjected to a considerable number of weapons tests. A review of The Aircraft Research and Development Unit (ARDU) tests conducted in past 10 years indicates that over 600 weapons have been released at the WPA by Defence alone. Future bookings of the range and the WPA programme indicate that a considerable number of weapons tests will be conducted and more commercial users will take advantage of the facilities at the range. ARDU has booked three weapons testing periods of one month each in each of the next three years. It is anticipated that heavy use of the range during this period is likely.

Based on previous test programmes, it has been conservatively assumed that there would be a requirement for up to 60 weapons tests per annum over the next three years, and that each of these tests would require a template that impinges on the Site 52a location for the NRWR. Hence, the potential risk of impact on the NRWR would be 60 p.a. x $1x10^{-6}$ = $6.0x10^{-5}$p.a., during this period. The potential release frequency of radioactive materials would be 0.7 (fraction of weapons that may breach the NRWR) x $6x10^{-5}$ p.a. = $4.2x10^{-6}$ p.a. These result may be considered conservative as:

- there could be considerably more weapons tests per annum than the assumed number, based on the proposed WIR test programme over the next three years; and
- in many cases the NRWR lies well within the safety template of the weapons required to be tested at the range (i.e. risk of impact is therefore greater than $1x10^{-6}$ per test).

This analysis does not include the commercial users of the range, which would increase the risk of impact even further.

Assessment of Risk Against ARPANSA Risk Criteria

ARPANSA has published risk criteria that states: "…risks must be as low as reasonably achievable (ALARA)". Satisfactory alternate sites, to Site 52a, are available for the location of the NRWR that not impacted by the WIR. It is obvious that these sites would be less risk than Site 52a and would comply with the ALARA principle required by ARPANSA.

Assessment of Risk Against Industry Criteria

Industry published criteria states that the risk of an undesired outcome (e.g. fatality, catastrophic environmental impact, catastrophic plant/equipment damage, national media/public impact, etc.) is unacceptable at a frequency exceeding $1x10^{-5}$ per annum. As the release of radioactive material could be classified as a catastrophic environmental event (particularly from the public and media angle), and as the frequency of such an incident has been calculated to be $4.2x10^{-5}$ per annum for Site 52a, this risk is unacceptable by industry standards.

Assessment of Risk Against CAF Directive 02/01

CAF Directive 02/01 – RAAF Aviation Risk Management (AVRM) states that FEG Commanders should issue guidelines on the assessment of risk in accordance with the methodology published in AVRM. ARDU has indicated that a weapon impact on the NRWR as a result of testing at the WIR would be classified as a "Disastrous" incident using the AVRM, as it would incite wide spread public condemnation of the ADF. Under the CAF Directive, ARDU has indicated that any operation resulting in a consequence classification of "Disastrous" would not be undertaken. Further, the CAF Directive directly equates widespread public condemnation with fatalities. Hence, the published risk criteria for fatalities should also be met for widespread public condemnation incidents. ARPANSA and other regulatory authorities (PlanningNSW) have published fatality risk criteria stating that the fatality risks from hazardous facilities must not exceed $1x10^{-6}$ p.a. It has been demonstrated that the risk of impact on the NRWR from activities at the WIR, and hence widespread public condemnation, is estimated to be $6x10^{-5}$ p.a. This exceeds the criteria of $1x10^{-6}$ p.a., and therefore under the CAF directive ARDU would be required to modify, and in some cases cease, operations at the existing WIR.

Hence, to reduce the risk to acceptable levels, it would be necessary to prevent the impact of safety templates on the NRWR at Site 52a. This would require the limitation of operations at the WIR.

Conclusions

Based on the published risk criteria and the assessed risks associated with the joint operation of the WIR/WPA and the NRWR at Site 52a the following conclusions are drawn:

1. In the majority of assessed risk cases, the operational risks in the WIR are intolerable or unacceptable;

2. In some of the assessed risk cases, the risks of operations at the WIR fall within the upper bounds of the "as low as reasonably practicable (ALARP)" or "as low as reasonably achievable (ALARA)" ranges, requiring further risk reduction.

3. In no case is the risk of operations at the WIR within the acceptable range.

4. The risk assessment is very conservative and actual risks would be expected to be higher than those estimated in this analysis.

5. The assessment takes no account of commercial users, which would increase the risk further.

6. In the event Site 52a is selected for the NRWR, in order for Defence to continue the use of the range it would be necessary to modify the current range use or to cease operations at the range to meet the risk profile required by the various risk management publications applicable to the range operations.

Recommendations

Based on the assessment conducted in this document and the conclusions drawn, the following recommendations are made:

1. In order to comply with the ALARP and ALARA principles stated in the various published risk criteria, it is recommended that an alternate site to Site 52a be selected for the NRWR. The two available alternate sites are not impacted by the operations at the WIR/WPA and hence comply with the ALARP and ALARA principles.

2. In the event Site 52a is approved for location of the NRWR, it is recommended that Defence limit the types of weapons tests as well as attack directions, release points and other test parameters to ensure

the safety templates do not impact the NRWR. Not only would this place additional financial burdens on the Department of Defence, it would limit or preclude a large number of operations at the range.

3. In the event Site 52a is approved for location of the NRWR, and Defence is not able to limit the use of the range, it is recommended that an alternate location for the range be found and that the range operations be relocated to this area. The alternate location of the range should be subjected to a rigorous risk assessment to ensure the risks associated with the new location meet the various published risk management criteria.

4. In the event Site 52a is approved for location of the NRWR, it is recommended that each commercial venture proposed at the WPA be subjected to a rigorous risk assessment to ensure the NRWR is not impacted above the published risk criteria.

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ABBREVIATIONS

Abbreviation	Description
AAW	Area Administrator, Woomera
ADF	Australian Defence Force
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ARDU	Aircraft Research and Development Unit
ARPANSA	Australian Radioactive Protection and Nuclear Safety Agency
AVRM	Aviation Risk Management
CAF	Chief of Air Force
DEST	Department of Education, Science and Training
DISR	Department of Industry Science and Resources
DoD	Department of Defence
DPS	Director of Property Services
FEG	Force Element Group
FTS	Flight Termination System
HE	High Explosives
kg	kilograms
kms	kilometres
m	Metres
m^2	square metres
MA	Managing Activity
Mil-Std	Military Standard
NRWR	National Radioactive Waste Repository
p.a.	per annum
SQN	Squadron
WIR	Weapons Instrumented Range
WPA	Woomera Protected Area

1 INTRODUCTION

1.1 Background

The Australian Department of Defence (Defence), manages the Defence Aerospace Test Range at Woomera, South Australia (the range). The range, which is located within the Woomera Prohibited Area (WPA), is used for the testing of ordnance released from aircraft and has been established with instrumentation for the monitoring and recording of ordnance tests.

The Radioactive Waste Section of The Department of Education, Science and Training (DEST) formerly within the Department of Industry Science and Resources (DISR) has been tasked with locating a suitable site for establishing the low level National Radioactive Waste Repository (NRWR). DEST has identified three suitable sites, the preferred site being within the confines of the range at Woomera.

Defence has raised concerns regarding the potential for ordnance impact on the NRWR and the requirement for consideration of the NRWR during range operations. Defence is concerned with the potential for limitation of the use of the range as a result of the NRWR and has commissioned HLA-Envirosciences Pty Limited (HLA) to assess the risks associated with the simultaneous operation of the range and the NRWR.

This document reports on the objectives, scope of work, methodology, analysis and conclusions of the operational risk assessment for the Defence Aerospace Test Range and National Radioactive Waste Repository at Woomera, South Australia.

1.2 Objectives

The objectives of the risk assessment are to:

- identify the hazards associated with operating the NRWR and the range simultaneously and develop hazard scenarios;
- assess the consequences of the identified hazardous scenarios;
- assess the frequency of the identified hazardous scenarios;
- estimate the risk of the identified hazardous scenarios;
- compare the estimated risks with published risk criteria; and
- prepare a report detailing the study findings and conclusions.

1.3 Scope of Work

The scope of work for the study is for an operational risk assessment of the Defence Aerospace Test Range and National Radioactive Waste Repository at Woomera, South Australia. The study includes:

- NRWR - Site 52a at Woomera, and
- Range activities that may impact NRWR – Site 52a at Woomera.

Whilst not within the scope of the study, other activities within the range area may impact Site 52a. These have been discussed qualitatively only in order to highlight other potential impacts on the proposed repository location.

Only a brief description of the WPA and the proposed NRWR at Site 52a is provided in this study. A more detailed description is contained in the main consolidated report.

2 BRIEF DECRIPTION OF NRWR AND RANGE OPERATIONS

2.1 The Low Level National Radioactive Waste Repository

The location of Site 52a, the DEST preferred location for the NRWR, is illustrated in **Figure 2.1**. **Figure 2.2** shows the location of the preferred NRWR at the Evetts Field West locality in the Woomera Prohibited Area (WPA).

2.1.1 Design of the NRWR

An engineered shallow trench repository, illustrated in **Figure 2.3**, for the disposal of low level waste is proposed. The near-surface disposal structure is expected to occupy and area of about 100m by 100m and would consist of one or more trenches about 20m deep. Figure 2.3 shows a typical repository structure.

A suitably engineered cover, of between 2 to 5m (Ref.4), will be placed over the buried waste to limit the infiltration of rainwater, discouraging human intrusion or intrusion by animals or plant roots, and inhibit erosion. The cover will be designed to ensure that only a negligible quantity of rainwater, falling directly on the repository, will percolate down to the depth of the buried waste. Nearly all rainwater will run off the cover or be evaporated back to the atmosphere.

The repository would be surrounded by a buffer zone so that the total area of the Site would be about 1.5kms by 1.5kms.

2.1.2 Operations at the NRWR

The proposed repository size will far exceed the current low level radioactive waste storage in Australia. Hence, it is proposed to develop the repository in a staged process. Stage 1 will commence with the development of a trench, about 20m deep, to store the existing low level radioactive waste located in various storages around the country. Once stored, the radioactive waste storage receptacles will be covered with layers of materials, between 2 to 5m deep (Ref.4), to control wind and water erosion and eliminate the possibility of accidental human/animal contact.

As further low level radioactive waste accumulates, at various locations throughout the country, additional trenches will be excavated on the end of, or adjacent to, the existing trench. The waste will then be transported to the repository and covered as detailed above.

Once the selected repository site has been confirmed a comprehensive monitoring programme will begin at the site, well before any radioactive material is stored in the repository. The monitoring will continue throughout the life of the repository, including a detailed survey of the background radiation around the repository to provide a basis for assessing the results of later surveys. Regular repository surveys will be conducted and an action plan developed to provide remedial action if required. The monitoring programme would include the following elements:

- collection and testing of vegetation samples from the Site and buffer zones for radioactive materials;
- collection and testing of soil samples
- installation of air samplers at the Site boundaries to collect upwind and downwind samples for testing;
- monitoring of ground water using sampling bores on the Site and in the buffer zones;

- monitoring of the surface water after major rain; and
- monitoring of flood drains beneath the waste for the presence of water (and if found testing for radioactive contamination).

During this monitoring phase and during the construction and ongoing operation of the NRWR, significant impacts will occur to the scheduling and operation of the Defence activities in the WPA.

2.2 The Woomera Prohibited Area

2.2.1 History and Future Development

Figure 2.2 shows the location of the WIR and Site 52a within the WPA. The WPA and associated ranges were initially developed in the late 1940's for the testing of guided weapons and other rocket powered vehicles to be launched in a westerly direction from sites near the range head. The use of the range has significantly changed and the WPA, and in particular the Woomera Instrumented Range (WIR), are now essential components of Defence's ability to test warlike materials. Also of importance is the attractiveness of the geography and infrastructure at the WPA for space operations including launches and recovery of space vehicles. Recent emphasis has focused on the testing of a wide variety of air-to-air and air-to-ground guided and un-guided weapons systems, and it is foreseeable that an increasing focus on space launch activities from the WPA is likely.

2.2.2 Brief Description of the WPA and WIR

Figure 2.4 shows the location and layout of the WPA and WIR. The WPA contains the WIR and several designated weapons practice target areas, which are used by Defence for the testing of warlike materials. Existing range facilities include:

- range control;
- timing;
- communications;
- telemetry;
- tracking facilities; and
- rocket launch emplacements.

These facilities include specially surveyed instrumentation emplacements for the optical tracking of aircraft and weapons in flight, launch sites, preparation and recovery facilities for high **explosive** weapons and rocket systems. The WIR also includes significant infrastructure for the support of ADF weapons tests and evaluation, and commercial space launch activities.

2.2.3 Brief Description of Range Operations

A large variety of air-to-air and air-to-ground weapons are employed by Defence and foreign military users of the WPA and WIR. Similarly, a variety of launch vehicles (experimental, commercial and research, using proven launch systems) are operated by Defence, foreign military and civilian (commercial/research) users of the WPA and WIR. Failures of any of the systems being used at the WPA and WIR may lead to weapons straying outside intended target areas and striking unintended locations.

This may have serious ramifications if personnel or sensitive equipment are located in the unintended strike zone.

To limit the potential for this occurrence, safety templates are developed and used for each of the systems under test by the system operators.

2.2.4 Safety Templates for Range Use

Each weapon tested has the capacity to fail during the test cycle. Minor failures of weapon or release components may have little or no effect on the outcome of the test and the weapon deployment continues along the designed trajectory or flight path. However, in the event of critical component failure, there is a potential for the weapon to deviate from the intended target and impact some distance from the target area. Failures may occur in any of the hardware or software systems used to control these weapons, leading to weapon deviation and impact away from the intended target. Human and software errors (e.g. the early or late release of the weapon) may also result in failure to impact the intended target resulting in impact away from the target zone.

It is noted, however, that human and software errors in the launch/release platform (aircraft) are not accounted for in the safety template development and must be considered as additional risks. Examples of such risks are:

- Incorrect weapon release computation in the aircraft mission computer; and
- Pilot release on the wrong target either by mis-identification of the target or through incorrect input of target co-ordinates to the mission computer.

As an example, there have been at least two incidents in the last 10 years of weapons impacting in close proximity to managed range facilities at Delamere Air Weapons Range (Northern Territory) and Salt Ash Air Weapons Range (Williamtown, NSW) due to incorrect target identification by pilots.

During weapons tests, test personnel are located at permanent instrumented points along the range to assist in the control of instrumented systems and the gathering of test data. In the event of critical failures in test weapon systems, there is a potential for the weapons to land in the areas where personnel are located, resulting in injuries or fatalities. The application of safety templates to each weapon test scenario ensures that scenarios where personnel are exposed to a hazard above an acceptable levels are not conducted.

Further mitigation of the risk to personnel and infrastructure can be achieved by the incorporation into some weapons systems of a Flight Termination System (FTS). The FTS is activated by the weapons control centre at the range head, in the event a weapon failure occurs and the weapon is observed to diverge from its allowable flight path by more than a predetermined acceptable degree. In this situation the weapon test manager will order a flight termination, which will destroy the weapon before it breaches the predetermined safety template.

Hence, to address the potential for overall system failure, in test weapons, a detailed safety analysis is conducted including:

- Hazard Identification (e.g. Failure Modes and Effects Analysis – FMEA);
- Consequence Analysis;

- Frequency Analysis; and
- Risk Analysis.

Where tests have previously been conducted on a specific weapon (i.e. ongoing life testing), data is retained on weapons behaviour and used in safety modelling. The results of the analysis are used to develop a series of probabilistic fatality risk contours for each weapon test. These contours are then used to establish a safety template for the weapon test, which is applied to the test range to ensure all personnel are located outside the template boundary. As an added safety measure buffer zones are added to the template to provide additional distance between the test zone and the instrument operation personnel.

For many experimental weapons tested at the WIR, safety templates are deterministic because of the lack of available statistical data on weapon releases of new systems, which can be used to generate probabilistic templates. Deterministic templates are generally accepted as equating to a $1x10^{-6}$ probabilistic template.

Defence has adopted US Range Commanders Council Standard 321-97 (Ref.2), which publishes acceptable risk criteria for range operations. The criteria selected by Defence is that personnel shall not be subjected to a fatality risk exceeding $1x10^{-6}$ per weapons test. The safety templates are thus developed to ensure personnel are located outside the fatality probability risk contour of $1x10^{-6}$ per weapons test.

Hence, when a weapons test is planned, a safety template is developed for the test sequence. This is overlaid on a map of the test range and the weapon application area is determined to ensure all personnel required to be on the range are outside the template boundary.

An example of a safety template is shown at **Figure 2.5**. It can be seen that for this template, the weapon application is by aircraft flying in a north to south direction. The aircraft is flying perpendicular to the test range centreline and instrumented points, at which personnel are positioned, are located outside the template boundary.

It can be seen in **Figure 2.5** that for this test, Site 52a is located within the template boundary and, hence, the risk of impact on the Site is greater than $1x10^{-6}$ in this case.

2.2.5 Typical Weapon Test

A brief description of a typical weapon test is given below. The selected weapon test is a non-guided bomb.

Three main types of non-guided bombs are tested at the WIR; 2000lb, 500lb and 25lb practice bombs. The bombs are deployed from aircraft in level flight or when the aircraft is climbing or diving. Prior to weapons test, a test plan is developed which includes the full series of tests required for the weapon, listing the required attack directions for the aircraft. The safety template for the bomb is then applied to the range for each attack direction to ensure personnel staffed instrument locations are outside the template boundary.

Figure 2.6 shows a typical template for an un-guided bomb as applied to the WIR. **Figure 2.7** shows a cross section of the bomb release and impact on the WIR. The test weapon (bomb) is loaded and the aircraft then deploys to the WIR. There are two methods of weapons release:

- **Instrument Assisted Release -** on approach to the WIR, the bomb deployment systems on board the aircraft indicates to the pilot the exact location of the bomb release point to ensure the weapon hits the intended target. Once released the bomb travels on a ballistic trajectory until it impacts the target.

- **Manual Release** – on approach to the WIR, the pilot may release the weapon based on a visual identification of the target or an interpretation of the target from a radar or infra-red image.

Failure to deploy the weapon at the required point of release will result in a failure to impact the target. Depending on the deployment location (i.e. before/after the optimum deployment point or to the left or right of the impact deployment point), the bomb will land outside the required target zone and possibly outside the template. However, templates are designed to limit this risk to a fatality probability of $1x10^{-6}$ per weapon test.

During the weapon test, the instruments on the WIR record the bomb trajectory and behaviour. The results of these tests may be used, for example, to verify predicted weapon behaviour amongst other uses.

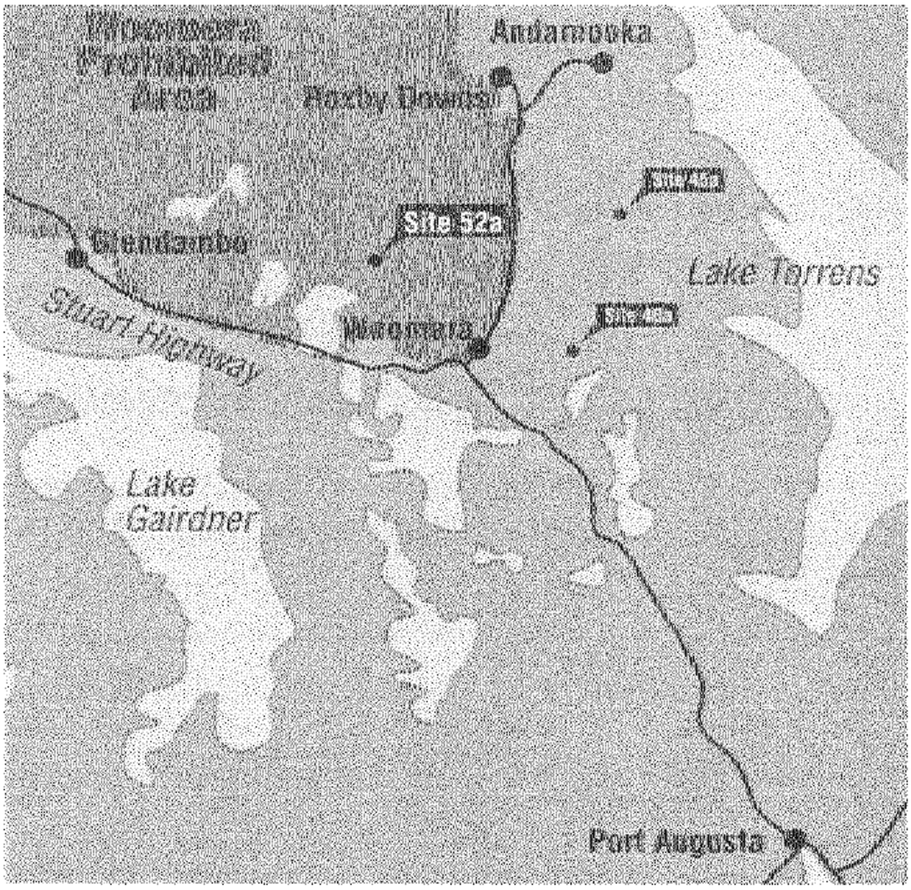


FIGURE 2.1
LOCATION OF SITE 52a IN THE WOOMERA PROTECTED AREA

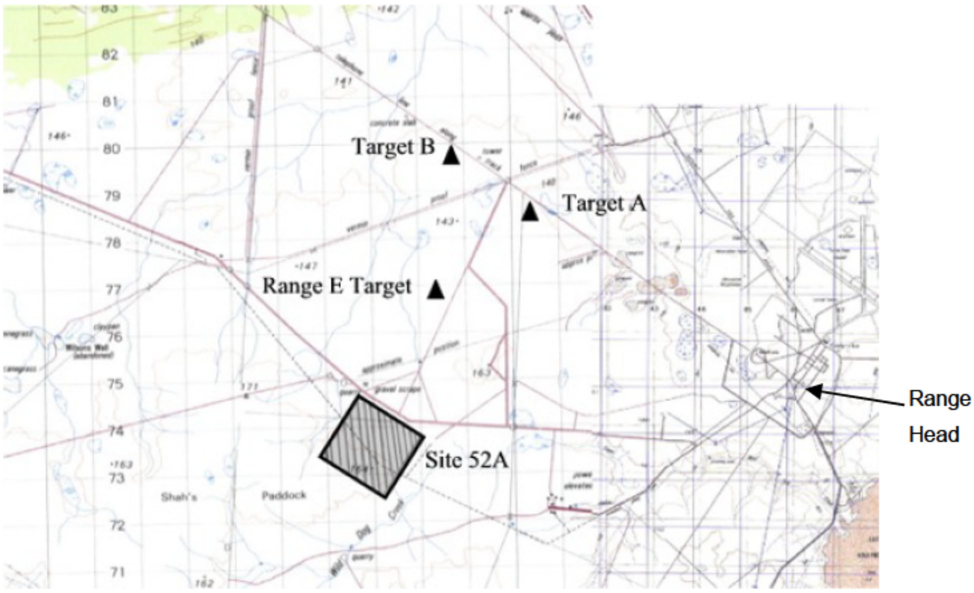


FIGURE 2.2
SITE 52a LOCATION WITHIN THE WEAPONS INSTRUMENTED RANGE

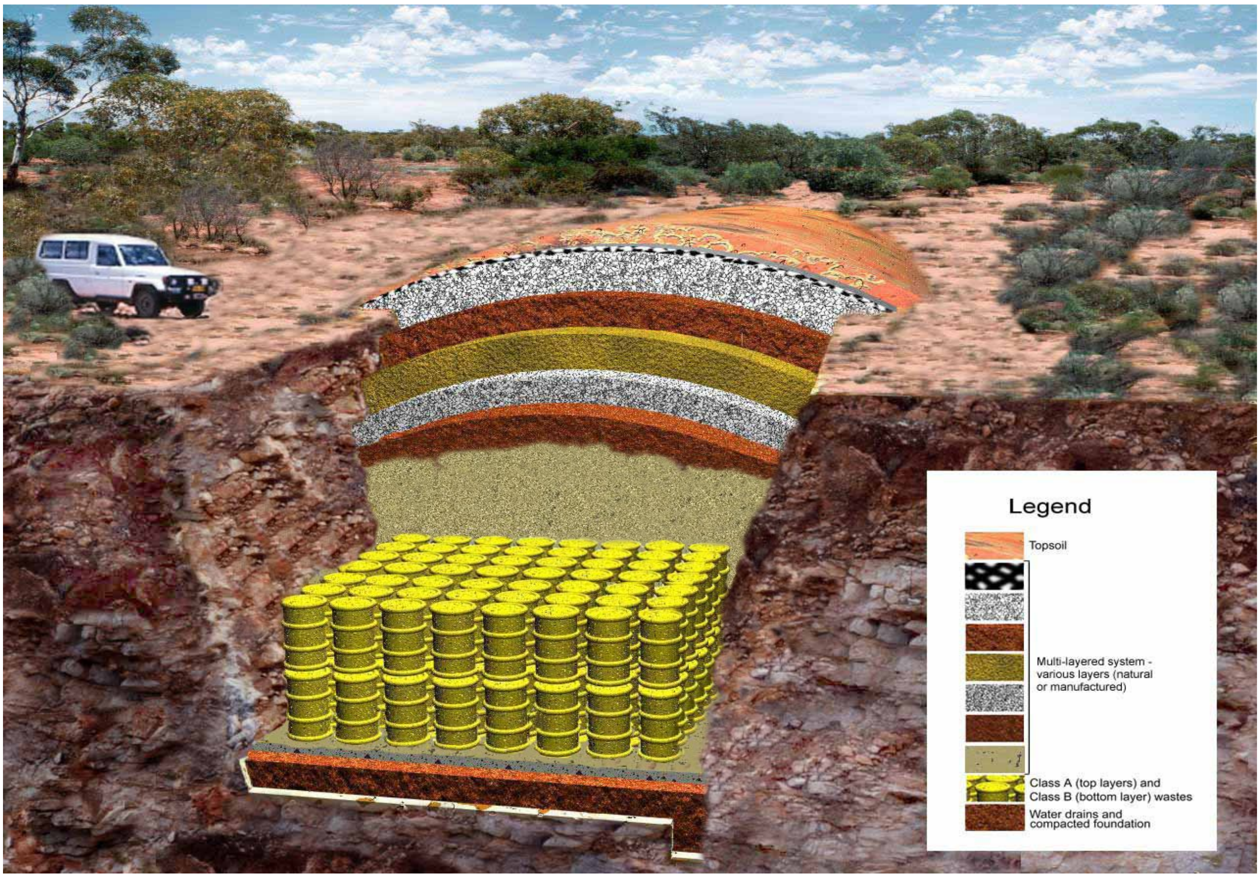


FIGURE 2.3
TYPICAL LOW LEVEL RADIOACTIVE WASTE REPOSITORY

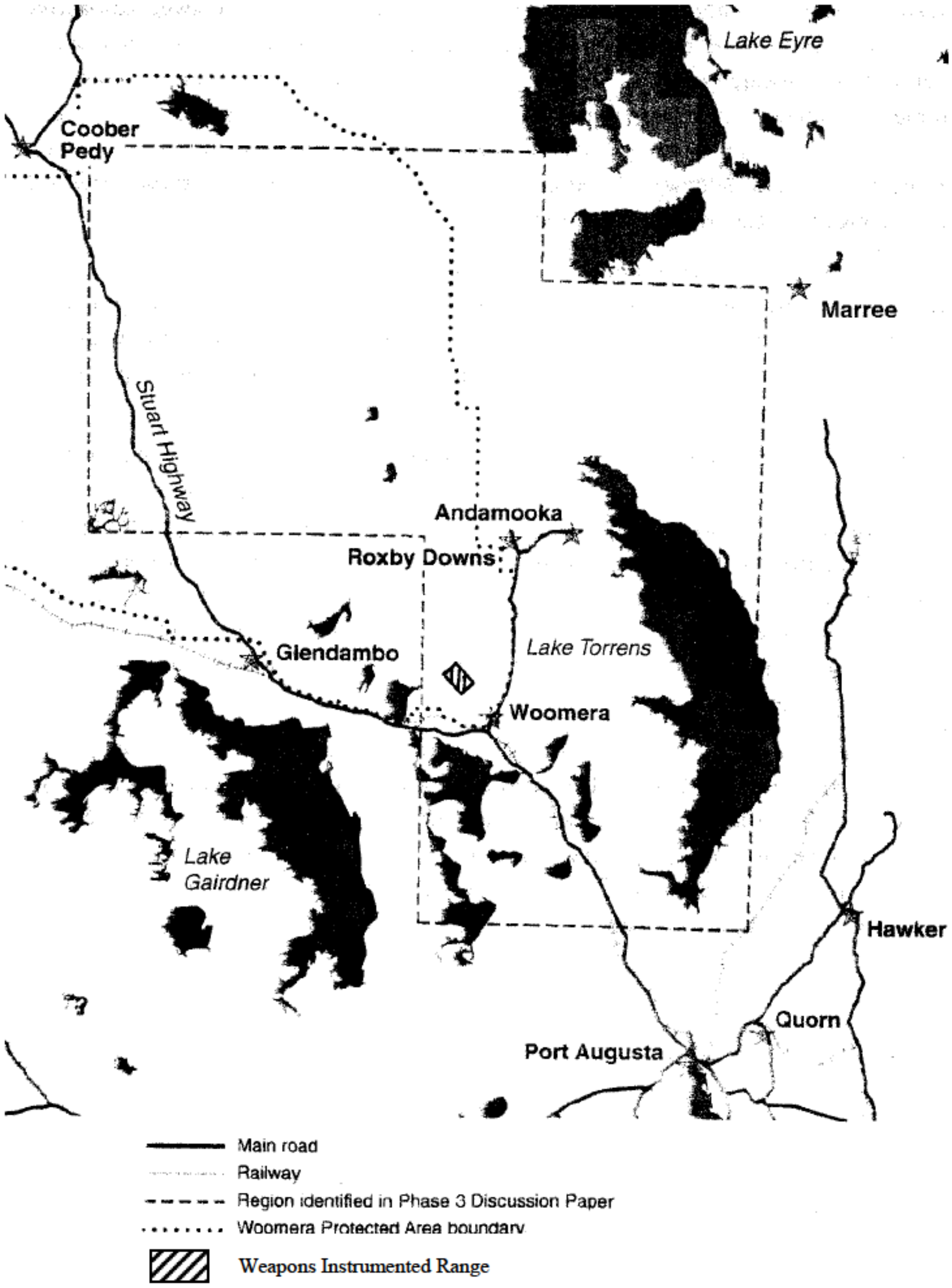


FIGURE 2.4
LOCATION OF THE WEAPONS INSTRUMENTED RANGE IN THE WOOMERA PROTECTED AREA

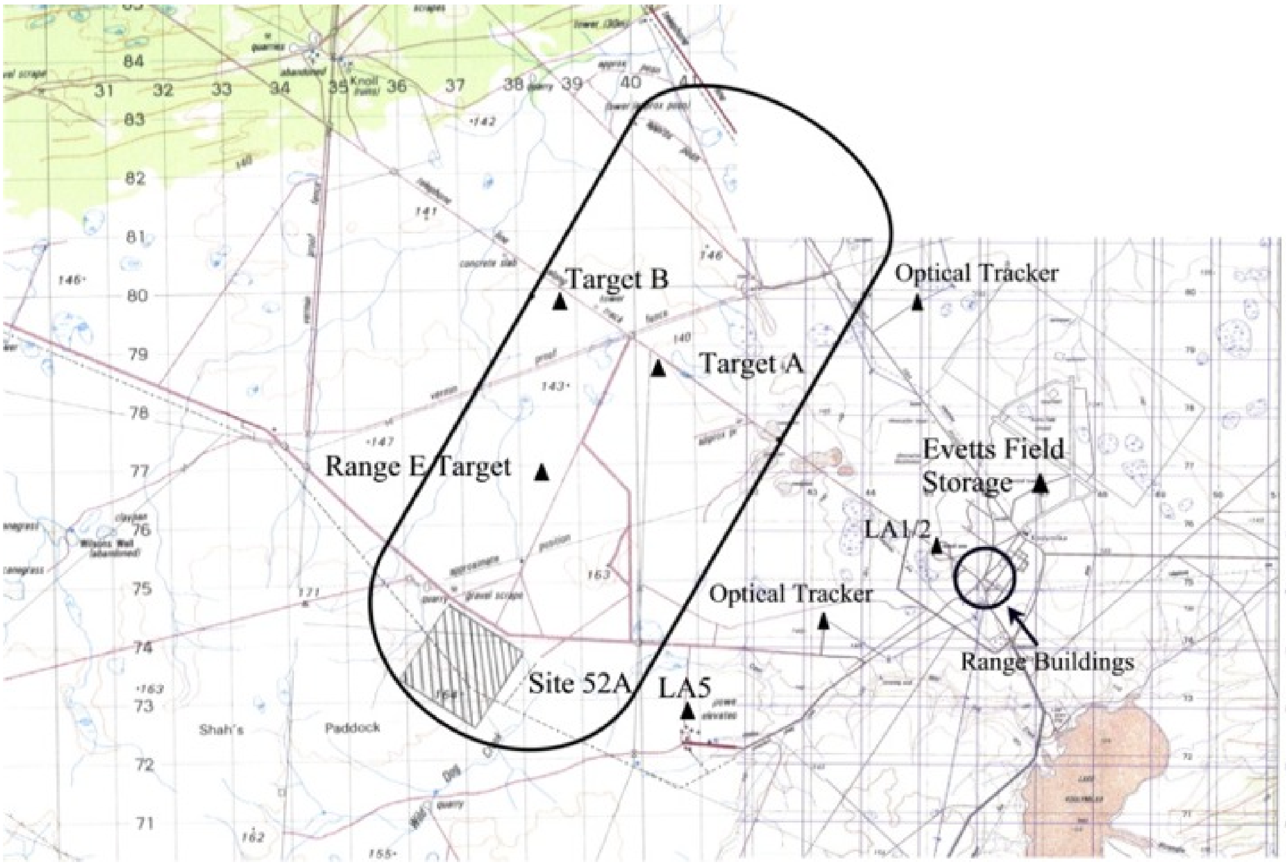
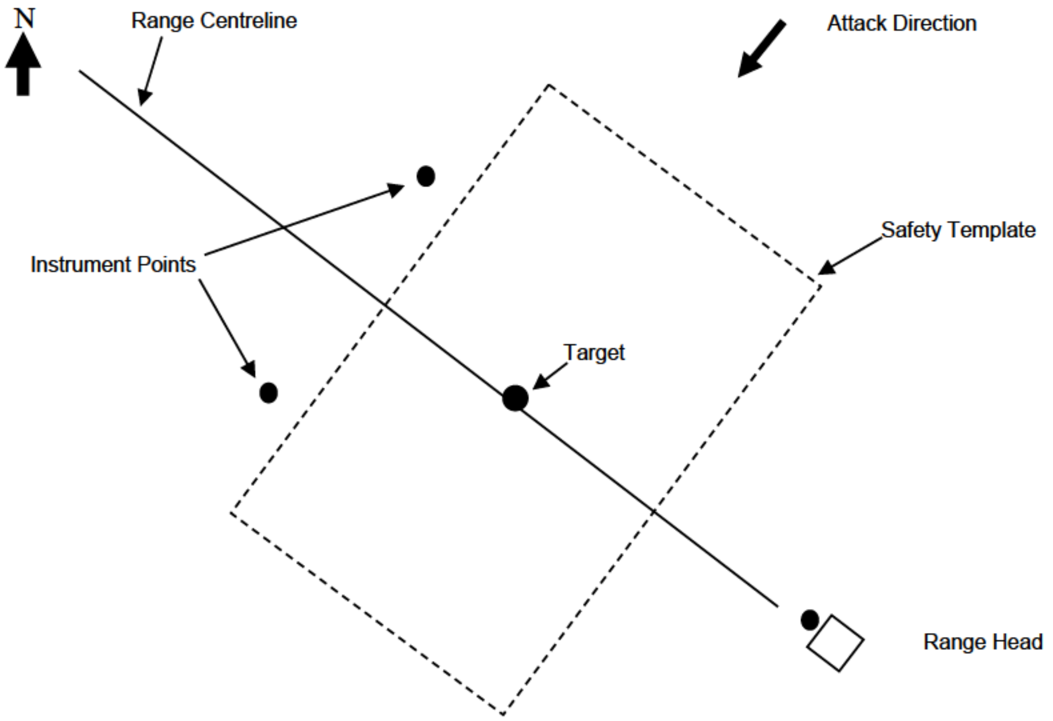


FIGURE 2.5
SAMPLE SAFETY TEMPLATE APPLIED TO THE WIR
(SHOWING THE LOCATION OF SITE 52a)



Not to
Scale

FIGURE 2.6
UN-GUIDED BOMB TEST SHOWING THE SAFETY TEMPLATE AND WIR

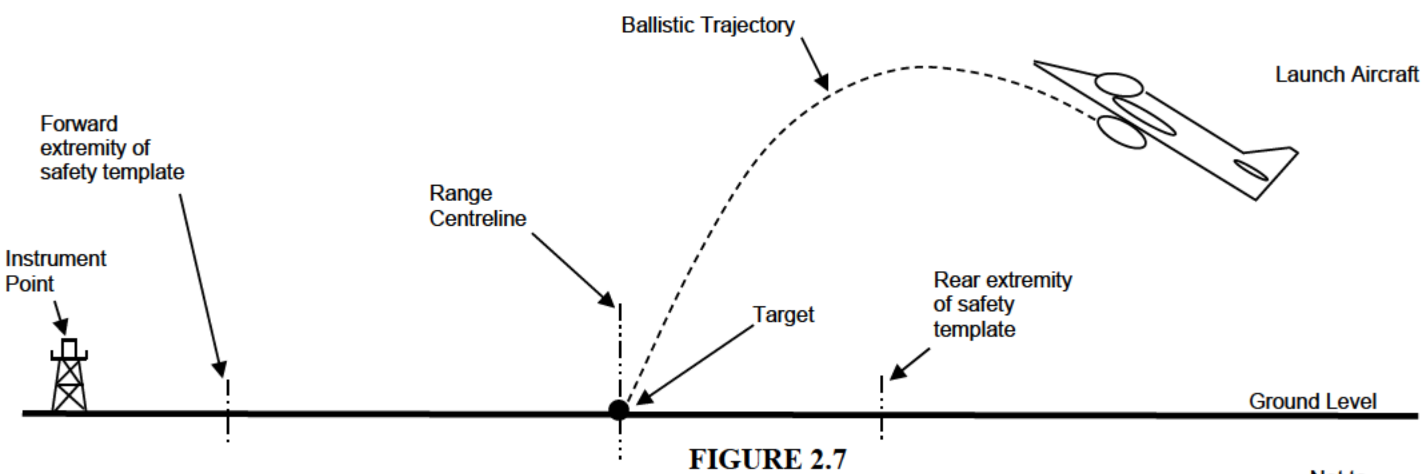


FIGURE 2.7
BOMB DEPLOYMENT FROM AIRCRAFT

Not to
Scale

3 METHODOLOGY

The risk assessment methodology was conducted as follows:

- **Data Gathering** – a number of visits were conducted to gather data and information relating to the operations at the WPA and WIR, and the design and operation of the NRWR. These visits included the following:
  - Visit to the Department of Industry, Science and Resources in Canberra to discuss the proposed design and operation of the NRWR.
  - Visit to the WPA and WIR to review the location of the proposed NRWR in relation to the weapons test area in the WIR.
  - Meeting with the Woomera Range Management to familiarise with the operations at the range.
  - Visit to the Aircraft Research and Development Unit (ARDU) to identify the types of tests conducted at the range, the likely hazards as a result of the tests, the consequence of identified hazards and the frequency of identified hazards.
- **Hazard Analysis** – a detailed hazard analysis was conducted using the data and information gathered from ARDU and other sources.
- **Consequence Analysis** – The consequences of each identified hazard was estimated based on the weapon impact information provided by ARDU. Where weapon impact was identified not to breach the NRWR, the incident was screened from further analysis. Only those incidents with the potential to breach the NRWR were carried forward for further analysis.
- **Frequency Analysis** – the safety templates were used as the basis for the frequency analysis. Safety templates have been developed to indicate the risk of fatality from an individual weapons test and contours for a fatality risk of $1x10^{-6}$ per test have been developed. These contours were used to assess the annual risk of impact on the NRWR Site.
- **Risk Assessment** – the consequence and frequency results were combined to determine the risk of impact on and breach of the NRWR from a weapon impact as a result of a weapon test failure. The results were compared to risk criteria from various published sources including ARPANSA, industry, and Chief of Air Force.

The results of the analysis were then compiled and a report developed including study conclusions and recommendations.

4 ANALYSIS AND RESULTS

4.1 Hazard Analysis

The WIR is used for testing a series of air-to-ground and air-to-air weapons. **Table 4.1** lists examples of the weapons that may be tested at the range.

TABLE 4.1
EXAMPLES OF WEAPONS TESTED AT WPA
(INCLUDES WEAPONS TYPES)

WEAPON	TYPE
Air-to-Ground	
Mk82 LDGP	500lb Bomb
Mk82 SEHD	500lb Bomb
Mk82 AIR	500lb Bomb
Mk84 LDGP	2000lb Bomb
Mk84 AIR	2000lb Bomb
BDU-33 C/B (AUST) LD	25lb Practice Bomb
BDU-33 C/B (AUST) HD	25lb Practice Bomb
LGTR	Laser Guided Training Round (50lb practice bomb)
GBU-10 PAVEWAY II	2000lb Laser Guided Bomb
GBU-12 PAVEWAY II	500lb Laser Guided Bomb
GBU-24V(1)/B PAVEWAY III	2000lb Laser Guided Bomb
GBU-24V(2)/B PAVEWAY III	2000lb Laser Guided Bomb
FZ-68	2.75 inch Folding Fin Rocket
CRV-7	2.75 inch Folding Fin Rocket
Stand-Off Weapons	
AGM-142E	3000lb Stand Off Guided Missile
KEPD 350	Cruise Missile
ALARM	70lb Guided Missile
Ait-to-Air	
AIM – 7M Sparrow	Guided Missile
AIM – 9L/M Sidewinder	Guided Missile
AIM – 120 AMRAAM	Guided Missile
AIM – 132 ASRAAM	Guided Missile

Future weapons development may introduce new weapons that are tested at the range, however, it is difficult to pre-empt the types of weapons that may be tested, and hence, the associated safety templates. Nonetheless, for this analysis, the existing weapons may be grouped into four main categories, which would also cover the anticipated weapons types to be tested in the future. The four main categories are:

- Bombs (ballistic – guided and ballistic – non-guided);
- Rockets (unguided);
- Air-to-ground precision guided munitions (aircraft launched missiles); and
- Air-to-air missiles.

A key note in relation to all weapons used at the WIR is that weapons used during tests do not contain high-explosives (HE). However, this does not preclude the use of HE in the future.

4.1.1 Hazards Associated with Bombs

Bombs are released from aircraft and strike the ground at a designated target zone. Bombs can be split into two groups; guided and un-guided.

Un-guided Bombs

When an unguided bomb is released from an aircraft its trajectory is ballistic, that is its trajectory follows a course determined by set parameters such as gravity, wind, speed, etc. Once released, the impact zone of the bomb can be readily calculated based on ballistic path. Hence, a target zone can be readily calculated based on the knowledge of ballistic parameters. However, failure to meet any parameter will result in the bomb landing away from the target.

Similarly, even if a weapon is released at the correct point, weapon separation problems (which form a considerable portion of new weapons tests) may result in the weapon releasing abnormally and landing significant distances from the intended target. Such effects may also be exacerbated by damage to weapon fins, wings or control services resulting from these weapon separation issues.

As it is likely Site 52a would be located within the safety template for such a weapon, as illustrated in **Figure 2.5**, a hazard exists that the ballistic parameters for weapon release are not met to such an extent that the bomb would fall in the area of Site 52a, resulting in potential breach of the repository. This potential incident has been carried forward for consequence analysis.

Guided Bombs

Unlike un-guided bombs, which travel on a predetermined trajectory, guided bombs are fitted with a guidance system comprising laser guidance equipment, fins and wings, which are deployed once the bomb is released. The laser guidance system is deployed to locate the target and guide the bomb using the wings and fins. As the weapon does not contain any propulsion system, the trajectory of this bomb is a modified ballistic path.

It is noted, however, that the potential for failure of test weapons is greatly increased in this case as there are added parameters (i.e. guidance systems, mechanical equipment, etc.) which are capable of failing leading to greater potential to miss the target.

Figure 2.5 shows a typical safety template, target and the location of Site 52a. Failure to meet the ballistic criteria would result in the potential for a bomb landing at any location within the template. The distance that the bomb fell away from the target would depend on the magnitude of failure to meet the ballistic criteria. For example if the target zone had been designed on a ballistic path, taking account of a set wind speed and release point, and the wind speed increased/decreased significantly or the release point varied significantly, the bomb would fall well clear of the target.

Like the un-guided weapons, the guided bombs also have a potential to miss the target and land anywhere within the safety template. As it is likely Site 52a would be within the template for these weapons, there is a potential for the bomb to strike the repository. This incident has been carried forward for consequence analysis.

4.1.2 Hazards Associated with Rockets

The rockets tested at the range are unguided weapons. The rockets are released from aircraft using a sight in the aircraft cockpit. The pilot aims the sight at the target and releases the rocket when the sight is aligned with the target. The rocket then flies under its own propulsion towards the target.

In the event of failure of the rocket motor, stability fins or other components, the rocket has the potential to veer from its path and strike the ground away from the target. The rocket has the potential to strike any point within the safety template. If Site 52a were located such that it was within the safety template for this weapons group there would be potential for a rocket to strike the repository.

This incident has been carried forward for consequence analysis.

4.1.3 Hazards Associated with Stand-Off Weapons

Stand –Off Weapons tested at WIR consist mainly of weapons fitted with a guidance system and rocket motor. These weapons are deployed from aircraft and once released the rocket motor is ignited and the weapon flies to the target under its own power. Guidance is typically provided by the weapon operator in the launch aircraft.

Like the rocket hazards described above, Stand-Off Weapons systems have the potential to fail in the areas of rocket motors, wings, guidance fins (mechanical), guidance systems (electronic) or other components. Failures of this type would result in the weapon veering from its path and striking the ground away from the target. The Stand-Off Weapon has the potential to strike any point within the safety template. It is likely that Site 52a would be within the safety template for this weapons group and, hence, there is a potential for Stand-Off Weapons to strike the repository.

This incident has been carried forward for consequence analysis.

4.1.4 Hazards Associated with Missiles (Air-to-Air)

Air to air weapons testing is conducted over the WIR test range to enable the range instrumentation to be used to monitor and record the tests. All air-to-air missiles are guided weapons and are release from an aircraft towards a target.

Like the rockets and precision guided weapons hazards described above, missiles have the potential to fail both mechanically (fins, motors, etc.) or electrically (guidance systems). Further, in the event of a target miss, the missile must at some stage return to the ground. In all cases (equipment failure and target miss) the missile will fall to the ground within the safety template.

As it is likely Site 52a would be located within the safety template for the test of this weapons group there is a potential for the missile to strike the repository. This incident has been carried forward for consequence analysis.

4.1.5 Safety Systems

A number of safety systems have been developed to ensure personnel and the range itself is placed at minimum risk. These are:

- **Safety Templates** – details of safety templates are discussed in **Section 2.2.4**. The safety template limits the potential for impact on personnel operating instruments and equipment around the range. The template is developed to ensure risks are maintained below acceptable criteria.
- **Explosives** – weapons currently tested at the WIR do not contain any high explosives (HE). Whilst weapons are designed to carry an HE charge, this charge is not installed during the weapons test. Hence, there is no current potential for major explosion when the weapon strikes the target. However, this does not preclude E weapons tests in the future.
- **Termination Systems** – some of the weapons tested are fitted with a termination system, which is controlled by the range commander. A set of criteria is developed for each test, based on designed fight path, weapon behaviour, etc. In the event of deviation outside the established test criteria, weapons are terminated and commence descent to ground immediately at the termination point. Safety templates are developed to account for termination systems.

4.2 Consequence Analysis

The hazard analysis identified that due to the relatively close proximity of Site 52a to the WIR centreline, there is a potential for test weapons to strike the NRWR as the repository is located within the safety templates of potential weapons test programs.

In the event of a weapon impact on or near the repository, there is a potential for the weapon to penetrate the ground for some distance before stopping. The distance of penetration is dependent on the weapon type and impact location. Each weapon type and the potential impact consequence is discussed below.

4.2.1 Consequences of Bomb (Guided and Un-guided) Impact

There are basically three bomb types tested at the WIR; 2000lb, 500lb and 25lb (practice bombs). **Figure 4.1** shows an example of a bomb trajectories and penetration profile. It is noted that a bomb may not continue on a direct trajectory into the ground once the ground is penetrated. Objects (rocks, etc.) underground may impact the bomb and cause its course to deviate. In some cases bombs at the range have entered the ground and been deflected by underground objects and resurfaced. In the event of direct penetration, potential travel distance into the ground is shown in **Table 4.2** for each bomb type.

It is evident from **Figure 4.1** and **Table 4.2** that the bomb types tested at the WIR have the potential to penetrate the repository as the proposed depth of cover is only 2 to 5m (Ref.4). The consequences of this are, that even where no explosives are fitted to the bombs, the repository confinement will be breached, leading to a potential release of stored materials via the crater or hole created by a bomb travelling through the repository.

In the worst case scenario, a bomb may strike the ground clear of the repository, be deflected by an underground object, travel through the repository and remain in the ground in or on the opposite side of the store. In this case, it may not be readily evident that the repository has been breached.

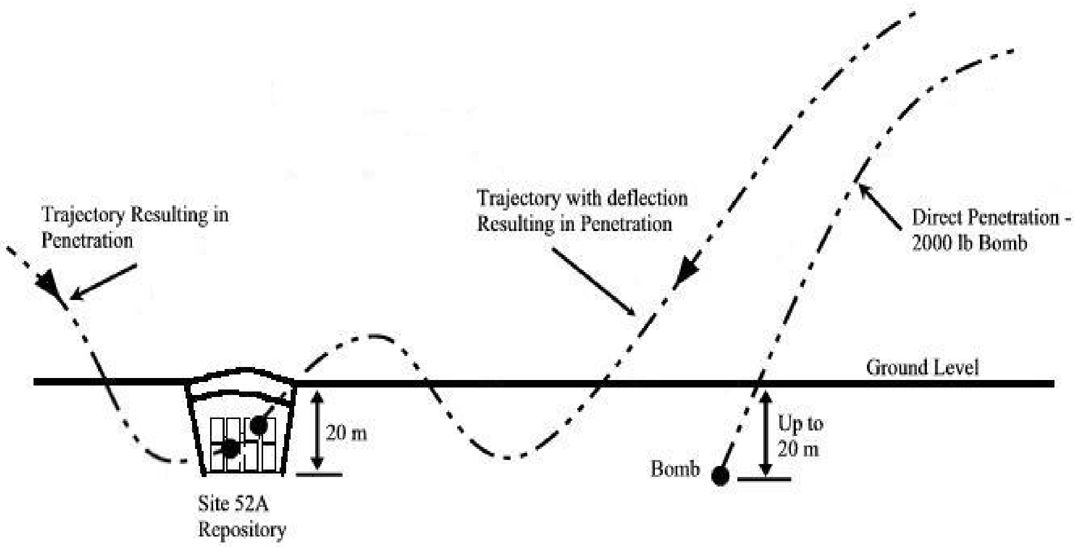


FIGURE 4.1
BOMB TRAJECTORY AND GROUND PENETRATION PROFILES

TABLE 4.2
PENETRATION DISTANCES INTO GROUND FOR VARIOUS BOMBS

Bomb Type	Penetration Distance (m)
2000lb Bomb	5-20m
500lb Bomb	5-10m
25lb Practice Bomb	0-5m

Table 4.2 lists current bombs tested at the WIR and current potential penetration distances. It is important to note that weapons development processes aims to increase the effectiveness of bombs, including penetration depth. Weapons are being designed to penetrate ever increasing thicknesses of concrete, further increasing possible penetration depths.

4.2.2 Consequences of Rocket (Unguided) and Missiles (Air-to Air) Impact

Unguided rockets and air-to-air missiles contain significantly less mass than bombs. The mass of such weapons, when striking the ground, may be less than 100kg. Whilst the low mass would initially appear to be insufficient to cause NRWR cover penetration, the velocity of these weapons approaches about 3000kmh at impact. The high kinetic energy may result in impacts similar to bombs described in **Section 4.2.1**. However, it is not expected that rockets/missiles will ricochet off underground objects and resurface or travel significant distances underground. It is estimated that Rockets/missiles will impact and penetrate into the ground about 0 to 5m.

It is understood that the soil cover over the top of the materials in the NRWR will be in the order of 2 to 5m (Ref.4). Hence, the repository may be breached by these weapons in a direct strike situation.

4.2.3 Consequences of Stand-Off Weapons Impact

Precision Guided Munitions may have a mass and trajectory similar to that previously described for large guided bombs. Hence, consequences of a Precision Guided Munition impacting the repository would be similar to those described above for large guided bombs (500 – 2000 lb).

4.2.4 Summary of Impact Consequences

In summary, the following consequences would be expected as a result of simultaneous operations of the WIR and the NRWR at Site 52a:

- The repository may be breached and/or the cover damaged by bombs, rockets/missiles and guided munitions in the event these weapons strike the repository leading to the potential for release of radioactive materials.
- In all cases where weapons impact the repository, it would be necessary to notify ARPANSA and cease weapons tests until an investigation had been conducted and the repository repaired. This would severely impact the continued use of the range and it would be necessary to postpone or cancel weapons tests during the investigation period.
- As stated above, impact of a weapon on the NRWR would require Defence to notify ARPANSA of the incident, which would place the incident in the public domain. Based on recent public and media response to radioactive material releases at uranium processing facilities in South Australia, the reaction to a projectile impact on the NRWR would result in widespread condemnation of the ADF. This would result in the classification of the consequences as catastrophic by the Chief of Air Force (CAF)(Ref.3).

Notes:
1. It is recognised that immediate release of low level radioactive materials from the proposed repository would probably not result in the significant raising of the background radiation levels as dispersion of the released materials into the surrounding soils would greatly dilute the released materials. However, undetected breach of the repository and continued release via the breach point may be detected above acceptable levels in the surrounding soil.
2. CAF has directed the ARDU ensure appropriate risk assessment techniques are used based on the RAAF Aviation Risk Management Directive.

4.3 Frequency Analysis

Section 2.2.4 describes the development of safety templates for the weapons tests at the WIR. **Figure 2.5** shows an example of a safety template and the outer template boundary, which represents the probability of fatality of $1x10^{-6}$ per weapon test. For locations within the template boundary the probability of fatality is much higher and increases to a maximum probability at the target.

The fatality probability is based on the potential for impact of a weapon in an area where personnel are located, the impact area being much smaller than the size of the repository. Weapon impact in a personnel staffed area is then considered to result in fatality. Hence, for this study, a value of $1x10^{-6}$ has been conservatively selected as the probability of impact on the waste repository from an individual weapon test at the WIR. This value is conservative due to the following factors:

- There is a potential for the majority of templates required for weapons testing at the WIR to cover the proposed repository at Site 52a. In many cases the proposed repository Site will lie well inside the template such that the probability of impact is higher than $1x10^{-6}$; and
- The surface area (or footprint) created by the NRWR (i.e. the actual storage facility area and not the buffer zone area) is significantly larger ($10{,}000m^2$) than that that created by instrument locations where personnel would be located ($400m^2$) and hence there is a greater probability of impact on the NRWR than personnel staffed areas.

In the past, the frequency of weapons tests at the WIR has varied from year to year. Since 1990 an average of 60 weapons tests have been conducted annually (includes all bombs, missiles and guided weapons). Future WPA bookings and the WPA annual programme are managed by the Area Administrator, Woomera (AAW), who is part of the Defence Support Centre – Woomera. The primary user of the area will continue to be Defence in the near term. However, several proposals for the use of the range by commercial agencies (primarily for space launch activities) have the potential to shift the predominant use of the range from Defence to commercial usage. For the sake of further conservatism, the impact of space launch activities has not been included in this assessment.

In the near term ARDU has booked three four week blocks for exclusive use of the range over the next three years. Testing during these blocks will be conducted by ARDU for the test and evaluation of new and existing weapons systems on the WIR. Whilst it is not possible, for security and other programme reasons, to list the exact weapons tests, it has been conservatively assumed that there would be up to 60 weapons tests in each of the next three years.

Based on this data, the number of weapons tests conducted at the WIR per annum in the short term has been conservatively estimated as 60. This includes all bomb, rocket, missile and guided munitions tests. However,, based on **Table 4.2** and other weapons impact performance data, not all weapons currently used have the potential to breach the repository. Based on weapon impact data provided by ARDU, and a repository cover of between 2-5m, a median value of 70% has been estimated as the proportion of proposed weapons tested that will have the capacity to breach the repository. Hence, the frequency that a weapon will strike the repository is calculated by multiplying the number of tests per annum by the probability of weapon impact on the repository:

Frequency of Impact in Site 52a Location = 60p.a. x $1x10^{-6}$ = 6×10^{-5} p.a.

The frequency of breach of the repository by a weapon impact is calculated by multiplying the frequency of weapon impact on the repository by the fraction of weapons capable of breaching the repository:

Frequency of Repository Breach (Site 52a) by a weapon = 0.7 x 6.0×10^{-5} p.a. = 4.2×10^{-5} p.a.

These results are very conservative as there has been no consideration of the potential impact on the Site from commercial users and the probability of impact will be increased as site 52a is falls further within selected safety templates.

4.4 Risk Analysis

4.4.1 Risk Criteria

A number of risk criteria would apply to the NRWR, both qualitative and quantitative. These are discussed below.

ARPANSA Risk Criteria

ARPANSA has adopted the National Heath and Medical Research Council's Code of Practice for the Near Surface Disposal of Radioactive Waste in Australia (Ref.1). This document lists a number of criteria in relation to the siting of a radioactive waste repository, including a fatality risk criteria of 1×10^{-6} p.a. (i.e. fatality risk from a waste repository must not be higher than 1×10^{-6}p.a.).

ARPANSA also uses the criteria published in the Regulatory Assessment Principles for Controlled Facilities (Ref.6), of which the NRWR would be such a facility. This criteria lists the frequency of exposure to a maximum effective dose or radiation in milli-Sieverts (mSv). The criteria indicates that a maximum exposure risk of 1×10^{-5} per annum just meets the safety limits and a maximum exposure risk of 1×10^{-7} per annum just meets the safety objectives. The document also states that the risk **must** be shown to be as low as reasonably achievable (ALARA) (Ref.6).

Industry Criteria

Various regulatory bodies have published risk criteria including the PlanningNSW (formerly the NSW Department of Urban Affairs and Planning), The Queensland Department of Emergency Services, Workcover Victoria and The United Kingdom Health and Safety Executive. The basic principle of all this criteria is to reduce the risk to as low as reasonably practicable (ALARP), which is in essence the same principle as ALARA adopted by ARPANSA.

Figure 4.2 reflects the generally accepted risk criteria concept for the siting of hazardous facilities in industry.

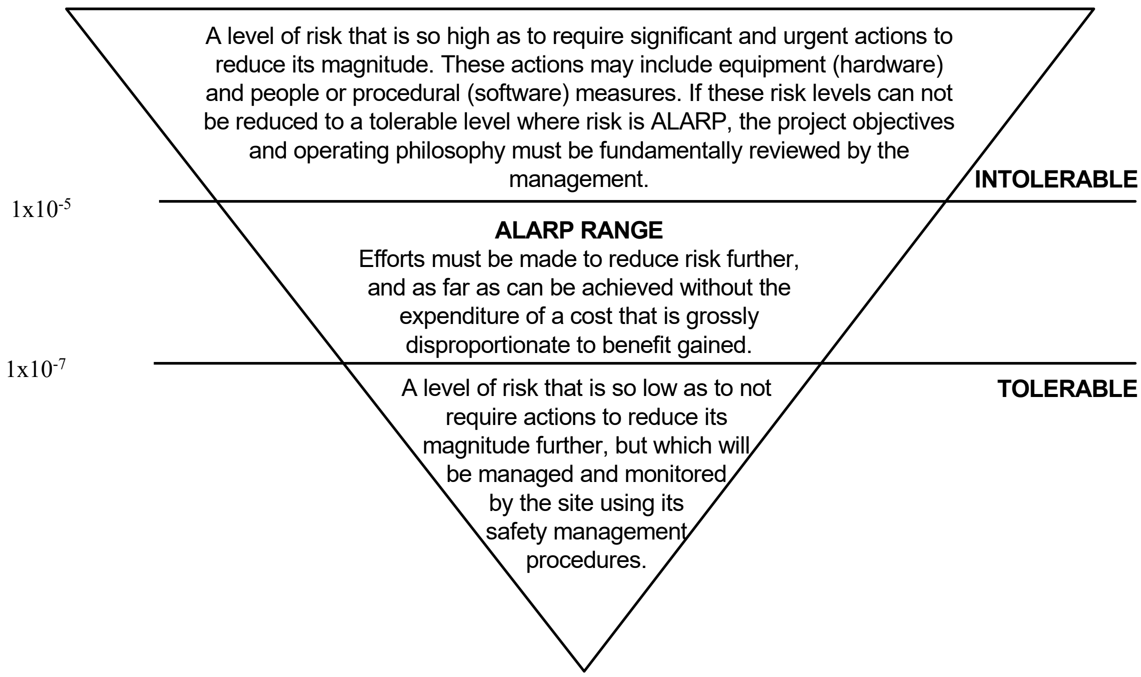


FIGURE 4.2
RISK CRITERIA FOR THE LOCATION OF HAZARDOUS FACILITIES

As risk is defined as "the likelihood of a specified undesired event occurring within a specified period or in specified circumstances" (Ref.7), in the case of the NRWR, the risk could be classified in a number of categories including the following (Ref.8):

- Risk of fatality as a result of exposure to released radioactive materials;
- Risk of severe environmental impact as a result of release of radioactive material; and
- Risk of adverse publicity and public/media condemnation of the Australian Defence Force (ADF) as a result of impact of a weapon on the NRWR.

Hence, using the criteria listed in **Table 4.2**, the risk of consequence outcome as listed above should fall below the frequency of 1×10^{-7} per annum to be acceptable and the ALARP principle must be applied where frequency is between 1×10^{-5} and 1×10^{-7}. Frequencies higher than 1×10^{-5} are unacceptable.

Department of Defence Criteria (RAAF AVRM)

In the Aviation Risk Management Directive (Ref.3) CAF has published a risk assessment methodology, including consequence levels for use in risk analysis. **Table 4.3** lists the consequence levels that are to be used when assessing hazards and risks using the RAAF AVRM (Ref.3).

TABLE 4.3
CONSEQUENCE (CAF Directive 02/01)

Consequence	Definition
Disastrous	- **Capability**: Indefinite loss of ADF capability provided by particular aircraft system - **Safety**: Many fatalities or numerous aircraft lost - **Mission**: Failure to achieve a mission that is essential to a strategic objective - **Public/Image/Morale**: Widespread public condemnation of ADF. Mass resignations and general disaffection within ADF
Critical	- **Capability**: Temporary loss or severe degradation to ADF capability provided by a particular aircraft system - **Safety**: Few fatalities of single aircraft loss - **Mission**: Failure to achieve a mission that is essential to an operational objective ad has significant strategic implications - **Public/Image/Morale**: Widespread public discontent with ADF or services, prolonged adverse national media attention and increased resignation rates
Major	- **Capability**: Substantial indefinite degradation to ADF capability provided by a particular aircraft system - **Safety**: Serious injuries that could result in permanent disabilities and/or aircraft category 4 damage - **Mission**: Failure to achieve a mission that is important to a strategic objective and will have serious tactical implications - **Public/Image/Morale**: Negative reaction by public defence interest groups and short term national media attention. FEG Morale seriously affected but recoverable
Moderate	- **Capability**: Substantial temporary degradation to ADF capability provided by a particular aircraft system - **Safety**: Injuries that could result in temporary disability and/or aircraft category 3/2 damage - **Mission**: Failure to achieve a mission that is important to an operational objective and has serious tactical implications - **Public/Image/Morale**: Local prolonged media attention and negative public reaction. FEG Morale slightly affected
Minor	- **Capability**: Significant temporary degradation to ADF capability provided by a particular aircraft system - **Safety**: Minor injuries that require medical attention or category 1 aircraft damage - **Mission**: Partial achievement of a mission that has significant tactical implications but des not affect achievement an operational objective - **Public/Image/Morale**: Local short-term media attention and negative public reaction, SQN Morale slightly affected

4.4.2 Risk of Impact on the NRWR (Site 52a) and Comparison with Risk Criteria

Assessment of Risk Against ARPANSA Criteria

As stated in **Section 4.2.4** the NRWR has been designed to store low-level radioactive waste and, as a result of any release events, it is considered that the levels of radiation would not cause fatalities. This was demonstrated in discussion with DEST and its consultants (Ref.9). Hence, under the ARPANSA fatality criteria alone, it would appear the NRWR meets the required criteria. However, a weapon incident at the NRWR resulting in impact and radioactive material release, would expose clean up crews to radiation. This risk should be avoided where possible, according to the ALARA principle required under the ARPANSA criteria. If alternate sites are available with lesser risk, these sites should be selected to ensure the risk is **as low as reasonably achievable (ALARA)**. Sites 45a and 40a are also acceptable sites for the location of the NRWR (Ref.4). These sites are not susceptible to missile, bomb or projectile risks and, hence, are lower risk than the preferred Site 52a location. Selection of these sites would meet the ARPANSA ALARA criteria. Failure to select an alternat site would result in failure to meet the ALAR principle.

Assessment of Risk Against Industry Criteria

Industry criteria focuses on risks including fatality, injury, nuisance, environmental issues, equipment damage and production loss. Whilst it has been recognised that the risk of fatalities as a result of releases of radioactive materials from the NRWR are negligible, the environmental impact has been assessed to have potentially severe consequence. A weapon impact resulting in release of radioactive waste would require considerable clean up and exposure of personnel to radioactive materials. Given the nature of radioactive waste and its perception in the community as a major environmental pollutant, the severity of such an event would require the application of the principles in **Figure 4.2**. Hence, a frequency of materials release and environmental impact exceeding $1x10^{-5}$ per annum would be intolerable.

Section 4.3 has demonstrated that the most conservative estimate of weapon impact on the NRWR is $4.2x10^{-5}$ per annum. In reality the impact frequency would be considerably higher. Nonetheless, this impact frequency exceeds the criteria listed in **Figure 4.2** and hence such an environmental risk is intolerable.

Assessment of Risk Against RAAF AVRM

RAAF AVRM (Ref.3) states "FEG Commanders are to achieve implementation of the risk assessment process within their Commands by developing working level instructions, ensuring AVRM application in decision making". Under these instructions ARDU has indicated that operations that could result in the classification of incident consequence as "Disastrous" must not be undertaken during ARDU activities.

Owing to the sensitive nature of radioactive facilities, any weapon impact on the NRWR would result in widespread media and public condemnation of the ADF, whether the facility was approved by ARPANSA, or designed, built and managed by DEST. As the incident would have been caused by the deployment of a weapon, the condemnation would impact the ADF. In review of the proposed location of the NRWR and the activities conducted in the WIR, ARDU has assessed the consequences of a weapon impact on the NRWR as "Disastrous", as indicated in **Table 4.3**.

It is noted that CAF (Ref.3) in **Table 4.5** of this study, equates widespread public condemnation of the ADF to fatalities. The criteria published by ARPANSA and other regulatory authorities (e.g.

PlanningNSW-Ref.5) states that fatality risk from hazardous facilities should not exceed $1x10^{-6}$ p.a. Hence, applying the CAF directive and, by corollary, an incident involving widespread public condemnation of the ADF should not occur with a frequency higher than $1x10^{-6}$ p.a. It has been shown in **Section 4.3** that the risk of weapon impact on the NRWR from operations at the WIR has been conservatively estimated to be $6x10^{-5}$ p.a. The risk of repository breach as a result of such incidents has been conservatively estimated to be $4.2x10^{-5}$ p.a. In both cases, the public condemnation of the ADF from such an incident would be widespread and exceeds the value of $1x10^{-6}$ p.a. This would indicate that under the CAF Directive (Ref.3) the NRWR and WIR cannot be operated simultaneously.

In the case of the joint operation of the NRWR and the WIR/WPA, the risk assessment indicates that the location of the NRWR at Site 52a will have severe limitations on how the range is used. The application of the CAF directive (Ref.3) will require ARDU to limit the operations at the range to certain weapons, attack directions, weapon release points and release criteria.

Additional Risks

The analysis in this study has not considered the potential for the aircraft, deploying the weapon at the WIR, to crash leading to impact of the aircraft on the NRWR. DEST consultants indicated that the probability of aircraft impact on the NRWR would be in the order of $2.4x10^{-4}$ p.a.(Ref.9). The cumulative risk of aircraft and weapon impact on the NRWR would therefore be $2.8x10^{-4}$ p.a. This is a considerable increase in the risk of impact on the NRWR.

Further, no consideration has been given to the impact of commercial ventures on the NRWR. It is understood that a number of proposed commercial operations are planning the use of the areas adjacent to where site 52a will be located. The safety templates for these operations will directly impact Site 52a. This may result in cancellation of these operations and loss of considerable revenue and expertise to Australia.

An example of such an event is the proposed trials of the X38, the “life boat” for the International Space Station. This trial resulted in a safety template that impacted the preferred location of the NRWR at Site 52a. The United States based trial authority opted to move the trial location from the WIR to an alternate area in the WPA. This meant that the X38 trial could not use the existing WIR instruments and, hence, temporary instrumentation must now be installed at significant cost to the US trial authority. As the use of the WIR increases, both commercially and for weapons tests, this event will recur on a regular basis if Site 52a is selected for the NRWR.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the published risk criteria and the assessed risks associated with the joint operation of the WIR/WPA and the NRWR at Site 52a the following conclusions are drawn:

1. In the majority of cases, the operational risks in the WIR are intolerable or unacceptable;

2. In some cases the risks of operations at the WIR fall within the upper bounds of the “as low as reasonably practicable (ALARP)” or “as low as reasonably achievable (ALARA)” ranges, requiring further risk reduction.

3. In no case is the risk of operations at the WIR within the acceptable range.

4. The risk assessment is very conservative and actual risks would be expected to be higher than those estimated in this analysis.

5. The assessment takes no account of commercial users, which would increase the risk further.

6. In the event Site 52a is selected for the NRWR, in order for Defence to continue the use of the range it would be necessary to modify the current range use or to cease operations at the range to meet the risk profile required by the various risk management publications applicable to the range operations.

5.2 Recommendations

Based on the assessment conducted in this document and the conclusions drawn, the following recommendations are made:

1. In order to comply with the ALARP and ALARA principles stated in the various published risk criteria, it is recommended that an alternate site to Site 52a be selected for the NRWR. The two available alternate sites are not impacted by the operations at the WIR/WPA and hence comply with the ALARP and ALARA principles.

2. In the event Site 52a is approved for location of the NRWR, it is recommended that Defence limit the types of weapons tests as well as attack directions, release points and other test parameters to ensure the safety templates do not impact the NRWR. Not only would this place additional financial burdens on the Department of Defence, it would limit or preclude a large number of operations at the range.

3. In the event Site 52a is approved for location of the NRWR, and Defence is not able to limit the use of the range, it is recommended that an alternate location for the range be found and that the range operations be relocated to this area. The alternate location of the range should be subjected to a rigorous risk assessment to ensure the risks associated with the new location meet the various published risk management criteria.

4. In the event Site 52a is approved for location of the NRWR, it is recommended that each commercial venture proposed at the WPA be subjected to a rigorous risk assessment to ensure the NRWR is not impacted above the published risk criteria.

6 REFERENCES

1. National Health and Medical Research Council (1992), "Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia".

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9. Draft Minutes from the NRWR Meeting, 23 January 2002, between Department of Defence and DEST, Russell Offices R4-2-2B.

DISTRIBUTION

Appendix A:
Operational Risk Assessment for the
The Australian Defence Organisation
Aerospace Test Range and the NRWR
at Woomera, South Australia

11 February 2002

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