Australian Government

ANSTO

Document Number 152977

AME Project No. C01056

ANSTO MAINTENANCE & ENGINEERING

INTERMEDIATE LEVEL WASTE CAPACITY INCREASE FACILITY

SITE CHARACTERISTICS AND SITE RELATED DESIGN BASIS

C01056

April 2021

AME		**Document No: 152977**			
		Document Title: ILWCI Site Characteristics and Site Related Design Basis			
REVISION SHEET		**AME Project No:** C01056			
Revision Letter	Description of Revision	Print name, date and sign or initial			
		Prepared	Checked/ Reviewed	Approved	Agreed
Rev 0	Original Issue	[redacted]	[redacted]	[redacted]	[redacted]
Notes: 1. Revision shall be verified in accordance with the Quality Plan for the job. 2. Revision to be agreed by the Client where relevant.					

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1 PURPOSE AND SCOPE

Based on current projections of Remote Handled Solid Waste (RHSW) production at the ANSTO Lucas Heights campus, existing storage facilities will reach full capacity from 2027 for certain waste streams. Therefore, for critical operations to continue, including the production of radiopharmaceuticals, an additional facility, referred to as the Intermediate Level Waste Capacity Increase (ILWCI) facility, is required to ensure that ANSTO is able to safely store and manage all RHSW produced until the National Radioactive Waste Management Facility (NRWMF) becomes available.

The Australian Nuclear Safety and Radiation Protection Agency (ARPANSA) document *Regulatory Guide – Applying for a licence for a radioactive waste storage or disposal facility* [1] provides the requirements and criteria for assessing the suitability of the site. The requirements include:

- Site demography, seismology, geology, topography, ecology, hydrology, and meteorology;
- The effect of nearby facilities and land usage; and
- The availability and reliability of offsite services such as electricity, water transportation and communication systems.

The following International Atomic Energy Agency (IAEA) safety standards are also relevant:

- *Site Evaluation for Nuclear Installations* (SSR-1) [2];
- *Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations* [3];
- *Seismic Hazards in Site Evaluation for Nuclear Installations* [4]*; and*
- *Storage of Radioactive waste* [5]*.*

This submission identifies and provides information and assessment to demonstrate that the ANSTO Lucas Heights campus is a suitable site for the proposed facility.

2 SITE CHARACTERISTICS

This section provides the description of the site characteristics that affect safety considerations in the design of the proposed facility. The proposed location of the ILWCI facility is within the boundary fence of the Lucas Heights site inside the Waste Management Precinct (WMP), as shown in Figure 1. The facility will be located between existing Buildings 64 and 61 and have road access from Dalton Avenue (Figure 2).

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Figure 1: Location of the waste management precinct at the ANSTO Lucas Heights campus

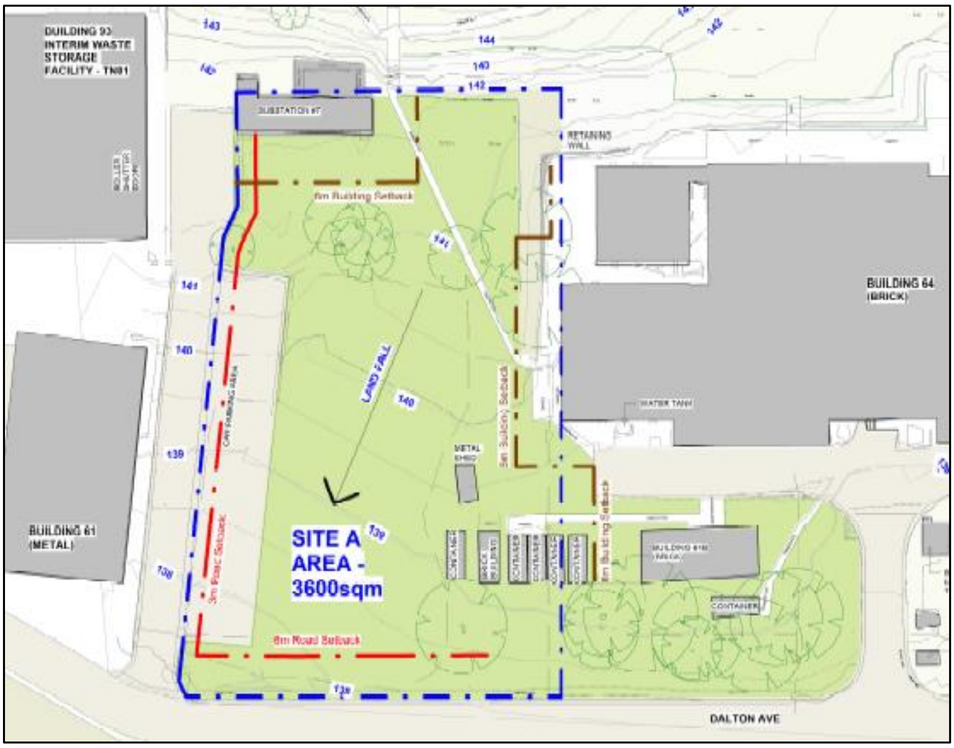

Figure 2: Proposed site for the Intermediate Level Waste Capacity Increase Facility

2.1 Geography

The ANSTO Lucas Heights campus is located in the suburb of Lucas Heights, about 35 km south-west of the Sydney Central Business District (CBD) on the dissected Woronora Plateau at an elevation of about 150 m Australian Height Datum (AHD). The site is approximately 2 km west of the Woronora River and 8 km south of the Georges River and is surrounded by bushland extending for several kilometres with no significant habitation in the north-west, west and south-west quadrants.

The Lucas Heights campus comprises approximately 600 ha of which 70 ha is developed whilst the remainder is a combination of landfill, brownfields and bushland. The 70 ha fenced area is surrounded by a 1.6 km radius buffer zone centred on the shutdown HIFAR research reactor. No residential development is permitted within the ANSTO buffer zone. The residential suburbs of Barden Ridge and Engadine are located in the north-east to south-east sectors adjacent to the ANSTO buffer zone boundary while the growing suburban area of Menai is located about 3 km further to the north-east. Residential development to the north of the site has been proposed.

Under the Sutherland Shire Local Environmental Plan (SSLEP) [6], land within the ANSTO buffer zone is zoned SP1 – Special activities (Research and Technology) (Figure 3). The zoning classification of part of the ANSTO buffer zone currently leased out as part of a municipal waste depot has been zoned SP1 – Special activities (Waste Recycling). There are small areas on the western perimeter of the buffer zone that are zoned RE1 – Public recreation. Land within the buffer zone is owned and administered by ANSTO with the exception of an area of land within the buffer zone to the east of the Woronora River. Land to the west of Heathcote Road within the Holsworthy Military Area is owned by the Commonwealth and administered by the Department of Defence, while a small portion is controlled and managed by Australian Estate Management on behalf of the Department of Administrative Services. An area immediately to the north of the buffer zone that contains Little Forest Legacy Site (formerly Little Forest Burial Ground) is also owned and administered by ANSTO. There are no Native Title claims on land controlled by ANSTO.

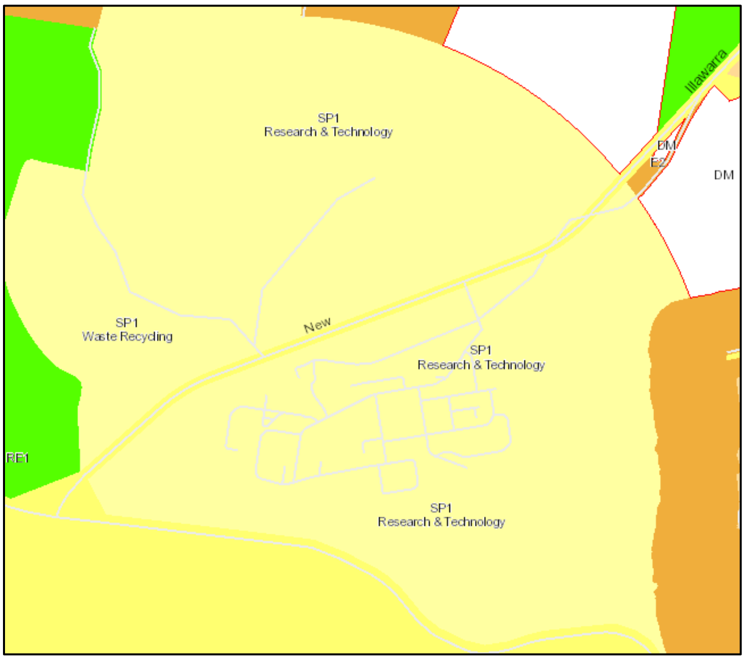

Figure 3: Sutherland Shire Local Environmental Plan - Land use zonings around the ANSTO Lucas Heights site

The current land use within and adjoining the ANSTO buffer zone is demonstrated in Figure 4. All of the area inside of the ANSTO buffer zone, including a small extension around the Little Forest Legacy Site, is held by the Commonwealth or its agencies except for a small section on the eastern side of the Woronora River which is Crown land. Parts of the crown land area have been proposed for residential development by the New South Wales (NSW) Department of Planning as part of the West Menai urban release and are currently zoned 1b -Rural (Future Urban) under the SSLEP.

ANSTO leases out the following portions of the buffer zone:

- The ANSTO Innovation Precinct, covering approximately 20 hectares, is located in the buffer zone outside the northern side of the site. ANSTO leases buildings and space (mainly offices and research laboratories) in this area to private companies.
- 115 hectares of the western portion of the buffer zone to SUEZ which operates the Lucas Heights Resource Recovery Park.
- 11 hectares near the intersection of Little Forest Legacy Site and New Illawarra Road to the Sutherland Police Community and Youth Club for use as a mini-bike track. The track is used by the club on Sundays.
- 1 hectare east of the site located in bushland is leased to the United Pistol Club. The two pistol ranges at the club are used by approximately 30 members on the weekends, although some ANSTO and APS club members also use the facility during weekday lunchtimes.

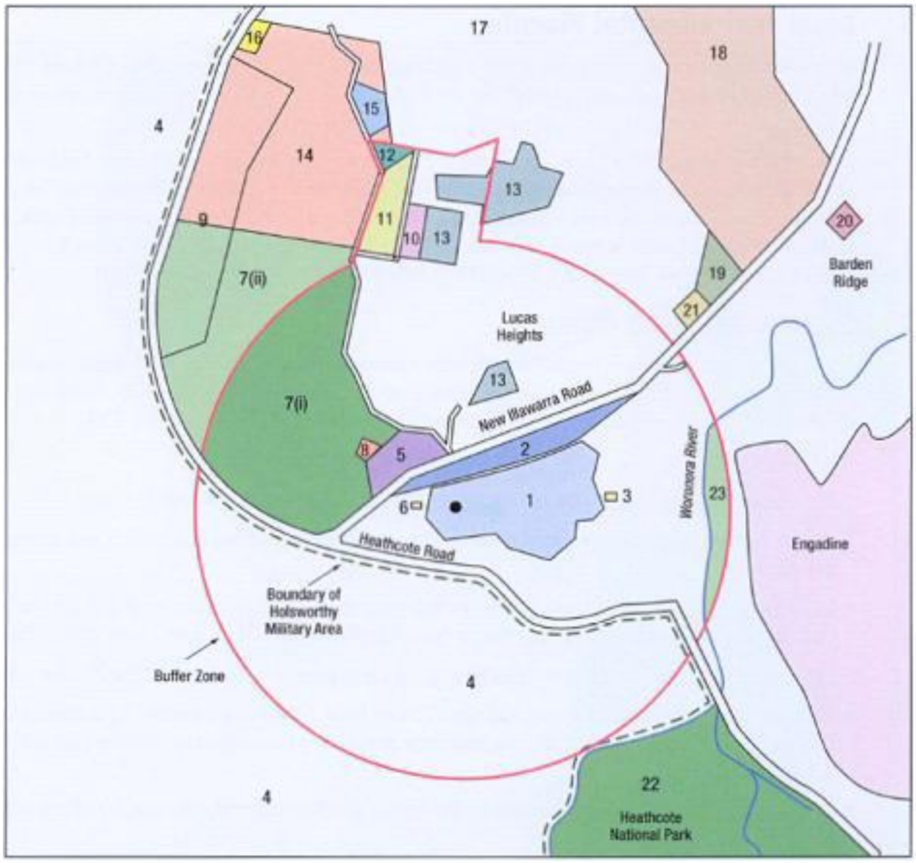

Figure 4: Land use within and adjoining the ANSTO buffer zone (red circle)

LEGEND

1. Lucas Heights campus
2. ANSTO Innovation Precinct
3. Police Pistol Range
4. Holsworthy Military Area
5. Sutherland Police Citizens Youth Club Minibike Track
6. OPAL Maintenance Store

7i SUEZ Lucas Heights Resource Recovery Park (area leased from ANSTO)

7ii SUEZ Lucas Heights Resource Recovery Park (Waste Service Land)

8. EDL landfill gas power generation plant
9. Sydney international clay target association (SICTA)
10. Little Forest Legacy Site
11. Harrington's Quarry, former municipal waste disposal site
12. Former IWC liquid waste disposal site
13. Former Sutherland Shire Council night soil disposal site
14. Proposed Lucas Heights conservation area
15. Proposed National Parks and Wildlife Service Nature Reserve
16. Gandangara Local Aboriginal Land Council Cultural Centre
17. Gandangara Local Aboriginal Land Council Land
18. Lucas Heights No.1 Depot site – Recreation Area
19. Jenko Pony Club
20. School
21. Concrete batching plant
22. Heathcote National Park
23. NSW Crown Land

2.2 Demography

2.2.1 Population around the ANSTO Lucas Heights campus

The estimated population within 25 km of the ANSTO Lucas Heights campus is shown in Table 1 [7].

Table 1: Estimated population in the 25 km surrounding the Lucas Heights campus

Zone	Direction	Zone start direction (degrees)	Zone end direction (degrees)	Population by distance					
				A	B	C	D	E	F
				1.6 - 3.2 km	3.2 - 4.8 km	4.8 -10 km	10- 15 km	15-20 km	20- 25 km
1	N	101.25	78.75			6475	29699	85228	148451
2	NNE	78.75	56.25		696	13113	80027	147415	166812
3	NE	56.25	33.75	53	5321	24252	90237	169009	199770
4	ENE	33.75	11.25	701	2602	34609	46259	37638	18667
5	E	11.25	348.75	3222	4845	16818	51644	23670	
6	ESE	348.75	326.25	2750	4569		422	1709	
7	SE	326.25	303.75	919	4373	1735			
8	SSE	303.75	281.25		791	776			
9	S	281.25	258.75			537	2123	6761	1216
10	SSW	258.75	236.25					*	*
11	SW	236.25	213.75					*	2857
12	WSW	213.75	191.25				9207	37241	924
13	W	191.25	168.75			*	34518	34352	58056
14	WNW	168.75	146.25			249	31214	19936	14832
15	NW	146.25	123.75			4729	42385	59150	19217
16	NNW	123.75	101.25				44385	127476	88132

** Population count for zones C13, E10, E11, F10 have been excluded from analysis due to changes in land use categorisation which excludes these buildings from population analysis. The sum of previous population values for these zones is 401, dwellings is 141 and buildings is 137; this is equal to 0.02% of the total population for the analysed region, so has been excluded entirely to avoid confusion.*

2.2.2 ANSTO Lucas Heights campus site population

During standard working hours (Monday – Friday, 7am-7pm) the maximum number of people onsite at the ANSTO Lucas Heights campus could be greater than 1,700 based on the number of current employees and average visitors each day shown in Table 2. However, due to annual and sick leave, working offsite, shift work the total on any one working day would be expected to be much less. It has been conservatively estimated that the maximum occupancy during business hours would not exceed 1,500 and after hours this would reduce substantially to less than 100.

Table 2: Estimated number of employees at Lucas Heights campus

Organisation	TOTAL	Estimated onsite in any one day	
		Business hours	After hours
ANSTO employees	1290	1032	80
Australian Federal Police (AFP)	*	*	*
Commonwealth Scientific and Industrial Research Organisation (CSIRO) employees	95	76	2
The Australian Institute of Nuclear Science and Engineering (AINSE)	6	5	-
Cafeteria and Motel employees	10	8	-
ANSTO Innovation Precinct	65	52	5
ANSTO training course attendees; maximum number	50 per session	50	-
ANSTO Childcare Centre – employees and children	50 per day	50	-
Visitors – school groups, general public	17,000 p.a.	100	-
Visitors – researchers, collaborators, facility users etc	6,500 p.a.	65	-
Totals		**1438 (+ AFP*)**	**87 (+ AFP*)**

**The number of AFP stationed onsite is considered a classified item of information and can be provided separately to the regulator if required.*
The estimates in this table are based off of available data as of December 2020.

After hours a minimum number of people are required to be on site including mandatory Open Pool Australian Light-water (OPAL) reactor operators, ANSTO health production workers, AFP, and site contract cleaners. Additionally, approximately 50 staff may choose to work into the evening or on weekends.

2.3 Meteorology

ANSTO operates a meteorology laboratory on the Lucas Heights site which has been recording data since 1968. The data captured includes wind speed, wind direction, temperature and rainfall. The data for Lucas Heights is available on ANSTO's website and published by the Bureau of Meteorology on the Lucas Heights Weather Observations page [8].

2.3.1 Winds

At the ANSTO Lucas Heights campus, there is an overall predominance of southerly winds. In the summer, daytime sea breezes from the south-east and north-east to east are most common. During winter, winds from the south predominate during the night with the distribution extending through to the west and north-west during the daytime. Autumn and Spring represent a transition between summer and winter with sea breezes observed later in the day and nocturnal winds indicative of regional drainage of cool air from the south-west.

During the daytime, the Pasquill Stability Category at Lucas Heights campus is usually D (occasionally A, B, or C) and E during the night. The meteorological laboratory has a tower that has enabled the upper wind frequencies at 49 metres to be measured. At this height, the wind directions are turned clockwise with respect to those at 10 metres. The wind speeds are higher, particularly at night when there are regional drainage winds free of surface influences.

Data on wind frequencies during precipitation has also been recorded at the Lucas Heights campus. Nearly 50% of the rain occurs with winds from the south-east to south. Approximately 45% of the rain is low intensity (less than 1 mm per hour). These precipitation rates are important in determining the wet deposition or wash-out of atmospheric aerosols and gases. Data on wind frequencies during light to moderate inversions (temperature gradient less than 7.5°C per 100 metres) and strong inversions (temperature gradient greater than 7.5°C per 100 metres) has also been collected.

For a more detailed description of the wind characteristics please refer to the OPAL siting safety assessment [9].

The natural hazard presented by severe winds is discussed in the OPAL SAR Chapter 3 (2004) and the summary is presented in Table 3.

Table 3: Wind annual exceedance frequencies at designated mean velocities

Wind Velocity (mph)					
75 (70-80)	85 (80-90)	105 (90-120)	135 (120-150)	165 (150-180)	190 (180-200)
Annual Exceedance Frequency (y^{-1})					
1.82E-02	3.80E-03	9.7E-04	2.47E-05	4.05E-06	9.21E-07

2.3.2 Barometric pressure variations

The OPAL Siting Safety Assessment [9] provides data on barometric pressure variations based on information from Mascot which has been corrected to compensate for the altitude difference. Both time of day and monthly data has been provided.

Minimum pressures are observed during the summer months whilst maximum pressures tend to occur in May and August. This observation corresponds to the latitudinal movement of large-scale pressure systems. Large pressure changes (1-2 hPa per hour) lasting several hours are associated with the passage of cyclones across the Queensland coast and are accompanied by winds from the south-west to north-west. Very large transient pressure changes (5-10 hPa per hour) generally last less than an hour and occur infrequently.

2.3.3 Rainfall and evaporation

Statistical data relating to rainfall for the years 1958 to 2020 were taken from the Bureau of Meteorology, these are presented in Appendix A.

2.3.4 Inversions and atmospheric mixing layers

The occurrence of stable temperature inversions leads to limited atmospheric mixing and worst-case conditions in terms of air pollution impact assessments. The OPAL Siting Safety Assessment provides data for these situations.

All recorded occurrences are ground-based nocturnal inversions. As the meteorological tower on the ANSTO Lucas Heights campus is only 50 metres high, the top of the ground-based inversions and the occurrence of upper level inversions could not be ascertained. The top of the inversions is estimated to be on average 120 metres above the ground. This estimate is based on the time for elimination of nocturnal inversions by surface heating after sunrise. An acoustic sounder has been used to study the development of atmospheric mixing layers associated with the dissipation of inversions. Nocturnal inversions occur on average 291 times per year with an average duration of 8-9 hours and an average intensity is 5 °C per 100 metres.

2.3.5 Turbulence climatology

ANSTO uses the US Environment Protection Authority [10] scheme for classifying atmospheric turbulence. This scheme uses the wind speed and fluctuation in wind direction data to determine atmospheric diffusion parameters called Pasquill stability categories. These categories range from A (the most unstable and most dispersive) to F (the most stable and least dispersive). Table 4, which is adapted from data in the OPAL Siting Safety Assessment, summarises the data on the Pasquill stability categories at the ANSTO Lucas Heights campus.

Table 4: Turbulence categorisation using [10] methodology

	Pasquill stability category					
	A	B	C	D	E	F
Height 10m	7.66%	3.74%	8.02%	45.92%	24.74%	9.92%
Height 49m	3.15%	3.94%	7.25%	58.70%	23.69%	3.27%

2.3.6 Bushfire weather

The ANSTO Lucas Heights campus is located near bush fire prone land. The risk of bushfire in the vicinity of the site increases during dry weather and peaks on days of high temperature, low humidity and strong winds. An assessment was completed to determine the Bushfire Attack Level (BAL) for the proposed site of the ILWCI facility within the ANSTO Lucas Heights campus [11]. This assessment took into consideration the vegetation communities (bushfire fuels) and the topography (effective slope) that combine to affect the potential behaviour of a bushfire. As shown in Figure 5, it was concluded that a very small portion of the proposed site was classified as BAL-40 and the remainder of the site was BAL-29 to BAL-LOW. No part of the site was classified as BAL-FZ meaning that exposure to flames from the fire is not an anticipated risk and at worst the site will be exposed to ember attack and burning debris ignited by windborne embers. The facility will need to be constructed to BAL-29 requirements [12]. The detailed design development process will ensure full compliance with such requirements.

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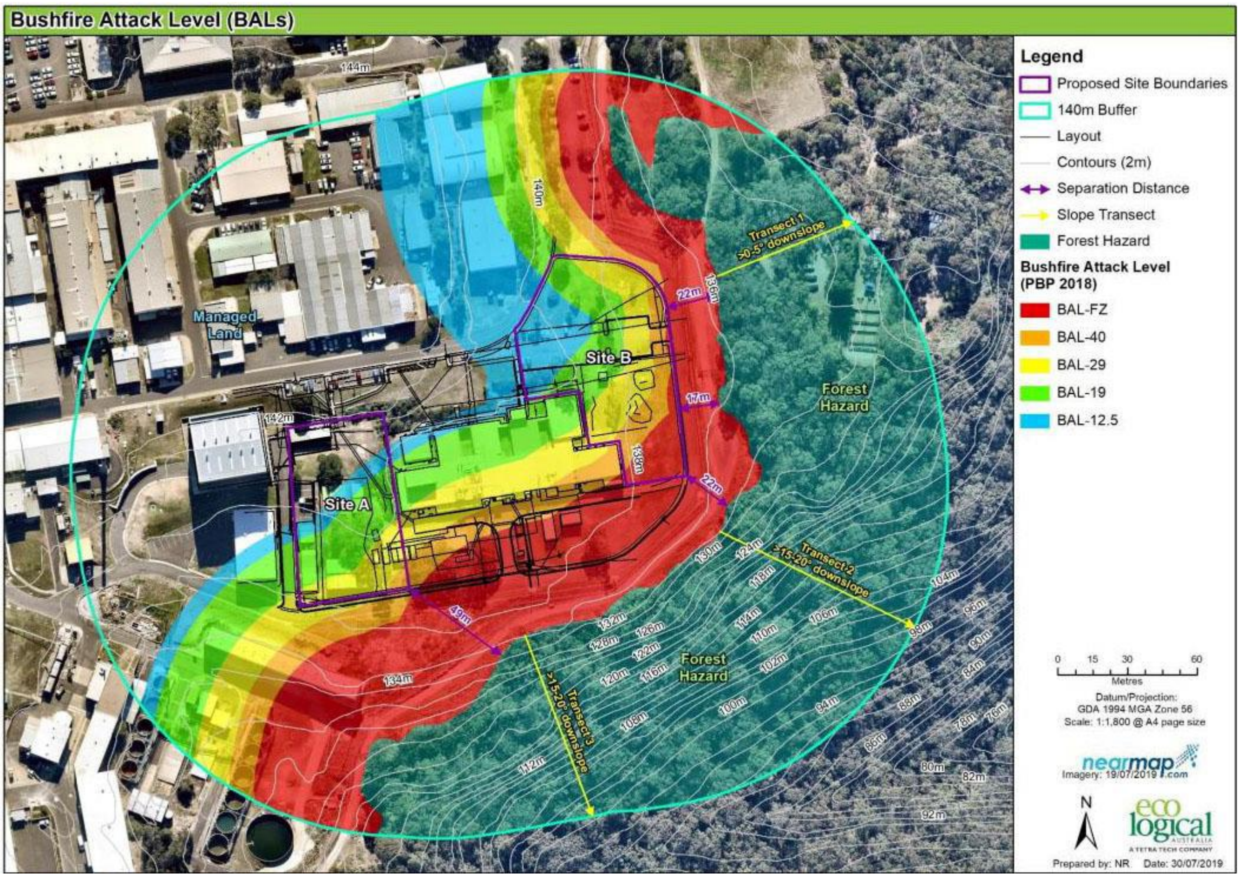

Figure 5: Bushfire attack level for the proposed site, depicted as Site A in the above image

The following bushfire protection measures for the ANSTO Lucas Heights campus are already in place:

- An internal 8-meter, two-way sealed perimeter road (Dalton Avenue) between the proposed development site and the forest vegetation to the south and east;
- External fire trail with turning area;
- Hydrant points both internal and external to security fence at regular intervals;
- Electricity to the proposed development site is located underground;
- Gas services to ANSTO facilities are installed and maintained in accordance with Australian Standard AS/NZS 1596 'The storage and handling of LP Gas' [13]; and
- Management of internal landscaping to Asset Protection Zone (APZ) standards.

Based on the existing measures it was determined that no additional bushfire protection measures were required for the proposed facility [12].

2.3.7 Atmospheric dispersion

The OPAL Siting Safety Assessment refers to studies that indicate that models for predicting atmospheric dispersion under highly stable or inversion conditions and for flat terrain are satisfactory for approximating the transport of airborne materials at the ANSTO Lucas Heights campus. These studies have used atmospheric tracers to show that wind flow patterns in the Woronora Valley are decoupled from the flow on the plateau above.

2.4 Hydrology

Geophysical and hydrogeological investigations of the ANSTO Lucas Heights campus have been conducted periodically. The most significant having been undertaken for the OPAL reactor site during the site assessment in June 1998. The geophysical study was undertaken to provide information on the subsurface conditions and any structures which may influence groundwater in the region of the proposed replacement reactor facility site. The hydrogeological study comprised drilling at 5 locations on the site to a maximum depth of 45 metres, lithological logging, installation of deep and shallow piezometers, groundwater sampling, water analysis and single packer hydraulic parameter testing at three locations. The reports of these investigations [14] [15] were submitted with the siting licence application for the OPAL reactor as supporting documents.

2.4.1 Surface hydrology

The surface hydrology is relevant to safety because radioactive material deposited in or above the ground may find its way into drainage channels, creeks or rivers through surface runoff. There are no known private dams in the vicinity that could be fed by runoff from the site and the OPAL Siting Safety Assessment concluded that there were no known groundwater bores that could be influenced directly by runoff from the site. The general topographic environment is such that no part of the ANSTO Lucas Heights campus is far removed from a natural drainage channel in the adjacent terrain.

The principal surface stream immediately adjacent to the site is the Woronora River. This river is incised deeply into the sandstone basin and is fed by surface runoff and groundwater. On either bank, there are a number of small tributaries which have steep gradients where they join the river. The Woronora river flows generally north-east from the Woronora Dam and passes within 2 km east of the site to an eventual outflow in the Georges River estuary. Even during dry periods, the Woronora River flows at a rate of several hundred thousand litres of water per day. However, during exceptionally hot, dry periods the river flow ceases because of evaporation losses. The river is tidal in its lower reaches.

On the north side of the ANSTO Lucas Heights campus, there is a ridge that is drained by the Mill and Barden creeks. These also empty into the Georges River estuary. The Little Forest Legacy Site is located in the surface water catchment of Barden Creek. The Barden and Mill creek water courses have generally been actively eroded in recent times exposing moderately unweathered rock. This has not occurred at the discharge point from the Lucas Heights campus where there are kaolinitic sands.

The Woronora River flow rates are available from Australian Water Technologies Pty Ltd (AWT), a trading arm of Sydney Water Corporation. AWT have had a gauging station on the Woronora River since May 1992 at a location known as the Needles (Station No.213211), which is situated east of the

ANSTO Lucas Heights campus at a distance of about 1 km outside the ANSTO buffer Zone boundary and downstream of the Lucas Heights campus. The AWT data [16] shows a mean monthly discharge in Megalitres per day for the period from mid-1992 to August 1997 in the range of 0.822 ML d-1 to 458.113 ML d-1 with an average discharge rate of 36.8 ML d-1.

Although the surface water hydrology is discussed here, there is no mechanism for release of radioactivity from the RHSW to be stored at the proposed ILWCI facility.

2.4.2 Groundwater hydrology

The groundwater hydrology is complicated by weathering and features of the Hawkesbury sandstone. The unweathered sandstone has a very low primary or intergranular permeability while the weathered sandstone has a considerably higher primary permeability.

The principal water-transmitting capability is dependent on secondary features such as joints and bedding planes in the Hawkesbury sandstone. Depending on local hydrogeological conditions, aquifers may respond in apparently confined, unconfined or intermediate conditions. Consequently, water levels in boreholes may reflect local conditions and not give a true indication of regional hydraulic gradients.

Standing groundwater levels are known for the northern area of the ANSTO Lucas Heights campus and for the Little Forest Legacy Site. The overall hydraulic gradient is to the north although locally the gradient is strongly influenced by structural and topographical features. The OPAL Siting Safety Assessment reports values for the hydraulic conductivity (permeability). The results show considerable variability.

Close to the Woronora River the groundwater level varies sympathetically with the level in the river. This variation probably extends some 30 metres from the centre of the river. Further from the river, it is expected that the groundwater level should generally only show a slight response to rainfall. As scattered claystone and shale bands occur in the Hawkesbury sandstone formation, there are likely a number of local subsurface conditions where a portion of the downward percolating groundwater is held back by these low permeability barriers.

An assessment of the proposed site for the ILWCI facility concluded that based on the elevated topographic setting of the site, the regional groundwater table is expected to be well below the proposed maximum depth of excavation. Seepage arising from normal stormwater infiltration should, however, be expected along the top of the rock surface and along fractures in the rock, particularly after periods of wet weather. It is anticipated that during construction and for long term the site will require perimeter drains connected to a sump and pump system. The basement will require permanent drainage below the floor slab to direct seepage to the stormwater drainage system [17].

Although the ground water hydrology is discussed here, the likelihood of any release of radioactivity from the proposed ILWCI Facility is considered to be not credible.

2.5 Geology and Soils

The regional and local geology of the site are discussed in the following sub-sections. For more detail geotechnical and geophysical studies [15] [18] submitted with the OPAL siting application can be referenced.

2.5.1 Geology

The ANSTO Lucas Heights campus is situated on the dissected Woronora Plateau, a physiographic unit effectively drained by numerous creeks and rivers, which extends south from Sydney in a ramp-like structure. The dominant rock formation is the Triassic age Hawkesbury Sandstone (approximately 192 m thick). The region forms a part of the Sydney Basin, whose physiographic development, tectonic history and broad structure are summarised elsewhere [19] [20] [21].

The predominant rock outcropping at Lucas Heights is medium to coarse quartzose sandstone. Minor components of dark grey shale, siltstone and sandstone/siltstone makes up approximately 5% of the total. The sandstone units are composed mainly of medium-coarse quartz grains bound by a secondary quartz-siderite cement with a clay matrix. The OPAL Siting Safety Assessment refers to an average value for unconfined compression strength of 2 x 107 Pa. There is a narrow doleritic dyke some 4-5 km in length outcropping in the ANSTO buffer zone.

The Hawkesbury Sandstone at the ANSTO Lucas Heights campus has been subject to laterisation and the depth of weathering is variable. The weathering effects vary from superficial colour changes with no loss of rock strength to the complete loss of strength and disaggregation of the soil. Weathering can extend to depths up to 30 metres. Generally, the soil cover over rock is very shallow and consists of sandy loam, gravel, clay and ironstone. The top layers of sandstone are often soft and underlain by clay seams of varying thickness. Water is often encountered during excavation.

A soil classification assessment was conducted in May 2019 in which soil samples from the proposed ILWCI site were analysed [22]. A description of materials from this assessment can be found in Table 5. The waste classification for material 1 is shown in Table 6 and the VENM assessment for material 2 in Table 7.

Table 5: Description of materials at the proposed site location [22]

	Material 1	Material 2
Material classified	Fill material consisting of a mixture of light brown loam, brown loam and grey loam with sandstone fragments.	Natural material consisting of yellow sands, olive sands and sandstone bedrock.
Location of material	In-situ material to an approximate depth ranging from 0.1-0.5m.	In-situ material beneath material 1.
Area	Approximately 3,850m^2	Approximately 3,850m^2

Table 6: Waste classification for fill material (Material 1) [22]

Olfactory indications	None observed
Discolouration/staining	None observed
Asbestos Assessment	No asbestos detected
Chemical classification	General solid waste (<CT1)
Putrescible waste	None observed
Disposal Classification	General Solid Waste (CT1)

Table 7: VENM Assessment for Material 2 [22]

Contaminated land register	Not listed
Acid sulphate soils	Not listed in an area of potential acid sulfate soils
Olfactory indications	None observed
Discolouration/staining	None observed
Asbestos assessment	No asbestos detected
Soil/bedrock type	The in-situ material to be excavated was consistent with the expected soil and bedrock type for the area
Classification	Virgin Excavated Natural Material (VENM)

2.5.2 Surface geology

Initial geotechnical investigations were conducted in July 2019 to determine the suitability of the proposed site for the ILWCI facility. This investigation included drilling two core boreholes firstly to a depth of 1.1 metres using solid flight augering methods and then advancing the boreholes to a depth of 10 metres to obtain 50 mm diameter continuous core samples of the rock for identification and strength testing purposes [17].

This study confirmed that the site levels ranged from approximately 137 - 141 metres AHD. Filling/topsoil, which was typically silty sand with grass roots, was encountered to the depths of 0.1 - 0.35 meters followed by very low to low and medium strength fractured sandstone to depths of 1.89 - 3.7 metres overlying medium to high strength, slightly fractured unbroken sandstone [17]. Free groundwater was not observed during auger drilling to depths of up to 1.1 metres. Laboratory testing of the rock core confirmed that the Point Load Strength Index (Is50) values ranged from low to very high strength (0.1 MPa to 3.1 MPa). The interpreted geotechnical model for the site comprised of loose to very loose topsoil and natural sands to approximately 1 metre over Hawkesbury Sandstone. In general, the sandstone comprised of 2 - 4 metres of highly weathered, fractured-slightly fractured, very low to medium strength rock. Below 4 metres the sandstone was more uniform being slightly fractured-unbroken, medium to high strength sandstone bedrock. It is expected that the groundwater table would be well below the proposed bulk excavation of the site.

Some suggestions for possible actions to be followed during construction have been made from the geotechnical assessors [17]. However, further surveys and assessments will be conducted prior to the commencement of any excavation activities.

2.6 Ecology

The OPAL Environmental Impact Statement (EIS) section 7.2, physical and biological characteristics, describes the site topography and chapter 12, flora and fauna, describes the ecology of the area surrounding the ANSTO Lucas Heights campus.

2.7 Seismology

The seismicity of the ANSTO Lucas Heights campus has been assessed and the seismic hazard is show in Table 8.

Table 8: Seismic hazards at the ANSTO Lucas Heights campus expressed as horizontal ground accelerations at four different return periods and at different spectral periods [23]

Return period (y)	100	1000	10,000	100,000
PHGA (zero period)				
Median	0.05	0.10	0.35	0.75
Mean	0.04	0.12	0.37	0.85
84th percentile	0.05	0.17	0.49	1.25
0.1s Spectral Amplitude				
Median	0.05	0.21	0.68	1.48
Mean	0.05	0.22	0.70	1.64
84th percentile	0.07	0.29	0.97	2.53
0.2s Spectral Amplitude				
Median	0.05	0.20	0.66	1.47
Mean	0.05	0.21	0.67	1.85
84th percentile	0.06	0.28	0.92	2.21
0.4s Spectral Amplitude				
Median	0.05	0.14	0.46	1.07
Mean	0.04	0.14	0.45	1.07
84th percentile	0.05	0.19	0.61	1.45
1.0s Spectral Amplitude				
Median	0.05	0.06	0.21	0.52
Mean	0.09	0.06	0.20	0.49
84th percentile	0.05	0.09	0.27	0.66

The ANSTO Lucas Heights campus is located on the sandstone Woronora Plateau in the Sydney Basin. The Australian Standard for Earthquake Loads (AS 1170.4, 2007) shows that the Sydney Basin lies in a low intensity seismic zone. While there are some features in the Sydney Basin indicative of past earthquake activity, the OPAL Siting Safety Assessment notes that no seismically active geological structures have been identified, and that there are no major fault lines within 35 km of the ANSTO Lucas Heights campus [24]. A consolidated report published in 2001 also supported this finding [25].

The geotechnical report conducted in July 2019 for the proposed ILWCI facility site concluded that, in accordance with AS1170-2007, a hazard factor of 0.08 and subsoil class of Be is considered to be appropriate for the site [17].

2.8 Site Services

The site has several key services that are supplied generally to most buildings and facilities. Interruption to these services (e.g., power, communications, water, compressed air, drainage, etc.) could be considered an initiating event for some systems within the facility. This will be assessed in the Safety Analysis Report (SAR).

2.8.1 Water Supply

The water reticulation system consists of supply pipelines, storage facilities, pump systems and site distribution systems. Water is supplied from the 230 megalitre Lucas Heights Reservoir (located approximately 2.1 kilometres away) via a gravity-fed pipeline. On reaching the Lucas Heights campus, water is received into two balance tanks before being pumped to a water tower near Einstein Avenue. It is then gravity-fed throughout the system by ring mains around each sector of the site. The multiple pump system is controlled with valves and the water tower can be bypassed by a pump direct from a balance tank into the ring main to increase the general site pressure. The total water storage capacity on the site is 1.5 megalitres. The requirement for backup or additional water supplies is described in the individual facility SARs.

2.8.1.1 Water requirements during facility construction

Additional water supplies required during construction of the proposed facility would not be significant. The Lucas Heights Reservoir System has the capacity to supply more water to ANSTO (which is equivalent to another 20 megalitres per month) and as such it would easily accommodate water supply requirements during construction.

2.8.1.2 Water requirements during operation

Additional water supplies required during operation of the proposed facility would not be significant.

The capacity of the existing water supply system is sufficient to meet the operational requirements of the proposed facility. Water requirements during operation of the proposed facility would be small amounts needed for eye wash and safety showers.

2.8.2 Wastewater

Infrastructure is currently in place at the ANSTO Lucas Heights campus for the treatment and discharge of low-level liquid wastes ('B' line wastewater), trade wastes ('C' line wastewaters), and non-radioactive sewage. This infrastructure includes delay tanks for collection from buildings with pipework to the low-level liquid and trade waste treatment facilities, a sewage treatment plant and a liquid waste disposal pipeline, most of which is located in the south-east corner of the ANSTO Lucas Heights campus.

2.8.3 Stormwater

Stormwater runoff from the Lucas Heights campus does not contribute to any public drinking water supply. It drains to three main discharge points and a number of small stormwater drain outlets. The main discharge points include:

- MDP Creek, which flows into the Woronora River;
- Strassman Creek, which flows into the Woronora River; and
- Bardens Creek, which flows into Georges River via Mill Creek.

Small capacity concrete retention bunds exist at each of these discharge points. Any accidental spills or releases of contaminated liquid which enter the site stormwater system can be contained and pumped back to the wastewater treatment system. Following inspection of the contents, the bunds are discharged daily in normal weather conditions in order to maintain capacity for potential spills and during periods of rainfall, the stormwater overflows are allowed to function. Accumulated sediments are removed from the dams every six months.

ANSTO regularly monitors radioactivity in stormwater leaving the site as well as sampling the Woronora River. Latest data shows that the concentrations of tritium in water has decreased since the closure of HIFAR and the gross alpha and beta measurements were well below the level considered safe for drinking water by the World Health Organization [26].

2.8.4 Electricity

The electricity supply at the ANSTO Lucas Heights campus consists of two independent 33 kilovolt (kV) feeders which converge to the main substation. The power is stepped down by two transformers to 11 kV and distributed from ANSTO's main switchboard to other ANSTO substations. The requirement for backup or additional power supplies is described in the individual facility SAR.

Power would be supplied from adjacent buildings via a feed implemented as part of construction of the facility. Electricity requirements during construction of the proposed facility would be addressed using temporary power boards or mobile generators, depending on the contractor's preference. Power boards could draw power from existing substations near buildings adjacent to the site of the proposed facility.

2.8.5 Compressed air supply

General usage compressed air is supplied by onsite compressors and a reticulation system. Where backup or additional compressed air is required for a specific facility or activity, this is described in the individual facility SARs.

Compressed air may be required for the proposed facility and will be assessed in the detailed design phase.

2.8.6 Communications/data services

The communications system at the ANSTO Lucas Heights campus consists of the following components:

2.8.6.1 Public address system

The public address system at ANSTO is used for major broadcasts to staff including emergency announcements. The system consists of two redundant systems of amplifiers, cables and loudspeakers. The network covers the whole of the ANSTO Lucas Heights campus and is divided into zones which can be selected to control the required range of coverage. Loudspeakers from both systems are located in all buildings which may be occupied, as well as, throughout the outdoor areas of the campus. Broadcasts may be made from ANSTO Security Operations Centre (ASOC). The existing public address system would be extended into the proposed facility.

2.8.6.2 Alarm System

The alarm system, which consists of a network of alarm sensors, detects events such as changes in the status of safety and plant systems. These sensors connect, via an extensive system of cabling and concentration points, to the ASOC for monitoring and response. Safety alarms and access control requirements would be extended from the existing site access and alarm network system into the proposed facility.

2.8.6.3 Telephone and related communications

The telephone system consists of a network of in-ground cables, radiating from a central Private Automatic Branch Exchange (PABX) room, to all occupied buildings. Cabling from the distribution frames connects a range of equipment to the network, including telephones, fax machines, data equipment, access control units, video conferencing facilities and ASOC. The PABX is connected to the Menai Exchange via a multichannel fibre optic link. The existing telephone system would be extended into the proposed facility by means of an underground multi-core cable to the building. Telephone(s) and related equipment would be installed in the building to meet the communication needs of the facility.

2.8.6.4 Computer network

The computer communication system consists of an extensive network of fibre optic cables and communication equipment configured as a ring system for enhanced reliability. The network connects centralised and distributed computer servers to computers and facilities throughout the ANSTO Lucas Heights campus, as well as connecting via a secure firewall to the external telephone network. General computer requirements for the facility would be met by extending the closest existing Ethernet network system in the form of underground fibre-optic cables to the facility.

2.8.6.5 Security system

The main security system provides for the physical protection of nuclear materials and facilities in accordance with national and international obligations. It consists of distributed detection and assessment equipment connected to a dedicated network meeting the requirements of a national security endorsed system.

2.9 Nearby Facilities

2.9.1 Facilities and activities at the ANSTO Lucas Heights campus

A wide range of activities take place on the ANSTO Lucas Heights campus typical of a small industrial facility or university campus. These include: various research activities in nuclear, health, minerals, materials, environmental and industrial applications; the production, manufacture and distribution of nuclear medicines; neutron beam analysis; ion beam analysis; accelerator mass spectrometry; silicon and gamma irradiation; and radiation waste treatment and management activities.

Some of the activities conducted at the ANSTO Lucas Heights campus have the potential to release minor quantities of hazardous materials. The safety of facilities and activities at the Lucas Heights campus, including those in adjacent buildings, are highly regulated by Safety Reliability Assurance (SRA), the Nuclear Materials Officer, the Area Health Physicist and the responsible section head as required by ANSTO Safety Standard Guides.

All ANSTO work areas where chemicals are stored must maintain a register of all their chemicals. ANSTO uses a chemical safety management system (ChemAlert™) to assist in the management of the site's hazardous chemicals. This system stores the most up to date information regarding the chemicals on site including Material Safety Data Sheets, chemical risks, and current inventory. The information is maintained regularly by the responsible Area Supervisors and readily available. The status of the chemical inventory of any facility at ANSTO can be found using a simple search tool on the company intranet. Guidance on maintaining information on chemicals and the stock inventory is provided in guidance document AG-5531 [27]. Current data indicates that there are some small quantities of flammable liquids stored in compliant stores in nearby buildings. Some non-flammable and cryogenic gases (Argon and Liquid Nitrogen) are stored in above-ground tanks near the proposed site. There are no issues arising from facilities on site that could impact the safe operations of the proposed facility.

Operations at the ANSTO Lucas Heights campus involving conventional industrial activities are subject to the Work Health and Safety Act and Regulations and, where no specific Commonwealth legislation exists, to the NSW WorkCover Occupational Health and Safety requirements in order to minimise industrial accidents. An industrial accident occurring at the Lucas Heights site, outside the proposed facility, that could significantly damage the waste form and its containment vessel is extremely unlikely. Few operations on site have sufficient stored energy to penetrate the design of the transport and storage vessels; none have the energy and proximity to cause an accident at the proposed facility. These will be addressed in the proposed facility's safety assessment and SAR.

2.9.2 Nearby Industrial Facilities

This section describes the types of facilities and activities that are conducted in close vicinity of the ANSTO Lucas Heights campus. The effect of these nearby facilities is assessed in section 3.3.3.

The ANSTO Innovation Precinct is located on the northern side of the main Lucas Heights campus area. This site is leased to various private companies.

The SUEZ Lucas Heights Resource Recovery Park spans approximately 165 hectares, of which 115 ha is located within the ANSTO buffer zone. The centre is a general waste disposal site taking in municipal and industrial solid waste from the south of Sydney. The site accepts waste from householders, small businesses and councils and is visited by over 157,000 cars and trucks per year.

In order to utilise the methane gas generated by the Resource Recovery Park, Energy Developments Limited operate two electricity generating plants. The nearest plant, currently rated at 12 MWe, is located some 450 metres northwest of the OPAL reactor facility site and a second smaller plant, less than 4 MWe, located 3 kilometres north-east. There is an underground 4-kilometre-long and 250 mm diameter gas pipeline between the two plants. The effect of these plants and pipeline on the ANSTO Lucas Heights campus is discussed in section 3.3.3. There are no major pipelines transporting gas within 10 km of the ANSTO Lucas Heights campus.

A review of the list of sites for storage of dangerous goods licensed under the Dangerous Goods Acts, 1975 within an 8 km radius of the ANSTO Lucas Heights campus (referenced in PLG 1998) reveals that there are no oil refineries, chemical plants, plastic manufacturing plants, or any industrial complexes that handle large quantities of hazardous materials. A paint manufacturing plant is located within 8 km of HIFAR. The types and quantity of the hazardous materials stored in that location are considered to pose no threat to the proposed facility.

2.9.3 Military Facilities

The Holsworthy Training Area is run by the Australian Army and includes an artillery range. It lies to the north, west and south of Lucas Heights, the boundary following the Heathcote Road and the Woronora River. Artillery practices are controlled by the Commander, Liverpool Area, whose standing orders invoke standard instructions for practice artillery training.

The Army takes great care to ensure that all practices using live ammunition at the Holsworthy Military Training Area are carried out safely. The frequency of artillery practice has been gradually scaled down and therefore, the likelihood of any military incident affecting ANSTO is low [28].

2.10 Transport Routes

Nearby transport accidents have the potential to affect the facility through overpressure following explosions, fires, generation of missiles, and release of toxic material. The following describes the local and regional characteristics involving air, road, rail and water transport.

2.10.1 Air Transport

There are two airports in the vicinity of the ANSTO Lucas Heights campus: Sydney (Kingsford Smith) Airport at Mascot, and Bankstown Airport. Sydney Airport is approximately 19 km north east of the site and accommodates all aircraft types. The Lucas Heights site lies within an air traffic lane in and out of Sydney Airport. Bankstown Airport is approximately 13 km north of the site and is used by light aircraft and helicopters only. Military aircraft also occasionally operate in the vicinity of the site owing to its proximity to the Holsworthy Army Training Area.

The ANSTO Lucas Heights campus is on the boundary of the Sydney control area where the lower limit of the controlled air space rises from 500 to 2000 feet above sea level. All civil and military aircraft are prohibited from entering the restricted airspace above the ANSTO Lucas Heights campus unless a prior air traffic clearance has been obtained by the pilot from the Civil Aviation Safety Authority (CASA). CASA regulation prohibits aircraft from flying lower than 2000 feet above sea level within a radius of one nautical mile (1.85 km) from HIFAR unless a CASA Air Traffic Control Clearance has been obtained by the pilot.

This restricted region is known as R521. ANSTO is the designated controlling authority and requires that a formal written request for permission for limited use of the designated airspace be obtained from the CEO. The HIFAR restricted area R521 is significantly overlapped by another restricted area over the Holsworthy Army Training Area. This second region (R555) prohibits aircraft from flying lower than 3000 feet above sea level [29].

2.10.2 Road Transport

The main roads near the ANSTO Lucas Heights campus are Heathcote Road and New Illawarra Road. Heathcote Road is not a major road for the transportation of hazardous chemicals between suppliers and their major customers. Heathcote Road and New Illawarra Road are used by suppliers of certain hazardous materials for local demands, such as those of ANSTO and the Holsworthy military base, as well as routes to other destinations. The hazardous materials for local demands are primarily petrol and diesel. ANSTO receives petrol delivery about once every 3 months, and it also gets modest shipments of bulk carbon dioxide, nitrogen, argon, and liquefied petroleum gas (LPG). A major supplier of petrol and diesel, AMPOL oil refinery, uses Heathcote Road about once every 3 weeks for a maxi tanker, which holds 40,000 litres petrol or 36,000 litres diesel. Mobil Oil uses Heathcote Road at a rate of six petrol trucks (average capacity of 40,000 litres) per day, for 6 days a week for delivery of the fuel from the company site at Silverwater to Wollongong.

Explosives for the Holsworthy military base are delivered from the Orchard Hills Ammunition depot approximately 3 to 4 times a year. Approximately 10 tonnes of the explosives are shipped each time in an explosive qualified vehicle or truck. The shipments of the explosives, however, do not pass through the Heathcote Road but instead through Liverpool to the north. Evaluation of potential effects of bulk chlorine and LPG transport is given in section 3.3. It is expected that the frequency of these shipments is declining in line with the decreasing frequency of artillery practice.

2.10.3 Rail and Water Transport

The Illawarra railway line passing through Engadine and Heathcote is approximately 2.2 km from the proposed facility site. The railway companies that use this line are Sydney Trains, Freight Corp, and Pacific National. Sydney Trains is a commuter rail and does not carry hazardous materials. Materials transported via rail do not have any effect on the proposed facility. The Woronora River, approximately 2 km to the east of the ANSTO Lucas Heights campus, is not a navigable waterway.

2.11 Baseline Environmental Radioactivity

Information on measured environmental radiation at the ANSTO Lucas Heights site and its vicinity is reported in the ANSTO annual environmental monitoring reports. These reports provide results of measured radioactivity and radiation levels for airborne emissions, low-level liquid effluent, and external radiation. All results are within the relevant discharge authorisations which also specify the standard or guideline (e.g. WHO Guidelines for Drinking Water Quality) against which compliance is assessed. ANSTO is committed to an ongoing monitoring programme for radioactivity in the environment and effluent discharges.

3 SITE RELATED DESIGN BASES

3.1 Requirements for Design Bases

This section uses the site characteristics presented in Section 2 to determine the potential effects of site related events on the design and operation of the proposed facility, including a description of the limiting external event design bases. The aim is to consider how these characteristics may affect either the safety of the waste or the management of an accident and ensure that they are taken into account in the design of the facility. This results in the specification of the site-related design bases of the plant which determine the design basis accidents for external events that are to be analysed in the Safety Analysis Report.

The facility concept is such that the safety of the waste will rely almost entirely on the inherent form of the waste. Therefore, the design basis for the facility is essentially only to provide a secure and suitable storage area for the waste packages.

In determining those external events for which a design basis needs to be specified for the facility, a review of external events was undertaken.

Table 9 shows a summary of external, natural and human induced site-related events identified for consideration of the safety of the facility. Some events are precluded by the specific location of the facility at the ANSTO Lucas Heights campus. Some natural events are routinely considered in the detailed design of the facility. Other events may determine a design basis parameter because they represent an extreme, or bounding case, condition. These include seismic activity, extreme wind (e.g. tornado) and aircraft crash onto the building. A set of design basis parameters for these events will be specified in ANSTO's requirements for the facility.

Table 9: Screening of potential natural and human induced events

Events	Comments
Natural Events	
Avalanche	The site location precludes this event
Bushfire	May need to be considered in the design
Costal erosion	The site location precludes this event
Drought	May need to be considered in the design
Flooding – local	Some areas on site could be prone to localised flooding. In addition, flooding due to internal events should be considered
Flooding – regional	The site location precludes this event
High summer temperature	May need to be considered in the design
Intense precipitation	Include in analysis of local flooding
Landslide	The site location precludes this event
Lightning	May need to be considered in the design
Low water supply	May need to be considered in the design
Low winter temperature	Temperatures rarely drop below 0ºC. Damage to pipes structures etc, by freezing is not credible.
Meteorite strike	Meteorite strikes are not considered credible
River diversion	The site location precludes this event
Sandstorm	The site location precludes this event
Seismic activity	May need to be considered in the design
Sinkhole	The site location precludes this event
Snowstorm	The site location precludes this event
Soil/rock freeze/thaw cycle	The site location precludes this event
Soil shrink – swell consolidation	May need to be considered in the design
Storm surge	The site location precludes this event
Tsunami	The site location precludes this event
Volcanic activity	The site location precludes this event
Waves	The site location precludes this event
Wind extreme	May need to be considered in the design
Human-induced Events	
Aircraft crash	Small likelihood of any effect at the ANSTO Lucas Heights campus. Aircraft crash on any single building is not credible [30].
Military activity	Small likelihood of any effect at the Lucas Heights campus. Shelling damaged to any single building is not credible [28].
Missiles from high energy equipment	Include in the analysis of onsite activities
Nearby industry	Nearby industry is too distant and low hazard to have any effect at the ANSTO Lucas Heights campus.
Onsite activities	The proximity to adjacent installations at the ANSTO Lucas Heights campus might need to be considered.
Road/rail activities	Railways are too distant to require consideration. Road accidents may need to be considered.
Ventilation air quality	May need to be considered in the design
Water supply quality	May need to be considered in the design

3.2 Design for External Natural Events

3.2.1 Seismic Activity

A design requirement is that the waste shall remain safe under the effects of severe ground motions without causing an unacceptable release of radioactivity. Severe ground motion is taken to be that expected to occur at the site with a frequency of exceedance less than or equal to 10-4 per annum. This corresponds to a Peak Horizontal Ground Acceleration (PHGA) of 0.37g [23].

Protection of the waste will rely on a combination of the waste packaging and the building design.

3.2.2 Meteorologically extreme events

3.2.2.1 Winds

The IAEA suggests that design basis winds and cyclones are evaluated on the basis of the maximum historical intensity within a radius of about 100 km of the site (IAEA 1987). If there is insufficient historical data, the maximum historical intensity can be extrapolated by means of a statistical technique. The HIFAR PSA [31] has produced a wind hazard analysis, including for tornadoes, using an accepted statistical approach for the ANSTO Lucas Heights site based on Sydney (Kingsford Smith) Airport data. The derived frequency exceedance curves for the fastest-mile wind speed and tornado-type wind, is reproduced in Figure 6.

For the proposed facility, the design basis for high winds including tornado-type winds is determined for a likelihood of exceedance of 10-4 per year. On this basis, the HIFAR PSA determined that the fastest mile wind speed is 105 mph (170 km per hour) for the Lucas Heights site. At a similar exceedance level, the highest tornado-type wind speed is 85 mph (135 km per hour). The design basis for the facility will include not only the pressure effects associated with the wind but also the gusting effects, the pressure drop and the missile effects in the case of the tornado-type winds. This will be considered in detail in the detailed design and will be assessed in the SAR if such incidents are found to be relevant and credible.

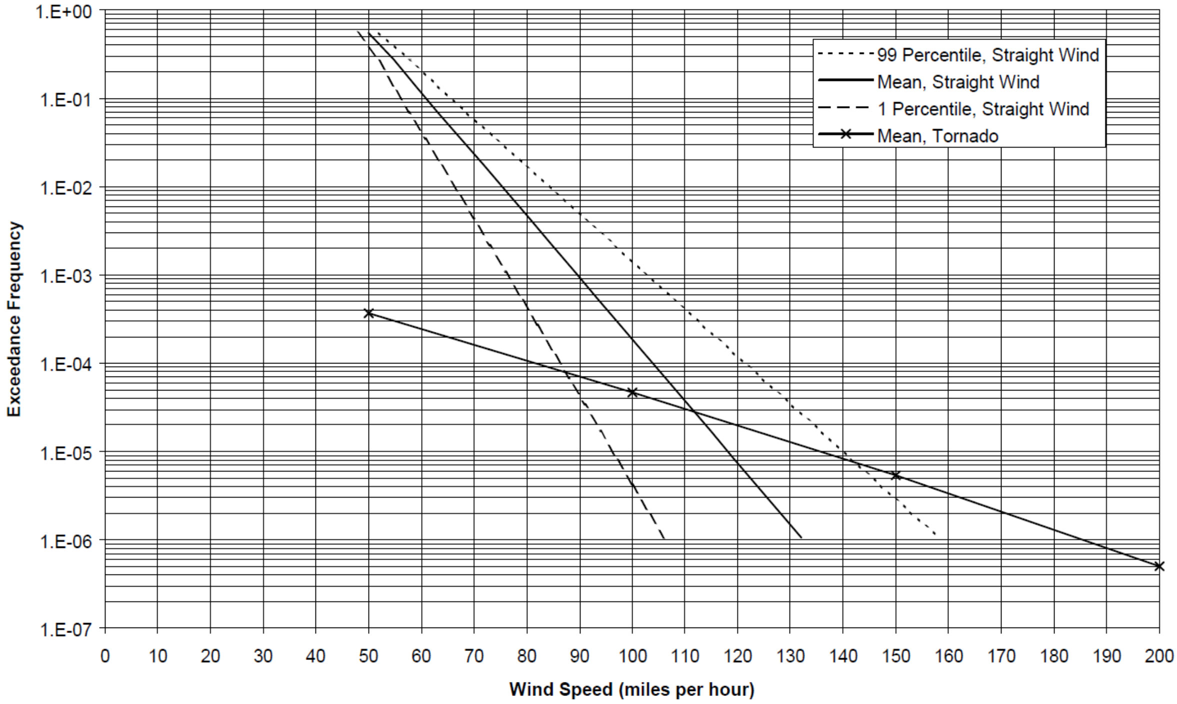

Figure 6: Exceedance frequency curves for the fastest mile wind speed and tornado type wind

3.2.2.2 High summer temperatures

Prolonged periods of high temperature can be expected in the summer at the Lucas Heights site. The design limit for maximum temperature is 50oC. High temperature effects (e.g., risk of fire) on the ILWCI facility will be bounded by a bushfire event.

3.2.2.3 Frost and low winter temperature

To date, the lowest temperature ever recorded at Lucas Heights was -0.7oC in August 1974. The lowest temperature recorded in 2020 was 3.1oC and the average minimum temperature so far is 6.0oC [32]. Temperatures below 2oC are uncommon and are not sustained for significant periods of time at the Lucas Heights site. Over the past 50+ years the mean number of days with temperatures 2oC or lower is 0.9 per annum [33]. Therefore, the design basis low temperature for the proposed facility has been set at 1oC.

3.2.2.4 Intense precipitation

The layout of the proposed facility will be such that the site will be capable of coping with heavy rainfall. The potential for local external flooding and stormwater drainage will be considered as part of the detailed design.

3.2.2.5 Fog

Heavy fog is very rare at Lucas Heights. Nevertheless, the effects of heavy fog will be included in the design for the proposed facility in terms of the atmospheric hydrosol loading on systems. Fog, however, is not anticipated to be a significant design parameter for this facility.

3.2.2.6 Hail

Hail is common in the region. However, hail represents a low risk hazard to the operation of the facility due to the underground storage of waste and the fact that waste transfers are not permitted under wet weather conditions.

3.2.2.7 Lightning

Frequent lightning strikes can be expected at the Lucas Heights site. The potential effects on plant and equipment will be considered as part of the detailed design of the facility. However, the facility will not be overly tall and is set somewhat on a slope such that other buildings and stacks in the vicinity will be significantly higher.

3.2.3 Hydrological or geological events

3.2.3.1 Water Supply

The effect of drought, low lake, dam or river water level, will not have any effect on the safety of the facility as water supply is not a safety-related feature. Any potential for loss of supply would only cause inconvenience for operators of this facility (loss of staff amenities) and would be known well in advance. The Lucas Heights site also holds a 1.5 Megalitre supply of stored water.

3.2.3.2 Soil shrink – swell consolidation

The potential for soil shrink-swell consolidation will be taken into account in the detailed design of the facility.

3.2.3.3 Landslide or sinkhole

During the detailed design stage, the foundation of the building will be developed based on the findings of the site geotechnical study [17]. It is likely that the building will have deep pad footings or bored piles founded on the sandstone bedrock. Although the preliminary findings of the study [17] suggested that pad footings founded on sandstone should be appropriate, further study/analysis would be undertaken to confirm the foundation design. Therefore, there would be no potential for a landslide or a sinkhole at the facility site.

3.2.4 Bushfires

The location of the ANSTO Lucas Heights campus is such that large bushfires can be expected every 8 to 12 years on average. These fires have the potential to burn up to the site boundary. The fire intensity and duration are dependent on a number of meteorological factors including prevailing wind strength and direction, temperature, and humidity. The Lucas Heights site is on relatively flat ground with sparse vegetation, which will reduce the intensity of the fire coming over the ridge. As detailed in section 2.3.6, the proposed site for the ILWCI facility is located in a lower risk area for bushfires. The site is surrounded by other buildings and a road and is unlikely to be significantly affected by bushfire. Furthermore, the effect of radiant heat from a bushfire on a building under steady state conditions was assessed concluding that the heat would be considerably less than solar heating [34].

The main design considerations for avoiding or minimising hazards from bushfire include compliance with relevant Australian building standards; the use of appropriate construction materials; appropriate design to avoid the collection of combustible material on or near buildings (e.g. leaves settling in guttering, roof or eaves); and maintaining recommended fire hazard reduction distances from bushland.

The facility will also be designed to withstand the smoke and hot debris that may fall on the building during a bushfire. The effects of aircraft crash bound the effects of bushfire in terms of high temperature debris. As explained below, crash of an aircraft (up to fighter jet category) would not cause a release of radioactivity.

3.3 Design for Human Induced External Events

3.3.1 Road and rail transport accident

The only hazardous substances regularly travelling the roads close to the ANSTO Lucas Heights site are petrol and diesel. The sodium cyanide carried by rail is too far away to affect the Lucas Heights site in the event of an accident and any explosives transported by road take an alternate route away from the Lucas Heights site. Although no large amounts of pressurised gas or toxic materials currently pass close to the Lucas Heights site, it is prudent to consider that such transport might commence at some point in the future operation of the facility. Accordingly, ANSTO contracted DNV Consultancy Services to provide an analysis of transport accidents on New Illawarra Road, at 520 metres, and the nearest railway line at 2,200 metres.

Five bounding scenarios have been developed and assessed for road and rail transport accidents close to the proposed replacement reactor facility site at the Lucas Heights campus [35]. These scenarios are:

- Boiling Liquid Expanding Vapour Expansion (BLEVE) of a full road tanker of LPG;
- LPG flash fire and vapour cloud explosion;
- Fire with possible explosion of a full road tanker of petrol;
- Explosion of a full semi-trailer load of ammonium nitrate; and
- Rupture of a full road tanker of chlorine.

The DNV analysis [35] concluded that the bounding scenarios for LPG BLEVE, petrol fire and ammonium nitrate explosion would have negligible consequences to people located in the open at the Lucas Heights site during any incidents and would have no significant impact on buildings, apart from the possibility of breaking glass windows from the explosion.

The rupture of an LPG road tanker and subsequent formation of a gas cloud could cause a flash fire killing people within the gas cloud up to 285 metres from the site of the rupture. There is a possibility of this gas cloud exploding in the bush surrounding the Lucas Heights campus. This would result in significant overpressure that could cause injury to people in the open and damage to unprotected structures. However, the greater distance together with the design and construction of the facility and the storage vessels would ensure that, in the unlikely event of a rupture of an LPG tanker, there would be no effect on the safe storage of the waste.

The worst consequences from a major leak of chlorine could lead to fatalities of people at 240 m from the rupture, unless they could shelter inside a sealed building with air not contaminated by the chlorine. At 3000 m from the leak there is a low likelihood of fatalities to people who remain outside during the incident, however, this is considered to be a conservative estimate. At present, there is no chlorine transported along the roads near the Lucas Heights campus, and no such transport is planned by NSW authorities. Even if such transport occurred, the likelihood of a major road accident on the section of road near the Lucas Heights campus would be low.

3.3.2 Aircraft crash

It has previously been determined for the HIFAR reactor that the likelihood of a crash of a commercial jet or general aviation aircraft on a building within Lucas Heights campus is 2x10-7 per year [31]. A subsequent analysis for OPAL using the DOE methodology concluded that the best estimate total impact frequency of Commercial Aviation (air carrier) was 1.1x10-8 per year with an upper bound of 4.8x10-8 [30].

The proposed facility has a smaller effective target aspect than both of these buildings. The RHSW will be stored in underground concrete pits and/or storage tubes at a depth of about 8 m - 10 m. Therefore, the estimated likelihood for this facility would be considerably smaller. For that reason, aircraft crash is considered beyond design basis for this facility.

3.3.3 Nearby industrial activities

Offsite accidents at nearby industrial facilities have the potential to affect the facility through overpressure following explosions, fires, generation of missiles, or release of toxic material. The potential effect of a nearby industrial accident on the proposed facility is similar to that of transport accidents involving hazardous materials near the Lucas Heights site and onsite activities.

The nearest pipeline to the Lucas Heights site is that providing landfill gas to the EDL electricity generating plants. Failure of this underground pipeline has the potential to release methane, a flammable gas. A hazard assessment of the 12 MW landfill gas electricity generation plant and the associated underground gas pipeline concludes that the EDL facility does not present a hazard to the Lucas Heights site [36]. The total mass of methane is very small, and the effects of an explosion or fire would be negligible at the distance between the plant and the facility site. Furthermore, the effects of burning of the released methane gas are bounded by aircraft crash effects. There are no other pipelines nearby which could impact the Lucas Heights site. As explained below, the impact of an aircraft (up to fighter jet category) would not cause a release of radioactivity.

A review of the list of sites for the storage of dangerous goods licensed under the Dangerous Goods Act within an 8 km radius of Lucas Heights reveals that there are no oil refineries, chemical plants, plastic manufacturing plants, or any industrial complexes that handle large quantities of hazardous materials. However, a paint manufacturing plant is located within 8 km of the site. The types and quantity of the hazardous materials stored in that location are considered to pose no threat to the proposed facility.

3.3.4 Military activities

The likelihood of a stray artillery shell from the Holsworthy Military Area hitting the HIFAR reactor was previously assessed and found to be not credible (less than 1 in 10 million years). Since that time, usage of the Holsworthy Military Area has reduced, and improved controls have been implemented [28]. Additionally, the location of the proposed facility is further from the area. Therefore, a lower likelihood exists for the proposed facility when built. The event is considered beyond the design basis.

3.4 Effect of Onsite Activities

3.4.1 Activities in other site buildings

Onsite activities have the potential to affect the facility through: overpressure following explosions, fires, generation of missiles, and releases of toxic material, cryogenic or radioactive material. The characterisation and management of Lucas Heights chemical hazards, including bulk chemical and other hazardous materials storage facilities, has been described by [37].

The location of the chemical storage facilities in relation to the proposed site for the ILWCI facility is such that, for all cases, the hazards presented by the type and quantity of chemicals and their distance from the facility are bounded by the hazards presented by a road transport accident as described in section 3.3.1. The potential for an accident leading to an uncontrolled release of radioactive material from any Lucas Heights campus building is small and, further, the potential effect on the facility of such an on-site accident is negligible. There are no large, high energy rotating machines or large, high pressure machines on the Lucas Heights site.

In considering the range of postulated initiating events arising from activities at the Lucas Heights campus:

- For explosions, the effects of overpressure and the effects of missile generation are bounded by fighter aircraft crash;
- The effects of onsite fires and bushfires are bounded by fire arising from fighter aircraft crash; and
- The effects of a release of airborne material affecting the ventilation and habitability of the facility have no impact on the safe storage of the waste. However, these will be taken into account in the development of emergency plans.

4 COMPLIANCE WITH REGULATORY ASSESSMENT REQUIREMENTS

4.1 Radiological impact

The RHSW will be stored in underground concrete pits and/or storage tubes at a depth of approximately 8.5 m. The majority of RHSW to be stored in the facility are either encapsulated in stainless steel vessels or immobilised using Synroc technology. There are no identified site characteristics which could adversely form a transfer pathway of radiological releases to humans. There are also no identified site characteristics that can lead to significant escape of nuclides to the geosphere after accidents. In any case, there are no identified accidents that could credibly lead to a release causing a significant radiological consequence, even within the facility.

Environmental measurements of radioactivity have been published since the 1960s. Recent environmental surveys (PPK 1988a; Hoffmann et al, various years through to the most recent) reveal no significant levels of radioactivity in air, soil or water at the ANSTO Lucas Heights site. For routine authorised releases, the main environmental pathway contributing to dose is external irradiation from airborne releases which comprise more than 80% of the total effective dose to members of the public (NNC 1998). Liquid effluent dose pathways make negligible contributions to public dose (NNC 1998) and this is substantiated by biota sampling that is undertaken at Potters Point and in the Woronora River.

4.2 Ongoing Site Evaluation

ANSTO, as the Facility Licence holder for the ILWCI facility (subject to the granting of relevant licences), is committed to ongoing site evaluation during the life of the facility. The objective of these future evaluations is to determine any changes that occur so as to identify those which may affect safety aspects of the storage facility. The possible changes include:

- Nearby industrial, transport and military facilities;
- Nearby institutional, recreational, and residential structures;
- Radiological impact due to an increase in the local population distribution;
- Site seismology because of new information;
- The construction of new buildings and structures at the ANSTO Lucas Heights site;
- Site micro-meteorology due to new buildings and structures; and
- The size and management of the buffer zone controlled by ANSTO.

Notwithstanding this commitment, it is noted that the Safety Assessment for the facility has not been able to identify any accident that could credibly lead to a radiological release with significant consequences.

4.3 Further Work

As per the report from Jacobs [11], the following work is required in preparation for the proposed facility:

- Demolition of kerbs along Dalton Avenue and the access road to the west of the proposed building;
- Earthworks to regrade perimeter of the building;
- Adjustment to the stormwater pit on access road to suit new exit driveway;
- New layback kerb along Dalton Avenue and access road to the west of the building;
- New heavy-duty pavement for semi-trailer ingress and egress routes from unloading bay;
- Footpaths to access the new building, including emergency egress points;
- Fencing demolition and/or realignment;
- Subsurface drainage around perimeter of below ground structures and connection to existing stormwater pits (clean subsurface water only);
- Connection of roof water system (or overflow if being reused) to new stormwater retention system;
- Utility relocation – adjustments (and/or protection) will be required to water supply on western side of building and at the driveway tie in points on Dalton Avenue.
- Telecommunications and sewer may also be impacted by the driveway tie-in on Dalton Avenue. Potholing and survey will be required to confirm depth;
- It does not appear that additional underground site stormwater infrastructure will be required;
- Retaining walls will be required; and
- Pumped system for seepage water from the basement storage.

5 CONCLUSIONS

On the basis of the site characteristics information and the specific site-related design basis considerations, it is concluded that the proposed site for the storage facility, within the Lucas Heights site, does not have any negative features which cannot be overcome by the high standard and quality of engineering design and construction which are required by ANSTO. The safety assessment for the facility shows that no significant design features are required for the facility other than those required for general buildings. This includes consideration of site-related characteristics and hypothetical accidents. These events, called Design Basis External Events (DBEEs) are identified in this submission as earthquakes, extreme winds, and light aircraft crashes. These DBEEs bound the effects of all other natural or human induced external events. The effect of these events will be analysed at the stage of the detailed design of the facility and reported in the Preliminary Safety Analysis Report. In summary, this site was selected because of the following features:

- The existing nuclear site with the adequate security infrastructure with site access controlled by the Australian Federal Police;
- Existing infrastructure including power, water supply, waste services and communications;
- Existing staff with the expertise in the area of radiation protection, maintenance and engineering, asset management, waste management and emergency response capabilities; and
- An established environmental monitoring program.

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Appendix A: Monthly and annual statistics of rainfall at Lucas Heights 1958 to 2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1958			302.3	66.6	7.6	140.8	25.9	54.3	22.2	28.8	18.6	55.9	
1959	104.8	126.5	186.3	42.2	9.0	42.9	141.1	42.8	40.2	196.3	129.2	123.1	1184.4
1960	55.2	83.3	53.7	27.2	137.0	47.2	60.1	34.1	50.2	173.9	62.0	273.1	1057.0
1961	75.9	58.9	53.3	87.1	13.3	70.8	37.2	208.2	34.1	39.8	432.2	170.0	1280.8
1962	159.5	134.2	45.7	56.1	270.3	2.3	60.5	95.8	71.4	18.4	15.6	168.5	1098.3
1963	200.0	65.5	282.5	195.7	169.8	229.8	29.2	247.5	62.0	46.7	40.6	234.7	1804.0
1964	9.7	27.4	107.1	169.0	16.3	401.4	5.4	35.6	26.9	86.2	52.1	24.6	961.7
1965	10.3	12.2	10.4	125.8	32.0	93.2	363.7	11.5	49.4	148.5	8.1	33.9	899.0
1966	20.4	80.3	83.2	85.0	18.3	102.6	18.3	67.0	56.7	52.8	190.9	84.7	860.2
1967	173.0	81.7	92.9	41.7	16.6	197.0	18.3	215.0	102.6	58.3	74.0	18.4	1089.5
1968	132.3	17.7	87.4	12.5	114.1	12.5	58.8	21.7	4.1				
1969		207.7	63.0	217.3	41.5	84.6	22.3	133.4	90.1	48.6	270.7	32.8	
1970	136.2	22.4	91.3	46.2	21.5	33.5	0.3	25.5	118.9	24.9	81.7	261.3	863.7
1971	67.2	171.7	74.5	30.0	48.3	15.5	13.8	65.8	33.8	3.0	71.5	150.9	746.0
1972	255.7	74.2	145.0	102.7	53.8	63.7	0.8	45.8	15.0	211.3	59.7	42.3	1070.0
1973	168.3	259.3	36.6	81.1	17.0	55.5	106.6	58.2	26.8	88.0	126.5	48.2	1072.1
1974	270.7	119.9	270.3	161.9	234.9	155.8	6.3	190.9	57.3	73.3	102.1	14.8	1658.2
1975	34.3	128.7	292.8	109.6	7.6	267.1	198.1	18.0	34.4	101.2	48.4	15.2	1255.4
1976	258.9	115.3	252.5	29.8	34.9	113.4	98.8	9.7	49.8	213.7	121.8	22.0	1320.6
1977	57.9	238.0	209.3	29.5	108.6	86.3	0.7	16.6	46.8	6.0	23.6	34.7	858.0
1978	250.9	22.5	329.5	86.5	76.3	449.7	17.0	15.2	68.7	50.9	94.2	121.1	1582.5
1979	40.3	12.2	109.3	19.8	100.2	99.7	18.8	5.9	35.2	37.6	70.9	6.4	556.3
1980	80.2	70.2	38.8	7.9	153.7	61.9	41.2	8.7	1.5	22.9	57.2	41.4	585.6
1981	52.0	165.2	14.3	190.8	91.6	57.6	39.8	6.4	7.2	141.8	152.6	93.3	1012.6
1982	39.2	20.9	139.1	11.4	4.1	70.9	69.8	1.3	174.5	43.6	9.8	14.3	598.9
1983	24.1	20.4	274.9	61.4	127.6	98.3	21.2	25.8	41.5	154.0	57.8	80.4	987.4
1984	148.7	133.2	157.7	93.2	75.2	72.9	141.1	13.1	31.4	26.3	312.3	76.1	1281.2
1985	7.1	29.4	70.8	209.0	154.0	163.9	111.4	25.2	62.6	213.6	103.6	103.6	1254.2
1986	179.6	51.6	21.3	56.5	22.7	5.4	24.0	403.8	50.4	56.2	127.6	28.7	1027.8
1987	44.4	19.2	134.0	8.4	78.8	53.1	93.6	360.2	10.3	191.4	98.4	65.7	1157.5
1988	83.7	83.3	47.4	397.6	114.4	44.6	135.8	27.3	121.6	0.0	146.5	112.9	1315.1
1989	104.5	44.3	108.9	365.5	96.1	187.4	17.9	36.8	0.6	12.3	54.5	72.5	1101.3
1990	64.1	443.0	90.3	287.6	146.2	21.4	45.6	218.4	57.8	34.9	17.6	56.4	1483.3
1991	53.6	24.4	27.8	28.3	48.0	409.5	90.6	9.8	15.6	10.0	34.4	259.4	1011.4
1992	123.6	298.2	80.2	93.6	37.8	70.5	11.4	19.6	18.0	33.6	143.4	185.8	1115.7
1993	50.2	88.8	142.0	29.6	15.8	34.3	65.0	69.0	81.8	54.6	57.3	40.6	729.0
1994	11.2	47.3	151.7	105.5	25.5	38.8	7.4	8.4	10.4	35.1	94.2	50.7	586.2
1995	122.1	47.6	205.2	14.2	199.9	40.4	1.0	0.0	249.3	34.4	135.4	93.9	1143.4
1996	136.0	64.1	33.7	33.2	143.4	51.8	78.4	130.5	74.8	31.2	70.8	68.8	916.7
1997	113.2	127.7	61.2	0.5	96.5	51.0	48.8	18.7	105.6	60.2	21.7	27.3	732.4
1998	75.0	56.0	15.5	161.0	203.3	80.2	86.8	316.3	37.7	26.7	110.3	37.8	1206.6
1999	111.9	196.5	40.2	94.3	48.6	66.6	163.3	31.2	22.7	211.0	32.7	112.8	1131.8
2000	29.6	11.0	217.6	31.9	34.5	34.2	31.4	19.2	37.2	55.1	150.3	46.4	698.4
2001	190.2	110.6	122.0	70.2	105.3	9.3	109.2	49.4	18.2	39.8	57.1	15.9	897.2
2002	55.2	293.2	143.3	15.4	48.6	17.4	26.4	14.3	7.0	1.4	14.5	59.8	696.5
2003	22.5	89.1	89.0	147.2	358.4	58.0	35.5	30.0	4.4	62.4	50.0	45.9	992.4
2004	38.9	92.5	52.8	107.4	9.2	5.4	37.4	68.3	35.9	219.1	71.2	67.0	805.1
2005	41.3	82.5	91.1	20.2	26.7	78.3	53.2	4.0	41.0	67.4	131.0	24.3	661.0
2006	77.9	93.8	34.7	2.4	17.6	69.0	51.7	41.8	156.4	6.1	35.3	87.6	674.3
2007	92.0	148.3	72.8	102.8	22.0	321.3	43.8	89.4	56.0	17.4	92.6	86.8	1145.2
2008	58.6	322.5	55.3	84.7	12.9	123.2	58.5	4.2	50.2	42.4	48.4	64.5	925.4
2009	25.4	71.2	43.4	141.1	94.6	75.4	32.6	3.6	27.6	108.2	21.6	48.9	693.6
2010	17.6	142.3	97.8	17.0	100.2	79.7	50.2	36.6	74.9	69.4	146.0	98.9	930.6
2011	44.3	7.1	261.4	148.9	114.6	76.4	164.5	62.2	65.2	24.6	173.5	56.0	1198.7
2012	116.0	152.2	228.1	109.8	21.6	122.2	38.4	6.2	17.9	38.3	35.1	28.2	914.0
2013	160.8	169.8	61.6	83.6	80.6	208.0	13.8	5.6	50.4	10.8	165.4	36.2	1046.6
2014	15.0	54.2	155.6	53.8	16.0	45.8	6.6	243.0	23.0	65.8	44.8	109.4	833.0
2015	147.9	66.1	29.0	282.3	65.4	61.8	46.3	70.4	28.9	31.2	98.6	48.7	976.6
2016	247.3	16.6	85.9	53.4	16.7	310.5	65.9	94.2	60.5	28.6	11.8	56.0	1047.4

2017	54.7	100.4	285.3	72.1	15.6	101.4	0.4	25.0	1.0	41.0	34.0	28.7	759.6
2018	19.5	58.7	45.6	13.6	12.2	82.0	11.8	4.2	29.2	141.4	92.5	64.8	575.5
2019	45.0	66.6	145.5	15.1	7.4	103.1	42.0	46.8	101.1	28.4	28.9	1.0	630.9
2020	104.2	383.5	114.2	69.9	81.7	44.7	162.4						