Radiological Risk Assessment and Preliminary Method Statement for the Remediation of the Radium Contaminated Area at HMS Daedalus (Site B)

V1.0

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Eagle Eye Environmental Solutions Ltd

The Old Dairy

Appuldurcombe Farm,

Wroxall, Ventnor,

Isle of Wight, PO38 3EW

01983 840778

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Prepared by:	Chris Murdock (RPA & RWA To Eagle Eye ES)
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Appendix A	Radiological Risk Assessment

1 Introduction

1.1 Purpose and Scope of Radiological Risk Assessment

1.1.1 The purpose of this Radiological Risk Assessment & Preliminary Method Statement (RAMS) is describe the risk and methods associated with the radiological remediation of Daedalus Park Site B “hot-spot”. It will assess the risk of this activity might have during planned remediation works and identify the safe working practices and controls that will be required during the proposed work to ensure;

- Appropriate protection of remediation operatives;
- Appropriate protection of other site users and the general public; and
- The control of radioactively contaminated materials.

2 Description of the Radiological Hazard

2.1 Nature and Location of Radioactive Contamination

2.1.1 Non-intrusive (walk over surveying) of of the Daedalus Park Site B south in 2007 identified a hot spot of radiation at grid reference point SU 56161 01454 (Ref 1) and this was again confirmed by a follow up survey conducted by Aurora in 2017 (Ref 2).

2.1.2 Invasive sampling by Entec in 2007 identified contaminated metal object in soil at a depth of 0.2 m with radium-226 activity concentration >4 Bq/g.

2.1.3 In June 2018 Eagle Eye ES and Eckert & Ziegler (E&Z) carried out sampling of this area removing 2 bags (approximate masses of 0.15 kg each) for analysis by E&Z at their laboratories.

2.1.4 Analysis of this material confirmed the presence of radioum-226 and it was estimated that the activity concentration of this radionuclide (and decay products) were as follows ((pers. comm E&Z):

Bag 1: 132.85 Bq/g

Bag 2: 32.87 Bq/g respectively. (Bq/g = Becquerels per gram)

2.1.5 It was noted that discrete metallic / ash items were present in this material with activity concentration to be significantly higher than the average value given above.

2.1.6 The results from this analyses are compared against the following The Environmental Permitting (England and Wales) Regulations 2016 (as amended)

Table 1 Relevant classification of radioactive wastes (radium-226 contamination soils)

Radionuclide	Origin of waste	EPR Out of Scope Activity (Bq/g)	NORM Exemption Activity (Bq/g)	Radioactive Waste Classification For This Material
Radium-226	Historic radium contamination / waste arising from remediation of land contaminated by radium[1]	1.0	5.0	**Permitted Very Low Level Waste (VLLW) or Low level waste (LLW)**

2.1.7 Peak RPA Ltd were contracted to be the RPA & RWA for this remediation project after removal of this material to the E&Z laboratory. As soon as the results from the survey of bag 1 and bag 2

[1] Evidence form historical use of the site and Ref 1

were available, and the non-exempt waste classification was determined, Peak RPA advised on the following:

- An EPR2016 radioactive waste permit is required in order for this work to proceed – no work in this immediate location can take place until this permit has been issued
- The waste bags (1 & 2) must be held by E&Z prior to disposal under the Daedalus site B permit
- Hold any work in this area and ensure the area is made safe as follows:
    - Cover the area by a tarpaulin
    - The area out to approximately 40 m2 (centred on the surveyed area) should fenced off to form a physical barrier restricting access. You are to arrange for dust suppression Harris fencing to be installed.
    - A sign should be placed on each side of the fence area warning of the radiation / contamination / asbestos risks and prohibiting access. From a radiation perspective the area inside the fence should be designated as a supervised area,

2.1.8 An EPR application to the Environment Agency is being drawn up.

2.1.9 From preliminary consideration of remediation methods, the heterogeneity of this material and the remediation method described later it is tentatively considered that the following volumes of waste material will be obtained from this site:

Table 2: Estimated maximum volumes of soil to be removed from site and consideration of radioactive waste classification

Approximate (maximum) Volumes (m3)	Waste Classification	Action
<10	Background (non-detectable radiation / contamination above natural site levels	Use as back fill material subject to consideration of asbestos content
<10	Out of scope (<1 Bq/g)	Consider for use as backfill or disposal to hazardous waste landfill after consideration of asbestos content
<5	NORM 1- 5 Bq/g	Hazardous / non-hazardous waste landfill in 200 litre drums
<5	> 5 Bq/g Permitted waste VLLW	Hazardous waste landfill as VLLW, packaged to ensure the activity contamination does not exceed 0.4 MBq per 0.1 m3 and no single item is > 40 kBq
<0.2	LLW	Transfer to permitted facility for direct incineration (e.g. Grundon) or to a facility permitted o accept radioactive LLW for onward transfer / disposal; e.g. Eckert & Ziegler, Didcot

NB the hazardous waste landfill requirement will principally be driven by potential asbestos content

3 Radiation Protection Considerations

3.1 Persons Likely to be affected by Radioactive Material

3.1.1 Eagle Eye ES is responsible for the remediation works and has been made aware of the presence of the radioactive contamination and the requirements to restrict access by the project Radiation Protection Adviser (RPA). The areas of contamination will be enclosed with Harris fencing with a single barrier access and egress point.

3.1.2 The only persons likely to be affected by the contamination in its current condition are those that enter the work area and come into direct contact with the contaminated soil. This should be restricted to the personnel who are appropriately trained and who understand the radiological risk associated with such contamination and the measures required to control and minimise exposure. Personnel working in the area are to be in the presence of a Radiation Protection Supervisor.

3.2 Public and other resident close by.

3.2.1 Access to the Daedalus site and this contamination area will be restricted both at the overall site boundary and the remediation boundary and fencing and signage and supervision will prevent unauthorised access to the work area.

3.2.2 Workers elsewhere on the site will be briefed on the access restrictions to the remediation site

3.2.3 Where required contamination control measure listed in section 7 e.g. damping down, will restrict any spread of contamination of dusts and contamination (exit) monitoring of operatives at the work boundary will ensure no contamination is removed from the site on PPE / clothing & equipment

3.2.4 It is not proposed that any trainees under the age of 18 years old will be undertaking the remediation works. Should this change for any reason this RRA will be reviewed and updated to account for the additional consideration of radiological exposure.

3.2.5 The work has been designed to ensure protection of workers and the general public in accordance with the requirements of the Ionising Radiation Regulations 2017 (IRR17).

3.2.6 Eagle Eye ES are registered with the HSE under Reg. 6 to:

- work with over 1000 kg of radioactive material containing artificial radionuclides or radioactive material containing naturally occurring radionuclides which are processed for their radioactive, fissile or fertile properties

4 Likelihood of Surface and Airborne Contamination Being Generated

4.1.1 Loose contamination may be generated during the work which can affect both surfaces and the air. This will be in the form of dust, soil particles and rubble.

4.1.2 Potential doses from inhalation and ingestion of radium-226 (Ra) contaminated dusts are modelled in the dose assessment (Section 5) with recommended control measures which are included below.

5 Assessment of Surface and Airborne Contamination Risks

5.1 Exposure pathways

5.1.1 Radiological analysis undertaken on samples collected during previous investigations undertaken (Refs. 1 & 2 and pers. comm Eckert & Ziegler) identified the elevated levels of radioactivity are due to elevated levels of radium decay series nuclides through the burial of ash produced from, burning of radium luminised aircraft dials.

The following prior radiological risk assessment has been completed by the Radiation Protection Adviser involved in this project. Radiological exposure from the following pathways are foreseeable and each is assessed here with recommendations on how to restrict exposure:

- Skin doses from direct contamination;
- Gamma doses from in-situ material and during excavation;
- Doses from inhalation of re-suspended material; and
- Doses from inadvertent ingestion of contaminated material.

5.2 Skin contamination by homogenously contaminated soil (not discrete higher activity objects)

5.2.1 Assumptions based on exposure (before controls measures are in place)

i) Person is not wearing PPE;

ii) Transfer of contamination of active material is 0.2763 mg / cm^2 directly onto the skin (Ref 3) and 10 times this onto clothing;

iii) The skin dose “coefficients” for the radium-226 decay chain nuclides (Ref 4) include contributions from both beta and gamma emission (beta emission dominate);

- The total skin dose coefficient for the ^{226}Ra assuming no radon loss is 6.56 mSv/h per kBq/cm^2;

iv) Any deposition of solid material onto the skin and clothing occurs at masses given in ii), this contamination remains in place for 8 h/d and the project length is at this stage assumed to be 5 working days. The activity concentration of 226Ra (in equilibrium to 210Po) is in the worst case assumed to be 10 Bq/g. Attenuation of the beta emissions by clothing is ignored.

v) The assumptions in v) should be considered to be worst case for cob.

5.2.2 Using the assumptions made in 4.1.2 the skin dose rates are calculated to be :

^{226}Ra and decay products : 8.0 µSv/h

5.2.3 This skin dose should be compared against the IRR17 dose limit of 500,000 µSv/y which, if averaged over a 240 day working year, equates to a daily limit of 2083 µSv or a 5 day project limit of 10415 µSv.

5.3 Skin contamination from exposure to beta / gamma emissions from single discrete objects

5.3.1 It is assumed during excavation up to five single discrete luminised article (a broken piece of aircraft dial) containing 40 kBq is uncovered. The dose rate to the skin will be 115,470 µSv/h (from beta & gamma emission) (Ref 3) assuming 226Ra in equilibrium to 210Po . It is unlikely that a discrete item will be present on the skin for more than 15 seconds before it is removed so it is assumed that over the course of the project 5 such items are present on the skin for 15 seconds. The total skin dose is 2405 µSv.

5.3.2 The total skin dose (from soil and discrete item contamination) is estimated to be ~2413 µSv, this dose should be compared against the IRR17 dose limit of 500,000 µSv /y which, if averaged over a 240 day working year, equates to a daily limit of 2083 µSv or a 5 day project limit of 10415 µSv.

5.3.3 Although the IRR17 skin dose limit is not expected to be challenged, even considering these very unlikely assumptions, to comply with Reg. 9 of IRR17 (restriction of exposure), it is necessary to implement the controls listed in section 7 to minimise exposures to as low as is reasonably practicable.

5.4 Gamma doses from in-situ material and excavation

5.4.1 The above assessment considers contamination to the skin. It is also necessary to consider the external gamma (and beta) doses that will result from operators being in close proximity to (but not in contact with) contaminated material and hotspots that are could be accounted during the excavation of the site.

Assuming the following:

a) that all areas of elevated Ra levels areas (i.e. all site material) are contaminated at the worst case activity concentrations (10 Bq/g ^{226}Ra) it is not absolutely clear what the geometry of this uniformly contaminated material is likely to, if it is present at all, but for the purposes of this assessment it is assumed that an infinite slab is uncovered and the contaminated slab has a depth of 25 cm.
b) the density of the slab is assumed to be 1.6 g/cm^2
c) in a single excavated trial pits one discrete radium luminised items with an activity of 40 kBq is found.

Assumed geometry	^{226}Ra* decay series dose rate µSv/h	
	At 10 cm above slab	At 100 cm above slab
25 cm infinite slab of contamination (10 Bq/g)[a]	5.1	4.7
From discrete unburied 40 kBq source[b]	85	0.8

[a]Modelled using MicroShield™, [b]Modelled using data form ref 4

Note the dose rates around the slab do not follow inverse square law as the contamination is not a point source.

As previous gamma radiation walkover surveys did not identify any areas of elevated radiation at current surface levels, it would be unrealistic to assume that, in the present work, the exposure of operators to the elevated levels modelled above will occur for 100% of the project time. Instead it is assumed that after removing the overlying background depths of soil to 30 cm a contaminated horizon occurs at each trial pit site.

- Over the 5 day project length it is assumed that operators are exposed to this "contaminated" horizon for 50% of the project length : 20 hours
- For 25% of these 20 hours the operator is positioned 10 cm form the contaminated ground and for the remainder they are 100 cm
    - Dose to operator spending 5 h at 10 cm is 26 µSv
    - Dose to operator spending 15 hours at 100 cm is 71 µSv
- Exposure to the discrete 40 kBq point is assumed to occur for 1 minutes at 10 cm distance before detection and implementation of the contingency plan.
    - Dose to the operator : 14 µSv
- Total whole body dose due to gamma radiation < 100 µSv

Note: these calculations will need to be revised if the project length differs from 5 days.

5.4.2 It is important to note here that these modelled results are based on the assumption that there is a significant buried layer of 10 Bq/g radium-226. A recent walk over survey of the site with a gamma dose rate meter found levels in near contact with the ground surface of 0.22 µSv/h. this is just over twice background but more than 20 times below the modelled levels here. Whilst the above assumption should be considered to be very pessimistic there is a risk that excavation of overlying material will reveal contaminated material that has previously been shielded by inert overlying soils. If this occurs dose rates will potentially increase significantly above current maximum levels of 0.22 µSv/h and it will be necessary to implement the controls listed in section 7 in order to minimise radiological exposure.

5.5 Doses from inadvertent ingestion of contaminated material

5.5.1 Whilst it is expected that the risk of inadvertent ingestion of this contaminated material is lower than inhalation risk it is still foreseeable and must be assessed here.

The following assumptions are made:

- Inadvertent ingestion of the contaminated material occurs at the same rate as the soil ingestion rate given in ref. 5 : 5 mg/h
- The active phase of this project takes 40 hours during which time ingestion occurs at this rate continually.
- The activity concentrations of ^{226}Ra in the material is 10 Bq/g respectively
    - In addition to the ingestion of fine soil particles deposited on the skin it is assumed that in the worst case the ingestion of 1 (No.) discrete 10 kBq particle occurs
- Ingestion dose coefficients are taken from ref. 6.

5.5.2 Worst case doses during excavation of the active area before dose restriction control measures

Decay chain	Committed effective dose from ingestion / µSv
Radium-226	Soil particles : 18.2 Discrete particle†: 45,700

^{226}Ra in secular equilibrium with decay products

The doses from inadvertent ingestion of soil particles are low but clearly, although extremely unlikely to occur, inadvertent ingestion of a 10 kBq discrete particle could result in a significant radiation dose. Control measures listed in section 7 are necessary to minimise this exposure:

6 Conclusions, area designation and dosimetry recommendations

6.1 Designation of Areas

6.1.1 Due to the potential generation of contamination and dose rate the identified “hot spots” work around this area is to be designated as 'Contamination & Radiation Supervised Area' and in accordance with the provisions of IRR17, with signage posted on access points to identify them as such and the nature of the radiation hazard prior to work in that area beginning.

6.1.2 All other areas will be monitored during works. Should radioactivity be detected above background levels designation as a supervised area will be initially set up.

6.1.3 The radioactive waste storage area is to be designated a controlled area.

6.1.4 Following remediation of the controlled area, the designated area may be reduced, dependent on the results of monitoring surveys taken in the remediated area.

6.2 Classification of Persons and Dose Monitoring

6.2.1 Based on the dose rates recorded and anticipated for the work persons would not require to be 'classified worker' in accordance with the provisions of IRR17.

6.2.2 Assessment of potential inhalation doses demonstrates that classification of workers would not be required.

6.3 Potential Accidents/Incidents, their Likelihood and Radiological Severity

6.3.1 See *Appendix A* for this assessment of incidents.

6.4 Conclusion

6.4.1 The radiological risks associated with remediation works of the soils from Daedalus Park Site B radium contaminated area are not considered to be significant if undertaken in a controlled manner and the identified control measures implemented.

7 Methodological Controls and Radiation Protection Considerations

7.1 Preliminary Methods to Control Radiation Exposure and Minimise the Generation of Contamination

This section details the preliminary method to minimise the exposure to radiation and contamination levels to site operatives and the risk of contamination spreading outside of the designated work area. An expanded version of this will be produced once the radiation detection equipment and site permit is available.

7.1.1 As personnel undertaking remediation work will be subject to an elevated dose rate they must minimise the time they are working within the affected area. The work should be planned to ensure that all activities that can be undertaken in a low background area (e.g. planning and preparation) are done so.

7.1.2 To minimise and control the generation of contamination, the following requirements apply to the work:-

- Personal Protective Equipment (including Respiratory Protective Equipment (RPE) as required by the RPA is to be worn (see below);
- Routine visual inspection of clothing will take place to check for damage and accumulation of active material
- A contamination monitor (Mini 900 44B or equivalent) will be on hand continually through this work to verify skin and clothing is free from contamination (this monitor is capable of detecting Bq levels of 226Ra decay series radionuclides over both small (point) or large areas sources.
- All personnel will be monitored and decontaminated as necessary using damp disposable wipes / tissues prior to egress from the controlled area

- All tools / equipment used are to be monitored at the end of the working day and decontaminated as necessary using damp disposable wipes / tissues;
- Dust suppression techniques will be employed during excavation works where airborne dusts are likely;
- Vehicular movement within the designated area will be kept to a minimum (when moving wastes in the secure unit);
- The excavation will only occur once a survey of the upper surface of the material to be extracted has been carried out. The excavation will be halted if radiation levels exceed a given count rate / dose rate as defined in the method statement.
  - The dose rate hold point is initially to be set at 5 µSv/h,
  - RPA to advise on the contamination meter hold point once the instrument/s to be used area known
- To restrict finger and skin exposure to point source discrete items the method statement will prohibit surveyors from picking up discrete items that have been identified as having elevated radiation more than 3 times background. Instead, such items will be moved using 30 cm tongs.
- Excavated material will be placed on heavy duty polyethene within the designated area and will be spread out to a depth of no more than 5 cm, width 10 cm for survey and characterisation
  - Survey limits for characterisation of waste will be provided by the RPA once the monitor type is known.
  - The RPA will provide counts per second limit for out of scope (<1 Bq/g), exempt 1-5 Bq/g and permitted material > 5 Bq/g (see waste classification in Table 2)
- Following waste classification VLLW and LLW will be secured in transport containers (expected to be 205 litre metal drums). If overnight storage is required then will need to be stored in a secure compound on site e.g. Locked Iso-Freight container.
- A clean change area will be set up where operators will remove their PPE and carry out contamination monitoring of clothing and skin. No PPE is to be worn outside the site's designated area boundary (is must be retained at the site boundary on exit)
- The time spent within the highest dose rate area should be minimised and, so far as is reasonably practicable, excavation of this material should so far as is reasonably predictable be completed by an operator within a mechanical digger as this will provide a good degree of shielding. Manual should only occur when mechanical access is not possible.
- Training in PPE removal prior to work starting to include a reminder on the importance of good occupational hygiene practices both within and outside of the designated area
- Prohibition of food / chewing gum etc. within the radiation work area.

7.2 Personal Protective Equipment

7.2.1 In order to undertake any excavation and removal work on the areas close to radioactive contamination the following PPE is mandatory:

- Approved Dosimetry (whole body TLD);
- Disposable coveralls with a hood;
- Steel Toe-Capped Boots
- Disposable overshoes;
- Protective eyewear when using tools;
- Suitable gloves for the nature of the work;
- Disposable nitrile gloves, worn over work gloves.
- High visibility jacket / vest; and
- Hard Hat.
- RPE (FFP3) – if resuspendable dusts are likely to be present

8 Asbestos fragment removal

8.1.1 Following previous works on site, a small quantity (>20kg) of asbestos cement (AC) was discovered. A test was carried out to determine the amount and type of asbestos contamination.

8.1.2 Test results

DETS Report No: 18-77425				
Eagle Eye Environmental Solutions Ltd		Date Sampled	20/06/18	
Site Reference: Daedalus		Time Sampled	None Supplied	
Project / Job Ref: NN910-2		TP / BH No	A1	
Order No: None Supplied		Additional Refs	None Supplied	
Reporting Date: 02/07/2018		Depth (m)	0.20 – 0.50m	
		QTSE Sample No	343090	
Determinand	**Unit**	**RL**	**Accreditation**	
Asbestos Screen (S)	N/a	N/a	ISO17025	DETECTED
Sample Matrix (S)	Material Type	N/a	None	Multiple cement fragments in soil
Asbestos Type (S)	PLM Result	N/a	ISO17025	Chrysotile

8.1.3 From the test result it was determined that the asbestos was confined to pieces of asbestos cement (AC)

8.1.4 Method for removal (based on HSE A11 – Removing asbestos cement (AC) debris)

- Dampen the AC debris with spray.
- Pick up pieces of debris and put them in the asbestos waste bag.
- Dispose of material via licenced ACM contractor

8.1.5 Picker should be asbestos qualified

8.1.6 PPE is outlined in section 7.2

9 Summary of Working Method Statement

The final method statement will include information on each of the following.

- Site preparation
    - Fencing and IRR17 supervised area signage 5-7 m from work area
    - Clean change and PPE (dirty) change area to be segregated : contamination monitoring using Ludlum 2000 44/2
        - Contamination defined as twice background
    - Create and label the following waste holding areas (all to be positioned within the supervised area):
        - Out of scope material with radiation levels consistent with site at background – to be used for backfill : covered tarpaulin.
        - NORM Exempt waste – waste material with low radiation levels indicating 226Ra up to 5 Bq/g – covered tarpaulin or skip
        - VLLW : waste containing discrete radium luminised dial fragments each with an activity no more than 40 kBq : contain in 205 litre drums
        - LLW : waste containing discrete radium luminised dial fragments each with an activity greater than 40 kBq : contain in 205 litre drums
        - VLLW and LLW drums to be positioned within the designated area work area but at a suitable distance to ensure that radiation levels emitted do not influence survey of excavated material
- Ground preparation
    - Tarp / polythene lay down area
    - Use of dust suppression sprays if ground is dry and dusts are likely to be resuspended
    - Use of excavator to remove up to 100 kg each pass
    - Site H&S rules to be followed to ensure operators are visible and away from the excavator
    - Excavator operator to place the excavated material into a 30 cm line now more than 5 cm deep
    - Surveyors to characterise the material using appropriate instrumentation e.g. Ludlum 2000 44/2 and Tracerco T404 dose rate meter
- Initial survey
    - Use of Tracerco dose rate meter to survey over the excavated material noting any area of dose rate > 1 µSv/h
    - If any dose rate exceeds 10 µSv/h then the survey should be halted the team move back to a dose rate below 0.5 µSv/h and a method drawn up for removal of this discrete item to waste containment (205 l drum) using 30 cm tongs
    - Sequentially remove discrete radiation items using the 30 cm tongs and characterise using the method below into VLLW & LLW streams.

- Detailed survey method statement
    - Use of calibrated Tracerco T404 gamma dose rate meter (or similar) and Ludlum to identify “hot-spots” in excavated material
    - Characterise waste according to the following:
        - VLLW (<40 kBq radium-226 item) for small items < 5 cm^2
            - Dose rate at 5 cm : < 10 µSv/h
        - LLW (>40 kBq) for small items <5 cm^2
            - Use conversion dose rate at 5 cm of 0.25 µSv/h per 1 kBq
            - So 50 µSv/h item at 5 cm suggest waste item activity is 200 kBq
    - Use of Ludlum 2000 / 44/2 radiation meter
        - To be used to locate “hot spots” which are then quantified using a gamma dose rate meter
            - Once these hot spots are removed from the line of excavated material the Ludlum 2000 44-2 is to be used to assess if the bulk material is out of scope or exempt according to the following:
                - Out of scope:
                    - count rate at 1 cm above the excavated material; or below local site background
                - NORM exempt up to 5 Bq/g
                    - Count rate at 1 cm above the excavated material <15 cps net of background
                - VLLW / LLW
                    - Count rate at 1 cm exceed 15 cps
                    - This prompts VLLW / LLW assessment / characterisation as discussed above
    - Grove’s Microshield™ modelling software has been used to determine the above thresholds for NORM material – assuming the following:
        - 5 x 5 x 5 cm geometry, in-situ bulk density 1.3 g/cm3, loss of 30 % radon, effective gamma energy of 226Ra decay progeny assumed to be 400 keV (based on empirical data obtained by Peak RPA using a 226Ra source).

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- E&Z will be carrying out the site surveying, they will provide :
    - additional methodology for waste characterisation based on the monitoring equipment they are to use
    - methods for
        - sample preparation and consignment
        - movement and storage of radioactive wastes (including waste accountancy)
        - packaging of radioactive waste for transportation

Post remediation

- post remediation reassurance monitoring will be provided according to the following method
- after excavation of the site back to the natural ground layer a full survey of the excavated site will be carried out using the Ludlum 2000 44-2 prior to backfilling with out of scope material
    - Hold point and re-excavation if any count rate exceeds site background + 10%
        - This +10% count rate is required because natural background typically shows small scale spatial variation of at least this level
- Once the above site survey of the excavated area is satisfactorily completed the site will be backfilled with out of scope material
    - Each excavator bucket of backfill will be surveyed back into the ground using the Ludlum 44-2
    - Hold point and re-excavation if any Ludlum 2000 44-2 count rate exceeds site background + 10%

References

1) Entec report Radiological Survey of Daedalus Site 2007.

2) Aurora : Radiological Survey of Daedalus Park Site 'B' For Tidebank, 2017

3) Holmes, KK; Shirai, JH; Richter, KY; Kissel, JC. (1999). Field measurement of dermal soil loadings in occupational and recreational activities. Environ Res 80: 148 - 157.

4) Radionuclide and Radiation Protection Data Handbook, Second Ed. 2002

5) Generalised Habit Data for Radiological Assessments NRPB W41, 2003

6) ICRP Compendium of Dose Coefficients based on ICRP Publication 60. 2002

Drawings

Appendices

Appendix A

Possible Radiological Accidents / Incidents their Likelihood, Radiological Severity and Control Measures During Remediation of Daedalus Site B by Eagle Eye ES

Hazards Identified	Caused By	Who is at risk?	Likelihood	Radiological Severity	Risk Level	Risk Control Measure(s)	Likelihood	Severity	Revised Risk Level with Control Measure(s)
Inhalation / ingestion of contamination resulting in contamination of persons	Working with contaminated soils Excavation and removal causing dusty conditions Careless methods of handling / excavating / removing contaminated materials Not wearing PPE / RPE	Eagle Eye ES / Remediation personnel	MEDIUM	LOW	MEDIUM	Facial Half Mask to prevent inhalation of soil particles Damping down of arisings if dusty conditions arise Regular monitoring of arisings Absolutely no eating, drinking or smoking within controlled area Wearing of disposable gloves, disposable coveralls and disposable shoe covers	LOW	LOW	LOW
		Contractor Staff	MEDIUM	LOW	MEDIUM		NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
		General Public	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE		NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
Ingestion of contamination through open cuts / wounds	Having an open cut / wound when working with contaminated materials Working on contaminated materials without PPE Receiving an injury while using tools e.g. chisel	Eagle Eye ES / Remediation personnel	LOW	LOW	LOW	Disposable coverall with hood, gloves and overshoes worn Covering up any cuts / wounds prior to undertaking the work Damping down of contaminated surface Regular monitoring Minimise use of tools and careful use of tools to avoid injury	LOW	NEGLIGIBLE	LOW
		Contractor Staff	MEDIUM	LOW	MEDIUM		LOW	NEGLIGIBLE	LOW

Hazards Identified	Caused By	Who is at risk?	Likelihood	Radiological Severity	Risk Level	Risk Control Measure(s)	Likelihood	Severity	Revised Risk Level with Control Measure(s)
External radiation exposure	Working in close proximity to Ra contaminated materials (beta and gamma emissions)	Eagle Eye ES /Remediation personnel	MEDIUM	LOW	LOW	Use of dose rate meter to confirm levels. Areas to be marked and operators to minimise time spent here. Hold point if dose rate exceeds 50 µSv/h (to be finalised) which may be revised downwards once initial measurements are made	LOW	LOW	LOW
		Contractor Staff	MEDIUM	LOW	LOW		LOW	LOW	LOW
Fire resulting in spread of contamination	Poor storage of combustible materials Ignition of combustible materials Other site works	All persons including fire brigade	LOW	NEGLIGIBLE	LOW	Combustible / flammable materials not to be stored with radioactive waste Radioactive waste stored in dedicated bags and a secure industrial unit	LOW	NEGLIGIBLE	LOW
Spillage of radioactive material during movement	Moving over rough ground Poor manual handling Not using	Eagle Eye ES / Remediation personnel	MEDIUM	LOW	MEDIUM	Movement of soils and within bags to be over the shortest distance possible No packages containing waste to be moved without being securely	LOW	NEGLIGIBLE	LOW

Hazards Identified	Caused By	Who is at risk?	Likelihood	Radiological Severity	Risk Level	Risk Control Measure(s)	Likelihood	Severity	Revised Risk Level with Control Measure(s)
	suitable container Not sealing the container properly Unbalanced load Not securing a container properly for movement	Eagle Eye ES / contractor staff	MEDIUM	LOW	MEDIUM	fastened Any container used for movement to be suitable for the work Wooden boarding to be used if required to provide a smooth surface All movements to be supported by RPA approved radiation monitoring	LOW	NEGLIGIBLE	LOW
Loss of radioactive materials	Poor storage arrangements Not accounting for waste Deliberate theft	All persons	LOW	HIGH	MEDIUM	Secure storage locations for waste Accountancy procedure for waste Site security Handover to authorised carrier	LOW	HIGH	MEDIUM

Radiological Risk Assessment Criteria

The following tables provide the assessment criteria upon which the Likelihood and Radiological Severity are based.

Likelihood	Radiological Severity			
	HIGH	MEDIUM	LOW	NEGLIGIBLE
HIGH	H	H	M	L
MEDIUM	H	M	M	L
LOW	M	M	L	N
NEGLIGIBLE	L	L	N	N

LIKELIHOOD	FREQUENCY
HIGH	≤1 year
MEDIUM	1 - ≤ 5 years
LOW	5 - ≤ 30 years
NEGLIGIBLE	> 30 years

RADIOLOGICAL SEVERITY	MAX. INDIVIDUAL EFFECTIVE DOSE
HIGH	≥ 6 mSv
MEDIUM	1 - ≤ 6 mSv
LOW	0.02 - ≤ 1 mSv
NEGLIGIBLE	< 0.02 mSv