Proof-of-Performance Report

RAAF Base Edinburgh Soil Trial

Ventia PFAS Soil Treatment Plant

7 February 2020

Document Approval

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EXECUTIVE SUMMARY

Ventia Utility Services Pty Ltd (Ventia) designed and installed a treatment plant capable of remediating PFAS contaminated soil at the RAAF Base Edinburgh, Edinburgh, SA. The technology was proven at the laboratory-scale for numerous soil types over several years. This report describes treatment results from the full-scale Proof-of-Performance (POP) test performed at the RAAF Base Edinburgh.

Soil Mass

Ventia treated 2,579t of PFAS contaminated soil from a former firefighting training area known as "P9" at RAAF Base Edinburgh between 19 July 2019 and 14 October 2019. 25 x ~100t batches (denoted A-Y) were treated in the Ventia plant as part of the POP test.

During treatment of a batch, soil was split into four 'intermediate fractions'; gravel, sand, fines and organics. After treatment, fractions were reformed into a 'treated and reformed' stockpile except for the organics fraction, which was managed as a waste stream.

Untreated soil had an average Particle Size Distribution (PSD) of 5% gravel, 20% sand and 74% fines. Following treatment, the mass of intermediate fractions showed a slight shift (2-3%) in the PSD from the gravel to the sand and fines fractions, which was expected given the mechanical nature of the plant processes.

Untreated Soil

In total 76 composite samples were collected from the 25 untreated feed batches with three composite samples collected per batch. Results showed average total and Australian Standard Leaching Procedure (ASLP) concentrations of PFOS + PFHxS were **2.9 mg/kg** (max 11.51 mg/kg) and **129 ug/L** (max 264 ug/L) respectively. Maximum observed PFOA concentrations were 0.24 mg/kg and PFOA ASLP were 6.5 μg/L.

Treated Soil

The treatment process was effective at removing PFOS + PFHxS and PFOA from soil and achieved the Performance Criteria for all Batches. Three composite samples were collected for each treated and reformed batch. Average PFOS + PFHxS total and ASLP concentrations were **0.3 mg/kg** and **12 μg/L** respectively. **The average PFOS + PFHxS removal efficiency (RE) was 90%**. Samples of the individual soil fractions were also collected prior to reforming for each batch (n=100) and aligned closely with the results of the soil once it had been reformed and resampled.

Retreatment

Batch E was retreated to assess the effectiveness of additional rounds of treatment. Each round of treatment achieved PFOS + PFHxS RE >80% for PFOS + PFHxS totals and ASLP. After 2 rounds of treatment a PFOS + PFHxS removal efficiency of 97% was achieved relating to treated concentrations of totals and ASLP of 0.2mg/kg and 5.4 μg/L. **Secondary treatment of material is therefore a feasible option for achieving lower treatment targets or where feed soil is higher in concentration** (i.e. where a higher removal efficiency is desired).

Precursors

Assessment of PFAS precursors via EOF and TOPA indicated that measurable precursors were not present in untreated soil samples. PFAS precursors did appear to be present in organics in measurable quantities (224-506% increase in PFAS observed after EOF and TOPA respectively). Ventia therefore recommends that organics are treated as a waste product rather than reused onsite.

Waste

The total volume of waste for all EDN soil treated (2,579t) was <0.7% and much lower than the pre-trial estimate of 3-5%.

In total there was 8.4t (0.3% wt./wt. or 3kg waste per tonne of treated soil) of organics generated.

There was no replacement of granular activated carbon (GAC) or ion-exchange resin (IX-Resin) required during the trial however the first stages of breakthrough were observed for the activated carbon. Worst case scenario is that GAC would be produced at coincidently 0.3% wt./wt. or 3kg waste per tonne of treated soil. Given there was no breakthrough for IX-Resin the volume of waste cannot be estimated but would be significantly lower than 0.3% wt./wt.

3t of cartridge filters were used during the trial however generation of this material is not expected to continue as routine plant operation continues in the future.

PFAS Mass Removal

In total there was up to 9.6 kg (dry weight) of PFOS + PFHxS removed from P9 during the trial representing c.96 x 20L containers of undiluted 3M 6% Light Water™ AFFF concentrate.

Based on the average PFOS + PFHxS concentration of feed soil (2.9 mg/kg reported by the primary lab and 4.7 mg/kg reported by Eurofins), average removal efficiency (90%), current throughput (~100t/day, wet weight) and average soil moisture (13%), during future works in P9 Ventia would remove 0.23-0.37 kg (dry weight) of PFOS + PFHxS per day during a single shift, equivalent to **3 x 20L undiluted 3M 6% Light Water™ containers per day.**

Conclusion

The POP test confirmed that Ventia's PFAS soil treatment plant could consistently remove PFOS + PFHxS to concentrations compliant with the performance criteria. **Figure 1** below illustrates the results of the POP test for each batch treated.

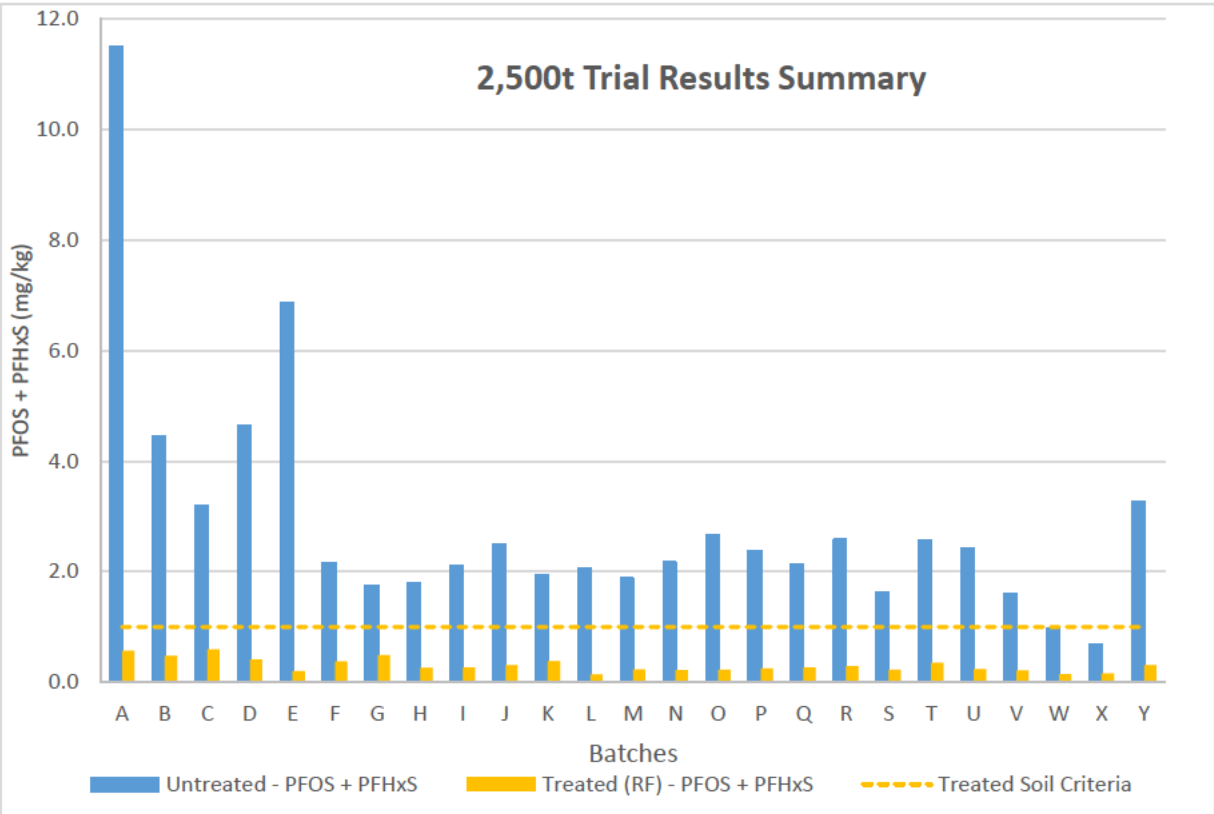


Figure 1. Summary of results illustrating untreated and treated soil concentrations per batch and the performance criteria.

The executive summary should not be read in isolation but should be read along with the body of the report. Please also note the confidential nature of this report and the disclaimer in **Section 12**.

1. INTRODUCTION

1.1. Background

Ventia Utility Services Pty Ltd (Ventia) in conjunction with CleanEarth Technologies Inc (CleanEarth) developed a treatment process for the remediation of per- and poly-fluoroalkyl substances (PFAS) contaminated soil. The Department of Defence (Defence) provided Ventia with the opportunity to conduct a proof-of-performance (POP) test to validate the process at full-scale at RAAF Base Edinburgh, Adelaide, SA. Ventia constructed and commissioned the treatment plant at RAAF Base Edinburgh between October 2018 and July 2019.

The proof-of-performance (POP) test involved the treatment of 2,500 tonnes (t) of soil excavated from the RAAF Base Edinburgh fire training area (FTA) identified as “P9”. On 12th September 2019 Ventia issued results for the treatment of the first 1,000t of soil and these results were presented at the Collaboration Point Meeting (19th September 2019) with Defence and the project advisors and stakeholders. On 10 December 2019 Ventia presented the results for the full 2,500t trial to the same group.

This current report presents the results of the treatment of the entire 2,500t (25 ~100t batches of PFAS contaminated soil).

The data presented in this report includes the following PFAS soil results:

- Untreated soil (Batches A-Y);
- Treated gravel, sand, fines and organics fractions from the treatment plant (intermediate fractions Batches A-Y); and
- Treated and reformed soil (Batches A-Y).

1.2. Objectives

As described in the Soil Excavation and Treatment Technical Specification (Technical Specification) the primary objectives of the Project are to:

- Excavate, stockpile and backfill soil from ‘soil source areas’ (SSAs) in accordance with the Technical Specification;
- Treat soil in accordance with the Technical Specification;
- Commence excavation, stockpiling, soil treatment and backfilling activities in a timely manner;
- Focus on source-zone mass removal, being the separation and removal of PFAS contamination from soil in a manner which maximises efficient use of resources and minimises excessive generation of waste across the Contract period. It is noted that source-zone mass removal refers to the total mass of PFAS removed from the environment, not the concentration of contamination in the excavated material;
- Implement appropriate materials tracking data, including waste classification processes;
- Manage the collection of any surface water or groundwater throughout the Project to ensure further contamination or migration of contamination does not occur;
- Manage excavations in accordance with all relevant environmental and work health and safety requirements;

- Collaboratively work with the Defence's Environmental Consultant to assist it to identify, minimise and manage any impacts to SSAs or adjoining areas during the excavation, treatment and/or backfilling of soil;
- Complete the Project in a cost-effective manner; and
- Comply with all regulatory and legislative requirements throughout the Contract.

For this POP, soil was sourced entirely from P9. Additional SSAs may undergo excavation, treatment and backfilling following the completion of this POP.

1.3. Performance Criteria

During the treatment process, soil was separated into different soil fractions (e.g. gravel, sand, fines and organics) and then 'reformed' into one material type following treatment. Performance Criteria for this POP applies to treated and reformed stockpiles (not intermediate fractions) and these criteria were used to assess whether soil was suitable to be re-used in the excavation area as backfill. The Performance Criteria for the POP were listed in Section 14.1 of the Technical Specification as follows:

14.1 Soil Treatment Criteria

Treatment criteria will be site specific and will consider State, Commonwealth and Defence reuse or disposal policy. The following minimum requirements, which consider the *PFAS National Environment Management Plan* (NEMP, 2018) are to be achieved.

a. **Standard 1 Test Criteria**

To be met for all soil treated.

Maximum PFOS + PFHxS	Soil – human health exposure for public open space land use (NEMP 2018)	1 mg/kg
Maximum PFOA	Soil- human health exposure for public open space land use (NEMP 2018)	10 mg/kg

b. **Standard 2a Test Criteria**

Where soil is to be reused on base, including returned to the excavated location, the maximum ASLP Leachable concentration of each batch must be below the average ASLP Leachable concentrations of the area surrounding the reuse location. The EC will determine an appropriate sampling and validation program.

Treated soils determined for reuse must be appropriate for backfilling in the specified locations including considerations of matters such as structural properties moisture content of the soil.

Standard 2b Test Criteria

Where treated soils are unable to be reused and it has been determined that treated soil will be disposed to an on-base engineered landfill, the requirements of the NEMP will apply as below.

1	Maximum PFOS + PFHxS	Maximum PFOA
ASLP Leachable concentration – clay lined landfill (NEMP 2018)	0.7 µg/L	5.6 µg/L
ASLP Leachable concentration – double composite lined landfill (NEMP 2018)	7 µg/L	56 µg/L

Standard 2c Test Criteria

Where it has been determined that treated soil will be disposed to an off-base landfill, the relevant jurisdictional and licence requirements will apply.

c. **Standard 3 Test Criteria**

Test		Criteria
Total Organic Fluorine	measure of precursors	> 90% reduction

The performance criteria from the Technical Specification are summarised in **Table 1** below:

Table 1. Treated soil reuse criteria

Source	Maximum PFOS + PFHxS (total soil)	Maximum PFOS + PFHxS (ASLP Leachable)	Maximum PFOA	PFAS Precursors (TOF/EOF/TOPA)
Technical Specification	1 mg/kg	c.200µg/L (determined by the Project Environmental Consultant)	10 mg/kg	>90% reduction

Precursor Criteria

The Technical Specification states that Total Organic Fluorine (TOF) should be used to assess the removal efficiency of PFAS precursors. TOF analysis refers to different methods at different commercial laboratories. TOF at Australian Laboratory Services (ALS) for example refers to combustion-ion-chromatography, mass spectrometry (CIC-MS) applied to soil extracts. As the extraction method targets the organic fluorine fraction of soil, the results also represent the organic fluorine fraction of soil.

Interestingly, Eurofins also offer a TOF analysis however their TOF method involves the direct analysis of soil samples using CIC-MS and therefore represents total fluorine including both the organic and inorganic fractions. Eurofins offer another method called Extractable Organic Fluorine (EOF) where CIC-MS is used to analyse soil samples after extraction.

Comparing the analysis between the two commercial labs, ALS's TOF method is therefore equivalent to Eurofins' EOF method. To the best of our knowledge only ALS is NATA accredited for the CIC-MS method.

Following discussions with Defence Technical Policy, the Environmental Consultant (AECOM) and the Project Management Contract Administrator (PMCA), TOF analysis was replaced with EOF and Total Oxidizable Precursor Assay (TOPA) for the first 3 batches of soil treated. These results were presented at the Collaboration Point to determine whether additional precursor sampling should be conducted for the 2,500t trial. At the Collaboration Point it was agreed that analysis from the first three batches did not conclusively show the presence of precursors in soil from P9 and, therefore, no further precursor analysis was required during the 2,500t trial. It was agreed the requirement for precursor analysis should be reviewed if soil from other SSAs was treated in future works.

Leachability Criteria

The Technical Specification does not provide Maximum PFOS + PFHxS (ASLP Leachable) criteria, however it does make the following statement:

"Where soil is to be reused on base, including returned to the excavated location, the maximum ASLP Leachable concentration of each batch must be below the average ASLP Leachable concentrations of the area surrounding the reuse location.

Treated soils determined for reuse must be appropriate for backfilling in the specified location including consideration of matters such as structural properties moisture content of the soil".

At the Collaboration Point meeting, AECOM provided Ventia with the residual PFOS + PFHxS ASLP concentration of soils in the immediate area (and below) of the excavation trial pit. These values were determined from a review of existing data and an additional investigation of P9. The following data was presented by AECOM in a PowerPoint presentation:

- 95% UCL Average concentration of 221.6 µg/L for PFOS + PFHxS
- Range from 5.5 µg/L – 432 µg/L for PFOS + PFHxS

In the absence of a maximum PFOS + PFHxS ASLP value in the Technical Specification, the PFOS + PFHxS ASLP value of 221.6 µg/L (as determined by AECOM) was used as the PFOS + PFHxS ASLP criteria.

Individual Fraction Criteria

Results from individual soil fractions did not have a performance criteria as each fraction contained varying concentrations of PFAS post-treatment based on particle size – with fine-grained soils retaining more residual PFAS post-treatment. Although no criteria existed for individual soil fractions, consideration of the concentrations of PFAS and the mass of the fraction in relation to the entire ~100t batch were made when determining whether soil fractions should be reformed.

Despite differing levels of contaminant reduction, the Interstate Technology and Regulatory Cooperation (1997) *Technical and Regulatory Guidelines for Soil Washing* advises that during soil washing (a treatment technology with many similarities to the Ventia PFAS Soil Treatment Plant), the reforming of coarse- and fine-grained soil post-treatment is suitable if the recombined concentrations do not exceed the performance criteria. Mass balance calculations were therefore used to assess which soil fractions could be reformed to meet the performance criteria.

ITRC (1997) also recommends the reforming of coarse- and fine-soil as it results in potentially lower treatment costs and matches the treated soil geotechnical properties more closely to that of the original untreated soil. Particle Size Distribution analysis was conducted on feed and treated and reformed stockpiles to assess changes in soil properties pre- and post-treatment (**Section 7.3**).

Off-site Disposal Criteria

The Technical Specification lists 'Standard 2b Test Criteria' which was to be applied if soil could not be reused on-site and was to be disposed to an on-base engineered landfill. Prior to the POP test it was agreed that if soil was not suitable for reuse onsite (e.g. waste products) then it would be disposed off-site. Standard 2b Test Criteria is therefore not applicable for this POP test, however Standard 2c Test Criteria provides guidance for off-site disposal of soil:

"Where it has been determined that treated soil will be disposed to an off-base landfill, the relevant jurisdictional and licence requirements will apply."

2. PROJECT SITES

2.1. Treatment Plant Compound

The treatment compound consists of the following elements as shown in **Annex A – Site Layout Map**:

- **Area A – Feed Stockpile Area.** The feed stockpile area is where stockpiles were received from P9 and where testing was undertaken prior to soil being fed into the treatment plant. Stockpiles in this area were stored and covered on a raised pad and managed in accordance with Ventia's Excavation and Stockpiling Management Plan (US-050052-OPS-MP-003).

- **Area B – Treatment Area**. Area B contains the treatment plant where the treatment of PFAS contaminated soil was undertaken. The treatment plant primarily consists of mineral processing equipment and water treatment equipment such as screens, conveyors, pumps, water jets and treatment vessels. Earthworks were undertaken in this area for footings, the construction of a sump, a HDPE liner, bitumen seal and a bund. All runoff from the plant is captured within the treatment plant footprint and treated within the treatment plant. The treatment plant also contains material bunkers where different soil fractions are deposited post-treatment.

- **Area C – Treated Soil Stockpiles**. Treated soil was stockpiled within Area C until it was tested and confirmed suitable for reuse on-site. This area is bunded and lined with bitumen hardstand. Leachate and surface water from this area was collected and pumped back into the treatment plant for treatment. Treated stockpiles were managed in accordance with Ventia's Excavation and Stockpiling Management Plan (US-050052-OPS-MP-003). Again, stockpiles were constructed in accordance with the Technical Specification.

- **Area D – Treated Soil Loading Area**. Once soil from Area C was confirmed as suitable for reuse as backfill in P9, it was transported to Area D for loading out onto trucks.

- **Area E – Offices and Ablutions**. Area E is a dedicated 'clean' area containing offices, ablutions, lunchroom and carparking to allow visitors and staff to visit the site.

Stockpile storage areas within the Treatment Plant Compound were constructed in accordance with the following documents or as otherwise agreed with the Defence Technical Policy Team:

- Technical Specification;
- Department of Defence (2018) Defence PFAS Framework – Construction and Maintenance Projects. V2.1 July 2019;
- Department of Defence (2018) Defence PFAS Framework – Engineered Stockpile Facility Performance Specification. V 1.0 (WIP). 12 March 2018;
- Ventia (2019) Excavation and Stockpiling Management Plan (US 050052 OPS MP 003).

The treatment plant site is approximately 11,000m^2 and is located adjacent to the airside operations area near the Ordnance Unloading Area. The area is relatively flat with sparse weeds and is bounded by a ~1m deep drainage line to the north and east of the site. A drainage line also cuts through the site and flows from west to east approximately 30-40m from the southern site boundary (**Annex B – Plant General Arrangement**).

2.2. Fire Training Area (P9)

The P9 Fire Training Area is located adjacent to the airside operations area near the Ordnance Unloading Area and Ventia's Treatment Compound. The site was historically used by Defence for fire training exercises, however fire training activities have temporarily ceased and the area is now vacant. It contains a smokeroom training building, a shed and shipping container that were used for fire training exercises.

P9 is located on the Adelaide Plains which is typically underlain by alluvial soils. The upper soils comprise of red brown sandy clays of the Pooraka Formation containing calcareous formations. Sandy or gravelly lenses are also present.

The site was surveyed by a licenced surveyor; the surface of the site slopes from about RL 16.70 in the north to RL 15.50 in the south and from RL 15.80 in the west to RL 16.10 in the east. There is also a swale that extends from the smokeroom to a drainage line along the west and north boundary of the site.

3. TREATMENT PROCESS

3.1. Soil Treatment Process

The PFAS soil treatment process involved the following primary elements:

- Excavation of soil in ~100t batches at the SSAs

- Mixing of each batch of untreated soil with an excavator to increase soil homogeneity

- Haulage of soil to the treatment compound
- Stockpiling of soil within feed soil area (**Area A, Annex A – Site Layout Map**) of the treatment compound
- Loading of soil from the feed soil area into the treatment plant
- Treatment of the soil within the plant (**Area B, Annex A – Site Layout Map**)
- Loading of treated soil into the treated soil area (**Area C, Annex A – Site Layout Map**)
- Preparation of treated soil for reuse at the SSAs (**Area D, Annex A – Site Layout Map**)
- Material tracking of batches of feed and treated soil from 'cradle-to-grave' as detailed in **Section 4**

The treatment plant used physical and chemical processes to remove PFAS mass from soil by transferring it into the aqueous phase; the PFAS was then removed from water using adsorbent media and the clean water recirculated in a closed-circuit water treatment system.

3.2. Treated Intermediate Fractions

The treatment plant separates soil fractions via size and density to produce the following soil products:

- Oversize
- Gravel
- Sand (fine and course)
- Fines
- Organics (fine and course)

During treatment, the above soil products were deposited into material bays throughout the treatment plant so any entrained porewater could free drain. During the POP test only gravel, coarse sand, fines and coarse organics were generated.

After treatment of a batch occurred, all the material bays were emptied, and the soil products (referred to as "Intermediate Fractions") were placed in the "Intermediate Stockpile Area". Intermediate fractions were labelled and stored in this area while the underwent testing. This process enabled traceability of each batch from cradle-to-grave.

3.3. Treated and Reformed Fractions

Once the Intermediate Fractions (sand, gravel and fines) were tested, they were reformed into one material type. Reforming occurred in either the Intermediate Stockpile Area or the Treated and Reforming Stockpile Area; the location of reforming depended on daily operational requirements. Reforming was conducted with an excavator and a loader which thoroughly mixed the soil fractions to form a consistent material type.

Once material was reformed, the Treated and Reformed Stockpile was tested. When results indicated that the material complied with the Performance Criteria, it was moved back to P9 for future backfilling.

3.4. Generated Wastes

The organics fraction was separated from other fractions and is stored on-site in sealed skip bins. In accordance with Section 14.4 of the Technical Specification, Ventia managed the organic material on-site.

During treatment, a variety of waste streams, in addition to organic material, were generated. This information is presented in **Section 8.7**. This material was also be managed in accordance with Section 14.4 of the Technical Specification.

3.5. Backfill

Following completion of sampling of the Treated and Reformed Stockpiles, Ventia provided the PMCA with a summary of the feed and treated results and a copy of the laboratory reports for each batch and made a request to backfill the soil in the excavation area. The PMCA provided this information to the Environmental Consultant (EC) to review the data and determine whether the soil was suitable to be reused as backfill. The EC confirmed that all batches for the trial were suitable to be reused in the excavation area as backfill.

Due to the wet treatment process and the high fines content of soil, treated soil was generally too wet to backfill immediately post-treatment. Limited storage space for treated soil meant that soil could not be spread out into thin layers to facilitate drying. To overcome this, ~1% lime was added to soil to make it more amenable to backfilling. Prior to this occurring, Ventia conducted PFAS totals and ASLP testing on soil pre- and post-liming and determined that lime did not materially change the PFAS mobility, refer to **Section 8.6.** Backfilled areas were covered with 200mm of topsoil or treated soil suitable for revegetation purposes.

3.6. Soil Sampling

The soil sampling plan used for the POP was described in detail in Ventia's (2019) *Trial Performance Plan (US-050052-ENV-TPP-001)*. The EC for the project (AECOM) endorsed Ventia's sampling plan and conducted validation and verification sampling throughout the trial as described in AECOM (2019) *Technical Memorandum 11*.

3.6.1 Sample Rate

The sample rate for feed and treated stockpiles was based on Table 3 of the Victorian EPA Industrial Waste Resource Guidelines (IWRG702 2010) which provided guidance on the characterisation of stockpiles of different volumes. Based on the excavation batches containing approximately 50-70m^3 of material, three samples per stockpile were collected. Feed and treated stockpiles were sampled at the same rate for consistency in characterisation.

As part of AECOM's validation and verification sampling, an extra seven soil samples were collected for each of the first five batches (Batches A to E). Batches A-E therefore had a total of 10 samples collected per batch of feed and treated soil. Ventia only analysed one of these extra samples for the first batch (Batch A), however AECOM analysed all extra samples.

Individual soil fractions were sampled at a rate of one sample per fraction. During the trial there were four soil fractions produced – gravel, sand, fines, organics – so four samples of individual fractions were collected per batch. Although sampling of individual fractions was not required by the Technical Specification, a review of these results in conjunction with the treated and reformed batches increased the confidence in compliance with the performance criteria during the trial. The data generated by sampling these fractions was also used to guide mass balance calculations prior to final testing of the treated and reformed stockpiles.

In total, there were 25 Batches (A-Y) for the trial. A summary of the soil sample analytical program is provided in **Table 2** below:

Table 2. Analytical Program

Analyte	Batches sampled	Untreated Stockpiles (3 per batch)	Treated	
			Individual Fraction (4 per batch)	Reformed Stockpile (3 per batch)
Total PFAS	25	76	100	76
ASLP PFAS	25	76	100	76
EOF	1-3	10	12	10
TOPA	1-3	10	12	10

In addition to sampling to determine the PFAS concentration of soil, one sample per batch of feed and treated and reformed material was sampled for particle size distribution (PSD). This information was used to assess whether the treatment process altered the PSD of material and to determine how the treatment plant performed under different soil conditions.

3.6.2 Soil Sampling Method

Given the limited guidance on PFAS soil remediation practices (particularly for soil washing), the sampling procedures outlined in the *Technical and Regulatory Guidelines for Soil Washing,* prepared by the ITRC (1997), were used to guide the sampling method for this POP. The ITRC is a credible state led coalition based in the U.S.A that publishes regulatory guidance documents for remediation technologies. These documents are written and reviewed by environmental professionals, including state and federal environmental regulators within the U.S.A. such as the EPA, Department of Energy, Department of Defence and Environmental Research Institute of the States.

ITRC (1997) was developed for treating metal contaminated soils using soil washing, however the general principals of the sampling approach are still relevant for this trial. In addition to ITRC (1997), guidance for sampling stockpiles in the Victorian *EPA Industrial Waste Resource Guidelines 2010* (IWRG702, 2010) and the NSW EPA *ENM Order* 2014 (NSW EPA, 2014) were adopted for this trial.

ITRC (1997) recommends collecting composite samples from stockpiles generated from soil washing. Additionally, composite sampling is also recommended for characterising stockpiles in NSW EPA (2014). For consistency in this POP, composite sampling was conducted at all times to characterise soil (e.g. untreated soil, individual soil fractions and treated and reformed soil). Composite sampling has limitations when sampling soils in-situ due to potential dilution of hotspots, however when sampling processed stockpiles, it will increase the representativeness of the sample.

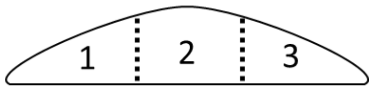
For this POP, a composite sample consisted of four equal sub samples collected and combined to form one bulk sample (approximately four kg). This material was then mixed together and a sub-sample was collected for laboratory analysis. This process was repeated for each sample. Samples were collected in a 3-dimensional systematic grid to account for spatial variability as recommended in IWRG702 (2010). Additionally, the collection of samples from the surface (e.g. top 100 mm) of the stockpile was avoided as recommended in IWRG702 (2010).

All soil samples were collected using disposable nitrile gloves. A new set of gloves was worn for each sample to minimise the risk of cross-contamination between samples and to remove the requirement for decontaminating sample tools.

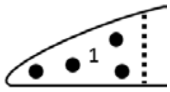
The soil sampling method used for this POP is summarised below:

Feed and Treated and Reformed Stockpiles

1. Three composite sample were collected from each batch/stockpile. The stockpile was divided into thirds with one sample collected from each third:



2. A composite sample was collected by combining four equal weight separate sub samples (~1kg each) from a defined third of the stockpile. These sub samples were combined into one bulk sample and placed in a pre-labelled 5L HDPE bucket.

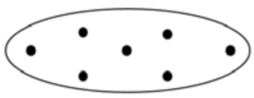


3. Soil was mixed thoroughly within the 5L bucket to obtain a homogeneous sample representative of the entire sampling interval. After mixing, a sub-sample was collected from the bucket and placed in a PFAS free 250 mL sample jar and send to the laboratory for analysis.

4. The remainder of the bulk sample was retained in the bucket which was then sealed and stored in an on-site laboratory.
5. Ventia and AECOM collected sub-samples from the same 5L the buckets in cooperation with each other to enable direct comparison between analytical results.

For Batches 1-5, an additional 7 soil samples were collected from each stockpile. This sampling procedure is summarised below:

1. Seven soil samples were collected from seven different locations on the stockpile (e.g. see top view of stockpile below for potential sample locations)



2. Approximately 4kg of soil was collected at each location and placed directly into a 5L bucket. Material was then mixed thoroughly.
3. For Batch A, Ventia collected one sub-sample from one of the extra 7 buckets and placed the material into a 250 mL jar for analysis. AECOM collected sub-samples from all the extra batches.

Intermediate Stockpiles

Samples of individual soil fractions were collected from the intermediate stockpile storage area using the same method as the Feed and the Treated and Reformed Stockpiles, however only one composite sample was collected per individual soil fraction. As only one composite sample was collected per soil fraction, the stockpile was divided into four equal parts with one sub sample collected from each section:

The four samples were then combined and mixed in a 5L HDPE bucket and sub-sampled into a 250mL PFAS free jar. The 5L buckets were then stored in the on-site laboratory.

4. MATERIAL TRACKING PROCESS

Material was tracked at each stage of the process from excavation to backfill (cradle-to-grave). To assist this process, nomenclature (consisting of a sequential lettering system) was generated that tracked each batch through excavation, stockpiling, treatment, reforming and finally backfilling.

Excavations were identified by placing the prefix “Ex” in front of the unique batch letter. An untreated stockpile included a prefix of “UT” followed by the unique letter. An individual soil fraction contained the prefix that represented that material type (e.g. “G” was used for the gravel fraction). A treated stockpile included the prefix “T”. Sample IDs used the same format as excavations and stockpiles and this information is presented below in **Table 3 and 4.**

Table 3 – Excavation and Stockpile Nomenclature

Material Description	ID	Location
Excavation Batch “A”	Ex – A	P9
Untreated Stockpile “A”	A – UT	Untreated Stockpile Area
Treated Stockpile “A”	A – T	Treated Stockpile Area

Table 4 – Soil Sample Nomenclature

Material Description	ID	Location
Stockpile A, Untreated, Sample 1	A- UT – 1.	Untreated Stockpile Area
Stockpile A, Gravel Fraction, Sample 1	A – G – 1,	Gravel Intermediate Area
Stockpile A, Organics (Coarse), Sample 1	A – O1 – 1	Coarse Organic Intermediate Area
Stockpile A, Sand (Coarse), Sample 1	A – S1 – 1	Coarse Sand Intermediate Area
Stockpile A, Fines, Sample 1	A –F – 1	Fines Intermediate Area
Stockpile A, Treated and reformed, Sample 1	A – T – 1	Treated and Reformed Area
Untreated, Intra-laboratory duplicate from Stockpile A	QC1-A-UT	Untreated Stockpile Area
Untreated, Inter-laboratory duplicate from Stockpile A	QC2-A-UT	Untreated Stockpile Area

In addition to the above, sample ID’s included the Site ID (0939) at the beginning and the date in reverse order at the end (YYMMDD).

A summary of the material tracking process is presented in **Figure 1** below:

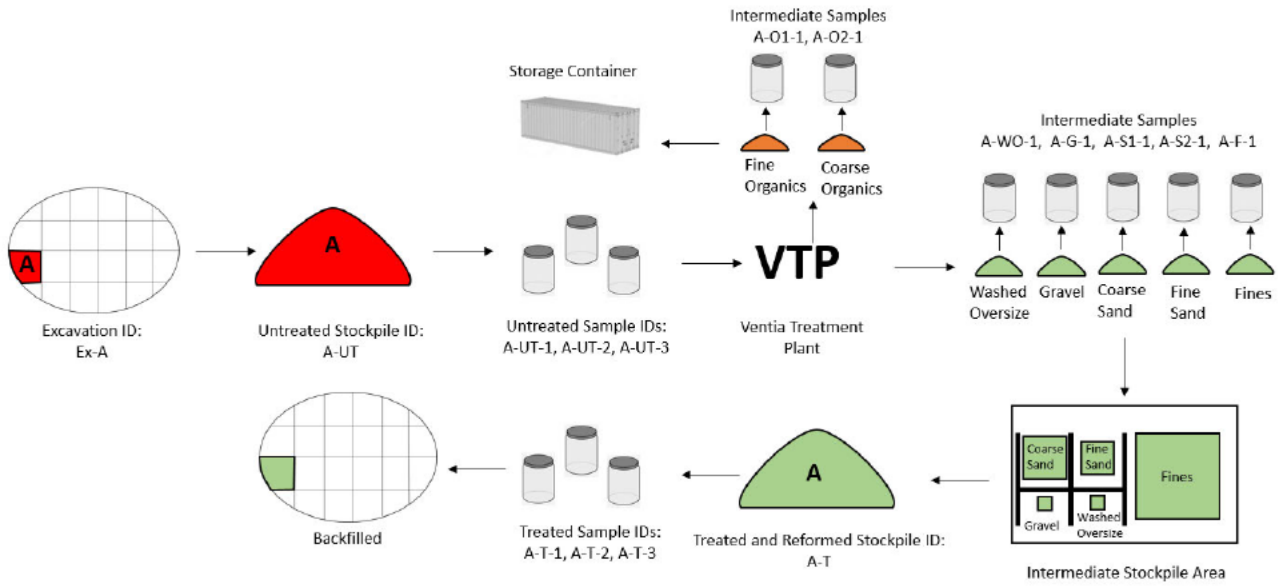


Figure 1. Treated soil was tracked from cradle-to-grave and sampled at multiple points of the process. In the example above Batch A is excavated, stockpiled and sampled (A-UT-1 to 3) as feed soil. This material is treated within the Ventia treatment plant. The generated waste (organics) and soil fractions (gravel, sand and fines) are sampled (A-O1-#, A-G-#, A-F-# etc.). Soil fractions are then reformed and sampled again (A-T-1 to 3) before being backfilled and waste material (organics) is stored on-site.

5. NATURE OF CONTAMINATION

5.1. Review of Fire Training Activities

The Detailed Site Investigation Addendum (JBS&G 2019) of RAAF Base Edinburgh notes that the main AFFF product used for fire training was 3M Light Water™, which is known to contain high concentrations of PFAS with the most predominant PFAS compound being perfluorooctane sulphonate (PFOS). 3M Light Water™ was first used on the RAAF Base in 1978 and its phaseout and replacement with Ansulite AFFF (which is understood not to contain PFOS) took place between 2005 and 2013.

27 PFAS soil source areas (SSAs)were identified in JBS&G (2019) and include current and former fire training areas, current and former AFFF storage areas and waste disposal areas. Of the 27 SSAs, AECOM (2018) identified six priority areas and average PFOS + PFHxS concentrations and estimates of PFOS mass of these areas are listed in **Table 5** below:

Table 5 – Priority Soil Source Areas

Priority area	Average sum of PFOS + PFHxS (from AECOM 2018)	PFOS Mass (kg)	% PFOS in 0-2m Soil Depth (from JBS&G 2019)
P1 AFFF Evaporation Pond	N/A^	1,091	45%
P4 Former Fire Training Area and Sub-surface Waste Dump	1.38 mg/kg	324	11%
P9 Static Rocket Firing area and Fire Training Area	3.88 mg/kg	124	5%

Priority area	Average sum of PFOS + PFHxS (from AECOM 2018)	PFOS Mass (kg)	% PFOS in 0-2m Soil Depth (from JBS&G 2019)
P10 Former Sewage Treatment Plant and Former Fire Fighting Training Area	2.21 mg/kg	230	9%
P11 Current Fire Fighting Station area and former AFFF Storage Area	13.65 mg/kg	221	9%
P15a Former Fire Training Area and Ordnance Unloading Area.	1.48 mg/kg	37	2%
P15b Former Fire Training Area and Ordnance Unloading Area.	7.4 mg/kg		
P16 Former Fire Training Area around the Engine Run Up (ERUP) Facility**	N/A^	349	14%
Total – 0-2m, 5mg/kg (sum of SSAs above)	N/A^	2,044	84%
Total – 0-2m, 1-5mg/kg	N/A^	173	7%
Total – 0-2m, 0.005-1mg/kg	N/A^	212	9%
TOTAL – 0-2m	N/A^	2429	100%

Notes:

*Table adapted from Table 1 in AECOM (2018) and JBS&G (2019)

**Currently under review by AECOM as a priority source area

^Value not calculated as it was not within the scope of the report

5.2. Review of In Situ Data from P9

P9 was recommended as the source of soil for the POP (AECOM, 2018). This recommendation was based on observed elevated PFAS soil concentrations and accessibility to the area. AECOM (2019) compiled all available data for P9 and presented a PFAS soil concentration map to assist in identifying the most appropriate place to excavate soil, see **Figure 2** from AECOM (2019) below. The maximum observed concentration of PFOS + PFHxS in P9 was 18.088 mg/kg in BH077 at 0.75 to 0.9 m bgl.

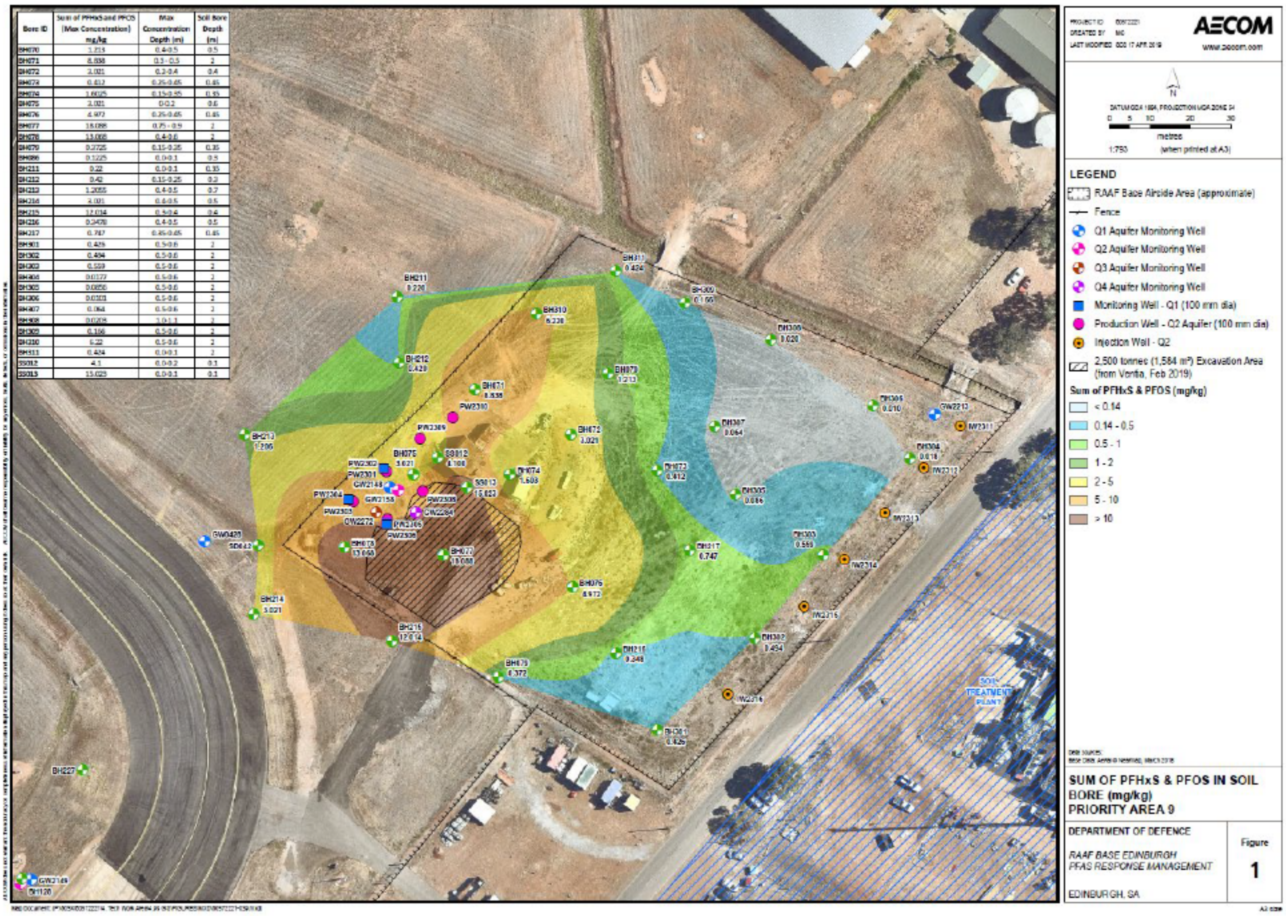


Figure 2. Sum of PFHxS & PFOS (mg/kg) in Soil Bores in Priority Area 9 (AECOM, 2019).

The mass of PFOS in the SSAs was estimated by AECOM (2018) and JBS&G (2019). **Table 6** presents the "most likely case" of PFOS mass in the soil for P9 as estimated by JBS&G (2019); the table lists the soil volume and PFOS mass for soil with three different concentration ranges. In total it is estimated that there was 124 kg of PFOS in P9.

Table 6 – PFOS Mass Estimate in P9

PFAS	Soil (m^3)	PFOS Mass (kg)	% of Mass
>5mg/kg*	7,825	81	65%
1-5 mg/kg	11,513	39	31%
>0.005-1mg/kg	9,014	4	3%
Total	28,352	124	--

*The highest reported concentration of PFOS in P9 was 18 mg/kg

^ Table adapted from Tables 9.1 – 9.5 from JBS&G (2019)

Note: PFAS mass calculations are limited to the upper 2m of P9. There is an unknown (but likely relatively low) quantity of PFAS mass in soil >2 m bgl

The boundary of the excavation in P9 was designed to target soils with the highest concentration of PFAS in P9 based on data provided in AECOM (2019) as illustrated above in AECOM (2019) **Figure 2**.

5.2.1 Data vs Depth

Surficial fill material (0.0-0.2 m) in P9 is typically less impacted by PFAS than the underlying sub-surface material. There is limited data for material >0.5 m bgl, however AECOM (2019) determined that maximum PFAS concentrations are typically reported at depths between 0.5 and 1.0 m bgl and have reduced to <5 mg/kg by 2 - 2.5 m, refer to **Figure 3** below:

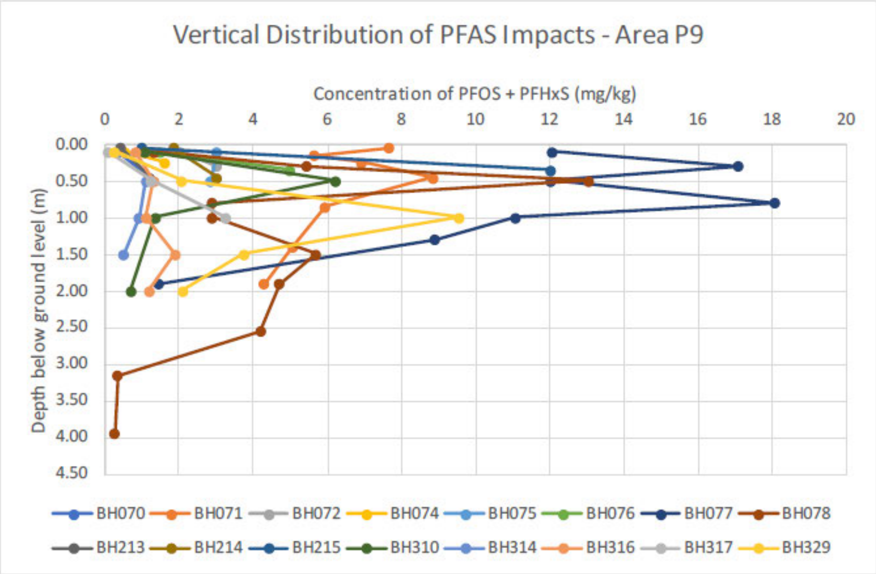


Figure 3 – Vertical Distribution of PFAS in P9. (Source: AECOM (2019) Technical Memo #15 DRAFT)

Figure 3 illustrates that only BH078 was extended beyond 2 m bgl in P9. Due to limited PFAS data >2 m bgl, calculations relating to PFAS mass made by AECOM and JBS&G are limited to the upper 2m of the soil profile.

5.2.2 % of PFOS + PFHxS, PFOA vs 28 PFAS

AECOM (2018) concluded that the majority of the Total PFAS concentration (>80% and up to 94% in P9) in soils is comprised of PFHxS + PFOS, with PFOA typically comprising <5%. This observation was consistent with the results of this POP, refer to **Figure 4**. The makeup of PFAS in P9 is likely due to the historical use of 3M Light Water™ which is known to have high concentrations of PFOS.

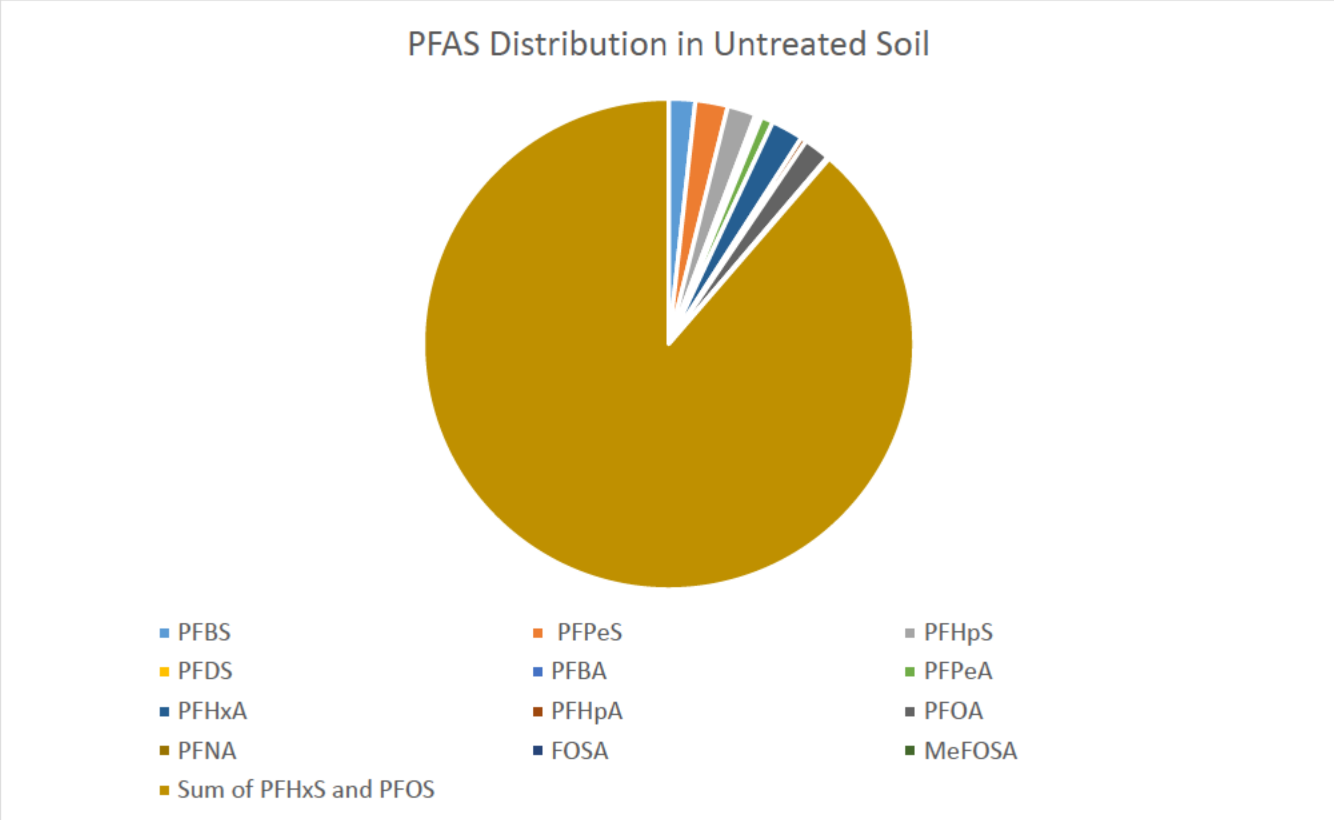


Figure 4 – PFHxS + PFOS vs 28 PFAS

5.2.3 Precursors

Prior to the 2,500t trial commencing, AECOM advised they had found limited evidence for the presence of precursors in P9 (pers comms). To confirm this observation samples from Batches A-C were analysed for EOF and TOPA. These results (refer to **Section 8.4**) agreed with AECOM's observations and were presented at the Collaboration Point Meeting. At the meeting it was agreed that additional precursor analysis would not provide value for the project and therefore would not be required for the remainder of the 2,500t trial.

6. DATA QUALITY

6.1. Quality Control

The results presented in this report are based on data produced by the primary lab used for PFAS analysis. For batches A-G the primary lab was Eurofins and for Batches H-Y, ALS was the primary lab. Every batch of untreated and treated soil had at least one sample analysed at both Eurofins and ALS.

The *Trial Performance Plan* lists the Data Quality Indicators for this POP. **Table 7** lists the duplicate requirements and acceptable relative percent difference (RPD%) for these samples. Due to expected sample heterogeneity, duplicate sample rates exceeded what was required in the *Trial Performance Plan* to assist in interpretation of data quality results. One intra-lab duplicate and one inter-lab duplicate was collected for each batch of Untreated and Treated soil.

There was no requirement in the *Trial Performance Plan* for duplicate samples to be collected for Intermediate Fractions as this data was not relied upon for final assessment against performance criteria. The frequency of duplicate samples was therefore calculated on the total number of Untreated samples (n = 76) and Treated and Reformed samples (n = 76).

Table 7. Field Data Quality Indicators

Indicator	Required Frequency	Result	Acceptance Criteria	No. of exceedances
Intra-lab Duplicates	10% of samples	32% of samples	<+/- 50%RPD	4
Inter-lab Duplicates	5% of samples	32% of samples	<+/- 50%RPD	30

There were four exceedances of the RPD criteria for intra-laboratory duplicate samples and thirty exceedances for inter-laboratory duplicates. Although there were several exceedances, the criteria assumed the media being tested was homogeneous and that the error was due to sampling or lab error. P9 soil was not homogenous and PFAS concentrations were variable. Furthermore, all RPD exceedances from Intra-laboratory duplicates were from untreated samples, there were no exceedances in treated samples. Exceedances were likely caused by the heterogenous nature of untreated soil and once the soil was treated it was homogenised which likely resulted in the lower RPDs in treated samples.

Unlike the intra-laboratory duplicate samples, the RPD exceedances from inter-laboratory duplicate samples were from both untreated and treated soil. A review of the data for each batch of untreated and treated soil showed that Eurofins consistently reported higher PFAS concentrations compared to ALS. Despite inter-laboratory duplicate exceedances, intra-laboratory duplicate analysis at both labs (Eurofins for Batches A-G and ALS from Batches H-Y) showed relatively low RPD values and therefore high precision.

The RPD exceedances from inter-laboratory duplicates is likely due to different analytical methods, however investigating this further was not within the scope of this POP. The discrepancies between the two labs is discussed further in **Section 6.2**.

Despite several reported exceedances of the intra-laboratory duplicate RPD criteria, most duplicate samples reported RPDs well within the acceptable range. Based on these exceedances being from heterogenous sample material and the relatively low RPDs reported for all other samples, Ventia considers the data obtained was suitable for the purpose of this POP.

6.2. Primary and Secondary Laboratory

After the primary lab was switched from Eurofins to ALS, the average concentration of PFAS in untreated and treated soil decreased. This decrease was originally attributed to variability of PFAS concentrations in the excavation area, however a review of results from both labs showed that Eurofins consistently reported higher concentrations of PFAS compared to ALS, refer to **Table 8**. Despite different concentrations reported between the two labs, overall PFAS removal efficiencies were comparable (92% at Eurofins, 89% at ALS, and overall 90% with data from the 'primary lab'). A list of the results from both labs for every batch is presented side-by-side in **Table 4** in **Annex E.**

Table 8. PFOS + PFHxS Concentrations (mg/kg)

Untreated Soil			Treated and Reformed Soil		
Primary Lab*	Eurofins	ALS	Primary Lab*	Eurofins	ALS
2.92	4.69	2.36	0.30	0.40	0.27

*Primary lab was Lab A for batches A-G and Lab B for batches H-Y.

A review of totals and ASLP data from ALS indicated that over 100% of the PFAS in most untreated samples was leaching from the soil, which is theoretically not possible. If the totals to leachate ratio was >100% it is an indicator that the totals PFAS concentration could be underestimated. Conversely, totals and leachate data from Eurofins indicated that they may have overreported untreated PFAS concentrations in some samples. The true concentration of PFAS in the untreated soil is likely somewhere between the values reported by the two labs. For this reason, data from both labs was used to provide a range when estimating PFAS mass removal in **Section 8.5**.

Discrepancies in PFAS concentrations between the two labs was likely due to the use of different analytical methods, however determining which lab was reporting the more accurate PFAS concentration was not within the scope of this POP. Determining which lab was producing the more accurate result did not materially change the conclusions of the POP test.

6.3. Anomalous Results

During the 2,500t trial, several samples were reanalysed due to inconsistencies in PFAS concentrations across samples within the same batch and abnormally high/low total PFAS results compared to PFAS ASLP results. A summary of samples that underwent reanalysis is presented in **Table 9**.

Table 9. Sample Reanalysis

Sample ID	Initial Lab Report	Initial Concentration PFOS + PFHxS	New Lab Report	New Concentration PFOS + PFHxS	Reason for Reanalysis
A-UT-1	666161	1.77 µg/L	670681	243 µg/L	ASLP result abnormally low compared to other samples in the batch
A-UT-2	666161	2.28 µg/L	670681	249.3 µg/L	ASLP result abnormally low compared to other samples in the batch
B-UT-3	668012	0.909 mg/kg	671233	4.71 mg/kg	Totals result abnormally low compared to other samples in the batch
E-UT-1	670686	11.2 mg/kg	670686-V2	5.91 mg/kg	Totals results abnormally high compared to inter-lab duplicate from batch
E-UT-2	670686	18.45 mg/kg	670686-V2	6.08 mg/kg	Totals results abnormally high compared to inter-lab duplicate from batch
E-UT-3	670686	40.4 mg/kg	670686-V2	8.62 mg/kg	Totals results abnormally high compared to inter-lab duplicate from batch
QC1-E-UT	670686	23.9 mg/kg	670686-V2	4.8 mg/kg	Totals results abnormally high compared to inter-lab duplicate from batch
H-UT-2	ES1926447	0.0116 mg/kg	ES1926447_1	1.6 mg/kg	Totals result was low compared to ASLP results

Anomalous results were predominantly from samples of untreated soil. From consultation with field and laboratory technicians, it is hypothesised that anomalous results were caused by sample heterogeneity in the untreated samples due to the inherent nature of fill material. In comparison, treated samples were homogenous and results were relatively consistent throughout the POP, likely due to significant soil processing and mixing through the treatment.

7. PROCESSING DATA

7.1. Feed Material

Feed material sourced from P9 was relatively dry (~15% moisture content) and consisted of brown silty clay with minor amounts of gravel. Limited foreign material such as brick, bitumen and concrete were also observed in surficial fill material. The first two batches of feed soil were $72m^3$, however the remainder of the batches were $54m^3$. Batch sizes were reduced following an in-situ density adjustment from 1.6 t/m^3 to 1.85 t/m^3 to achieve a batch size of ~100 tonnes (refer to **Section 7.3**).

Prior to transportation of excavated material to the feed stockpile area, soil batches were mixed with the excavator and sieve bucket to improve homogeneity to enable more accurate characterisation of feed soil during soil sampling.

7.2. Material Processing

During the POP test the PFAS soil treatment plant gradually increased the treatment rate from ~40t /day (via a single 12hr shift) at the beginning to ~80t / day at the end. Since the POP test has been completed ~100t/d has been consistently achieved. The treatment plant is designed to treat a range of soils and as such there are a variety of different soil fractions that can be generated through treatment. For this POP test, four intermediate fractions were generated:

- Gravel;
- Coarse Sand;
- Coarse Organics; and
- Fines.

Fine sand and fine organics were not generated as these fractions were not significantly present in soils from P9. There were minor volumes (<1 tonne per batch) of the washed oversize fraction generated, however this material was predominantly clay balls >80mm that were generated during the first steps of the treatment process. Washed oversize material was crushed with the excavator bucket to <80mm and reprocessed through the treatment plant.

7.3. Particle Size Distribution

Particle size was measured several ways pre- and post-treatment to monitor changes in size distribution during treatment. Detailed results are presented in **Table 2**, **Annex E**. Laboratory samples were collected from untreated soil and treated and reformed soil for Particle Size Distribution (PSD) analysis at an accredited laboratory. The actual masses of soil fractions generated from the plant during treatment of each batch (Treated – Intermediate Fractions) were also measured using a calibrated load cell on a frontend loader to determine PSD. These results are summarised in **Table 10.**

Table 10. Particle Size Comparison Batches A-Y

Batch	Gravel (>5mm)	Sand (0.15-5mm)	Fines (<150um) Content
Units	% wt./wt.	% wt./wt.	% wt./wt.
Untreated	5	20	75
Treated – Intermediate Fractions	9	10	77
Treated – Reformed	2	21	77

One sample per untreated batch was analysed for PSD. On average, feed material consisted of c.75% fines (<150µm) with c.20% sand (150µm-5mm) and c.5% gravel (5-80mm). The mass of intermediate fractions showed was 77% fines, 10% sand and 8% gravel. Once reformed, the PSD was 77% fines, 21% sand and 2% gravel. The untreated and treated (reformed) distribution showed a slight (2-3%) shift from gravel size particles to clay / silt size particles. Interestingly, the intermediate fractions showed more gravel and less sand than the untreated and treated fractions. This is possibly due to underreporting of larger gravel sized particles, which have a high mass to number of particles ratio compared to finer grained particles such as sand, silt and clay. Given, the distribution for the intermediate fractions was determined on a 100t scale compared to the c.1kg lab-scale for the untreated and treated reformed fractions the contribution from gravel particles was better represented in the intermediate fractions.

7.4. Soil Mass

The mass of untreated soil was measured four ways:

- By surveying the in-situ volume of each batch and calculating the mass using the measured in situ density of soil from P9;
- Using a calibrated scale on the feed conveyor (referred to as a Beltweigher);
- By measuring the average weight of a loader bucket and counting the number of buckets per batch; and
- Measuring the weight of each batch using a load cell on the loader.

Based on the results of the four methods, the method adopted to achieve ~100t batches, consisted of surveying the excavation and marking it into equal grids that contained ~54m^3. Based off a measured in-situ density (1.85 t/m^3), each of these grids would generate ~100 tonnes. The mass of treated soil was recorded through a calibrated load cell on a front-end loader. Soil moisture content was also used to calculate differences between the 'wet' and 'dry' weight of soil. The processes used to measure soil weight are described in the following sub-sections.

7.4.1 Survey

The excavation area was surveyed before, during and after excavations to generate batches of ~100 tonnes and to confirm excavation volumes at the completion of the POP test. The excavation area was marked out into equal grids and each grid was excavated to a depth of 2m bgl. Surveys of the excavation area are provided in **Annex C**.

7.4.2 In Situ Density

Prior to excavation works, the in-situ density of soil was estimated to be 1.6 t/m^3. Testing conducted by a geotechnical consultant following excavation of Batch A and Batch B confirmed material in P9 has an average in situ density of ~1.85 t/m^3. The volume (m^3) of excavation batches was subsequently decreased from 70 m^3 to 54 m^3 to achieve batch sizes of 100t. This data is presented in **Annex D**.

7.4.3 Beltweigher

A Beltweigher located at the front-end of the treatment plant was used to measure the soil mass (tonnes) of each batch. At the conclusion of the POP test, the Beltweigher recorded a total of 2,579 tonnes of soil that was fed into the plant. This number excluded any material that underwent re-treatment (e.g. gravel or Batch E).

7.4.4 Calibrated Loadcell on Front-end Loader

The front-end loader used for emptying the material bays of the intermediate fractions (gravel, sand, fines, organics) contained a calibrated load cell for the POP test. Each time the loader picked up a bucket of an intermediate fraction, the mass and fraction (gravel/sand/fines/organics) was recorded. This method was used to record the recovered mass of soil post-treatment for each batch. This mass is referred to as the "treated mass" and is the total volume of each of the four soil fractions.

7.4.5 Moisture Content

Every soil sample in this POP test was analysed for moisture content and this data was used to determine the moisture content of each Batch. These values were used to calculate differences in the 'wet' and 'dry' weight of soil. The treatment process generally added 15-30% moisture to soil. Determining the 'dry' weight of untreated and treated soil was used to confirm that approximately the same mass that entered the treatment plant was recovered post-treatment. The dry weight of soil was also used for PFAS mass calculations.

7.4.6 Soil Mass Summary

Table 11 below and **Table 1, Annex E**, show the volumes and masses of soil excavated and recovered post-treatment. In summary, 2,579t wet weight (measured using the Beltweigher) of soil was excavated as part of the POP; corresponding to 2,256t dry weight. The material post-treatment was 3,391t wet weight and 2,206t dry weight (measured using calibrated loader scales). The variance pre- and post-treatment was -32t (-1%) dry weight and 1,153 (24%) wet weight. The increase in the wet weight was a result of hydration of soil during the wet treatment process and in line with expectations. The variance between the dry weight measures is within the measurement limits of error from the two measurement systems.

Table 11. Summary Batches A-K

Untreated Mass			Treated Mass			Dry Weight Variance
Wet (t)	Moisture (%)	Dry (t)	Wet (t)	Moisture (%)	Dry (t)	
2,579	13	2,237	3,390	35	2,205	-32 t / 1%

8. OPERATIONAL LEARNINGS

During the trial there were various learnings that arose through the excavation, treatment and backfilling process. These learnings along with recommendations to enable a more streamline approach for future PFAS remediation works at RAAF Base Edinburgh are outlined below.

8.1. Project Timeframes

Based on the operational learnings from the 2,500t Trial, Defence requested Venita provide an estimate for the time it would take to excavate, treat, validate, dry and backfill approximately 2,000m^3/3,700t of soil from a new Soil Source Area (SSA) at Edinburgh RAAF Base. Providing an exact timeframe for this to occur is not possible without knowledge of the source area, e.g. soil type, topography, access and underground services, however **Table 12** below provides an approximate length of time for each activity if no delays are experienced:

Table 12. Project Activity Time Estimates for a 3,700t Soil Source Area

Activity	Rate	Total Time (work days)
Excavation	200t + per day	Max 19 days
Treatment	100t per day	37 days
Validation	10 days per 100t batch	--
Drying	Dependant on stockpile storage space*	N/A
Backfill	200t + per day	Max 19 days
Total	N/A	Total timeframe depends on stockpile storage space

*If soil can be spread into thin layers and lime mixed through it, soil can dry significantly quicker than when it is stockpiled in the current stockpile storage area.

Although excavation, treatment and backfilling can occur at a relatively rapid rate, the timeframe for future projects will be limited by validation and drying of soil. Currently there is capacity for 500t of soil to be stored on the treated stockpile storage area in Ventia's treatment compound. The validation process (sampling, laboratory analysis and EC review of results) means that soil must remain there for a minimum of 10 days before it can be moved from the area and used as backfill. Therefore, after the treatment of five batches, no further treatment could occur for another five days while soil awaits validation. Furthermore, by storing treated soil in this limited space, it cannot be spread into thin layers to facilitate drying, meaning that even after soil has been validated it may not be suitable for backfilling.

Treating soil every day is the most cost-effective path forward for future remediation works and any delays in treatment should be avoided. In order to avoid treatment delays and to enable cost effective works to be conducted, Ventia has prepared several recommendations for future PFAS soil treatment works at Edinburgh RAAF Base in **Sections 8.2-8.6**.

8.2. Feed Soil Requirements

Maintaining a steady supply of dry and homogenous feed soil is crucial to minimise downtime of the process. During the trial, rainfall and the identification of underground services in the excavation area caused delays to soil treatment. Additionally, feed soil required screening to create a homogenous matrix for treatment, to observe the material for UXO, foreign debris and potential asbestos and to enable more accurate PFAS characterisation.

For future works, Ventia recommends the following to improve risks associated with feed soil:

- Increase the feed soil storage area to enable a large supply of feed soil if excavation cannot occur;
- Construct a shade structure over feed soil to protect it from inclement weather; and

- Sufficiently mix feed soil with a sieve bucket to improve homogeneity for treatment and PFAS characterisation and to inspect the material for foreign debris.

8.3. Storage of Treated Soil

Due to the wet treatment process, treated soil becomes more hydrated than feed soil, and may require drying or subsequent processing prior to backfill to meet 95% compaction. During the trial, due to soil with a high fines content (average of 75% but over 90% fines in some batches) and limited stockpile storage space, soil had to be spread into thin layers to enable it to dry adequately for backfilling and compaction.

Adding 1% lime to soil helped with drying, however due to the long process involved in getting approval to backfill treated soil, the stockpile storage area was often exhausted. For soil to be backfilled, it had to be sampled and results reviewed by the EC. In total this process took a minimum of seven working days and was often subject to laboratory delays.

During future works, treatment throughput could increase which will mean treatment may have to cease if there is insufficient room to store and dry treated soil. To ensure future treatment can continue continuously, Ventia recommends the following:

- Allow soil to be used as backfill prior to receiving analytical results; and
- Significantly increase stockpile storage space to allow soil to be spread into thin layers. This could be done by extending the boundary of P9 or utilising other space within the RAAF Base, e.g. the unoccupied golf course adjacent to the soil treatment plant.

8.4. Precursors

Analysing precursors via a range of tests is recommended at the beginning of treating soil from a new source area. If precursors are present, then additional analysis may be warranted. There are several methods for analysing precursors (TOPA, EOF, TOF) and it is unlikely one test will provide a robust answer, however, TOPA appeared to have the most consistent and reliable results

8.5. Gravel

Edinburgh soil typically had low (<c.5%) gravel content which resulted in poor attrition between the individual gravel pieces during treatment. When this occurred clay-balls were deposited with the gravel in the treatment bay meaning the gravel had to be retreated. This did not significantly impact daily operations as the total volume of gravel was low, however it should be taken into consideration for future treatment.

8.6. Lime Treated Soil and Revegetation

After consultation with the PMCA and the EC, 1% lime was added to soil to assist with drying. Prior to this occurring, two trials were conducted to assess the impact of lime to soil pH and PFAS concentrations. Initially a lab scale trial using 5kg soil samples was conducted and results indicated that lime increased soil pH and had a negligible impact to PFAS concentrations. A larger scale trial was then conducted on Batch E and J soil, refer to **Table 13**.

Table 13. Summary of PFAS and Lime Results

Analyte		Untreated/ Background	Treated	1% Lime
Batch E	pH	9.5	8.6	11.3
	PFOS+PFHxS (ug/L)	305	4.9	8.51
	PFOS+PFHxS (mg/kg)	3.99	0.153	0.184

Analyte		Untreated/ Background	Treated	1% Lime
Batch J	pH	9.47	9.03	11.27
	PFOS+PFHxS (ug/L)	127.33	10.65	12.67
	PFOS+PFHxS (mg/kg)	2.49	0.31	0.18
Average	pH	9.48	8.82	11.28
	PFOS+PFHxS (ug/L)	216.7	10.25	10.59
	PFOS+PFHxS (mg/kg)	3.24	0.26	0.20

PFAS results indicated that adding lime made no material change to PFAS concentrations or leachability. Adding lime to Batch E and Batch J increased the pH from 8.6 to 11.3 and 9.03 to 11.27 respectively which was in line with expectations.

In accordance with the *Soil Excavation and Treatment Technical Specification*, Ventia ensured that where backfilling occurred, the soil matrix at or near the surface was conducive to revegetation. Although revegetation hasn't commenced, **Figure 5** below shows that native grass was able to grow in a matrix of treated and reformed soil with 1% lime added. If revegetation is not successful, a layer of topsoil may be placed on top of the backfilled soil to assist in revegetation of the area.

Figure 5. Extract of Treated and Reformed Batch V with 1% lime, soil pH 11 and approved RAAF Edinburgh grass mix successfully growing one month after germination.

8.7. Environmental Performance

During the construction, commissioning and operation of the PFAS soil treatment plant for the 2,500t trial, Ventia was audited by the PMCA (GHD) and the EC (AECOM). GHD conducted two Health and Safety audits in February and August 2019. AECOM conducted two Environmental Audits in June and October 2019. All issues identified in the Audits were successfully closed out and recommendations to improve health and safety or environmental management were implemented. Improvements to site operations recommended by the audits included improved dust management using a water cart and more frequent weed management.

9. RESULTS

9.1. Untreated Feed Soil

A summary of the untreated feed soil results is presented in **Table 14**. The average presented in **Table 10** is a 'weighted average' based on the average PFAS concentration and mass (t) of each batch. The average untreated PFOS + PFHxS concentration for the POP was 2.9 mg/kg.

Table 14. PFAS Results for Untreated Feed Soil

	PFOS + PFHxS	PFOS + PFHxS ASLP	PFOA	PFOA	Sum PFAS	Sum PFAS
Units	mg/kg	µg/L	mg/kg	µg/L	mg/kg	µg/L
Min	0.67	47.60	0.01	0.43	0.89	49.67
Max	11.51	264.95	0.24	6.50	12.19	292.35
Weighted Avg.	2.9	129.34	0.05	2.26	3.28	147.97

Results showed the majority of PFAS detected consisted of PFOS + PFHxS (**Figure 4**). This was in line with findings made by AECOM (2018). PFOA comprised little of the total PFAS concentration and all treated and reformed samples reported concentrations of PFOA below the performance criteria. For the remainder of the POP report, the discussion of results will focus on PFOS + PFHxS data. For PFOA results, refer to **Annex E**.

9.2. Intermediate Fractions

Overall, the sand contained the lowest residual PFAS concentrations and had the highest removal efficiency. The fines fraction reported relatively consistent PFAS removal efficiencies and all PFAS concentrations <1 mg/kg. Gravel results initially reported PFAS concentrations <0.5 mg/kg, however in some batches, the limited supply of gravel and high clay content meant the gravel fraction required additional treatment. Following additional treatment, residual PFAS concentrations were <1 mg/kg. The organics fraction reported PFAS removal in every sample with PFAS concentrations <1 mg/kg in all batches except for D, E and F (max concentration of 1.9 mg/kg).

A weighted average calculated using the PFAS concentrations and the mass (t) of the Intermediate Fractions was used to determine whether the fractions (gravel, sand and fines) would be suitable for reforming. The organics fraction was not reformed in any stockpiles. Overall, calculating the weighted average of the Intermediate Fractions proved to be an effective tool at estimating the final Treated and Reformed PFAS concentration as weighted average results were generally in-line with results from samples collected after the fractions were reformed.

9.2.1 Gravel

On average, gravel made up c.9% (wt./wt.) of the mass of treated intermediate fractions. Batches with limited gravel content and a high clay content resulted in reduced attrition between individual gravel pieces. Reduced attrition resulted in various amounts of clay being deposited with the gravel and lower PFAS removal in some batches.

For batches where attrition was reduced, the gravel fraction was sampled and set aside and placed into two bulk gravel stockpiles: E-K and L-Q. These stockpiles were then retreated to successfully remove clay (refer to **Figure 6** below). Results from samples of retreated gravel (G-RT-1 to 7) confirmed a reduction in PFAS concentrations compared to poorly washed gravel (e.g. E-G-1, F-G-1, G-G-1, H-G-1, I-G-1). Following retreatment, the gravel was divided equally into batches E-K and L-Q. After Batch Q, all gravel was successfully washed on the initial treatment round and no re-treatment was required.

Figure 6. Gravel from Batches E to K. Gravel from Batch E (Left) after one round of treatment with clay balls and coating of fines. Gravel from Batches E-K after re-treatment (Right) showed removal of clay balls and the coating of fines.

Table 15 summarises the gravel results for this trial. Average PFOS + PFHxS removal was 83% and all samples were < 1 mg/kg. A full list of gravel results for each batch is provided in **Annex E Table 5**.

Table 15. Gravel PFOS + PFHxS Summary

	Particle Size Distribution	PFOS + PFHxS	Removal Efficiency	PFOS + PFHxS ASLP
Units	% wt./wt.	mg/kg	%	µg/L
Average	9%	0.39	83%	22.92
Min	1%	0.02	65%	10.80
Max	28%	0.84	99%	55.20

9.2.2 Sand

Sand comprised of approximately 10% of the treated soil in this trial. Only coarse sand was generated, there was no recorded fine sand. **Figure 7** illustrates that sand was red/brown in colour and relatively homogenous. Intermediate Results of the sand fraction are presented in **Table 16.** Sand consistently had the highest PFAS removal efficiency and consistently reported concentrations of PFAS well below 1 mg/kg. A full list of sand results for each batch is provided in **Annex E Table 5.**

Figure 7. Sand in the material bay is red/brown in colour and homogenous.

Table 16. Sand PFOS + PFHxS Summary

	Particle Size Distribution	PFOS + PFHxS	Removal Efficiency	PFOS + PFHxS ASLP
Units	% wt./wt.	mg/kg	%	µg/L
Average	10%	0.08	97%	3.31
Min	1%	0.02	88%	1.11
Max	21%	0.39	99%	9.92

9.2.3 Fines

The Intermediate Results of the fines fraction were relatively consistent throughout the trial. Fines made up most of the treated material (approximately 77%) and were generally brown silty clay, refer to **Figure 8. Table 17** summarises the results from the fines fraction. Results were generally below 1 mg/kg and the average removal efficiency was 85%. A full list of fines results for each batch is provided in **Annex E Table 5.**

Figure 8. Treated fines, generally consisting of brown silty clay.

Table 17. Fines PFHxS + PFOS Summary

	Particle Size Distribution	PFOS + PFHxS	Removal Efficiency	PFOS + PFHxS ASLP
Units	% wt./wt.	mg/kg	%	µg/L
Average	77%	0.36	85%	12.48
Min	64%	0.13	46%	3.19
Max	92%	1.21	94%	30.40

9.3. Treated and Reformed Stockpile PFAS Results

After a batch was treated and its Intermediate fractions reformed together (excluding organics), it was sampled to evaluate compliance with the performance criteria. All samples from treated intermediate stockpiles (n = 76) and treated and reformed stockpiles (n = 76) had concentrations below 1 mg/kg except for one sample (A-T-4), which reported a concentration of 1.006 mg/kg. The weighted average removal efficiency of PFHxS + PFOS was 90%. Additionally, all samples reported concentrations of PFOA below 10 mg/kg. A summary of this data is presented in **Table 18.**

Table 18. Average Concentrations of PFHxS + PFOS in Untreated, Treated Intermediate Fractions and Treated Reformed Fractions

	PFOS + PFHxS (mg/kg)				PFOS + PFHxS – ASLP (µg/L)			
	Untreated	Intermediate	Treated	RE %	Untreated	Intermediate	Treated	RE %
Weighted Average	2.9	0.30	0.30	90%	127	12	12	91
Performance Criteria	--	--	**1**	--	--	--	**~200**	--

Based on the data presented in **Table 18** and **Table 3 in Annex E**, the performance criteria for this POP has been met. As soil met Standard 2a of the performance criteria (ASLP criteria) and was able to be reused on base, Standard 2b and Standard 2c of the performance criteria were not applicable. Standard 2b and Standard 2c only apply if soil is unable to be reused on-site.

9.4. PFAS Precursors

PFAS precursors were measured using a range of analysis for the first three batches of soil – Batches A-C. The analysis included:

- Extractable Organic Fluorine (EOF); and
- Total Oxidisable Precursor (TOP) Assay.

The results are shown in **Table 3, Annex E** and are summarised in **Table 19.**

Table 19. PFAS Precursor Data for Batches A-C

	Sum PFAS as F	EOF	RE%	Sum PFAS	Sum PFAS TOPA	RE%
Fractions	mgF/kg	mgF/kg	%	mg/kg	mg/kg	%
Untreated	4.89	3.96	-	7.53	7.63	-
Gravel	0.24	2.39	40%	0.36	0.36	95%
Sand	0.05	0.35	91%	0.08	0.07	99%
Fines	0.32	1.72	57%	0.50	0.51	93%
Organics	0.27	1.34	66%	0.41	0.92	88%
Treated (gravel, sand and fines fractions above)	0.37	0.50	87%	0.58	0.72	91%

Notes: Sum PFAS as F was estimated assuming ~65% of PFAS is fluorine in-line with the % fluorine in PFOS

The sum of PFAS as F and EOF did not increase in untreated samples as would be unexpected if precursors were present. The sum PFAS compared to sum PFAS TOPA increased slightly in untreated samples but this increase is within the range expected from analytical variability. Both tests therefore did not indicate the presence of PFAS precursors in untreated samples.

Interestingly, there did appear to be measurable precursors detected by both tests in the organics fraction (waste stream). EOF compared to Sum PFAS as F increased from 0.27 to 1.34 mgF/kg (506% increase) and sum of PFAS to sum PFAS TOPA from 0.41 to 0.92 mg/kg (224% increase).

Irrespective of the presence or absence of precursors average EOF concentrations in treated (and reformed) samples were 0.5 mgF/kg compared to 3.96 mgF/kg in untreated samples relating to an 87% removal efficiency. Similarly, sum PFAS TOPA results in untreated samples were 7.63 mg/kg and in treated samples were 0.72 mg/kg relating to an 91% removal efficiency.

9.5. PFAS Mass

The mass of PFAS was calculated in untreated soil, intermediate fractions and treated and reformed soil. This was calculated to determine the proportion of residual PFAS left on treated soil and to accurately track the mass of PFAS removed by the treatment process.

Section 6.2 discusses issues determining PFAS mass in untreated soil due to different PFAS concentrations reported by the primary and secondary lab. PFAS mass estimates in this section are therefore presented as three scenarios:

- Primary lab (data from the primary lab used for each batch);
- Eurofins (data from Eurofins for each batch of untreated and treated soil); and
- ALS (data from ALS for each batch of untreated and treated soil).

The true PFAS mass estimate likely sits somewhere between the three values presented in **Table 20. Table 4 in Annex E** provides a more detailed breakdown of this data for each scenario on a batch by batch basis. Additionally, **Table 2** in **Annex E** provides information on soil mass and moisture content which were used to calculate PFAS mass.

Table 20. PFOS + PFHxS Mass

Data Set	Avg Untreated PFOS + PFHxS Concentration (mg/kg)	Untreated PFOS + PFHxS Mass (PFAS in kg)	Avg Treated PFOS + PFHxS Concentration (mg/kg)	PFOS + PFHxS Mass Removed (PFAS in kg)	PFOS + PFHxS Mass Removal %
Primary Lab	2.9	6.53	0.30	5.9	90%
Eurofins	4.69	10.5	0.40	9.6	92%
ALS	2.36	5.3	0.27	4.7	89%

In total, there was between 5.3-10.5 kg of PFOS + PFHxS mass in the 2,579t of soil excavated for this POP and between 4.7-9.6 kg of PFOS + PFHxS mass was removed.

The residual PFOS + PFHxS mass in treated soil was ~0.7kg; **which accounted for a removal efficiency of 89-92% of the PFOS + PFHxS mass.**

9.6. Retreatment

During this trial one batch was selected to undergo retreatment to evaluate whether additional round of treatment could continue to remove PFAS in soil. Batch E contained the highest untreated concentration of PFOS + PFHxS and was therefore selected to undergo retreatment as it was expected that it would contain the highest residual concentrations of PFAS following the first round of treatment.

Results from retreatment are presented in **Table 21** below. During the first round of treatment there was a 81% reduction in PFOS + PFHxS. During the second round of treatment there was an additional 81% removal efficiency for totals (difference between 1.2mg/kg and 0.2 mg/kg) and an additional 92% removal efficiency for ASLP (difference between 6.4 mg/kg and 1.8 mg/kg). **Overall this represents a 97% reduction in totals PFOS + PFHxS after two treatments.**

Table 21. Retreatment Results for Batch E

	PFOS + PFHxS	Removal Efficiency	PFOS + PFHxS ASLP	Removal Efficiency
Units	mg/kg	%	ug/L	%
Batch E – Untreated	6.4	-	234	-
Batch E – Treated Intermediate Weighted Average	1.2	81	24	90
Batch E – Retreated Intermediate Weighted Average	0.2	81	1.8	99
Batch E – Retreated Reformed	0.2	97	5.4	98

Additionally, as described in **Section 9.2.1**, gravel was successfully retreated in this trial.

9.7. Wastes

The type and volume of waste generated from treatment of soil are presented in **Table 22**. The total volume of waste for all EDN soil treated (2,579t) was <0.7% and much lower than the pre-trial estimate of 3-5%.

Currently the water treatment vessels within the soil treatment plant have ~12m^3 each of Granular Activated Carbon (GAC) and Ion-Exchange Resin (IX Resin). Early stages of breakthrough were observed in GAC post-trial but not in IX-Resin during the trial. The worst-case rate of GAC produced is therefore known for GAC and is provided in **Table 22**. The rate of IX-resin however is still unknown. Ventia will continue to monitor breakthrough in the vessels and will aim to provide this data following treatment of additional soil.

Table 22. Wastes Streams

Waste	Volume of Waste	Rate of Waste Generation	Average PFOS + PFHxS (mg/kg) Concentration
Organics and low-density rubbish such as sticks, roots, plastic, debris	8.4t (wet wt.) per 2,579t treated	0.3% (wt./wt.) or 3kg/t	0.35
Spent Granular Activated carbon (GAC)	<8.4t (wet wt.) per 2,579t treated	<0.3% (wt./wt.) or 3kg/t	<c.1,000
Spent Ion-Exchange Resin	TBC	TBC	TBC
Spent cartridge filters	~3t	0.1% (wt./wt.) or 1kg/t	<1

9.7.1 Organics

Only coarse organics were generated during this trial; there was no recorded fine organics. Organics comprised 0.3% of the total treated soil at a volume of 8.4 tonnes. Organic material generally consisted of grass, leaves, twigs and other matter as pictured in **Figure 9**. Average PFOS + PFHxS removal efficiency was 88.6%. Results are summarised in **Table 23** and a full list of organics results for each batch is provided in **Annex E Table 5.**

Figure 9. The organic fraction contained an array of material and was relatively minor percentage of the total treated volume.

Table 23. Organics PFHxS + PFOS Summary

	Particle Size Distribution	PFOS + PFHxS	Removal Efficiency	PFOS + PFHxS ASLP	Leach Ratio
Units	% wt./wt.	mg/kg	%	µg/L	-
Average	0.3%	0.35	88.6%	14.87	329%
Min	0.0%	0.03	12.7%	0.00	0.0%
Max	1.1%	1.88	98.6%	47.20	1076%

9.8. Backfilling and Compaction

As per the Technical Specification, treated and approved soil was successfully backfilled and compacted. Compaction testing was undertaken by Coffey, a qualified geotechnical consultant. The consultant undertook 12 compaction tests within the trial area which all met the 95% standard compaction criteria, which is nominated in the Technical Specification. The geotechnical results are provided in **Annex G.**

The 95% standard compaction criteria is a common industrywide compaction standard for general bulk backfill activities; noticeable subsidence would not be expected with this level of compaction. Following the completion of remediation works in P9, the area will be revegetated in accordance with Ventia's CEMP.

9.9. Summary

The average PFOS + PFHxS concentration in untreated soil was 2.9 mg/kg and the average PFOS + PFHxS concentration in treated soil was 0.3 mg/kg. All treated batches had PFOS + PFHxS concentrations <1mg/kg and PFOA concentrations <10 mg/kg and were compliant with the performance criteria listed in **Section 1.3.**

Although there were no criteria for PFOS + PFHxS removal efficiency (RE), the weighted average RE was 90% as presented in **Figure 10**.

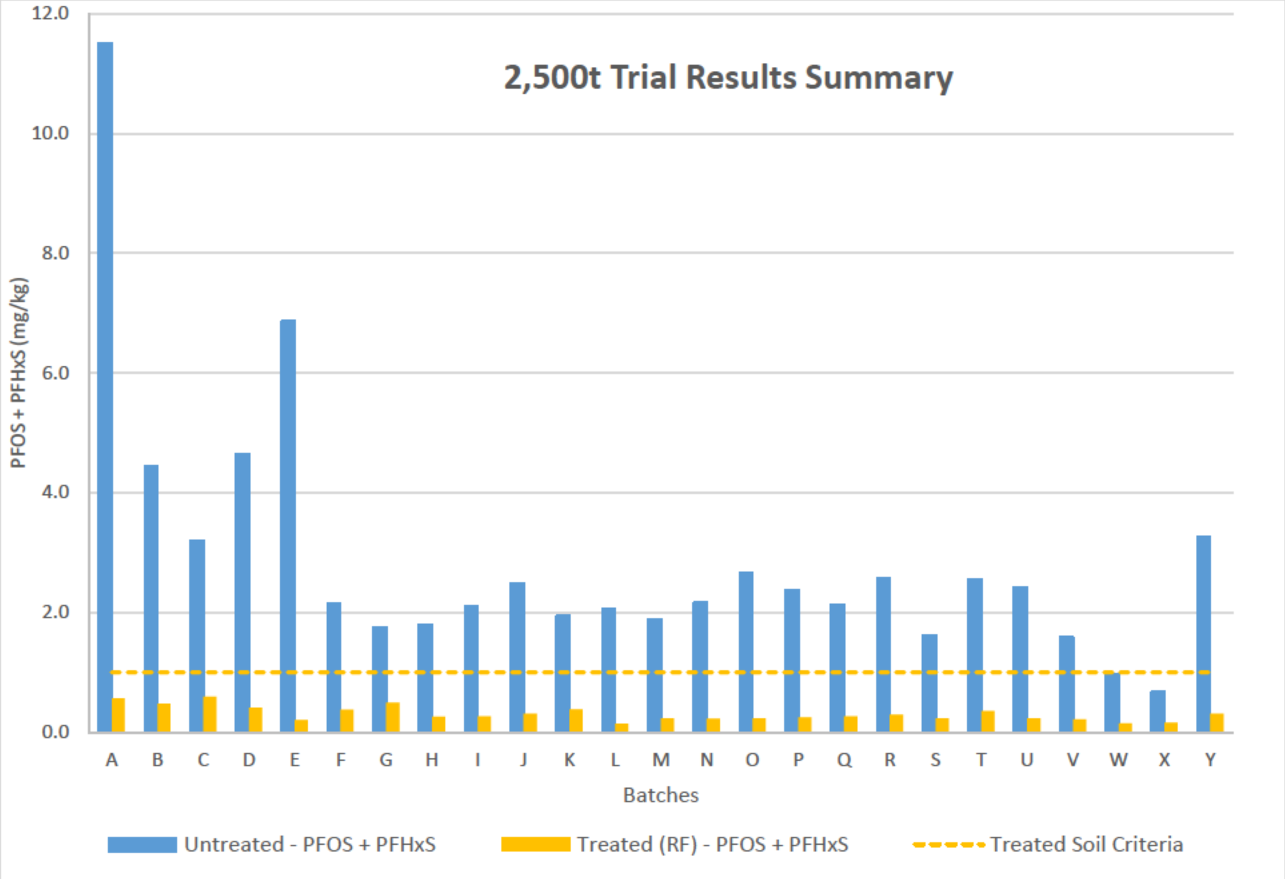


Figure 10. Summary of results illustrating untreated and treated soil concentrations per batch and the performance criteria.

10. DISCUSSION

10.1. Soil Mass

There was 2,579t of soil (2,237t dry weight) treated from the P9 fire-training area consisting of 25 batches (A-Y). Batches ranged in size from 63-140t. The mass of soil was measured through a belt weigher for feed soil and calibrated load cells on a front-end loader for treated soil. The mass of soil recovered through the treatment process was ~2,232t (dry weight), which accounted for a -1% difference. The 1% difference is within reasonable the measurement variability for the two measurement methods.

Untreated soil had an average PSD distribution consisting of 6% gravel, 18% sand and 76% fines. Following treatment, the mass of intermediate fractions showed gravel was 7%, sand was 14% and fines was 80%. This represents a slight shift in the PSD of ~4% from the sand fraction to fines, which is expected given the mechanical nature of many of the plant processes.

10.2. Soil Results

In total, 76 composite samples were collected from the 11 untreated feed batches. Results showed average PFOS + PFHxS was **2.92 mg/kg** (max 15.3 mg/kg) and PFOS + PFHxS ASLP was **154 µg/L** (max 328 µg/L). Additionally, all samples reported concentrations of PFOA below 10 mg/kg (max 0.38 mg/kg) and PFOA ASLP below 7.7 µg/L.

The treatment process was effective at removing PFOS + PFHxS from soil to achieve the performance criteria for all Batches. All samples from treated intermediate stockpiles (n = 100) and treated and reformed stockpiles (n = 76) had concentrations below 1 mg/kg PFOS + PFHxS except for one sample (A-T-

4), which reported a concentration of 1.006 mg/kg. Average PFOS + PFHxS concentrations of treated soil were **0.3 mg/kg** (max 1.006 mg/kg) and PFOS + PFHxS ASLP concentrations were **12.1 µg/L** (max 31.3 µg/L).

Batch E had one of the highest feed concentrations and was retreated to assess the effectiveness of additional rounds of treatment. Batch E had average concentrations of PFOS + PFHxS and PFOS + PFHxS ASLP respectively of 6.4 mg/kg and 234 µg/L in untreated soil and 1.2 mg/kg and 23.5 µg/L in recovered treated intermediate fractions. Following a 2nd treatment pass through the plant concentrations of PFOS + PFHxS and PFOS + PFHxS ASLP respectively were 0.2 mg/kg and 1.8 µg/L (2nd treatment intermediate fractions) and 0.2 mg/kg and 6 µg/L once the material treated twice was reformed.

The results indicated a 81% removal efficiency for totals and 88% removal efficiency for ASLP after one treatment and an additional 81% RE totals and 92% RE ASLP after the 2nd treatment resulting in an overall removal efficiency of 97% totals and 99% ASLP for the two treatment passes. Ventia therefore considers that secondary treatment of material is a feasible option for achieving lower treatment targets or where feed soil is higher in concentration (i.e. where a higher removal efficiency is desired).

10.3. PFAS Precursors

Assessment of PFAS precursors via EOF and TOPA indicated that precursors were not present in untreated soil samples at measurable levels.

Assessment of the presence of PFAS precursors would be appropriate if the location of the feed soil was to change in future works at RAAF Base Edinburgh, however this could be addressed in testing soil insitu during environmental investigations of the source-area.

PFAS precursors did appear to be present in organics in measurable quantities (224-506% increase in PFAS observed after EOF and TOPA respectively). Ventia therefore recommends that organics are treated as a waste product rather than reused onsite even though many organics results were below the performance criteria of 1 mg/kg PFOS + PFHxS.

10.4. Wastes

The total volume of waste for all EDN soil treated (2,579t) was <0.7% and much lower than the pre-trial estimate of 3-5%.

There was 8.4t tonnes (0.3% wt./wt. or 3kg waste per tonne of treated soil) of organics generated from this trial. Organic material is currently stored on-site in sealed skip bins and it has been proposed to be disposed of at a licensed facility for thermal treatment.

There was no replacement of GAC or IX-Resin required during the trial however the first stages of breakthrough were observed for the activated carbon. Worst case scenario is that GAC would be produced at coincidently 0.3% wt./wt. or 3kg waste per tonne of treated soil. Given there was no breakthrough for IX-Resin the volume of waste cannot be estimated but would be significantly lower than 0.3% wt./wt.

Approximately 0.1% wt./wt. of cartridge filters were also produced during the trial however as treatment is optimised with long-term operation this volume will continue to decrease.

10.5. Comparison to Drinking Water Guidelines

To assess beneficial reuse options for treated soil, Defence requested that ASLP results be compared to Australian Drinking Water Guidelines (ADWG) (2011) for PFOS + PFHxS (0.07 ug/L). The ASLP is a single-point leaching test that assesses leaching under a specific set of environmental conditions, however these conditions are extremely conservative and do not specifically represent those at RAAF Base Edinburgh. Comparing results to these guidelines may therefore not be representative of the risk that soil poses to groundwater. Ventia understands that AECOM are currently conducting tests using the Leaching

Environmental Assessment Framework (LEAF) to assess PFAS leachability using a range of environmental conditions but results of this were not available at the time of issuing this report.

The average ASLP concentrations of untreated and treated soil were 127.9 ug/L and 12.1 ug/L respectively. As the average treated ASLP concentration exceeded ADWG (2011), additional treatment rounds would be required to meet drinking water guidelines, refer to **Table 24** and **Table 25**. These tables assume that each treatment round will result in a RE of 91% (average ASLP RE for the trial).

Table 24. Theoretical PFOS + PFHxS ASLP Results from re-treatment using P9 soil

PFOS + PFHxS Concentration	Treatment Rounds
127.9 ug/L	N/A – starting concentration
11.51 ug/L	1
1.04 ug/L	2
0.09 ug/L	3
0.008 ug/L	4

Table 25. Treatment of P9 soil required to meet Drinking Water Guidelines for PFOS + PFHxS

PFOS + PFHxS	Treatment Rounds
100 x Drinking Water Guidelines – 7 ug/L	2
10 x Drinking Water Guidelines – 0.7 ug/L	3
Drinking Water Guidelines – 0.07 ug/L	4

10.6. Equivalent PFOS + PFHxS Mass

The mass of PFOS + PFHxS removed during the trial was approximately 5.9kg as estimated using data from the primary laboratory, however **Section 9.5** describes how this value may be underestimated. Using data from Eurofins it is estimated that there may have been as much as 9.6kg of PFOS + PFHxS removed.

PFOS + PFHxS concentrations in typical 3M 6% Light Water™ foam are 5-15g/L. A 20L container of foam would therefore contain 100-300g of PFOS + PFHxS. The amount of PFOS + PFHxS removed by Ventia during the POP test is therefore equivalent to up to 96 x 20L containers of undiluted AFFF concentrate.

Based on the average PFOS + PFHxS concentration of feed soil (2.9 mg/kg), average removal efficiency (90%), current throughput (~100t/day, wet weight) and average soil moisture (13%), during future works in P9 Ventia expect to continue to remove 0.23-0.37 kg (dry weight) of PFOS + PFHxS per day, equivalent to 3 x 20L 3M 6% Light Water™ containers per day, refer to **Table 26**.

Table 26. Equivalent PFOS + PFHxS

	Untreated PFOS + PFHxS (mg/kg)	RE	Daily Throughput (wet) (t)	Daily dry PFAS Mass Removed (kg)	Daily Equivalent 3M 6% Light Water™ containers (100-300g of PFOS + PFHxS each)
Primary Lab	2.9	90%	100	0.23	0.8-2.2
Eurofins	4.7	90%	100	0.37	1.2-3.2

JBS&G estimated the mass of PFOS + PFHxS in the P9 fire-training area as shown in **Table 5** as 124kg. During treatment of the 2,579t, between ~5% and 8% of the PFOS + PFHxS mass of the fire-training area was removed.

11. CONCLUSION

During the trial, 2,579t of PFAS contaminated soil from P9 was treated using Ventia's PFAS Soil Treatment Plant in 25 x ~100t batches (A-Y). On average 90% of PFOS + PFHxS was removed and the performance criteria was achieved for all batches.

The total volume of waste for all EDN soil treated (2,579t) was <0.7% and much lower than the pre-trial estimate of 3-5%.

In total there was up to 9.6 kg (dry weight) of PFOS + PFHxS removed from P9 during the trial and this represented up to 96 x 20L containers of undiluted 3M 6% Light Water™ AFFF concentrate.

12. DISCLAIMER

Ventia provides this information on the basis that it remains confidential in accordance with clause 20.2 of the Contract (ATM ID: PFAS 17/18 095, PFAS Soil Excavation and Treatment – RAAF Base Edinburgh). The information in this report is considered 'trade secrets' of Ventia as it relates to our PFAS technology, process and results of our trial which are commercially confidential. Disclosure of this information to our competitors or the industry would result in a loss of our competitive advantage.

13. REFERENCES

- AECOM (2018) Technical Memorandum 4 (TM004-A Draft)
- AECOM (2019) Technical Memorandum 11 (TM011-A Final)
- The Heads of EPAs Australia and New Zealand (HEPA) and the Australian Government Department of the Environment and Energy (DoEE), 2018 PFAS National Environmental Management Plan
- Interstate Technology & Regulatory Council, 1997, Technical and Regulatory Guidelines for Soil Washing
- JBS&G (2019) Detailed Site Investigation Addendum Report: RAAF Base Edinburgh Environmental Investigation of PFAS (52234/117,720 (Rev 0))
- NSW EPA (2014) The Excavated Natural Material Order
- Victorian EPA (2010) Industrial Waste Resource Guidelines

14. GLOSSARY OF TERMS

The following table outlines key terms used in this document and associated procedures.

Term	Definition
CA	Contract Administrator (also known as the Project Manager Contract Administrator)
DMP	Design Management Plan
EC	Environmental Consultant
HDPE	High-Density Polyethylene
IBC	Intermediate Bulk Container
PFAS	Per- and Poly-Fluoroalkyl Substances
PFAS IMB	PFAS Investigation and Management Branch
PLC	Programmable Logic Controller
PMCA	Project Manager Contract Administrator
SiD	Safety in Design
SME	Subject matter Expert
SSA	Soil Source Area
XPEL®	Ventia's PFAS Soil Treatment Plant

ANNEX A. SITE LAYOUT MAP

ANNEX B. PLANT GENERAL ARRANGEMENT

ANNEX C. EXCAVATION MUD-MAP AND SURVEY

ANNEX D. INSITU DENSITY DATA

ANNEX E. POP TEST RESULTS

ANNEX F. LABORATORY REPORTS

ANNEX G. COMPACTION TEST RESULTS