CRCCARE
A safer, cleaner environmental future

matCARE™ technology for PFAS remediation

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Cooperative Research Centre for **Contamination Assessment and Remediation of the Environment**

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The Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) is a national centre of excellence conducting research on environmental contamination assessment and remediation. It was established in 2005 under the Australian Government's CRC Program in collaboration with major industry end users, state environment protection authorities (EPAs), the Department of Defence, leading research provider organisations, and service providers including analytical laboratories and environmental consultants.

CRC CARE's major objective is to develop innovative solutions for challenging environmental contaminants (conventional and emergent), including the management of waste containing recalcitrant contaminants. Along with technology development, CRC CARE builds capacity in the Australia remediation sector through education and training, and collaborates with state and territory jurisdictions develop guidance that complements and supports policy. Examples of CRC CARE's work in this area include: contributing to the National Environmental Protection (Assessment of Site Contamination) Measure (NEPM) by developing health screening levels for petroleum hydrocarbons (PH) and standard operating procedures for determining contaminant bioavailability; and leading the development of the National Remediation Framework, which in November 2019 was endorsed as best practice by the Heads of EPAs Australia and New Zealand.

The Department of Defence has provided funding for CRC CARE to develop an innovative technology for the remediation of AFFF-contaminated wastewater. Given the recalcitrant nature of AFFF chemical constituents – in large part due to their very strong C-F bond, which does not easily mineralise – CRC CARE developed a modified clay as an immobilisation technology for the treatment of soil, surface water and groundwater contaminated with per- and- poly-fluoralkyl substances (PFAS). matCARE™ is a patented technology that has been used in containerised mobile wastewater treatment plants to remediate wastewater contaminated with PFAS as a result of firefighting training at various Royal Australian Air Force (RAAF) sites throughout Australia, including Edinburgh (SA), Pearce (WA) and Townsville (QLD). It was also used to remediate PFAS-contaminated wastewater at Adelaide Airport. matCARE is effective in treating perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexane sulfonate (PFHxS) and another 25 PFAS substances. matCARE also sorbs a wide range of other pollutants, including PH and chlorinated hydrocarbons (CH), which are likely to be associated with PFAS.

Having developed and refined matCARE™ and the associated tailor-made containerised mobile facilities, CRC CARE is currently expanding its matCARE™ production capacity. We are also investing in resources to further increase our capability to design and build medium- and large-scale PFAS treatment plants to meet current customer demands. CRC CARE-has also produced nano-matCARE™ slurry that has been demonstrated with the treatment of PFAS-contaminated concrete slabs. This technology is now available for field application.

CRC CARE won a prestigious award from the CRC Association at its 2011 annual conference for the development of matCARE. This technology has also twice been a finalist in The Australian Innovation Challenge (2014 and 2015) and was a finalist in the 2013 Banksia Awards.

This report summarises matCARE technology utilisation.

1. Remediation of PFAS-contaminated wastewater at RAAF Edinburgh and RAAF Pearce

CRC CARE has undertaken PFAS wastewater remediation at RAAF Bases Edinburgh and Pearce, where aqueous film-forming foam (AFFF) wastewater treatment plants were commissioned on 9 February and 26 June 2011, respectively. The RAAF Edinburgh plant has successfully treated about 918,000L of AFFF-contaminated wastewater stored in a pond whereas RAAF Pearce plant has treated about 65,000L. The wastewater was contaminated during firefighting training exercises. The wastewater has been remediated to a level below the limit of report, which is 5 µg/L, with more than 99% of PFAS (99.7% of PFOS and 98.8% of PFOA) removed. A detailed report for this activity is provided in Appendix-A.

2. Remediation of PFAS-contaminated wastewater at RAAF Townsville

CRC CARE has been engaged by Airservices Australia for the remediation of PFAS-contaminated wastewater at RAAF Townsville, QLD. The contaminated wastewater was generated from rinsing and washing the AFFF foam-holding tanks of three fire trucks. The treatment target is to bring down the concentration of PFOA to below 0.56 ug/L and PFOS + PFHxS to below 0.07 ug/L, as per drinking water standards based on the PFAS National Environment Management Plan (NEMP) 2018.

All chemical analysis was carried out by NATA-accredited laboratory Australian Laboratory Services (ALS). Chemical analyses of the wastewater samples collected from Frac Tank 1 showed high levels of PFAS present in the wastewater: 1,420 ug/L of PFAS after oxidation (TOP), 27.4 ug/L of total PFAS, 2.39 ug/L of PFOA, and 0.25 ug/L of PFOS + PFHxS. A moderate concentration (2,320 ug/L) of total petroleum hydrocarbons (TPH) was also detected at before treatment.

CRC CARE deployed a mobile treatment plant to RAAF Townsville on 28 October 2019 along with professional staff including a material scientist, a technical officer and specialised contractors to carry out the wastewater treatment activities. The mobile treatment plant consists of matCARE filtering cartridges and a series of pre- and post-filter units. Treatment started on 31 October 2019 and finished on 08 November 2019. A total of 56,687L of wastewater was successfully treated, such that all 28 compounds of PFAS and TPH have been removed to below detection limits (less than 0.01 ug/L for PFAS and less than 100 ug/L for TPH).

The mobile treatment plant was decommissioned and with all waste disposed on 11 November 2019 as per the proposed work plan and schedule. All operations were carried out according to the workplan, with no incidents or injuries occurring throughout the entire process (commissioning, treatment and decommissioning). A detailed report for the activity is provided in Appendix-B.

3. Remediation of PFAS-contaminated wastewater at RAAF Darwin

CRC CARE conducted the remediation of PFAS-contaminated wastewater at RAAF Darwin. Laboratory analyses indicated that the wastewater was mainly contaminated with AFFF constituents, particularly PFOS and PFOA. Laboratory testing results showed that matCARE

successfully removed PFOS and PFOA to concentrations below detection limits. Similarly, column studies confirmed the effectiveness of the technology in achieving clean-up of PFOS, PFOA and TPH to a level below the contaminants' detection limits.

The results for the treated water samples (outlet) show that the PFAS water concentrations meet the drinking water guidelines provided by the National Health and Medical Research Council. According to these guidelines, the drinking water concentrations should not exceed 0.07 µg/L for PFOS and PFHxS combined, and 0.56 µg/L for PFOA. Following treatment with matCARE, PFOS +PFHxS and PFOA levels were 0.059 µg/L and 0.0094 µg/L, respectively – well below the guideline concentrations. A detailed report for the activity is provided in Appendix-C.

4. **Remediation of PFAS-contaminated wastewater at Adelaide Airport**

Airservices Australia engaged CRC CARE to remediate PFAS- and PH-contaminated wastewater at Adelaide Airport. Chemical analyses of samples indicated that the wastewater was mainly contaminated with PFAS constituents including PFOS and PFOA, as well as PH. Lab testing results showed that matCARE successfully removed PFAS and TPH from the wastewater to concentrations below detection limits. CRC CARE designed a mobile treatment plant based on treatability test results and completed 50,000 litres of wastewater treatment followed by an additional 40,000 litres of live firefighting training water contaminated with PFAS and . The remediation works demonstrated CRC CARE's capability in remediating wastewater contaminated by PFAS and TPH. A detailed report for the activity is provided in Appendix-D.

4. Trialling immobilisation of PFAS contamination in soil at RAAF Darwin

CRC CARE's sorption studies showed that matCARE has very high capacity to adsorb PFOS, up to 50 mg per gm of matCARE. Furthermore, following adsorption, an insignificant amount of PFOS desorbed, at a rate that decreased with time.

CRC CARE undertook treatability studies to determine the application dose for matCARE for the remediation of contaminated soils at RAAF Darwin, with 10g/100g soil found to be the optimum application dose. The study was carried out for a one-year period on the contaminated soil as well as on soils spiked with additional amounts of PFOS.

Toxicological studies demonstrate that PFOS caused a significant drop in the rate of nitrification although there was little effect on dehydrogenase activity. These rates increased in remediated samples, indicating a significant reduction in toxicity due to the immobilisation of PFOS.

CRC CARE undertook treatability studies to optimise the application rate of matCARE for effective immobilisation of water-extractable PFOS in the contaminated soils. Subsequent toxicity assessments demonstrated that PFOS was toxic to soil microorganisms even at a concentration of 200 mg/kg. Immobilisation of PFAS using matCARE significantly reduced the toxicity of PFOS to soil microorganisms. Further studies showed that PFOS has great potential to accumulate in earthworms, and hence to enter the food chain.

CRC CARE conducted pilot-scale laboratory studies to develop technology for deploying matCARE in the field, with very promising results. Subsequently, a field trial confirmed the technology's ability remediate PFOS-contaminated soils under field conditions. A detailed report for the activity is provided in Appendix-E.

5. matCARE trial for PFAS-contaminated groundwater at RAAF Richmond

matCARE remediation technology has been proven in laboratory bench-scale tests for PFAS-impacted groundwater and is now ready to scale up for field trials at a contaminated groundwater site at RAAF Richmond, NSW.

CRC CARE is scaling up matCARE from bench scale to the field using an innovative horizontal-reactor permeable reactive barrier (PRB) as shown in figure 1 below. A PRB allows contaminated groundwater to pass through a barrier that contains reactive material – in this case the matCARE adsorbent – that irreversibly binds the PFAS, allowing the treated groundwater to pass through downgradient of the plume.

The site of the trial is a former fire training area that has for over 40 years used 3M's Light Water AFFF product, which contains PFOS, PFOA and other PFAS. The PFAS-impacted plume has been characterised through a detailed site investigation to determine the lateral and vertical extent of the contamination in addition to the hydraulic properties of the aquifer. This provides critical information for the design of the horizontal reactor PRB.

The horizontal reactor configuration of the PRB comprises a 1-metre diameter x 1.7-metre long steel casing that contains a cylindrical reactor packed with the matCARE material. The horizontal reactor is shallow buried in a pit located on the airfield above the PFAS-impacted groundwater plume. The location is subject to RAAF operational requirements and is away from the main flight line to eliminate any impact to Defence capability.

CRC CARE has constructed 200 mm diameter extraction wells that intercept the high-concentration areas of the PFAS plume. Contaminated groundwater is pumped to the horizontal reactor PRB where it comes into contact with and binds irreversibly to the matCARE adsorbent material. The flow rate of the impacted groundwater through the reactor is determined by the adsorption kinetics of the matCARE adsorbent, previously determined in the laboratory column studies. This provides the optimum residence time to maximise binding efficiencies of the matCARE material, ensuring that PFAS is removed from the groundwater to below guideline levels stated in the PFAS NEMP.

The treated groundwater that exits the horizontal reactor PRB is then redirected through a series of pipes back into the aquifer via 100 mm diameter reinjection wells located upgradient of the treatment area of the plume. Figure 2 provides a plan view of the re-injection and extraction wells and horizontal reactor PRB. Groundwater modelling based on the aquifer hydraulic properties determines the optimal injection and extraction rates for treatment of the groundwater plume and hydraulic containment of the contaminated groundwater within the treatment area. This push-and-pull effect of the injection and extraction wells, respectively, increases the local hydraulic gradient within the treatment area and captures the contaminated groundwater between the injection and extraction wells. The rate of treatment can be increased through the horizontal reactor PRB subject to the optimum residence time to remove the PFAS from the contaminated groundwater.

The horizontal reactor can be reconfigured into a vertical design whereby large diameter wells of 1.2 meter diameter are installed into the contaminated aquifer and the reactor that contains the matCARE is placed into the base of the over-diameter groundwater well. This provides an in-situ treatment option and can be deployed in areas of contamination where there are no restrictions on crane heights for installation of the large-diameter groundwater wells. Such restrictions exist for operational RAAF airfields whereby large cranes can impinge on the air space of landing and departing aircraft, and for which a horizontal reactor configuration is more suitable. A horizontal configuration would also be suitable for other sites not located on airfields or for airfields with low aircraft movements.

Remediation design for the PFAs impacted groundwater using matCARE™ composite

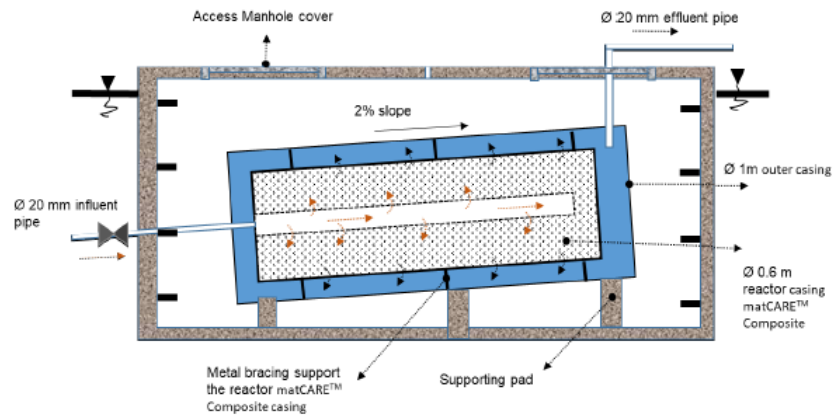

Figure 1 Cross sectional map of the subsurface matCARE™ Composite reactor

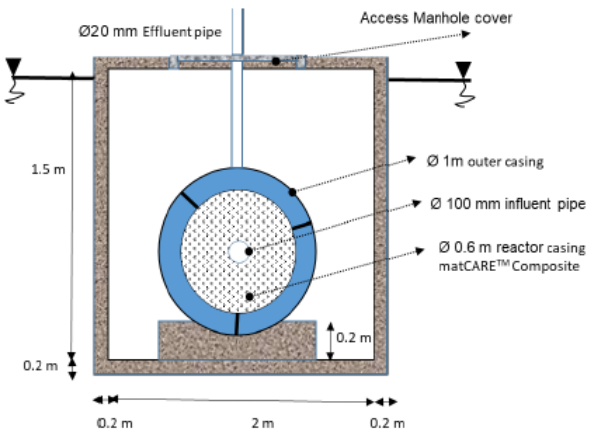

Figure 2 Cross sectional map of the subsurface matCARE™ Composite reactor

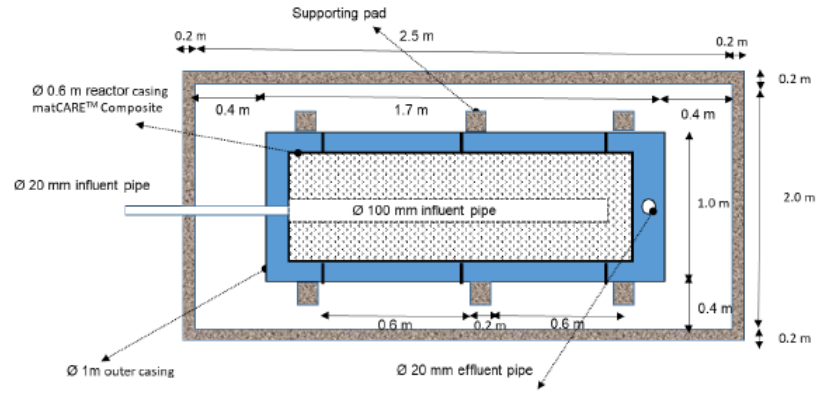

Figure 3 Cross sectional map of the subsurface matCARE™ Composite reactor

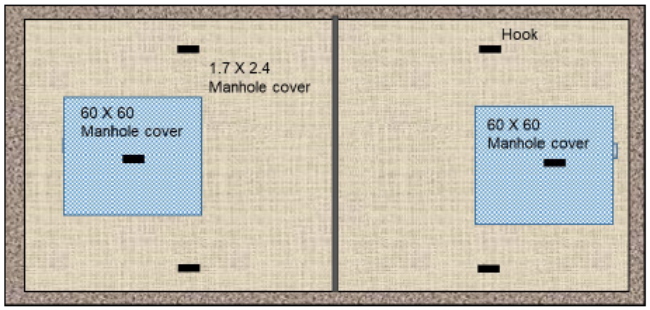

Figure 4 Top view matCARE™ Composite reactor

Figure 1: Horizontal permeable reactor design for matCARE technology trial at RAAF Richmond

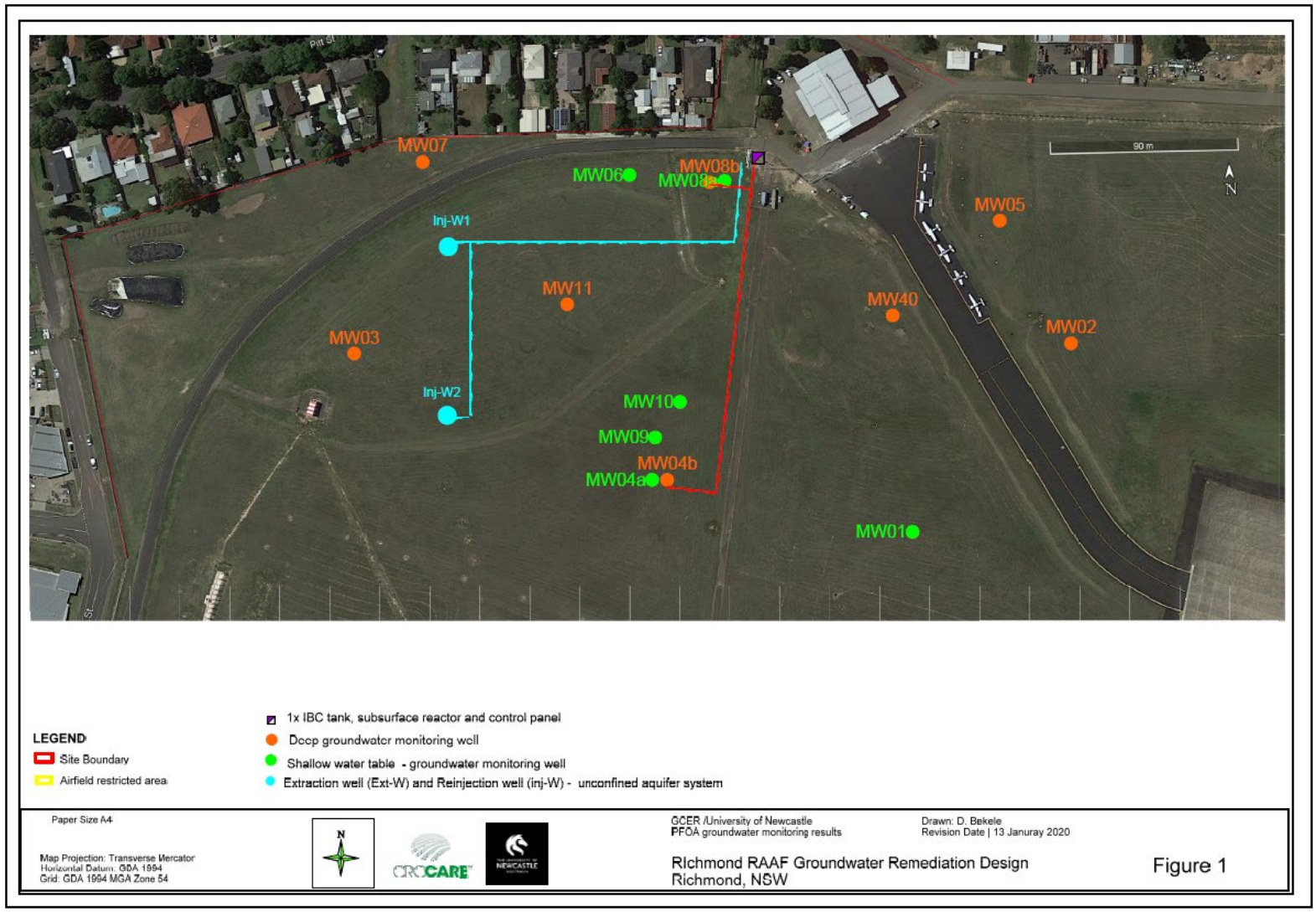

Figure 2: Extraction and injection system as part matCARE technology trial at RAAF Richmond