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Submission to Joint Standing Committee on Foreign Affairs, Defence and Trade Parliamentary Inquiry:

Management of PFAS in and around Defence Bases

Term of Reference covered:

e) the adequacy of Commonwealth and state and territory government environmental and human health standards and legislation, and any other relevant legislation;

29th June 2018.

Executive Summary

This submission refers to item e) in your terms of reference, regarding the adequacy or otherwise of existing State and Territory legislation and the more realistic and practical approach being taken in Europe and US, where a whole of incident assessment of the environmental impacts of fires in Major Hazard Facilities (MHFs) derives a different set of conclusions. This submission is intended to improve understanding of these complex issues and lead to better informed decision making. Evidence and references to scientific research papers are provided to help understand the complexities which may not have been fully considered previously. Clearly there is major community concern around contaminated sites and communities where legacy C8 fluorinated firefighting foams have been intensively used in the past, when assurances were provided that these products were safe for widespread use. It is not therefore surprising that they were used widely, especially for training. Management practices have changed dramatically in the last 18 years, which prevent such extensive use. Fluorinated foams are only recommended for front-line duty for large hazardous fires,

predominantly in Major Hazard Facilities(MHFs). Wherever possible training should be conducted using Fluorine Free Foam (F3) agents or surrogate alternatives to fluorinated foams.

Fluorochemical and firefighting foam manufacturers have voluntarily developed more environmentally benign high purity (≥98% C6) short-chain C6 agents, to meet the US EPA's stringent PFOA stewardship program (2006-2015). Adequate equivalency in terms of C6 fire performance compared to legacy long-chain C8 agents is achievable, as the industry transitions towards more environmentally benign short-chain C6 and fluorine free alternatives. Best practice now recommends non-fluorinated foams be used extensively for most active firefighter training and for applications where smaller fires are normally experienced like Emergency Fire & Rescue Services. However, despite significant improvements in Fluorine Free Foam(F3) technology over the last 20 years, leading F3 products still suffer from a lack of fuel shedding additives, which make them vulnerable to sudden and unpredictable flare-ups, flashovers and sustained re-ignition, particularly where forceful application and fuel in depth fires are concerned. Consequently unnecessary increased risks may be placed on critical life safety protection, and the ability to minimize incident spread and re-involvement if these F3 agents are expected to be used for more serious in-depth flammable liquid fires, as found in fuel terminals, oil refineries, chemical and pharmaceutical plants, civil airports aerodromes and heliports, helidecks, offshore platforms, military sites and their assets, large oil tanker ships, cruise ships and others carrying hazardous flammable liquid cargoes, the ports/jetties where they load/unload, and large mine sites with significant inventory of flammable and combustible liquid fuels, and a workforce often vulnerable to incidents in their workspaces whether underground, above ground or in large vehicles with significant fuel loads.

This submission aims to help the reader understand the complexities of these issues, the need for separation of legacy C8 long-chain PFAS chemicals as Persistent, Bioaccumulative and Toxic (PBT) from the proven more environmentally benign short-chain C6 alternative agents which are neither categorised Bioaccumulative, nor Toxic.

Selection of the most suitable agent should be dependent upon whole of incident risk-based assessments, not only of suitability for the specific application, but also to ensure that fast, effective, efficient and reliable agents are chosen to best protect life safety, while also minimising escalation risk, resulting damage, community and environmental impacts.

Currently these short-chain C6 fluorinated chemicals and firefighting foam agents are likely to be incorrectly caught up with PBT fluorinated substances as is the case in Queensland[90] and South Australia[23]. NICNAS' own recent Rules and Guidelines consultation also unwisely suggests grouping all ≥C4-≤C20 fluorinated chemicals together, which is misleading and unrepresentative. This current approach also seems to contradict its 2015 IMAP tier II Environmental Assessments of PFOS & PFOA[38,39] as PBT and short-chain PFCAs as P, not B, not T[40], and its 2016 IMAP Tier II Human Health Assessment's Occupational and Public Risk Characterisations[41] concluded: ***"Therefore, the chemicals are not considered to pose an unreasonable risk to workers' health."*** and … "***the public risk from direct use of these chemicals is not considered to be unreasonable***."

Further extensive evidence and scientific research confirms that short-chain ≤C6 fluorochemicals (and substances containing them like firefighting foam agents), are categorised as not Bioaccumulative and not Toxic[66-78]. This justifies their separation from PBT long-chain ≥C8 fluorochemicals in both human health and environmental hazard bands, as NICNAS' own IMAP Tier II Environmental and Human Health Assessments, confirm[40,41].

Recent US Washington State legislation[48,49] has exempted PFAS firefighting foams for use in Major Hazard Facilities (MHF) - specifically: oil refineries, fuel terminals, airports, military applications and chemical plants, from legislated PFAS based firefighting restrictions. This is based on testimonies from leading fluorine free foam (F3) manufacturers that these agents are unsuitable for fuel in depth fires because they have no fuel shedding capability and can themselves burn, when applied to large volumes of volatile fuels. Extensive evidence confirms this position. MHFs have a duty of care, not only to protect the environment, but also to protect their facility and the community from fire. Selecting a foam which is seen to fulfil duty of care to the environment but fails to provide effective fire protection will place life safety, the MHF and the surrounding community at risk.

These testimonies clearly reinforced that poor fire-fighting performance increases adverse environmental impacts and places life safety at unnecessarily increased risk from slow knockdown, poor flashback resistance, unreliable post fire securement, increased risk of escalation etc. Longer extinguishment times also increase risk of escalation, creates more toxic combustion products, while also increasing risk to life, property and business continuity. Use of larger quantities of foam and water generally creates more toxic/contaminated effluent, and increases risk that loss of containment will occur. Fire-fighting performance therefore CANNOT be ignored or isolated when making selection decisions aimed at minimizing environmental Impacts, as they are an integral part of achieving the best outcomes for minimizing adverse impacts from fires, particularly in MHFs.

This contrasts directly with South Australia[23] which has implemented a total PFAS firefighting foam ban, perhaps without full and thorough consideration of the implications of a major fire in a large volatile fuel storage installation, or military facility for example?

We should not ignore the significant PFAS contamination that is also occurring daily from Waste Water Treatment plants (WWTP)[5], landfall leachate[6] and dust in our own homes[7], from the 95% of PFAS chemical usage outside firefighting foams[8], in stain repellent treatments for upholstery, carpets, clothing, glossy magazines, cleaning agents, cosmetics, food packaging etc.

etc. to which we are all exposed daily. This is being released in substantial quantities every day of every year via WWTP effluents and landfill leachate into our environment.

In addition, the Australian Government Department of Health's independent health expert panel for PFAS[42] has recently published its comprehensive review of over 220 scientific research papers and reports, determining that ***"The panel advised the evidence does not support any specific screening or health interventions for highly-exposed groups — except for research purposes. It also concluded there was insufficient evidence of causation between PFAS exposure and any adverse health outcomes."*** This Report's[31] concluding advice to the Minister confirmed "***There is no current evidence that supports a large impact on an individual's health." …***and ***"In particular, there is no current evidence that suggests an increase in overall cancer risk."*** Other research similarly confirms that volatile breakdown products from fires seem to be causing increased cancer risk to firefighters, probably from known carcinogens like Polycyclic Aromatic Hydrocarbons (PAHs), eg. Benzo[a] pyrene.

This more balanced, realistic and common sense "whole of incident" approach by Washington State coupled with Australia's Expert health panel confirming no current evidence supporting significant impacts on human health or suggesting an increase in overall cancer risk, seems to be accepting short-chain ≤C6 PFAS based firefighting foams as the key way forward across Australia in future. It will not only maintain both expected fire performance levels and life safety protections, which we currently take for granted, and continues to be an expectation by our communities, … But also minimises the adverse environmental impacts of fires, when the whole of incident impacts are fully considered and taken into account.

It is therefore strongly recommended that PFAS chemicals should therefore be divided into two main fluorinated groups in Australia:

- **RESTRICTED from ALL future uses:** Legacy PFAS chemicals, containing a long-chain sequence of ≥7 but ≤20 fully fluorinated carbon atoms (as they are emerging contaminants of concern and responsible for significant localised contamination), and

- **PERMITTED for all future MAJOR HAZARD FACILITIES usage (including the broader categories discussed above**): C6 PFAS chemicals that predominantly contain short- chain fully fluorinated carbon atom sequence of ≤6, (plus everything else that meets the fluorotelomer chemical definition outside the restricted category above), without causing significant human health or environmental concerns e.g. also chemicals ≥21 fully fluorinated carbon atoms**.**

This would resolve the current confusion and misleading situation many foam users face, substantially increase life safety and reduce risks of fire incident escalation, particularly if this

were applied to the broader MHF category, allowing continued use of ≤C6 agents into the future.
This approach also provides the necessary further qualification and separation of environmentally more benign C6 PFAS (short-chain ≤C6) from PBT legacy PFAS (long-chain ≥C8). It also avoids such a large and unweildy PFAS group being misleadingly and unjustly formed, when there are clearly unequal hazards to both human health and the environment (as demonstrated) by legacy C8 PFAS and C6 short-chain PFAS chemicals and their resulting firefighting foam agents. We cannot continue to misleadingly treat these dissimilar chemicals in the same PBT category. Changing the current boundaries as recommended above, conveniently resolves this unacceptable, unnecessary and unjust confusion/dilemma to the benefit of regulators, foam users and the public safety of our wider communities.

Adopting such changes would restrict legacy long-chain ≥C8 PFAS agents, preventing use of POP listed PFAS chemicals (desirable by most foam users and regulators), while allowing significantly more environmentally benign ≤C6 PFAS agents to continue fast effective protection of life safety, minimising escalation and damage, particularly in all Major Hazard Facilities (where it has been shown F3 agents are unsuitable and potentially dangerous), while also reducing adverse community and environmental impacts from such whole of incident fires into the future.

1. Contents

2. Focus

Thank you for the opportunity to make a submission to this Parliamentary Inquiry.

I am unable to contribute to most of the Terms of Reference, as I am not involved in the vicinity of these Defence bases, but I do have specific firefighting foam expertise, which may contribute valuable information to your Inquiry in the broader perspective of these PFAS agents and why they have been used, and are necessary to address these major hazards. I also draw your attention to relevant international legislation relating to PFAS firefighting foam agents, which are important to consider.

My focus is therefore on your terms of reference point ***e***) ***the adequacy of Commonwealth and state and territory government environmental and human health standards and legislation, and any other relevant legislation.***

3. Background

Australia is not unique in having PFAS contamination issues around Defence and Aviation sites, similar problems are occurring in USA[1] and Europe[2]. These are legitimate public concerns[3,4], but we should not ignore the significant PFAS contamination that is also occurring daily from Waste Water Treatment plants (WWTP)[5], landfall leachate[6] and dust in our own homes[7], from the 95% of PFAS chemical usage outside firefighting foams[8], in stain repellent treatments for upholstery, carpets, clothing, paper sizing like glossy magazines, cleaning agents, cosmetics, food packaging etc. etc. to which we are all exposed daily. This is being released in substantial quantities every day of every year via WWTP effluents[5] and landfill leachate[6] into our environment.

The reason these sites have been using PFAS based foams goes back to the 1967 USS Forrestal disaster[9], which resulted in 134 lives lost, 62 injured and 21 aircraft destroyed.

This incident employed the use of first generation Fluorine Free Foams (F3), a protein based agent. As a result of this failure to adequately control these fires, research was focused on the development of Aqueous Film Forming Foams (AFFF) using fuel shedding and film forming PFAS ingredients to quickly and effectively control and extinguish such future fires, to prevent a similar tragedy occurring. This subsequently led to the development of AFFFs and the US Mil-F Specification[10] fire test for acceptance of firefighting foams by the US Military. Widely regarded as the world's toughest foam specification, modern US Mil Spec AFFFs are exclusively used by civil aviation and all military sites throughout the USA. Recently the US Airforce has spent over US$6m transitioning to the more environmentally benign short-chain C6 AFFF agents[11]. This fire test standard and agents meeting its tough requirements, has also been adopted by many other Military organisations around the world. Similarly tough Military fire protection standards are used in Australia, with Def [Aust] 5706:2009 [12]to which C6 AFFF agents would comply.

The first AFFF agents meeting this tough MilF Spec standard were produced by 3M in USA[13], widely exported overseas, including Australia, where there was subsequently a manufacturing plant in NSW, now owned and operated by Solberg[14].

These 3M agents were produced using the ElectroChemical Fluorination (ECF) process which led to persistent breakdown products including PFOS, PFOA and PFHxS[15]. Defence facilities were seemingly being told they were quite safe by 3M, so used them liberally particularly in training over many years, usually at specific training facilities, which has led to the quite severe contamination -the subject of this inquiry. Some Fire brigades also used them extensively for training (eg. CFA Fiskville[16]), which has also led to site contamination. 3M announced it was ceasing manufacture of these ECF chemicals in 2000[17], following US EPA pressure due to expected adverse environmental and human health impacts. Their manufacturing cessation was completed in USA and most other places by late 2002[15], but Australia was delayed until late 2003[18].

These ECF long-chain PFAS chemicals are substances of very high concern, as they are confirmed Persistent, Bioaccumulative and Toxic (PBT)chemicals[19]. PFOS was listed as a Persistent Organic Pollutant (POP) under the UN's Stockholm Convention in 2009[20], while PFOA and PFHxS are also currently under review for future POP listing, possibly by 2020.

173 of the 187 signatory countries to the Stockholm Convention have ratified a ban on the use of substances[21] which either contain or could breakdown to PFOS. Australia, along with USA, Russia, Malaysia, India, Italy and Israel have still not ratified this 2009 amendment to the Convention, although Australia's Department of Environment and Energy (DoEE) released a Regulatory Impact Statement (RIS)[22] for public comment in Nov. 2017 recommending a national PFOS phase out in Australia, which is widely supported by the fire industry.

4. All PFAS are not like PFOS

it is important to realise that there are potentially thousands of PFAS chemicals, some of high concern and others far less so. They are not all like PFOS with harmful side-effects. They are generally being split into two groups Long-chain and short-chain referring to the harmful and more environmentally benign groups. Some regulators insist on lumping all PFAS together in a single undesirable or "banned" category (eg. South Australia [23]), possibly for convenience, but this misleadingly ignores the important and unique role these PFAS chemicals can play in preventing major fires from escalating out of control, and thereby minimizing the adverse environmental impacts of the whole incident, as evidenced by these 3 incidents where fluorinated foams were used[24-26].

The PFAS chemicals of high concern are generally the so called "long-chain" PFAS of ≥8 carbon atoms in the molecule's chain, often referred to as ≥C8s. Some of these are derived only from the ECF process like PFOS and PFHxS.

As well as being derived from the ECF or Simon Cell (3M) process, PFOA can also breakdown in small quantities from precursors used in long-chain ≥C8 fluorotelomer surfactants produced from the competing telomerisation process[27] by DuPont, Chemours, Arkema, Asahi Glass, Daikin, Solvey etc., but without PFOS or PFHxS as breakdown products. This telomerisation process also used a range of chain-length PFAS chemicals. The leading firefighting foam manufacturers (apart from 3M) typically included around 50% C6 agents in their AFFF formulations before 1982, and typically 95-97% C6 in their AFFF agents after 1982[28]. C6 agents have therefore been used and well proven for over 2 decades with it's main breakdown product being the C6 PFHxA (PerFluoroHexanoic Acid), with very little content able to break down to PFOA (which is a more significant breakdown product of ECF process fluorosurfactants and Teflon coatings).

5. UN Stockholm Convention

This major Internationally treaty was first signed in 2001 under the United Nations Environment Program, and is now ratified by 187 countries. It prevents the use and harm from a list of 12 dangerous chemicals (including highly toxic pesticides) categorised as Persistent Organic Pollutants (POPs)[29]. 2009 saw PFOS added to this POP list[30].

173 of those 187 Countries have also ratified the 2009 amendment[31] adding 9 other chemicals including **PFOS** to the UN's Persistent Organic Pollutants (POP) list (NZ ratified in 2016).
The few major developed countries which have not yet ratified PFOS include: USA, Russia, **Australia**, Italy, Malaysia, India and Israel.

2017 saw the UN Review Committee adopted a recommendation to list **PFOA** as a POP under UN Stockholm Convention, based upon its PBT substance designation[32]. It is likely PFOA will be fully accepted/listed as a POP by 2019. BUT ...there are some important specific exemptions under EU REACH Legislation for ≤C6 PFAS (see 6 below).

PFHxS has also been accepted as meeting the POP criteria at the UN Convention's Oct. 2017 review meeting[33]. It is therefore likely to be assessed during 2018/19 with potential addition to the POP list in future – possibly by 2020.
PFOS, PFOA and PFHxS are all breakdown products from the ECF process and contained in 3M Lightwater™ branded AFFF and AR-AFFF products (*PFOS & PFHxS are only derived from these products*).

6. EU Legislation allows C6 PFAS usage

Despite recommendations to the contrary and UN's current assessment of PFOA for POP listing under the Stockholm Convention, ECHA (European Chemicals Agency) and its Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulations, increased the proposed PFOA impurities level for short-chain C6 fluorochemicals, in recognition of it's acceptance of their acceptability for continued use.

The low 2ppb PFOA impurity level proposed by Germany, was increased in this EU legislation 2017/1000[34], issued in June 2017, to:

- *25ppb of PFOA, its salts and*
- *1,000ppb for one or a combination of PFOA related substances, including precursors.*

ECHA also confirmed firefighting foams already in use were exempted from this impurity restriction, so effectively C8 fluorotelomer surfactant based foams purchased before July 2020, could still be used across Europe until their expiry date. This legislation becomes effective from July 2020, with a 3 year transition period.

This is important legislation because it fully accepts the presence of small unavoidable PFOA impurities and unintended contaminants in high purity ≤C6 fluorosurfactants currently being manufactured - and the products in which they are incorporated – now, and into the future.

It therefore includes ≤C6 fluorosurfactants being used in C6 firefighting foams across the European Union including UK, Norway, Iceland and Liechtenstein.

7. US EPA PFOA Stewardship program

The US EPA in its voluntary PFOA stewardship program from 2006[35], recognised this need for change. It encouraged a transition to more benign alternatives using short-chain C6 fluorotelomer surfactant based products, which behave very differently from long-chain legacy products.

This Stewardship program was voluntarily adopted by all leading fluorochemical manufacturers in 2006, with 2 key milestones:

- *by year-end 2010: removal 95% PFOA, higher homologues and precursors from products, facilities & waste streams, which were **achieved**[36].*
- *by year-end 2015: work towards elimination of PFOA, its higher homologues and precursors from those facilities, products & waste streams, which were **also achieved**[37].*

The US EPA's 2016 report[37] confirmed these stewardship goals for virtual elimination of PFOA were achieved by end 2015, encouraging transition to short-chain C6 fluorinated alternatives. These high purity C6 products contain generally ≥98% short-chain ≤C6 PFAS in the fluorosurfactants used in the resulting C6 firefighting foams.

8. NICNAS recognises major difference

NICNAS, the chemicals regulator in Australia, has confirmed through its 2015 IMAP (Inventory Multi-tiered Assessment and Prioritisation) Environmental Tier II assessments that legacy long-chain ≥C8s like PFOS[38] & PFOA[39] are categorised PBT. The assessment confirms "***It is not currently possible to derive a safe environmental exposure level for such chemicals and it is therefore not appropriate to characterise the environmental risks for these chemicals in terms of a risk quotient***."

Its 2015 IMAP Environmental Tier II assessment of short-chain PerFluoroCarboxylic Acids (PFCAs) and direct precursors (including PFHxA)[40] confirms in its Hazard characterisation summary that ***"Hexanoic acid, undecafluoro-; hexanoic acid, undecafluoro-, ammonium salt; pentanoic acid, nonafluoro-;***

pentanoic acid, nonafluoro-, ammonium salt; butanoic acid, heptafluoro-; and butanoic acid, heptafluoro-, anhydride are categorised as:

- ***P***
- ***Not B***
- ***Not T*** "

Further findings confirmed that ***"The chemicals in this group are not PBT substances according to domestic environmental hazard criteria."*** and ***"The chemicals in this group are not prioritised for further assessment under the IMAP Framework."***

In addition, its 2016 Tier II C6 Human Health Assessment's Occupational and Public Risk Characterisations[41] concluded: ***"Therefore, the chemicals are not considered to pose an unreasonable risk to workers' health."*** and … "***the public risk from direct use of these chemicals is not considered to be unreasonable***.***"***
This stark contrast seems to misleadingly become blurred in their recent Draft Industrial Chemicals - Rules and Guidelines. It is hoped and expected that this will become rectified following their recent public consultation, where a separation between PBT Legacy Long-chain ≥C8 PFAS chemicals and the more environmentally benign P, NOT B, NOT T short-chain ≤C6 agents is necessary to acknowledge these substantial differences, and prevent them being categorised as equally hazardous to either human health or the environment.

9. Australia's Department of Health confirms PFAS not harmful to human health.

It appears some regulators may have been over-cautious and over-reacting to a perceived threat from PFAS chemicals? …but now there is less need for so much concern.

Australia's Medical experts have reviewed all the human health data available regarding PFAS studies. Australia's extensive and detailed Department of Health Expert PFAS Panel Report[42] to the Minister concluded very recently (early May 2018) that "***There is no current evidence that supports a large impact on an individual's health." …***and ***"In particular, there is no current evidence that suggests an increase in overall cancer risk."*** This seemingly includes legacy long-chain PFAS (PFOS, PFHxS and PFOA), as well as significantly less benign short-chain ≤C6 PFAS chemicals degrading to PFHxA and PFBA.

The fire industry supports DoEE's PFOS RIS recommendation 4, to ban PFOS use across Australia as soon as possible. It also recommends a transition away from other telomer based long-chain ≥ C8 foam concentrates to environmentally more benign high purity ≤C6 short-chain telomer foam agents which are proven highly effective, efficient, reliable, while also retaining the critical high levels of life safety expected for casualties, firefighters, other responders, plus affected communities[43]. Such C6 agents are proven to be fast, minimising toxic smoke production, minimising fire spread and resulting damage, minimising agent usage, minimising noxious firewater run-off and inherent risk of containment overflows, while also minimising harmful environmental effects of the whole fire incident.

There were two particularly important finding areas in the Report's Exec Summary[42]:
a) "***Differences between those with the highest and lowest exposures are generally small, with the highest groups generally still being within the normal ranges for the whole population****. There is mostly limited or no evidence for an association with human disease accompanying these observed differences."* *"**There is no current evidence that supports a large impact on an individual's health. In particular, there is no current evidence that suggests an increase in overall cancer risk.*** *The main concerning signal for life-threatening human disease is an association with an increased risk of two uncommon cancers (testicular and kidney). These associations in one cohort were possibly due to chance and have yet to be confirmed in other studies."*

b) "*The published evidence is mostly based on studies in just seven cohorts (see Kirk et al. 2018, page 15-16[44]).* ***These cohorts have generated hundreds of publications but there is a high risk that bias or confounding is affecting most of the results reported****. There are very large numbers of comparisons being done in many studies, such that the risk of random variation in exposures and outcomes being interpreted as real associations is greatly increased. This is compounded by the fact that there are multiple PFAS, and other environmental or occupational hazards, so that there may be interacting toxic effects, and it is hard to isolate the association with one or two analysed compounds.* ***Many of the biochemical and disease associations may be explainable by confounding or reverse causation (see Section 6.15). Many studies had limited power to detect important associations."***

"Our advice to the Minister in regards to public health is that the evidence does not support any specific biochemical or disease screening, or health interventions, for highly exposed groups *(except for research purposes)."*
This seems to be a radical departure from previous rather cautious advice from health professionals globally, and seems fairly categoric that PFAS are NOT a human health problem!

This Expert Panel report[42] includes the health effects of PFAS exposure on cancers; liver and kidney function; thyroid effects; neonatal, infant and maternal outcomes from exposure during pregnancy; reproductive outcomes; immunological effects; Neurodevelopmental ad neurophysiological effects; diabetes, glycaemic control and metabolic syndromes; obesity, BMI and overweight issues; cardiovascular effects; respiratory & skeletal effects. Reverse causality and confounding may be able to explain previous findings, particularly in regard to suspected disease links. Limitations and issues about the human evidence base highlighted in key international reports and systemic reviews were also assessed, finding it still concluded that ***"The panel advised the evidence does not support any specific screening or health interventions for highly-exposed groups — except for research purposes. It also concluded there was insufficient evidence of causation between PFAS exposure and any adverse health outcomes."***

The Australian Government is still committed to supporting communities and responding effectively to PFAS contamination. This commitment has included reducing exposure from contaminated drinking water, providing mental health and counselling services, funding an epidemiological study into potential health effects and providing access to free blood tests for PFAS on a voluntary basis to help those communities fearful of exaggerated claims, media hype and speculation. "*After considering all the evidence, the Panel's advice to the Minister on this public health issue is that the evidence* **does not** support *any specific health or disease screening or other health interventions for highly exposed groups* *in Australia, except for research purposes.* ***Decisions and advice by public health officials about regulating or avoiding specific PFAS chemicals should be mainly based on scientific evidence about the persistence and build-up of these chemicals****."* These important findings must be adequately taken into account when considering any restriction of these chemicals which must be proportionate to the risk, which on this evidence is significantly less than previously envisaged.

10. Breakdown products of fire cause increased cancer risk

Substantial scientific evidence from the Monash University 2015 Australian firefighter Study[45], Kirk & Logan's Queensland firefighter study [46]and Stec et al's 2018[47] occupational exposure study of UK firefighters that all confirm it is the volatile breakdown products of the fire, including known carcinogenic PAH's (Polycyclic Aromatic Hydrocarbons), like Benzo (a) pyrene, 3-MCA, and 7,12-dimethylbenz[a]anthracene, to which firefighters are being exposed, which is causing increased cancer risk in firefighters as an occupationally exposed group, at higher levels than the average population.

The Monash study[45] showed 79% of the fires attended by career, paid part-time, and volunteer firefighters were in buildings, vehicles or bushfires, where water alone is normally used and Class B fluorinated foams would not be required. On the rare occasions foam may be used for specific large bushfires, it would only be a Class A fluorine free type, without PFAS chemicals.

11. Queensland's Environmental Management of Firefighting Foams Policy - 2016

This Queensland Policy[92,93] fully embraced F3 agents, encouraging their use as far as possible, thereby largely avoiding any perceived problems associated with using fluorochemicals, despite legacy issues at Airservices Australia operated civil airports where despite the last 8 years of F3 usage, PFOS is still leaching from saturated concrete fire training pads, even when it rains[94]!

This policy focused heavily on the firefighting foam agent impacts to the environment once the fire was out, in isolation from the adverse impacts from the rest of the incident. Such an approach is misleading and delivers different answers to those derived when the whole of incident environmental impacts are considered. It also misleadingly assumes F3 agents would provide equivalency to fluorinated foam performance on large fires where flammable fuel in-depth fires are likely at Major Hazard Facilities (MHFs), while largely excluding many other important fire incident considerations. ***Does this give us the right answers?*** Some say it is blinkered, and over-precautionary, not based on objective risk assessments, that it is too simplistic a response to a far more complicated problem, and probably doesn't provide the best answers, for many high risk situations[95,96]. MHFs have a duty of care, not only to protect the environment, but also to protect their facility and the community from fire. Selecting a foam which is seen to fulfil duty of care to the environment but fails to provide effective fire protection will place life safety, the MHF and the surrounding community at risk.

ALL fluorinated foams - not just PFOS, are required to be disposed of by incineration.

Any persistent foams/chemicals/contaminated runoff is defined as regulated waste, for incineration, so irrespective whether fluorinated or F3 agent is used, the resulting run-off from any fire should be collected and incinerated, allowing only F3 from training use to go to Waste Water Treatment Plants. Although runoff from training (LPG fuelled rigs excepted perhaps) is also likely to contain noxious breakdown products like Polycyclic Aromatic Hydrocarbons [PAHs] and Volatile Organic Compounds [VOCs], some of which are known carcinogens and harmful to our environment.

Contaminated water values are so low that irrespective of whether C6, F3 or water alone is used in most incidents, there is likely to be residual PFAS contamination from the 95% of other fluorochemical sources that could be involved in the fire, particularly from structural and vehicle fires, where stain repellent carpets, fabrics and consumer products like cosmetics, glossy magazines and food packaging are also likely to be involved!

Most firewater runoff in Queensland is now likely to be regulated waste for incineration – whether Fluorine Free, short-chain C6 or long-chain C8 foam is used – even where NO foam is used, and is not allowed to go to Waste Water Treatment Plants for disposal, as it is everywhere else in the world (except the 173 countries where PFOS is prohibited[21])!

A focus on the foam's environmental impacts alone is misleading… without the whole incident's environmental impacts being adequately considered, which produces different answers! One has to question whether this policy is actually delivering the lowest environmental impacts for Queenslanders and what adverse implications it has on unnecessarily increased life safety risks for MHF workers, their contractors and surrounding communities?

12. South Australia's Environment Protection (Water Quality) Amendment Policy 2018

April 2017 saw EPA South Australia propose a PFOS & PFOA ban in firefighting foams. This was welcomed by the fire industry, but May 2017 saw public justification presentations, followed by a public consultation process, which closed in June 2017.

Their Draft Amendment was issued in November 2017, unexpectedly proposing to ban ALL PFAS both long and short-chain based foam concentrates …despite 7 of the 11 submissions provided agreeing to ban long-chain ≥C8 foams as originally proposed, but NOT short-chain ≤C6. Only 4 local submissions (36%) actually supported a FULL PFAS foam ban. Further clarification and justification was sought, seemingly falling on "deaf ears" it seems, as the Ban was announced 30th January 2018 on **ALL PFAS** firefighting foams across South Australia!

There are major concerns by the Fire Industry and fom user that the critical life safety and minimised escalation poential of these incidents may not have been adequately taken into account, with life safety being unnecessarily exposed to increased risk where forceful application and fuel in-depth fires are likely ot occur.

13. US Washington State PFAS legislation – 2018: Testimonies convinced legislators to exempt MHFs from PFAS firefighting foam restrictions

PFAS-containing foams including aqueous film-forming foams (AFFF) and alcohol-resistant aqueous film-forming foams (AR-AFFF) are widely recognised and proven to be the most effective firefighting foam agents currently available to protect life safety and valuable assets against major flammable liquid fires. Recognition of this is now included in US Washington State legislation[49,50] restricting the use of PFAS based Firefighting Foams, except for Major Hazard Facilities (MHFs), following testimony to the House Environment Committee[50] where these issues were discussed at length during compelling testimonies from research and testing staff at two leading F3 manufacturers.

Sworn testimony by these two F3 manufacturers to the US Washington State House Environment Committee confirmed that "*I have a very grave concern that this total ban would take away the ability to extinguish large catastrophic fires such as process area fires in refineries or fuel storage tanks, large atmospheric fuel storage tanks and the reason is that quite honestly, the fluorine free foams lose a lot of their effectiveness when you get into Fuel-In-Depth type fires*" and *"…the fluorine free foams are very effective on spill fires but once you get to a situation where the foam actually has to plunge below the surface because of the application techniques, the fluorine free foams actually pick up some of that fuel and by the time the foam comes to the surface after plunging below it, it actually burns".*

These testimonies clearly re-inforce that poor fire-fighting performance increases adverse environmental impacts and places life safety at unnecessarily increased risk from slow knockdown, poor flashback resistance, unreliable post fire securement, increased risk of escalation etc. Longer extinguishment times also increase risk of escalation, creates more toxic combustion products, while also increasing risk to life, property and business continuity.
Use of larger quantities of foam and water generally creates more toxic/contaminated effluent, increases risk that loss of containment will occur. Fire-fighting performance therefore CANNOT be ignored or isolated when making selection decisions aimed at minimizing environmental Impacts, as they are an integral part of achieving the best outcomes for minimizing adverse impacts from fires, particularly in MHFs.

13.1 This Washington State Senate Bill 6413 legislation[48,49] confirms:
Training: PFAS-containing foams (AFFF and AR-AFFF) may not be discharged or otherwise used in Washington State for training purposes from 1st July 2018.

Emergency Use for Specified Sectors: The legislation does not restrict the use of PFAS-containing foams (AFFF and AR-AFFF) on fires involving specific Major Hazard Facility uses.
Manufacturers may only sell or distribute PFAS-containing foams (AFFF and AR-AFFF) for use in Washington State for the following specific uses, from 1st July 2020:

- **Airport and Military Applications** where the use of a PFAS-containing firefighting foam is required by Federal law, including but not limited to the requirements of 14 C.F.R. 139.317 (such as military and FAA-regulated civil airports).

- **Petroleum Terminals** (as defined in RCW 82.23A.010 *"**Terminal**" means a fuel storage and distribution facility that has been assigned a terminal control number by the internal revenue service. "**Petroleum product**" means plant condensate, lubricating oil, gasoline, aviation fuel, kerosene, diesel, motor oil, benzol, fuel oil, residual oil, and every other product derived from the refining of crude oil, but the term does not include crude oil or liquefied gases. "**Rack**" means a mechanism for delivering petroleum products from a refinery or terminal into a truck, trailer, railcar, or other means of non-bulk transfer. "**Non-bulk transfer**" means a transfer that does not meet the definition: bulk transfer of fuel by pipeline or vessel.)*
- **Oil refineries**
- **Chemical plants** (as defined in WAC 296-24-33001 - *A large integrated plant or that portion of such a plant other than a refinery or distillery where flammable liquids are produced by chemical reactions or used in chemical reactions*.)

Municipal Fire Departments and all other non-specified applications in Washington State are required to use firefighting foam agents that do not contain PFAS chemicals.

Manufacturers of PFAS-containing foams must notify sellers of their products in Washington State of these restrictions in writing before July 1, 2019. The final Bill as passed can be viewed at: http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bills/Senate%20Passed%20Legislature/6413-S.PL.pdf

13.2 Summary PFAS Foam Justifications (extracted from testimony video)[50]

A summary of the justifications accepted by Washington State Legislature in revising their proposed restrictions are identified below (paraphrased from video).

- Grave concerns expressed about continued ability to extinguish major fires in process areas, oil storage tanks and aircraft crashes if a complete ban went ahead, while dikes, bunding and modern management practices prioritise collection and containment of firewater runoff, treatment and safe disposal, preventing its discharge into the environment.
- While effective in most smaller spill fires, F3 loses its effectiveness for fuel in depth type fires. Where F3 is plunged below the fuel surface, it picks up fuel, rises to the surface and burns.
- Such problems are exacerbated in crude oil tanks where fatal boil-overs could result from slow or ineffective actions.
- Gulf refinery, Pennsylvania fire – no self-healing, no film formation and 8 firefighters died when disrupting the foam blanket which did not heal as they had expected, and usually happens with fluorinated alternatives to protect firefighters.
- Spraying Jet fuel was pooling into a dike fire, which led to tanks 4 then 5 then 10 also igniting. Once set up, it took specialty AFFFs 20 mins to put the fire out. This allowed firefighters safely into pooling fuel areas, disrupting it to use dry chemical to extinguish spraying fire and halt incident, without injury. Implication: without it, escalation and potential fatalities were probably inevitable.
- Double or triple application rates of F3 in such situations, was confirmed as usually unable to effectively control such major incidents.
- Removing such a vital tool is not safe, particularly when protecting people potentially trapped and facing death, without the critical benefits PFAS based foams can provide.

- Look at best practices, use non-fluorinated foams where we can, but retain short-chain chemistry critical for serious aircraft crash and major industrial fires to save lives and minimize damage.

13.3 Military Sites and their Assets

This specific area is particularly relevant to this Inquiry. Reliable, rapid and effective knockdown fires at all Military sites and assets (including Naval, Airforce & Army assets eg. submarines, aircraft carriers, aircraft, tanks etc.) is critical to minimising loss of life and disruption from any fire incident. Fluorinated foams are proven to be essential in such situations to protect life safety, prevent escalation, maintain continued functionality and minimise any risk of munitions also becoming involved as evidenced by their ability to pass the toughest fire test standards eg. MilF Spec[10,12,13,53]. Fluorinated agents can also minimise the dangers of additional exposure to potential chemical, radiation or nuclear (CBRN) hazards either on site, or in nearby assets, which may arise if swift fire control and extinction is not achieved. Furthermore, a major fire dealt with slowly or ineffectively by alternative non-fluorinated (F3) agents could severely jeopardise a critical mission, kill critical personnel, and/or substantially weaken our national security. Non-fluorinated agents were unsuccessfully used in the USS Forrestal aircraft carrier tragedy in 1967[9] where the fire escalated out of control with the loss of 134 lives, 62 injured and 21 aircraft destroyed. A surge of renewed vigor was injected into the development of AFFFs to ensure such a tragedy did not happen again.

Despite technological improvements in Fluorine free technology since 2000, they still fundamentally lack any fuel shedding additives[51,52,53], so are vulnerable to sudden unpredictable flare-ups and flashovers leading to sustained ignition of the foam blanket, and are unproven for such extreme situations. No known F3 agent currently meets rigorous Military firefighting foam test standards like Def Aust 5706:2009[12], UK Def 42-40 iss 2: 2002[54], nor US MilF Spec 24385F (SH):1994[10], which explains why they are currently unacceptable to any advanced Military services worldwide.

Research clearly shows[55-57] that typically 2-3 times more F3 agent and water resources are required for a given sized fire, compared to C6 AFFF, with considerably slower and less reliable results. This is particularly relevant to Military vessels which could also cause increased risk of instability or potentially sink unexpectedly during a fire incident, since significantly larger volumes of runoff could unavoidably be contained inside the ship's hull, unnecessarily placing lives at increased risk of loss and/or danger.

C6 agents have also been verified to deliver equivalent performance to C8 firefighting foam agents. Leading firefighting agents are currently available that contain high purity ≥98% C6 and ≤2% C4 fluorotelomer based chemicals[64,89]. Some of these C6 agents when they breakdown produce no more than 15ppt of PFOA or 0.0000000015%, from use strength foam solution yet provide equivalent firefighting performance to legacy C8 based fluorotelomer surfactants with the same amount of fluorochemical in the firefighting agent. This has been evidenced by equivalency in the highest performing US Milspec (MilF 24835F[SH]) firefighting foam fire test[80]. Use of C6-based fluorotelomer surfactants in these Mil-spec approved foams is not new: Some of the leading MilF approved foams have been using predominantly C6 based surfactants (>95-97%) for more than three decades, very effectively[86].

14. Other MHF categories missing from Washington State legislation

This Washington State legislation - perhaps unintentionally - excludes some important applications normally also considered as Major Hazard Facilities, which should be included in this critical category for continued C6 PFAS foam agent usage. MHFs have a duty of care, not only to protect the environment, but also to protect their facility and the community from fire. Selecting a foam which is seen to fulfil duty of care to the environment, but fails to provide effective fire protection will place life safety, the MHF and the surrounding community at risk.

These include:

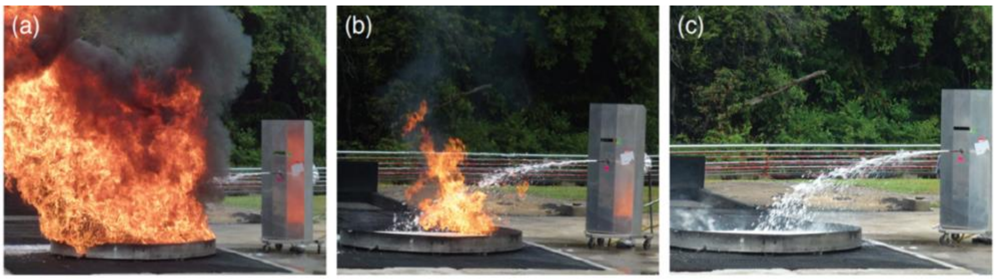
14.1 Aerodromes, Helidecks, Heliports, Aircraft Hangars and Maintenance Areas

Similarly important for life safety as Airports, and therefore requiring inclusion as critical hazard areas within the MHF category, where equally reliable, rapid and effective knockdown of fires is critical to minimising loss of life, prevention of escalation, while also effectively maintaining functionality and minimising site and traffic disruption from any fire incident. Fluorinated foams are so far proven to be essential in such situations[51-53].

ICAO sets internationally accepted requirements for firefighting foam fire tests that are widely accepted by the aviation industry. However relevant ICAO fire test requirements changed in 2013 re-defining the fuel as Kerosene rather than Jet A1/Avtur, and for all ICAO Level testing, allowing edge flame flickers for 120 seconds rather than extinction within 60 seconds, as previously[58]. The flashpoint of Kerosene is 37ºC to 65ºC, whereas the flashpoint of Jet A1 is 38ºC, defining it as clearly a flammable liquid.

The highlight event at an Aviation Fire conference in Singapore July 2016[59] was intended to showcase a leading F3 agent's aviation capabilities on an ICAO level B fire, but unfortunately it had to be replaced last minute by a 3% C6 AFFF effectively providing control and extinction, without edge flickers, despite humid 32°C conditions (as shown in photos below)[59]. The F3 manufacturer explained "***We demonstrated C6 AFFF as too many environmental factors were not under our control to do F3***". Several delegates protested that "*those variables usually happen during fire incidents*", it was disappointing as, while a demonstration can be cancelled, real fire emergencies cannot.

This same fire was unable to be extinguished twice using F3 the day before, and apparently even caught alight the separator alight, which also confirms very poor fire control.



ICAO Level B Fire test demo in Singapore, 2016.
(a) pre-burn; (b) ≤C6 AFFF fire control; (c) ICAO Level B ≤C6 AFFF extinguishment

Several delegates had not appreciated that fuel volatility usually increased with increasing ambient temperatures, while foam quality usually decreases; making fires harder to extinguish. Such fire tests are usually conducted at 15-20°C to enable comparison. One can argue that the safety margin should be adequate as recommended application rates usually double test rates and many variables including temperature, long pre-burns, wind/rain effects, hot metals, obstructions, faulty equipment, foam blanket interruption, training short-falls and many more demands are placed on this safety margin. The ICAO Airport Services Manual (Doc 9137) requires[58] that "*foam must flow freely over the fuel surface, must resist disruption due to wind or exposure to heat or flame and should be capable of re-sealing any rupture cause by disturbance of an established foam blanket*." Can F3 and C6 AFFF agents equally meet these criteria?

Aviation foams must deliver quick knockdown as seconds can mean the difference between life and death. The risk of fires burning back again is a serious trap for passengers and firefighters – so resisting re-ignition is critical.

This cancelled F3 demonstration re-inforces our duty of care to passenger's and firefighter's lives; confirming challenging test conditions better represents the day a fire strikes. Foam without fluorine doesn't mean "no problems" as some regulators seem to believe. There are no substitutes for appropriate firefighting performance, as every second counts towards saving lives.

In August 2016, a Boeing 777 aircraft crash-landed during an "attempted go-around" at Dubai airport in 48°C heat with wind-shear conditions[60,61]. All 300 passengers and crew safely disembarked the plane despite a fuel fire developing. Foam was applied to suppress the fire. Only after evacuation a brave firefighter tragically lost his life in a fuel tank explosion after 9 minutes. Extensive foam application to the fuselage continued, but full control of the fire was not achieved until approximately 16 hours after the impact. The plane was destroyed.

The final investigation has not been concluded by the Gulf Civil Aviation Authority, so the cause of this failure and whether the foam type in use or the very high ambient temperatures were contributory factors is not yet known, but remains a possibility.

This raises further important questions …Are the current ICAO test requirements relevant to all locations, and is the foam's vulnerability to volatile fuels taken into account? Does ambient temperature perhaps play a more significant part than the current fire test suggests? Are we perhaps eroding our margins of safety beyond what is responsible, when many F3s (and perhaps lower quality AFFF agents) effectively have little or no fuel shedding capabilities when flames are still present nearby? Is there an increased incident escalation risk when high performance C6 AFFFs are not used? Fuel shedding additives are needed to prevent sudden flashbacks occurring. Could this be a contributory factor as fuel volatility increase with ambient temperatures, to a level where the foam may not be able to adequately control the fire?

Had this been a serious aircraft mechanical failure, that specific model would have been taken out of service until the investigation was completed and the cause quickly established beyond doubt, before the plane could be considered acceptable for continued service, possibly following a fleet maintenance overhaul or component replacement recall, depending on the established cause. Why do we still have no established cause for this Dubai aircraft fire to burn for 16 hours? … seemingly a foam attack failure?

This suggests there is currently insufficient evidence to confirm these F3 agents are capable of rapid, efficient, effective and reliable control of fuel in depth fires and those where forceful application of foam is required to save lives (despite having ICAO Level B fire test certificates – to the latest dumbed down changes).

Caution is therefore recommended before embarking upon any PFAS-free foam or F3 alternative usage for these often life critical applications. Although F3 agents have been in use by Airservices Australia since 2010 at all their main State and Territory airports around Australia, we also see their acceptance overseas for protecting aviation hazards, although this seems largely based on approval documentation meeting post 2013 ICAO Leve B fire test protocols[58], with seemingly limited significantly more onerous verification testing, which should better represent real-life emergency conditions. Singapore[59] and Dubai[60,61] seem to shed uncertainty on whether F3s will operate effectively in some of the higher ambient summer temperature scenarios, which are routinely encountered by the aviation industry across most of Australia, most of the year!

There appears to be no documented instances where F3 agents have been successfully proven effective in significant aircraft crash incidents around the world since their introduction to this sector around 10 years ago, which is surprising and quite scary as a regular airline passenger! This is surprising despite their extensive use at all Australian airports operated by Airservices Australia since 2010, and other major European airport hubs. Could this be placing the general public at unnecessarily increased risk of harm?

I have personally discussed this with Airservices Australia's Chief Fire Officer, ARFF (Glenn Wood) recently at a conference in Singapore, where he confirmed they had not had any significant fire incidents anywhere across Australia where F3 had been used. UK Airport representatives at the same conference, also using F3 agents for their front-line duty, similarly could not recall a single significant incident where F3 agents had been used, so it's inherent suitability is essentially ***untried*** and ***untested*** in reality, on any substantial live aircraft fires where passenger life safety is a key and very visible priority - particularly under varying and potentially hostile conditions. Except perhaps the August 2016 Dubai Airport B777 fire incident6[0,61], where the investigation has not yet been completed! This would seem to be an unacceptable position for any life safety product, particularly when there appears to be evidence of a potential 2016 foam failure incident at Dubai?

I have dealt with these matters in some detail, because they directly relate to the criticality of quick, effective, efficient and reliable fire protection for all Military sites and Assets across Australia, whose continued use of C6 fluorinated firefighting foams should form part of this Inquiry.

14.2 Offshore Platforms & Oil Rigs

Offshore platforms and oil rigs handle large volumes of volatile crude oil every hour of every day, and often contain or are linked to accommodation areas for shift-working personnel. They also regularly transport personnel and equipment by helicopter. Life safety is paramount on such structures requiring rapid, reliable, efficient and effective protection. This also maintains operational functionality, minimises damage and avoids dangers of additional exposure to potential chemicals hazards from other processes which may be conducted on such platforms. These platforms are self-contained, so in fire incidents there is no escape except into life-rafts as a last resort (which may be very hazardous particularly in rough seas). The critical nature of fast, efficient, effective and reliable fluorinated foam systems on these installations cannot be over-stated, particularly when research evidence shows[55-57] that typically 2-3 times more F3 agent and water resources are required for a given sized fire, compared to C6 AFFF, with considerably slower and less reliable results. Such platforms take weight restrictions very seriously and usually use 1% foam concentrates to save weight over cheaper 3% alternatives. A 1% F3 agent used 2015 in Norwegian offshore sector caused foam pump failure through unexpected severe corrosion of bronze mechanical components, which was deemed unacceptable, and had not occurred with AFFF agents[62].

14.3 Large Oil tanker ships, Cruise ships and Other Vessels Carrying Dangerous Flammable Liquid Cargoes and Associated Ports/Jetties where they Berth.

Such vessels like Military vessels require rapid, reliable, efficient and effective protection of life safety for ship's passengers and crew, which is considered paramount. Usage of less effective F3 agents requiring higher application rates and delivering slower fire control is jeopardising safety of both the personnel and the vessel unnecessarily. Continued use of the least amount of environmentally more benign C6 fluorinated agents is therefore strongly recommended to protect lives, minimise vessel damage and maintain operational functionality, while reducing fire water runoff produced inside the vessel (which also avoids the risk of instability or sinking unexpectedly) during a fire incident. This is particularly relevant when research confirms that typically 2-3 times more F3 agent and water resources are required for a given sized fire[55-57], compared to C6 AFFF, with considerably slower and less reliable results.

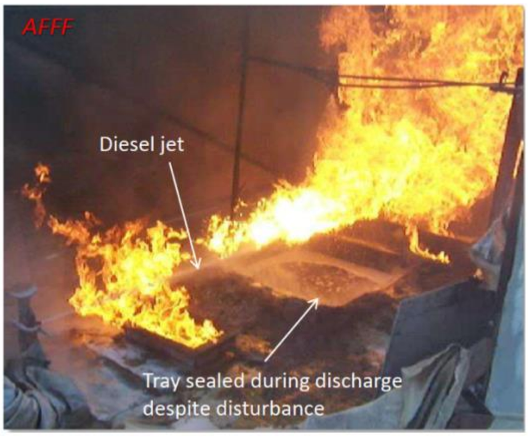
14.4 Other Large Industrial Plants

There are several large industrial sites which store large volumes and/or a wide variety of flammable fuels both hydrocarbon and polar solvent based products, which do not easily fit into the earlier categories. They often have complex processing which uses significant volumes of solvents and flammable liquids in their processing areas eg. Pharmaceutical Cos, Paint Cos, Plastics Cos, Metal smelting and processing Cos etc. etc. These usually have bunded containment areas to catch fuel within the process areas and bulk storages, so should also be considered as MHFs where C6 fluorinated foams should be permitted for future use.

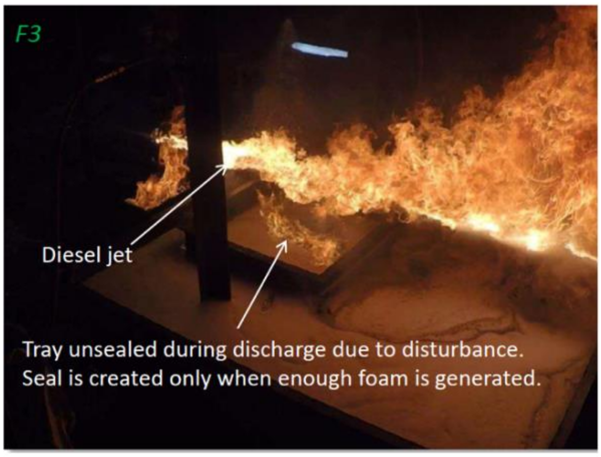
14.5 Mine Sites & their Vehicles

Many mine sites are remote, self-contained and have large storage and usage of volatile, combustible fuels and other hazardous chemicals on site. It is therefore considered critical to life safety survival that they are able to use the most effective, fast acting fluorinated foam agents, to control fires quickly, prevent their spread and protect life safety of site personnel and contractors, particularly when they may also be severely constricted underground.

Pre-engineered vehicle systems rely on fast acting non-aspirating foam spray systems to prevent danger to personnel and protect vehicle assets. Testing has shown that F3 agents are not simply drop in replacements for AFFF agents, and usually require re-engineering of these vehicle systems, to accommodate increased nozzle spacing, often requiring a change to aspirating nozzles as F3 agents generally have no film forming capability[63].



AFFF: effective as non-aspirated spray. Film resists re-ignition from diesel jet at lower application rate & less affected by pressure disturbances



F3: needs aspiration to seal vapours. Higher application rates needed to offset losses & pressure disturbances

Cylinder sizes and pipework diameters may also need to be increased for the same risk, with varying pressure decays and duration times, adding unnecessary dead weight to the vehicle. F3's thicker viscosity also makes it significantly harder to mix adequately with water into a uniform solution. F3s also have a reputation for poor stability as a premix over time, so may not operate correctly if stored in premix form for some time before required to activate on a fire. This could place both occupant(s) and vehicle at unnecessarily but potentially life threatening risk of harm.

In addition, before any foam is accepted for MHF usage (or any other use for that matter), foam users should be encouraged to conduct more thorough testing using the specific fuels and equipment that they are using on site, and at ambient/fuel temperatures more typically experienced by them year round in Australia.

This is clearly a better way to adequately verify any firefighting foam's suitability for duty, by practically confirming it can provide adequately quick, effective, efficient and reliable life safety and damage limitation objectives under a range of likely operational conditions on that specific site. This means demonstrating the foam is suitable for use at several different ambient temperature conditions representing typical summer and winter temperatures on specific fuels stored on site, as a valuable confirmation of the generic "piece of paper approval" provided by for example an ICAO Level B, EN1568, Lastfire or UL 162 fire test certificates.

Such local testing of proposed foams on site - BEFORE adoption and usage - using existing equipment on representatively large fires with realistic pre-burn times and ambient temperatures that are likely to be faced in an emergency, is key to finding a suitably reliable product any foam user can trust. Otherwise, how can any foam user have any confidence that the proposed foam will work effectively for them, when fire strikes under his specific fuel loads, equipment set-ups, and site conditions?

15. Additional Justifications for retaining ≤C6 agents for MHFs.

Short-chain ≤C6 fluorotelomer surfactants are substantially different in environmental behaviour from legacy long-chain ≥C8 fluorochemicals. Typically, only around 2% fluorochemical is used in these high purity short-chain ≤C6 fluorotelomer based firefighting foams[64,65]. Although these C6 PFAS are still Persistent (benefit for fire use & storage), the remaining 98% is still biodegradable and is not considered Bioaccumulative, nor Toxic and are widely considered significantly more environmentally benign. Scientific research[45,66-78] confirms short-chain C6 fluorosurfactant based foam agents behave very differently from legacy C8 long-chain fluorinated foams because they are:

- NOT Bioaccumulative, nor Biopersistent, nor Biomagnifying.
- NOT Toxic to aquatic organisms and mammals (including humans).
- NOT carcinogenic, nor mutagenic, nor genotoxic, nor developmental nor reproductive toxicants.
- NOT shown to be harmful to human health.
- CANNOT qualify for POP listing since at least 2 of 4 critical conditions required by the Stockholm Convention, are NOT Met.

These C6 Fluorotelomer surfactants used in firefighting foams do not use ≥C8 precursors, PFOS, PFHxS or PFOA as ingredients and these cannot breakdown to PFOS, PFHxS or PFOA. The main breakdown product is short-chain C6 PFHxA (PerFluoroHexanoic Acid), the 5,3 Acid and PFBA (C4). There is an unavoidable minute trace of PFOA created as a by-product of the production process[79,63,64,] at a few ppb level which is well below the REACH and EU contaminant restriction levels for PFOA, defined in recently passed 2017 EU legislation[34].

PFHxA has been extensively tested and confirmed as:

- Equivalent % C6 to C8 achieves same MilF Spec fire performance [10,80-82].
- Short-chain PFHxA seems fully excreted through human kidneys/urinary system with half-life in humans averaging 32 days[67] so it does not remain and build up in the body ot potentially dangerous levels.
- Different from C8 human half-lives of PFOS 5.4 yrs; PFHxS 8.5 yrs; and PFOA 3.5 yrs[68]
- Accepted and reviewed by major global regulatory bodies including US EPA[37], Washington State[48,49], UK Environment Agency[83,84], REACH[34], ECHA[85], & NICNAS in Australia[40,41]. Isn't it time other regulators across Australia accepted it also?

15.1 2016 UL testing –Swedish Research Institute.

The Swedish Research Institute conducted a series of comparative fire tests to the US Underwriters Laboratories UL 162 protocol in 2016[86]. It uses a square 4.65sq. metre fire tray with Heptane hydrocarbon fuel - a tight and consistent "gasoline type" specification. A UL fire test inspector was present, but what was particularly interesting were the effects of foam expansion in the success or otherwise of extinguishing this fire. UL is exceptional amongst fire tests in many ways, but particularly because the test nozzle is adjusted, to specifically match the foam characteristics of a particular proprietary real-life piece of equipment. This may be a top pourer for tank protection, foam branchpipe, or foam sprinkler. It ensures that representative foam quality from those delivery devices can be demonstrated to adequately extinguish a baseline fire test effectively, at a reasonably small but meaningful scale.

Fluorine Free Foams (F3) and C6 AFFF agents were being tested under the same climatic conditions across the same days[57]. Good quality foam with a median expansion ratio of around 7-7.5:1 was no problem as both foams passed this test, although the F3 agent required a 50% higher application rate with 25% more time to achieve extinguishment, as it had no film forming or fuel shedding capabilities.

Table 1: Effects of Foam Expansion: F3 v C6 AFFF				
Foam Type	**C6 AFFF**	**F3**	**C6 AFFF**	**F3**
	Higher Expansion		Lower Expansion	
Expansion Ratio	6.9	7.5	3.6	4.4
Application rate	7.6L/min	11.4L/min	7.6L/min	11.4L/min
Application time (mins)	3	**5**	3	**5**
90% control time (min:sec)	1:08	0:56	1:26	1:50
Extinction time (min:sec)	1:46	**2:10**	2:14	**3:24**
Burnback resistance	5%@5min	Self-extinct	10%@5min	Failed
Litres foam used: 90% control	8.6	10.6	10.9	20.9
LITRES foam used: Extinction	**13.4**	**24.7**	**17**	**38.8**

Courtesy: Swedish Research Institute/Dafo-Fomtec

When the foam expansion was reduced to 4.4:1 to match different pieces of standard equipment aiming to be approved, the F3 agent not only took 56% longer to extinguish than it did at 7.5:1, the foam quality was too poor to protect the foam blanket against re-ignition, failing the burnback test. The lower expansion ratio produced lower quality foam, unable to prevent sustained ignition to below the 25% allowed burning area during 5 minutes of this demanding test, so expansion can seriously affect whether the fire stays out, ...or not. This could perhaps mean the difference between saving a life ...or losing one in a real fire emergency.

In contrast the C6 foam easily passed the test at a lower 3.6:1 expansion, only 20% slower than its earlier test at 6.9:1, still at the significantly lower application rate, but 35% faster than the F3 agent and with only 10% of the tray area ignited after 5 minutes, resisting re-ignition very well. This confirms the efficiency, effectiveness and reliability of C6 agents, compared to less efficient, less effective and more unreliable F3 alternatives.

Interestingly the amount of foam used to extinguish these tests was dramatically different. The F3 foam required a substantial 24.7litres of concentrate to extinguish at 7.5:1, and a much larger 38.8 litres to extinguish at 4.4:1, while failing to keep the fire under control for 5 minutes. The C6 foam used just 13.4 litres and 17 litres of concentrate respectively, around half the F3 foam used, but achieving faster control, extinction, and effectively prevented re-ignition for much longer than the burnback test required. Consider scaling this up to a real fire scenario, ...substantially less C6 foam would have been needed, less smoke, noxious breakdown products and less run-off emitted, less risk of escalation and re-ignition, reducing the extent of the incident, with less risk of overflowing containment areas potentially carrying pollutants into the environment unnecessarily. Less runoff to collect, treat and dispose of; also means less risk of PFAS or any other noxious breakdown products of the fire escaping into the surrounding environment. Should some unavoidably escape, substantially less volume of a much less toxic, non-bioaccumulative chemical, with much less associated contaminated run-off, would be entering the environment, which is surely likely to help minimise the adverse impacts of the

incident, than had far more of a more toxic F3 agent been used instead? -plus the associated increased noxious runoff!
Its still not ideal, ...but when disaster strikes its usually best to deal with it quickly, effectively and reliably, using least agent and creating less potentially noxious firewater run-off and smoke. This should provide our best chance of protecting life safety, reducing community disruption and environmental harm, particularly in Major Hazard incidents involving large volumes of volatile fuels.

15.2. 2016 Spain testing: Wide Differences F3 v C6

This major comparison of over 80 equivalent fire tests was conducted in Spain during 2016[56]. F3 differences increased with lowering application rates, reflecting tougher conditions.

At the median 2.5L/min/m^2 test application rate, average fire control times for F3 were 60% slower on gasoline and 50% slower on Jet A1 fuel, than C6 AFFF. F3 took 80 secs for fire control, with C6 AFFF taking just 30 seconds – almost 3 times faster – with 3 times more safety margin (see table 2).

Test/Fuel	FFF (F3) 1	2	3	4	5	AFFF 1	2	3	4	5
Gas. 95O	YES	NO	NO	NO	Late	YES	YES	YES	YES	Late
Heptane	YES	NO	NO	YES	Late	YES	YES	YES	YES	YES
Jet A1	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES
Diesel	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

NB: 1-5 above represent five unique, commercially available AFFFs and F3 foams

Table 2: All ≤C6 AFFFs PASS ALL fuel fire tests at 2.5L/min/m²
(1,3,4 = C6s; 2&5 = C8s)

C6 AFFFs were more versatile, more resilient, more effective, and more reliable, ...exactly what is needed by Major Hazard Facilities.

An analysis of extinguishment success between F3 and C6 highlights further concerns. At the median 2.5L/min/m^2 test application rate 3 of the 5 Fluorine free products failed to extinguish the gasoline fire, and one struggled. **Significantly ALL the F3 foams FAILED to extinguish the Jet A1 fuel at any application rate** (see table 3)**.** No F3 extinguished gasoline at the lower rate, but some also failed to extinguish gasoline at the highest rate. *Is this acceptable, when seconds count to save a life?*

	l/min·m²	1,25	2,50	3,75
FFF	Gasoline	NO	YES/NO	YES/NO
	Heptane	YES	YES	YES
	Jet A-1	NO	NO	NO
AFFF	Gasoline	YES	YES	-
	Heptane	YES	YES	-
	Jet A-1	YES	YES	-

Table 3: Most F3s FAIL to EXTINGUISH Gasoline and Jet A1 tests at ALL rates. ≤C6 AFFFs PASS ALL fuels at ALL rates.
(C6 passes but not tested at higher rate as passed all fuels at lower rates.)

Why are F3s only reliably extinguishing Heptane fires - the most commonly used fire test fuel? Yet Gasoline and Kerosene (of which Jet A1 is a specific type), are far more widely found fuels in use and storage at industrial sites around the world. Are we at risk of "breeding F3 foams" simply to pass fire tests and gain approvals?

…rather than providing a robust and reliable capability on a wide-range of fuels and fire scenarios, to protect our communities in the real world?

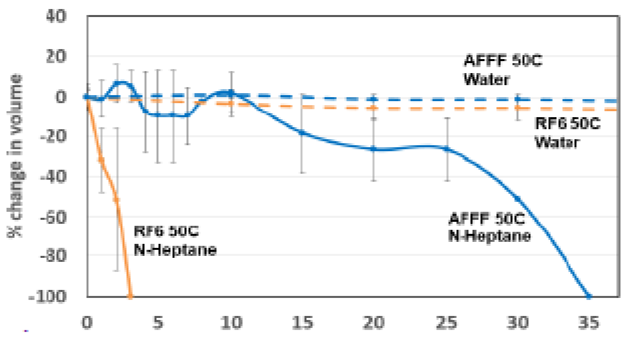
15.3 Lack of Fuel shedding is a critical F3 weakness

Without fluorochemical ingredients foam agents have little fuel shedding capability and poor vapour sealing, usually due to elevated levels of hydrocarbon surfactants (detergents) in the foam formulation[51,52]. Consequently they are unable to rapidly, effectively and reliably control and extinguish fuel in depth fires and those where foam is forcefully applied (which is most realistic emergency fire sceanrios). High detergency attracts the hydrocarbon fuels into the foam bubbles, as evidenced by 2012 research[51,52].

This showed slower control and extinction, which could often result in bigger fires. Fuel build up in a F3 blanket can lead to sudden flashbacks and re-ignition as shown in the video of these research tests[52]. Watching the fluorine free foam flash and burn away on a range of hydrocarbon fuels, with 50% foam collapse typically after about 5 minutes explains why fuel shedding capability is essential for efficient, reliable and effective firefighting of large volatile flammable liquid fires. Direct comparison with C6 Fluorotelomer surfactant based AFFFs shows C6 agents exhibit neither flashbacks nor a burning foam blanket, and undergo no foam collapse even after 10 minutes, as graphically demonstrated in this comparative video test of F3 and C6 AFFF agents www.youtube.com/watch?v=IuKRU-HudSU. Consequently, more water and foam resources are likely to be needed as a result of using F3 agents, plus more damage and escalation with increased life safety risk for casualties, firefighters and other emergency responders, is likely to occur as a result, particularly when forcefully applied onto volatile flammable liquid fuels.

Further research, presented by Chang Jho (USA) at an Aviation Conference in Singapore, July 2016 showed adding very small amounts of C6 fluorochemical (0.035%) to a fluorine free base allowed ignition but prevented sustained burning[87]. Increasing to 0.042% C6, enabled ignition and sustained burnback to be prevented. On more viscous pseudoplastic foam bases, 0.065% C6 enabled both ignition and sustained burning to be resisted. It was found that the more volatile the fuel the shorter the period an F3 blanket was capable of resisting breakdown. C6 AFFF was unaffected by any fuel, consistently resisting breakdown for more than 30 minutes. Few delegates realized that usually <2% C6 fluorochemical is needed in modern fluorinated foams to achieve critically reliable fuel shedding capabilities, on a wide range of fuels.

2015 US Naval Research Laboratory research observations[87] concluded:



"AFFF had a much longer foam lifetime than fluorine free RF6, when exposed to n-heptane, fluorination appears to reduce degradation.

The presence of fuel influences foam degradation with RF6 foam lifetime changing from one hour on water to 3 minutes on n-heptane degradation [compared to AFFF lasting 35 minutes on n-heptane], seen during extinction may be caused by fuel and not pool temperature."

Surprisingly changes to ICAO fire tests[58] made in 2013 now allow these flicker fires, effectively extending fire extinction times from 60 seconds to 120 seconds, increasing risk to life safety.
This is particularly surprising when seconds count to save a life! Whilst C6 AFFF/FFFP foams have been demonstrated to be effective and reliable, it may not be so with F3 agents without fuel shedding and resultant flashbacks, potentially exposing lives unnecessarily, particularly when forcefully applied to fuel in-depth fires. The more volatile the fuel like gasoline, the worse the adverse effect is likely to be.

Foam Property	Advantage	AFFF	F3
Fuel Repellency *	Yes	Yes	No
Fuel Shedding	High	High	Low
Fuel Pickup	Low	Low	High
Film Formation*	Yes	Yes	No
Foam spreading on fuel*	Yes	Yes	No
Fuel spreading on foam*	No	No	Yes
Fuel emulsification	Low	Low	High
Flammability of contaminated foam	Low	Low	High
Degradation of contaminated foam	Low	Low	High
Heat resistance of foam	High	High	Low

*Fundamental differences between AFFF and F3 foams

This foam property performance comparison chart (left) helps to highlight key differences between these 2 foam types.

Comparative 2013 video of side by side extinguisher fire testing [53] re-confirms 2008 research[55] that C6 fluorochemical based foams can be 3 times faster at extinguishing volatile hydrocarbon fuel fires than F3, and provide 4 times longer protection against re-ignition after the fire when C6 foam agents are used[53]. It makes for compelling viewing www.youtube.com/watch?v=3MG2fogNfdQ .

15.4 Key Factors Required for Major Hazard Facilities (MHFs)

There are a number of key factors that can be summarized from the above evidence, as being widely considered essential for fires in MHFs to be effectively controlled and rapidly extinguished. This allows adequate provision of life safety protection and minimised risk of incident escalation. These include:

- Minimising life safety risks
- Minimising escalation potential
- Reducing community disruption
- Reducing volumes of firewater runoff
- Reducing smoke and breakdown products generated
- Reducing foam and water resources needed and used
- Avoidance of Bioacumulative, and Toxic chemical usage
- Less risk of containment overflow into the environment
- Less runoff to collect, treat and dispose of safely, in accordance with the Authority Having Jurisdiction.

In addition, all fire water effluent (including that from system testing/training) could potentially be contaminated with a range of potentially polluting materials apart from PFAS. This could include:

- Hydrocarbons
- VOC's Volatile Organic Compounds (VOC's)
- PAH's (Polycyclic Aromatic Hydrocarbons)
- Water soluble polymers
- Biocides
- Solvents

All fire water effluent is therefore potentially hazardous, regardless of the type of foam agent used. All fire water effluent from foam system testing or training should therefore be:

- Contained
- Tested for contamination
- Treated/disposed in accordance with local regulations

In accordance with Industry best practice as defined in Fire Protection Association Australia's Information Bulletin IB-06[88] and the USA's FireFighting Foam Coalition –Best Practice Guidance for use of Class B Firefighting Foams[89].

15.5 Assessment confirms C6 cannot be POP listed

≤C6 agents behave very differently from ≥C8s like PFOS, PFHxS and PFOA which are confirmed PBT with PFOS already being POP listed under the UN Stockholm Convention[30]. PFOS has also been banned from use in EU[90] and Canada[91] for several years. The Australian Dept. of Environment and Energy has issued a PFOS RIS (Regulatory Impact Statement) for consultation[43], recommending a PFOS ban across Australia as the cheapest and most environmentally advantageous of the 4 options presented. This PFOS ban gained widespread support across the fire industry as there are alternative and equally effective short-chain C6 agents available, which are necessary to protect life safety and MHFs.

An Environ International report[66] assessed C6 short chain fluorotelomers for potential POP listing and concluded that only one of the four essential criteria -Persistence, Bioaccumulation, Long Range Transport [Mobility], and adverse harmful human or environmental effects – which includes Toxicity - was being met. That was Persistence. These short-chain C6 agents were proven not to be Bioaccumulative nor Toxic, nor harmful to humans[40]. Short-chain fluorochemicals have subsequently been shown to be mobile, but without Bioaccumulation and Toxicity issues, this would not seem to be adequate justification for prohibition, rather restriction to use in Major Hazard Facilities where life safety could otherwise be placed at unnecessary and increased risk, along with severe incident escalation potential.

Important scientific research work confirms the main C6 degradation product is PFHxA (PerFluoroHexanoic Acid) which is fully excreted through the human urinary system with a half-life average in humans of just 32days[66]. This contrasts dramatically with long-chain average human half-lives of 3.8 years for PFOA, 5.4 years for PFOS and 8.5 years for PFHxS[67-69]. The half-life of PFHxA in other representative mammalian animals (rats and monkeys) also shows similarly short half-lives, compared to these long-chain fluorochemicals (see Table 4 below).

Table 4: Comparison between human half-life of legacy C8 PFAS being several years, while short-chain C6 PFAS averages only 1 month, so does not accumulate and build up in humans to levels of potential concern.

Measurement	PFOS (ECF)	PFHxS (ECF)	PFOA (ECF), [reaction trace in FT]	PFHxA [FT]
Half life in rats	3mths	7 days	1-6 days	1-2 hrs
Half life in monkeys	3-6mths	4mths	3 Wks	1-2 days
Half life in **humans**	**5.4yrs**	**8.5 yrs**	**3.8yrs**	**Av. 32 days**

NB: (ECF) = ElectroChemical Fluorination process
[FT] = FluoroTelomer process

Sources:
Russell 2013, Elimination Kinetics Perfluorohexanoic Acid in Humans & comparison rats & monkeys;
Rotander 2015,Novel fluorinated surfactants tentatively identified in firefighters by controlled approach;
Environ Int'l 2014,Assessment of POP criteria for specific short-chain perfluorinated Alkyl substances;
Olsen 2007, Half-life serum elimination of PFOS, PFHxS, PFOA in retired fluorochemical production workers;
OECD 2013 - Synthesis of PFCs

The importance of this can be seen in Ski Wax Technician studies[97], where they start the season with residual levels of short-chain PFHxA which rises through the ski season (see Fig 12.), falling to background levels during the off season. It appears the short average 32day half-life ensures PFHxA is excreted during the off-season back to residual levels, so they begin the next season at the background population level, without experiencing upward trending levels over time.

This is contrary to the upward trending levels of PFOA, and PFNOA in the technician's blood which is significantly correlated to the number of years in the occupation. Exposure is occurring faster than these long-chain C8 chemicals seem to be excreted from the body, presumably due to their long half-lives in humans. PFOA results reached a plateau and then began declining around 2008, as new well ventilated waxing trucks were introduced. Technicians sometimes suffered from flu-like symptoms caused by exposure to fluorinated wax, but experienced a higher physical tolerance to the exposure at the end of the season compared to the beginning.

16. Conclusions

The evidence and research presented confirms that all fire types can pollute, whether fluorinated or fluorine free agents. Legacy C8 foams are confirmed PBT and should be restricted from use. Short-chain ≤C6 fluorochemicals (and substances containing them), are very different, categorised as **not** Bioaccumulative and **not** Toxic and should therefore continue to be used to provide adequate protection of life safety and minimise damage in all our Major Hazard Facilities (MHFs). In a whole of incident assessment these C6 agents provide fast, effective and reliable fire control and extinguishment which generally minimises adverse impacts to our environment. Fuel repellency and quick spreading to seal vapours from release seem critical to delivering vital fire performance objectives to save life. This clearly justifies separation from legacy long-chain ≥C8 fluorochemicals - which foam users are transitioning away from - but remain a significant public legacy concern (from PFOS, PFOA & PFHxS) in terms of both potential human health and environmental hazards.

Coupled with the Australian Department of Health's Expert PFAS panel's Report and US Washington State's recent PFAS firefighting foam restriction legislation exempting Major Hazard Facilities (albeit in rather limited form) which was based on strong testimony confirming " ***…very grave concerns that this total ban would take away the ability to extinguish large catastrophic fires such as process area fires in refineries or fuel storage tanks, large atmospheric fuel storage tanks and the reason is that quite honestly, the fluorine free foams lose a lot of their effectiveness when you get into Fuel-In-Depth type fires.*** "

"Fluorine free foams are very effective on spill fires but ***once you get to a situation where the foam actually has to plunge below the surface, because of the*** (forceful) ***application techniques, the fluorine free foams actually pick up some of that fuel, and by the time the foam comes to the surface after plunging below, it is actually burning****."*

These testimonies clearly re-inforced that poor fire-fighting performance increases adverse environmental impacts and places life safety at unnecessarily increased risk from slow knockdown, poor flashback resistance, unreliable post fire securement, increased risk of escalation etc. Longer extinguishment times also increase risk of escalation, creates more toxic combustion products, while also increasing risk to life, property and business continuity. Use of larger quantities of foam and water generally creates more toxic/contaminated effluent, and increases risk that loss of containment will occur. Fire-fighting performance therefore CANNOT be ignored or isolated when making selection decisions aimed at minimizing environmental Impacts, as they are an integral part of achieving the best outcomes for minimizing adverse impacts from fires, particularly in MHFs.

This more balanced, realistic and common sense "whole of incident" approach by Washington State accepting short-chain ≤C6 PFAS based firefighting foams should be replicated across Australia as the key way forward. It will not only maintain both expected fire performance levels and life safety protections, which we currently take for granted, and continues to be an expectation by our communities, … But also minimise the adverse environmental impacts, when the whole fire incident impacts are fully considered and taken into account.

It is therefore strongly recommended that PFAS chemicals should be divided into two main fluorinated groups in Australia:

- **RESTRICTED from ALL future uses:** Legacy PFAS chemicals, containing a Long-chain sequence of ≥7 but ≤20 fully fluorinated carbon atoms (as they are emerging contaminants of concern), and

- **PERMITTED for all future MAJOR HAZARD FACILITIES usage (including the broader categories discussed above)**: C6 PFAS chemicals that predominantly contain short-chain fully fluorinated carbon atom sequence of ≤6, plus everything else that meets the fluorotelomer chemical definition, without causing significant human health or environmental concerns e.g. chemicals ≥21 fully fluorinated carbon atoms.

This would resolve the current confusion and misleading situation many foam users face, substantially increase life safety and reduce risks of fire incident escalation, particularly if this were applied to the broad MHF category, allowing continued use of ≤C6 agents into the future.
This approach also provides the necessary further qualification and separation of environmentally more benign C6 PFAS (short-chain ≤C6) from PBT legacy PFAS (long-chain ≥C8). It also avoids such a large and diverse PFAS group being misleadingly formed, where there are clearly unequal hazards to both human health and the environment (as demonstrated) by legacy ≥C8 PFAS compared to short-chain ≤ C6 PFAS chemicals and their resulting firefighting foam agents. They cannot continue to be misleadingly treated in the same category. Changing the current boundaries, conveniently resolves this unacceptable and unnecessary confusion/dilemma to everyone's benefit.

Adopting such changes would restrict legacy long-chain ≥C8 PFAS agents, preventing use of POP listed PFAS chemicals (desirable by most foam users and regulators), while allowing significantly more environmentally benign ≤C6 PFAS agents to continue fast effective protection of life safety, minimising escalation and damage, particularly in all Major Hazard Facilities, while also reducing adverse community and environmental impacts from such whole of incident fires into the future.

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References

1. Military Times, April 2018 - DoD: At least 126 bases report water contaminants linked to cancer, birth defects, https://www.militarytimes.com/news/your-military/2018/04/26/dod-126-bases-report-water-contaminants-harmful-to-infant-development-tied-to-cancers/

2.Martinsen K, 2012 - Polyfluorinated compounds at fire training facilities: Assessing Contaminated soil at 43 Norwegian airports, Section for Waste Treatment and Contaminated Ground Common Forum Meeting, Bilbao, Spain 23 Oct. 2012

http://www.emergingcontaminants.eu/application/files/8214/5217/1295/05_PresentationF_cpds_at_No_airports_Martinsen.pdf

3. Sydney Morning Herald , 2018 - Toxic Secrets: Where the sites with PFAS contamination are near you, 17th June 2018, https://www.smh.com.au/national/nsw/toxic-secrets-where-the-sites-with-pfas-contamination-are-near-you-20180616-p4zlxc.html

4. Canberra Times, 2017 – Federal government considering phasing out Toxic firefighting Chemicals, 21st April 2017, https://www.canberratimes.com.au/national/act/federal-government-considering-phasing-out-toxic-firefighting-foam-chemicals-20170421-gvpb16.html

5. Kim S-K, et al 2012 - Wastewater treatment plants (WWTPs)-derived national discharge loads of perfluorinated compounds (PFCs), https://www.sciencedirect.com/science/article/pii/S0304389411014026

6. Lang J , Field J et al, 2017 – National Estimate of PFAS release from Landfill leachate (US), https://www.ncbi.nlm.nih.gov/pubmed/28103667

7. Guo Z et al (US EPA), 2009 - PerFluoroCarboxylic Acid content in 116 Articles of Commerce, https://www.oecd.org/env/48125746.pdf

8. UNIDO, 2009 - PerFluoroOctane Sulfonate (PFOS) Production and Use: Past and Current Evidence https://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Stockholm_Convention/POPs/DC_Perfluorooctane%20Sulfonate%20Report.PDF

9. USS Forrestal, 1967 – Rocket causes deadly fire on aircraft carrier (US) http://www.history.com/this-day-in-history/rocket-causes-deadly-fire-on-aircraft-carrier

10. US Military Specification Mil-F 24385F (SH), 1994 -Fire Extinguishing Agent, Aqueous Film Forming Foam (AFFF) Liquid Concentrate, for fresh and Seawater https://www.wbdg.org/ccb/FEDMIL/f24385f.pdf

11. US Airforce, 2016 – Airforce awards replacement firefighting foam contract http://www.af.mil/News/Article-Display/Article/915057/af-awards-replacement-firefighting-foam-contract/

12. Australian Government, 2009 - Australian Defence Standard Def (AUST) 5706 Foam, Liquid Fire Extinguishing; 3 percent and 6 percent Concentrate Specification http://www.defence.gov.au/estatemanagement/governance/Policy/Environment/Pollution/docs/Guidelines/DEFAUST5706FoamLiquidFireExtinguishingPerCentAnd6PerCentConcentrateSpecification.pdf

13.US Department of Defence, 2014 - MIL-F-24385 QPL/QPD History for Type 6 AFFF, http://www.dcfpnavymil.org/Systems/AFFF/QPL%2024385%20HISTORY%20-%20TYPE%206.pdf

14. Solberg, 2015 – Ted Schaefer Retires, https://www.solbergfoam.com/getattachment/ed5edc8f-0698-47dc-8968-6cc4eb573d21/Solberg%E2%80%99s-Ted-Schaefer-Retires-%E2%80%93-Recognized-for-Hi.aspx

15. Santoro (3M), 2008 – Brief History of PFC production, products and Environmental Presence http://www.astswmo.org/Files/Meetings/2008/2008-Mid-Year_Meeting/Santoro.pdf

16. Parliament of Victoria, 2016 - Senate Inquiry into CFA Training College at Fiskville – Final Report http://www.parliament.vic.gov.au/file_uploads/ENRRDC_Fiskville_Inquiry_Final_Report_myHbwdGN.pdf

17. 3M & EPA, 2000 – EPA and 3M Announce Phase out of PFOS, 16May 2000, https://yosemite.epa.gov/opa/admpress.nsf/0/33aa946e6cb11f35852568e1005246b4

18. Australian Department of Defence, 2003 – Environmental Issues Associated with Defence use of AFFFs, http://www.defence.gov.au/FOI/Docs/Disclosures/387_1415_Document.pdf

19. NICNAS, 2015 - Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environment Tier II Assessment for Direct precursors to PerFluoroOctane Sulfonate (PFOS) https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/direct-precursors-to-perfluorooctanesulfonate-pfos

20. UNEP, 2009 – PFOS included in The Stockholm Convention Persistent Organic Pollutants (POP) List http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx

21. UNEP, 2018 – PFOS 2009 Amendment - Countries Ratification List to Stockholm Convention, http://chm.pops.int/Countries/StatusofRatifications/Amendmentstoannexes/tabid/3486/Default.aspx

22. Australian Government, Department of Environment and Energy 2017 – National Phaseout of PFOS – Regulatory Impact Statement, https://www.environment.gov.au/system/files/consultations/52aef54d-1588-471a-b0f0-c5f67bd36e0d/files/pfos-ris-consultation-national-phase-out.pdf

23. South Australia EPA, 2018 – Environment Protection (Water Quality) Amendment Policy 2018, https://legislation.sa.gov.au/LZ/V/POL/2018/ENVIRONMENT%20PROTECTION%20(WATER%20QUALITY)%20AMENDMENT%20POLICY%202018_30.1.2018%20P%20521/30.1.2018%20P%20521.UN.PDF

24. Persson H and Lönnermark, 2004 –Tank Fires: Review of Fire Incidents 1951-2003, Brandforsk Project 531-021, SP Swedish National Testing and Research Institute, (See 82m dia. Orion Tank Fire p A32) http://rib.msb.se/Filer/pdf%5C19108.pdf

25. Singapore Transport Safety Investigation Bureau, 2017 – Final Report into Boeing 777 engine Fire at Changi Airport on 27th June 2016, https://www.mot.gov.sg/docs/default-source/about-mot/investigation-report/b773er-(9v-swb)-engine-fire-27-jun-16-final-report.pdf

26. Jacdec,2016 – Korean Air B777 engine Fire Incident at Japan's Haneda Airport, http://www.jacdec.de/2016/05/27/2016-05-27-korean-air-boeing-777-300-engine-fire-at-tokyo-haneda/

27. Norwegian Pollution Control Authority (Sft), 2007 – PFOA in Norway, Report TA 2354 http://www.miljodirektoratet.no/old/klif/publikasjoner/2354/ta2354.pdf

28. Jho C, 2018 – "C6 Foams v Legacy C8 Foams and Fluorine Free Foams – What you need to know" Singapore Aviation Academy – 18th IAFPA Aviation Seminar, Singapore, 9-11May 2018.

29. UNEP, 2001 – Stockholm Convention on Persistent Organic Pollutants set for signature 22-23rd May 2001, https://www.un.org/press/en/2001/unep89.doc.htm

30. UNEP, 2009 – PFOS included in The Stockholm Convention Persistent Organic Pollutants (POP) List http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx

31. UNEP, 2017 – PFOS 2009 Amendment - Countries Ratification List to Stockholm Convention, http://chm.pops.int/Countries/StatusofRatifications/Amendmentstoannexes/tabid/3486/Default.aspx

32. UNEP, 2017 – POP Review Committee: Risk Management Evaluation on PFOA as POP. http://chm.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/Default.aspx

33. UNEP, 2017 – POP Review Committee: Norwegian proposal to list PFHxS as POP. http://chm.pops.int/Convention/POPsReviewCommittee/Chemicals/tabid/243/Default.aspx

34. European Commission (EU), 2017 - COMMISSION REGULATION (EU) 2017/1000 of 13 June 2017 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards perfluorooctanoic acid (PFOA), its salts and PFOA-related substances. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1000&from=EN

35. US Environmental Protection Agency (EPA), 2006 – PFOA Stewardship program Description and invite, http://www.epa.gov/sites/production/files/2015-10/documents/dupont.pdf

36. US Environmental leader, 2012 – DuPont, 3M/Dyneon meet EPA Perfluorinated Chemical Goals, https://www.environmentalleader.com/2012/02/companies-meet-epa-perfluorinated-chemical-goals/

37. US EPA, 2016 – PFOA Stewardship Program final report of 2015 goals met, https://www.epa.gov/sites/production/files/2017-02/documents/2016_pfoa_stewardship_summary_table_0.pdf

38. NICNAS, 2015 - Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environment Tier II Assessment for Direct precursors to PerFluoroOctane Sulfonate (PFOS) https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/direct-precursors-to-perfluorooctanesulfonate-pfos

39. NICNAS, 2015 - Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environment Tier II Assessment for PerFluoroOctanoic Acid(PFOA) and its direct precursors https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/perfluorooctanoic-acid-and-its-direct-precursors

40.NICNAS, 2015 – Inventory Multi-tiered Assessment and Prioritisation (IMAP) Environmental Tier II Assessment for Short Chain PerfluoroCarboxylic Acids and their direct precursors, http://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/short-chain-perfluorocarboxylic-acids-and-their-direct-precursors

41. NICNAS, 2016 - Inventory Multi-tiered Assessment and Prioritisation (IMAP) Human health Tier II Assessment for short-chain Perfluorocarboxylic Acids and theirdirect precursors https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-group-assessment-report?assessment_id=1686

42. Australian Government, Department of Health, 2018 – Expert Health Panel for PFAS Report, May2018
http://www.health.gov.au/internet/main/publishing.nsf/Content/C9734ED6BE238EC0CA2581BD00052C03/$ File/expert-panel-report.pdf

43. Australian Government, Department of Environment and Energy 2017 – National Phaseout of PFOS – Regulatory Impact Statement,
https://www.environment.gov.au/system/files/consultations/52aef54d-1588-471a-b0f0-c5f67bd36e0d/files/pfos-ris-consultation-national-phase-out.pdf

44. Kirk M, Bräunig J, Mueller J, et al, 2018 - The PFAS Health Study: Systematic Literature Review. Canberra: The Australian National University, Canberra.
https://rsph.anu.edu.au/files/PFAS%20Health%20Study%20Systematic%20Review.pdf

45. Sim M and Glass D, 2014 – Final Report Australian Firefighters' Health Study, Monash University Centre for Occupational and Environmental Health, Dec.2014
http://www.coeh.monash.org/downloads/finalreport2014.pdf

46. Kirk K and Logan M, 2015 - Structural firefighting ensembles - accumulation and offgassing of combustion products, Journal of Occupational and Environmental Hygiene, DOI: 10.1080/15459624.2015.1006638
https://www.tandfonline.com/doi/abs/10.1080/15459624.2015.1006638?journalCode=uoeh20

47. Stec A. et al, 2018 - Occupational Exposure to Polycyclic Aromatic Hydrocarbons and Elevated Cancer Incidence in Firefighters https://www.nature.com/articles/s41598-018-20616-6

48. US Washington State legislature – Senate Bill 6413, Restrictions on PFAS chemicals in firefighting foams, http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bills/Senate%20Passed%20Legislature/6413-S.PL.pdf

49. US Washington State legislature – Engrossed House Bill Report ESSB6413 outlining testimony which amended the bill, making exceptions for continued Major Hazard Facility usage.
http://lawfilesext.leg.wa.gov/biennium/2017-18/Pdf/Bill%20Reports/House/6413-S.E%20HBR%20APH%2018.pdf

50. US Washington State Legislature – Video to House Environment Committee of Testimony regarding proposed PFAS firefighting foam ban across State Jurisdiction, Submissions 15th March 2018.
https://www.tvw.org/watch/?eventID=2018021146

51. Jho C, 2012 – Flammability and Degradation of Fuel Contaminated Fluorine Free Foams, MDM publishing http://www.dynaxcorp.com/resources/pdf/articles/Flammability-IFF.pdf

52. Jho C, 2012 – You Tube Video "Flammable firefighting foams!" – Laboratory testing to verify fuel pickup of F3 foams www.youtube.com/watch?v=IuKRU-HudSU

53. Angus Fire, 2013 – You Tube Comparative video tests "AFFF v fluorine free foam", evidence slower extinction and poorer burnbacks without short-chain C6 fluorosurfactant additives, www.youtube.com/watch?v=3MG2fogNfdQ

54. UK Ministry of Defence, 2002 - Defence Standard Def 42-40issue 2, Foam Liquids, Fire Extinguishing (Concentrates, Foam, Fire Extinguishing) https://infostore.saiglobal.com/en-us/standards/defstan-42-40-2-2002-500909/

55. Schaefer T, et al, 2008 - Sealability Properties of Fluorine-Free Firefighting Foams, University of Newcastle, Australia, Fire Technology Vol 44.issue 3 pp297-309 http://novaprd-lb.newcastle.edu.au:8080/vital/access/manager/Repository/uon:4815;jsessionid=E0140D586B0467E75B68993EBC83A1CA?exact=sm_subject%3A%22vapour+suppression%22

56. Castro J, 2016 – Fluorine Free Foams – Where is the Limit?, Singapore Aviation Academy and International Airport Fire Protection Association Seminar, Singapore July 2016.

57. Ottesen J-O, & Jönsson J-E, 2017 - AFFF v F3 Foams in Industrial Firefighting Systems – Trends, Performance, Concerns and Outlook, JOIFF Catalyst p7-8, iss3, Jul17, http://joiff.com/wp-content/uploads/2017/07/July_2017.pdf

58. International Civil Aviation Organization (ICAO), 2014 – Airport Services manual (Doc 9137) Part 1 4th Edition, Rescue and Firefighting, https://www.bazl.admin.ch/dam/bazl/de/dokumente/Fachleute/Flugplaetze/ICAO/icao_doc_9137_airportservicesmanualpart1withnoticeforusers.pdf.download.pdf/icao_doc_9137_airportservicesmanualpart1withnoticeforusers.pdf

59. Willson M, 2016 – Can Fluorine Free Foams (F3) take the fire security heat? International Airport Review, iss 6, p31-35 - Nov 2016. http://www.firefightingfoam.com/assets/Uploads/ARTICLES-/Willson-IAR-6-2016-Can-F3-Agents-take-the-Heat.pdf

60. General Civil Aviation Authority UAE, 2016 – Air Accident Investigation Preliminary report AIFN/0008/2016 issued 5Sept.2016 https://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/90/2016-2016%20-%20Preliminary%20Report,%20AAIS%20Case%20AIFN-0008-2016%20-%20A6-EMW.pdf

61. Willson M, 2018 – "Is Life Safety at Increased Risk?" – Fire Middle East Magazine, January 2018.
62. Norwegian University of Science & Technology (NTNU), 2015 – Failure Report on Bronze Foam Pump Offshore from RF1, 1% F3 foam concentrate.

63. Hafey C, 2018 – AS5062:2016, Fire Performance Testing with F3 Solutions, Fire Protection Association Australia's Future of Firefighting Foam Seminar, Brisbane Feb.2018.

64.Dynax Corporation, 2018 – Advert "All green for REACH 2020 …3 years early!" confirming Environmentally More Benign foams achieved with ≥C6 concentrates and <15ppt (0.0000000015%) PFOA or C8 impurities I the use strength foam solution, Fire & Rescue Magazine Q2 (May) 2018

65.Kleiner E, Jho C – Recent Developments in 6:2 Fluorotelomer Surfactants and Foam Stabilisers, 4th Reebok Foam Seminar, Bolton, UK, 2009

66. Environ International, 2014 – "Assessment of POP Criteria for Specific Short-Chain Perfluorinated Alkyl Substances" prepared for FluoroCouncil. http://www.fluorocouncil.com/PDFs/Assessment-of-POP-Criteria-for-Specific-Short-Chain-Perfluorinated-Alkyl-Substances.pdf

67. Russell, Nilsson, Buck, 2013 – Elimination Kinetics of PerFlouroHexanoic Acid in Humans and comparison with mouse, rat and monkey, Chemosphere, Sep2013 ISSN 1879-1298 http://www.biomedsearch.com/nih/Elimination-kinetics-perfluorohexanoic-acid-in/24050716.html

68. Olsen G et al, 2007 - Evaluation of the Half-life (T1/2) of Elimination of Perfluorooctanesulfonate (PFOS), Perfluorohexanesulfonate (PFHxS) and Perfluorooctanoate (PFOA) from Human Serum, 2007. http://www.chem.utoronto.ca/symposium/fluoros/pdfs/TOX017Olsen.pdf

69. Rotander A et al, 2015 -Novel Fluorinated Surfactants Tentatively Identified in Firefighters Using LC-QTOF-MS/MS and a Case-control Approach, Environ. Sci. Technol. 49(4) 2 pp2434-2442 DOI 10.1021/es503653n http://pubs.acs.org/doi/abs/10.1021/es503653n

70. Organisation of Economic Co-operation and Development (OECD), 2013 –Synthesis Paper on Per and Poly fluorinated Chemicals (PFCs)– FINAL, https://www.oecd.org/env/ehs/risk-management/PFC_FINAL-Web.pdf

71. Korzeniowski S et al, 2013 –Biodegradation, Toxicology and Biomonitoring: AFFF Fluorotelomer based Short-chain Chemistry, Reebok Conference, Bolton, UK March 2013.

72. Chengalis C.P., Kirkpatrick J.B., Radovsky A., Shinohara M., 2009a -A 90-day repeated dose oral gavage toxicity study of perfluorohexanoic acid (PFHxA) in rats (with functional observational battery and motor activity determinations). Reprod. Toxicol. 27, 342-351

73. Chengalis C.P., Kirkpatrick J.B., Myers N.R., Shinohara M., Stetson P.I., Sved D.W., 2009b - Comparison of the toxicokinetic behaviour of perfluorohexanoic acid (PFHxA) and nonafluorobutane -1-sulfonic acid (PFBS) in monkeys and rats. Reprod. Toxicol. 27, 400-406

74. Loveless S.E. et al, 2009 - Toxicological Evaluation of Sodium Perfluorohexanoate. Toxicology 264 (2009) 32–44.

75. H. Iwai, M. Shinohara, J. Kirkpatrick, J.E. Klaunig, 2011 - A 24-Month Combined Chronic Toxicity/Carcinogenicity Study of Perfuorohexanoic Acid (PFHxA) in Rats, , Poster Session, Society of Toxicologic Pathology, June 2011

76. Serex, T. et al, 2008 - Evaluation of Biopersistence Potential Among Classes of Polyfluorinated Chemicals using a Mammalian Screening Method. SOT 2008 Poster #958

77. Hoke et al, 2015 – Aquatic hazard, bioaccumulation and screening risk assessment for 6:2 Fluorotelomer sulfonate, Chemosphere 128(2015) pp258-265 http://www.ncbi.nlm.nih.gov/pubmed/25725394

78. Butenhoff J, 2009 – Mechanistic and Pharmacokinetic Determinants of PerFluoroAlkyl Toxicity, 2009.

79. Kleiner E, 2011 - 40 yrs of Saving Lives: C6 Fluorotelomer Surfactants and their use in Firefigthing Foams, Dynax Corporation at American Chemical Society, San Diego, USA, Mar2016 https://ep70.eventpilotadmin.com/web/page.php?page=Home&project=ACS16spring

80. US Department of Defence, 2017- Qualified Products (QPL) Database for Mil-F24385F approved firefighting foams http://qpldocs.dla.mil/search/parts.aspx?qpl=1910

81. Willson M, 2013 –What do recent ICAO Fire test Changes Mean for Airports? – International Fire Protection iss 55, p57-60, Aug. 2013. http://ifpmag.mdmpublishing.com/magazine-archive/

82. Firefighting Foam Coalition, 2016 – Transition Achieved, IFJ Q2 June 2016 http://ebooks.hgluk.com/~production/ebooks/ifj/ifj_q2_2016/pageflip.html

83. Gable M, 2014 – "Firefighting foams: fluorine vs non-fluorine", UK Environment Agency, Fire Times, Aug-Sep 2014.

84. Gable M, 2017 - The Environmental Impact of Fire Service Activities - UK Environment Agency, International FireFighter Magazine, Aug.2017 https://iffmag.mdmpublishing.com/the-environmental-impact-of-fire-service-activities/

85. European Chemicals Agency (ECHA), 2015- Committee for Socio-Economic Analysis (SEAC) Opinion on an Annex XV Dossier Proposing Restrictions on PerFluoroOctanoic Acid (PFOA), its Salts and PFOA-Related Substances, (condition 5d, p6) http://echa.europa.eu/documents/10162/563e9186-6fde-442f-94db-fc7cd534054e

86. Underwriters Laboratories (UL) 1994 - UL 162 Standard for Foam Equipment and Liquid Concentrates, 7th Edition http://ulstandards.ul.com/standard/?id=162_7

87. Jho C, 2016 – "Interactions of Firefighting Foam with Hydrocarbon fuel – Some Fundamental Concepts", Singapore Aviation Academy-IAFPA Foam Seminar, Singapore, 20-22 July 2016.

87. Fire Protection Association Australia, 2017 - Selection and Use of firefighting Foam, V2 Revised and updated Information Bulletin IB-06, http://www.fpaa.com.au/technical/technical-documents/information-bulletins/ib-06-v11-selection-and-use-of-firefighting-foams.aspx

88. Firefighting Foam Coalition, 2016 – Best Practice Guidance for Use of Class B Firefighting Foams http://fffc.org/images/bestpracticeguidance2.pdf

89. European Union, 2006 – Directive 2006/122/EC, PFOS restriction from use across EU after 27 June 2011 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:372:0032:0034:en:PDF

90. Environment Canada, 2008 – SOR 2008-178 Perfluorooctane Sulfonate and its Salts and Certain Other Compounds Regulations http://laws-lois.justice.gc.ca/eng/regulations/SOR-2008-178/page-1.html

91. Dynax Corporation, 2015 – Advert confirming Environmentally More Benign foams achieved with ≥99% C6 and ≤1% C4 fluorochemical purity and <7ppb (0.0000007%) PFOA or C8 impurities.

92. Queensland Department of Environment and Heritage Protection (DEHP), 2016 – Management of Firefighting Foam Policy, July 2016 http://www.ehp.qld.gov.au/assets/documents/regulation/firefighting-foam-policy.pdf

93. Queensland Department of Environment and Heritage Protection (DEHP), 2016 – Management of Firefighting Foam Policy's Explanatory Notes, July 2016 http://www.ehp.qld.gov.au/assets/documents/regulation/firefighting-foam-policy-notes.pdf

94. Baduel C et al, 2015 - Perfluoroalkyl Substances in a Firefighting Training Ground (FTG), Distribution and Potential Future Release, https://www.researchgate.net/profile/Christine_Baduel/publication/276151390_Perfluoroalkyl_substa

nces_in_a_firefighting_training_ground_FTG_distribution_and_potential_future_release/links/55e7b9a708ae21d099c15634.pdf?origin=publication_detail&ev=pub_int_prw_xdl&msrp=bbVZSR_iYRA8qxCUd8zNXPQ4qvb04fqJ1JZ47Lj1PYz6XuKSp3zr-15tIFxHMojlH7f4BJ9xuz8fjfoEb6ZH-w.K586zRpGT3xjnS63DMN1y-bd5dxAhe3Tv0A5g4ycRffvHZJQHwEZE-6yvhDuh_iewb8IjTuNFv4wqsqvI0JaJg.42lkF_qtvbGO2lB9nqNtCR7TxR5vR1nMXro3r-7chGOfmWTmxrBiAIG7Vi8lA7pUsfg5eHFCOxVGNDqevUvH0w

95. Willson M, 2017 – Queensland's "Management of Firefighting Foam" Policy – Part 1, Asia Pacific Fire Magazine, iss 60, January 2017. http://apfmag.mdmpublishing.com/queenslands-management-of-firefighting-foam-policy-part-1/

96. Willson M, 2017 – Queensland's "Management of Firefighting Foam" Policy – Part 2, Asia Pacific Fire Magazine iss 61, April 2017. https://apfmag.mdmpublishing.com/queenslands-management-of-firefighting-foam-policy-part-2/

97. Nilsson H, 2012 – Occupational Exposure to Fluorinated Ski Wax, PhD Thesis, Orebro University, Sweden https://www.diva-portal.org/smash/get/diva2:543228/FULLTEXT02.pdf

Appendix A – About Willson Consulting

Thank you for inviting an open and consultative submission process to engage with interested stakeholders as part of this Parliamentary Inquiry. I am confident this approach will produce a better, more broadly accepted, robust, meaningful, useful and implementable outcome, which also has an increased chance of being understood, respected and valued by the wider community after its deliberations and recommendations are concluded, because of this process and the broader understanding achieved which I hope will contribute to its final outcome.

Willson Consulting is nationally and internationally recognised for providing Environmental and Fire Protection Consultancy Services, specializing in the area of firefighting foams, foam systems, their suitability, applications, system designs, environmental impacts and remediation.

It is run by Director Mike Willson, B.Sc Hons, MCIM. Mike has over 30 year's fire industry experience as an international specialist in Class B firefighting foams, fluorinated and fluorine free, their application and impacts, and design of foam systems, with expertise across product development, systems design, performance testing and evaluation, end-user sector requirements, environmental impacts, remediation and major incident emergency response. He has a wide range of clients including foam users, manufacturers, fire service Cos, Industry Associations and provides guidance through the minefield of complexity surrounding firefighting foams, to help achieve the best outcomes in decision making.

He was nominated as UK foam expert to the UK Government's 2004 PFOS (PerFluoroOctanyl Sulphonate) Strategy Review. He contributed major improvements to bunded areas, storage tank protection and LNG application additions as a member of the European CEN Standard Committee's development of Fixed Foam Firefighting Systems standard EN13565-2:2009.

He is therefore well qualified to make representation in response to this Parliamentary Inquiry, by explaining the relevant existing legislation framework, nationally and internationally and uncovering the full complexity of these firefighting foam issues.

This opportunity to provide comment to this Parliamentary Inquiry and express concerns is appreciated. These comments are intended to improve the understanding of strengths and weaknesses of C6 short-chain and F3 agents in realising the importance of fast, effective and reliable action to protect critical life safety, minimise incident escalation which also minimises the overall environmental and societal impacts of the whole incident's assessment. Hopefully it clarifies and justifies separation of dangerous legacy C8 PBT chemicals of the past, from environmentally more benign and acceptable C6 short-chain (not B, not T) alternatives of today, to provide better informed decision making. These C6 agents are widely considered necessary to ensure the continued life safety of site personnel, emergency responders and communities in and adjacent to our Major Hazard Facilities, including Defence sites around Australia, into the future.

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